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Memorandum

To: Massachusetts Program Administrators and Energy Efficiency Advisory Council

From: Decker Ringo and Nick Beaman; Guidehouse

Date: September 17, 2021

Re: Heat Pump Water Heaters - 2021 Quick Hit Study

This memo summarizes Guidehouse's findings from a review of heat pump water heater (HPWH) products incentivized through the Residential Existing Buildings program. This quick hit study examined HPWH products that were rebated by the program in 2020. The goals for this study were to:

- Develop savings estimates for HPWHs given the typical size and efficiency of the baseline products and the products rebated through the program
- Update the program's cost estimates for different water heater types and efficiency levels

The research team drew upon findings from the 2018 Water Heating, Boiler, and Furnace Cost Study (RES 19)[1], which estimated the installation costs of different water heater types using contractor surveys, webscraping, and program invoices. In the current quick hit study, the team used engineering calculations, wage and price indices, and retail price webscraping to develop HPWH cost and savings values for 2021. This memo presents the team's findings, which are further detailed in an attached spreadsheet.

Summary

The Mass Save program rebates HPWH products through four distinct measures, described in Table 1.[2] The measures are defined by the baseline equipment type, the water heater tank capacity (in gallons), and the product's uniform energy factor (UEF).[3] For smaller (≤55 gallons) electric water heaters, we assume that baseline products heat water using electric resistance heating elements. For larger (>55 gallons) electric water heaters, we assume that baseline products incorporate a heat pump, since Federal appliance standards require that residential electric WH products at this size have a minimum efficiency greater than 1.0 UEF.

Table 1. Residential HPWH Measures Offered through Mass Save Program

Baseline Equipment Type	Capacity	Eligible Efficiency Levels	Rebate Amount
Electric WH	>55 gallons	≥2.7 UEF	$150
Electric WH	≤55 gallons	≥2.0 UEF	$600
Oil WH (storage or tankless coil)	≤55 gallons	≥2.0 UEF	$600
Propane WH	≤55 gallons	≥2.0 UEF	$400

[1] https://ma-eeac.org/wp-content/uploads/RES19_Assembled_Report_2018-09-27.pdf
[2] Mass Save (2021). "Electric Heat Pump Water Heaters." Available at: https://www.masssave.com/en/saving/residential-rebates/electric-heat-pump-water-heaters
[3] UEF is a measure of water heater efficiency. The higher the UEF value is, the more efficient the water heater. UEF is determined by the Department of Energy's test method outlined in 10 CFR Part 430, Subpart B, Appendix E.

Table 2 summarizes the findings from this study. For each of the four HPWH measures, the table provides the UEF, energy consumption, and total installed costs at the baseline and efficient levels. Following Table 2, this memo provides more discussion regarding the methodology and data sources used in this analysis. These results are applicable to standard rebates and to income eligible rebates.

Table 2. Summary of UEF, Costs, and Consumption at Different Efficiency Levels for Residential HPWH Measures

Product Class	Baseline				Typical Program Replacement				Energy Savings (not incl. heating fuel penalty)	Electric Demand Savings	Incremental Installed Cost (not incl. labor)	Incremental Labor Cost	Total Labor Cost, High Efficiency Level
	UEF Level	Energy Use	Electric Demand	Baseline Cost (no labor)	UEF Level	Energy Use	Electric Demand	Efficient Cost (no labor)					
Electric Storage to HPWH, <55 gal	0.92 UEF	2,440 kWh	0.183 kW	$1,179	3.50 UEF	641 kWh	0.058 kW	$2,131	1,799 kWh	0.125 kW	$952	$138	$622
Electric Storage to HPWH, >55 gal	2.20 UEF	1,020 kWh	0.092 kW	$1,994	3.40 UEF	660 kWh	0.059 kW	$2,548	360 kWh	0.033 kW	$554	$106	$692
Propane Storage WH to HPWH, ≤55 gal	0.62 UEF	57 kWh, 17.1 MMBtu propane	0.006 kW	$1,308	3.50 UEF	888 kWh	0.080 kW	$2,131	-831 kWh 17.1 MMBtu Propane	-0.074 kW	$823	$32	$622
Oil-fired WH (storage or indirect) to HPWH, ≤55 gal	0.79 UEF (blend of storage, indirect)	57 kWh, 18.1 MMBtu fuel oil	0.006 kW	$1,985	3.50 UEF	1,195 kWh	0.108 kW	$2,131	-1,138 kWh 18.1 MMBtu fuel oil	-0.102 kW	$146	-$82	$622

