



# Impact Evaluation of the Heat Pump Water Heater and Electronically Commutated Motor Measures

**Prepared for:**

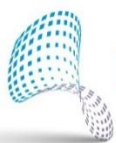
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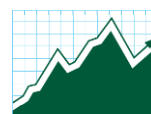
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Ridgeline Energy Analytics

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**Demand Side Analytics**  
DATA DRIVEN RESEARCH AND INSIGHTS



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## NOTICE

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# 1 EXECUTIVE SUMMARY

In July 2024, Efficiency Maine selected Demand Side Analytics and Ridgeline Energy Analytics (the Evaluation Team) to perform an independent impact evaluation of the heat pump water heater (HPWH) and electronically commutated motor (ECM) circulator pump measures offered through the Efficiency Maine Retail and Distributor Initiatives. For the HPWH measure, our evaluation focused on participants from January 1, 2023, through June 30, 2024. For the ECM circulator pump (ECMCP) measure, our evaluation focused on participants from fiscal year 2023 (FY2023), which began July 1, 2022, and ended June 30, 2023. [Table 1](#) shows the number of units to receive program support and average per-unit reported gross savings values over the relevant time periods.

Table 1: Per-Unit Impacts by Measure

Measure	Units	kWh	Winter kW	Summer kW	Natural gas (MMBtu)	Propane (MMBtu)	Heating Oil (MMBtu)	Kerosene (MMBtu)
HPWH <sup>[a]</sup>	14,742	683	0.120	0.074	0.232	0.796	4.340	0.130
ECMCP	14,777	113	0.040	N/A	N/A	N/A	N/A	N/A

<sup>[a]</sup> The per-unit factors in this row are averaged across multiple TRM savings schedules.

## 1.1 EVALUATION FINDINGS

### 1.1.1 HEAT PUMP WATER HEATERS

The HPWH evaluation included a web-based participant survey, a pre/post advanced metering infrastructure (AMI) analysis, a metering study, and distributor interviews. [Table 2](#) presents the core impact evaluation results for the HPWH measure. Realization rates are the ratio of verified gross savings, as determined by the evaluation, to the unadjusted gross savings. We provide some discussion around the realization rates in [Section 3.3.1](#) and a discussion on key drivers in [Table 3](#). The net-to-gross ratio (NTGR) was estimated through the participant survey and corroborated with findings from the distributor interviews.





Table 2: HPWH Impact Evaluation Results (January 2023 – June 2024)

Metric	Unadjusted Gross	Realization Rate	Gross Verified	NTGR	Net Verified	
Units	14,742	N/A	14,742	N/A	14,742	
Annual Energy Savings	Energy (kWh)	10,073,875	43.4%	4,371,150	84.2%	3,680,509
	Natural Gas (MMBtu)	3,425	105.9%	3,627	84.2%	3,054
	Propane (MMBtu)	11,738	74.1%	8,698	84.2%	7,324
	Heating Oil (MMBtu)	63,980	81.8%	52,334	84.2%	44,065
	Kerosene (MMBtu)	1,916	15.4%	295	84.2%	248
Winter kW	1,769	70.0%	1,238	84.2%	1,043	

	Metric	Unadjusted Gross	Realization Rate	Gross Verified	NTGR	Net Verified
Peak Demand Savings	Summer kW	1,098	60.4%	663	84.2%	559

In [Table 3](#), we present the primary realization rate drivers for our evaluation of the HPWH measure.

**Table 3: Primary Realization Rate Drivers – HPWH Measure**

Impact Factor	Discussion
 $kWh/y_{HWL}$	$kWh/y_{HWL}$ represents the energy required to serve the annual hot water load (HWL) and is a key input for several algorithms in Efficiency Maine’s Retail/Residential Technical Reference Manual (TRM). The current TRM assumption, which is drawn from the prior HPWH evaluation and based on the 2015 Residential Energy Consumption Survey, is 2,821 kWh. Our evaluated value, which is based on results from the metering study, is 1,534.
 $EAF_{EE}$	The efficiency adjustment factor (EAF) is the ratio of field-based measurements of HPWH efficiency to rated HPWH efficiency. The prior evaluation found an EAF of 0.88, while we found an EAF of 0.50. There are two key drivers of our EAF. First, many of the metered HPWHs operate in hybrid mode. When “high demand” mode (electric resistance) kicks in, the efficiency of the HPWH is poor. Second, rated efficiency values assume more hot water usage than what we observed in the field. Efficiency decreases due to standby losses when hot water usage is low.
 $EAF_{Base}$	The prior evaluation and current TRM algorithms do not apply an efficiency adjustment factor to the baseline water heater efficiencies. However, baseline storage water heaters experience standby losses just like HPWHs do. We apply an adjustment factor to the baseline efficiencies in our study, which increases the savings.
 Decision type	“Decision type” refers to whether the HPWH replaced a functioning water heater (“retrofit”) or not (“lost opportunity”). Prior evaluation results are based on a split of 19% retrofit and 81% lost opportunity. Based on findings from our participant survey, we used a split of 13/87 for homes with an electric water heating baseline and a split of 40/60 for homes with a non-electric water heating baseline. This change led to increased savings for the average electric baseline home and increased electrification loads for the average non-electric baseline home.

In [Table 4](#), we show the distribution of self-reported income by program pathway. Household income levels were collected as part of the participant survey (see [Section 3.2.3.6](#)). The three distinct program pathways are described in [Section 3](#).

**Table 4: Distribution of Self-Reported Income by Program Pathway**

Program Pathway	Self-Reported Income Bin <sup>[a]</sup>		
	Low	Medium	High
Mail-in – Retail	13.2%	31.9%	54.9%
Instant – Retail	23.1%	44.5%	32.4%
Instant – Distributor	12.6%	42.1%	45.3%
<b>Overall</b>	<b>17.9%</b>	<b>42.2%</b>	<b>39.9%</b>

<sup>[a]</sup> Respondents who declined to select an income bin are not included in these percentages.

### 1.1.2 ECM CIRCULATOR PUMPS

The ECM circulator pump evaluation included a metering study, a price elasticity analysis, distributor interviews, and contractor interviews. Table 5 presents the core impact evaluation results for the measure. Because 97% of rebated pumps were installed in residential premises, our evaluation focused on the residential application. The values in Table 5 do not include commercial installations. The realization rate is the ratio of unadjusted gross savings to the gross verified savings we produced as part of the evaluation. We estimated the NTGR through the price elasticity analysis and corroborated the results with findings from the distributor and contractor interviews.


Table 5: Residential ECM Circulator Pump Impact Evaluation Results (FY2023)




Metric		Unadjusted Gross	Realization Rate	Gross Verified	NTGR	Net Verified
Units <sup>[a]</sup>		14,304	N/A	14,304	N/A	14,304
Annual Energy Savings <sup>[a]</sup>	Energy (kWh)	1,440,413	46.9%	675,149	79.5%	536,743
	Natural Gas (MMBtu)	0	N/A	0	N/A	0
	Propane (MMBtu)	0	N/A	0	N/A	0
	Heating Oil (MMBtu)	0	N/A	0	N/A	0
	Kerosene (MMBtu)	0	N/A	0	N/A	0
Peak Demand Savings <sup>[a]</sup>	Winter kW	519	28.7%	149	79.5%	118
	Summer kW	0	N/A	4	79.5%	3

<sup>[a]</sup> ECM circulator pumps installed in commercial premises are not included in these totals.

In Table 6, we present some of the primary realization rate drivers for this evaluation.

Table 6: Primary Realization Rate Drivers – ECM Circulator Pump Measure

Impact Factor	Discussion
 Hours of use	Based on our metering study, we calculated an average annual hours of use value of 812 for residential applications. The prior TRM assumption of 1,374 hours was adapted from the 2016 Efficiency Vermont TRM.

Impact Factor	Discussion
 $\Delta kW_{\max}$	$\Delta kW_{\max}$ is a function of efficient wattage and baseline wattage. Prior assumptions regarding efficient and baseline wattage were drawn from the 2016 Efficiency Vermont TRM (14.4 Watts and 87.7 Watts, respectively). Evaluated values were based on metering data from ECM pumps and spot amp and power readings taken from non-ECM pumps while in the field (20.1 Watts and 78.1 Watts, respectively).
 $CF_w$	The winter coincidence factor ( $CF_w$ ) estimate is based on predicted pump runtime during the ISO-NE winter peak period. Our weather-normalized estimate is 17.9%, meaning 17.9% of ECM circulator pumps are operating during the winter peak period on average. The prior TRM assumption of 49.5% was a ratio of the average heating degrees during winter on peak hours to maximum heating degrees using typical meteorological year (TMY) data weighted for Portland, Caribou, and Bangor.
 Typical weather data	“Weather-normalized” impact estimates represent expected impacts during a typical weather year. There are a few flavors of “typical” weather data available to evaluators. Many inputs in the Efficiency Maine TRM are based on TMY <sub>3</sub> weather data, which is developed using weather data from 1991 to 2005. For this evaluation, we weather-normalized our impact estimates using TMY <sub>x</sub> data. TMY <sub>x</sub> conditions are generally warmer than TMY <sub>3</sub> conditions (which correlates with lower predicted space heating loads).

### 1.2 TRM RECOMMENDATIONS

For the HPWH measure, we recommend modifying select algorithms, introducing new impact factors, updating impact factors, and updating per-unit savings values. We do not cover all the recommended updates in this section – see [Section 3.5](#) for the comprehensive update recommendations. We touch on key impact factors in [Table 7](#) and updated per-unit savings values in [Table 8](#). The per-unit values shown in [Table 8](#) blend impacts across homes where the HPWH is an efficiency measure (53.6% of homes) and homes where the HPWH is an electrification measure (46.4% of homes). Additionally, note the factors in [Table 8](#) combine our proposed updates with a current assumption for HPWH uniform energy factor (UEF) and do not match our gross verified per-unit savings values (which reflect the average UEF of the program-supported HPWH during the period of investigation).

Table 7: Key HPWH Impact Factors

Factor	Evaluated Value	Discussion
$kWh/yr_{HWL}$	1,534	This metric represents the annual water heating load for an electric water heater with a COP of 1.0 and was estimated via the HPWH metering study. Per-unit savings values are a function of this metric.
$EAF_{EE}$	0.50	This is an efficiency adjustment factor (EAF) for HPWHs that accounts for standby losses and inefficiencies related to HPWHs running in electric resistance mode.

EAF <sub>Base</sub>	0.75	This is an efficiency adjustment factor for baseline water heaters that accounts for standby losses. It is not included in current TRM algorithms but we recommend adding it.
% Retrofit	25%	This is touched on in <a href="#">Table 3</a> see the "Decision Type" row. The current TRM assumes 19% of installations are retrofit and 81% are lost opportunity. Based on our participant survey, we (1) found the split varies by baseline fuel and (2) estimated an overall split of 25% retrofit and 75% lost opportunity.

Table 8: Resulting TRM Per-unit Saving Values for HPWH

Metric		Per-unit Value <sup>[a]</sup>
Annual Energy Savings	Energy (kWh)	356
	Natural Gas (MMBtu)	0.26
	Propane (MMBtu)	0.62
	Heating Oil (MMBtu)	3.57
	Kerosene (MMBtu)	0.02
Peak Demand Savings	Winter kW	0.095
	Summer kW	0.049

<sup>[a]</sup> These per-unit values blend impacts across homes where the HPWH is an efficiency measure and homes where the HPWH is an electrification measure. Additionally, these per-unit values do not match evaluated per-unit values because these are based on a more current EUF assumption

[Table 9](#) shows our recommended TRM factors for residential ECM circulator pump installations. We do not have any recommended modifications to the algorithms.

Table 9: ECMCP TRM Factors – Residential Applications

Impact Factor	Evaluated Value
Watts <sub>Base</sub>	78.2
Watts <sub>EE</sub>	20.1
CF <sub>W</sub>	17.9%
CF <sub>S</sub>	0.6%
ΔkW <sub>max</sub>	0.0581
ΔkW <sub>wp</sub>	0.0104
ΔkW <sub>sp</sub>	0.0003
Annual Hours	812
ΔkWh	47.2
Energy Period Factor (EPF) – Winter Off	51.7%
EPF – Winter On	39.7%
EPF – Summer Off	5.1%
EPF – Summer On	3.5%

Impact Factor	Evaluated Value
Net-to-gross ratio	79.5%
In-service rate	100%

### 1.3 COST EFFECTIVENESS

We used the results of the gross and net impact evaluations in combination with two different sets of avoided costs to compute benefit-cost ratios for 15 different HPWH benefit-cost scenarios and 11 different ECM circulator pump benefit-cost scenarios. We considered both retrospective and prospective scenarios, defined as follows:

- Retrospective Scenarios:** Utilize the avoided costs, and methodology and assumptions (M&As) in place during FY2023 and FY2024. These years were both part of the Efficiency Maine 2023-2025 Triennial Plan (Triennial Plan V, or TPV). TPV uses avoided costs from the 2021 Avoided Energy Supply Component Study (AESC 2021)
- Prospective Scenarios:** Utilize the avoided costs and M&As in place for Efficiency Maine’s 2026-2028 Triennial Plan (Triennial Plan VI, or TPVI). TPVI uses avoided costs from the 2024 Avoided Energy Supply Component Study (AESC 2024)

All benefit-cost (BC) analysis utilized the Efficiency Maine primary benefit-cost test, which takes the perspective of all utility customers (participants and non-participants). [Section 5](#) provides a full discussion of the methodology, scenarios considered, and the results. The ECMCP results reflect residential installations only since those were the focus of our evaluation.

In the primary prospective HPWH scenario (last row in [Table 10](#)), the net present value of the benefits is estimated to be 1.94 times greater than the net present value of the costs. For the primary prospective ECM circulator pump scenario (last row in [Table 11](#)), the net present value of the benefits is estimated to be 1.35 times greater than the net present value of the costs. An important piece of context for the ECM circulator pump results is that the incentive Efficiency Maine provides exceeds the incremental measure cost (and for some promotional periods, the incentive was more than twice the incremental measure cost). A “low incentive” scenario for ECM circulator pumps, which uses an incentive value less than the incremental cost, produces a BC ratio of 2.08 – meaning the net present value of the benefits is estimated to be more than twice the net present value of the costs (see [Table 69](#) and [Table 71](#) for more information on this scenario).

Table 10: HPWH Benefit-Cost Ratios

Scenario	Perspective	Costs	BC Ratio
2021 Gross Evaluated	Retrospective	AESC 2021	1.51
2024 Gross Evaluated	Prospective	AESC 2024	1.94

Table 11: ECM Circulator Pump Benefit-Cost Ratios

Scenario	Perspective	Costs	BC Ratio
2021 Gross Evaluated	Retrospective	AESC 2021	1.10
2024 Gross Evaluated	Prospective	AESC 2024	1.35

## 2 INTRODUCTION

The primary objectives of this research were to evaluate annual energy savings, peak demand savings, and cost-effectiveness of the HPWH and ECMCP measures. For the evaluation of the HPWH measure, our key evaluation steps included:

- **Use AMI data to perform a pre/post analysis.** This analysis examined the changes in participants' electric consumption patterns after installing a HPWH. Outputs from this analysis include average annual energy and summer/winter peak demand savings estimates. The analysis included a matched comparison group of non-participants, and the general form of the regression model followed the Lawrence Berkeley National Laboratory (LNBL) Time-of-Week Temperature (TOWT) model.
- **Meter program-supported HPWHs in a sample of 20 households.** The metering data was used to estimate key TRM factors, such as the annual energy required to deliver the annual hot water demand (kWh/yr<sub>HWL</sub>) and an efficiency adjustment factor for HPWHs that accounts for standby losses and inefficiencies related to HPWHs running in electric resistance mode.
- **Field a web-based participant survey.** The survey informed net-to-gross results and was a key input into the AMI analysis, as we used the survey to probe for decision type (lost opportunity or retrofit) and water heating baseline fuel.
- **Conduct distributor phone interviews.** We conducted phone interviews with five HPWH distributors. The goal of the interviews was to assess the influence of the Efficiency Maine discounts on sales of qualified heat pump water heaters.

Our key evaluation steps for the evaluation of the ECMCP measure included:

- **Meter 41 program-supported ECM circulator pumps in a sample of 22 households.** The metering results were used to estimate average annual energy savings, summer/winter peak demand savings, and energy period factors for residential installations.
- **Conduct distributor and contractor phone interviews.** We interviewed a sample of five ECMCP distributors and 15 ECMCP contractors. These interviews informed net-to-gross results. Specifically for the ECM circulator pump measure, distributors are among the most qualified to discuss program administration, incentives, successes, and market impacts.
- **Perform a price elasticity analysis.** In a price elasticity analysis, the goal is to understand how variations in incentive level affect sales volume. Outputs from this analysis established the net-to-gross ratio for ECMCPs.

Table 12 summarizes our evaluation approach for each measure. We provide details on our evaluation of the HPWH measure in Section 3 and the ECM circulator pump measure in Section 4. Because only 3% of ECM circulator pumps rebated in FY2023 were installed in commercial buildings, our evaluation focused on residential installations.

Table 12: Overview of Approach by Evaluation Topic

Evaluation Topic		AMI Analysis	Metering	Surveys / Interviews	Price Elasticity Modeling
Heat Pump Water Heaters	Annual energy impact	✓	✓	✓	
	Summer and winter peak impacts	✓	✓	✓	
	Energy period factors	✓	✓	✓	
	Peak coincidence factors	✓	✓	✓	
	Hourly load shape	✓	✓	✓	
	In-service rate			✓	
	Net-to-gross ratio			✓	
	Determine the appropriate baseline			✓	
ECM Circulator Pumps	Annual energy impact		✓		
	Summer and winter peak impacts		✓		
	Energy period factors		✓		
	Peak coincidence factors		✓		
	In-service rate			✓	
	Net-to-gross ratio			✓	✓

### 3 HEAT PUMP WATER HEATERS

Through the Efficiency Maine Retail and Distributor Initiatives, Efficiency Maine provides rebates on ENERGY STAR-certified heat pump water heaters for residential and commercial customers in Maine. There are three distinct program pathways:

- **Mail-in – Retail.** Participants fill out and submit a rebate form after purchasing an eligible HPWH and are sent a rebate check in the mail.
- **Instant – Retail.** Participants scan a QR code while in store, provide their contact information via web form, and receive an instant discount barcode via email (immediately after submitting contact information). The discount is applied when the barcode is scanned at the register.
- **Instant – Distributor.** Plumbers receive an instant discount when purchasing eligible HPWHs through participating distributors, and then pass the cost savings on to customers (i.e., participants purchase the HPWH from the plumber at a reduced cost.) Customers who purchase their HPWH directly from Granite Group also fall under this pathway.

Table 13 summarizes reported program activity over our evaluation period (January 2023 through June 2024).

Table 13: Reported Program Metrics

Metric		Program Pathway			Total
		Mail-in – Retail	Instant – Retail	Instant – Distributor	
Units		772	5,532	8,438	14,742
Annual Energy Savings	Energy (kWh)	541,770	3,727,195	5,804,910	10,073,875
	Natural Gas (MMBtu)	187	1,258	1,980	3,425
	Propane (MMBtu)	642	4,304	6,792	11,738
	Heating Oil (MMBtu)	3,350	24,009	36,621	63,980
	Kerosene (MMBtu)	100	719	1,097	1,916
Peak Demand Savings	Winter kW	95	655	1,019	1,769
	Summer kW	59	407	632	1,098

Our evaluation of the HPWH measure included four key evaluation activities: a web-based participant survey, phone interviews with HPWH distributors, a pre/post analysis with AMI data, and a metering study. The remainder of this chapter is organized as follows:

- In Section 3.1, we summarize key evaluation findings.
- In Section 3.2, we provide details on the participant survey.
- In Section 3.3, we provide details on both the AMI analysis and the metering analysis.
- In Section 3.4, we provide details on the distributor interviews.
- In Section 3.5, we provide our comprehensive TRM recommendations for the HPWH measure.

### 3.1 HIGH-LEVEL EVALUATION FINDINGS

Table 14 summarizes some of our high-level evaluation findings. We provide greater detail on these findings in subsequent sections.

Table 14: High-Level HPWH Evaluation Findings

Topic	Findings
Domestic hot water baseline fuel	We found that 54% of participants had electric water heaters before installing the program-supported HPWH. Of the 46% with non-electric baselines, most used oil. Often, the replaced oil-fired system was integrated with the home’s space heating.
Annual energy impact of a HPWH	For homes with electric baselines, we estimated 1,298 kWh of annual energy savings. For homes with non-electric baselines, we estimated 862 kWh of additional annual electric use. The average “all-in” MMBtu impact (inclusive of the energy impact of the HPWH itself and, for premises with a fossil fuel baseline, MMBtu savings associated with the electrification of the premise’s water heating load) was 5.44 MMBtu.
Program impact on customer-level purchasing decisions	Overall, we estimate the freeridership rate is 15.8% and the NTGR is 84.2%. In other words, we believe 15.8% of program participants would have installed a HPWH even without the program.
Program impact on distributor-level stocking, sales, and awareness	Distributors were asked to rate how influential the incentive program has been in reaching the current level of awareness and adoption of HPWHs among Maine contractors. On a scale from 0 (not influential) to 10 (extremely influential), the average rating was 9.8.
Customer satisfaction	92% of survey respondents reported that they probably would, definitely would, or already have recommended a HPWH to family, friends, or neighbors.
Cost effectiveness	In the prospective gross scenario, we estimate the measure returns \$1.94 of benefits per \$1 of cost using the Efficiency Maine primary cost test.
In-service rate	No survey respondents indicated that their program-supported HPWH had not been installed.

### 3.2 PARTICIPANT SURVEY

As part of our evaluation of the HPWH measure, we fielded a web-based participant survey. Participants with valid email addresses from January 2023 through June 2024 were invited to take the survey. Table 15 shows key participation metrics over this period. Overall, we had an 11.9% response rate.<sup>1</sup> Key research areas for the survey include freeridership, baseline fuel, and decision type (retrofit vs. lost opportunity).

<sup>1</sup> Note “bounced” emails are included in the denominator of the response rate calculation. Bounced emails are emails that were rejected by the recipient’s email server or emails sent to addresses that don’t exist. In total, 33 survey invitation emails were bounced.

Table 15: Participation Counts (January 2023 – June 2024)

Metric	Value
Rebated HPWHs	14,742
Unique installation addresses	14,621
Survey invitation emails sent	8,455
Completed surveys	1,002
Response rate	11.9%

Key high-level findings from the participant survey include:

- Approximately 16% of participants indicated that they would have installed a HPWH without a rebate. This response was notably higher (44%) among new construction participants (which represented about 6% of respondents).
- Respondents whose baseline fuel was non-electric were approximately three times more likely to be replacing a functioning water heater (as opposed to replacing a non-functioning water heater) than respondents whose baseline fuel was electric.
- High-income respondents (self-reported) were more likely to be replacing a functioning water heater (as opposed to replacing a non-functioning water heater) than other respondents. See [Section 3.2.3.6](#) for more information on self-reported income ranges.
- Almost half of the respondents (48%) also installed a heat pump within the last three years. The transition of space heating from oil to electric is certainly correlated with HPWH adoption since the domestic hot water in many Maine homes is served by the boiler.

### 3.2.1 FREERIDERSHIP & NET-TO-GROSS

One of the primary purposes of the participant survey was to answer the question: What percentage of HPWH rebate recipients would have purchased the HPWH anyway, without financial support from Efficiency Maine? Such participants are known as freeriders. The net-to-gross ratio (NTGR) for the HPWH measure is the complement of the freeridership rate:

$$NTGR = 1 - Freeridership$$

#### 3.2.1.1 Methodology

The method we used for calculating freeridership follows the approach laid out in the Evaluation Framework for Pennsylvania Act 129 Phase IV Energy Efficiency and Conservation Programs.<sup>2</sup> Under this framework, the freeridership score is the sum of a participant intention score and a program influence score. The intention question seeks to understand what participants would have done absent the rebate, and the influence question seeks to understand how influential the program was on the participant’s decision to purchase a HPWH. The intention and influence scores each range from 0 to 0.5 and are given equal weight in the freeridership calculation:

$$Freeridership = Intention Score + Influence Score$$

<sup>2</sup> Available at [https://www.puc.pa.gov/media/1584/swe-phaseiv\\_evaluation\\_framework071621.pdf](https://www.puc.pa.gov/media/1584/swe-phaseiv_evaluation_framework071621.pdf).

### 3.2.1.2 Intention

The participant intention question was:

*Imagine you never learned about the Efficiency Maine incentive for the purchase of a heat pump water heater. Which of the following best describes what you would have done?*

1. *I would not have purchased any water heater.*
2. *I would have purchased a water heater, but not a heat pump water heater.*
3. *I would have purchased a heat pump water heater without the rebate.*
4. *I would have purchased a heat pump water heater without the rebate a year or more later.*
5. *I don't know*

Table 16 shows the distribution of responses and the intention score for each response. The response distribution was evenly distributed with option 4 standing out as the least common response.

Table 16: Intention Scoring

Response	% of Respondents	Intention Score
1. I would not have purchased any water heater	22%	0
2. I would have purchased a water heater, but not a heat pump water heater	26%	0
3. I would have purchased a heat pump water heater without the rebate	21%	0.5
4. I would have purchased a heat pump water heater without the rebate a year or more later	10%	0
5. I don't know	20%	Remove from scoring

### 3.2.1.3 Influence

The program influence question required participants to provide a Likert scale response to several different prompts. The question and prompts table are shown below.

*Please indicate on a scale of 1-5 (where 1 means not important and 5 means extremely important) how important each of the following was in your decision to purchase a heat pump water heater. I purchased my heat pump water heater because...*

- Factor 1: *...the rebate lowered the cost of the water heater*
- Factor 2: *...it was easy for me to apply for / receive the rebate [for mail-in retail pathway]*  
*...it was easy for me to get the instant discount [for instant retail pathway]*  
*...it was easy for me to purchase the water heater at the reduced cost [for instant distributor pathway]*
- Factor 3: *...the Efficiency Maine savings example ("they can save more than \$500 per year in electricity") was compelling.*
- Factor 4: *...of recommendations from my friends or family*
- Factor 5: *...of recommendations from my installer [if HPWH was not self-installed]*

For each participant, the maximum Likert scale response was retained, and the influence score was assigned based on the mapping shown in [Table 17](#).

Table 17: Influence Scoring

Scale	Influence Score
1 – Extremely unimportant	0.50
2 – Unimportant	0.50
3 – Neutral	0.25
4 – Important	0
5 – Extremely important	0

If one of the last two options (“because of recommendations from my friends or family” or “because of recommendations from my installer”) received the highest Likert response, a follow-up question was asked. The follow-up question was:

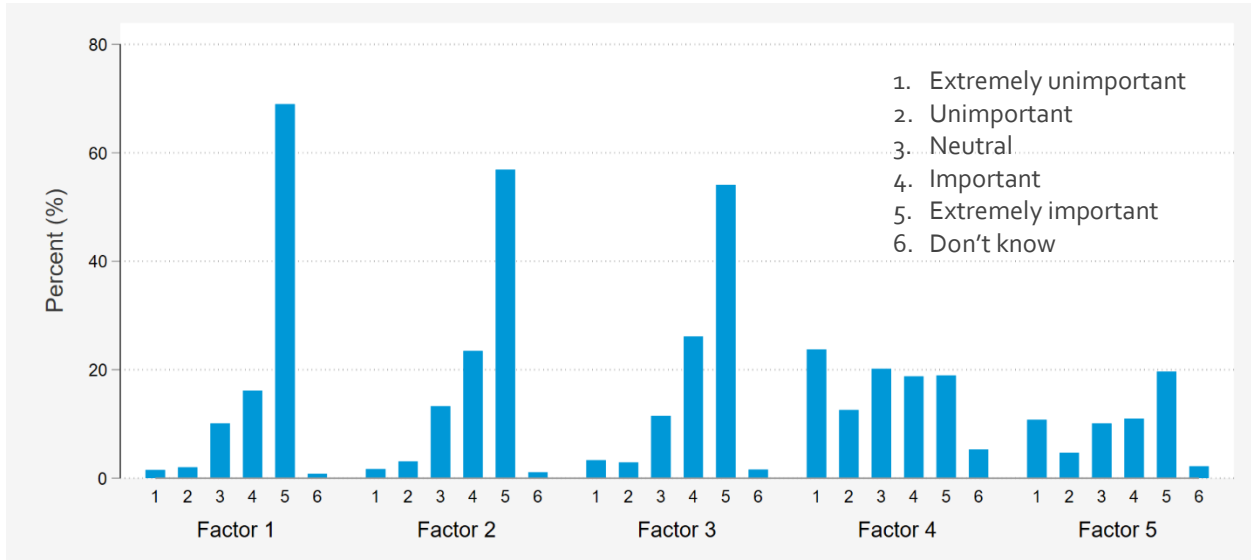
*You indicated that a recommendation was the most important factor in your decision. Did the person who recommended the heat pump water heater mention that Efficiency Maine programs could help offset the cost?*

1. *Yes*
2. *No*
3. *I don't recall*

An influence score of zero was assigned to the “Yes” responses and 0.5 to the “No” responses. Participants who responded with “I don’t recall” were removed. Section 6.3.1 shows two influence scoring examples.

[Figure 1](#) shows the distribution of responses to the primary influence question. Most people cited the rebate itself, how easy it was to receive the rebate or purchase the HPWH at a reduced cost, or the savings example as either somewhat important or extremely important in their purchase decision.

Figure 1: Distribution of Influence Responses



**3.2.1.4 NTG Results**

Table 18 shows NTGR results by program pathway. Most program participants went through the Instant – Distributor pathway, but most survey respondents went through the Instant – Retail pathway. This discrepancy can be explained by the fact that we had better email address coverage for the Instant – Retail participants since these participants must provide an email address to get the instant discount. The metrics in the “Overall” row are weighted based on the population pathway distribution. Overall, we estimate the freeridership rate is 15.8% and the NTGR is 84.2%.

Table 18: NTGR Results by Program Pathway

Pathway	% of Rebates	% of Respondents	Freeridership Rate	NTGR
Mail-in – Retail	5.2%	11.7%	20.4%	79.6%
Instant – Retail	37.5%	50.2%	7.9%	92.1%
Instant – Distributor	57.3%	38.1%	20.6%	79.4%
<b>Overall</b>	<b>100%</b>	<b>100%</b>	<b>15.8%</b>	<b>84.2%</b>

Table 19 shows a crosstab of the intention and influence scores. Respondents in the lower right cell (intention = 0.5, influence = 0.5) are full freeriders. Respondents with a freeridership score greater than 0 but less than 1 are partial freeriders. Most respondents who indicated that they would have purchased a heat pump water heater without the rebate (intention = 0.5) also indicated that something about the program (the rebate, ease of participation, the savings example, etc.) was important in their decision to purchase a HPWH.

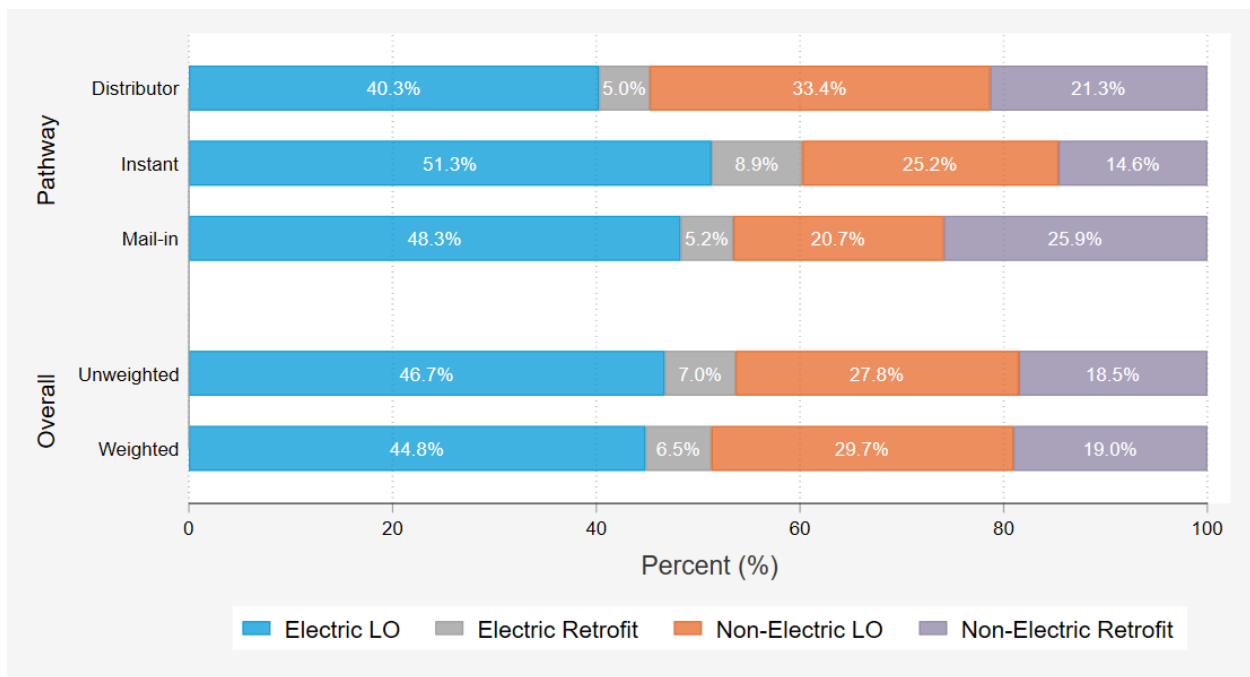
Table 19: Influence and Intention Score

Influence Score	Intention Score		Total
	0	0.5	
0	572	192	764
0.25	4	8	12
0.50	3	7	10
<b>Total</b>	<b>579</b>	<b>207</b>	<b>786</b>

### 3.2.2 BASELINE BINS

To determine the appropriate baseline for measuring the energy impacts associated with the HPWH installation, participants were asked about the installation: whether the HPWH replaced an existing water heater, the condition of the prior water heater (if applicable), the fuel of the prior water heater (if applicable), and other fuels they considered prior to purchasing the HPWH. Using the survey responses, we binned each respondent into one of four baseline fuel and decision type bins: electric lost opportunity, electric retrofit, non-electric lost opportunity, and non-electric retrofit. Figure 2 shows the results by program pathway. (The “Weighted” row applies the “% of Rebates” weights from Table 18.) Homes with a non-electric baseline fuel were significantly more likely to install a retrofit HPWH than homes with an electric baseline fuel. Additional details about the relevant baseline questions are in subsequent sections.

Figure 2: Baseline Bins



### 3.2.2.1 Baseline Fuel

Our assignment of baseline fuel for each respondent relied on questions about the installation type, the prior water heating fuel (if applicable), and other fuels considered. [Table 20](#) provides additional details.

Table 20: Baseline Fuel Assignment by Installation Type

Installation Type	Baseline Fuel Assignment
Replacement (83% of respondents)	Assigned based on prior water heating fuel.
New Construction (6% of respondents)	Assign based on other fuels considered. If they said “none” or identified both electric and non-electric options, we assumed a like-for-like electric baseline. This was the more common baseline among lost opportunity installations.
Additional Unit (10% of respondents)	Same as new construction.

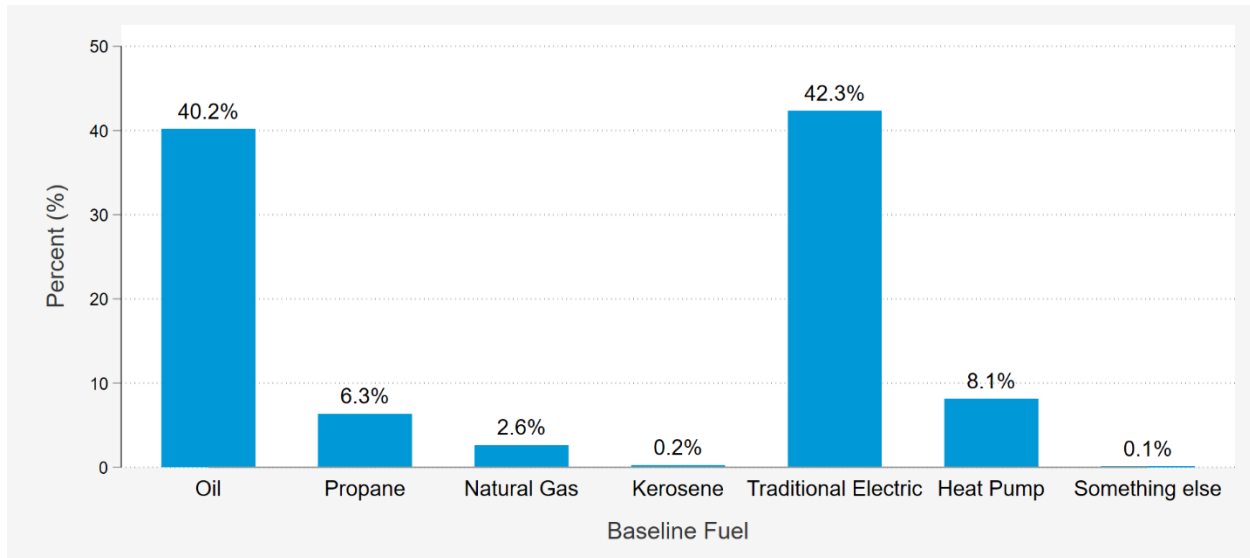
The baseline fuel question and response options are shown below. This question was only asked if the respondent said they replaced an existing water heater. We reviewed the open-ended responses for participants who selected the “Something else” option and assigned these participants to one of the provided baseline fuels if possible.

*Thinking back to before installing the program-supported heat pump water heater, what type of fuel did the prior water heater use?*

1. *Oil*
2. *Propane*
3. *Natural gas*
4. *Kerosene*
5. *Traditional electric*
6. *Electric heat pump*
7. *Something else (specify)*

The distribution of responses is shown in [Figure 3](#). The most common response was traditional electric (42%) followed by oil (40%). Overall, half of respondents said their prior water heater was electric and half indicated their prior water heater was powered by fossil fuels.

Figure 3: Baseline Fuel Responses



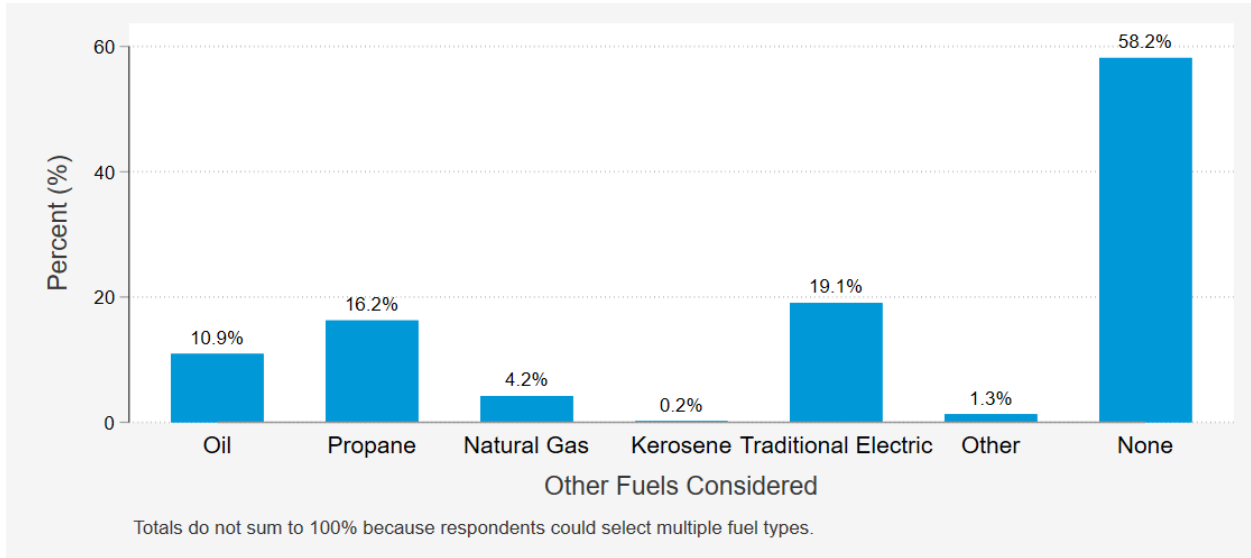
The question about other fuels considered is shown below. Note all respondents were asked this question and multiple selections were allowed, meaning a single participant could have theoretically selected every option.

*Before purchasing the program-supported heat pump water heater, what other water heating fuel options did you seriously consider? Select all that apply.*

1. *Oil*
2. *Propane*
3. *Natural gas*
4. *Kerosene*
5. *Traditional electric*
6. *Something else (specify)*
7. *Did not consider other options*

Figure 4 shows what percentage of participants selected each option. Most respondents indicated that they did not consider other fuel options. Among those that responded with “Something else”, the majority responded with a type of unit (on demand, tankless, integrated) rather than a fuel.

Figure 4: Other Heating Fuels Considered



Overall, 53% of respondents were placed in the electric baseline bin and 46% were placed in the non-electric baseline bin. Another 1% could not be categorized using the responses provided. Ignoring this 1%, the baseline bin percentages are 54% and 46% for electric and non-electric respectively.

### 3.2.2.2 Decision Type

Our assignment of decision type (lost opportunity or retrofit) for each respondent relied on questions about the installation type and the motivation for replacing the prior water heater (if applicable). Table 21 provides additional details.

