NAVIGANT

Water Heating, Boiler, and Furnace Cost Study (RES 19)

Final Report

Prepared for:

The Electric and Gas Program Administrators of Massachusetts
Part of the Residential Evaluation Program Area

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EXECUTIVE SUMMARY

The Massachusetts Residential Heating and Cooling Program offers prescriptive rebates for several types of water heaters, furnaces, and boilers. The incremental energy-efficiency-related costs of heating, ventilation, and air conditioning (HVAC) and water heating equipment can evolve quickly, especially for products at higher efficiency levels. While designs of heating products at the baseline efficiency level have changed little in the last 20 years, there has been considerable development at mid- and high-efficiency tiers. Rheem has significantly redesigned its heat pump water heater (HPWH) while GE Appliances has exited the HPWH market entirely. Costs of on-demand gas tankless water heaters have dropped rapidly and demand for tankless water heater products has risen. While rebates and efficiency standards have helped drive these market shifts, it is important to re-examine rebate levels and amounts to ensure the program is properly incentivizing efficiency-driven features.

Evaluation Objectives & Methodology

The goal of this study was to evaluate the energy-efficiency-related costs of single family home installations of water heater, boiler, and furnace products currently rebated through the Residential Heating and Cooling program.

Navigant developed the Water Heating, Boiler, and Furnace Cost Study to answer the following questions:

- What are the consumer costs of purchasing and installing residential water heaters, boilers, and furnaces in both the retrofit and replace on burnout (ROB) scenarios, and what proportion of these costs go towards equipment, labor, and other costs (such as installation kits)?
- What are the relationships between cost and efficiency for water heaters, boilers, and furnaces?
- What are the total costs and incremental costs associated with installing water heaters, boilers, and furnaces at different efficiency levels with different configurations?

Evaluation Activities

This study relies on three main data sources: 1) a survey of HVAC contractors and plumbers in Massachusetts, 2) retail prices gathered by webscraping, and 3) program rebate invoices for water heater product classes. This study combines data from these three sources to construct cost-efficiency curves that describe the total installed cost of water heater, boiler, and furnace products across the available range of efficiency levels for each product type.

The evaluation team first defined the representative product sizes that are typically installed in the PAs' service areas. The team then gathered cost data by surveying contractors, webscraping retail prices, and reviewing program invoices. The team then merged the data from these three sources to construct cost-efficiency curves. Table 1 describes the scope and rationale for each activity in this cost study.

Table 1. Cost Study Activities

Activity	Rationale
Survey of HVAC Contractors and Plumbers in Massachusetts	Surveys can provide accurate cost estimates for specific installation scenarios relevant to this study. Survey data was used to assess how installation costs change depending on product efficiency.
Webscraping of Retail Product Price Data	Webscraping is inexpensive and yields price data across many brands, sizes, and efficiency levels. The number of data points collected via contractor surveys was limited to avoid survey fatigue, and webscraping data may be used to fill in the gaps between and above the efficiency levels probed in the contractor survey.
Review of Program Invoice Data for Water Heaters	Program rebate invoices provide the actual cost that customers paid to install a specific piece of equipment. Invoices sometimes provide details about cost categories such as labor, equipment, and supplies. This study used invoices for water heater classes because the survey response rate was very low for questions related to water heater costs.
Construction of Cost-Efficiency Curves	Webscraped retail price data was scaled to estimate the prices that contractors typically charge for products. Then, the scaled retail data was combined with contractor survey data to construct cost-efficiency curves that cover the full range of product efficiencies available in the market.

Source: Adapted from Stage 3 Evaluation Plan for Water Heating, Boiler, and Furnace Cost Study (RES 19)

Findings & Considerations

Table 2 presents the total installed cost for each product type at the baseline efficiency level and at the efficiency levels rebated through the Residential Heating and Cooling Program. Section 3.2 of this report presents complete cost curves covering the full range of product efficiencies available for each product type.

Table 2. Total Installed Cost of Furnaces, Boilers, and Water Heaters at Program Rebate Levels[1]

Product Type	Representative Size	Total Installed Cost, by Efficiency Level		
Natural Gas Furnaces	80 MBH input	**80% AFUE[2]**	**95% AFUE**	**97% AFUE**
		$3,966	$5,557	$6,370
Propane Furnaces	80 MBH input	**80% AFUE[2]**	**95% AFUE**	
		$3,589	$5,284	
Oil Furnaces	91 MBH input	**83% AFUE**	**86% AFUE**	
		$5,099	$5,772	
Natural Gas Boilers	110 MBH input	**82% AFUE**	**90% AFUE**	**95% AFUE**
		$6,042	$9,210	$9,471
Propane Boilers	110 MBH input	**82% AFUE**	**90% AFUE**	
		$6,595	$9,363	
Oil Boilers	119 MBH input	**84% AFUE**	**86% AFUE**	
		$6,866	$7,664	
Natural Gas Combination Boilers	120 MBH input (space heating)	**82% AFUE**	**90% AFUE**	**95% AFUE**
		Not found	$10,530[3]	$10,530
Propane Combination Boilers	120 MBH input (space heating)	**82% AFUE**	**90% AFUE**	**95% AFUE**
		Not found	$10,631[3]	$10,631
Natural Gas On-Demand Tankless Water Heaters	199 MBH input	**0.80 UEF (Non-condensing)**	**0.87 UEF (Condensing)**	
		$2,853	$3,596	
Propane On-Demand Tankless Water Heaters	199 MBH input	**0.80 UEF (Non-condensing)**	**0.87 UEF (Condensing)**	
		$2,874	$3,614	
Natural Gas Storage Water Heaters, ≤55 gallons	40 gal., 40 MBH, Medium Draw	**0.58 UEF**	**0.64 UEF (E-STAR)**	
		$1,591	$1,647	
	50 gal., 40 MBH, High Draw	**0.60 UEF**	**0.68 UEF (E-STAR)**	
		$1,653	$2,023	
Natural Gas Storage Water Heaters, ≥75 MBH input	50 gal., 100 MBH, High Draw	**0.59 UEF**	**0.80 UEF (E-STAR)**	
		$2,900	$4,381	
Electric Storage Water Heaters, ≤55 gallons	50 gal., Medium Draw	**0.92 UEF (Elec. Resistance)**	**2.00 UEF (E-STAR, Heat Pump)**	
		$1,469	$2,110	
Electric Storage Water Heaters, >55 gallons	80 gal., High Draw	**2.20 UEF**	**2.70 UEF**	
		$2,263	$2,714	
Indirect Water Heaters, attached to boiler	45 gallons	**Boiler Fuel Type**		
		Natural Gas, Propane, or Oil	$2,919	