Heating Fuel Penalty:
For electric storage WH to HPWH ≤55 gallons: -0.50 MMBtu fuel oil, -0.10 MMBtu nat. gas, and -0.07 MMBtu propane
For propane storage WH to HPWH ≤55 gallons: -0.67 MMBtu propane
For oil-fired storage WH to HPWH ≤55 gallons: -0.67 MMBtu fuel oil
For electric storage WH to HPWH >55 gallons: No fuel penalty

Methodology

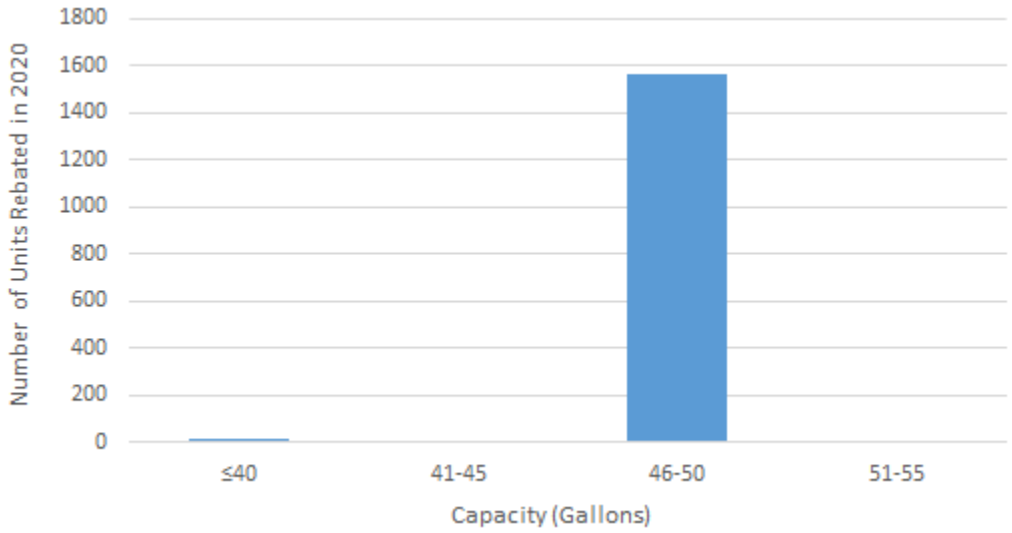
This section describes the methodology used to determine or calculate the various data points that are presented in this analysis. The attached spreadsheet[4] applies this methodology to each of the product classes considered in this analysis and includes detailed data sources and calculations.

Representative HPWH Product Size and Efficiency

For both of the HPWH product types offered through the Mass Save program (≤55 gallons and >55 gallons), the evaluation team examined participant data to determine the representative size and efficiency of products that participants purchase. The PAs provided the evaluation team with participant rebate data for the 2020 program year.

For the smaller class of HPWH (≤55 gallons), the team found that over 99% of the units rebated in 2020 had a capacity of 50 gallons and an efficiency rating of 3.2 UEF or higher, with an average efficiency rating of 3.5 UEF. Figure 1 shows the distribution of capacities for ≤55-gallon HPWH units and Figure 2 shows the distribution of efficiency ratings for 50-gallon HPWHs rebated in 2020. For the energy savings calculations in this analysis, the team selected the mean capacity of 50 gallons and the mean efficiency of 3.5 UEF as the representative unit capacity and efficiency.