Table 21: Decision Type Assignment by Installation Type

Installation Type	Decision Type Assignment
Replacement (83% of respondents)	Assigned based on the respondent’s motivation for replacing their prior water heater.
New Construction (6% of respondents)	All new construction installations were mapped to lost opportunity.
Additional Unit (10% of respondents)	All additional unit installations were mapped to lost opportunity.

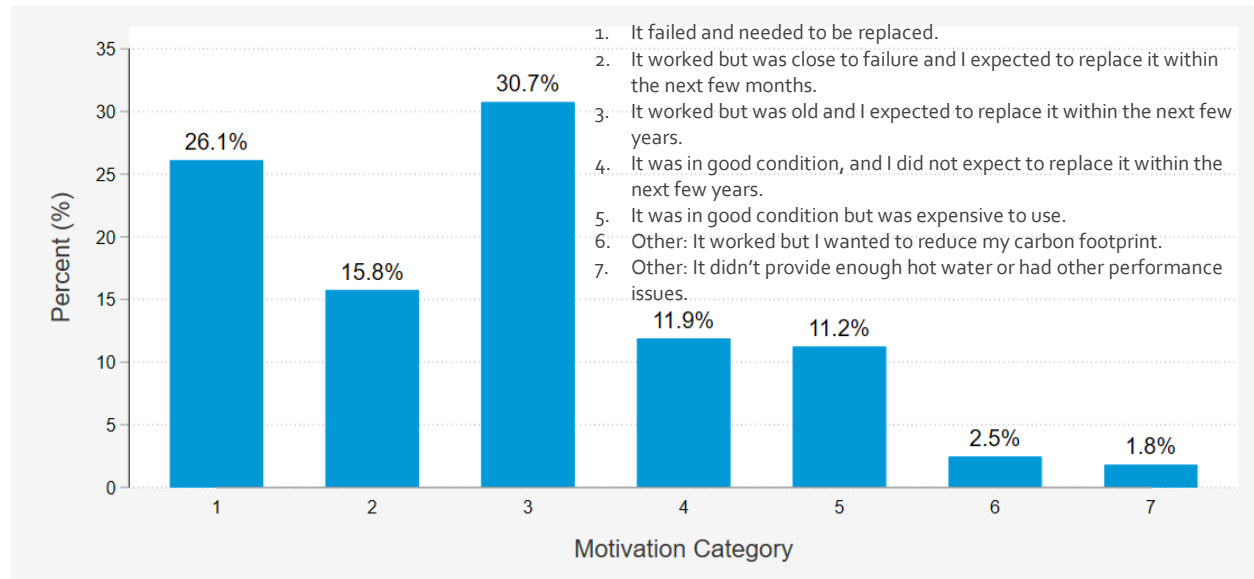
The motivation question is shown below. We reviewed open-ended responses from participants who selected “Something else” and assigned each to one of the other categories. Response options 6 and 7 were not actually part of the survey, but these were common themes among respondents who selected the “Something else” response option. Response options 1, 2, 3, and 7 are categorized as “lost opportunity” and response options 4, 5, and 6 are categorized as “retrofit”.

*What best describes the condition of the water heater that was replaced by the program-supported heat pump water heater?*

1. *It failed and needed to be replaced.*
2. *It worked but was close to failure and I expected to replace it within the next few months.*
3. *It worked but was old and I expected to replace it within the next few years.*
4. *It was in good condition, and I did not expect to replace it within the next few years.*
5. *It was in good condition but was expensive to use.*
6. *It worked but I wanted to reduce my carbon footprint.*
7. *It didn't provide enough hot water or had other performance issues.*
8. *Something else (specify).*

Figure 5 shows the distribution of responses.<sup>3</sup> The most common response was option 3. Overall, approximately 75% of respondents who replaced an existing water heater would be classified as lost opportunity measures and approximately 25% are classified as retrofit.

Figure 5: Motivation to Install Responses

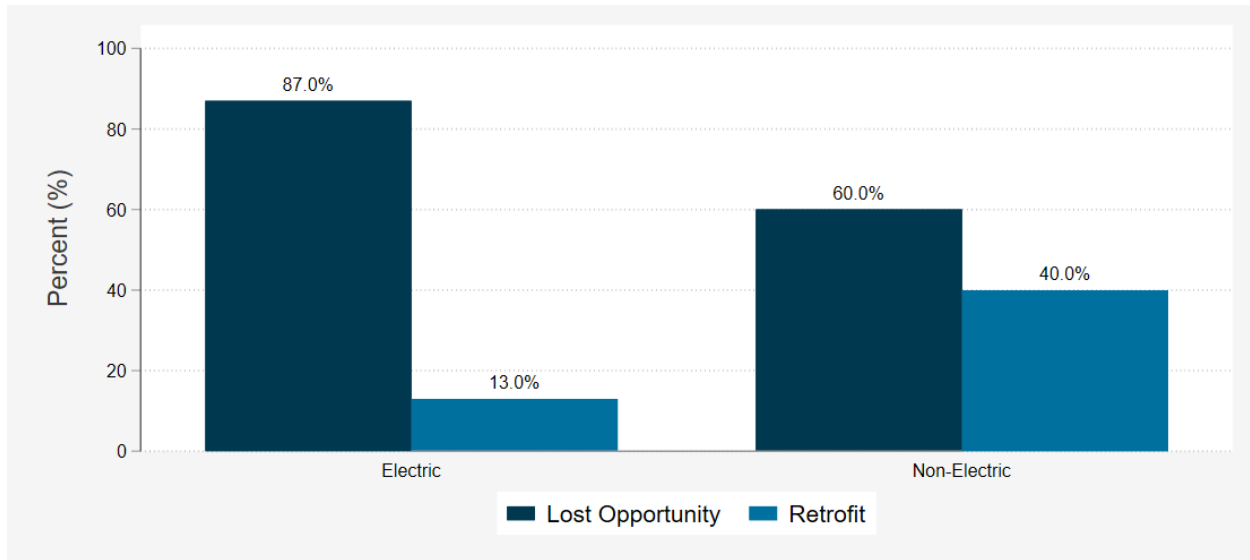


### 3.2.2.3 Decision Type by Baseline Fuel

Figure 6 shows the distribution of decision type by baseline fuel. Respondents whose baseline fuel was non-electric were approximately three times more likely to be in the retrofit bin than respondents whose baseline fuel was electric.

<sup>3</sup> Respondents who replied "Other" to the question about replacement type were not asked the motivation question. Based on their open-ended responses to the replacement type question, most of these respondents were mapped to retrofit. These respondents are not included in the summary figure.

Figure 6: Decision Type by Baseline Fuel Type



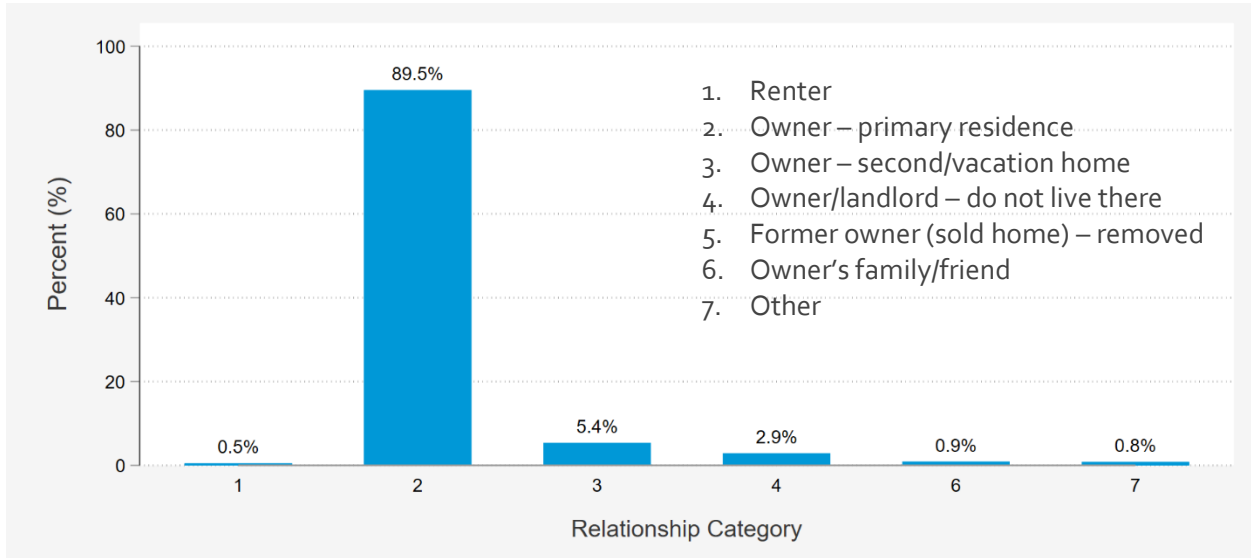
### 3.2.3 HOME CHARACTERISTICS

Participants were asked to describe their home in order to understand how the heat pump water heaters would be used. These questions also identified other recent changes to the house that might affect their household energy use, which is relevant for the AMI analysis.

#### 3.2.3.1 Relationship to Home

To determine how the participants use the property, they were asked about their relationship with the dwelling. Approximately 90% of the respondents indicated that they are the owner and the home is their primary residence. Another 8% are owners but do not live on the property full-time or they rent it out. By design, respondents that selected “former owner” did not continue with the rest of the survey. [Figure 7](#) shows the full distribution of responses. Relationships in the “other” category included property managers or owners who live in one unit but rent another unit on the property.

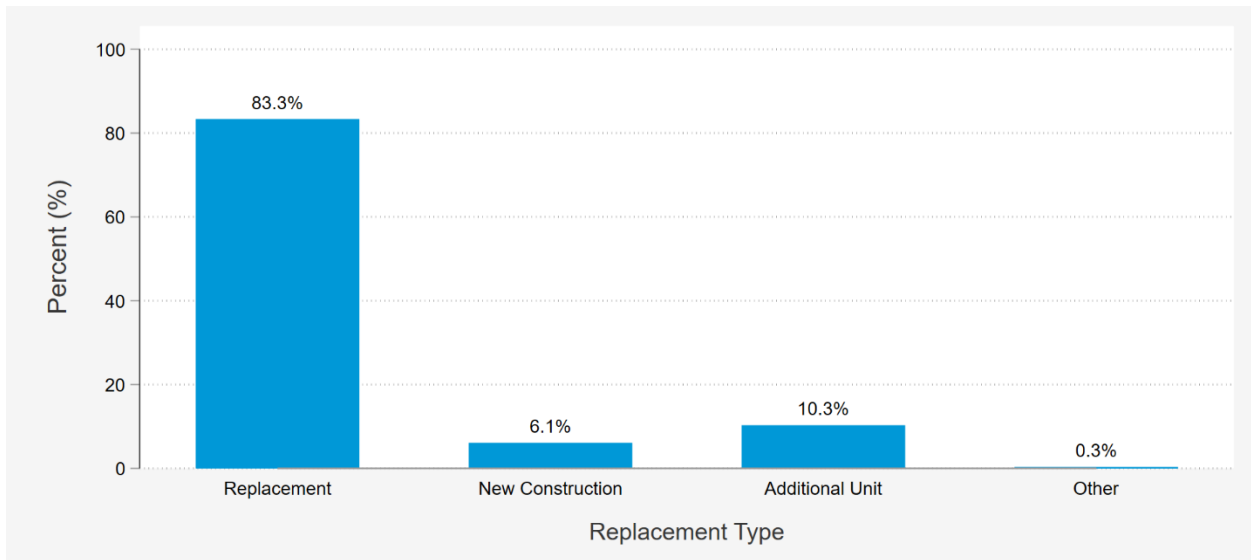
Figure 7: Relationship to the Home



### 3.2.3.2 Installation Type

Participants were asked whether the rebated HPWH replaced an existing water heater, installed the HPWH in a new home, or installed the HPWH to supplement another water heater. The distribution of responses is shown in Figure 8. Approximately 83% of respondents indicated that the HPWH replaced an existing water heater.

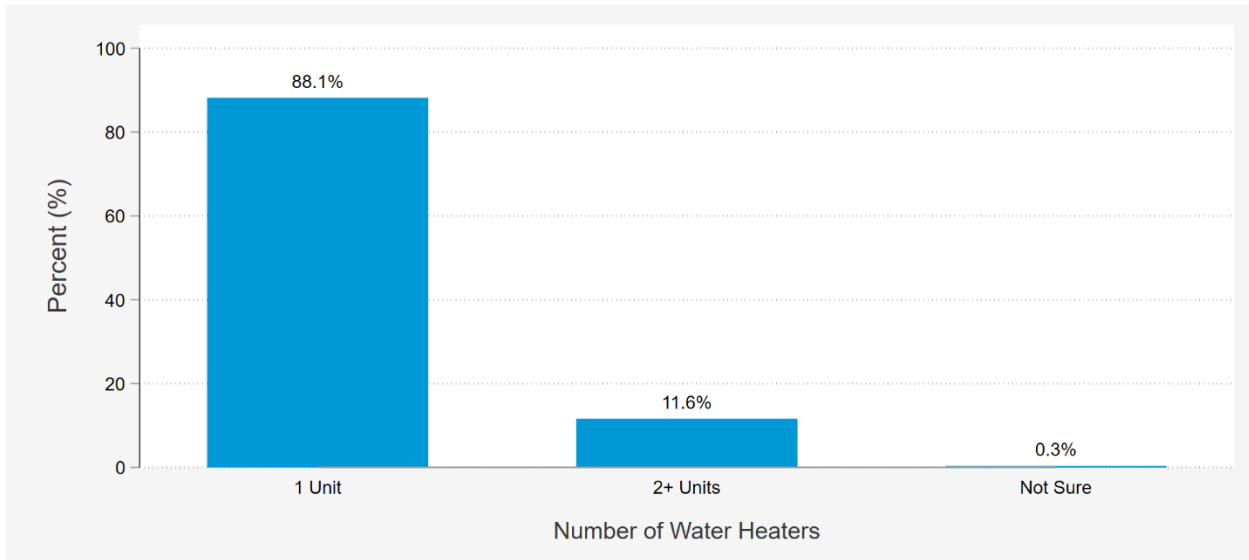
Figure 8: HPWH Installation Type



### 3.2.3.3 Number of Water Heaters in the Home

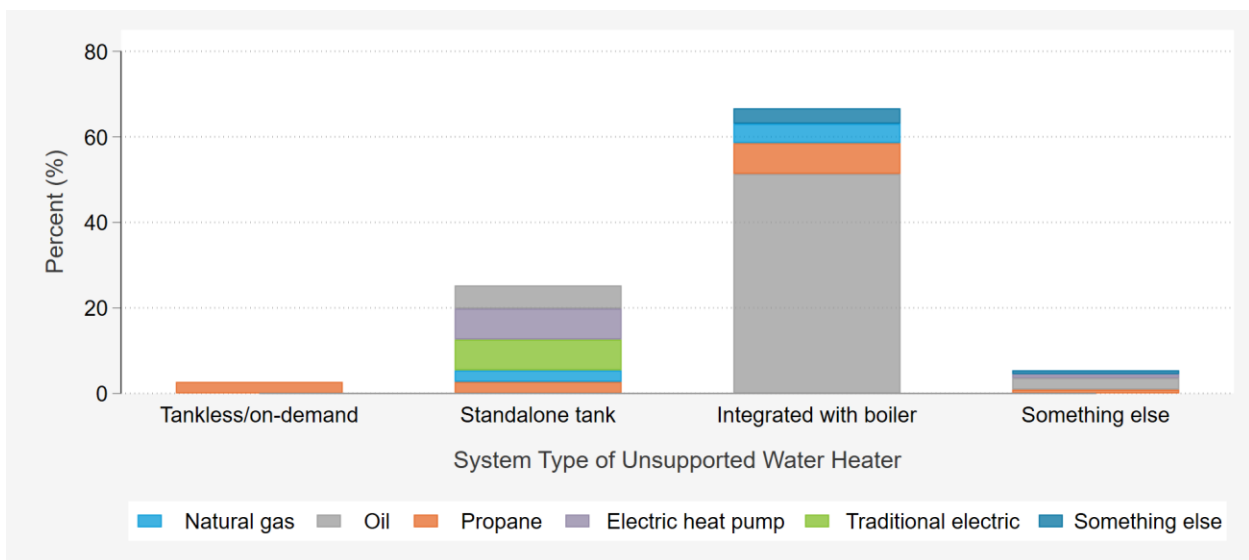
Figure 9 shows the percentages for the number of water heaters present in the home. Most participants only have one water heater (88%). Approximately 12% of respondents have more than 1 water heater.

Figure 9: Number of Water Heaters in Home



If a respondent said they have more than one water heater in their home, they were asked follow-up questions about the type and fuel of the other water heater. Figure 10 summarizes the responses to both questions. For the other water heater, 67% use a system that is integrated with their boiler and 25% use a standalone tank. Oil was the most common fuel for the other water heaters (51%). Another 19% use a different fossil fuel (propane or natural gas) and 16% use a form of electric water heater. Participants who recorded “something else” as their other fuel source mentioned solar, wood, or no other source.

Figure 10: Other Water Heaters in the Home

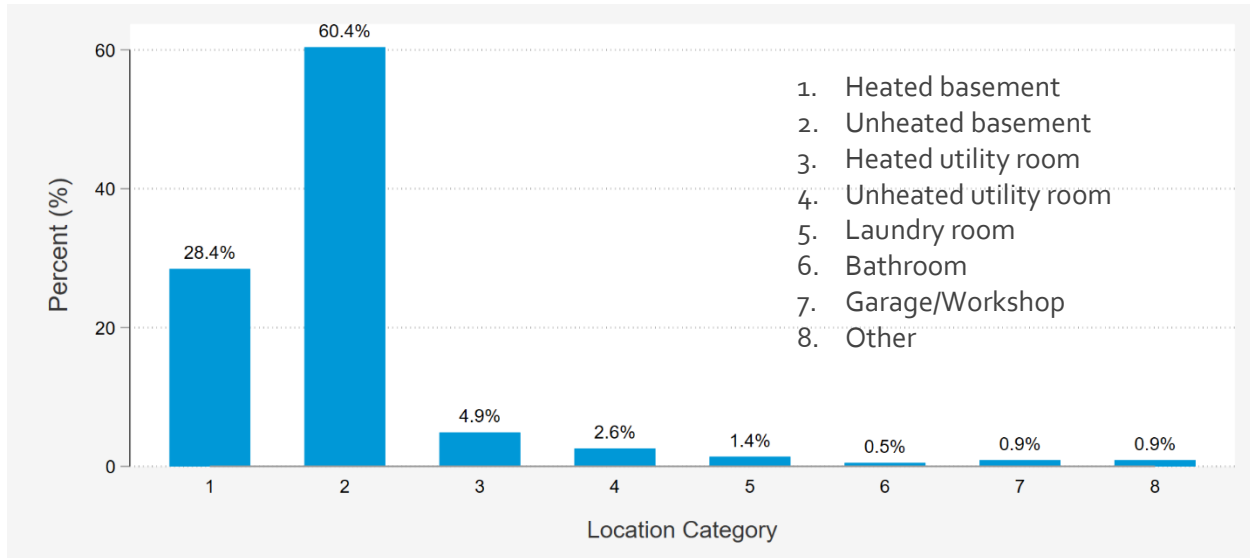


### 3.2.3.4 Location of Water Heater

We also asked where the HPWH was installed in the home. 88% of those who responded indicated that it was installed in the basement. Most of the basements were categorized as “unheated.” Figure 11

shows the percentages of all location options. For those who answered “other”, most stated the kitchen, a closet, or another room in the house. For premises with two or more water heaters, the distribution of the location for the secondary water heaters was similar to the location of the primary water heater.

Figure 11: Location of Primary Water Heater



### 3.2.3.5 Home Size

Participants were asked about the size of their home and the number of people who live there. Most of the homes (66%) were below 2,000 square feet, with the highest percentage in the 1,500 to 1,999 square feet range. Figure 12 shows the distribution of responses. Figure 13 shows the distribution of responses for the number of people who live at the residence. Most participants indicated that two people live in the home (54%).

Figure 12: Home Size

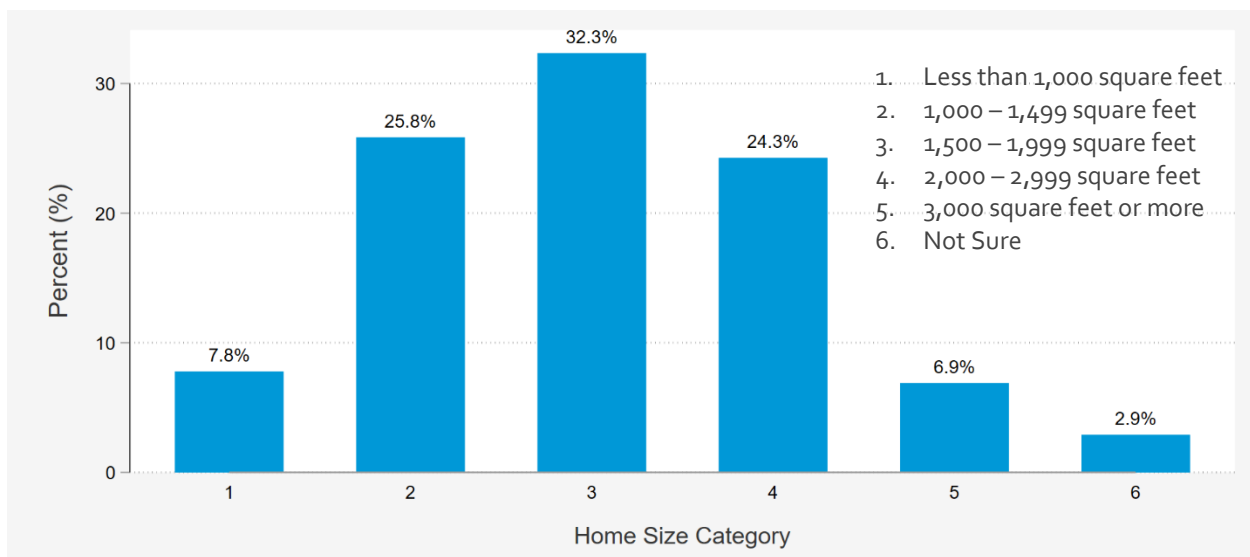
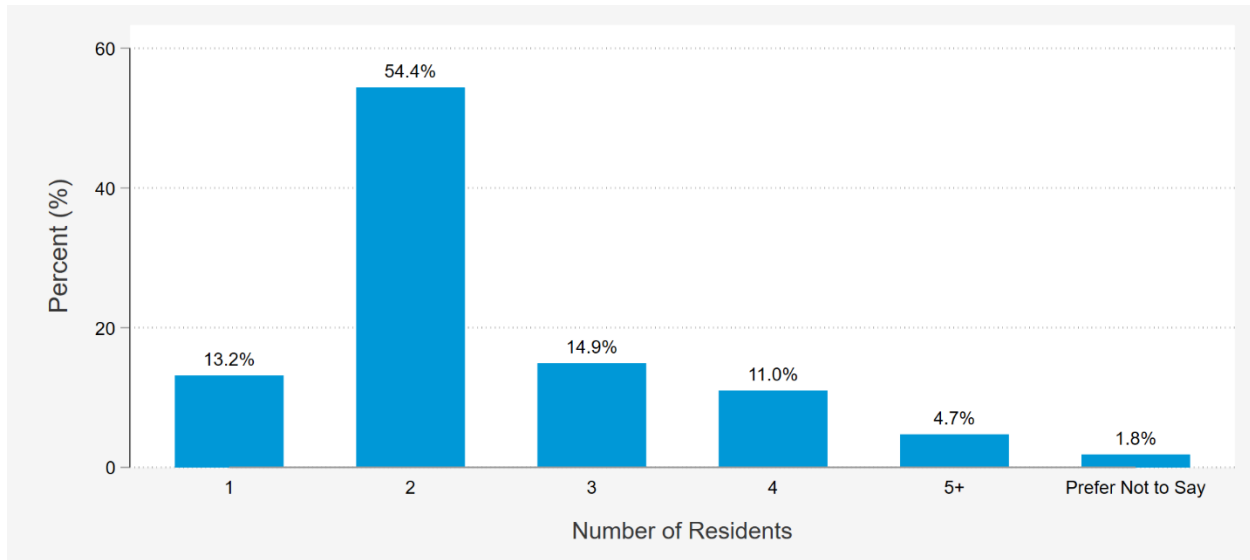


Figure 13: Number of Residents in Home



### 3.2.3.6 Self-Reported Household Income

Survey participants were asked to select the income range that best describes their adjusted gross household income. The income range options they could select from were based on the number of people living in their home, which was also self-reported. Table 22 shows the income options for each household size. We mapped Option 1 to Low Income, Option 2 to Medium Income, and Option 3 to High Income. Table 23 shows the distribution of responses by program pathway.

Table 22: Household Annual Income Ranges

Household Size	Option 1	Option 2	Option 3
1	\$0 - \$35,000	\$35,000 - \$70,000	\$70,000+
2	\$0 - \$46,000	\$46,000 - \$100,000	\$100,000+
3	\$0 - \$57,000	\$57,000 - \$100,000	\$100,000+
4	\$0 - \$68,000	\$68,000 - \$100,000	\$100,000+
5	\$0 - \$79,000	\$79,000 - \$100,000	\$100,000+
Prefer not to say	\$0 - \$50,000	\$50,000 - \$100,000	\$100,000+

Table 23: Distribution of Self-Reported Income by Program Pathway

Program Pathway	Self-Reported Income Bin <sup>[a]</sup>		
	Low	Medium	High
Mail-in – Retail	13.2%	31.9%	54.9%
Instant – Retail	23.1%	44.5%	32.4%
Instant – Distributor	12.6%	42.1%	45.3%
<b>Overall</b>	17.9%	42.2%	39.9%

<sup>[a]</sup> Respondents who declined selecting an income bin are not included in these percentages.

### 3.2.3.7 Home Changes and Load Modifiers

Participants were asked about work that was completed on their home in the last three years such as home additions, envelope improvements, and load modifiers like heat pumps and EV chargers. The most frequent responses were “installed heat pump” (48%), “none of these” (32%), and “major insulation work” (24%).<sup>4</sup> 16% of respondents indicated that they installed a solar PV array and 10% indicated that they installed an electric vehicle (EV) charger. The percentages for all options are shown in Table 24.

Table 24: Type of Work on Home in the Past Three Years

Type	% of Residents
Installed heat pump	47.8%
Major insulation work (attic, basement, wall insulation)	24.3%
Replaced majority of windows or doors	15.5%
Installed solar PV array	15.5%
Installed electric vehicle (EV) charger	9.5%
Installed induction stove	7.9%
Major addition (added living space)	5.6%
Installed heat pump clothes washer/dryer	3.3%
Installed hot tub or pool heater	3.2%
Home energy storage	2.5%
None of these	32.1%

### 3.2.4 OPERATION AND SATISFACTION

In this section, we present results concerning how the participants are using their HPWH as well as their level of satisfaction regarding installation and performance.

#### 3.2.4.1 Prior HPWH Familiarity

Participants came to the program with varying levels of knowledge about heat pump water heaters. 76.5% of responses indicated that they had prior knowledge of HPWHs before participating in the program. Table 25 shows the distribution of familiarity responses.

Table 25: Prior Knowledge of Heat Pump Water Heaters

Familiarity	% of Responses
I had not heard of heat pump water heaters.	10.1%
I heard about heat pump water heaters from friends or family but had no direct experience.	36.9%
I learned about heat pump water heaters from my own research.	30.3%

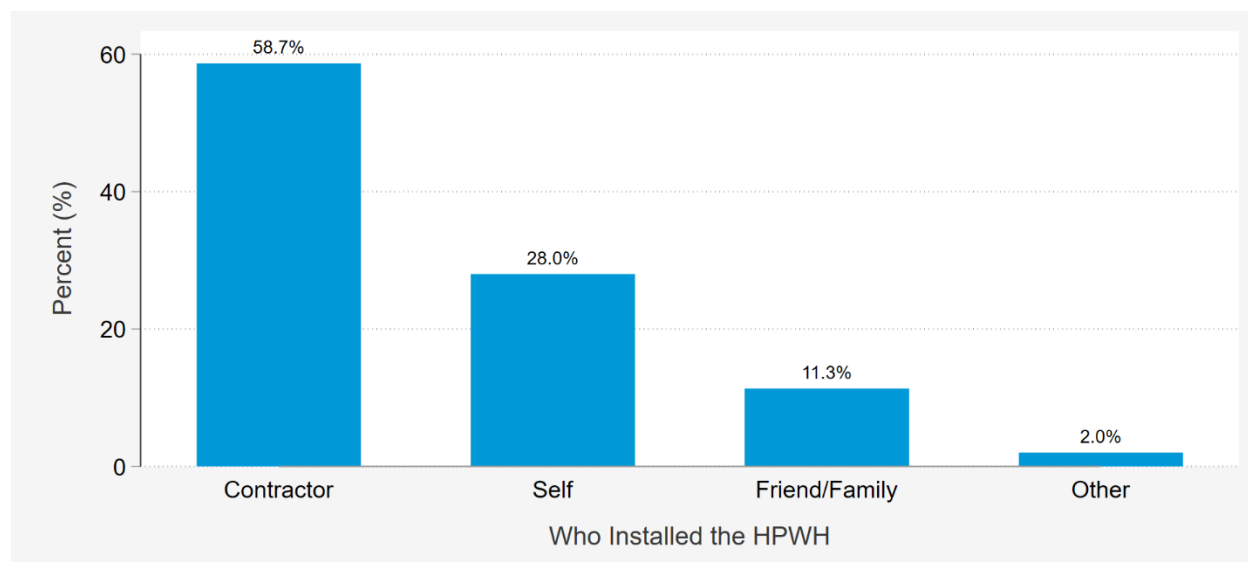
<sup>4</sup> The “none of these” response did not distinguish between those who did not do work on their home and those who did major work but the type of work was not one of the response options.

Familiarity	% of Responses
I learned about the heat pump water heaters from the rebate programs.	11.3%
I already had a heat pump water heater.	9.3%
I do not recall.	2.0%

### 3.2.4.2 Heat Pump Water Heater Installation

Most participants (59%) hired a contractor and over a quarter of respondents performed the installation themselves. The distribution of installers is displayed in Figure 14. Participants who responded with “other” were not asked to specify who they meant.

Figure 14: Who Installed the Water Heater?



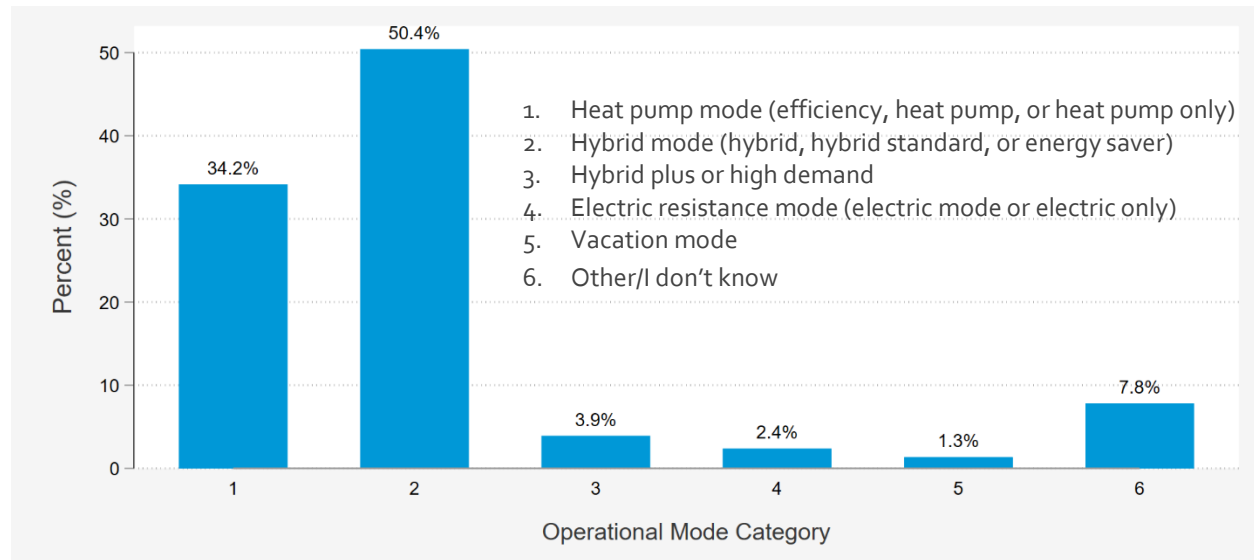
Of the participants who used a contractor to install their HPWH, 81% responded that they would recommend their installer to others and 6% would not recommend their installer. When those who responded negatively were asked why they would not recommend them, 68% stated that the contractor/plumber did not install the unit correctly or did not do what they requested. Another 26% mentioned the high cost or lack of transparency regarding the cost as their reason. Six people specifically stated that their installer had the rebate sent to themselves instead of the homeowner. Five of these six people participated through the Instant – Distributor pathway and it’s possible that the “rebate” terminology confused them. The sixth person participated through the mail-in pathway.

### 3.2.4.3 Operational Mode Understanding

HPWHs come with different operational modes that attempt to balance energy efficiency and hot water delivery. Operational mode nomenclature differs across the different manufacturers, but the efficiency options generally range from heat pump mode (most efficient) to electric resistance mode (least energy efficient but fastest hot water recovery). When we standardized the responses for each water heater manufacturer based on the function of the modes, we found that most participants (50%) set their units to the hybrid mode (variously named hybrid, hybrid standard, or energy saver mode).

The next most popular setting was the heat pump mode (variously named efficiency, heat pump, or heat pump only mode). The “electric only” mode was the least common response (1%). However, some participants indicated in an open-ended response that they would run out of hot water unless they used the electric mode. [Figure 15](#) shows the percentage distribution for all responses.

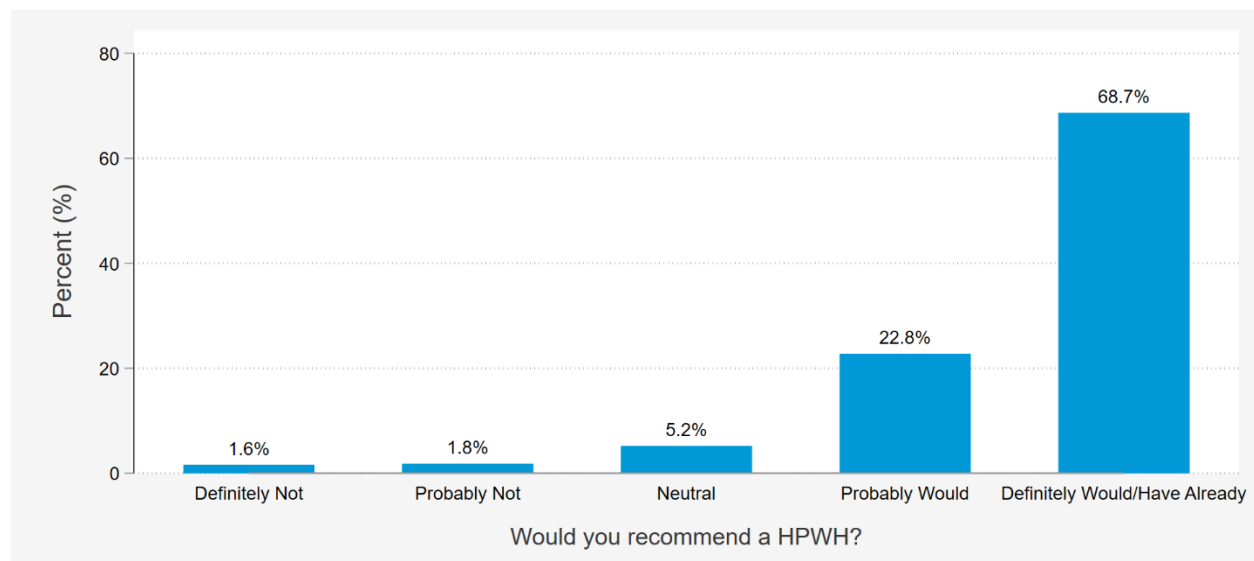
Figure 15: Operational Mode



### 3.2.4.4 Recommendation Likelihood

To determine participants’ satisfaction, we asked how likely they were to recommend HPWH to friends, family members, or neighbors. [Figure 16](#) shows the percentages for each level of likelihood. A majority responded that they would probably recommend HPWHs, would definitely recommend HPWHs, or have already recommended them (91%).

Figure 16: Recommendation Likelihood



Respondents who said they would “definitely not” or “probably not” recommend a HPWH were asked why they felt that way. Their reasons included insufficient hot water supply, repeated unit maintenance, and higher cost. Many stated that they were not saving money because the unit needs to be repaired often and they had to pay a charge for the labor. Based on the open-ended responses like “Very happy with the product”, “Saves money”, “We like the heat pump water heater”, it’s clear that some of the respondents misinterpreted the Likert scale.

### 3.3 IMPACT ANALYSIS

To estimate the energy impacts of program-supported HPWHs, we performed a pre/post AMI analysis for a sample of 252 premises that received a rebate or instant discount on a HPWH purchased between January 2023 and June 2024. We also metered a sample of 20 program-supported HPWHs. All homes included in the AMI analysis and metering sample responded to the participant survey discussed in Section 3.2. The objective of the AMI and metering analyses was to develop updated impact factors and per-unit savings assumptions for incorporation in Efficiency Maine’s Retail/Residential TRM. We summarize our data sources, modeling methods, and the results from our analysis in subsequent sections. Section 3.5 presents our TRM recommendations, which include updated per-unit savings values, updated impact factors, and slightly modified algorithms.

#### 3.3.1 SUMMARY OF FINDINGS

Table 26 shows our evaluated per-unit kWh and kW impacts and reported per-unit values. The reported per-unit values reflect an average across two different TRM savings schedules. The values in the “Blended Baseline” rows represent weighted averages of the impacts for homes with electric baselines and for homes with non-electric baselines. The realization rates in the “Blended Baseline” rows are somewhat misleading due to the weighted averaging. The realization rates for the electric and non-electric baseline rows are more representative of evaluation findings. Table 29 provides a lengthier discussion of realization rate drivers.

Table 26: Evaluation Results – Per-unit kWh and kW

Impact Factor		Reported (Evaluation Period)	Evaluated	Relative Precision (80% Confidence)	Realization Rate
ΔkWh	Electric Baseline	1,942	1,298	8.4%	66.8%
	Non-electric Baseline	-946	-862	13.6%	91.1%
	Blended Baseline	683	297	10.8%	43.5%
ΔkW <sub>sp</sub>	Electric Baseline	0.212	0.118	18.6%	55.7%
	Non-electric Baseline	-0.103	-0.040	47.8%	38.8%
	Blended Baseline	0.074	0.045	32.1%	60.8%
ΔkW <sub>wp</sub>	Electric Baseline	0.305	0.269	11.4%	88.2%
	Non-electric Baseline	-0.119	-0.130	22.6%	109.2%
	Blended Baseline	0.120	0.084	16.3%	70.0%

By baseline fuel, Figure 17 shows evaluated load shapes during the summer and winter peak periods. The top row shows the energy savings load shape for premises with electric baselines. For these premises, the HPWH is an energy efficiency measure. The bottom row of the figure shows the added kW load shape for homes with non-electric baselines. The left column isolates the summer peak period (with the peak hours highlighted in orange), and the right column isolates the winter peak period (with the peak hours highlighted in purple). The savings load shape and the HPWH load shape both follow the expected trajectory – peaks in the morning and evening and low overnight. The seasonal difference in the savings load shape is negligible, and the difference between summer and winter peak savings values is mostly attributable to the different peak periods (1-5 PM for summer, 5-7 PM for winter).

Figure 17: Peak Period Load Shapes by Baseline Fuel

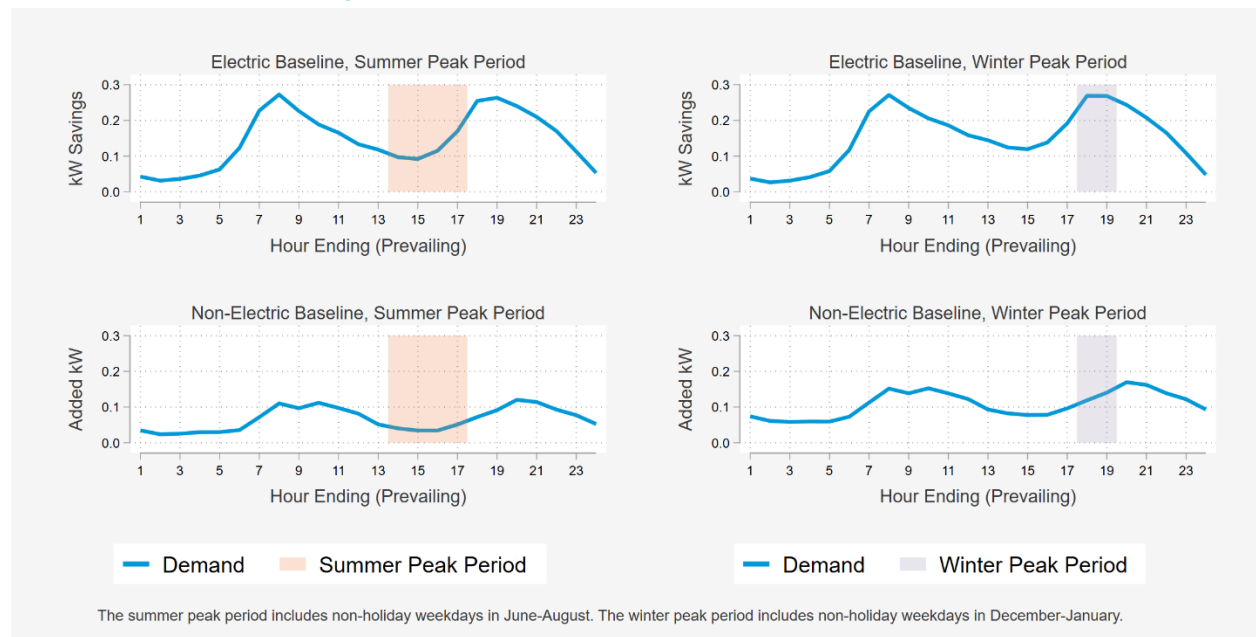


Table 27 shows our evaluated per-unit MMBtu impacts and current TRM assumptions. These MMBtu impacts represent the reduced fossil fuel consumption related to the electrification of household water heating load – they do not include MMBtu impacts related to the HPWH itself. “All-in” MMBtu impacts, inclusive of the reduced fossil fuel consumption and the MMBtu associated with the electricity use of the HPWH, are discussed below the table. As noted, the values in the “Blended Baseline” columns represent a weighted average of the impacts for homes with electric baselines and for homes with non-electric baselines. The relative precision for the MMBtu impacts is tied to the kWh/yr<sub>H<sub>WL</sub></sub> metric and does not account for uncertainty in the fuel shares that were estimated via the participant survey.