Source: Navigant analysis of product cost data from contractor survey, a review of program invoices,and webscraping

[1] Task 7 of this cost study produced a separate memo that estimates the total and incremental costs and the energy savings for water heater classes in this table based on the new UEF efficiency metric. For some classes, the Task 7 memo estimates savings using a market-based baseline (as opposed to code) or using a baseline of a different water heater type (e.g., the baseline for gas on-demand tankless water heaters is gas storage water heater).

[2] For gas- and propane-fired furnaces, the PAs use a negotiated baseline level of 85% AFUE. However, at the representative capacity of 80 MBH, there are no furnace models on the market between 80.2% and 92% AFUE. PAs may wish to estimate the the total installed cost at the 85% negotiated baseline as the average of the total installed costs at 80% AFUE and 92% AFUE. This average is $4,597 for gas furnaces and $4,238 for propane furnaces.

[3] This table intentionally reports the same total installed cost for combination boilers rated at 90-94% AFUE and 95% AFUE. Our analysis concluded there is no incremental cost between 90% and 95% AFUE for combination boilers.

This study estimated the total installed costs across the range of available efficiencies for water heating, boil, and furnace products rebated by the Residential Heating and Cooling Program. The program may reference these costs in its cost-benefit analysis to refine the rebate efficiency thresholds and the incentive amounts that are offered for these products.

There are two strategies the Program Administrators (PAs) could pursue to improve the cost effectiveness of water heater, boiler, and furnace rebate offerings.

- **Consideration 1:** The PAs should consider discontinuing the lower rebate level of 90% AFUE for combination boilers and continue incentivizing the adoption of higher-efficiency 95% AFUE models that appear to be a less expensive option for customers.
    - **Finding 1:** The webscraping of retail product prices found that the least expensive combination boilers (at the representative size of 120 MBH input) are rated at 95% AFUE. Additionally, one of the survey respondents indicated that combination boiler products rated at 95% AFUE often have lower wholesale prices than combination boilers rated between 87% and 94% AFUE.

- **Consideration 2:** The evaluation team does not have access to shipment or sales data that would indicate the number of low-efficiency electric hot water heater installations that have been allowed because of DOE's enforcement policy. The evaluation team reached out to survey respondents to ask how frequently these large electric resistance water heaters are installed in Massachusetts. Five contractors responded to our follow-up questions, and they indicated that installations of electric resistance water heaters above 55 gallons capacity are somewhat rare in Massachusetts. Because the response rate for our follow-up questions was limited, the PAs may consider pursuing additional survey efforts to understand how prevalent these models are in Massachusetts. If the high-volume electric resistance models are found to be prevalent, the PAs should consider reassessing the baseline for the large electric storage water heater product class.
    - **Finding 2:** The evaluation team identified several 80-gallon electric water heater models on the market that meet the definition of residential electric storage water heaters, but do not meet the federal minimum standards for residential electric storage water heaters. These non-compliant models use electric resistance heating elements, which are less efficient than the heat pump technology that the program has been considering as the baseline technology for water heaters above 55 gallons capacity. The U.S. Dept. of Energy (DOE) published an enforcement policy stating that at least until March 31, 2018, DOE will not seek penalties for the failure to properly certify water heater models that meet certain criteria.[4] It is not clear whether this policy will be extended beyond March 31. In the meantime, these non-compliant models are available for residential customers to purchase and install.

[4] The DOE Enforcement Policy Statement Regarding Testing, Compliance with the Applicable Energy Conservation Standards, and Certification for Certain Consumer Water Heaters is available on DOE's website: https://energy.gov/sites/prod/files/2018/01/f47/Enforcement%20Policy-ConsumerWH_Def_1-2018.pdf

1. INTRODUCTION

1.1 Program Background

The Massachusetts Residential Heating and Cooling Program offers prescriptive rebates for several types of water heaters, furnaces, and boilers. The incremental energy-efficiency-related costs of heating, ventilation, and air conditioning (HVAC) and water heating equipment can evolve quickly, especially for products at higher efficiency levels. While designs of heating products at the baseline efficiency level have changed little in the last 20 years, there has been considerable development at mid- and high-efficiency tiers. Rheem has significantly redesigned its heat pump water heater (HPWH) while GE Appliances has exited the HPWH market entirely. Costs of on-demand gas tankless water heaters have dropped rapidly and there is increased demand for on-demand gas products. While rebates and efficiency standards have helped drive these market shifts, it is important to re-examine rebate levels and amounts to ensure the program is properly incentivizing efficiency-driven features.

The goal of this study was to evaluate the energy-efficiency-related costs of single family home installations of water heater, boiler, and furnace products currently rebated through the Residential Heating and Cooling program.