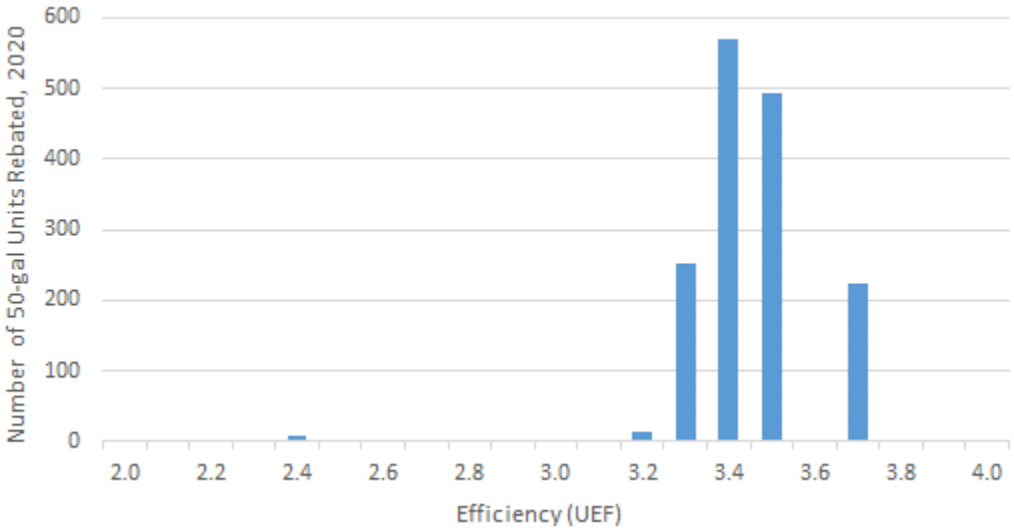
Figure 1. Distribution of HPWH (≤55 gal) Product Capacity in Records for Program Year 2020



Quantity of Rebated Units	1,583
Mean	50 gal.
Median	50 gal.
Mode	50 gal.
Representative Capacity Selected	**50 gal.**

[4] See attached spreadsheet with filename HPWH_QuickHit_WaterHeater_Characterization_v1.xlsx

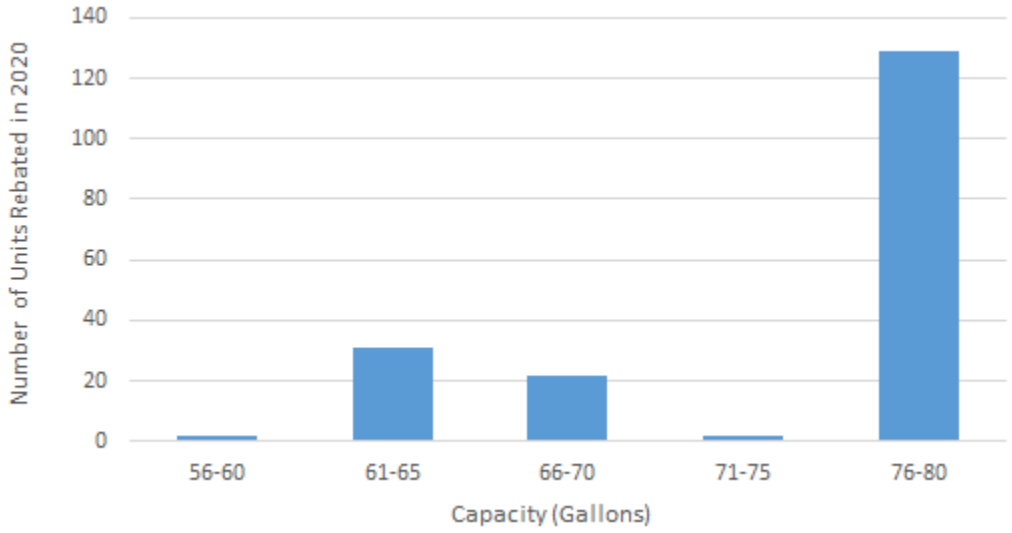
Figure 2. Distribution of 50-gallon HPWH Product Efficiency for Units in Program Year 2020