Table 27: Evaluation Results – MMBtu

Baseline Fuel	MMBtu Savings	Blended Baseline MMBtu Savings			
		TRM Value (Evaluation Period)	Evaluated Value	Relative Precision (80% Confidence)	Realization Rate
Natural gas	10.19	0.23	0.25	15.3%	109%
Propane	10.19	0.80	0.61	15.3%	76%
Oil	9.40	4.34	3.55	15.3%	82%
Kerosene	9.40	0.13	0.02	15.3%	15%
The savings values under the Blended Baseline column are weighted averages. For example, the 3.55 value is a weighted average of no oil savings (for homes with non-oil baselines) and 9.40 MMBtu of oil savings (for homes with oil baselines).					

Table 28 shows “all-in” energy impacts by baseline fuel, representative of both the energy impacts of the heat pump water heater itself (converted from kWh to MMBtu at a rate of 0.003412 MMBtu per kWh) and the MMBtu savings associated with reduced fossil fuel usage related to the electrification of the household domestic hot water (DHW). The average program participant saves 5.44 MMBtu annually by installing a heat pump water heater. Though not explicitly stated, the “all-in” MMBtu in the current TRM is 8.01. The realization rate for this all-in metric is 65%.





Table 28: Fossil Fuel Impacts – All-in at Site

Baseline Fuel	MMBtu Impact			Share of Participants
	From HPWH	From DHW Fuel Switching	Total	
Electric	4.43	0.00	4.43	53.6%
Natural gas	-2.94	10.19	7.25	2.5%
Propane	-2.94	10.19	7.25	6.0%
Oil	-2.94	9.40	6.46	37.7%
Kerosene	-2.94	9.40	6.46	0.2%
<b>Weighted Average</b>	<b>1.01</b>	<b>4.43</b>	<b>5.44</b>	<b>100.0%</b>

Finally, Table 29 discusses key drivers of the evaluation realization rates. The biggest driver is the kWh/y<sub>HWL</sub> metric. Our evaluated value, which is an output of the metering study, is approximately 54% of the prior value, which was drawn from West Hill Energy and Computing’s (WHEC) 2020 Heat Pump Water Heater impact evaluation report.<sup>5</sup>

<sup>5</sup> West Hill Energy and Computing. Heat Pump Water Heaters Impact Evaluation. Available at [https://www.energymaine.com/docs/WHEC\\_EMT\\_HPWH\\_Impact\\_Evaluation\\_Full\\_Report\\_with\\_Appendices\\_12\\_11\\_2019.pdf](https://www.energymaine.com/docs/WHEC_EMT_HPWH_Impact_Evaluation_Full_Report_with_Appendices_12_11_2019.pdf)

Table 29: Realization Rate Drivers

Impact Factor	Discussion
 kWh/y <sub>HWL</sub>	<p>kWh/y<sub>HWL</sub> represents the energy required to serve the annual water heating load and is a key input for many of the TRM algorithms. The 2020 WHEC evaluation assumed an annual water heating load of 2,821 kWh, which was adapted from the 2015 Residential Energy Consumption Survey. Our evaluated kWh/y<sub>HWL</sub> value, which is based on results from the metering study, is 1,534.</p>
 EAF <sub>EE</sub>	<p>The efficiency adjustment factor (EAF) is the ratio of field-based measurements of HPWH efficiency to rated HPWH efficiency. The prior evaluation found an EAF of 0.88, while we found an EAF of 0.50. There are two key drivers of our EAF. First, many of the metered HPWHs operate in hybrid mode, which blends heat pump mode (very efficient) with electric resistance mode (inefficient). Second, rated efficiency values assume more hot water usage than what we observed in the field. Standby losses occur when hot water usage is low, decreasing efficiency.</p>
 EAF <sub>Base</sub>	<p>The prior evaluation and current TRM algorithms do not apply an efficiency adjustment factor to the baseline water heater efficiencies. However, baseline water heaters can have standby losses just like HPWHs do. We apply an adjustment factor to the baseline efficiencies in our study, which increases the savings.</p>
 Decision type	<p>“Decision type” refers to whether the HPWH replaced a functioning water heater (“retrofit”) or not (“lost opportunity”). Prior evaluation results are based on a split of 19% retrofit and 81% lost opportunity. Based on findings from our participant survey, we used a split of 13/87 for electric baseline homes and a split of 40/60 for non-electric baseline homes. This change led to increased savings for the average electric baseline home and increased electrification loads for the average non-electric baseline home.</p>

### 3.3.2 DATA SOURCES

#### 3.3.2.1 Rebate Data

The pre/post analysis was performed on a sample of premises that received a rebate for a HPWH purchased between January 2023 and June 2024. In total, Efficiency Maine provided discounts for 14,742 heat pump water heaters during this period. This count does not include any units that were rebated through the Low-Income Direct Install (LIDI) program. Those units are covered in [Section 6.1](#).

In addition to energy and demand savings values, program tracking data also included information about the installed equipment, such as the make and model, and information about the rebate recipient (name, email address, and physical address). The information about the recipient was used to map program participants to utility accounts. We merged the make and model information with the ENERGY STAR qualified products list (QPL) to obtain additional information about the rebated units, such as storage volume, uniform energy factor (UEF), and expected annual electricity use. [Table 30](#) provides averages for these three variables for the full rebate population, the AMI analysis sample, and

the metering sample. The QPL also contains information regarding HPWH draw pattern. Over 90% of the rebated HPWHs have a “medium” draw pattern.

Table 30: HPWH Specs

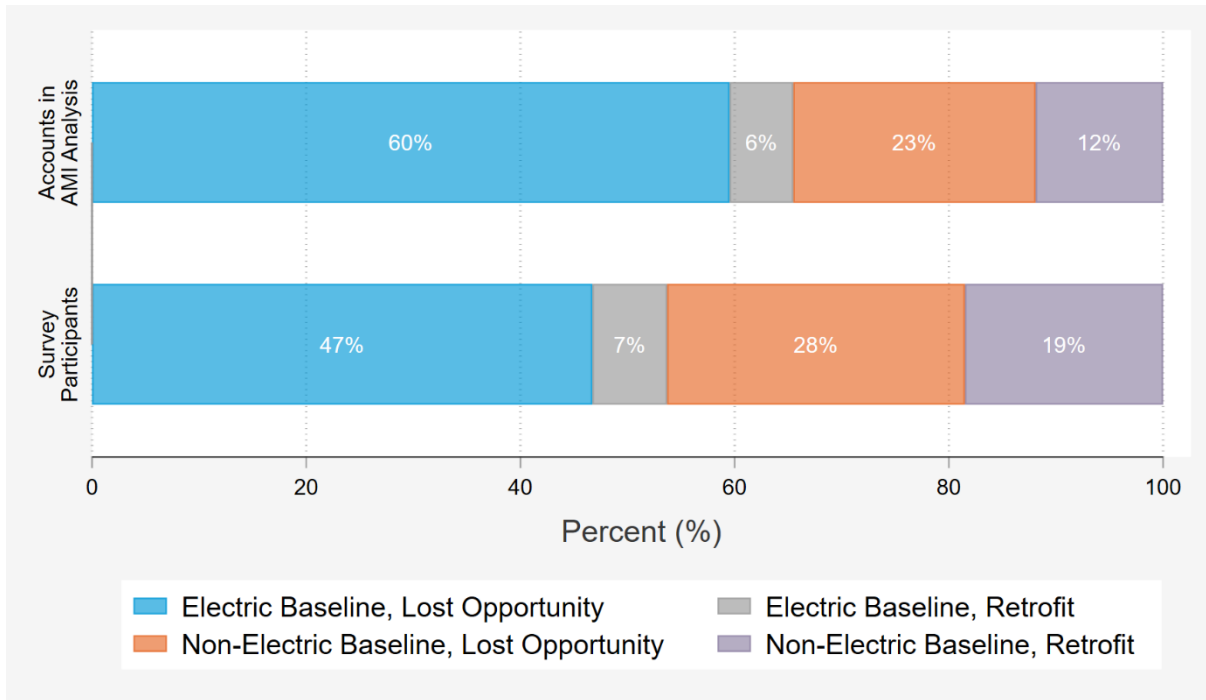
Variable	Average for...		
	Rebate Population	AMI Sample	Metering Sample
Storage Size (gallons) <sup>[a]</sup>	47.1	46.2	45.8
Uniform Energy Factor	3.62	3.68	3.58
Annual Electric Use (kWh/year)	919	898	927
<sup>[a]</sup> Rated capacity is shown here and in the ENERGY STAR QPL. Rated capacity is typically a few gallons less than normal capacity (e.g., a “50-gallon” HPWH may have a rated capacity of 47 gallons).			

In addition to the HPWH rebate data, we also used heat pump rebate data and electric vehicle (EV) rebate data for the analysis. The heat pump and EV rebate data was used to filter out premises that installed a heat pump or purchased an EV within one year of purchasing the HPWH, as these other load modifiers would make it difficult to isolate the effect of the HPWH.

### 3.3.2.2 Survey Data

As part of our evaluation, we fielded a web-based participant survey. The survey is discussed in greater detail in [Section 3.2](#). The survey was instrumental to our AMI analysis, as we used participant responses to map each respondent to one of four baseline bins: electric retrofit, electric lost opportunity, non-electric retrofit, or non-electric lost opportunity. [Figure 18](#) shows the distribution of baseline bins for accounts in the AMI analysis and for respondents from the participant survey. Overall, most homes had an electric fuel baseline and were lost opportunity installations. The distributions differ because impacts for some categories (new construction, for example) cannot be measured through an AMI analysis. We weighted the results from the AMI analysis to reflect the baseline bin distribution of the survey participants.

Figure 18: Baseline Bins



The participant survey included several other questions that were also used as data points in our AMI analysis. The bullet list below describes some of these questions.

- **Replacement type.** Some HPWHs replaced existing water heaters (84%), some were installed in a new construction setting (6%), and some were installed in addition to an existing water heater (10%). New construction premises were removed from the AMI analysis.
- **Other home modifications.** We probed for other changes that were made at the home, such as the installation of heat pumps, solar panels, or the addition of an EV. Homes that installed a heat pump or purchased an EV within a year of their HPWH installation were removed from the analysis. Likewise, homes that installed solar panels prior to or within a year of their HPWH installation were removed from the analysis.
- **Operation mode.** HPWHs have different operation modes, ranging from heat pump only (most efficient) to hybrid mode to high demand mode (least efficient). We used self-reported operation mode to explain differences in annual impact estimates from the AMI analysis.
- **Occupancy and living square footage.** These variables were primarily used to explain differences in annual impact estimates from the AMI analysis.

### 3.3.2.3 Interval Data

We requested hourly interval data for all 1,002 survey respondents and for a sample of 10,000 homes that have not received a HPWH rebate. The latter group was used to develop a matched control group. In total, we received interval data for 899 of the 1,002 participants and for 9,794 of the comparison homes. This section provides summaries of the interval data. Note these summaries are not weather-normalized. Additionally, only premises included in the final analysis file are included in the summaries.

Figure 19 and Figure 20 show average daily consumption throughout the analysis window for the electric baseline accounts and non-electric baseline accounts, respectively (see the blue line in each figure). Note these figures represent a blend of pre-HPWH and post-HPWH data. The purple area in the background shows average daily temperature (see the secondary Y axis on the right side of the figure). Most spikes and dips in consumption can be traced to similar spikes in weather conditions. Figure 19 shows a steady decrease in daily consumption over time, consistent with homes replacing electric resistance water heating with HPWHs, and Figure 20 shows a steady increase in daily electric consumption consistent with the electrification of DHW loads.

Figure 19: Average Daily Consumption in Time, Electric Baseline Accounts

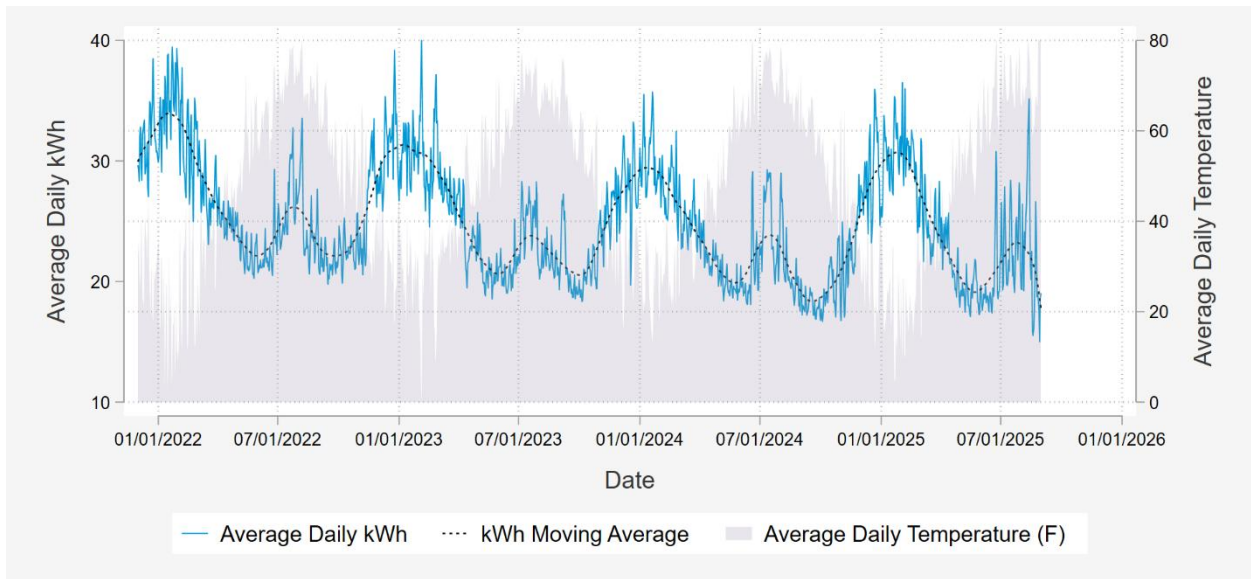


Figure 20: Average Daily Consumption in Time, Non-Electric Baseline Accounts

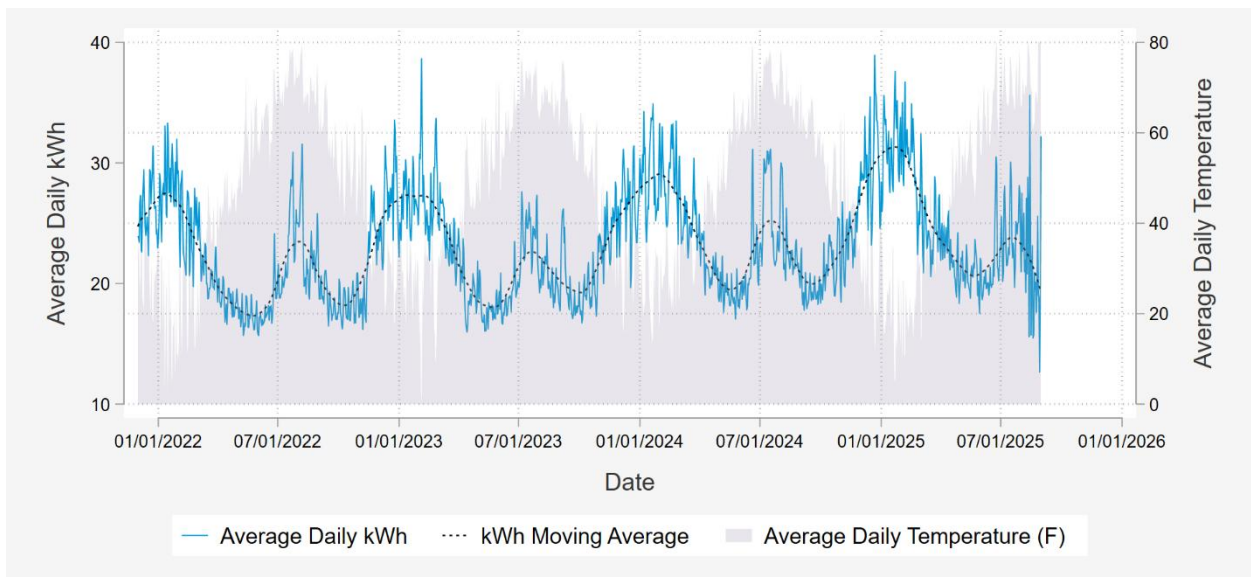


Figure 21 and Figure 22 show average hourly load shapes by month and period (pre HPWH and post HPWH) for the electric baseline accounts and non-electric baseline accounts, respectively. For the electric baseline participants, post-HPWH efficiency savings are evident throughout the day. Among the non-electric baseline participants, the delta between pre-HPWH demand and post-HPWH demand is the HPWH itself, but recall that these load shapes are not weather normalized. Normalized figures are shown in Section 3.3.4.1.

Figure 21: Average Hourly Load Shape by Month, Electric Baseline Accounts

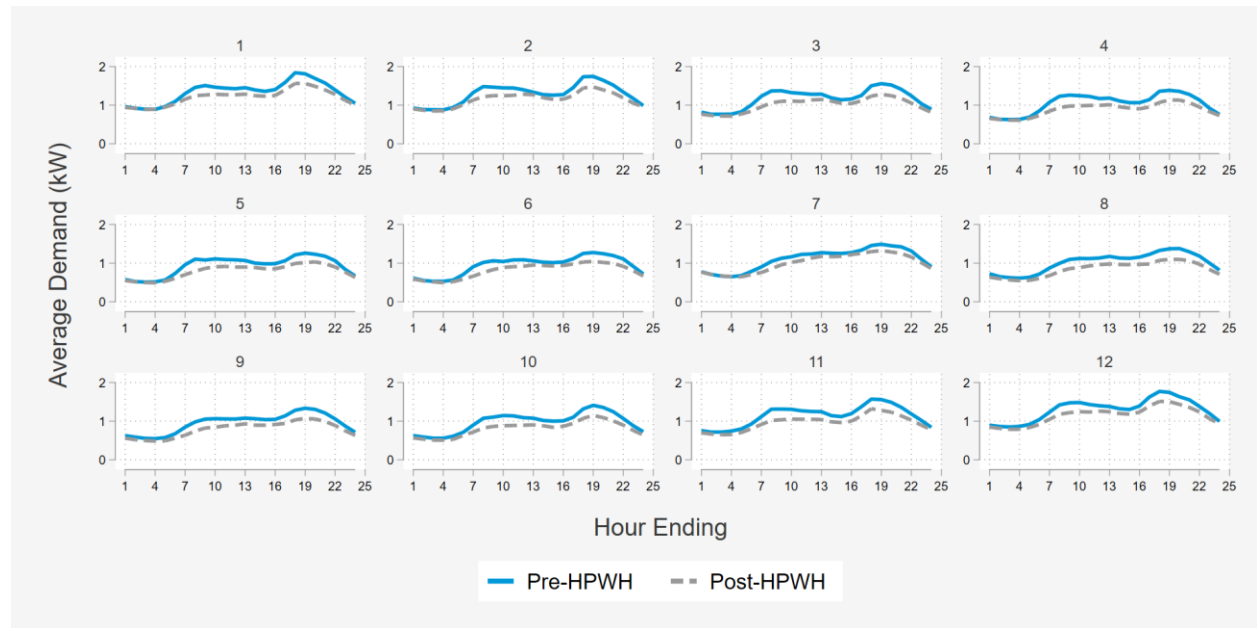
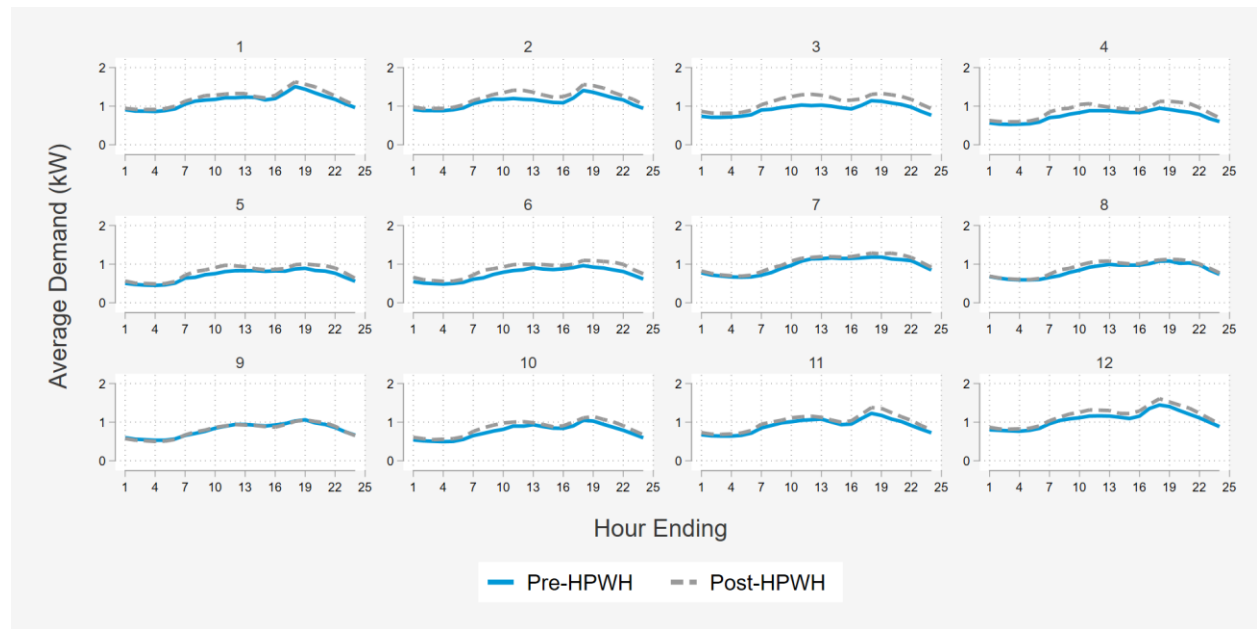


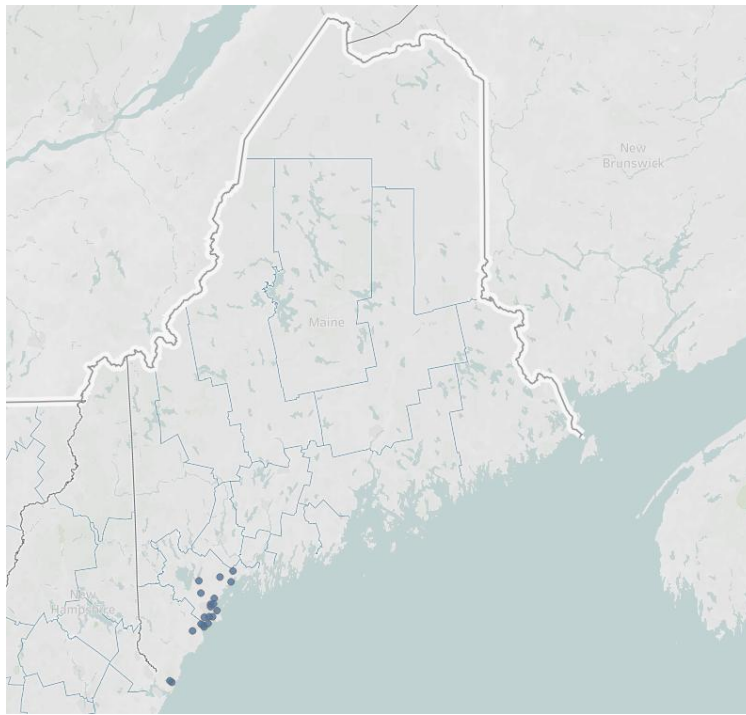
Figure 22: Average Hourly Load Shape by Month, Non-Electric Baseline Accounts



### 3.3.2.4 Metering Sample

For a sample of 20 program participants, we metered water flow, temperature difference, and electrical use of the program-supported HPWH. The participant survey (see [Section 3.2](#)) was used to recruit homes for the metering sample. [Figure 23](#) shows the geographic distribution of these 20 homes. Although the meters were installed entirely in southern Maine, we do not expect that DHW behavior would vary much by region. Additionally, impact estimates were weather-normalized to the entire state, and the interval data discussed in the previous section covered premises across the state. Meters were installed in February/March of 2025 and retrieved in September/October 2025.

[Figure 23: Geographic Distribution of Metering Sample](#)



### 3.3.2.5 Weather Data

Two different weather datasets were used in the analysis: (1) actual historical weather records to help understand the relationship between household electric consumption and weather, and (2) typical meteorological year (TMYx) weather data representative of a “normal” weather year in Maine.<sup>6</sup> Regarding the historical weather data, each home in the analysis was mapped to a weather station based on a zip-to-station map provided by Efficiency Maine. [Figure 24](#) shows the map with the weather station locations indicated by a black circle and the associated zip codes color-coded as shown in the legend.

Regarding the TMYx data, we developed a population-weighted 8760 TMYx profile using TMYx data from Portland, Bangor, and Caribou. The weights used were drawn from the Efficiency Maine TRM

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<sup>6</sup> Multiple variations of TMYx data are available at <https://climate.onebuilding.org/>. For the evaluation, we used the 2009-2023 version.

(Portland – 71.2%, Bangor – 23.4%, and Caribou – 5.4%). The population-weighted 8760 TMYx profile was used to produce weather-normalized impact estimates.

Figure 24: Zip-to-Station Map

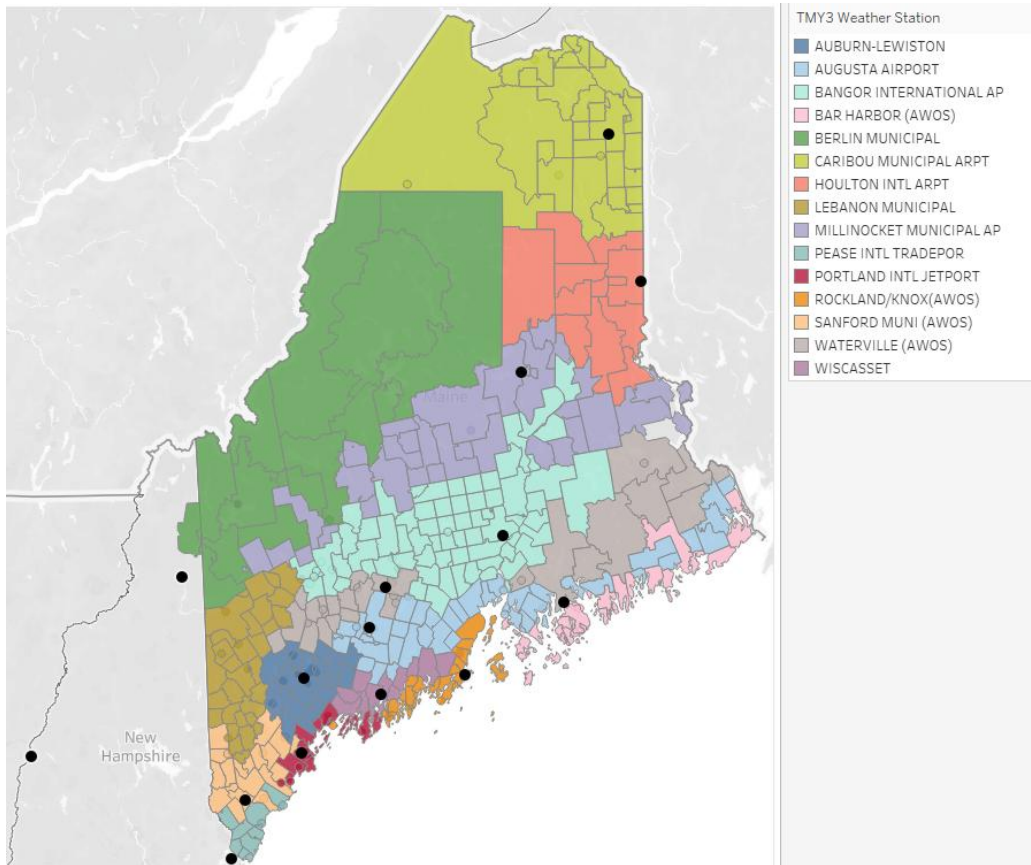
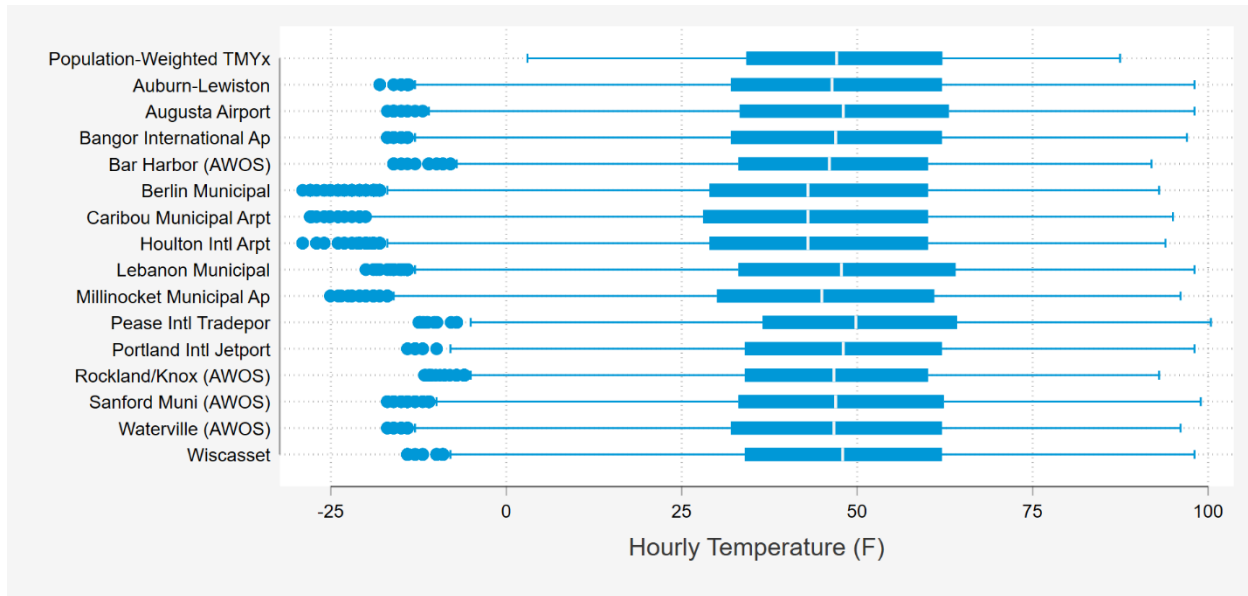


Figure 25 shows the distribution of hourly temperatures (January 2022 – June 2025) for each of the weather stations used in our analysis. The distribution is also shown for the weighted average TMYx profile. The white line in the middle of each box represents the median (or typical) hourly temperature, and each box runs from the 25<sup>th</sup> percentile of the temperature distribution to the 75<sup>th</sup> percentile. The population-weighted TMYx temperature range is smaller than the range of observed weather conditions for the individual stations, but this is because the TMYx temperatures are averaged across three stations to develop the population-weighted profile. This averaging reduces the range of the data.

Figure 25: Distribution of Temperature Records During Analysis Period



### 3.3.3 METHODS

Evaluation results draw from two primary analyses: a pre/post AMI analysis and a metering study. We marry the results from each analysis with TRM algorithms and assumptions regarding baseline water heater efficiencies to develop kWh, kW, and MMBtu impact estimates. Methods for the AMI analysis are discussed in [Section 3.3.3.1](#), and methods for the metering analysis are discussed in [Section 3.3.3.2](#). Results are provided in [Section 3.3.4](#), and TRM recommendations are provided in [Section 3.4](#).

#### 3.3.3.1 AMI Analysis

At a high level, we used a regression analysis to understand the relationship between household electric consumption, outdoor air temperature, and period (pre-installation or post-installation). Separate regression models were created for each premise, and then we cast the modeled relationship over a normal weather year. We used the weather-normalized results to produce estimates of annual energy impacts, winter and summer peak demand impacts, winter and summer coincidence factors, and energy period factors. Relative precision for each impact factor is estimated at the 80% confidence level. The following sections provide additional details.

##### 3.3.3.1.1 PREPARING THE INTERVAL DATA FOR ANALYSIS

In preparing the interval data for analysis, our goal is to isolate accounts where we expect that there is sufficient data for a pre/post comparison, there are no confounding load modifiers, and there are no data quality issues. Key steps in preparing the data include:

- Checking for zeroes, missing observations, and duplicates in hourly interval data. Days with missing observations or zero daily kWh are removed from the analysis.
- Create visualizations of average daily loads and the relationship between consumption and temperature to identify potential issues (like the summaries in [Section 3.3.2.3](#)).

- Review the distribution of account-level annual consumption (pre-enrollment and post-enrollment) and flag potential outliers.
- Review consumption patterns for homes that generate their own electricity (via solar panels).
- Merge in technology adoption dates; remove accounts with insufficient data for the analysis or with confounding technology installations (such as heat pumps, solar PV, or an EV).

Table 31 shows the number of accounts we removed from our analysis while reviewing and preparing the analysis dataset. Our final analysis dataset had 151 homes with an electric baseline, 75 homes with a non-electric baseline, and 26 homes that installed the HPWH as a secondary unit. A significant number of the homes in our AMI sample also installed heat pumps, solar panels, or purchased an EV during the analysis period. For these homes, a pre/post AMI analysis will confound the HPWH impact with the impact of the heat pump(s), EV(s), or solar panels. These homes were removed under the “Confounding load modifying technology” filter, which flags homes that (1) installed heat pumps within a year of installing the HPWH, (2) installed solar panels before or within a year of installing the HPWH, or (3) purchased an EV within a year of installing the HPWH.

Flagging the homes with confounding load modifiers relied on a mix of self-reporting (from the participant survey), cross-checking against Efficiency Maine heat pump and EV rebate data, and a review of daily and hourly load patterns for homes that were annual impact outliers. Homes with non-electric water heating baselines were more likely to have confounding load modifier issues (notably, heat pump installations) than homes that were already using electricity for water heating, as many of these homes with a non-electric water heating baseline electrify their space heating and water heating in tandem.

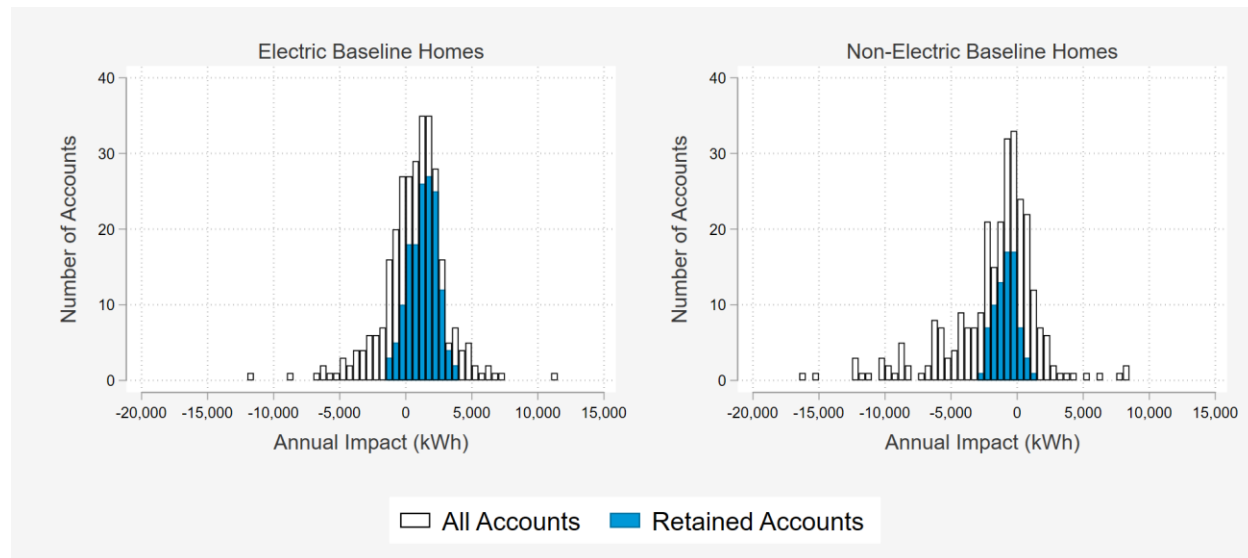
Table 31: Number of Accounts Removed from Analysis

Filter	Number of Accounts Remaining			
	Electric Baseline	Non-Electric Baseline	Additional Unit	Total
<b>Total accounts with AMI</b>	---	---	---	<b>899</b>
New construction or unknown baseline	381	356	97	834
Insufficient pre- or post-enrollment data (< 1 year)	341	318	86	745
Confounding load-modifying technology	163	89	34	286
Several days of zero load (> 5%)	160	88	32	280
High pre or post annual consumption (> 40,000 kWh)	160	88	32	280
Low pre or post annual consumption (< 3,000 kWh)	151	75	26	252
<b>Total accounts after filtering</b>	<b>151</b>	<b>75</b>	<b>26</b>	<b>252</b>

Though we removed the homes with confounding load modifying technology from reporting summaries, we did calculate annual impacts for them. Figure 26 shows the distribution of annual impacts for all homes with at least eight months of pre- and post-HPWH data. The left panel of the figure represents homes with electric water heating baselines, and the right panel represents homes with non-electric water heating baselines. Within each panel, the blue bars represent accounts that were not filtered out (n = 151 for electric baseline and n = 75 for non-electric baseline), and the

transparent/white bars represent all accounts (inclusive of the accounts that were not filtered out). The central tendency of the blue and transparent bars is similar across baseline fuels. Homes that installed heat pumps or purchased EVs predominantly fall in the left side of the “All Accounts” distributions.

Figure 26: Comparison of Results With and Without Load Modifier Filter



### 3.3.3.1.2 SELECTING A MATCHED COMPARISON GROUP

The goal in using a matched comparison group is to help control for exogenous factors that could affect energy consumption, like variation in supply rates and return-to-office mandates. To develop the matched comparison group, Efficiency Maine provided Demand Side Analytics (DSA) with approximately 3.5 years of interval data for a control pool of 10,000 accounts. Most of the control pool homes had not received a HPWH, heat pump, or EV rebate from Efficiency Maine (70%), but we also selected some homes that had received a heat pump rebate from Efficiency Maine for the control pool (30%) since many of the HPWH rebate recipients installed heat pumps a year or more prior to installing the HPWH.

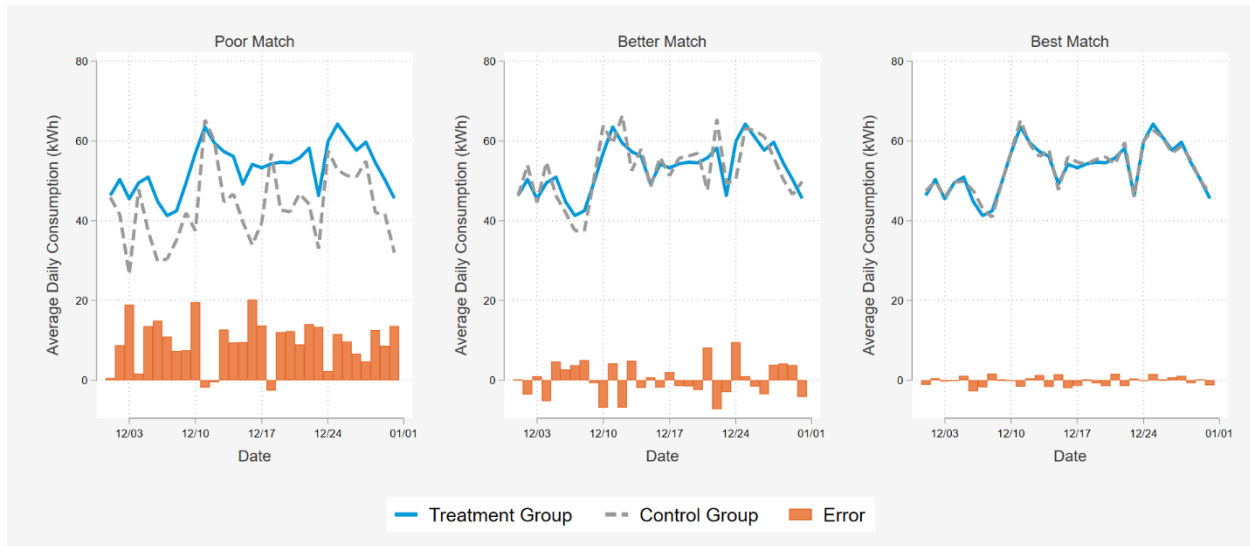
After preparing the interval data for analysis, our goal was to match each HPWH rebate recipient with one control pool account based on variables like:

- Weather-normalized annual consumption (pre-HPWH) or consumption bins
- Weather sensitivity of load or sensitivity bins
- Overnight demand (to identify homes with EVs)
- Average demand during ISO-NE summer and winter peak periods
- Geographic location

Using different combinations of the variables noted above, we made 30 different matched comparison groups. To determine which combination of variables can produce the best matched comparison group, we assessed the performance of each of the 30 matching models using a false experiment. In essence,

we ran a difference-in-differences model over a period when the HPWHs had not yet been installed. This allows us to assess the accuracy of the matching models and identify the one that is most accurate and unbiased. Figure 27 illustrates this approach for three hypothetical matching models. The right panel shows the “best” match in this illustrative example.