1.2 Study Objectives

This study sought to answer the following research questions:

- What are the consumer costs of purchasing and installing residential water heaters, boilers, and furnaces in both the retrofit and replace on burnout (ROB) scenarios, and what proportion of these costs go towards equipment, labor, and other costs (such as installation kits)?
- What are the relationships between cost and efficiency for water heaters, boilers, and furnaces?
- What are the total costs and incremental costs associated with installing water heaters, boilers, and furnaces at different efficiency levels with different configurations?

1.3 Structure of this Report

The remainder of this report is organized into three sections. Section 2 contains the study methodology and describes the data collection and analysis approaches. Section 3 presents the results of the analyses. Section 4 provides considerations for program offerings and the evaluation team's conclusions. Appendix A provides the contractor survey that was administered during this study.

2. METHODOLOGY

2.1 Overview and Sources of Data

This study relies on three main data sources: (1) a contractor survey conducted in Task 4, (2) retail prices gathering by webscraping in Task 3, and (3) a sample of program rebate invoices that were reviewed in Task 8. There are advantages and disadvantages associated with each of these data sources, as described in Table 3.

Table 3. Data Sources for Product Costs and their Advantages and Disadvantages

Data Source	Advantages	Disadvantages
Contractor Survey	Surveys can be an accurate source of information, since costs are provided by companies that conduct the product installation and billing.	It is expensive to gather large amounts of survey data due to the outreach efforts required and the incentive rewards for participants. The number of data points gathered by survey must be limited to avoid survey fatigue. Contractors are likely to offer estimates from memory instead of going through past invoices, so survey data is subject to recall bias.
Webscraping	Webscraping is inexpensive and can yield data across many brands, sizes, and efficiency levels.	Most customers do not purchase equipment online, and webscraped prices must be adjusted to estimate the marked-up prices that contractors charge for products. Webscraping does not provide installation costs. Webscraped data encompasses many retailers and brands, so the costs must be normalized.
Rebate Program Invoices	Rebate invoices contain the actual costs that customers paid to install a specific product.	Rebate invoices may not represent present-day prices because there is a time lag between the date a customer pays an invoice and the date when the invoice may be retrieved and analyzed. Invoices often do not contain detailed cost category data, and invoices may contain other services rendered that do not pertain to the product being analyzed.

Source: Navigant analysis

The methodology in this study combines data from these three sources to construct cost efficiency curves that describe the total installed cost of water heaters, boilers, and furnaces across a range of efficiency levels. At a high level, this study used the following methodology. The evaluation team first defined the

representative product sizes of each product type that are typically installed in the PAs' service areas. The team then gathered cost data by surveying contractors, webscraping retail prices, and reviewing water heater rebate invoices. The team then merged the data from these three sources to construct cost-efficiency curves. By scaling the webscraping data to align with the survey data and invoice data, the evaluation team estimated the real price paid by customers in the PA service areas. The results from this approach cover a wide range of efficiencies with greater resolution than what is provided by the survey or invoice data alone.

The following sections describe each of these steps in detail.

2.2 Representative Product Sizes

For each of the product types covered in the RES 19 study, the evaluation team selected a representative product size based on an examination of participant data. The PAs provided the evaluation team with participant rebate data assembled by Energy Federation Inc. (EFI) for the period of January 1, 2016 through July 31, 2017. The evaluation team organized, cleaned, and filtered these rebate records by product type, and then team identified and removed any outlier records which the team believed to contain erroneous data. Where necessary, the team filled in gaps in the rebate data by referencing product certification information in the AHRI Directory of Certified Product Performance.

To select the representative sizes for each product, the evaluation team first selected a capacity metric, and then calculated summary statistics of the capacity metric over all the relevant participant records provided by the PAs. The team then plotted histograms to examine the distribution of rebate claims across the range of product capacities. For most product types, the summary statistics provided a clear indication of the representative capacity. As an example, the natural gas combination boiler product type reports capacity in terms of the heat rating in thousands of British thermal units per hour (MBH). The 236 participant records for that product type have mean, median, and mode all equal to 120 MBH. This clearly indicates that 120 MBH is the representative size for natural gas combination boilers. For some product types, the evaluation team used a combination of statistics and expert judgment to select the most representative capacity. For example, the distribution of natural gas furnace capacities had two peaks: there are large numbers of records both at 60 MBH capacity and at 80 MBH capacity. The evaluation team selected 80 MBH as the representative size for natural gas furnaces, since that capacity is closest to the mean capacity of 74 MBH.

Table 2 (on page v) lists the product types included in the RES 19 study, along with the representative capacity(s) that the evaluation team selected for each product.

2.3 Survey of HVAC Contractors and Plumbers

In Task 4 of this study, the evaluation team obtained data from Massachusetts contractors via a web survey. Over a period of six weeks, the evaluation team contacted a sample of 142 HVAC contractors in Massachusetts with significant experience installing water heater, boiler, and furnace products, as evidenced by the program rebate records. The evaluation team emailed survey invitations to 112 of the contractors in that sample, and 11 contractors completed the online survey.

The evaluation team designed the survey to obtain cost information around one cost driver: efficiency. The evaluation team requested cost data at the efficiency levels that are currently rebated through the MassSave program.

The survey asked contractors to provide cost information in several billing categories: burdened labor costs, equipment costs including markups, supplies costs (plumbing supplies, seals, tools, etc.) and other

costs (travel, warranty, insurance, overhead, etc.) for each scenario. By requesting equipment costs as a single line-item cost, the evaluation team can compare the equipment costs provided by contractors with the retail costs retrieved by webscraping in Task 3 of this study.

The final version of the contractor survey is included in Appendix A of this report.