Quantity of Rebated Units	1,561
Mean	3.5 UEF
Median	3.4 UEF
Mode	3.4 UEF
Representative Efficiency Selected	**3.5 UEF**

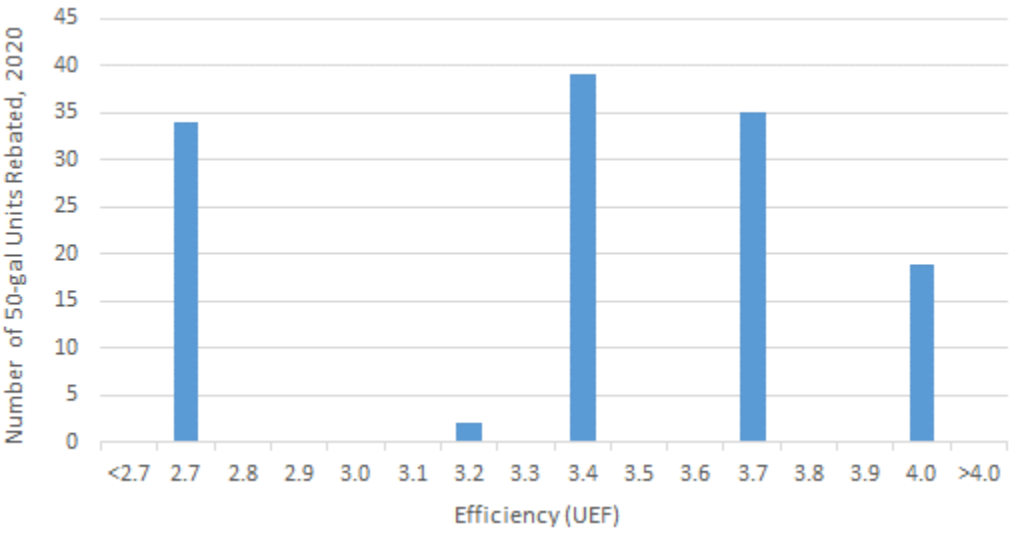
For the larger class of HPWH (>55 gallons), the team found that some customers purchase 65- and 66-gallon units, but most customers (about 70% of the units rebated in 2020) purchase a capacity of 80 gallons. Figure 3 shows the distribution of capacities for >50-gallon HPWHs and Figure 4 shows the distribution of efficiency ratings for 80-gallon HPWH units rebated in 2020. For the energy savings calculations in this analysis, the team selected 80 gallons and 3.4 UEF as the representative unit capacity and efficiency for large HPWH products.

Figure 3. Distribution of HPWH (>55 gal) Product Capacity in Records for Program Year 2020



Quantity of Rebated Units	186
Mean	76 gal.
Median	80 gal.
Mode	80 gal.
Representative Capacity Selected	**80 gal.**

Figure 4. Distribution of 80-gallon HPWH Product Efficiency for Units in Program Year 2020



Quantity of Rebated 80-gallon Units	129
Mean	3.4 UEF
Median	3.4 UEF
Mode	3.4 UEF
Representative Efficiency Selected	**3.4 UEF**

The representative product capacities described above align with the HPWH analysis conducted for the RES 19 study completed in 2018. However, the representative efficiencies described above are higher than the efficiency values used to calculated energy savings in 2018. The 2018 analysis calculated savings using a minimum eligible efficiency rating of 2.45 UEF[5] for HPWH ≤55 gallons and the rebate threshold efficiency level of 2.7 UEF for HPWH >55 gallons. Over the past three years, newer, more efficient products have entered the market and, based on the 2020 program data, the more efficient models appear to be popular with participants.

Energy Savings Analysis

For each water heater measure, the team calculated energy savings as the difference between the baseline energy consumption and the efficient-level energy consumption. The team calculated energy consumption at each of these levels by dividing the water heating load by the water heater efficiency rating. The team assumed that customers using different fuels may have different water heating loads, and the team used the best available sources to determine water heating loads for each fuel type.