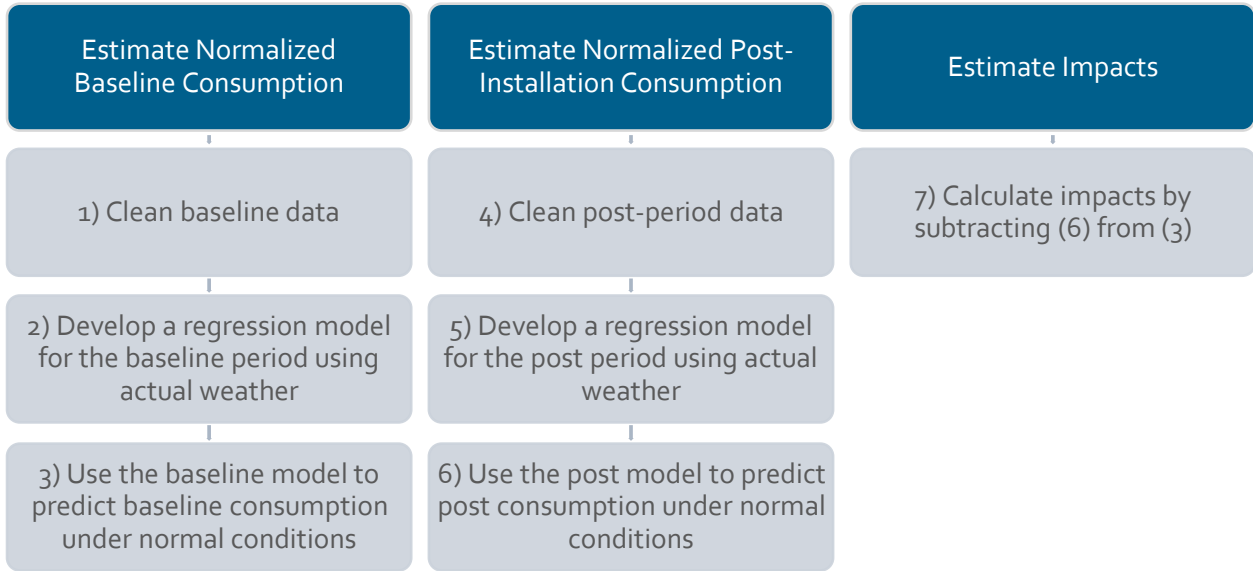
Figure 27: Hypothetical False Experiment Results



### 3.3.3.1.3 REGRESSION MODELING

Producing an estimate of the weather-normalized HPWH impact via a pre/post AMI analysis entails two steps. First, we model the relationship between pre-installation load and weather and cast this relationship over a “normal” weather year. We then repeat this process for the post-installation period. The weather-normalized impact is the difference between weather-normalized consumption in the pre and post periods. Additional details are below, and Figure 28 summarizes the process.

Figure 28: Developing Weather-Normalized Impacts



The general form of the regression model, as well as the set of independent variables used, follow LBNL's Time-of-Week Temperature (TOWT) Model. The dependent variable is hourly electric consumption from the utility revenue meter. Because the relationship between outdoor air temperature and electric demand may differ depending on the temperature level, we estimated the relationship for several separate temperature bins (effectively, piecewise regression). For the time-of-week variable, we used 168 categorical indicator variables – one for each hour of the week – that capture idiosyncratic patterns in occupancy and electric consumption. As noted, we developed separate models for each participant. We also developed separate models for each home in the matched comparison group. Comparison group homes inherit the in-service date from the participant they were matched to. Additional modeling methods are detailed in [Table 32](#).

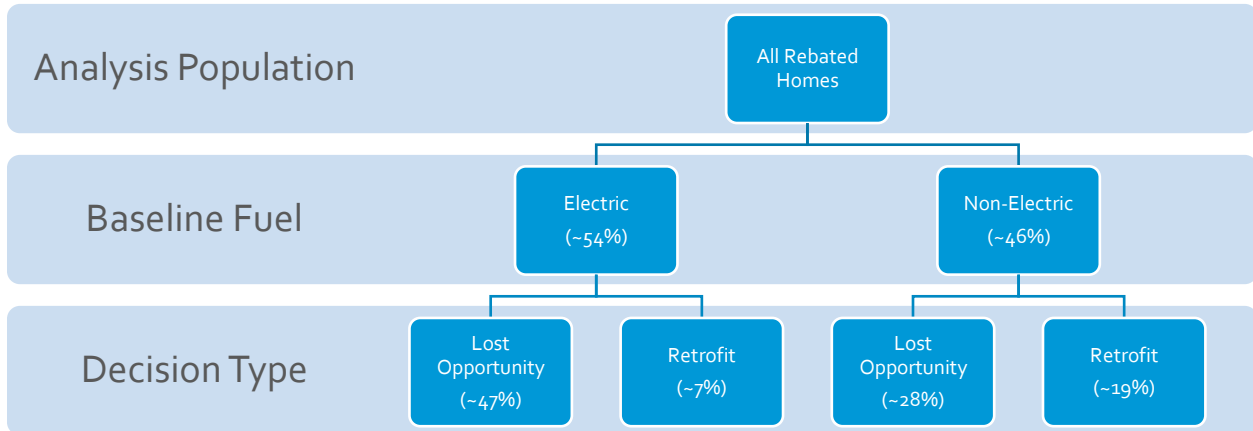
Table 32: Additional Details on Modeling Approach

Component	Modeling Approach
Blackout period	<p>The exact in-service date for each HPWH is not known. The purchase date is known for most records in the tracking data, but not all. For HPWHs that were rebated through the distributor pathway, the in-service date is likely very close to the purchase date. For others, the in-service date and purchase date may show greater variation.</p> <p><b>Approach:</b> To account for unknown in-service dates, we applied a blackout period (i.e., removed data) as follows:</p> <ul style="list-style-type: none"> <li>Records with a purchase date: We removed the two weeks immediately following the purchase date for HPWHs that went through the distributor pathway. For the others, we removed three weeks immediately following the purchase date.</li> <li>Records without a purchase date: We removed two weeks on both sides of the enrollment date for HPWHs that went through the distributor pathway. For the others, we removed three weeks on both sides of the enrollment date.</li> </ul>
Analysis timeframe	<p>Since the HPWHs were not all installed at the same time, each premise had a different number of pre-installation and post-installation days.</p> <p><b>Approach:</b> To balance the dataset, we kept one year of pre-installation data and one year of post-installation data. When trimming the data, we accounted for the blackout period (i.e., the blackout period is not part of the pre or post year).</p>
Netting out changes in comparison group consumption	<p>The matched comparison group was included in the analysis to help account for exogenous factors that could affect energy consumption.</p> <p><b>Approach:</b> A difference-in-difference approach was used:</p> $Diff_{Participant} = Post_{Participant} - Pre_{Participant}$ $Diff_{Comparison} = Post_{Comparison} - Pre_{Comparison}$ $Impact = Diff_{Participant} - Diff_{Comparison}$

### 3.3.3.1.4 BASELINE ADJUSTMENTS

Customer baselines were a primary concern for this analysis. There are two factors to consider when determining the correct baseline for each participant: decision type (retrofit or lost opportunity) and baseline fuel (electric or non-electric). Using responses from the participant survey, we placed each premise into one of the four bins at the bottom of [Figure 29](#). The weights shown in the figure were derived from the survey analysis (see [Section 3.2](#)).

Figure 29: Baseline Bins



In the pre/post AMI analysis, baseline consumption reflects whatever water heater was in place prior to installing the program-supported HPWH. For lost opportunity measures, the baseline is a code minimum or standard efficiency water heater rather than what was in place prior to the HPWH. For homes that had non-electric water heating, the pre/post analysis does not capture the reduction in fossil fuel consumption from the replaced water heater. For three of the four baseline bins in Figure 29, we supplemented the pre/post AMI analysis with engineering adjustments as follows:

- Electric baseline, lost opportunity measure.** A pre/post AMI analysis does not capture the correct baseline since the existing electric water heater would presumably be less efficient than a code-minimum new electric resistance water heater.<sup>7</sup> We used the following equation to adjust the savings estimates from the AMI analysis. In this equation,  $UEF_{HPWH}$  represents the UEF of the participant’s HPWH,  $UEF_{Code}$  represents the UEF of a code-minimum electric resistance water heater of the same size and draw pattern as the HPWH, and  $UEF_{Existing}$  represents the UEF of a code-minimum electric resistance water heater using the federal standard prior to 2015.

$$Adjusted\ AMI\ Savings = AMI\ Savings * \frac{UEF_{HPWH} - UEF_{Code}}{UEF_{HPWH} - UEF_{Existing}}$$

- Electric baseline, retrofit measure.** A pre/post AMI analysis captures the correct baseline. No adjustment is needed.
- Non-electric baseline, lost opportunity or retrofit.** A pre/post AMI analysis shows the added load related to the electrification of the household’s water heating. We did not adjust the electrification impact. However, the AMI analysis does not capture the reduction in fossil fuel consumption from the replaced water heater. We used the estimated energy required to provide annual hot water demand (from the metering results) and assumed baseline thermal efficiencies (from federal code) to estimate MMBtu savings.

<sup>7</sup> Federal codes and standards can be found here: <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C>

### 3.3.3.1.5 WEIGHTING

From the participant survey, we know most of the program-supported HPWHs replaced another DHW system, but some were installed in a new construction setting and some were installed in addition to an existing DHW system. However, new construction homes were excluded from the pre/post AMI analysis since these homes have insufficient pre-HPWH data. Some “additional unit” homes were included in the analysis, but a pre/post analysis can only measure added load – not energy savings against a code-minimum baseline – for these homes. Since the distribution of installation type for homes in the AMI analysis did not match the distribution for homes in the survey, we used analysis weights to align our AMI analysis results with the split of replacements, additional units, and new construction installations observed in the participant survey. By baseline fuel, Table 33 shows our weighting approach for the annual energy (kWh) and peak demand (kW) impact estimates.

Table 33: Weighting Approach for kWh and kW Impact Estimates

Baseline Fuel	Component	Weight <sup>1</sup>	Source
Electric	(1) Replacement – Retrofit	13%	AMI analysis
	(2) Replacement – Lost Opportunity	67%	AMI analysis with baseline adjustment
	(3) New Construction	8%	Weighted average of components (1) and (2) but with a baseline adjustment also applied to (1)
	(4) Additional Unit	12%	Same as (3) above
Non-Electric	(1) Replacement – Retrofit	40%	AMI analysis
	(2) Replacement – Lost Opportunity	49%	AMI analysis
	(3) New Construction	3%	Weighted average of components (1) and (2)
	(4) Additional Unit	8%	AMI analysis

<sup>1</sup> Weights are derived from the participant survey.

### 3.3.3.2 Metering Analysis

For a sample of 20 program-supported HPWH, we metered water flow, water temperature (supply and return), and electric use over a 9-month period spanning February 2025 to October 2025. We provide additional details regarding the metering set up in Section 6.2.1. We used the metering results to estimate annual electric consumption, annual heat delivered, annual gallons of water, and the coefficient of performance (COP) for each metered unit. Annual heat delivered is a key metric for the HPWH measure characterization in the Efficiency Maine TRM.

#### 3.3.3.2.1 MEASURING HEAT DELIVERED

For flows of hot (and cold) fluid where the temperature of the flow is changed, this equation calculates the change in energy in the fluid flow:

$$\Delta E = \dot{m} \cdot c_p \cdot (T_s - T_r)$$

Where:

- $\Delta E$  is the energy removed or provided
- $\dot{m}$  is the mass flowrate as determined by the volumetric flowrate and density of the fluid
- $c_p$  is the specific heat of the working fluid
- $T_s$  is the supply temperature
- $T_r$  is the return temperature

This equation simplifies based on heating water, a water  $c_p$  of 1 Btu/lb./°F, and a density of 8.34 lb./gal:

$$\Delta E = \text{flow} * 500.4 * (T_S - T_R)$$

Where:

- $\Delta E$  is the energy removed or provided in Btu/hr
- Flow is the volumetric flowrate in gallons per minute (gpm)
- 500.4 is the unit conversion of lb./hr per gpm (8.34 \* 60 minutes)
- $T_S$  is the supply temperature
- $T_R$  is the return temperature

For each HPWH in the metering sample, we metered the three necessary components of the formula above (flow,  $T_S$ , and  $T_R$ ), which enables the calculation of  $\Delta E$ . The heat added for a period is the heat rate in Btu/hr times the period in hours.

### 3.3.3.2.2 ANNUALIZING

For each HPWH in the sample, we used regression modeling to develop weather-normalized estimates of annual electric use, annual gallons of water used, and annual heat delivered. The modeling framework was similar to the TOWT framework used for the AMI analysis (see [Section 3.3.3.1.3](#)). The independent variables in the models were outdoor air temperature (specifically the average daily temperature) and time of week indicator variables (168 categorical indicator variables – one for each hour of the week – that capture idiosyncratic patterns in occupancy and HPWH load). We developed separate models for each metered premise.

After developing the regression models, we used the models to estimate annual electric use, gallons, and heat delivered during a typical weather year. TMYx data was used for the typical weather year profile (see [Section 3.3.2.5](#)).

### 3.3.3.2.3 COEFFICIENT OF PERFORMANCE

COP is calculated as the ratio of heat gain (in Btu) to total electricity consumption (converted to Btu). Using weather-normalized annual results from the regression analysis, we calculated the COP for each metered HPWH as follows:

$$COP = \frac{\text{Normalized Annual Water Loop Heat Gain (Btu)}}{\text{Normalized Annual Input kWh} * 3412 \left( \frac{\text{Btu}}{\text{kWh}} \right)}$$

### 3.3.4 RESULTS

Results for the AMI analysis are presented in [Section 3.3.4.1](#), results from the metering study are presented in [Section 3.3.4.2](#), MMBtu impacts are presented in [Section 3.3.4.3](#), and a comparison between AMI results and metering results is included in [Section 3.3.4.4](#). We combine the results across the AMI and metering studies with TRM algorithms to develop a full set of updated impact factors and per-unit impact estimates. We present the full suite of TRM recommendations in [Section 3.5](#). Evaluated per-unit savings values are shown in [Table 34](#) below. These per-unit values blend impacts across homes where the HPWH is an efficiency measure (53.6% of homes) and homes where the HPWH is an electrification measure (46.4% of homes).

Table 34: Evaluated Per-Unit Savings

Metric	Evaluated Value	Relative Precision at 80% Confidence
Annual Energy (kWh)	297	10.8%
Summer Peak Demand (kW)	0.045	32.1%
Winter Peak Demand (kW)	0.084	16.3%
Natural Gas (MMBtu)	0.25	15.3%
Propane (MMBtu)	0.61	15.3%
Oil (MMBtu)	3.55	15.3%
Kerosene (MMBtu)	0.02	15.3%

#### 3.3.4.1 AMI-Based Results

[Table 35](#) shows impact estimates by baseline fuel. Impacts for homes with an electric baseline are positive, as the HPWH is expected to produce energy savings related to an electric resistance water heater. Likewise, impacts for a non-electric baseline are negative since the HPWH represents added electric load. Estimates for reduced fossil fuel consumption for non-electric baseline homes are covered in [Section 3.3.4.3](#).

Table 35: Annual Energy and Peak Demand Impact Estimates

Baseline Fuel	Impact Factor	Evaluated Value	Relative Precision at 80% Confidence
Electric	$\Delta kWh$	1,298	8.4%
	$\Delta kW_{sp}$	0.118	18.6%
	$\Delta kW_{wp}$	0.269	11.4%
Non-Electric	$\Delta kWh$	-862	13.6%
	$\Delta kW_{sp}$	-0.040	47.8%
	$\Delta kW_{wp}$	-0.130	22.6%
Blended	$\Delta kWh$	297	10.8%
	$\Delta kW_{sp}$	0.045	32.1%
	$\Delta kW_{wp}$	0.084	16.3%

### 3.3.4.1.1 ANNUAL ENERGY IMPACTS

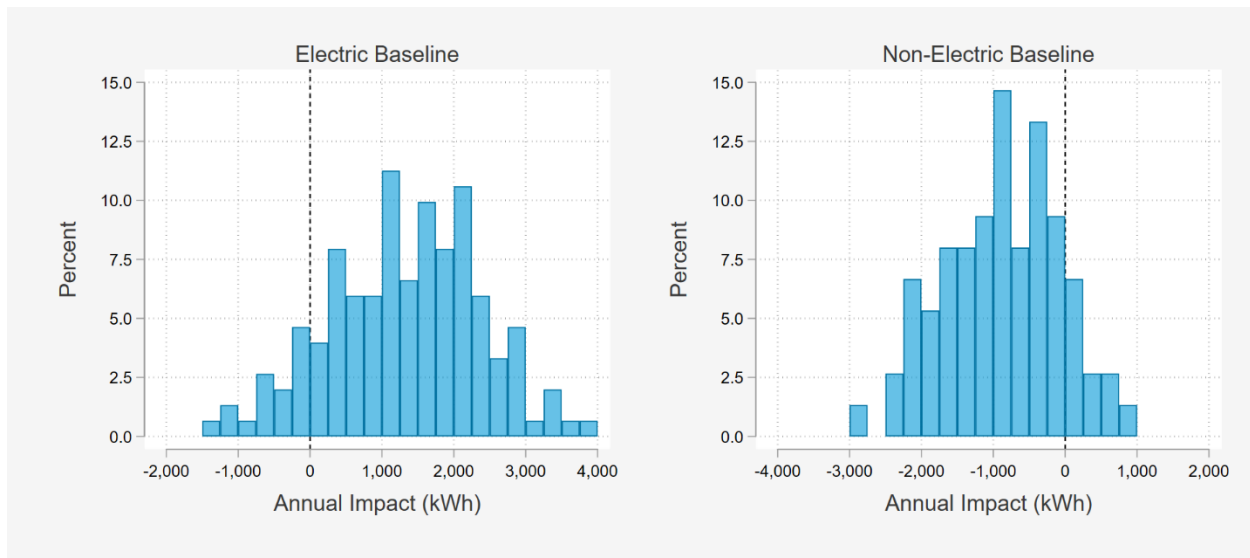
Table 36 shows the average impact estimate by baseline fuel and replacement type. For homes with an electric baseline, annual efficiency savings were 1,298 kWh on average. For homes with a non-electric baseline, the added electric energy use was 862 kWh on average. Using baseline fuel weights from the participant survey, the weighted average impact is 297 kWh savings per year.

Table 36: Annual kWh Impacts by Baseline Fuel

Baseline Fuel	Impact Estimate (kWh/yr)	Relative Precision at 80% Confidence	Share of Blended Baseline
Electric	1,298	8.4%	53.63%
Non-Electric	-862	13.6%	46.37%
<b>Blended Baseline</b>	<b>297</b>	<b>10.8%</b>	---

Figure 30 shows the distribution of weather-normalized annual impacts by baseline fuel. The central tendency of these figures is the focus. Impacts for individual homes are noisy, but the result is reliable on aggregate. That said, the tails of the distributions were reviewed for possible heat pump or occupancy interference. Homes with such issues were removed from the analysis (and are not included in the figure).

Figure 30: Distribution of Annual kWh Impacts by Baseline Fuel



### 3.3.4.1.2 PEAK DEMAND IMPACTS

Table 37 shows summer and winter peak demand impacts by baseline fuel. Our summer and winter peak definitions align with the peak period definitions in Efficiency Maine’s TRM.<sup>8</sup> Homes with an electric baseline reduced their water heating load by an estimated 0.118 kW during the summer peak window and 0.269 kW during the winter peak window. The difference between these two values is largely attributable to the difference in peak period definitions. The winter peak hours (5-7 PM) are more coincident with hot water usage than the summer peak hours (1-5 PM). Homes with a non-electric baseline added an estimated 0.040 kW during the summer peak window and 0.130 kW during the winter peak window. The difference between these values is attributable to (1) peak period definitions and (2) HPWHs using more energy in the winter than in the summer. On (2), we believe this is because ambient room temperatures and inlet water temperatures are lower during the cooler months, meaning more energy is required to heat the water.

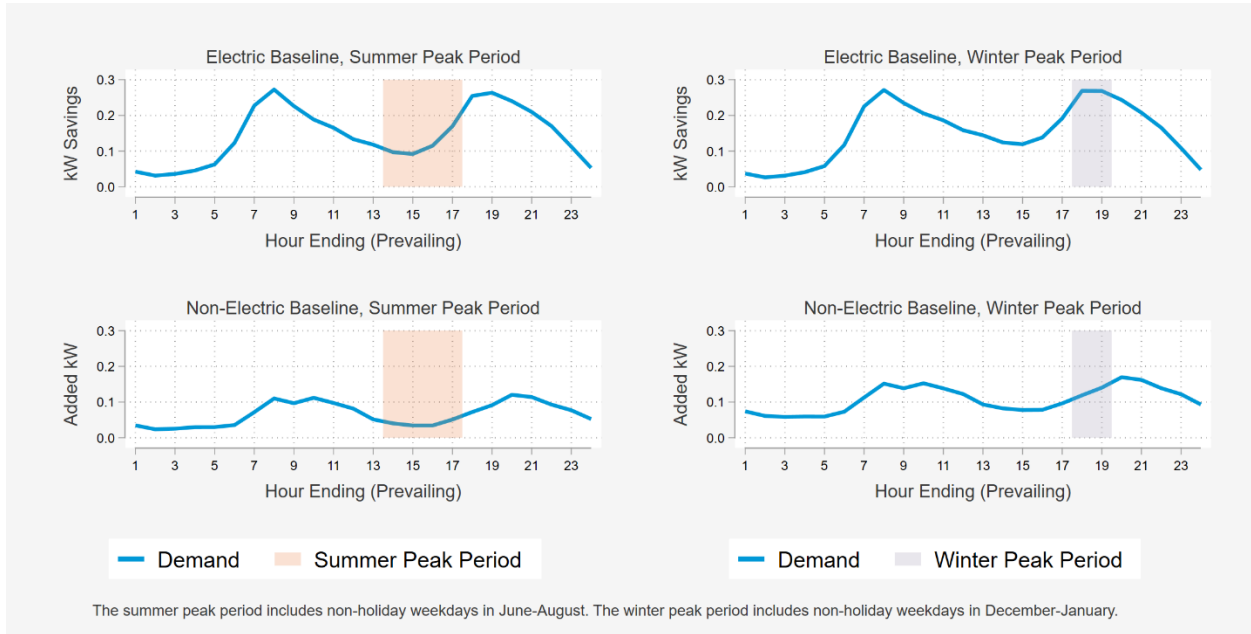
Table 37: Peak Demand Impacts by Baseline Fuel

Season	Baseline Fuel	Peak Demand Impact (kW)	Relative Precision at 80% Confidence	Share of Blended Baseline
Summer	Electric	0.118	18.6%	53.6%
	Non-Electric	-0.040	47.8%	46.4%
	<b>Blended Baseline</b>	<b>0.045</b>	<b>32.1%</b>	---
Winter	Electric	0.269	11.4%	53.6%
	Non-Electric	-0.130	22.0%	46.4%
	<b>Blended Baseline</b>	<b>0.084</b>	<b>16.3%</b>	---

By baseline fuel, Figure 31 shows load shapes during the summer and winter peak periods. The top row shows the savings load shape for premises with electric baselines, and the bottom row shows the added kW load shape for homes with non-electric baselines. The first column isolates the summer peak period (with the peak hours highlighted in orange), and the second column isolates the winter peak period (with the peak hours highlighted in purple).

<sup>8</sup> The peak definitions in the TRM align with the ISO-NE summer and winter peak definitions. Summer: 1:00 to 5:00 PM on non-holiday weekdays in June, July and August. Winter: 5:00 to 7:00 PM on non-holiday weekdays in December and January.

Figure 31: Peak Period Load Shapes by Baseline Fuel and Season

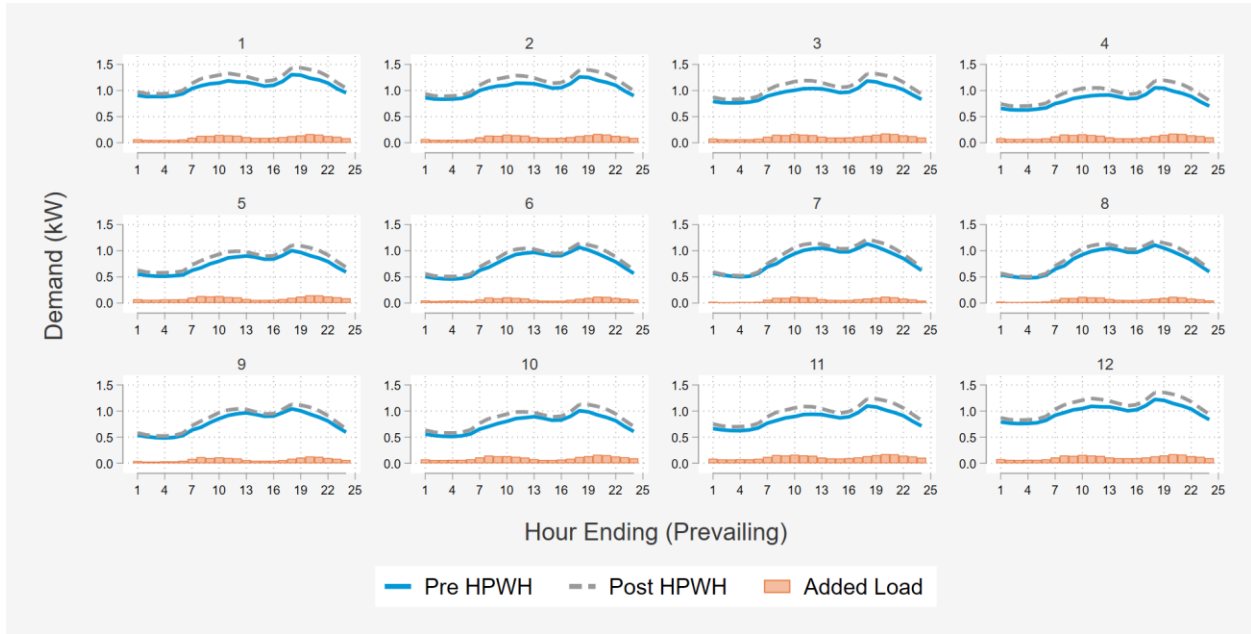


By month, Figure 32 and Figure 33 show weather-normalized load shapes for average pre-HPWH household consumption (blue line), average post-HPWH household consumption (gray line), and the HPWH load impact (orange bar). Figure 32 isolates homes with an electric baseline, and Figure 33 isolates homes with non-electric baselines. Load shapes are fairly consistent across months, showing both morning and evening peaks of similar magnitudes. This is true for both homes with savings (electric baseline) and added electric load (non-electric baseline).

Figure 32: Normalized Load Shapes by Month, Electric Baseline



Figure 33: Normalized Load Shapes by Month, Non-Electric Baseline



### 3.3.4.1.3 ENERGY PERIOD FACTORS

Table 38 shows energy period factors (EPFs) by baseline fuel and for the blended baseline scenario. In the blended baseline scenario, most of the impact occurs during the winter peak period. We aligned our energy period definitions with those in Efficiency Maine’s TRM<sup>9</sup>:

- **Summer off peak energy period:** 11:00 PM to 7:00 AM on non-holiday weekdays and all hours on weekends and holidays during June through September (4 months)
- **Summer on peak energy period:** 7:00 AM to 11:00 PM on non-holiday weekdays during June through September (4 months)
- **Winter off peak energy period:** 11:00 PM to 7:00 AM on non-holiday weekdays and all hours on weekends and holidays during October through May (8 months)
- **Winter on peak energy period:** 7:00 AM to 11:00 PM on non-holiday weekdays during October through May (8 months)

Table 38: Energy Period Factors

Period	Electric Baseline	Non-Electric Baseline	Blended Baseline
Summer off peak	12.4%	11.6%	12.0%
Summer on peak	19.7%	12.9%	16.6%
Winter off peak	28.7%	38.7%	33.4%
Winter on peak	39.2%	36.8%	38.1%

<sup>9</sup> See the Retail/Residential TRM link at <https://www.energymaine.com/about/library/policies/>

#### 3.3.4.1.4 SUBGROUP ANALYSIS

We used self-reported results from the participant survey to segment the AMI savings estimates. Specific grouping variables include household living area, household occupancy, whether the HPWH is in a heated or unheated space, self-reported income group, HPWH operational mode (heat pump only or not), and program pathway (distributor instant, retail instant, or retail mail-in).<sup>10</sup> Figure 34 shows annual impacts across subcategories for homes with an electric baseline, and Figure 35 shows annual impacts across subcategories for homes with a non-electric baseline. Subcategories with fewer than 15 homes are excluded from the figures, as are “I don’t know” and “Prefer not to say” categories. Recall that homes with electric and non-electric baselines have directionally opposite impacts since the HPWH is an efficiency measure for homes with electric baselines and an electrification measure for homes with non-electric baselines.

Noting that differences across subgroups of interest were not found to be statistically significant, key directional findings from the subgroup analysis include:

- On average, electrification loads were:
  - Higher for HPWHs located in unheated spaces compared to HPWHs located in heated spaces. We did not directly measure the interactive effects with the heating systems in the case of heated spaces, but the AMI analysis did capture interactive effects for the electric cooling/heating systems but not fossil fuel heating systems.
  - Higher for homes with more occupants
  - Higher for high-income households
- On average, efficiency savings were:
  - Higher in low-income households
  - Higher in homes that reported operating their HPWH in hybrid mode. While this finding seems counterintuitive, the selected mode is correlated with hot water usage. Participants who run their HPWH in hybrid mode tend to use more hot water, which means they also used more hot water with their previous electric resistance unit. While the percentage savings might be smaller than homes that operate in heat pump only mode, the absolute kWh savings are larger in homes that use more domestic hot water.

Using model numbers from the program tracking data, we were able to identify the storage volume (gallons) and UEF of each rebated HPWH. We examined the relationship between these two variables and the annual HPWH impacts. Findings from this comparison are:

- There were no directional findings from this comparison, largely due to the lack of variation in storage volume.

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<sup>10</sup> Income group is based on self-reported household income. Respondents were provided three income bins based on their household size and were asked to select the bin that their adjusted gross household income falls in.

- Larger UEFs generally produced greater savings for homes with electric baselines and smaller electrification loads for homes with non-electric baselines. The differences were not statistically significant.

Figure 34: Annual Impacts by Subgroup, Electric Baseline

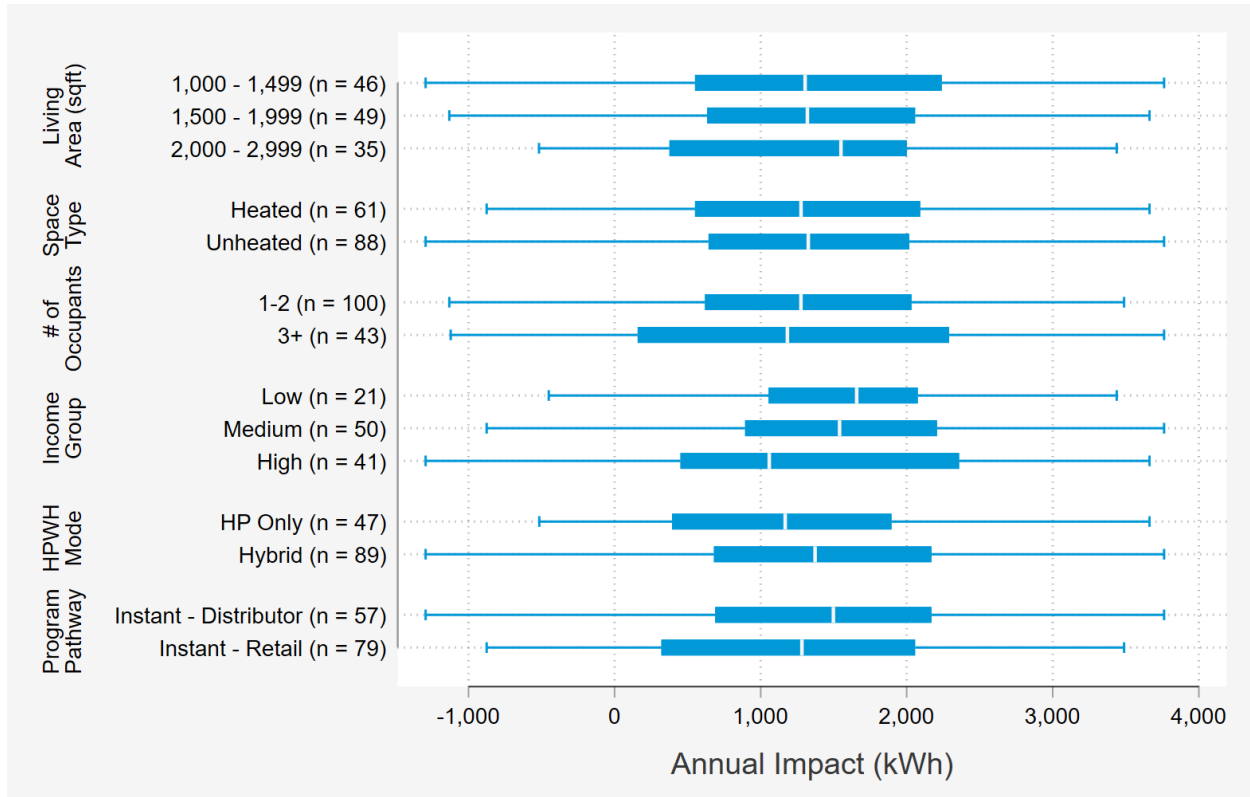
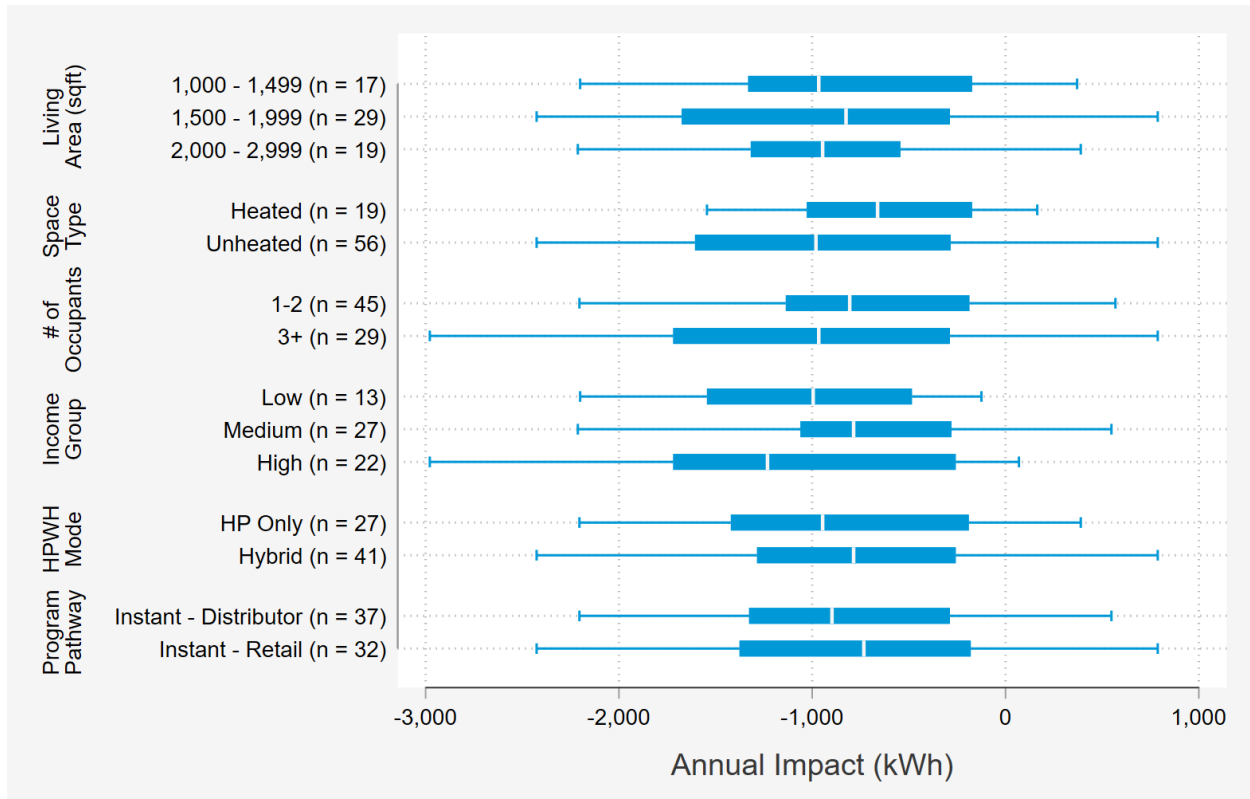


Figure 35: Annual Impacts by Subgroup, Non-Electric Baseline



### 3.3.4.1.5 MATCHED COMPARISON GROUP

Our best-matching model had six matching dimensions: cold weather sensitivity, weather-normalized annual consumption, 98th percentile of overnight load, average daily base load, average kW during ISO-NE summer peak, and average kW during ISO-NE winter peak. [Figure 36](#) visualizes average daily consumption in the participant and matched comparison groups over a period with enough pre-HPWH observations. (Homes in the matched comparison group inherit the pre-post transition date from the participant they are matched to.) Average daily consumption for the two groups shows strong alignment.

Figure 36: Average Daily Consumption Time Series, Pre-Enrollment

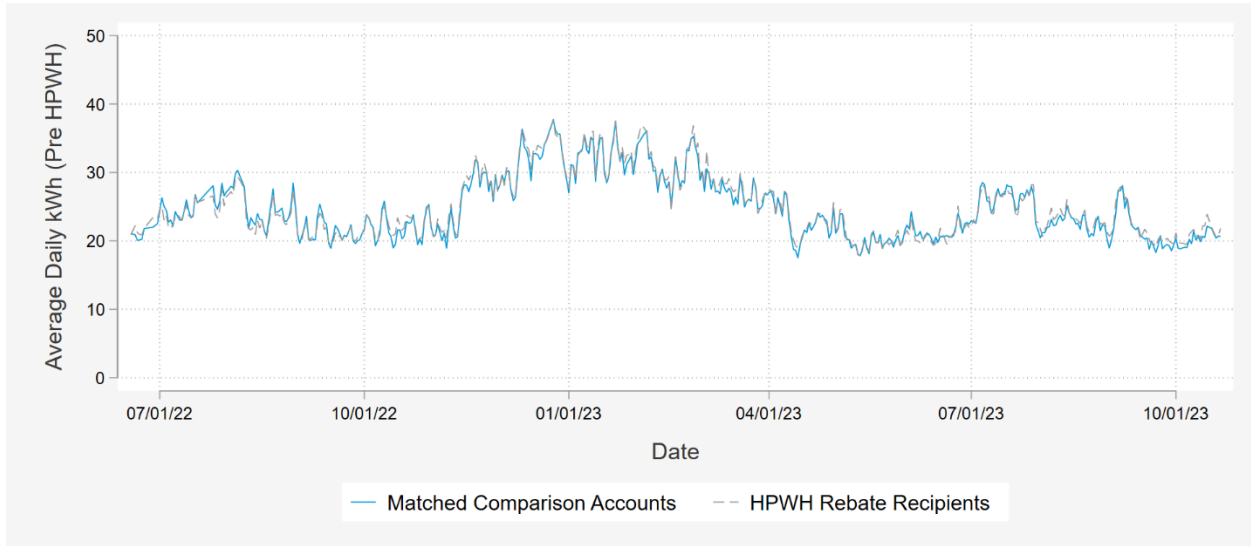


Figure 37 and Figure 38 provide additional comparisons between participants and the matched comparison group. Figure 37 shows the distribution of weather-normalized annual consumption for the rebate recipients (pre HPWH) and for homes in the matched comparison group. Figure 38 compares average demand during the ISO-NE summer and winter peak periods for the participants and matched comparison accounts. Like with Figure 36, these figures suggest there is strong alignment between the participant group and the matched comparison group.