2.4 Program Invoice Review for Water Heaters

The response rate was particularly low for water heater questions posed on the contractor survey described in section 2.3. Although eleven contractors responded to the survey, six of those respondents declined to provide water heater cost data, resulting in a survey response of n=5. At the suggestion of the lead study PA, the evaluation team reviewed a sample of program rebate invoices for different water heater classes to provide an additional data source to inform the estimation of water heater costs.

In an add-on Task 8 of this study, the evaluation team sampled and reviewed 30 rebate records for each of the eight water heater product types in this study. The team extracted cost information from these records and compiled summary cost statistics for each water heater product class. Then, the team compared the costs observed on water heater rebate invoices to the cost results from the contractor survey. From this comparison, the evaluation team observed the following:

- For two of the classes (Gas Storage WH at 50-gal and Gas Storage WH >55-gal >75 MBH), the contractor survey results match the invoice results.
- For two other classes (Gas Storage WH at 40-gal and Indirect WH), the contractor survey results are just above the 75% quartile of the invoice results.
- For the remaining four classes (Gas and Propane On-Demand WH, and Electric Storage WH <55-gal and >55-gal), the contractor survey results are very high compared to the costs observed in program invoice records.

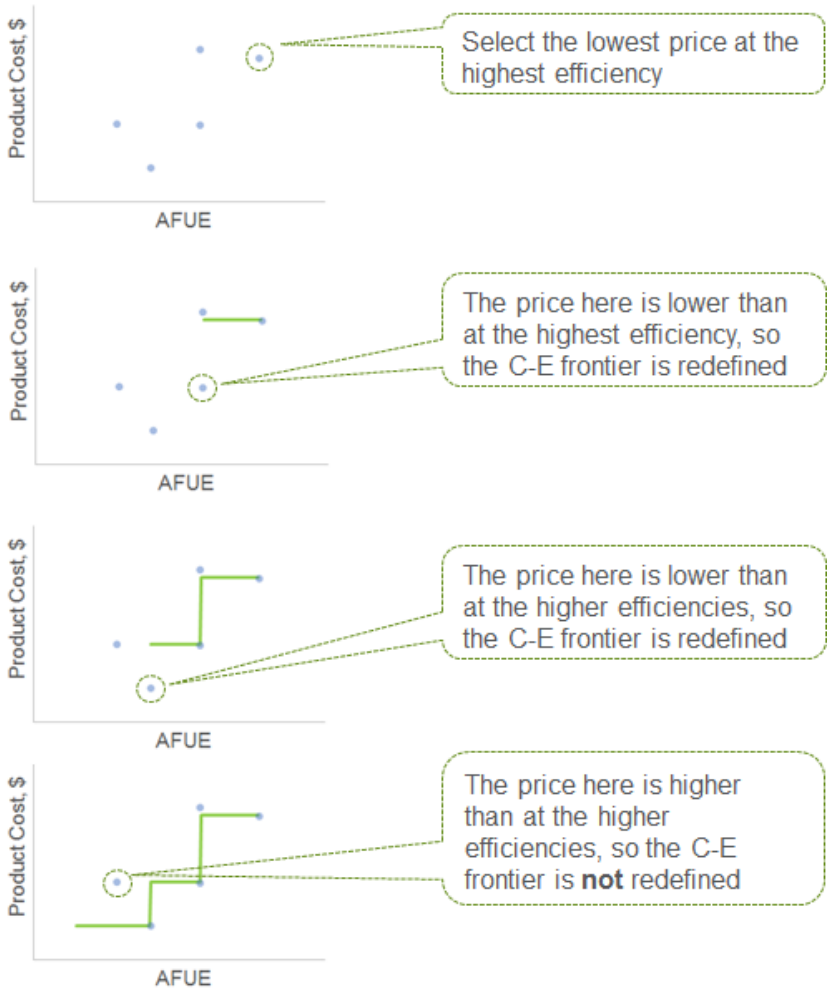
Based on the results of this program invoice review, the evaluation team decided to calibrate the cost-efficiency curves (described in section 2.6 of this report) to fit the average total installed costs from this program invoice review instead of calibrating curves to the contractor survey results for six water heater product classes: Gas On-Demand WH, Propane On-Demand WH, Electric Storage WH <55-gal, Electric Storage WH >55-gal, Gas Storage WH at 40-gal, and Indirect WH.

2.5 Webscraping the Retail Cost-Efficiency Frontier

In Task 3 of this study, the evaluation team gathered retail prices of water heater, boiler, and furnace products using webscraping. The team subtracted the estimated costs of any non-efficiency-related features that were included with various product models. The team identified outlier models that had a quoted retail price significantly lower than the price of peer models and removed these outliers from the webscraped data set.

For each of the product types and representative capacities in Table 2 (on page v), the evaluation team used webscraped data to develop a cost-efficiency frontier describing the retail costs across the full range of available efficiency levels. The cost-efficiency frontier represents the minimum product price required to achieve a given efficiency. To determine the cost-efficiency frontier, the team used a “waterfall” approach with the following steps: 1) the highest efficiency available is determined; 2) the least expensive system at the highest efficiency is selected as the cost-efficiency frontier model at that efficiency; 3) then, for each efficiency lower than the maximum, the cost-efficiency frontier is defined as the lowest price available at that efficiency or at the next efficiency level above. With this definition, the cost-efficiency frontier cannot decrease as the efficiency goes up. In other words, the cost-efficiency frontier either remains constant or goes up as the efficiency goes up. The process for determining the cost-efficiency frontier is illustrated in Figure 1.