For electric water heaters, the team referenced the metered electric consumption for the water heating end use from the 2020 Massachusetts Residential Baseline Study[6] and calculated the typical water heating load for electric homes as the water heating electric consumption multiplied by the typical electric resistance WH efficiency of 0.92 UEF.

For natural gas-, propane-, and fuel oil-fired water heaters, the team referenced typical energy consumption for water heating end uses in New England from the Energy Information Administration's 2015 Residential Energy Consumption Survey (RECS).[7] For natural gas- and propane-fired water heaters, the team assumed a typical baseline efficiency of 0.62 UEF based on on-site characterization survey results gathered for the MA Residential Baseline Study. Fuel oil customers use a mix of standalone oil-fired water heaters and indirect water heaters connected to the customers' oil-fired boilers. The team estimated a weighted average efficiency of 0.79 UEF representing the mix of standalone and indirect oil-fired WH products in the installed base.[8]

Heating Fuel Penalty

HPWH products draw ambient heat from their surroundings to heat water, and they are typically installed in the conditioned space of a home. The Massachusetts TRM specifies heating fuel penalties to account for additional space heating energy consumption when a non-HPWH is replaced with an HPWH. The heating fuel penalties specified in the 2020 Report version of the MA TRM[9] are based on an impact study of heat pump water heaters prepared for the Massachusetts Electric PAs in 2017.[10]

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[5] For HPWH ≤55 gallons, the rebate threshold is 2.0 UEF. However, no commercially available models are rated at exactly 2.00 UEF, so the 2018 analysis used the lowest efficiency models that met program specifications, with an efficiency rating of 2.45 UEF.

[6] MA Residential Baseline Study (2020), p.36. Available at: https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Ph4-Comprehensive-Report-2020-04-02.pdf

[7] EIA RECS Table CE4.7 shows consumption by end use for households in New England that use different heating fuels. Available at: https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce4.7.pdf

[8] MA Residential Baseline Study (2020), p.95, provides saturation of oil-fired water heaters: 4% of homes have standalone oil-fired WH, 14% of homes have indirect oil-fired WH. Assume UEF of 0.62 for standalone oil WH and AFUE of 84.4% for indirect WH, based on RES 1 Onsite Characterization Results (assume tankless coil WH have same efficiency as oil-fired boilers)

[9] Measure Code RES-WH-HPWH, version 4.

[10] Navigant (2017) "Heat Pump Water Heaters Impact Study: Volume 1 Final Report" http://ma-eeac.org/wordpress/wp-content/uploads/Heat-Pump-Water-Heater-Impact-Study-Volume-1.pdf

The operating efficiency of HPWH products describes how much electricity the water heater consumes to deliver a specific amount of hot water. Like lower-efficiency HPWH products, high-efficiency HPWHs draw heat from their surroundings. High- and low-efficiency HPWHs transfer about the same amount of ambient heat to the hot water tank. The primary difference is in how much electricity they consume to achieve this task. Since we do not expect that ambient heat use will change with newer or more-efficient HPWH products, the team recommends no change to the heating fuel penalties specified in the MA TRM.

Water Heater Cost Updates

When program participants install new water heaters, they typically hire a contractor or plumber who will deliver and install the water heater in the participant's dwelling. The RES 19 cost study conducted in 2018 used a contractor survey, retail price webscraping, and program invoices to estimate the amount that contractors charge their customers for equipment, labor, supplies, and other costs at different efficiency levels. The magnitude of these various cost components will change over time at different rates due to different macroeconomic factors. For example, equipment prices rose rapidly over the past 18 months due to raw material cost increases. Meanwhile, HVAC contractor wages in Massachusetts rose at a faster rate in 2018-2020 than in the prior three years, likely due to effects of the COVID-19 pandemic.

Given the timeframe of the current study, it was not feasible for the team to conduct a contractor survey or to review program invoices. Instead, the team gathered and used new retail price data along with publicly-available wage data and inflation adjustors to estimate the total installed cost of different water heater products in 2021.