Figure 37: Distribution of Weather-Normalized Annual Consumption, Pre-HPWH

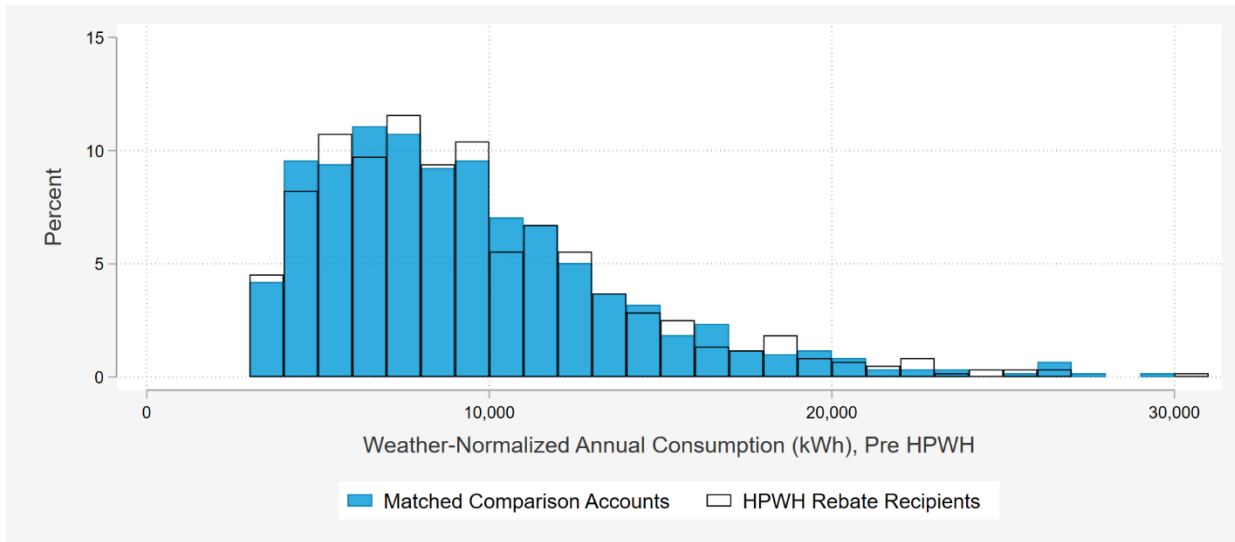
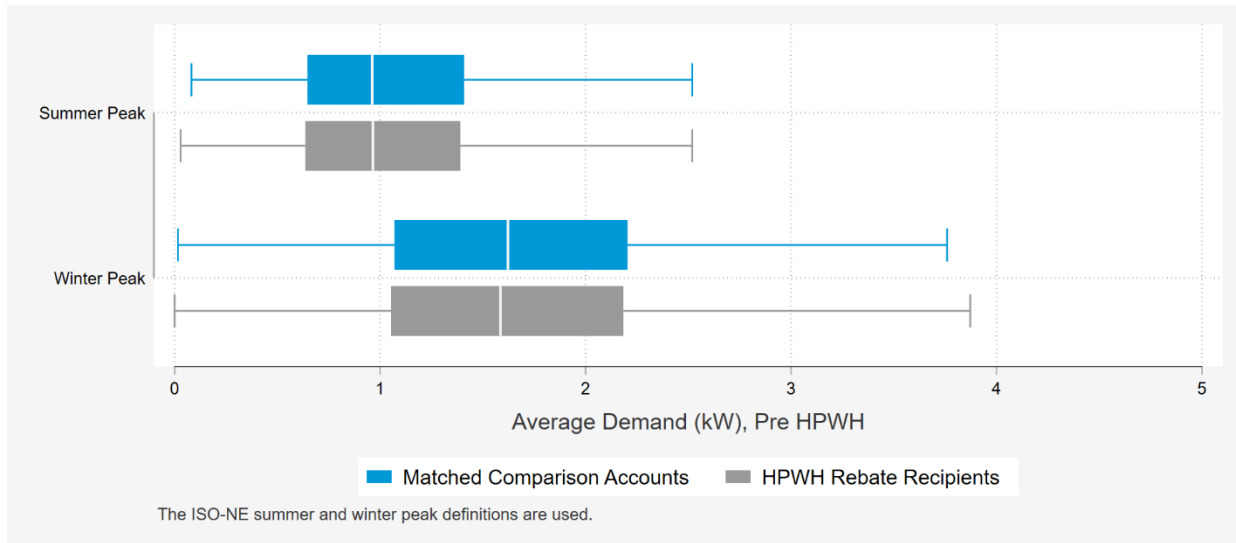


Figure 38: Distribution of Average Demand during the ISO-NE Peak Periods



### 3.3.4.2 Metering-Based Results

Results from the metering analysis – including summary statistics and weather-normalized annual metrics are provided in subsequent sections. We also include a discussion on factors that affect COP in [Section 3.3.4.2.3](#) and a comparison of COP and UEF in [Section 3.3.4.2.4](#).

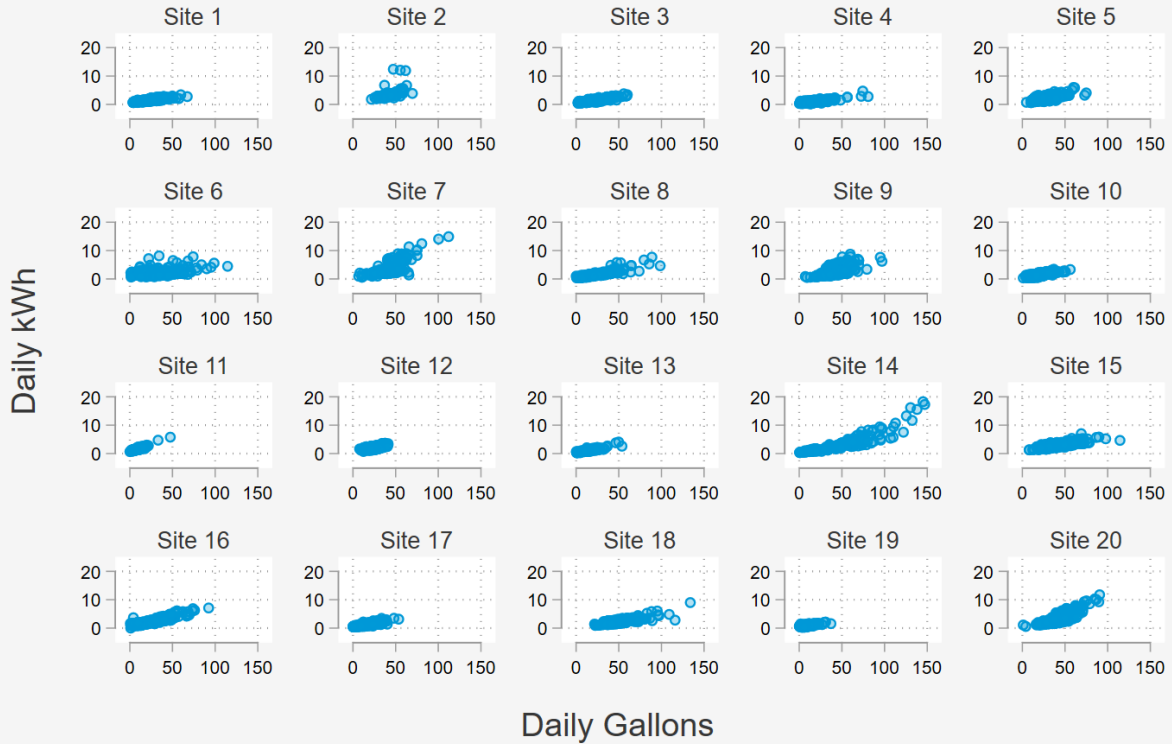
#### 3.3.4.2.1 USAGE SUMMARIES

Summary statistics from the metering analysis are shown in [Table 39](#). These statistics reflect usage during the 9-month metering period and are not weather-normalized. The relationship between daily kWh and daily gallons of water was as expected – greater volume generally leads to greater electricity use. [Figure 39](#) visualizes this relationship for each premise in the metering sample.

Table 39: Meter Data Summaries (n = 20)

Metric	Average
Daily kWh	2.3
Daily Gallons	29.0
Daily Heat Delivered (Btu)	14,601
Daily Heat Delivered (kWh)	4.3

Figure 39: Relationship between Daily kWh and Daily Gallons



For Site 14, daily gallons exceeded 150 on 19 days. These days are not included in the figure.

### 3.3.4.2.2 ANNUALIZED METRICS

Table 40 shows annualized metrics from the metering analysis. The annualized gallons metric of 10,236 gallons per year is equivalent to 28 gallons per day. The “Annual Heat Delivered (kWh)” metric is key for Efficiency Maine’s HPWH TRM characterization.

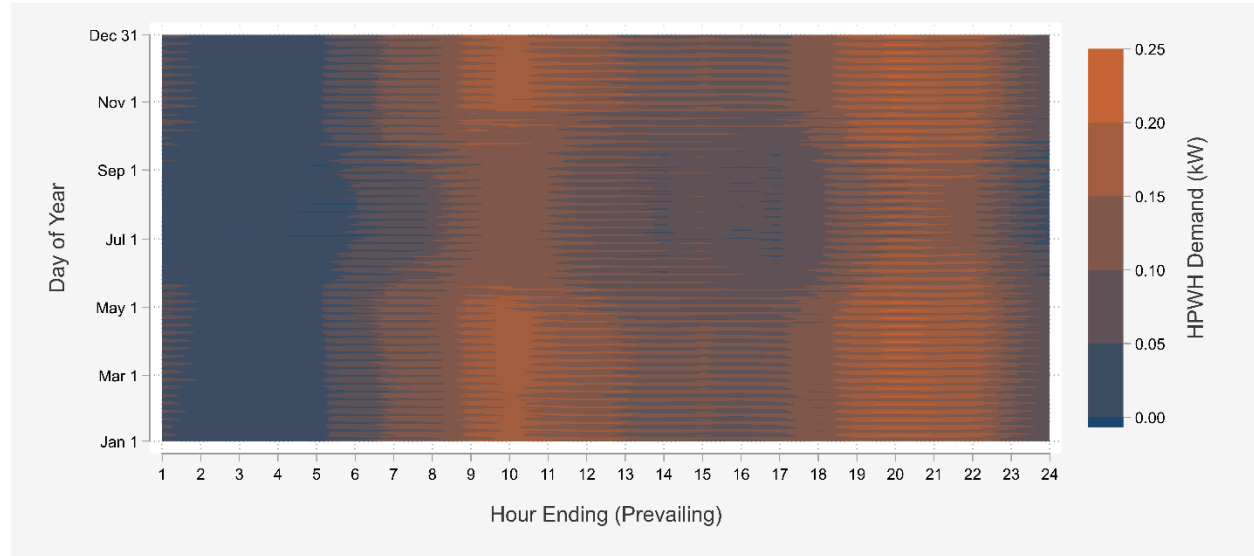
Table 40: Annualized Estimates from Metering Analysis (n = 20)

Metric	Evaluated Value	Relative Precision (80% Confidence)
Annual kWh	855	14.7%
Summer Peak kW	0.056	19.2%
Winter Peak kW	0.143	30.6%
Annual Gallons	10,236	15.0%
Annual Heat Delivered (Btu)	5,233,489	15.3%
Annual Heat Delivered (kWh) <sup>[a]</sup>	1,534	15.3%
COP	1.79	6.9%

<sup>[a]</sup> This metric represents the annual water heating load for a theoretical electric water heater with a COP of 1.0.

Figure 40 shows how annual HPWH consumption is distributed across the 8,760 hours of a year. Pockets of orange represent times when HPWH loads are higher, and pockets of blue represent times when the HPWH is not heating water. The morning and evening peaks (around 10 AM and 9 PM) trail water use peaks by an hour. There is some seasonality to HPWH demand, with summer loads typically being smaller than non-summer loads. This seasonality is likely a function of (1) cooler inlet water temperatures outside of the summer and (2) greater standby losses when indoor temperatures are lower.

Figure 40: HPWH Demand Heat Map based on Metering Sample

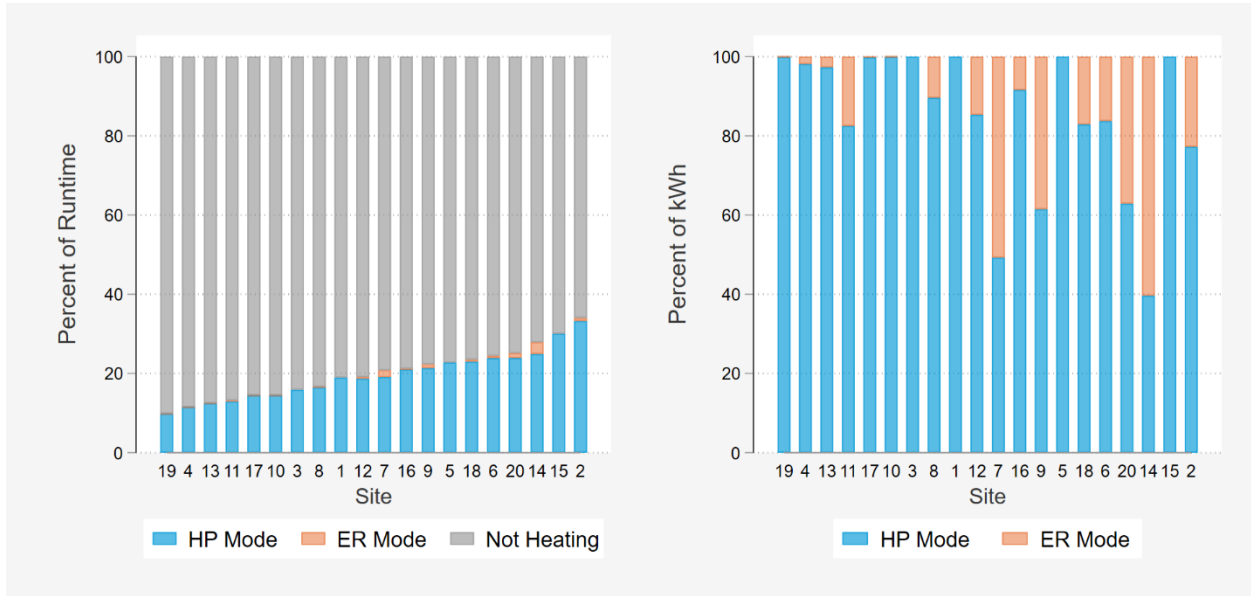


### 3.3.4.2.3 FACTORS AFFECTING COP

The COP is the ratio of the heat provided by the HPWH to the energy input required to provide the heat. Larger COP values indicate greater efficiency. While many factors can affect efficiency (inlet water temperature, ambient temperature of the room where the water heater is located, etc.), there are two key drivers: the HPWH's operational mode (heat pump only or hybrid) and the amount of hot water the occupants typically use.

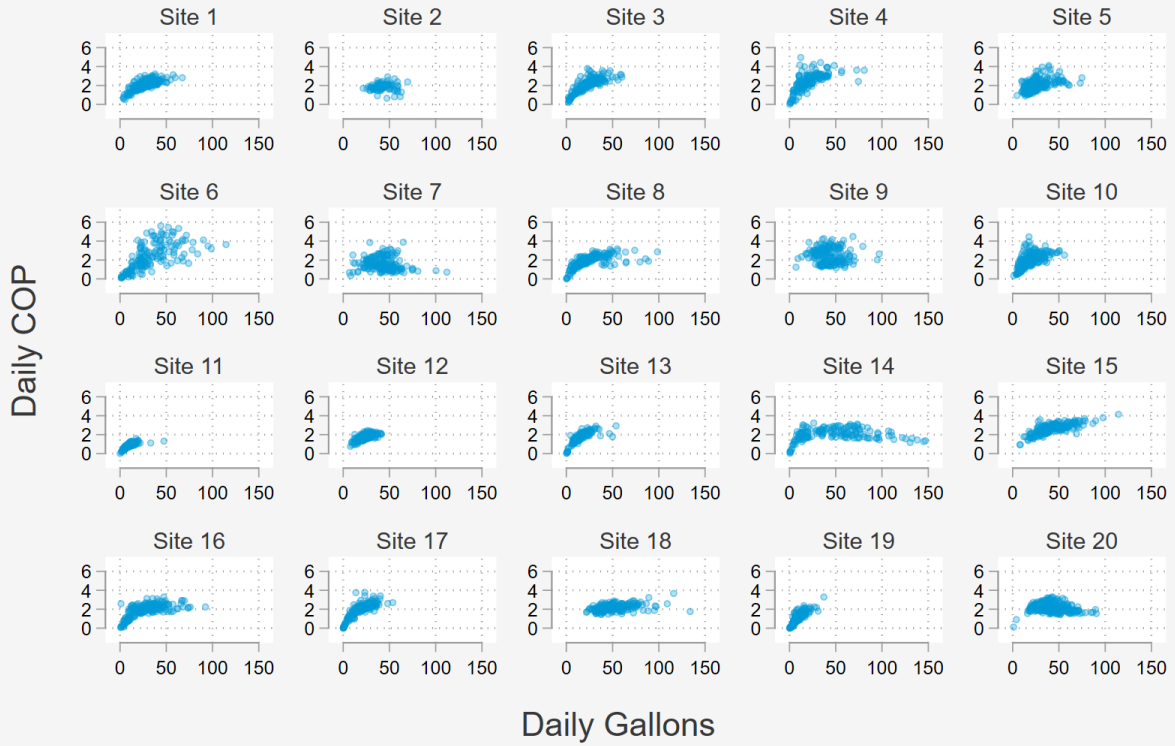
Regarding **operational mode**, over half of the HPWHs in the metering sample operated in a hybrid mode that blends heat pump mode (most efficient) and electric resistance (less efficient). HPWHs that only operate in heat pump mode will generally have higher COPs than HPWHs that operate in hybrid mode, as the electric resistance (ER) heating will decrease the overall efficiency of the unit. The power draw of a HPWH while in ER mode is 8-10 times greater than the power draw in heat pump mode. By premise, Figure 41 splits runtime (left panel) and electricity consumption (right panel) by operation mode. Though the HPWHs run predominantly in heat pump mode, the difference in power draw between the two modes leads to a greater split in total kWh by mode.

Figure 41: HPWH Runtime and kWh by Operational Mode



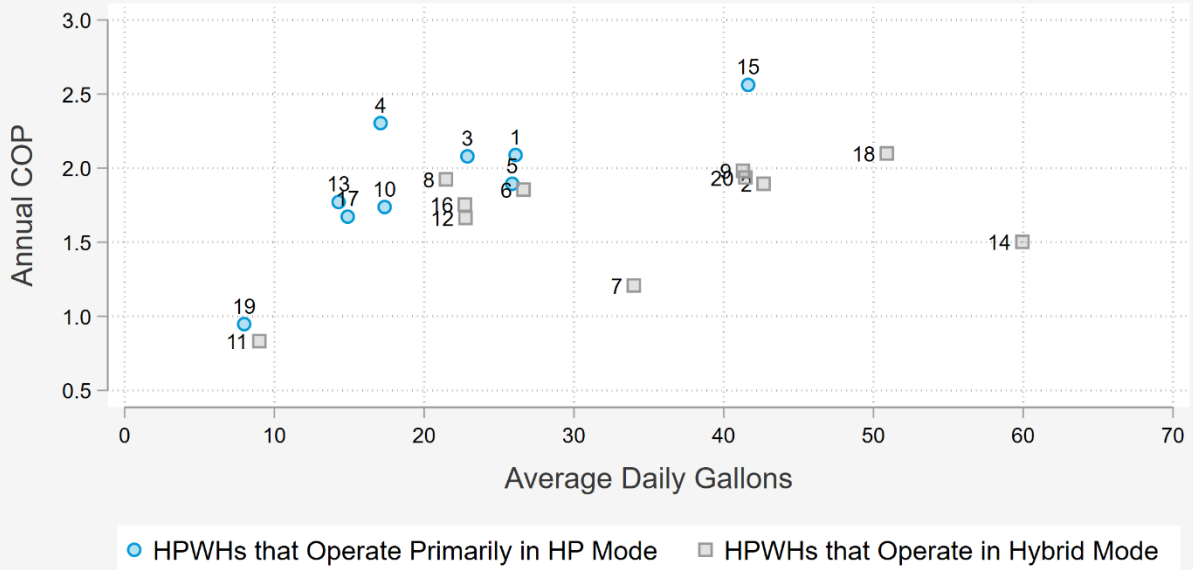
Regarding **hot water usage**, HPWHs in homes with lower hot water loads have greater standby losses relative to useful work performed than HPWHs in homes with higher hot water loads. Standby losses occur when the heated water in the tank cools down to a point where it must be heated again. These losses reduce the overall efficiency of the HPWH. [Figure 42](#) compares daily hot water use (gallons) with daily COP for each of the homes in the metering sample. Hot water loads vary across sites, but COP generally increases (and eventually plateaus) as daily hot water use increases. [Figure 43](#) compares the annualized COP for each metered HPWH with the annualized hot water load of the household. The color of the dots indicates whether the HPWH runs primarily in heat pump mode (blue) or not (gray). Not surprisingly, the HPWHs with the lowest annual COPs are the ones where (1) the HPWH spends more time operating in electric resistance mode or (2) hot water usage is relatively low.

Figure 42: Relationship between Daily COP and Daily Hot Water Use



For Site 14, daily gallons exceeded 150 on 19 days. These days are not included in the figure.

Figure 43: Relationship between Annual COP and Annual Hot Water Use



### 3.3.4.2.4 COP VS UEF

The average COP for HPWHs in the metering sample was 1.8, and the average UEF for HPWHs in the metering sample was 3.6. While the prior section touches on key drivers of the field-based COP value, we wanted to understand why the COP and UEF differed. This section touches on differences between the two metrics.

The UEF is a laboratory-based metric used to compare water heater efficiency under standardized test conditions. Water heaters are assigned to one of four draw pattern (usage) bins (very small, low, medium, or high) based on expected daily hot water demand, and UEF is determined through a controlled test that measures first-hour delivery and operates the unit over a prescribed 24-hour draw profile with fixed inlet water temperature, ambient air temperature, and draw timing. Measured energy input and delivered hot water are combined to calculate UEF. [Table 41](#) details the test procedure.

COP is an efficiency measure calculated as the ratio of thermal energy delivered to electrical energy consumed, using measured water flow, inlet and outlet temperatures, and metered electrical input. Because COP is based on in situ measurements, it is sensitive to ambient conditions, inlet water temperature, hot water draw patterns, operating modes, setpoints, and included standby losses. As a result, field-measured COP values may not match rated UEF values and should be interpreted as representative of actual site performance rather than standardized efficiency.

**Table 41: Notes on UEF Testing**

Testing Variable	UEF Description	Field Notes
Operating mode	Tested under default manufacturer control settings in hybrid mode, however the resistance element only turns on if needed	Most of the HPWHs in the metering sample ran in hybrid mode. More frequent resistance element engagement increases energy use and lowers COP
Draw size and timing	Prescribed 24-hr draw profiles based on usage bins	Actual draw volumes and timing vary by household and are often more clustered. Irregular or clustered draws increase resistance element engagement and reduce overall system efficiency
Ambient room temperature	Held between 65°F and 70°F	Cooler ambient air reduces available heat, requiring longer compressor runtime and increasing energy consumption. It is common for HPWH to be installed in unheated basements in Maine
Inlet water temperature	Held between 56°F and 60°F	This can be much lower in the field – especially in Maine during the winter. Colder inlet water increases the required temperature lift, leading to higher energy use
Standby losses	Incorporated implicitly through the standardized 24-hour test cycle	Varies with tank location, ambient conditions, and usage frequency. Increased standby losses reduce useful thermal output per unit of energy consumed, lowering measured COP

### 3.3.4.3 MMBtu Impacts

By baseline fuel, fossil fuel impacts are shown in Table 42. The “From HPWH” column represents the annual impact of the HPWH converted from kWh to MMBtu. The “From DHW Fuel Switching” column represents fossil fuel savings due to the electrification of the home’s DHW load. The “Total” column is the sum of the prior two. Weights drawn from the participant survey are shown in the “Share of Participants” column. On average, participants save 5.44 MMBtu annually.

Table 42: Fuel Agnostic MMBtu – All-in at Site

Baseline Fuel	MMBtu Impact			Share of Participants
	From HPWH	From DHW Fuel Switching	Total	
Electric	4.43	0.00	4.43	53.6%
Natural gas	-2.94	10.19	7.25	2.5%
Propane	-2.94	10.19	7.25	6.0%
Oil	-2.94	9.40	6.46	37.7%
Kerosene	-2.94	9.40	6.46	0.2%
<b>Weighted Average</b>	<b>1.01</b>	<b>4.43</b>	<b>5.44</b>	<b>100.0%</b>

Table 43 shows expected MMBtu impacts for the average participant. These are calculated using the fuel switching MMBtu and participant share from Table 42. For example, a home with a natural gas baseline will save 10.19 MMBtu of natural gas by electrifying water heating, but only 2.5% of homes have a natural gas baseline. The remaining 97.5% of homes do not see any natural gas savings. The 0.25 MMBtu in the first row of Table 43 is a weighted average of 10.19 (2.5%) and 0 (97.5%).

Table 43: Blended Fossil Fuel Impacts

Baseline Fuel	MMBtu Impact
Natural gas	0.25
Propane	0.61
Oil	3.55
Kerosene	0.02

### 3.3.4.4 Comparison of AMI-Based Results and Metering-Based Results

Table 44 compares results from the AMI analysis – specifically for homes with non-electric baselines – with results from the metering analysis. Note that the results shown in the table are not based on the same set of homes, as we do not have sufficient data for a direct comparison of AMI-based results with meter-based results for a common set of homes.<sup>11</sup> Instead, we compare the results for the 20 metered homes with the results for all non-electric baseline homes in the AMI analysis. The comparison shows

<sup>11</sup> Of the twenty homes in the metering sample, eight had an electric baseline. Of the twelve homes with non-electric baselines, eight had a confounding load modifier issue (heat pump, solar panels, or an EV purchase) that would muddy the analysis and three others did not have sufficient pre- or post-HPWH data for a pre/post analysis.

strong alignment in both the magnitude of load impacts and the distribution of load impacts throughout the year.

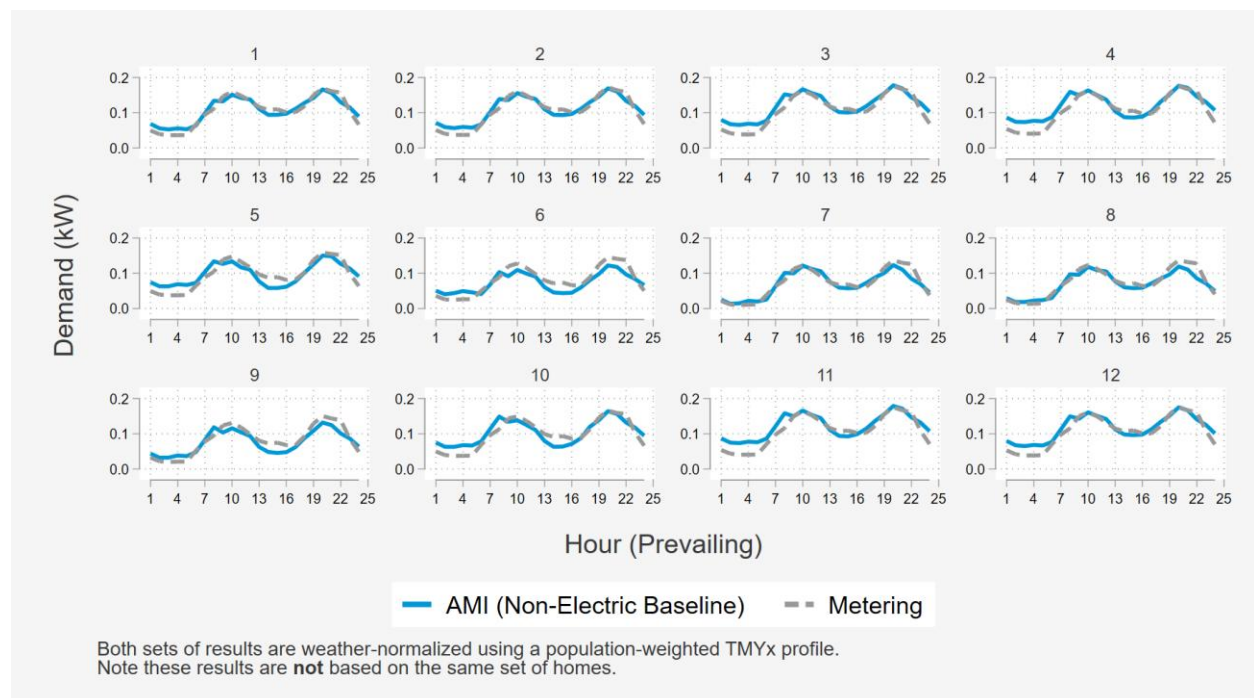
Table 44: Comparison of AMI-Based Results and Metering-Based Results

Variable	AMI-Based Estimate	Metering-Based Estimate
Annual kWh	862	855
Summer Peak kW	0.040	0.056
Winter Peak kW	0.130	0.143
Summer Off	11.6%	11.3%
Summer On	12.9%	15.8%
Winter Off	38.7%	33.3%
Winter On	36.8%	39.6%

Average self-reported home occupancy for the AMI group was 2.4. The average for the metering sample was 2.2.

By month, Figure 44 shows estimated hourly HPWH load shapes from both the AMI analysis and the metering analysis. With the caveat that these results are not based on the same set of homes, the results are encouraging – the timing and magnitude of the morning and afternoon peaks are similar. For this specific comparison, AMI-based estimates seem to be slightly higher than metering-based estimates overnight and slightly lower in the afternoon.

Figure 44: Hourly HPWH Load Shapes by Month and Analysis Type





### 3.4 DISTRIBUTOR INTERVIEWS

To assess the influence of Efficiency Maine discounts on sales of qualified HPWHs, we conducted phone interviews with five HPWH distributors. Sample selection was based on volume of ECM circulator pump installations. (The interviews also contained questions about circulator pumps. See [Section 4.3](#) for details on the circulator pump interview findings.) The five distributors we interviewed accounted for 91% of HPWHs rebated through the Instant – Distributor pathway over our evaluation period.

Ultimately, findings from the interviews are used qualitatively. The net-to-gross estimate for the HPWH measure (84.2%) is based on participant interviews (see [Section 3.2](#)). The findings from the interviews directionally agree with the NTG modeling results: program discounts have generally increased the stocking, sales, awareness, and adoption of HPWHs. [Table 45](#) summarizes the key findings.

**Table 45: Directional Findings from Distributor and Contractor Interviews**

Topic	Interview Findings
Program impact on HPWH stocking and sales	Overall direction:  All five distributors indicated they have seen a significant increase in sales of HPWHs since they began participating in the program.
Program impact on HPWH awareness and adoption	Overall direction:  Distributors were asked to rate how influential the incentive program has been in reaching the current level of awareness and adoption of HPWHs among Maine contractors. On a scale from 0 (not influential) to 10 (extremely influential), the average rating was 9.8.

Key findings from specific HPWH questions are shown below.

- How has your company’s participation in Efficiency Maine’s Distributor program influenced your stocking and sales of heat pump water heaters in recent years?
  - All five distributors indicated that they have observed large growth in the sales of HPWH since the start of their participation in the program.
- Approximately what percentage of water heater sales in the past year do you think were heat pump water heaters?
  - Average: 49%
  - Range: 30% to 75%
- What type of trends are you seeing in the DHW space? How different do you think your answer to the previous question might be in 5 years?
  - Opinions were mixed. Two don’t expect much to change in the next five years. Two expect legislation will increase HPWH sales. Two cited electric resistance as on the way out, and one also suggested oil is on the way out. Three suggested tankless sales will increase.
- In the last year, approximately what percentage of the time did you recommend program-qualifying HPWH models when discussing water heater options with buyers?
  - Average: 80%

- Range: 50% to 100%
  - Two interviewees did not answer this question.
- What percentage of the time would you be recommending HPWHs if Efficiency Maine discounts were not available?
  - Average: 53%
  - Range: 10% to 100%
  - Two interviewees did not answer this question.
- On a scale from 0 to 10, where 0 is not at all influential and 10 is extremely influential, how influential has Efficiency Maine’s program been in reaching the current level of awareness and adoption of HPWH among Maine contractors?
  - Average: 9.8
  - Range: 9 to 10
- Do you think heat pump water heaters will eventually become the market standard in Maine even without program discounts?
  - The consensus was no, but one stated that it could happen with federal legislation. All five indicated that the discounts were extremely important for HPWHs to become the market standard.

### 3.5 TRM RECOMMENDATIONS

This section details our recommended changes to the HPWH measure in Efficiency Maine’s Retail/Residential TRM. The current TRM configuration of the HPWH measure is shown in [Figure 45](#). Savings algorithms key off the  $kWh/y_{HWL}$  metric, which represents the annual energy required to provide the annual hot water load. Our recommendations for per-unit savings values and other impact factors are in [Section 3.5.1](#), and our recommendations for algorithm updates are in [Section 3.5.2](#).

Figure 45: Current HPWH Measure Configuration

DEEMED GROSS ENERGY SAVINGS (UNIT SAVINGS)	
Demand Savings <sup>207</sup>	$\Delta kW_{SP} = 0.078$ $\Delta kW_{WP} = 0.125$
Annual Energy Savings <sup>208</sup>	Electric = 755 $\Delta kWh/y$ Natural Gas = 0.22 MMBtu Propane = 0.75 MMBtu Oil = 4.34 MMBtu Kerosene = 0.13 MMBtu
GROSS ENERGY SAVINGS ALGORITHMS (UNIT SAVINGS)	
Demand Savings	Electric Baseline $\Delta kW_{SP} = \Delta kWh/y * LSF_{SP}$ $\Delta kW_{WP} = \Delta kWh/y * LSF_{WP}$ Non-electric Baseline <sup>209</sup> $\Delta kW_{SP} = -0.103$ $\Delta kW_{WP} = -0.119$
Annual Energy Savings	Electric Baseline $\Delta kWh/y = kWh/y_{HWL} * (1/Eff_{BASE} - 1/(UEF_{EE} * EAF))$ Non-electric Baseline $\Delta kWh/y = kWh/y_{HWL} * (-1/(UEF_{EE} * EAF))$ MMBtu = $kWh/y_{HWL} * 0.003412 / Eff_{BASE}$
Definitions	Unit = 1 heat pump water heater $kWh/y_{HWL}$ = Annual energy required to provide the annual hot water demand <sup>210</sup> $LSF_{SP}$ = Summer peak load shape factor (kW/kWh/yr) $LSF_{WP}$ = Winter peak load shape factor (kW/kWh/yr) $EF_{BASE}$ = Energy factor of electric resistance water heater $UEF_{EE}$ = uniform energy factor of heat pump water heater EAF = efficiency adjustment factor 0.003412 = Conversion factor: 0.003412 MMBtu per kWh $Eff_{BASE}$ = efficiency factor for non-electric water heater baseline

### 3.5.1 PER-UNIT GROSS SAVINGS

Table 46 shows our recommended per-unit gross savings values along with the comparable values in the current Efficiency Maine TRM (v2026.3). Note that the evaluated values in this table do not match our per-unit evaluation results due to differences in UEF assumptions (the values here are based on a more recent UEF assumption). The “Source” column indicates whether the proposed value is primarily an output of the AMI analysis or metering analysis. The weighting underpinning most of these metrics came from the participant survey.

Table 46: Per-Unit Gross Savings

Metric	Value		
	Current TRM	Proposed	Source
Annual Energy Savings (kWh), Electric Baseline	1,995	1,367	AMI analysis
Annual Energy Savings (kWh), Non-Electric Baseline	-850	-814	AMI analysis
Annual Energy Savings (kWh), Blended Baseline	755	356	AMI analysis
Summer Peak Demand (kW), Electric Baseline	0.217	0.124	AMI analysis
Summer Peak Demand (kW), Non-Electric Baseline	-0.103	-0.037	AMI analysis
Summer Peak Demand (kW), Blended Baseline	0.078	0.049	AMI analysis
Winter Peak Demand (kW), Electric Baseline	0.313	0.283	AMI analysis
Winter Peak Demand (kW), Non-Electric Baseline	-0.119	-0.122	AMI analysis
Winter Peak Demand (kW), Blended Baseline	0.125	0.095	AMI analysis
Annual Natural Gas Savings (MMBtu)	0.22	0.26	Metering analysis

Metric	Value		
	Current TRM	Proposed	Source
Annual Propane Savings (MMBtu)	0.75	0.62	Metering analysis
Annual Oil Savings (MMBtu)	4.34	3.57	Metering analysis
Annual Kerosene Savings (MMBtu)	0.13	0.02	Metering analysis

### 3.5.2 ALGORITHMS AND DEFINITIONS

Table 47 shows current TRM algorithms (v2026.3) along with our proposed algorithms. The proposed changes are minor and often only affect notation. We introduced one new impact factor,  $EAF_{Base}$ . This is an efficiency adjustment factor for the baseline water heater. The derivation of this value is discussed later. We also added formulas for summer and winter peak demand impacts in homes with non-electric baselines.

Table 47: TRM Algorithms

Metric	Formula
Annual Energy, Electric Baseline	Current: $\Delta kWh = kWh/y_{HWL} * \left( \frac{1}{UEF_{Base}} - \frac{1}{UEF_{EE} * EAF_{EE}} \right)$ Proposed: $\Delta kWh_{EB} = kWh/y_{HWL} * \left( \frac{1}{EUF_{Base} * EAF_{Base}} - \frac{1}{UEF_{EE} * EAF_{EE}} \right)$
Annual Energy, Non-Electric Baseline	Current: $\Delta kWh = kWh/y_{HWL} * \left( -\frac{1}{UEF_{EE} * EAF_{EE}} \right)$ Proposed: $\Delta kWh_{NEB} = kWh/y_{HWL} * \left( -\frac{1}{UEF_{EE} * EAF_{EE}} \right)$
Summer Peak Demand, Electric Baseline	Current: $\Delta kW_S = \Delta kWh * LSF_{SP}$ Proposed: $\Delta kW_{SEB} = \Delta kWh_{EB} * LSF_{SEB}$
Summer Peak Demand, Non-Electric Baseline	Current: $-0.103$ Proposed: $\Delta kW_{SNEB} = \Delta kWh_{NEB} * LSF_{SNEB}$
Winter Peak Demand, Electric Baseline	Current: $\Delta kW_W = \Delta kWh * LSF_{WP}$ Proposed: $\Delta kW_{WEB} = \Delta kWh_{EB} * LSF_{WEB}$
Winter Peak Demand, Non-Electric Baseline	Current: $-0.119$ Proposed: $\Delta kW_{WNEB} = \Delta kWh_{NEB} * LSF_{WNEB}$
MMBtu	Current: $MMBtu = kWh/y_{HWL} * 0.003412 * \frac{1}{Eff_{Base}}$ Proposed: $MMBtu = kWh/y_{HWL} * 0.003412 * \frac{1}{UEF_{Base} * EAF_{Base}}$

Table 48 shows definitions for the impact factors from the algorithms in Table 47.

Table 48: Impact Factor Definitions

Factor	Description
$kWh/y_{HWL}$	Annual energy required to provide the annual hot water demand
$LSF_{SEB}$	Load shape factor for summer peak demand, electric baseline (kW/kWh/yr). Replaces $LSF_{SP}$
$LSF_{SNEB}$	Load shape factor for summer peak demand, non-electric baseline (kW/kWh/yr).
$LSF_{WEB}$	Load shape factor for winter peak demand, electric baseline (kW/kWh/yr). Replaces $LSF_{WP}$
$LSF_{WNEB}$	Load shape factor for winter peak demand, non-electric baseline (kW/kWh/yr).
$EAF_{EE}$	Efficiency adjustment factor for HPWH.
$EAF_{Base}$	Efficiency adjustment factor for baseline water heater.
$UEF_{EE}$	Uniform energy factor of the HPWH.
$UEF_{Base}$	Energy factor for the baseline water heater. Formerly denoted $Ef f_{Base}$ .
0.003412	Conversion factor (MMBtu/kWh)

### 3.5.3 IMPACT FACTORS

Table 49 shows the impact factors in the current TRM and our recommended values. The “Source” column indicates whether the proposed value is primarily an output of the AMI analysis or metering analysis. The baseline efficiencies and  $EAF_{Base}$  are discussed in greater detail in the sections that follow.

Table 49: Impact Factors

Name	Value		
	Current TRM	Proposed	Source
$kWh/y_{HWL}$	2,821	1,534	Metering analysis
$LSF_{SEB}$	0.000109	0.000091	AMI analysis
$LSF_{SNEB}$	N/A	0.000046	AMI analysis
$LSF_{WEB}$	0.000157	0.000207	AMI analysis
$LSF_{WNEB}$	N/A	0.000150	AMI analysis
$EAF_{EE}$	0.88	0.50	Metering analysis
$EAF_{Base}$	N/A	0.75	Metering + AMI
$UEF_{Base}$	See Section 3.5.5.		

### 3.5.4 BASELINE EFFICIENCY ADJUSTMENT FACTOR

We used outputs from the AMI and metering analyses, combined with the baseline efficiencies discussed in the prior section, to estimate an efficiency adjustment factor for baseline water heaters. The logic flows as follows:

- We estimate homes with electric baselines save 1,298 kWh annually. We estimate homes with non-electric baselines increase their electric usage by 862 kWh annually (or -862 in savings). This implies a baseline electric water heater uses 2,160 kWh annually (1,298 + 862 = 2,160).<sup>12</sup>
- Our estimate for annual energy required to provide the annual hot water demand was 1,534 kWh/y<sub>HWL</sub>. If a baseline electric water heater requires 2,160 kWh for this work, then the efficiency is 0.71 (1,534 / 2,160 = 0.71)
- The energy adjustment factor is a ratio of the actual efficiency to the expected baseline efficiency. The actual efficiency is 0.71, and the expected baseline efficiency is 0.941. 0.941 is a weighted average of the baseline efficiencies in Table 53 (using weights of 13% and 87% for retrofit and lost opportunity, respectively).