Figure 1. "Waterfall" Process for Determining the Cost-Efficiency Frontier



Source: Navigant analysis

The webscraping task generated one cost-efficiency frontier for each product type, where the frontier represents the minimum retail product price required to achieve a given efficiency. The evaluation team recognizes that the online retail prices of heating products may not match the prices that contractors charge customers for these products. This is because the price of products purchased online is marked up by the online retailer, whereas the price of installed products is marked up once by the wholesale vendor and again by the contractor performing the installation. As described in the following section, the retail prices gathered through webscraping were merged with contractor survey data to estimate the actual equipment costs that customers pay to purchase products from contractors.

2.6 Cost-Efficiency Curve Construction

This section describes how the evaluation team combined contractor survey data and program invoice data at a limited number of efficiency levels with webscraped retail prices to estimate a complete cost-efficiency curve for each product type across the full range of efficiency levels available in the market. The contractor survey covered two or three efficiency levels for each product type: the baseline efficiency level and the efficiency levels that are currently rebated by the Residential Heating and Cooling Program. The evaluation team limited the contractor survey to two or three efficiency levels to avoid survey

respondent fatigue, and program invoice data is only available for products that meet the program's rebate efficiency level. However, the market for each product type covers a wider and more granular range of efficiencies than the levels covered by the contractor survey and the program invoice data.

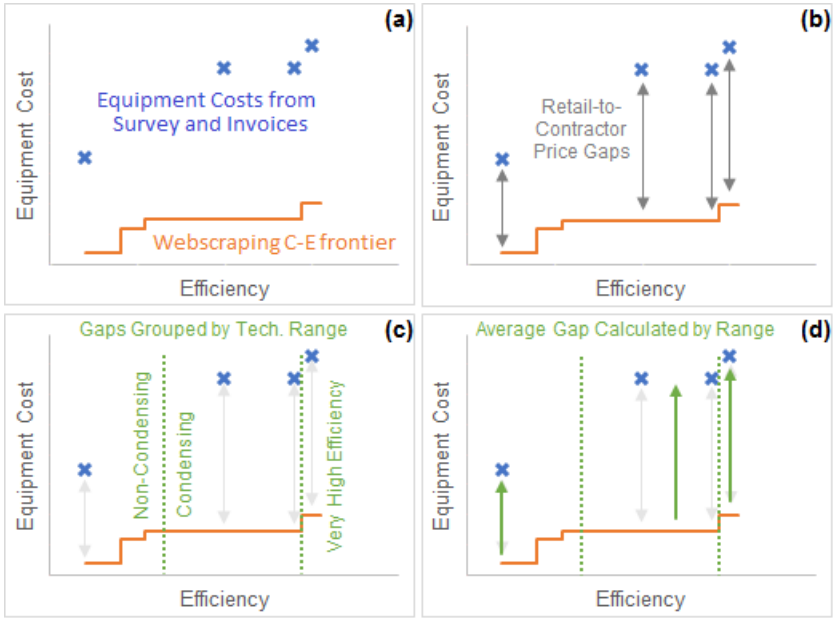
The team used a three-step process to adapt the webscraping data to "fill in the gaps" between and above the survey data and invoice data. The team first determined how contractor- and invoice-reported equipment costs relate to online retail product prices. Understanding this relationship allows the team to estimate what contractors would charge for systems that were included in webscraping but not included in the contractor survey. The team analyzed the non-equipment installation costs from the contractor survey and program invoices to determine how installation costs vary with product efficiency. The team then combined these findings with the webscraping data to calculate the cost-efficiency relationship for each product type. Each step of this process is described below:

1. **Determine the price gap between retail prices and contractor equipment costs.** Survey respondents and program invoices provided equipment costs at two or three efficiency levels for each product type. To determine the typical gap between online retail prices and typical contractor prices, the evaluation team compared the average equipment costs from the contractor survey and program invoices to the webscraped retail prices at each efficiency level covered in the survey. The evaluation team found that the retail-to-contractor price gap[5] varies with the product type (water heaters, furnaces, boilers, etc.) and the product efficiency. The evaluation team analyzed each product type independently to determine an accurate retail-to-contractor price gap for each case, considering the specifics of the technologies used and how they may affect the cost of the equipment and the maintenance/warranty requirements. Upon comparing the survey and invoice data with the webscraping data, the evaluation team found that applying an additive price gap yields more accurate final costs than applying a multiplicative price gap. In other words, the difference between the webscraping data and the survey/invoice data is better characterized by a dollar amount differential (an "additive price gap"), as opposed to a percentage change (a "multiplicative price gap").

   The general process to generate the retail-to-contractor price gaps is explained in Figure 2 below. (a) the team started with equipment costs from the contractor survey and the webscraping cost-efficiency frontier; (b) the additive price gaps were calculated for each surveyed point; (c) the surveyed points were separated into general technology ranges to determine which price gaps correspond to the same range and should therefore be averaged together; and (d) the average price gap was calculated for each technology range.

[5] This report uses the terms "retail-to-contractor price gap" and "price gap" to describe the difference that the evaluation team observed between online retail prices and contractor equipment costs. This report intentionally avoids the term "markup," because contractors do not typically purchase and re-sell products from online retailers. Contractors typically source equipment from wholesalers. This analysis uses online retail prices as a starting point because online retail prices are readily available and they provide useful information regarding the cost differential between different models in the same product class.

Figure 2. General Process to Develop the Retail-to-Contractor Price Gap for Products



Source: Navigant analysis

2. **Analyze the non-equipment installation costs.** The evaluation team analyzed the contractor survey and program invoice results for the non-equipment installation costs associated with labor, supplies, and other costs. For gas-, propane-, and oil-fired products, the team calculated installation costs separately for non-condensing products and condensing products. This was done because condensing products generally require a more complex installation, potentially including condensate pumps, special flue gas piping, and other additional costs. For electric water heaters, the team calculated installation costs separately for resistance heaters, heat pump water heaters, and high-efficiency heat pump water heaters. This was done because heat pump water heaters often have more complex installation requirements. Heat pump water heater installations may require modifications to the installation space to accommodate their larger size (relative to baseline electric water heaters), and to allow sufficient airflow for the heat pump to operate.