Equipment Costs

Since the RES 19 cost study was completed in 2018, water heater unit prices have risen due to inflation and due to increases in raw material costs. Based on past discussions with HVAC contractors, the team expects that contractors will pass any increase in product costs along to their customers. Contractors often purchase products at wholesale prices and sell them to customers at a markup, such that the water heater prices advertised by retail vendors (e.g., hardware stores) do not represent the per-unit equipment price that customers pay to contractors. So, while the advertised retail prices of WH products do not represent what customers pay, the proportional differences between retail prices should reflect the proportional price changes that customers experience over time.

Our team conducted a retail price survey of a select set of water heater products in 2018 and then surveyed the same products again in 2021. These subsequent surveys enable us to quantify the proportional price change for different product types from 2018 to 2021. The results of this survey indicate that on average, from 2018 to 2021:

- The retail prices of fuel-fired storage water heaters increased 33% (number of surveyed products=30)
- The retail prices of electric storage water heaters increased 19% (n=48), with similar trends for electric resistance and heat pump water heaters
- The retail prices of indirect water heaters increased 13% (n=20)

Our team also gathered retail prices for new products that have been introduced to the market since 2018 and confirmed that the products covered in the price survey described above are still competitively priced with other products on the market.

Installation Costs

Labor costs: The team assumed that a water heater installation today would require the same amount of labor hours as an installation conducted in 2018, and that any labor cost increases would be due to changes in the contractors' wage rate. Since 2018, the average hourly wages of HVAC installers in Massachusetts increased by 8.1%.[11]

Supplies and Other costs: The team assumed that a water heater installation today would require the same supplies and incidentals as an installation conducted in 2018, and that the purchaser price index (PPI) is an accurate predicter of price inflation. Since 2018, the PPI for plumbing, heating and air-conditioning contractors increased 6.2%.[12]

To estimate the labor, supplies, and other costs for water heater installations in 2021, the team applied the factors described above to the cost components reported in the 2018 RES 19 study.[13]

Total Installed Costs

Table 3 summarizes the cost components of the baseline and measure-level water heaters examined in this study. Incremental measure costs and incremental labor costs are presented earlier in this memo, in Table 2. These results are applicable to standard rebates and to income eligible rebates.

Table 3. Baseline and Measure-Level Installation Cost Components for HPWH Measures

Measure	Baseline Costs ($)					Efficient Level Costs ($)				
	Equip.	Labor	Supplies	Other	Total	Equip.	Labor	Supplies	Other	Total
Electric Storage --> HPWH, <55 gal	869	484	155	155	1,663	1,752	622	304	75	2,753
Electric Storage --> HPWH, >55 gal	1,521	586	111	362	2,580	2,101	692	121	326	3,240
Propane Storage WH --> HPWH, ≤55 gal	981	590	179	148	1,898	1,752	622	304	75	2,753
Oil-fired WH (storage or indirect)* --> HPWH, ≤55 gal	1,492	704	377	116	2,689	1,752	622	304	75	2,753

* Costs for baseline oil-fired water heaters represent a blend of costs for indirect water heaters attached to an oil-fired boiler and costs for a standalone oil-fired storage water heater. The proportions used in this blend are based on the observation that 4% of Massachusetts homes have standalone oil-fired WH and 14% of homes have an indirect oil-fired WH. Source: MA Residential Baseline Study (2020) p.95.

[11] U.S. Bureau of Labor Statistics, Occupational Employment and Wage Statistics. The average wage rate for Heating, Air Conditioning, and Refrigeration Mechanics and Installers (Occupation code 49-9021) in Massachusetts rose from $28.79/hour in May 2018 to $31.13/hour in May 2020 (the most recent year available). https://www.bls.gov/oes/tables.htm

[12] U.S. Bureau of Labor Statistics, BLS Producer Price Indices. The PPI for series ID PCU23822X23822X rose from 129.1 in May 2018 to 137.1 in May 2020. https://www.bls.gov/ppi/databases/data.htm

[13] Navigant (2018) "Water Heating, Boiler, and Furnace Cost Study (RES 19)." See cost components in Table 4. Available at: https://ma-eeac.org/wp-content/uploads/RES19_Assembled_Report_2018-09-27.pdf