Following the logic above, here is the formula we used to determine  $EA_{Base}$ :

$$EA_{Base} = \frac{kWh/y_{HWL}}{(\Delta kWh_{EB} + -1 * \Delta kWh_{NEB})} * \frac{1}{UEF_{Base}} = \frac{1,534}{1,298 + 862} * \frac{1}{0.941} = 0.75$$

### 3.5.5 BASELINE EFFICIENCIES

Estimates for annual natural gas, propane, oil, and kerosene savings rely on (1) the energy required to provide annual hot water demand ( $kWh/y_{HWL}$ ) and (2) baseline water heating efficiencies for each of these fuel types. The first component is an output of the metering study. The baseline efficiencies are drawn from federal water heating code. Table 50 shows current baseline efficiencies and our recommended values. Notably, our proposed baseline efficiencies for the retrofit case are *higher* than the efficiencies for the lost opportunity case. This counterintuitive result can be explained by weighting (a more efficient type of water heater receives greater weight in the retrofit case) and is discussed in more detail below. The proposed factors in Table 50 do not reflect the baseline adjustment factor of 0.75 discussed in the prior section. We show adjusted baseline efficiencies later in this section.

Table 50: Updated Baseline Efficiencies

Baseline Fuel	$UEF_{Base}$ Retrofit		$UEF_{Base}$ Lost Opportunity		Share of Blended Savings	
	Current TRM	Proposed	Current TRM	Proposed	Current TRM	Proposed
Electric	0.9299	1.078	1.007	0.920	56.4%	53.6%
Natural Gas	0.675	0.694	0.9	0.671	1.9%	2.5%
Propane	0.675	0.694	0.9	0.671	6.6%	6.0%
Oil	0.756	0.758	0.756	0.725	34.1%	37.7%
Kerosene	0.756	0.758	0.756	0.725	1.0%	0.2%

<sup>12</sup> The “baseline electric water heater” predominantly reflects electric resistance water heaters but also includes some heat pump water heaters.

As noted, the baseline efficiencies are based on federal codes. We used 2004-2014 water heater code for retrofit installations and 2015-2029 water heater code for lost opportunity installations.<sup>13</sup> We also used efficiencies for hot water boilers to develop weighted baseline efficiencies, as many rebate recipients previously had indirect hot water systems where the home's boiler was used to heat domestic water.<sup>14</sup>

Federal efficiency standards as of January 2004 were based on product classes (storage, instantaneous, or indirect) and were a function of the rated storage volume of the water heater. Figure 46 shows the 2004-2014 code algorithms. When federal code was updated in 2015, the algorithms were expanded. The updated algorithms were separated by product class, water heater draw pattern, and rated storage bins. Figure 47 shows the current algorithms for gas-fired storage water heaters. When developing the baseline efficiencies for this evaluation, we assumed a 50-gallon storage volume and a medium draw pattern.

Figure 46: Prior Water Heater Baseline Code (2004-2014)

Product class	Energy factor as of January 20, 2004
Gas-Fired Storage Water Heater	$EF = 0.67 - (0.0019 \times \text{Rated Storage Volume in gallons})$
Oil-Fired Storage Water Heater	$EF = 0.59 - (0.0019 \times \text{Rated Storage Volume in gallons})$
Electric Storage Water Heater	$EF = 0.97 - (0.00132 \times \text{Rated Storage Volume in gallons})$
Tabletop Water Heater	$EF = 0.93 - (0.00132 \times \text{Rated Storage Volume in gallons})$
Gas-Fired Instantaneous Water Heater	$EF = 0.62 - (0.0019 \times \text{Rated Storage Volume in gallons})$
Instantaneous Electric Water Heater	$EF = 0.93 - (0.00132 \times \text{Rated Storage Volume in gallons})$

Figure 47: Current Water Heater Baseline Code for Gas-fired Storage Water Heaters

Product class	Rated storage volume and input rating (if applicable)	Draw pattern	Uniform energy factor <sup>1</sup>
Gas-fired Storage Water Heater	≥20 gal and ≤55 gal	Very Small	$0.3456 - (0.0020 \times V_r)$
		Low	$0.5982 - (0.0019 \times V_r)$
		Medium	$0.6483 - (0.0017 \times V_r)$
		High	$0.6920 - (0.0013 \times V_r)$
	>55 gal and ≤100 gal	Very Small	$0.6470 - (0.0006 \times V_r)$
		Low	$0.7689 - (0.0005 \times V_r)$
		Medium	$0.7897 - (0.0004 \times V_r)$
		High	$0.8072 - (0.0003 \times V_r)$

<sup>13</sup> Available at <https://www.federalregister.gov/documents/2010/04/16/2010-7611/energy-conservation-program-energy-conservation-standards-for-residential-water-heaters-direct> and <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430>

<sup>14</sup> For the indirect case, we conservatively assume 100% indirect and no tankless coils.

Table 51 shows baseline efficiencies for natural gas and propane baselines, and Table 52 shows baseline efficiencies for oil and kerosene baselines. The values in the “Weight” column were drawn from the participant survey and sum to 100% within each decision type. Directionally, the results seem counterintuitive, as the weighted average retrofit baseline efficiency is higher than the weighted average lost opportunity efficiency. The counterintuitive result can be explained by the difference in the weights for the two decision types. Specifically, the weight for the indirect class – which is the most efficient class – is larger for the retrofit baseline case than it is for the lost opportunity baseline case. The result is that the weighted average for the retrofit case is higher, even if the efficiencies of the storage and instantaneous classes are lower for retrofits.<sup>15</sup>

Table 51: Baseline Efficiencies for Natural Gas and Propane Baselines

Decision Type <sup>[a]</sup>	Class	Efficiency Factor	Weight	Weighted Average	
				Unadjusted	Adjusted <sup>[b]</sup>
Retrofit	Gas-fired storage	0.575	36%	0.694	0.520
	Gas-fired instantaneous	0.620	14%		
	Indirect (off the gas-fired boiler)	0.800	50%		
Lost Opportunity	Gas-fired storage	0.563	55%	0.671	0.504
	Gas-fired instantaneous	0.810	14%		
	Indirect (off the gas-fired boiler)	0.800	31%		

<sup>[a]</sup> Retrofits represent 40% of installations for participants with non-electric baselines and lost opportunity represents 60%.  
<sup>[b]</sup> The adjusted value incorporates the baseline efficiency adjustment factor of 0.75.

Table 52: Baseline Efficiencies for Oil and Kerosene Baselines

Decision Type <sup>[a]</sup>	Class	Efficiency Factor	Weight	Weighted Average	
				Unadjusted	Adjusted <sup>[b]</sup>
Retrofit	Oil-fired storage	0.495	14%	0.758	0.569
	Indirect (off the oil-fired boiler)	0.800	86%		
Lost Opportunity	Oil-fired storage	0.528	28%	0.725	0.544
	Indirect (off the oil-fired boiler)	0.800	72%		

<sup>[a]</sup> Retrofits represent 40% of installations for participants with non-electric baselines and lost opportunity represents 60%.  
<sup>[b]</sup> The adjusted value incorporates the baseline efficiency adjustment factor of 0.75.

Table 53 shows baseline efficiencies for electric baselines. The retrofit case includes three water heater classes – electric storage, electric instantaneous, and HPWH. We included HPWHs because a few survey respondents indicated that their program-supported HPWH replaced another functioning HPWH. The lost opportunity case assumes code minimum (storage or instantaneous) and does not include HPWHs. The efficiency factors for storage and instantaneous are drawn from federal code. The efficiency factor for HPWHs requires some discussion. The value in the table (2.37) is lower than the rated efficiency of

<sup>15</sup> For gas-fired storage, the efficiency value we show for the retrofit case is actually higher than the efficiency value for the lost opportunity case (which is based on more recent code). The 2004-2014 code uses a single baseline formula, while the 2015-2029 code has separate formulas based on water heater draw pattern and storage volume bins. The formulas are shown in Figure 46 and Figure 47.

the HPWHs in our evaluation (3.58) but higher than the field-based efficiency we determined through the metering study (1.79). We calculated 2.37 by dividing the field-based efficiency, which does not need an efficiency adjustment, by  $EAF_{Base}$  (0.75). Thus, when the efficiency adjustment is applied to 2.37, the result equals our estimated field efficiency value.

Table 53: Baseline Efficiencies for Electric Baseline

Decision Type <sup>[a]</sup>	Class	Efficiency Factor	Weight	Weighted Average	
				Unadjusted	Adjusted <sup>[b]</sup>
Retrofit	Electric storage	0.904	84%	1.078	0.808
	Electric instantaneous	0.930	4%		
	HPWH	2.370 <sup>[c]</sup>	12%		
Lost Opportunity	Electric storage	0.9207	94%	0.920	0.690
	Electric instantaneous	0.910	6%		

<sup>[a]</sup> Retrofits represent 13% of installations for participants with electric baselines and lost opportunity represents 87%.  
<sup>[b]</sup> The adjusted value incorporates the baseline efficiency adjustment factor of 0.75.  
<sup>[c]</sup> See the discussion prior to this table for context around this value. Based on the metering analysis, we estimate the actual efficiency is 1.79.

### 3.5.6 DECISION TYPE

Table 54 shows the distribution of decision type by baseline fuel. These estimates are drawn from the participant survey (see Section 3.2.2.3).

Table 54: Distribution of Decision Type by Baseline Fuel

Baseline Fuel	Decision Type	
	% Retrofit	% Lost Opportunity
Electric	13%	87%
Non-Electric	40%	60%
<b>Overall</b>	<b>25%</b>	<b>75%</b>

### 3.5.7 NET-TO-GROSS

Our estimated NTG ratios for each program pathway are in Table 18. We used the participant survey to develop these estimates (see Section 3.2). The metrics in the “Overall” row are weighted based on the “% of Rebates” column. Overall, we estimate the freeridership rate is 15.8% and the NTGR is 84.2%.

Table 55: NTGR Results by Program Pathway

Pathway	% of Rebates	% of Respondents	Freeridership Rate	NTGR
Mail-in – Retail	5.2%	11.7%	20.4%	79.6%
Instant – Retail	37.5%	50.2%	7.9%	92.1%
Instant – Distributor	57.3%	38.1%	20.6%	79.4%
<b>Overall</b>	<b>100%</b>	<b>100%</b>	<b>15.8%</b>	<b>84.2%</b>

## 4 ECM CIRCULATOR PUMPS

Through the Efficiency Maine Distributor program, Efficiency Maine provides rebates on electronically commutated motor (ECM) circulator pumps with brushless permanent magnet motors and variable speed controls for the circulation of hot water that is used for hydronic heating and sometimes domestic hot water. [Table 56](#) summarizes program activity over our evaluation period (FY2023). There are no reported summer peak demand, fossil fuel, water, or wood savings associated with this measure. Because only 3% of ECM circulator pumps (ECMCPs) rebated in FY2023 were installed in commercial buildings, our evaluation focused on residential installations.

Table 56: ECM Circulator Pump FY2023 Rebate Metrics

Customer Type	Units	Annual Energy Savings (MWh)	Winter Peak Demand Savings (MW)
Residential	14,304	1,441	0.52
Commercial	473	234	0.02
<b>Total</b>	<b>14,777</b>	<b>1,675</b>	<b>0.54</b>

Our evaluation of the ECM circulator pump (ECMCP) measure included four key evaluation activities: a price elasticity analysis, phone interviews with ECMCP distributors and contractors, and a metering study. The remainder of this chapter is organized as follows:

- In [Section 4.1](#), we summarize key evaluation findings.
- In [Section 4.2](#), we provide details on the price elasticity analysis.
- In [Section 4.3](#), we provide details on the distributor and contractor interviews.
- In [Section 4.4](#), we provide details on the metering study.
- In [Section 4.5](#), we provide our comprehensive TRM recommendations for the ECMCP measure.

### 4.1 HIGH-LEVEL EVALUATION FINDINGS

[Table 57](#) summarizes some of our high-level evaluation findings. We provide greater detail on these findings in subsequent sections.

Table 57: High-Level ECMCP Evaluation Findings

Topic	Findings
Annual energy impact of an ECMCP	We estimate an ECMCP installed in a residential application saves 47 kWh annually relative to a baseline circulation pump with a shaded pole motor.
Typical application	While most ECMCPs serve as supply or return pumps in a hydronic heating system, a few program-supported ECMCPs in our metering sample supplied heat exchangers in a DHW system or DHW in addition to space heating. As a result, we estimate non-zero summer peak demand savings.
Price elasticity / NTG	Based on our price elasticity analysis, our estimated NTGR for ECM circulator pumps is 79.5%.

Topic	Findings
Program impact on ECMCP stocking and sales	Four out of five interviewed distributors indicated stocking and sales of ECM pumps have increased because of the incentives. 60% of the interviewed contractors indicated that the incentives have influenced their stocking and sales of ECM pumps.
Program impact on ECMCP awareness and adoption	Distributors were asked to rate how influential the incentive program has been in reaching the current level of awareness and adoption of ECM pumps among Maine contractors. On a scale from 0 (not influential) to 10 (extremely influential), the average rating was 8.2.
Cost effectiveness	In the prospective gross scenario, we estimate the measure returns \$1.35 of benefits per \$1 of cost.

## 4.2 PRICE ELASTICITY ANALYSIS

The goal of a price elasticity analysis is to understand the relationship between the quantity of a good demanded and its price. We can use the relationship to estimate sales quantity of the product at varying levels of price. Of interest for this evaluation is the quantity of ECM circulator pumps that *would have been sold* had Efficiency Maine’s rebates not been available. This value is known as the counterfactual, and an estimate of the counterfactual is a key output of a price elasticity analysis. We use the counterfactual to estimate program lift – or the net impact of the program – as well as the freeridership rate and the net-to-gross ratio (NTGR):

$$\text{Program lift} = \text{Observed Volume} - \text{Counterfactual Volume}$$

$$\text{Freeridership rate} = \frac{\text{Counterfactual Volume}}{\text{Observed Volume}} * 100\%$$

$$\text{NTGR} = \frac{(\text{Observed Volume} - \text{Counterfactual Volume})}{\text{Observed Volume}} * 100\%$$

The analysis makes a simplifying assumption that the overall volume of circulator pumps sold in Maine during the analysis period was not impacted by the presence of the rebates and that the Efficiency Maine’s efforts simply increased the market share of efficient pumps (at the expense of inefficient pumps).

Our modeling results indicate that approximately 4 out of 5 circulator pump purchases would have been the lower cost standard efficiency option absent program discounts. We provide additional details on the analysis in subsequent sections.

### 4.2.1 SUMMARY OF THE REBATE DATA

We used five years of historical rebate data to perform the price elasticity analysis, covering the period between April 2019 and July 2024. By calendar year, [Table 58](#) summarizes the number of rebates provided and the average incentive level during this window. The increasing incentive levels are a response to increasing retail prices and a couple of promotional periods in 2023. Note that paperwork stipend fees provided to the distributors are not included in the average incentives.

Table 58: Summary of Rebate Data

Year	Number of Rebated ECMCPs	Average Incentive Level
2019 <sup>[a]</sup>	2,294	\$51
2020	7,443	\$76
2021	8,735	\$81
2022	12,112	\$86
2023	16,841	\$102
2024 <sup>[a]</sup>	6,246	\$88

<sup>[a]</sup> denotes incomplete year of tracking data

Figure 48 shows the number of pumps sold and the average incentive level during each month in the five-year analysis window. Two promotional periods are highlighted in purple. Program volume clearly increases as incentives increase. In addition to the incentive response, there is a seasonality to rebate volume. More pumps are rebated in the winter than in the summer. Presumably, circulator pump installations are lighter when space heating loads are light. The price elasticity modeling accounts for this seasonality.

Figure 48: Average Per-Unit Incentive and Volume by Month

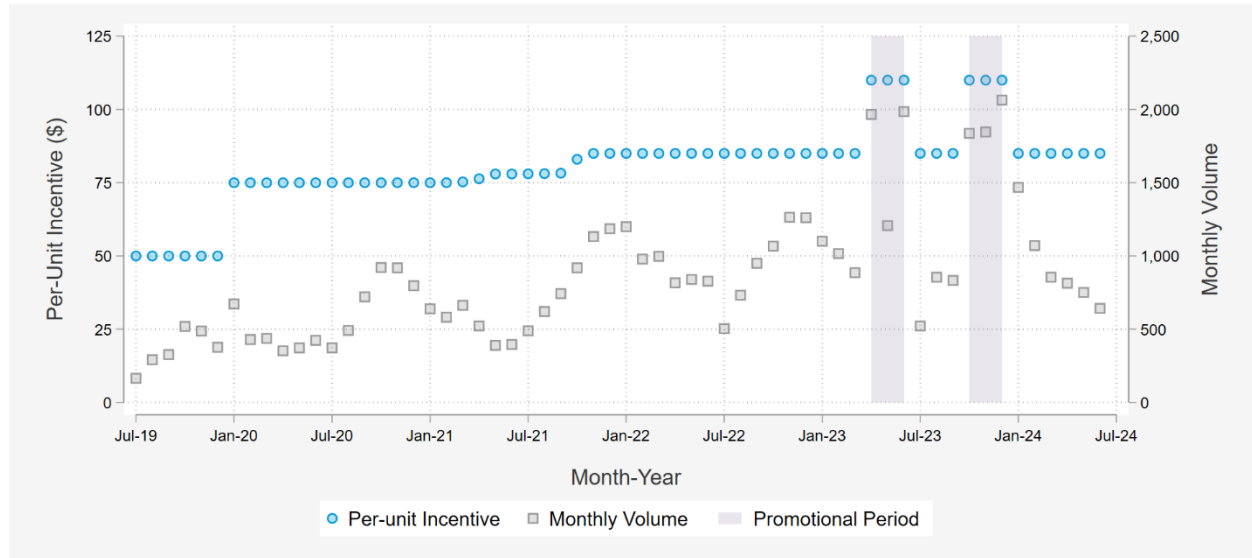
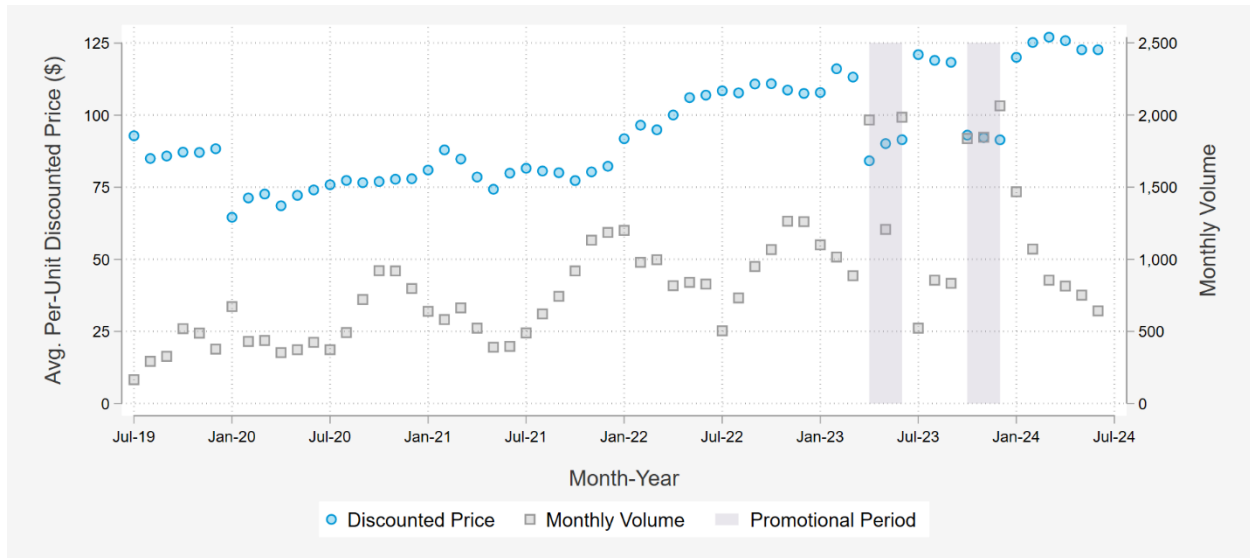


Figure 49 mirrors Figure 48 but replaces incentive level with the discounted price. Program volume increases in response to lower customer-facing prices over time. In estimating the effect of incentive levels on sales, it is important to account for changes in retail price over time. Higher incentive levels over the last five years generally coincide with higher retail prices.

Figure 49: Average Per Unit Discounted Price and Volume by Month



#### 4.2.2 PREPARATION OF THE ANALYSIS DATASET

The key steps in preparation of the analysis dataset were:

- **Interpolating retail prices for 2019 and 2020.** Retail prices for this period were not collected. To interpolate missing values, we modeled the relationship between retail price, time, and manufacturer via regression. We used predicted retail prices from the resulting regression model to replace missing retail prices.
- **Correcting outlying retail prices observed in the raw data.** For each year in the dataset, we flagged retail price outliers. For a small percentage of pumps rated 44 watts, which is the rating of 90% of pumps in our sample, retail prices were far above the average retail price of about \$200. We believe many of these high retail prices were erroneous. Overall, 3% of retail prices were flagged as outliers. We used predicted retail prices from the regression model discussed above to replace outlier retail prices. The outliers themselves were withheld from the regression model.

#### 4.2.3 MODELING METHODS

We used a Poisson regression model to estimate price elasticity of demand coefficients. Actual rebated quantity was modeled as a function of the natural logarithm of the discounted price. In addition, our model controlled for retail prices rising over time due to inflation, seasonal effects on ECM circulator pump purchases, the dollar value of the paperwork stipend fee over time, and increasing ECM circulator pump adoption over time. The model was estimated at the year-month-level over a period between July 2019 and April 2024.

After developing the model, we used model outputs to estimate ECM circulator pump sales volume at a price point that reflects no rebate (and no paperwork stipend). This is the relevant counterfactual for

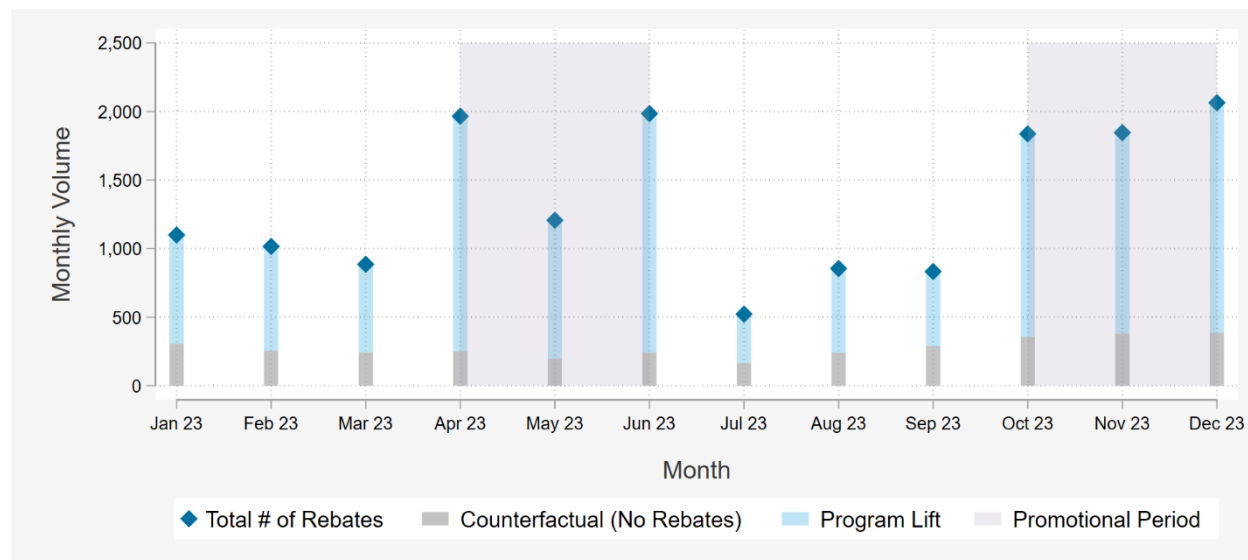
our analysis, and estimates for the freeridership rate, program lift, and the program NTGR are all tied to the estimated counterfactual.

#### 4.2.4 RESULTS

We estimated a price elasticity coefficient of -1.6, which indicates that a 10% decrease in the customer-facing price of an ECM circulator pump results in a 16% increase in monthly purchased quantity. Figure 50 shows the observed monthly rebates and the predicted monthly sales volume under the “no incentive” counterfactual. The difference between the observed value and the “no incentive” counterfactual represents the program lift, or the net impact of the program. As expected, the net impact is higher during promotional periods with a higher incentive. Aggregating the net impact and actual sales across months for calendar year 2023, we find the net-to-gross ratio is 79.5%:

$$NTGR = \frac{(Observed\ Volume - Counterfactual\ Volume)}{Observed\ Volume} * 100\% = \frac{12,807}{16,117} * 100\% = 79.5\%$$

Figure 50: Observed Volume, Counterfactual Volume, and Program Lift by Month



### 4.3 DISTRIBUTOR AND CONTRACTOR INTERVIEWS

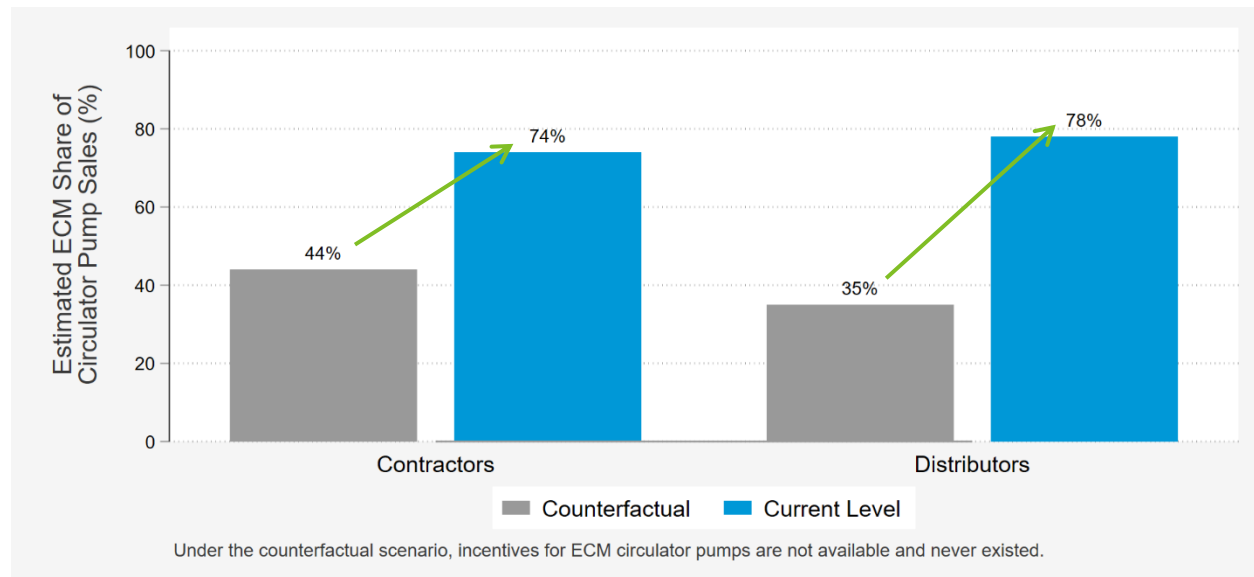
To assess the influence of Efficiency Maine discounts on sales of qualified circulator pumps, we conducted phone interviews with five distributors and fifteen contractors. Sample selection was based on volume of ECMCP rebates. There were fourteen unique ECMCP distributors in FY2023, and five of them accounted for 90% of FY2023 rebates. We interviewed these five distributors. The battery of questions for the distributor interview was much longer than the battery for the contractor interviews, and each interview lasted about 30 minutes. The distribution of ECMCP contractors was not as top-heavy as the distribution of ECMCP distributors. There were approximately 1,300 unique ECMCP contractors in FY2023, and the top fifteen contractors accounted for 18% of FY2023 installations. Contractors generally did not respond to interview requests sent over email, so we performed a cold-call campaign and interviewed contractors who would agree to give us five minutes of their time. The

order of the cold calls followed FY2023 rebate volume. Our contractor interview sample accounted for 9% of FY2023 rebates.

Ultimately, findings from the interviews are used qualitatively. The net-to-gross estimates for the ECMCP (79.5%) measure is based on price elasticity modeling (see [Section 4.2](#)). The findings from the interviews directionally agree with the NTG modeling results: program discounts have generally increased the stocking, sales, awareness, and adoption of ECMCPs. [Table 59](#) summarizes the key findings, and [Figure 51](#) shows the estimated share of circulator pump sales that are currently ECM and the estimated share under a counterfactual scenario where the incentives are not available and the incentive program never existed.


The distributor and contractor interviews did not uncover any reason to modify the current in-service rate assumption of 100% in Efficiency Maine’s TRM.

**Figure 51: Estimated Share of Circulator Pump Sales that are ECM**



**Table 59: Directional Findings from Distributor and Contractor Interviews**

Topic	Interview Findings
Program impact on ECMCP stocking and sales	<p>Overall direction: <span style="color: green;">↑</span></p> <p>Four out of five distributors indicated stocking and sales of ECM pumps have increased because of the incentives. Overall, distributors thought the share of circulator pump sales that are ECM would drop from an estimated current level of 78% to about 35% in a counterfactual scenario where incentives would not be available in the future and the incentive program never existed.</p> <p>60% of the contractors indicated that the incentives have influenced their stocking and sales of ECM pumps. Contractor responses to the counterfactual question above mirrored distributor responses – 74% of circulator pump installations in the past year were ECM, and they expect this percentage would drop to 44% in the counterfactual scenario.</p>

Topic	Interview Findings
Program impact on ECMCP awareness and adoption	<p>Overall direction: </p> <p>Distributors were asked to rate how influential the incentive program has been in reaching the current level of awareness and adoption of ECM circulator pumps among Maine contractors. On a scale from 0 (not influential) to 10 (extremely influential), the average rating was 8.2.</p>

**4.3.1 DISTRIBUTOR INTERVIEWS**

The five distributor interviewees in our sample had an average of 20 years of experience (range: 6-50 years), and job titles included inside sales, plumbing and hydronics sales, special projects manager, general manager, and president. Overall, the interviewees believe that the program discounts have increased the sales of ECM circulator pumps in Maine and fueled a circulator pump market transformation.

Key findings from specific questions are shown below.

- How has your company’s participation in Efficiency Maine’s Distributor program influenced your stocking and sales of hydronic circulator pumps in recent years?
  - Four out of five indicated that the stocking and sales of ECM pumps has increased in response to the incentives. The fifth indicated no significant change in volume (and also said stocking them has always been a necessity).
- In the last year, about what percentage of the time did you recommend program-qualifying ECM models when discussing circulator pumps with buyers?
  - Average: 75%
  - Range: 60% to 90%
- What percentage of the time would you be recommending ECM circulator pumps if Efficiency Maine discounts were not available?
  - Average: 61%
  - Range: 40% to 90%
- How have contractors’ views/opinions of ECM circulator pumps changed in recent years?
  - There was skepticism early on, but contractors are more confident in the pumps now.
- On a scale from 0 to 10, where 0 is not at all influential and 10 is extremely influential, how influential has Efficiency Maine’s program been in reaching the current level of awareness and adoption of ECM circulator pumps among Maine contractors?
  - Average: 8.2
  - Range: 7 to 9
- Do you think ECM circulator pumps will eventually become the market standard in Maine even without program discounts?
  - Four out of five said yes, and the other said that it would not happen without discounts or legislation.
- Do you see differences in purchase patterns in Maine compared to neighboring states? What are the drivers for any differences relative to Maine?

- Three stated that they observe more ECM pump sales in Maine than other states, with two specifically identifying New Hampshire as a state with lower sales for ECM pumps. One distributor mentioned that New York, Rhode Island, and Massachusetts have incentives, but the price for the pumps is higher than Maine, leading to fewer sales than Maine.
- Approximately what percentage of the circulator pump sales [in the last year] do you think were ECM?
  - Average: 72%
  - Range: 50% to 95%
- Imagine a hypothetical scenario in which Efficiency Maine never offered discounts on ECM circulator pumps and the discounts were not going to be available in the next 12 months. Under that hypothetical scenario, what share of your circulator pump sales do you anticipate would be ECM in the next 12 months?
  - Average: 35%
  - Range: 5% to 50%
- Can you walk me through your thought process for the prior question?
  - Three out of five indicated shares would decrease due to the cost. Another thought the percentage would decrease but did not cite a specific reason. The other indicated the share would not change now that the technology has been adopted.

#### 4.3.2 CONTRACTOR INTERVIEWS

DSA spoke with fifteen contractors and recorded their responses to four questions regarding their stocking practices and the circulator pump market. [Table 6o](#) shows the four questions and a summary of the responses. Key findings include:

- 60% of the contractors interviewed indicated that the discounts have influenced their selection of circulator pumps.
- When scoping a project, 60% of the contractors interviewed typically propose just the ECM model. Another 27% present both ECM and non-ECM options.
- Overall, contractors thought the share of circulator pump installations that are ECM would drop from 74% to 44% in a counterfactual scenario where incentives would not be available in the future and the incentive program never existed.

Table 6o: Contractor ECM Program Questions

Question	Interview Findings
Q1. How has the availability of Efficiency Maine’s instant discounts influenced your selection of hydronic circulator pumps in recent years?	60% of respondents (9 of 15) indicated that they would sell fewer ECM circulator pumps without the discounts. Four others cited the ECM option as superior and indicated that their share of circulator pump installations that are ECM is not affected by the discounts. The remaining two seemed unaware of the incentives.

Question	Interview Findings
Q2. Do you usually present homeowners with a non-ECM option when scoping a project? Or do you simply propose an efficient ECM model?	60% of respondents (9 of 15) indicated that they typically present the ECM option, 27% (4 of 15) indicated that they typically present both options, and 13% (2 of 14) present the non-ECM option.
Q3. Thinking about all of the circulator pump installations your company has done in Maine in the last year, approximately what percentage of the installations were ECM?	The average response was 74%, though three did not directly answer the question. Six contractors were in the 90-100% range, two said around 80%, two said about 50%, and two indicated it was low.
Q4. Imagine a hypothetical scenario in which Efficiency Maine never offered discounts on ECM circulator pumps and no discounts were going to be available in the next 12 months. Under that hypothetical scenario, what share of your circulator pump installations do you think would be ECM in the next 12 months?	The average response was 44%. More than half of the interviewees indicated that they expected the installations of ECMs would be below 50% if no discounts were offered. Three contractors said they expected the percentage to be around 0%. Four others expected to still have more than 75% of their installations as ECMs because it is a superior product.

#### 4.4 METERING ANALYSIS

To understand the energy impacts of ECMCPs in residential applications, we metered a sample of 41 program-supported ECM circulator pumps in 22 Maine homes. The metering period varied by house but generally ran from November 2024 through March 2025. The objective of the metering study was to develop updated per-unit savings assumptions for incorporation in the Efficiency Maine TRM. In subsequent sections, we summarize our data sources, modeling methods, and the results from our analysis. Our TRM recommendations for residential installations are provided in [Section 4.5](#).

##### 4.4.1 DATA SOURCES

###### 4.4.1.1 Program Tracking Data

In total, Efficiency Maine provided discounts for 14,777 ECM circulator pumps during fiscal year 2023 (FY2023). [Table 61](#) shows the aggregate savings metrics for FY2023.

Table 61: FY2023 Reported Savings

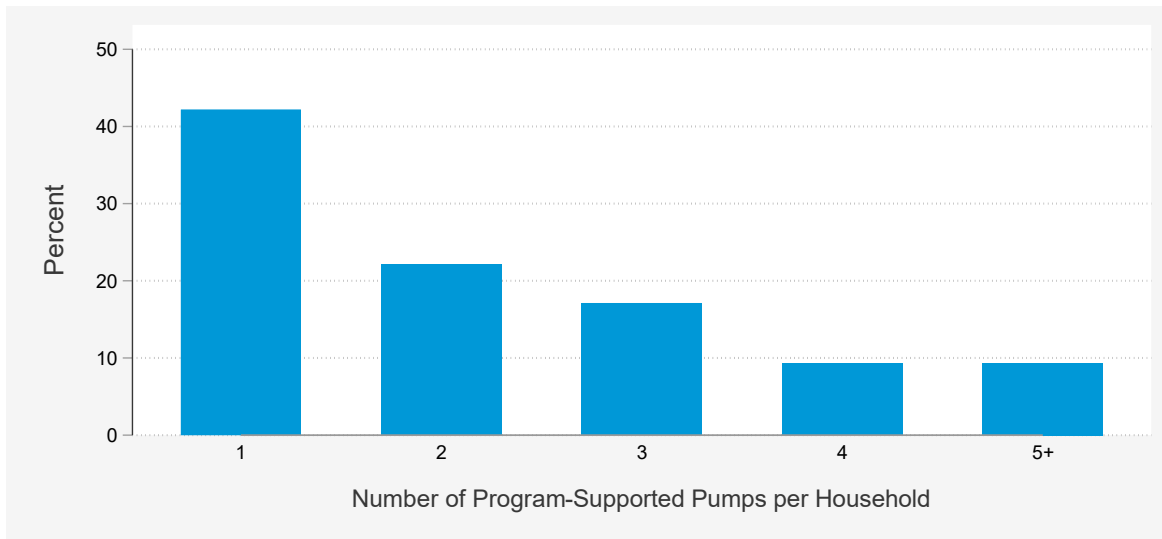
Metric	Residential	Commercial	Total
Installed Measure Quantity	14,304	473	14,777
Energy Savings (MWh)	1,441	234	1,675
Winter Peak Demand Savings (MW)	0.52	0.02	0.54

Installation addresses were not collected for approximately 75% of tracking data records, so these records were removed from the sample frame. Additionally, we removed commercial enrollments from our sample frame because fewer than 5% of pumps were installed in commercial buildings. Note the

claimed winter peak savings for all residential ECM circulator pumps is 0.0363 kW, but this value is higher for commercial pumps and varies based on pump size.

Many participants installed multiple program-supported pumps. [Figure 52](#) shows the distribution of the number of program-supported pumps per home for installations where the address was collected. The average number of pumps per home was slightly greater than two. The height of the bars is dictated by households, not pumps.

**Figure 52: Number of Program-Supported Pumps per Household**



#### 4.4.1.2 Metering Sample

The sample frame for our analysis was FY2023 participants whose addresses were collected. From this group, we recruited 22 homes to participate in the metering study. In total, we metered 41 program-supported ECM circulator pumps (for an average of 1.86 pumps per home). Meters were installed during fall 2024. Some installations included a cellular gateway to provide remote access to the data and others stored the data locally. Our technicians collected meters from the homes without remote communications in March 2025. We also downloaded data from the meters in homes with remote communications in March 2025, but left the devices in place to gather additional spring data. [Figure 53](#) shows the geographic distribution of participating homes. While in the field, our technicians also took spot measurements on non-ECM pumps to inform the Watts<sub>Base</sub> metric.

Figure 53: Geographic Distribution of Metering Sample

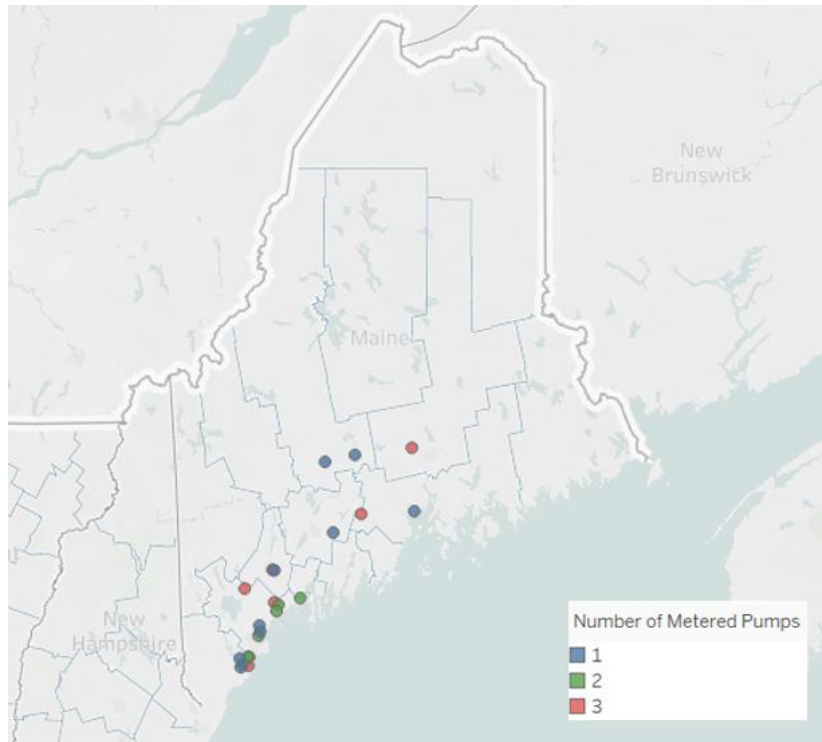


Table 62 summarizes the pump models that were in our metering sample. The average rated wattage across all pumps in our sample was 44.4 watts.

Table 62: Pump Models

Pump Model	Rated Watts	Metering Count	Metering Percent
Model 1	44	3	7.3%
Model 2	45	4	9.8%
Model 3	44	30	73.2%
Model 4	44	3	7.3%
Model 5	58	1	2.4%
<b>Total</b>	<b>44.4</b>	<b>41</b>	<b>100%</b>

Most of the pumps we metered served as supply or return pumps in a hydronic heating system, but a few of them served a domestic hot water (DHW) system or DHW in addition to space heating. We confirmed that the pumps serving DHW were indeed ECM circulator pumps supplying heat exchangers, not recirculator pumps.<sup>16</sup> Table 63 shows the distribution of pump applications for the pumps in our metering sample.