3. **Calculate the total installed costs.** The evaluation team first calculated the total installed costs of each webscraped product record by adding the webscraped cost, the appropriate retail-to-contractor price gap (calculated separately for each product type and technology) and the installation cost (specific to the technology used at a given efficiency level). Then, the team applied a waterfall process to the resulting data points, leading to the total installed cost curves.

The three-step process described above yielded the cost curves and cost tables that are presented in section 3.2 of this report.

3. FINDINGS

In this section, the combined results of the analysis are presented and discussed. This includes the following:

- The installation costs of various installation factors, which were determined based on survey data
- The total installed costs for each product type as a function of efficiency, which were determined by combining survey and webscraping data

3.1 Installation Costs of Different Product Types and Technologies

This sub-section presents the non-equipment installation costs associated with labor, supplies, and other costs, which the evaluation team calculated as the average of program invoice records reviewed (for Gas and Propane On-Demand WH and Electric WH classes) or as the average of the responses provided to the contractor survey (for all other classes). The team separately calculated the installation costs for each product type and for different product technologies within each product type. For instance, the team calculated different installation costs for non-condensing products and condensing products. Table 4 presents the installation cost categories for all product types and technologies considered in this study.

Table 4. Cost of Residential Installations for Furnace, Boiler, and Water Heater Products

Product Type	Fuel	Installation Costs, by Product Technology and Cost Category						Technology Threshold
		Labor	Supplies	Other	Labor	Supplies	Other	
		Non-Condensing Products			**Condensing Products**			
Furnace	Natural Gas	$1,392	$463	$256	$1,790	$736	$276	90% AFUE
	Propane	$1,241	$364	$284	$1,732	$607	$296	90% AFUE
	Oil	$1,662	$537	$271	$1,790	$736	$276	90% AFUE*
Boiler	Natural Gas	$1,698	$1,047	$326	$2,640	$1,750	$312	90% AFUE
	Propane	$1,708	$1,122	$354	$2,586	$1,881	$337	90% AFUE
	Oil	$2,014**	$1,048**	$301**	--***	--***	--***	N/A***
Combination Boiler	Natural Gas	--†	--†	--†	$2,974	$1,813	$336	90% AFUE
	Propane	--†	--†	--†	$2,999	$1,863	$336	90% AFUE
On-Demand Tankless WH	Natural Gas	$989	$287	$230	$1,190	$415	$224	0.83 UEF
	Propane	$989	$308	$230	$1,190	$433	$224	0.83 UEF
Storage WH, Medium Draw	Natural Gas	$546	$169	$139	--‡	--‡	--‡	N/A‡
Storage WH, High Draw	Natural Gas	$745	$317	$129	$895	$517	$188	0.80 UEF

Product Type	Fuel	Installation Costs, by Product Technology and Cost Category						Technology Threshold
		Labor	Supplies	Other	Labor	Supplies	Other	
		Electric Resistance Products			**Heat Pump Products**			
Storage WH, 50-gallon	Electric	$448	$146	$146	$575	$286	$71	1.0 UEF
		Low-Efficiency Heat Pumps			**High-Efficiency Heat Pumps**			
Storage WH, 80-gallon	Electric	$542	$105	$341	$640	$114	$307	2.7 UEF

* Installations of condensing oil furnaces are very rare. The webscraping conducted in this cost study only identified one condensing oil furnace product available on the market. The total costs calculated for oil-fired furnaces at the program rebate threshold of 86% AFUE used the installation costs associated with non-condensing oil furnace products.

** These represent costs for an 84% AFUE oil boiler. The survey results indicate an installation cost increase of $302 for 86% AFUE oil boilers. At 86% AFUE, condensate should not develop inside the boiler, but additional installation costs are associated with managing condensate that could develop in the flue pipes.

*** The evaluation team determined that installations of condensing oil-fired boilers are extremely rare in Massachusetts, and thus the team did not probe the installation costs of condensing oil-fired boilers.

† The evaluation team could not identify any non-condensing combination boiler products on the market. Several respondents to the contractor survey stated that they are not aware of any non-condensing combination boilers.

‡ The evaluation team could not identify any medium-draw gas storage water heaters that incorporate condensing technology.

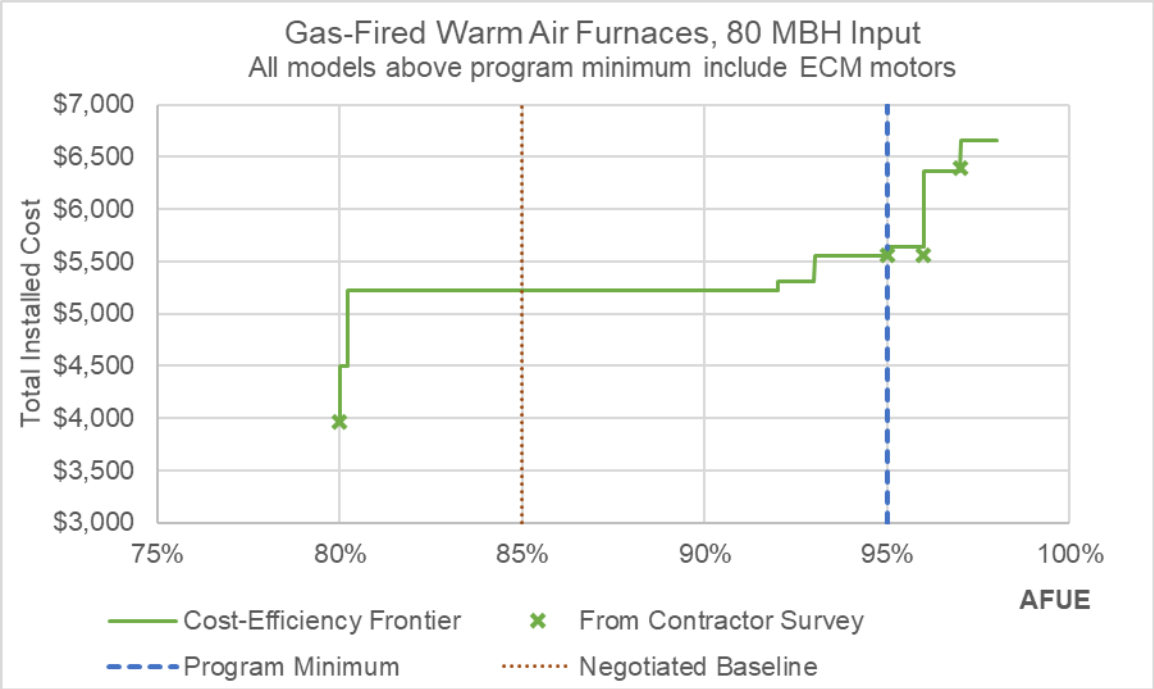
Source: Navigant analysis of contractor survey data and program invoice data

3.2 Total Installed Costs of Furnaces, Boilers, and Water Heaters

This section presents the cost-efficiency curves developed for each of the product types examined in this study. The costs presented below represent the total installed cost to the customer, including the costs associated with labor, supplies, equipment and other costs. There is a sub-section here for each product type and each subsection contains a plot and table showing how the total installed cost of the product changes as product efficiency increases. The cost-efficiency plots use green “X” markers to indicate the average of the total installed costs gathered in the contractor survey at a given efficiency level.

3.2.1 Furnaces – Natural Gas

Total Installed Cost of Natural Gas Furnaces at 80 MBH input capacity

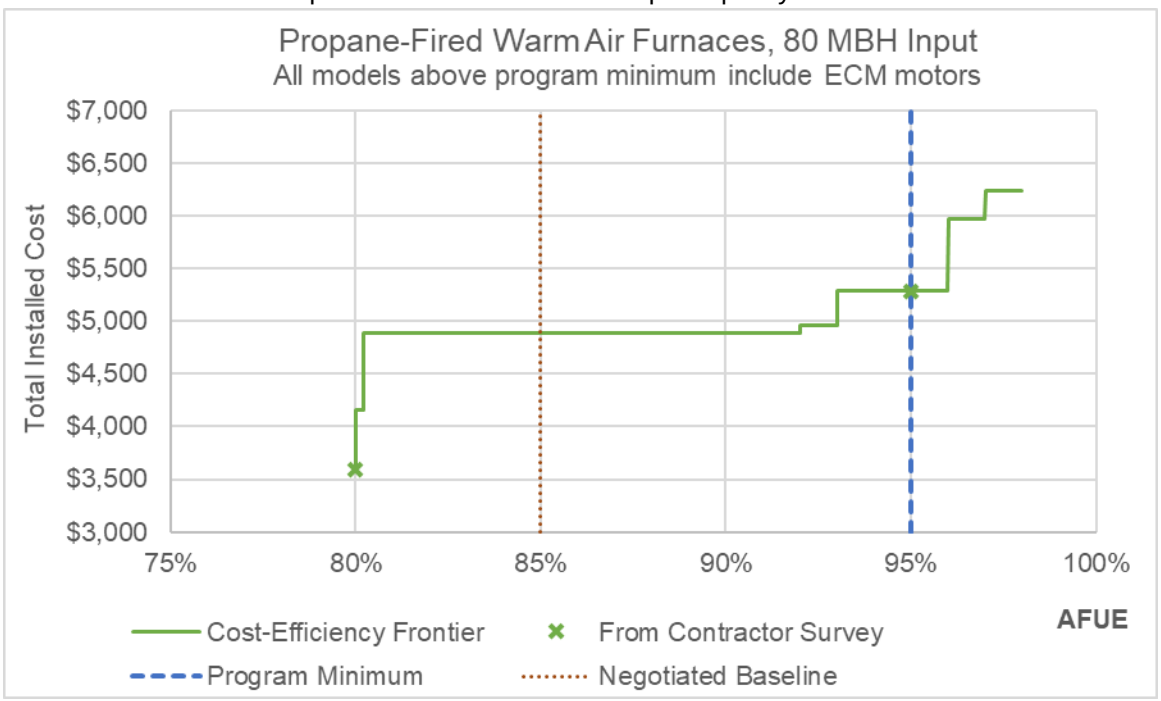


Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Natural Gas Furnaces at 80 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 80.0%	$3,966
80.1 – 80.2%	$4,495
80.3 – 92.0%	$5,227
92.1 – 93.0%	$5,312
93.1 – 95.0%	$5,557
95.1 – 96.0%	$5,635
96.1 – 97.0%	$6,370
97.1 – 98.0%	$6,661