<sup>16</sup> The DHW circulating pumps supply hot water to the heat exchangers contained within the indirect hot water storage tanks. They don't directly pump the DHW.

Table 63: Pump Applications

Application	Count	Percent
Hydronic Space Heating	36	87.8%
Domestic Hot Water and Space Heating	2	4.9%
Domestic Hot Water	3	7.3%
<b>Total</b>	<b>41</b>	<b>100.0%</b>

#### 4.4.1.3 Meter Data

We metered both flow (gallons per minute) and current (amps), but this analysis focuses on the current readings. The current meters logged amperage in 1-minute intervals. To convert logged amperage into power (watts), we took a series of true power measurements for several operating points to establish the power factor. The average measured voltage was 121 and the average measured power factor was 0.554. The amps-to-watts conversion formula is as follows:

$$Watts = Amps * Voltage * Power Factor$$

We provide additional details regarding the metering set up in [Section 6.2.2](#).

[Figure 54](#) shows average hourly load shapes during the 24/25 winter for each of the pumps in our sample. The Y axis shows Percent On, which is equal to the average wattage for the hour divided by the pump’s average power draw when operating. The number above each figure consists of a home ID and a pump ID. For example, the three pumps in the top left (10.1, 10.2, and 10.3) are all in the same house (DSA ID 10). For homes with multiple pumps, we generally see that one of the pumps shows considerably more runtime than the other(s). The three in the top left are a good example – pump 10.2 runs significantly more often than pump 10.1 or pump 10.3.

Figure 54: Winter Load Shapes

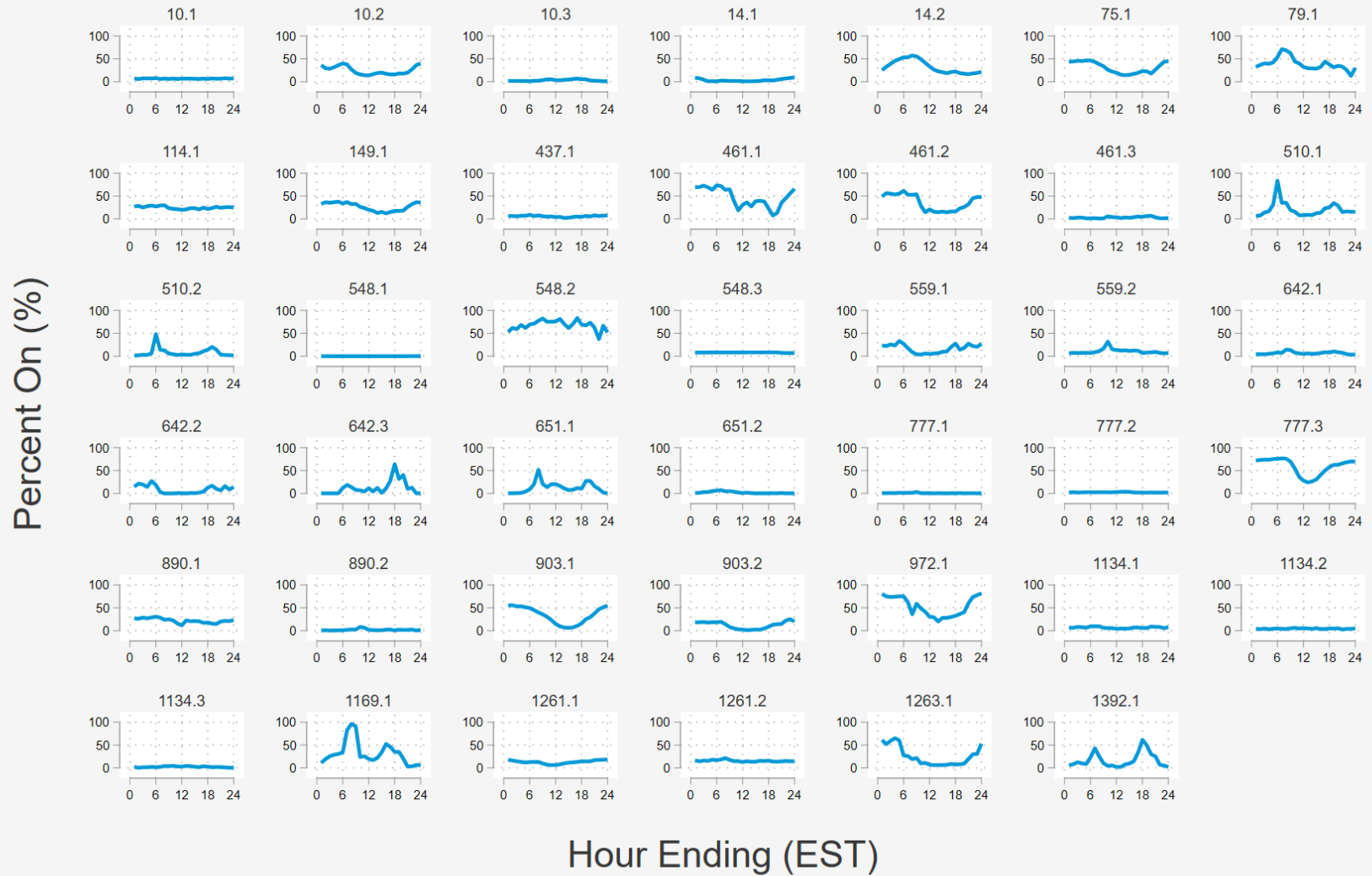
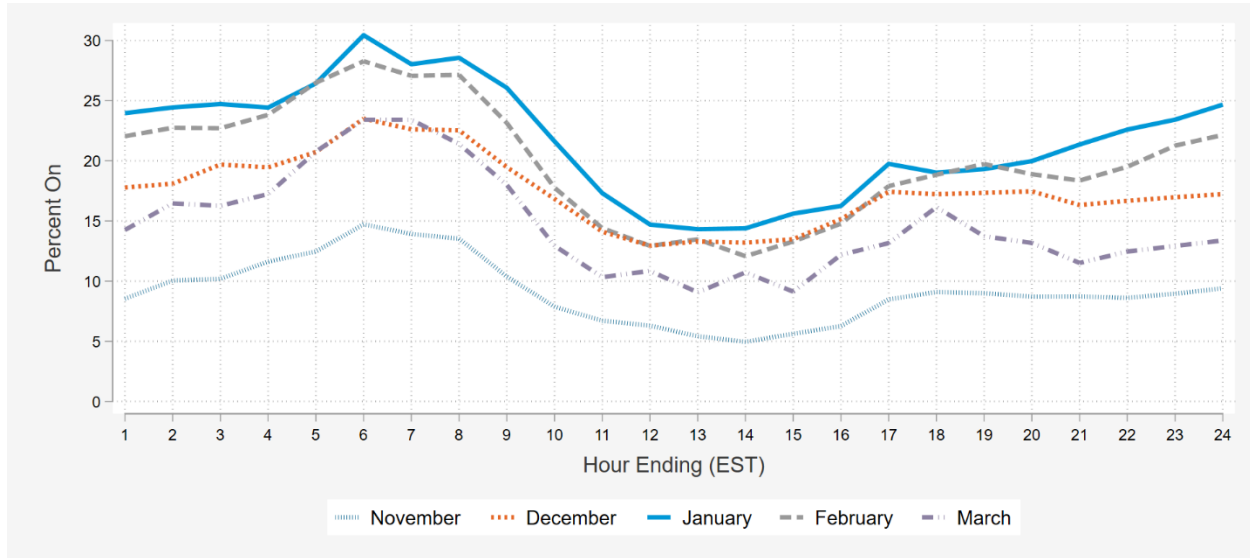


Figure 55 shows average hourly load shapes for each month in the metering period. Runtime was highest in January and February (light blue and gray) and lowest in November (dark blue). Across the sample, runtime tends to peak in the morning (between 6 AM and 8 AM), drop during the late morning, and then start to climb again in the afternoon and evening as temperatures drop. The profiles in this figure are not weather-normalized.

Figure 55: Sample Load Shapes by Month



#### 4.4.1.4 Weather Data

Two different weather datasets were used in the analysis: (1) actual historical weather records to help understand the relationship between pump runtime and weather, and (2) typical meteorological year (TMYx) weather data representative of a “normal” weather year in Maine.<sup>17</sup> Regarding the historical weather data, each home in the metering sample was mapped to a weather station based on a zip-to-station map provided by Efficiency Maine. Figure 56 shows the map with the weather station locations indicated by a black circle and the associated zip codes color-coded as shown in the legend. Several of the stations on the map were not used in the analysis.

Regarding the TMYx data, we developed a population-weighted 8760 TMYx profile using TMYx data from Portland, Bangor, and Caribou. The weights used were drawn from the Efficiency Maine TRM (Portland – 71.2%, Bangor – 23.4%, and Caribou – 5.4%). The population-weighted 8760 TMYx profile was used to produce weather-normalized savings estimates.

<sup>17</sup> Multiple variations of TMYx data are available at <https://climate.onebuilding.org/>. For the evaluation, we used the 2009-2023 version.

Figure 56: Zip-to-Station Map

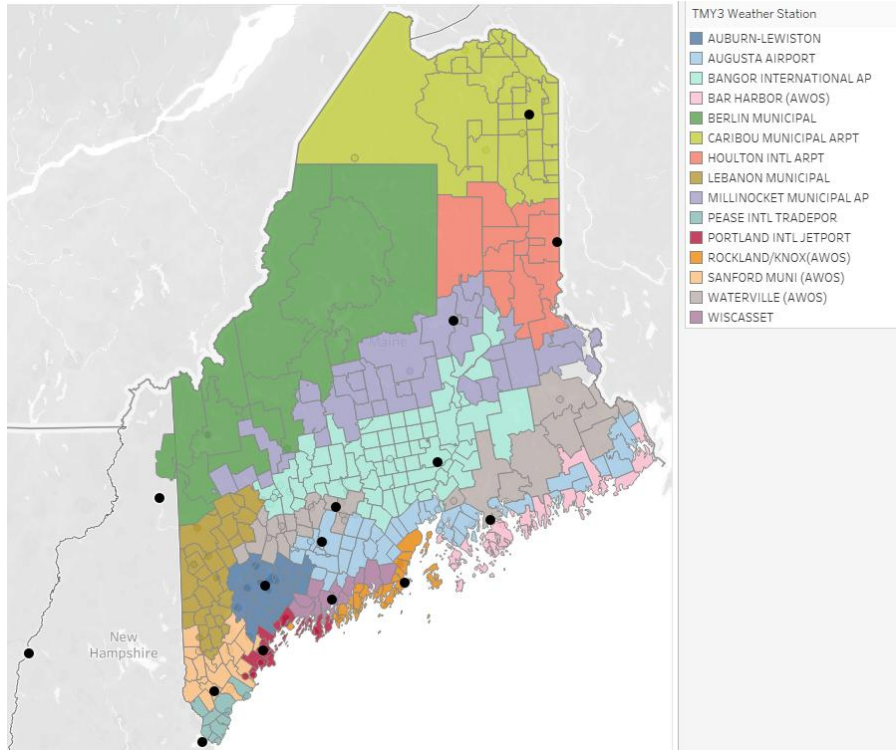
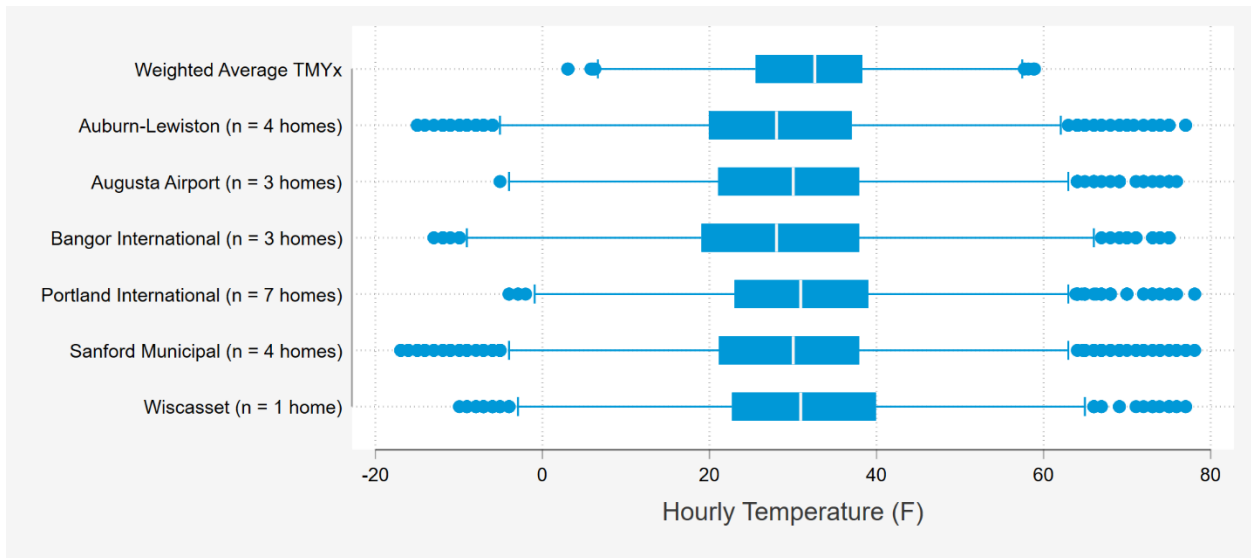


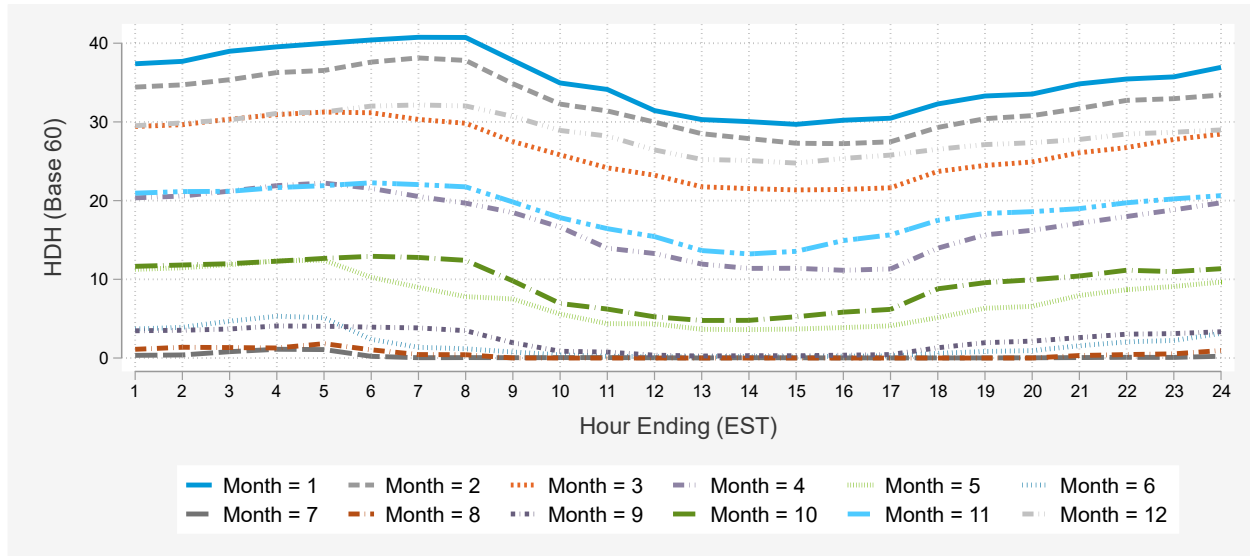
Figure 57 shows the distribution of hourly temperatures (November 2024 – March 2025) for each of the six weather stations used in our analysis. The distribution is also shown for the weighted average TMYx profile during the same period. The TMYx temperature range was fully covered in our analysis period weather data. All homes experienced sub-zero temperatures during the metering period.

Figure 57: Distribution of Temperature Records during Metering Period



Using the population-weighted 8760 TMYx data, [Figure 58](#) shows average hourly heating degree hours (HDH) for each month. A base of 60 was used in the HDH calculation. Average HDH60 peaks in January and February and is virtually zero in July and August.

Figure 58: HDH60 Hourly Profile by Month, TMYx



#### 4.4.2 METHODS

[Table 64](#) summarizes our analysis approach for each impact factor. At a high level, we used a regression analysis to understand the relationship between pump runtime and outdoor air temperature, and then we cast this relationship over a normal weather year. The weather-normalized results were used to produce estimates of annual operating hours, winter and summer coincidence factors, and energy period factors. Relative precision for each impact factor is estimated at the 80% confidence level. The following sections provide additional details.

Table 64: Summary of Analysis Approach

Impact Factor	Approach
Watts <sub>EE</sub>	For each pump, review the distribution of wattage across intervals when the pump is running. The median wattage value across these intervals is the estimate of Watts <sub>EE</sub> . Note 1-minute interval current data converted to power was used for the determination of Watts <sub>EE</sub> .
Watts <sub>Base</sub>	Assign each ECM pump to a non-ECM baseline pump. Estimate the average wattage of the baseline pumps based on spot amp and power readings taken from non-ECM pumps while in the field.
CF <sub>W</sub>	Use results from regression analysis to predict consumption under TMYx conditions. The CF <sub>W</sub> estimate is based on predicted consumption during the ISO-NE winter peak period (December-January non-holiday weekdays, 5:00 – 7:00 PM).
CF <sub>S</sub>	Use results from regression analysis to predict consumption under TMYx conditions. The CF <sub>S</sub> estimate is based on predicted consumption during the ISO-NE summer peak period (June-August non-holiday weekdays, 1:00 – 5:00 PM). Summer runtime is mostly limited to pumps that supply heat exchangers in a DHW system.
ΔkW <sub>max</sub>	$\Delta kW_{max} = (Watts_{Base} - Watts_{EE}) / 1,000$
ΔkW <sub>wp</sub>	$\Delta kW_{wp} = CF_W * (Watts_{Base} - Watts_{EE}) / 1,000$
ΔkW <sub>sp</sub>	$\Delta kW_{sp} = CF_S * (Watts_{Base} - Watts_{EE}) / 1,000$
Hours	Use results from regression analysis to predict consumption under TMYx conditions. Sum the number of run hours for each pump in a typical weather year, then find the average.
ΔkWh	$\Delta kWh = Hours * (Watts_{Base} - Watts_{EE}) / 1,000 * ISR$
EPF <sub>S</sub>	Use results from regression analysis to develop weather-normalized 8760 load profiles. Determine the share of consumption in each of the four energy period factor windows defined in the Efficiency Maine TRM.

#### 4.4.2.1 Watts<sub>EE</sub> and Watts<sub>Base</sub>

Watts<sub>EE</sub> and Watts<sub>Base</sub> represent the typical electrical demand of the ECM pump and the baseline non-ECM pump. Our Watts<sub>EE</sub> estimate for each pump is equal to the median wattage during intervals in which the pump is running. Figure 59 visualizes the distribution of wattage for two pumps. In the left panel, the median wattage is approximately 22.3. In the right panel, the median is approximately 12.0. Respectively, these are the Watts<sub>EE</sub> estimates for these two pumps.

After estimating Watts<sub>EE</sub> for each pump, we used an 80% confidence interval to estimate the sample average Watts<sub>EE</sub> and relative precision. No regression modeling was used for the Watts<sub>EE</sub> estimate. We

also used a confidence interval approach for  $Watts_{Base}$ . While in the field, our technicians took spot amp and power measurements on non-ECM pumps. Table 65 shows the average wattage for the relevant models. Each ECM pump in our sample was assigned to one of these baseline pumps based on pump manufacturer.

Figure 59: Wattage Distribution when Pump is Running

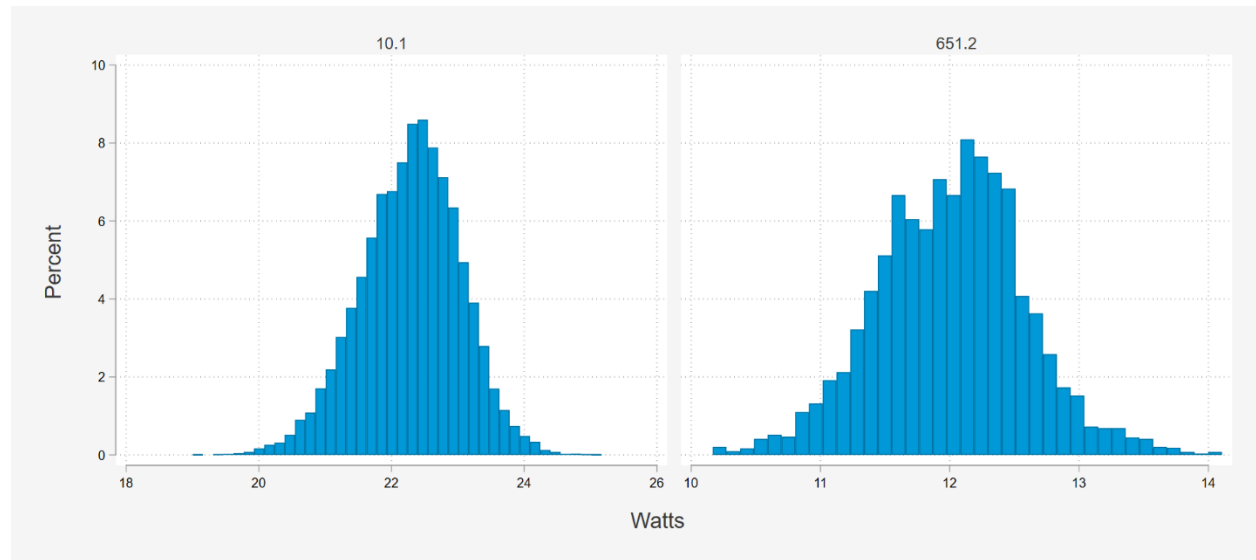


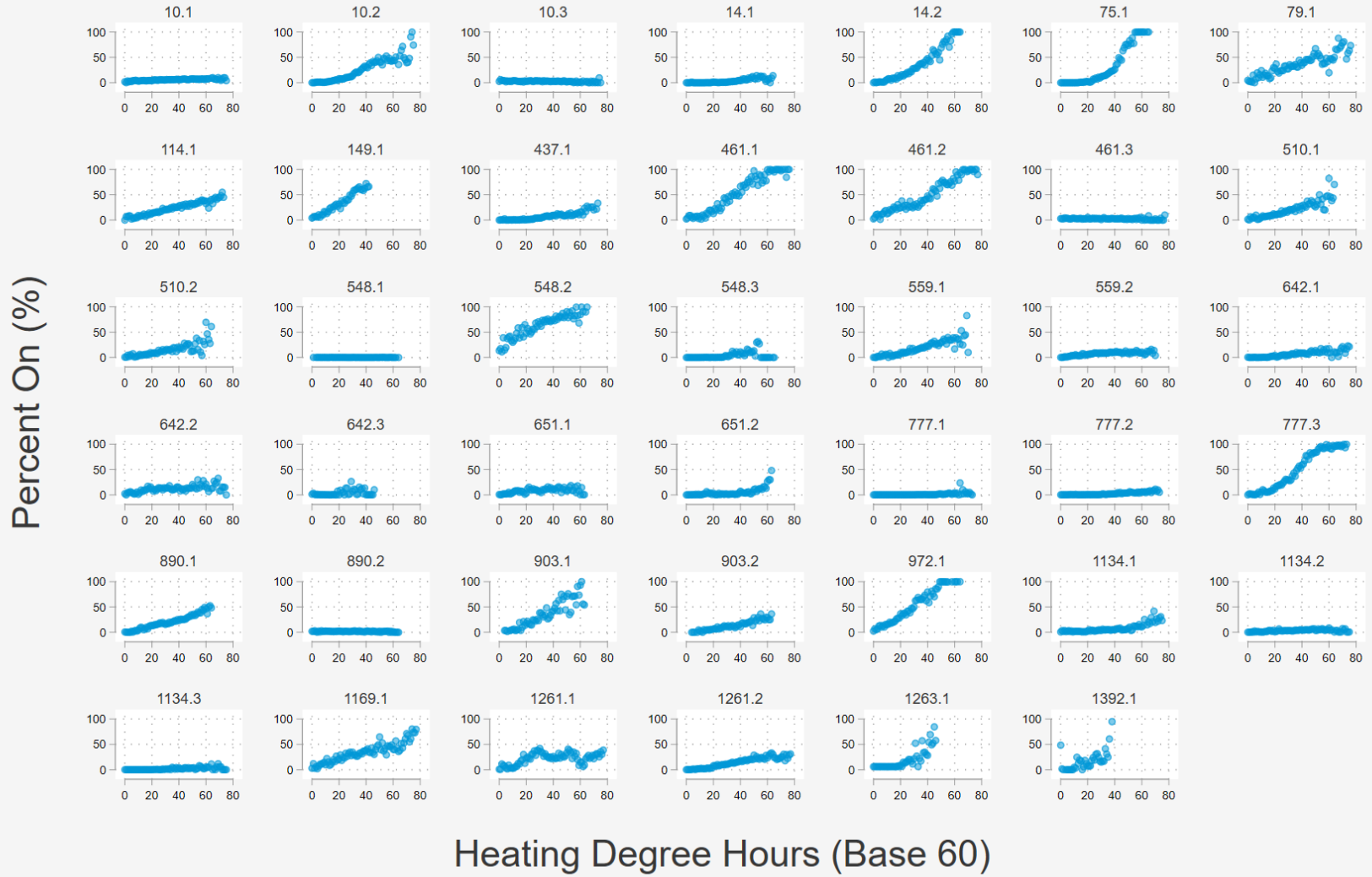
Table 65: Baseline Pump Wattage

Pump Model	Baseline Pump Power (W)
Model 1, Model 2	89.5
Model 3, Model 4, Model 5	76.6

#### 4.4.2.2 Regression Analysis

We used a regression analysis to estimate coincidence factors, annual runtime hours, and energy period factors. For each pump, we modeled the relationship between pump runtime and outdoor air temperature. Heating degree hours (HDH base 60) were used as an independent variable in the regression models rather than temperature. The regression analysis also controlled for time of day and time of week (weekday vs. weekend/holiday). Figure 60 visualizes the relationship between runtime and HDH60 for each pump. Runtime generally increases as temperatures drop – especially for the pumps with the most runtime.

Figure 6o: Relationship between Percent On and HDH60 by Pump



The regression model specification is shown below. Note we ran separate models for weekdays and for weekend/holidays.

$$PCTON_t = \beta_0 + \beta_1 * HDH60_t + \sum_{i=2}^{24} \beta_i * (HR_{i,t}) + \epsilon_t$$

Where:

- $PCTON_t$  represents the percentage of the hour in which the pump was running during hour  $t$ . This is calculated by dividing the average wattage for the hour by the pump's  $Watts_{EE}$ .
- $\beta_0$  represents the average of  $PCTON$  during hour ending 1 (12-1 AM) when HDH60 equals zero.
- $\beta_1$  represents the incremental effect of each HDH60 on  $PCTON$ .
- $HDH60_t$  represents the number of heating degree hours during hour  $t$ , where heating degree hours is calculated as the maximum of (1) zero and (2)  $60 - \text{outdoor air temperature}$ .
- $\beta_2$  represents the difference between the average of  $PCTON$  during hour ending 1 and hour ending 2 (when HDH60 equals zero). Definitions for  $\beta_3$  through  $\beta_{24}$  are similar.
- $HR_{2,t}$  is an indicator variable that equals 1 during hour ending 2 (1-2 AM) and equals 0 otherwise. Definitions for  $HR_{3,t}$  through  $HR_{24,t}$  are similar.
- $\epsilon_t$  represents random error.

The estimate of  $\beta_1$  captures the change in pump runtime in response to outdoor temperature, and the estimates of  $\beta_2$  through  $\beta_{24}$  can be used to estimate the non-weather-dependent hourly load shape. After estimating model parameters for each pump, we used the coefficients to predict Percent On under TMYx weather conditions for each hour in a hypothetical year. The output from this analysis is a weather-normalized 8760 load profile for each pump. We used these 8760 profiles to estimate the following factors:

- **Winter coincidence factor:** Find the average of predicted PCTON across all non-holiday weekdays in December and January, 5-7 PM.
- **Summer coincidence factor:** Find the average of predicted PCTON across all non-holiday weekdays in June, July, and August, 1-5 PM. For any pump that serves a hydronic heating system, runtime is predicted to be zero during summer hours where the temperature exceeds 60 degrees (F).
- **Annual hours of runtime:** Sum predicted runtime (in hours) over the full year for each pump, and then find the average.
- **Energy period factors:** Sum predicted runtime (in hours) in each of the four energy periods for each pump, then convert to shares and find the average. The four energy periods are defined as follows: Winter On Peak: 7 AM to 11 PM on non-holiday weekdays during October through May; Winter Off Peak: 11 PM to 7 AM on non-holiday weekdays and all hours on weekends and holidays during October through May; Summer On Peak: 7 AM to 11 PM on non-holiday weekdays during June through September; Summer Off Peak: 11 PM to 7 AM on non-holiday weekdays and all hours on weekends and holidays during June through September.

The estimates above, as well as the estimates for Watts<sub>EE</sub> and Watts<sub>Base</sub>, are used to calculate the  $\Delta kW$  and  $\Delta kWh$  impact factors. The formulas are shown in Table 64. Relative precision for these factors was estimated in quadrature (square root of the sum of squares), while relative precision for the other factors was estimated using the margin of error from an 80% confidence interval:

$$Relative\ Precision = \frac{Margin\ of\ Error\ at\ 80\%\ Confidence}{Impact\ Estimate}$$

#### 4.4.3 RESULTS

Table 66 shows our evaluation results. On average, we found that ECM circulator pumps in residential applications reduce peak demand by approximately 0.0104 kW during the winter peak period and reduce energy consumption by about 47.2 kWh annually. The presence of non-zero summer peak demand savings reflects the fact that some ECM circulator pumps will serve heat exchangers in DHW systems. The summer peak demand impact is minimal on average (0.0003 kW).

Table 66: Per-Unit Impact Factors – ECMCPs in Residential Applications

Impact Factor	Evaluated Value	Relative Precision at 80% Confidence
Watts <sub>Base</sub>	78.2	1.1%
Watts <sub>EE</sub>	20.1	10.0%
CF <sub>w</sub>	17.9%	17.8%
CF <sub>s</sub>	0.6%	69.5%
$\Delta kW_{max}$	0.0581	10.0%
$\Delta kW_{wp}$	0.0104	20.4%
$\Delta kW_{sp}$	0.0003	70.1%
Annual Hours	812	19.0%
$\Delta kWh$	47.2	21.5%
EPF – Winter Off	51.7%	---
EPF – Winter On	39.7%	---
EPF – Summer Off	5.1%	---
EPF – Summer On	3.5%	---

Figure 61 summarizes the typical 8760 pump runtime profile via heat map. Pockets of orange represent hours where runtime is high, and pockets of blue represents hours where runtime is low. As expected, most of the runtime occurs during winter mornings and evenings when outdoor temperatures are the lowest. There is also some runtime during the mornings and evenings in the shoulder months. Summer runtime is mostly limited to pumps that serve heat exchangers in DHW systems. For pumps that serve space heating, we assumed that runtime would be zero during any June-August hour where the temperature exceeds 60 degrees (meaning HDH<sub>60</sub> is zero). We did allow for non-zero space heating runtime predictions in June-August if TMY<sub>x</sub> temperatures dropped below 60 degrees. Figure 58 showed average hourly HDH<sub>60</sub> for each month of the TMY<sub>x</sub> year. Average HDH<sub>60</sub> is virtually zero in July and August and occasionally non-zero during June mornings and evenings.

Figure 61: Pump Runtime Heat Map

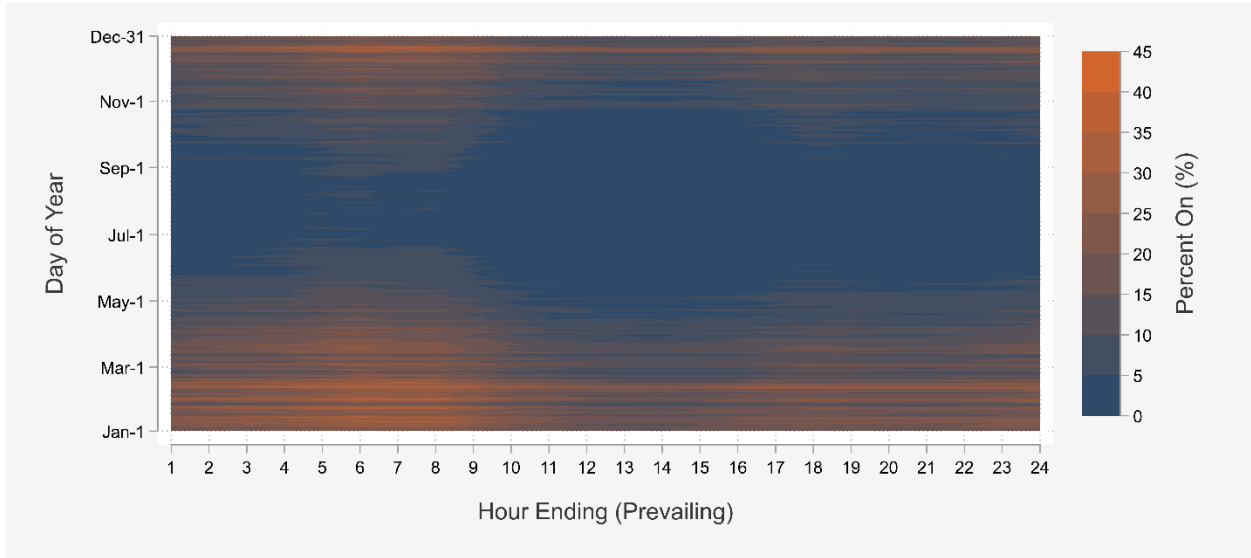


Figure 62 shows weather-normalized runtime across December and January non-holiday weekdays. For reference, runtime during the winter peak hours is denoted with black circles, and TMYx temperatures are shown in purple. ECM circulator pump runtime peaks between 6-8 AM when outdoor temperatures are lowest. During the winter peak window, percent runtime is 17.9%.

Figure 62: Normalized Runtime During Winter Peak Period

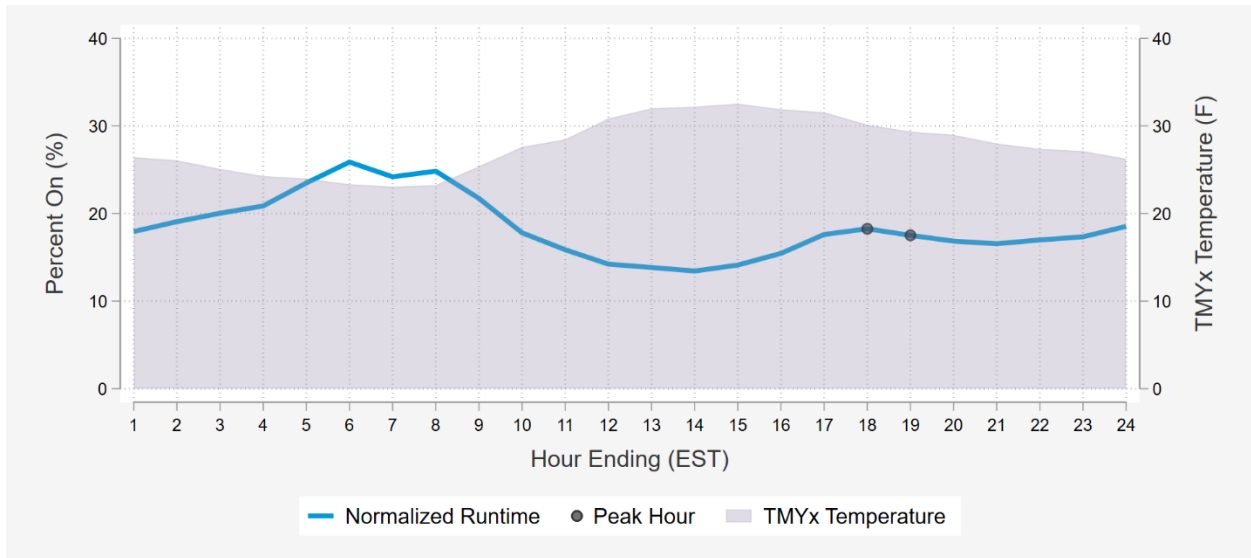


Figure 63 shows weather-normalized runtime across June, July, and August non-holiday weekdays. Note the Y-axis in this figure ranges from 0% to 8% (compared to 0% to 40% in Figure 62). Most of the pumps in our sample serve space heating, and June-August runtime for these pumps is practically zero. This figure effectively shows a DHW load shape. Runtime is low because the DHW runtime is averaged with heating runtime, and the heating runtime carries most of the weight.

Figure 63: Normalized Runtime During Summer Peak Period

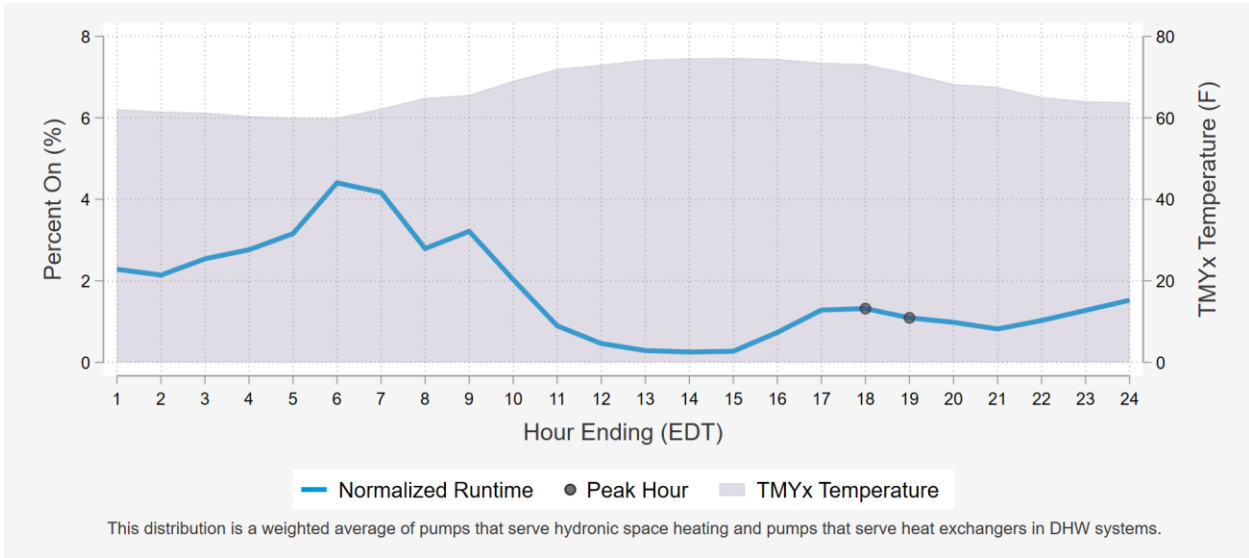
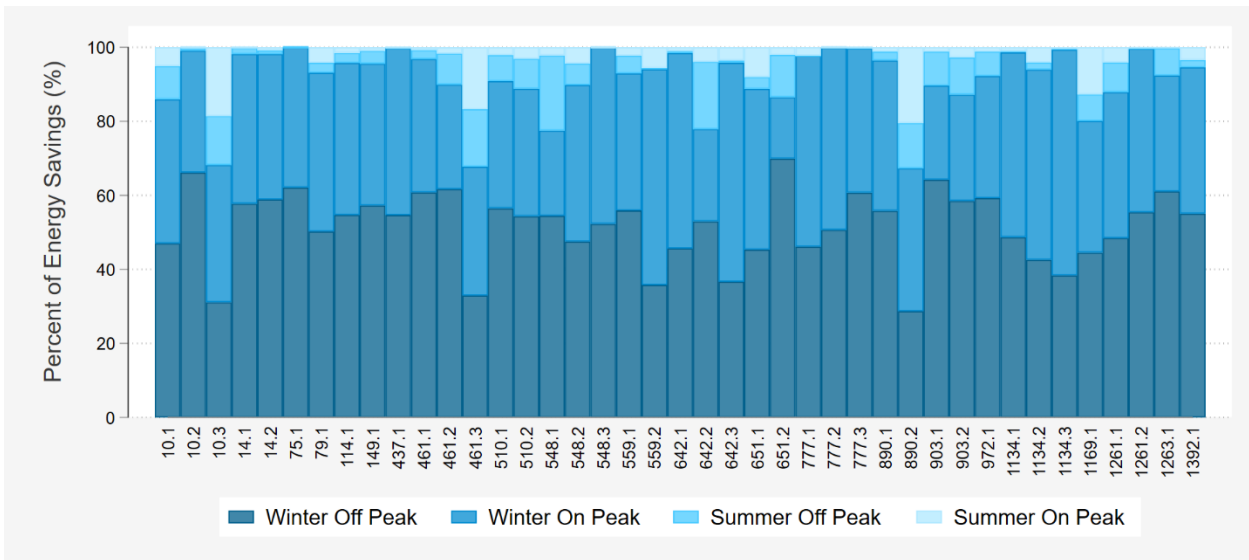


Figure 64 shows energy period factors for each pump. Darker blue colors represent winter periods and lighter blue colors represent summer periods. For EPFs, the “summer” definition includes June through September whereas the summer peak definition excludes September. Most of the savings occur in the winter when temperatures are relatively low. The pumps with the most summer on peak runtime (10.3, 461.3, 890.2, and 1169.1) are all used in DHW systems which run year-round.

Figure 64: Energy Period Factors by Pump



## 4.5 TRM RECOMMENDATIONS

Our per-unit TRM recommendations for residential ECM circulator pumps are in [Table 67](#). The table also shows the per-unit residential savings values that were in the TRM during the evaluation period.

Table 67: ECMCP TRM Recommendations – Residential Applications

Impact Factor	Reported Value <sup>[a]</sup>	Evaluated Value	Relative Precision (80% Confidence)	Realization Rate
Watts <sub>Base</sub>	87.7	78.2	1.1%	---
Watts <sub>EE</sub>	14.4	20.1	10.0%	---
CF <sub>W</sub>	49.5%	17.9%	17.8%	36.2%
CF <sub>S</sub>	0	0.6%	69.5%	---
$\Delta kW_{max}$	0.0733	0.0581	10.0%	79.3%
$\Delta kW_{wp}$	0.0363	0.0104	20.4%	28.7%
$\Delta kW_{sp}$	N/A	0.0003	70.1%	---
Annual Hours	1,374	812	19.0%	59.1%
$\Delta kWh$	100.7	47.2	21.5%	46.9%
EPF – Winter Off	56.1%	51.7%	---	---
EPF – Winter On	39.8%	39.7%	---	---
EPF – Summer Off	3.1%	5.1%	---	---
EPF – Summer On	1.0%	3.5%	---	---
In-service rate	100%	100%	---	---
Net-to-gross ratio	75.0%	79.5%	3.6%	---

<sup>[a]</sup> Retail/Residential version 2025.2

## 5 BENEFIT-COST ANALYSIS

Efficiency Maine’s primary benefit-cost test examines the cost effectiveness of program offerings from all utility customers’ perspective. This includes both participants of the program and non-participants. Table 68 lists and defines the relevant costs and benefits streams for the HPWH and ECM circulator pump impact evaluations.<sup>18</sup>

Table 68: Elements of Benefit-Cost Test

Cost or Benefit	Element	Description
Costs	Incremental Measure Cost	Incremental cost of the efficient measure relative to the baseline.
	Incentives	Incentives are excluded from the primary benefit-cost test unless the incentive is greater than the incremental measure cost, in which case the incentive is used in lieu of the incremental measure cost.
	Program Delivery Costs	Direct costs to manage and market programs.
	Increased Fuel Consumption	For fuel-switching measures, the increased fuel cost is treated as a cost.
Benefits	Avoided Cost of Electric Energy	Avoided cost of marginal generation by costing period (summer on-peak, summer off-peak, winter on-peak, winter off-peak). These costs include Demand Reduction Induced Pricing Effects (DRIPE).
	Decreased Fuel Consumption	Reduced usage of fuel as a result of program participation.
	Avoided Generating Capacity Costs	Value of avoided generation capacity during system peak. Calculated using a weighted average of the summer and winter demand impacts (2/3 winter demand and 1/3 summer) for retrospective scenarios. For prospective scenarios, summer and winter demand are valued separately.
	Avoided Transmission Capacity Costs	Deferred or eliminated investments in transmission capacity. Calculated using a weighted average of the summer and winter demand impacts (2/3 winter demand and 1/3 summer) for retrospective scenarios. For prospective scenarios, summer and winter demand are valued separately.
	Avoided Distribution Capacity Costs	Deferred or eliminated investments in distribution capacity. Calculated using a weighted average of the summer and winter demand impacts (2/3 winter demand and 1/3 summer) for retrospective scenarios. For prospective scenarios, summer and winter demand are valued separately.
	Line Losses	Value of reduced losses of energy and demand from generation to customer.
	Reduced Environmental Impacts	Value of avoided CO <sub>2</sub> and other emissions not embedded in the cost of supplying electricity or fuel.

<sup>18</sup> Efficiency Maine staff testimony regarding avoided costs in Efficiency Maine’s Triennial Plan VI is available at [https://www.efficiencymaine.com/docs/TPVI\\_Appendix\\_E1\\_Avoided\\_Costs\\_11-24.pdf](https://www.efficiencymaine.com/docs/TPVI_Appendix_E1_Avoided_Costs_11-24.pdf).

## 5.1 APPROACH

The evaluation team used two different sets of avoided costs and methodology and assumptions (M&As) in the analysis depending on the scenario.

- **Retrospective Scenarios:** Utilize the avoided costs and M&As in place during FY2023 and FY2024. These years were both part of the Efficiency Maine 2023-2025 Triennial Plan (Triennial Plan V, or TPV). TPV uses avoided costs from the 2021 Avoided Energy Supply Component Study (AESC 2021). The real discount rate used to calculate the present value of costs and benefits was 3.68%.<sup>19</sup> In scenarios that consider net-to-gross results, the Efficiency Maine perspective on incentives aligns with the 2017 National Standard Practice Manual for Energy Efficiency (NSPM). The NSPM recommends program administrators exclude incentives paid to free riders from cost effectiveness screening that includes participant impacts: “the net cost of free riders is zero under any test that includes participant impacts.”
- **Prospective Scenarios:** Utilize the avoided costs and M&As in place for Efficiency Maine’s 2026-2028 Triennial Plan (Triennial Plan VI, or TPVI). TPVI uses avoided costs from the 2024 Avoided Energy Supply Component Study (AESC 2024). The real discount rate for FY2026 is 3.93%.

The most notable differences between the avoided costs for TPV (AESC 2021) and TPVI (AESC 2024) are (1) avoided costs for natural gas and delivered fuels are higher under TPVI, (2) TPVI values summer and winter capacity separately (though winter capacity has a value of \$0 through 2046), and (3) the use of a Social Cost of Carbon to monetize greenhouse gas impacts in TPVI rather than the marginal abatement methodology used in TPV.

The evaluation team developed fifteen different benefit-cost scenarios for HPWHs and eleven different scenarios for ECMCPs. Note the ECMCP scenarios reflect residential installations only. We conducted the modeling in an Excel version of Efficiency Maine’s measure-screening tool. Prior to using the Excel version, we checked for consistency between the Excel calculator and the Cost Benefit Analysis Tool (CBAT) module in effRT. Once we were satisfied with the consistency of our modified Excel calculator and CBAT in effRT, we loaded the results of the impact evaluation and ran the scenarios laid out in [Table 6g](#).

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<sup>19</sup> The discount rate for FY2024 was 3.68% and the discount rate for FY2023 was 2.43%.

Table 6g: Benefit-Cost Scenarios

	Scenario	Perspective	Costs	Gross or Net	Description
Heat Pump Water Heaters	H-R1 2021 Gross Evaluated	Retrospective	AESC 2021	Gross	Based on the verified gross impacts determined by the impact evaluation
	H-R2 2021 Gross Replica	Retrospective	AESC 2021	Gross	Based on impact factors and gross per-unit savings assumptions that were in place during January 2023-June 2024.
	H-R3 2021 Net Evaluated	Retrospective	AESC 2021	Net	Based on the verified net impacts determined by the impact evaluation
	H-R4 2021 Net Replica – Instant NTG	Retrospective	AESC 2021	Net	Based on impact factors and net per-unit savings assumptions that were in place during January 2023-June 2024. The NTGR from the instant rebate (77%) is applied.
	H-R5 2021 Net Replica – Mail-in NTG	Retrospective	AESC 2021	Net	Based on impact factors and net per-unit savings assumptions that were in place during January 2023-June 2024. The NTGR from the mail-in rebate (92%) is applied.
	H-P1 2024 Gross Evaluated	Prospective	AESC 2024	Gross	Based on the verified gross impacts determined by the impact evaluation
	H-P2 2024 Gross Lower Bound	Prospective	AESC 2024	Gross	Based on the verified gross impacts, using the lower bound of the 80% confidence interval for the kWh/yr <sub>HWL</sub> metric, determined by the impact evaluation
	H-P3 2024 Gross Upper Bound	Prospective	AESC 2024	Gross	Based on the verified gross impacts, using the upper bound of the 80% confidence interval for the kWh/yr <sub>HWL</sub> metric, determined by the impact evaluation
	H-P4 2024 Gross Evaluated – Old EUL	Prospective	AESC 2024	Gross	Based on the verified gross impacts determined by the impact evaluation but with a shorter effective useful life (EUL) assumption (13 years vs 15 years)
	H-P5 2024 Gross Evaluated – TRM Recommendations	Prospective	AESC 2024	Gross	Based on per-unit TRM recommendations reflecting evaluation results and a current UEF assumption
H-P6 2024 Gross FF Base	Prospective	AESC 2024	Gross	Based on the verified gross impacts determined by the impact evaluation – non-electric baseline only	
H-P7 2024 Gross Electric Base	Prospective	AESC 2024	Gross	Based on the verified gross impacts determined by the impact evaluation – electric baseline only	
H-P8 2024 Net Evaluated	Prospective	AESC 2024	Net	Based on the verified net impacts determined by the impact evaluation	
H-P9 2024 Net Lower Bound	Prospective	AESC 2024	Net	Based on the verified net impacts, using the NTGR from the program pathway with the lowest NTGR value determined by the impact evaluation	
H-P10 2024 Net Upper Bound	Prospective	AESC 2024	Net	Based on the verified net impacts, using the NTGR from the program pathway with the highest NTGR value determined by the impact evaluation	

	Scenario	Perspective	Costs	Gross or Net	Description
ECM Circulator Pumps	E-R1 2021 Gross Evaluated	Retrospective	AESC 2021	Gross	Based on the verified gross impacts determined by the impact evaluation
	E-R2 2021 Gross Replica	Retrospective	AESC 2021	Gross	Based on impact factors and gross per-unit savings assumptions that were in place during FY2023
	E-R3 2021 Net Evaluated	Retrospective	AESC 2021	Net	Based on the verified net impacts determined by the impact evaluation
	E-R4 2021 Net Replica	Retrospective	AESC 2021	Net	Based on impact factors and net per-unit savings assumptions that were in place during Fy2023
	E-P1 2024 Gross Evaluated	Prospective	AESC 2024	Gross	Based on the verified gross impacts determined by the impact evaluation
	E-P2 2024 Gross Lower Bound	Prospective	AESC 2024	Gross	Based on the verified gross impacts, using the lower bound of the 80% confidence interval for $\Delta kWh$ determined by the impact evaluation
	E-P3 2024 Gross Upper Bound	Prospective	AESC 2024	Gross	Based on the verified gross impacts, using the upper bound of the 80% confidence interval for $\Delta kWh$ determined by the impact evaluation
	E-P4 2024 Gross Evaluated – Low Incentive	Prospective	AESC 2024	Gross	Based on the verified gross impacts determined by the impact evaluation but with an incentive value less than the incremental measure cost (\$50 instead of \$95)
	E-P5 2024 Net Evaluated	Prospective	AESC 2024	Net	Based on the verified net impacts determined by the impact evaluation
	E-P6 2024 Net Lower Bound	Prospective	AESC 2024	Net	Based on the verified net impacts, using the lower bound of the 95% confidence interval for the NTGR determined by the impact evaluation
E-P7 2024 Net Upper Bound	Prospective	AESC 2024	Net	Based on the verified net impacts, using the upper bound of the 95% confidence interval for the NTGR determined by the impact evaluation	

We calculate the net present value of each cost and benefit component and compute a ratio with the benefits in the numerator and costs in the denominator. A ratio greater than 1.0 indicates that the measure is cost-effective because the present value of the benefits exceeds the present value of the costs. A ratio of less than 1.0 indicates that the measure is not cost-effective because the present value of the benefits is less than the present value of the costs.

## 5.2 RESULTS

### 5.2.1 HEAT PUMP WATER HEATERS

Table 70 shows the benefit-cost ratio for each of the HPWH scenarios using Efficiency Maine’s primary test. In the primary prospective gross scenario (scenario H-P1), we estimate the measure returns \$1.94 of benefits per \$1 of cost. Note HPWH installations associated with the Efficiency Maine Low-Income Direct Install measure were not included in the analysis.

Table 70: HPWH Benefit-Cost Ratios

	Scenario	Perspective	Costs	BC Ratio
H-R1	2021 Gross Evaluated	Retrospective	AESC 2021	1.51
H-R2	2021 Gross Replica	Retrospective	AESC 2021	2.28
H-R3	2021 Net Evaluated	Retrospective	AESC 2021	1.46
H-R4	2021 Net Replica – Instant NTG	Retrospective	AESC 2021	2.16
H-R5	2021 Net Replica – Mail-in NTG	Retrospective	AESC 2021	2.24
H-P1	2024 Gross Evaluated	Prospective	AESC 2024	1.94
H-P2	2024 Gross Lower CI	Prospective	AESC 2024	1.71
H-P3	2024 Gross Upper CI	Prospective	AESC 2024	2.33
H-P4	2024 Gross Evaluated – Old EUL	Prospective	AESC 2024	1.74
H-P5	2024 Gross Evaluated – TRM	Prospective	AESC 2024	2.14
H-P6	2024 Gross FF Base	Prospective	AESC 2024	1.37
H-P7	2024 Gross Electric Base	Prospective	AESC 2024	2.17
H-P8	2024 Net Evaluated	Prospective	AESC 2024	1.31
H-P9	2024 Net Lower	Prospective	AESC 2024	1.30
H-P10	2024 Net Upper	Prospective	AESC 2024	1.32

We offer the following observations based on the results of the benefit-cost analysis:

- The retrospective scenarios generally produce lower BC ratios than the prospective scenarios. This result is largely a function of the different avoided cost datasets.
- The BC ratio for scenario H-P6, which isolates premises where the prior water heating fuel was non-electric, looks poor relative to the other scenarios. This is partially due to the treatment of fuel-switching costs in Efficiency Maine’s benefit-cost framework. If the increase in electric costs were treated as negative benefits rather than costs, the BC ratio would be 1.86 rather than 1.37.

### 5.2.2 ECM CIRCULATOR PUMPS

Table 71 shows the benefit-cost ratio for each of the ECM circulator pump scenarios using Efficiency Maine’s primary test. In the primary prospective gross scenario (scenario E-P1), we estimate the measure returns \$1.35 of benefits per \$1 of cost. Note these results reflect residential installations only.

Table 71: ECM Circulator Pump Benefit-Cost Ratios

	Scenario	Perspective	Costs	BC Ratio
<b>E-R1</b>	<b>2021 Gross Evaluated</b>	<b>Retrospective</b>	<b>AESC 2021</b>	<b>1.10</b>
E-R2	2021 Gross Replica	Retrospective	AESC 2021	2.90
E-R3	2021 Net Evaluated	Retrospective	AESC 2021	1.06
E-R4	2021 Net Replica	Retrospective	AESC 2021	2.78
<b>E-P1</b>	<b>2024 Gross Evaluated</b>	<b>Prospective</b>	<b>AESC 2024</b>	<b>1.35</b>
E-P2	2024 Gross Lower CI	Prospective	AESC 2024	1.10
E-P3	2024 Gross Upper CI	Prospective	AESC 2024	1.60
E-P4	2024 Gross Evaluated – Low Incentive	Prospective	AESC 2024	2.08
E-P5	2024 Net Evaluated	Prospective	AESC 2024	1.86
E-P6	2024 Net Lower CI	Prospective	AESC 2024	1.83
E-P7	2024 Net Upper CI	Prospective	AESC 2024	1.90

We offer the following observations based on the results of the benefit-cost analysis:

- While all BC ratios are greater than 1, the retrospective scenarios produced lower BC ratios than the prospective scenarios. This result is largely a function of the different avoided cost datasets.
- Efficiency Maine’s incentives for ECM circulator pumps are significantly higher than the incremental measure cost. In scenario E-P4, we modified the incentive value so that it is less than the incremental measure cost. This scenario results in a BC ratio of 2.08.
- These benefit-cost results reflect the residential ECMCP measure which was the focus of the evaluation. Efficiency Maine also incentivizes larger ECM circulator pumps in commercial businesses. Because the vast majority of program-supported ECMCP are residential, the benefit-cost results of the measure across sectors would be very similar to the values in Table 71.

## 6 APPENDICES

### 6.1 LOW-INCOME DIRECT INSTALL

#### 6.1.1 INTRODUCTION

The heat pump water heater (HPWH) impact evaluation presented in the body of this report focused on residential HPWHs delivered through the Instant Distributor, Instant Retail, and Mail-In Retail pathways. In each of these pathways, participants are responsible for self-installing the HPWH or selecting a contractor to perform the installation, and the program incentive only offsets a portion of the full cost of the system. During FY2024 and a portion of FY2025, Efficiency Maine also delivered HPWHs through the Low-Income Direct Install (LIDI) program. This offering fully subsidized the equipment and installation cost and coordinated installation through a program-participating contractor. The purpose of this appendix is to extrapolate findings from the HPWH impact evaluation to the LIDI program. The LIDI HPWH measure was discontinued at the end of FY2025, so the analysis is purely retrospective in nature. The LIDI HPWH measure has a separate characterization entry in the Efficiency Maine Technical Reference Manual (TRM) and differs from the primary HPWH measure in several important ways:

- 1) **The baseline fuel is known for each installation.** For each measure installation, the unadjusted gross savings stored in effRT either reflect an electric resistance baseline or an oil-fired integrated domestic hot water and space heating baseline (tankless coil). Savings are attributed to a different program depending on baseline fuel.
- 2) **The decision type is exclusively retrofit.** This is typical for income-qualified direct installation programs because the program is actively replacing working, inefficient systems rather than capturing natural turnover in equipment stock.
- 3) **The installation is paired with installation of low-flow devices.** In some homes, contractors pair the HPWH installation with low-flow showerheads, bathroom faucet aerators, and kitchen faucet aerators. These devices work in conjunction with the new HPWH to lower energy consumption for domestic hot water tasks in the homes.

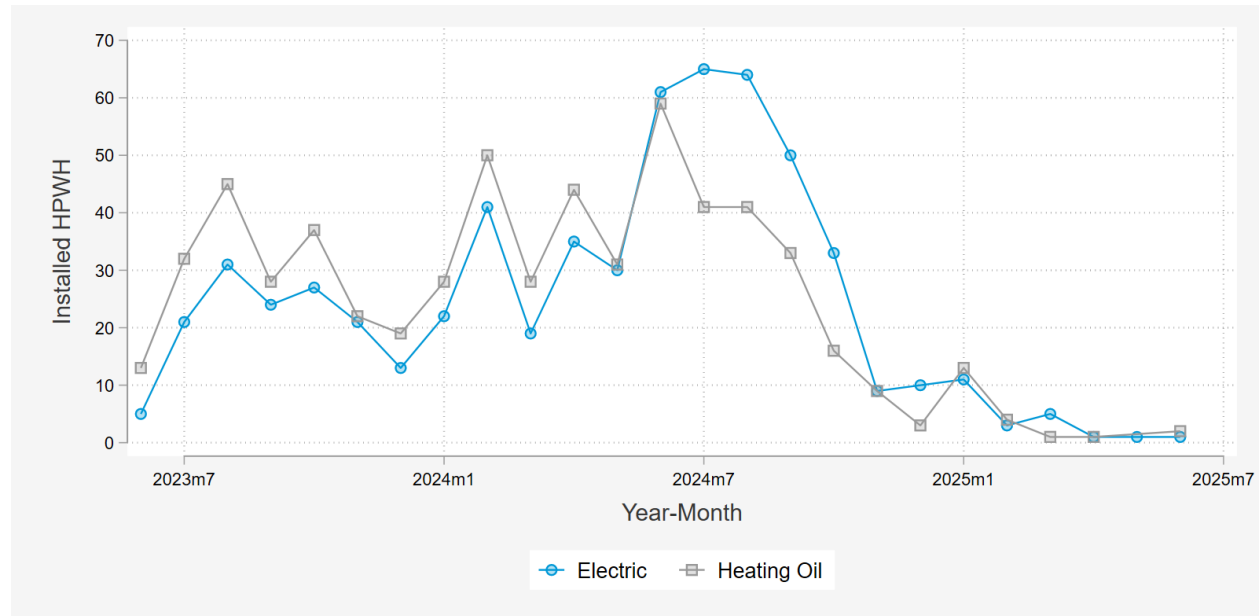
Table 72 shows the unadjusted gross resource savings by program name. The in-service rate and realization rates are all 100% for this measure, so the adjusted gross savings are equivalent to the unadjusted gross savings. The electric baseline measure records electric energy efficiency savings, while the fossil fuel baseline measure records heating oil savings and electric increases.

Table 72: LIDI Gross Savings Claims

Program Name	Installed Measure Quantity	kWh	Winter kW	Summer kW	Heating Oil (MMBtu)
LIDI – Electric	603	1,028,013	161.6	112.1	---
LIDI – Other Fuels	600	-504,312	-71.4	-61.8	12,222
<b>LIDI Total</b>	<b>1,203</b>	<b>523,701</b>	<b>90.2</b>	<b>50.3</b>	<b>12,222</b>

Figure 65 shows the measure installation quantity by month over the two fiscal year period separately for electric and fossil fuel baseline units.

Figure 65: LIDI HPWH Installations by Month and Baseline Fuel Type



Per-unit savings were largely consistent over the two-year period. Table 73 shows the savings assumptions stored in effRT for most installations. A limited number of units (n = 20) installed early in FY2024 claimed savings based on a prior TRM characterization with slightly different per-unit electric savings assumptions.

Table 73: Predominant Per-Unit Savings Assumptions

Program Name	kWh	Winter kW	Summer kW	Heating Oil (MMBtu)
LIDI – Electric	1,705	0.268	0.186	0
LIDI – Other Fuels	-838	-0.119	-0.103	20.37

The foundation of the LIDI HPWH measure characterization is the kWh/y<sub>HWL</sub> parameter. This term represents the annual domestic hot water load of a home expressed in kWh. The stipulated value in the TRM of 2,364 kWh comes from the 2020 West Hill Energy and Computing Heat Pump Water Heater Evaluation.<sup>20</sup> That study recommended Efficiency Maine apply a lower value for kWh/y<sub>HWL</sub> in low-income programs than market rate programs (2,821 kWh) based on lower metered hot water consumption among the low-income households in that study’s evaluation sample.

<sup>20</sup>

[https://www.energymaine.com/docs/WHEC\\_EMT\\_HPWH\\_Impact\\_Evaluation\\_Full\\_Report\\_with\\_Appendices\\_12\\_11\\_2019.pdf](https://www.energymaine.com/docs/WHEC_EMT_HPWH_Impact_Evaluation_Full_Report_with_Appendices_12_11_2019.pdf)

This assumption is used to estimate 1,705 kWh of annual electricity savings for electric baseline installations using the following equation and inputs.

$$\Delta kWh = \Delta kWh/y_{HWL} * \left( \frac{1}{EF_{Base}} - \frac{1}{(COP_{EE} * EAF)} \right)$$

Where:

- Coefficient of Performance (COP<sub>EE</sub>) = 3.4
- Efficiency Adjustment Factor (EAF) = 0.83
- EF<sub>Base</sub> = 0.9299

The 838 kWh annual increase in electric consumption from fossil fuel baseline installations comes from the same equation with the 1/EF<sub>Base</sub> term removed.

The 20.37 MMBtu of annual heating oil savings comes from the equation below and an assumed efficiency of 39.6% for tankless coil domestic hot water systems.

$$\Delta MMBtu = kWh/y_{HWL} * \left( \frac{0.003412}{EF_{Base}} \right)$$

The summer and winter demand impacts are the product of a load shape factor (LSF) and the estimated annual electricity savings.

A key finding of the HPWH evaluation presented in the body of this report was that the 2,821 kWh assumption overstated the true value for kWh/y<sub>HWL</sub>. Based on our AMI analysis and metering activities, we estimated a value of 1,534 kWh. This translates to approximately 10,000 gallons of domestic hot water (DHW) usage annually. Our participant survey – which did not include LIDI participants – returned an estimated 2.34 occupants per household. Given the modest DHW consumption found in the primary impact evaluation and the lack of information about household occupancy among LIDI participants, we have no basis to assume lower (or higher) hot water usage among LIDI participants. Therefore, our verified savings calculations use a value of 1,534 for the kWh/y<sub>HWL</sub> parameter.

Another key finding of the HPWH impact evaluation was the need for two distinct efficiency adjustment factors (EAF<sub>EE</sub> and EAF<sub>Base</sub>) which capture the effects of two distinct phenomena.

- 1) To reflect the fact that HPWHs do not operate at the rated UEF in practice because homeowners or contractors will often set the HPWH to hybrid mode, and this leads to the use of the resistance coils when DHW demand is high. This phenomenon applies to HPWHs (or EAF<sub>EE</sub>) only.
- 2) To capture inefficiencies due to standby losses. When energy is used to heat water, and that heat is lost to the surrounding space, no useful work is performed, and the efficiency of the system suffers. The issue of standby losses is most acute when DHW consumption is low because there is less useful heat delivered to dilute the losses. This phenomenon applies to both HPWHs and baseline units with storage tanks.

Our evaluated results apply the EAF values of 0.50 (HPWHs) and 0.75 (Base) to calculate the energy use associated with our annual DHW load assumption.

The make and model of each HPWH installed by the LIDI program is recorded in effRT along with the tank size and Uniform Energy Factor (UEF). All installed HPWH were 50-gallons and the average UEF was virtually identical at 3.447 for both fossil fuel and electric baseline units.

## 6.1.2 RESULTS

### 6.1.2.1 Electric Resistance Baseline

Evaluated electricity savings for LIDI HPWH replacing an existing electric resistance water heater were calculated using the algorithms below and the parameter values shown in [Table 74](#).

$$\Delta kWh = kWh/y_{HWL} * \left( \frac{1}{EF_{Base} * EAF_{Base}} - \frac{1}{(COP_{EE} * EAF_{EE})} \right)$$

$$\Delta kW_{wp} = \Delta kWh * LSF_{W_{EB}}$$

$$\Delta kW_{sp} = \Delta kWh * LSF_{S_{EB}}$$

Table 74: Electric Baseline Savings Parameters

Parameter	Value	Source
kWh/y <sub>HWL</sub>	1,534	DSA HPWH Impact Evaluation (AMI + Metering)
EF <sub>Base</sub>	0.904	US DOE energy efficiency standard (10 CFR Part 430) for a 50-gallon electric resistance water heater prior to 4/16/2015
EAF <sub>Base</sub>	0.75	DSA HPWH Impact Evaluation calibration of AMI and metering. Captures inefficiency introduced by standby tank losses
EAF <sub>EE</sub>	0.50	DSA HPWH Impact Evaluation calibration of AMI and metering. Captures inefficiency introduced by standby tank losses as well as units operating in hybrid mode
COP <sub>EE</sub>	3.447	Average rated UEF of program-installed units FY2024 and FY2025
LSF <sub>W<sub>EB</sub></sub>	0.000207	DSA HPWH Impact Evaluation. Ratio of winter peak demand savings to annual electricity savings among participants with an electric baseline
LSF <sub>S<sub>EB</sub></sub>	0.000091	DSA HPWH Impact Evaluation. Ratio of summer peak demand savings to annual electricity savings among participants with an electric baseline

[Table 75](#) shows the results based on the estimated per-unit savings and the total number of units claimed in FY2024 and FY2025. The per-unit kWh savings are 1,372, and the per-unit winter and summer peak kW savings are 0.284 and 0.125, respectively.

Table 75: Electric Baseline Evaluated Savings and Realization Rates

Resource Savings	Unadjusted Gross	Evaluated	Realization Rate
Number of Units	603	603	100.0%
kWh	1,028,013	827,610	80.5%
Winter kW	161.6	171.3	106.0%
Summer kW	112.1	75.3	67.2%

**6.1.2.2 Fossil Fuel Baseline**

Evaluated electricity and oil savings for LIDI HPWH replacing existing tankless coil water heaters were calculated using the algorithms below and the parameter values shown in Table 76.

$$\Delta kWh = kWh/y_{HWL} * \left( \frac{-1}{(COP_{EE} * EAF_{EE})} \right)$$

$$\Delta kW_{wp} = \Delta kWh * LSF_{W_{NEB}}$$

$$\Delta kW_{sp} = \Delta kWh * LSF_{S_{NEB}}$$

$$\Delta MMBtu = kWh/y_{HWL} * \left( \frac{0.003412}{EF_{Base} * EAF_{Base}} \right)$$

Table 76: Fossil Fuel Baseline Savings Parameters

Parameter	Value	Source
kWh/y <sub>HWL</sub>	1,534	DSA HPWH Impact Evaluation (AMI + Metering)
EF <sub>Base</sub>	0.396	Efficiency Maine TRM assumption for the efficiency of existing tankless coil systems
EAF <sub>EE</sub>	0.50	DSA HPWH Impact Evaluation calibration of AMI and metering. Captures inefficiency introduced by standby tank losses as well units operating in hybrid mode
EAF <sub>Base</sub>	1.00	This indicates the absence of an efficiency adjustment factor for tankless coil units. No additional adjustment factor is needed beyond the 39.6% efficiency captured by the EF <sub>Base</sub> term
COP <sub>EE</sub>	3.447	Average rated UEF of program-installed units FY2024 and FY2025
LSF <sub>W<sub>NEB</sub></sub>	0.000150	DSA HPWH Impact Evaluation. Ratio of winter peak demand to annual HPWH electricity consumption among participants with a fossil fuel baseline
LSF <sub>S<sub>NEB</sub></sub>	0.000046	DSA HPWH Impact Evaluation. Ratio of summer peak demand to annual HPWH electricity consumption among participants with a fossil fuel baseline

Table 77 shows the results based on the estimated per-unit savings and the total number of units claimed in FY2024 and FY2025. The per-unit kWh impacts are -890, and the per-unit winter and summer peak kW impacts are -0.134 and -0.041, respectively.

Table 77: Electric Baseline Evaluated Savings and Realization Rates

Resource Savings	Unadjusted Gross	Evaluated	Realization Rate
Number of Units	600	600	100.0%
kWh	-504,312	-534,030	105.9%
Winter kW	-71.4	-80.1	112.2%
Summer kW	-61.8	-24.6	39.7%
MMBtu (Oil)	12,222	7,930	64.9%

### 6.1.2.3 Overall Impacts

The realization rates shown in Table 75 and Table 77 can be difficult to interpret because electricity impacts are both positive and negative. Table 78 expresses the kWh impacts in MMBtu using a conversion rate of 1 kWh = 0.003412 MMBtu. The overall energy realization rate for the LIDI HPWH measure is 64%.

Table 78: Fuel Agnostic MMBtu at Site Results

Program Name	Unadjusted Gross			Evaluated		
	kWh	Oil MMBtu	MMBtu at Site	kWh	Oil MMBtu	MMBtu at Site
LIDI – Electric	1,028,013	-	3,508	827,610	0	2,824
LIDI – Other Fuels	-504,312	12,222	10,501	-534,030	7,930	6,108
<b>LIDI Total</b>	<b>523,701</b>	<b>12,222</b>	<b>14,009</b>	<b>293,580</b>	<b>7,930</b>	<b>8,932</b>
<b>Aggregate Realization Rates</b>				<b>56.1%</b>	<b>64.9%</b>	<b>63.8%</b>

The results for summer and winter peak demand savings are also a mix of positive and negative savings. Table 79 shows the aggregate summer and winter peak demand impacts across the two LIDI programs. The peak demand realization rates were much closer to 100% than the energy realization rates.

Table 79: Overall Summer and Winter kW Results

Program Name	Unadjusted Gross		Evaluated	
	Winter kW	Summer kW	Winter kW	Summer kW
LIDI – Electric	161.6	112.1	171.3	75.3
LIDI – Other Fuels	-71.4	-61.8	-80.1	-24.6
<b>LIDI Total</b>	<b>90.2</b>	<b>50.3</b>	<b>91.2</b>	<b>50.7</b>
<b>Seasonal Demand Realization Rates</b>			<b>101.1%</b>	<b>100.8%</b>

### 6.1.3 DISCUSSION

Our extension of the HPWH impact evaluation results to the LIDI program suggests that the existing measure characterization in the Efficiency Maine TRM generally overstates the electricity and fossil fuel savings. Our evaluated summer and winter peak demand savings were much closer to the gross savings claims stored in effRT than the energy savings. Although the LIDI HPWH measure has been retired, we offer the following suggested modifications to the TRM entry for completeness:

- Lower the assumed value of kWh/y<sub>HWL</sub> to 1,534. While we did not meter flow or HPWH energy usage in LIDI participant homes, this parameter was a core output of the broader impact evaluation and our best estimate of how Mainers use their HPWH.
- Incorporate the updated efficiency adjustment factors from the HPWH impact evaluation for both storage tank baseline units and HPWH.
- Adopt the seasonal load shape factor (LSF) values from [Table 74](#) for electric baseline units and the seasonal LSF values from [Table 76](#) for fossil fuel baseline units. These would replace the LSFs that are currently in the TRM.
  - The evaluated LSFs for fossil fuel baseline units are less “peaky” than the LSFs for electric baseline units because they reflect the consumption of the HPWH. Our impact evaluation found that HPWHs tend to have a flatter load profile than electric resistance units due to the longer recovery time.
- We generally expect DHW usage to be correlated to occupancy. Given the direct install nature of the offering, it might prove useful to ask contractors to record the number of occupants in the home during installation (should the LIDI offering return in the future).

## 6.2 METERING DETAILS

### 6.2.1 HEAT PUMP WATER HEATERS

#### Metering Water Flow

Water flow is needed to calculate heat delivered and ultimately COP. Our team used Keyence ultrasonic flow meters for metering water flows (pictured right). The advantage of these systems is that they do not require modifying plumbing. We have tested them against Daikin system internal flow meters installed in air-to-water heat pumps, and they agreed within 3%. We have also tested them against in-line turbine meters and against bucket and stopwatch tests, and in each case, they agreed within 2% or better.



#### Metering Temperature

We used strap-on sensors to measure supply and return temperature. To optimize readings, we apply thermal grease to the sensor and pipe and then insulate the sensors with at least 0.5 inches of foam insulation. We calculate and correct for surface temperature error using

standard heat transfer equations. Because we are measuring delta T, the error and needed correction are small. We use Hobo MX equipment that logs data and stores it for up to 6 months locally.

### Metering Electrical Use

We used eGauge meters for metering HPWH load. The meters hold one year of 1-minute data with no data loss, even when WiFi or cellular connections drop out.

### The Combined Metering System

Table 8o shows which meters are used to meter HPWHs.

Table 8o: Metering Equipment Used for HPWHs

Metered Parameter	Meter Model
Power logger	Egauge 3000, 3110, 4115, 4130, 4030
CT	Magnalab CT
Temperature	Onset SD-Temp-x;
Flow	Keyence FD-Q32, Keyence FD-R32
Temperature and flow logging	MX 1105 logger; MX Gateway as needed

### 6.2.2 ECM CIRCULATOR PUMPS

The circulator pumps evaluated serve as supply or return pumps in hydronic heating systems. In most cases the heating system is providing space heating. In some cases, the heat loop served by a circulation pump provides heating to the domestic hot water system. Pumps serving space heating run during the heating season when the zone that they serve calls for heat. This runtime will vary from as much as half the time to infrequently for lightly heated zones. Pumps serving DHW systems generally run year-round.

Our team installed metering equipment on 41 ECM pumps. The team metered the power of each ECM pump and flow on 34 out of 41 pumps metered. In addition to metering ECM pumps, the team took spot power readings on a sample of 6 baseline pumps. This included measuring amps, voltage, power factor, and water flow across a range of flows on each pump for a total of approximately 30 different data points. The team used these measurements to calculate the baseline input power for each pump.

### Metering Water Flow

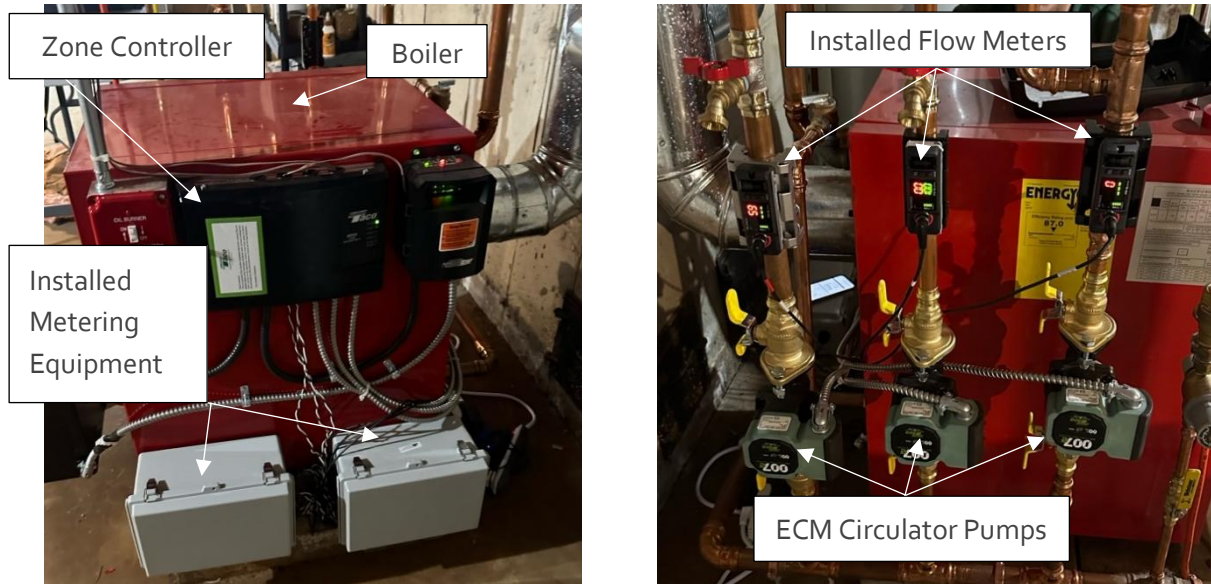
Water flow is needed to determine how the pump is being used, the pressure head in baseline pumps, and the efficiency of the pump and motor combination. Our team used Keyence ultrasonic flow meters for metering water flows and metered the flow for 85% of the pumps monitored. The advantage to these systems is that they do not require modifying plumbing.

### Metering Electrical Use

Circulator pumps rarely have their own breaker, so panel metering was not possible for metering electrical use or run time. Ridgeline used a converter that takes a signal from a 333mV current transformer that is compatible with a Hobo MX 1105 that will log data up to 1 year. The system only transmits 0.333 Volts, so it is safe. After initial site testing, we determined that safely metering at the pump is generally impractical. In most cases, the CT was placed in the zone control panel where there

was typically room to install it. To convert logged amperage into power, we also took a series of true power measurements to establish the power factor for several operating points. The following photos show an example installation of our power metering equipment.

Figure 66: Installed Metering Equipment Example



### The Combined Metering System

Table 81 shows which meters are used to meter circulator pumps.

Table 81: Metering Equipment Used for Circ Pumps

Metered Parameter	Meter Model
Power logging	333mV CT, mV AC to VDC converter
CT	Magnalab CT
Flow	Keyence FD-Q20, 32, 50, Keyence FD-H20, 32, 50
Temperature and flow logging	MX 1105 logger;
Communication	MX Gateway

## 6.3 HPWH PARTICIPANT SURVEY

### 6.3.1 INFLUENCE SCORING EXAMPLES

To calculate the freeridership, participants were given an influence score based on their responses to questions regarding the reasons they chose to participate in the rebate program. See Section 3.2.1.3 for more details on the influence question and scoring. In this section, we give examples of how we used responses to the influence question to calculate an influence score for each respondent.

#### 6.3.1.1 Example 1

In the first example, suppose the participant responded to the questions as follows.

Please indicate on a scale of 1-5 how important each of the following was in your decision to purchase a heat pump water heater. I purchased my water heat pump water heater because...

Table 82: Example One Responses

Factor	1	2	3	4	5	Don't know
... the rebate lowered the cost of the water heater.				x		
... it was easy for me to apply for / receive the rebate.			x			
... the Efficiency Maine savings example was compelling.		x				
... of recommendations from my friends or family.			x			
... of recommendations from my installer.				x		

The highest Likert response for this participant is a four, and the influence score associated with a Likert response of four is zero. Thus, this individual would receive an influence score of zero. The “recommendation” rows were ignored because they were not the highest Likert scores assigned.

Table 83: Example One Scoring

Factor	Likert Response	Influence Score
... the rebate lowered the cost of the water heater.	4	0
... it was easy for me to apply for / receive the rebate.	3	0.25
... the Efficiency Maine savings example was compelling.	2	0.50
... of recommendations from my friends or family.	3	Undetermined
... of recommendations from my installer.	4	Undetermined

### 6.3.1.2 Example 2

In this example, suppose the participant gives the following responses:

Table 84: Example Two Responses

Factor	1	2	3	4	5	Don't know
... the rebate lowered the cost of the water heater.			x			
... it was easy for me to apply for / receive the rebate			x			
... the Efficiency Maine savings example was compelling.		x				
... of recommendations from my friends or family.			x			
... if recommendations from my installer				x		

Because this respondent assigned the highest Likert score to one of the recommendation factors, they were asked an additional question:

*You indicated that a recommendation was the most important factor in your decision. Did the person who recommended the heat pump water heater mention that Efficiency Maine programs help offset the cost?*

Table 85: Additional Question

Response Option	Response	Influence Score
Yes	x	0
No		0.50
I don't recall		Removed

These responses would be scored as shown in Table 86. This individual would receive an influence score of zero, as this is the minimum influence score in the table.

Table 86: Example Two Scoring

Factor	Likert Response	Influence Score
... the rebate lowered the cost of the water heater.	3	0.25
... it was easy for me to apply for / receive the rebate.	3	0.25
... the Efficiency Maine savings example was compelling.	2	0.50
... of recommendations from my friends or family.	3	Undetermined
... of recommendations from my installer.	4	0