3.2.2 Furnaces – Propane

Total Installed Cost of Propane Furnaces at 80 MBH input capacity

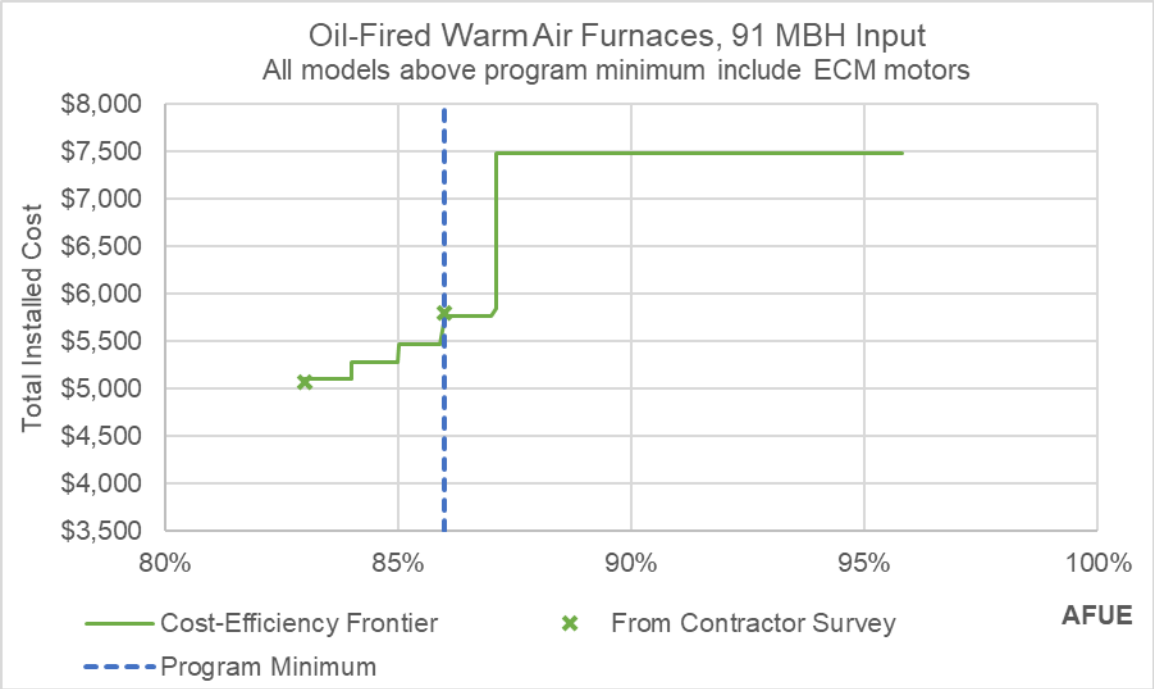


Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Propane Furnaces at 80 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 80.0%	$3,589
80.1 – 80.2%	$4,153
80.3 – 92.0%	$4,886
92.1 – 93.0%	$4,966
93.1 – 96.0%	$5,284
96.1 – 97.0%	$5,964
97.1 – 98.0%	$6,242

3.2.3 Furnaces – Oil

Total Installed Cost of Oil Furnaces at 91 MBH input capacity

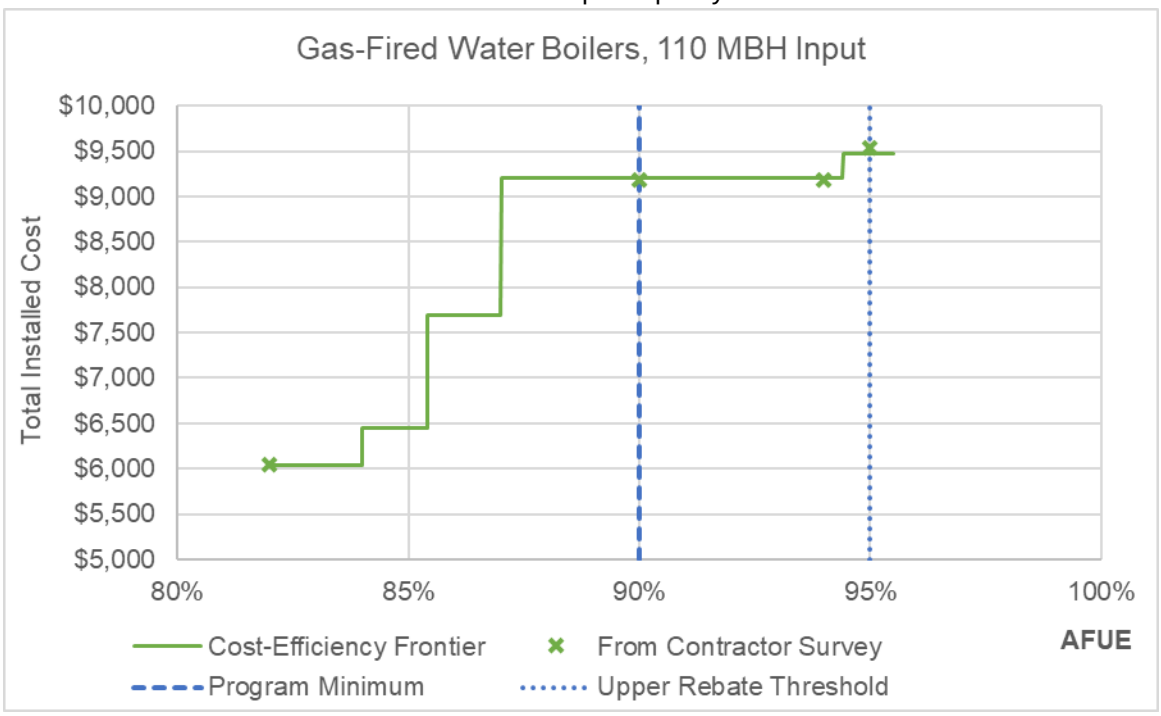


Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Oil-Fired Furnaces at 91 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 84%	$5,099
84.1 – 85.0%	$5,285
85.1 – 85.9%	$5,468
86.0 – 87.0%	$5,772
87.1%	$5,842
87.2 – 95.8%	$7,490

3.2.4 Boilers – Natural Gas

Total Installed Cost of Gas Boilers at 110 MBH input capacity

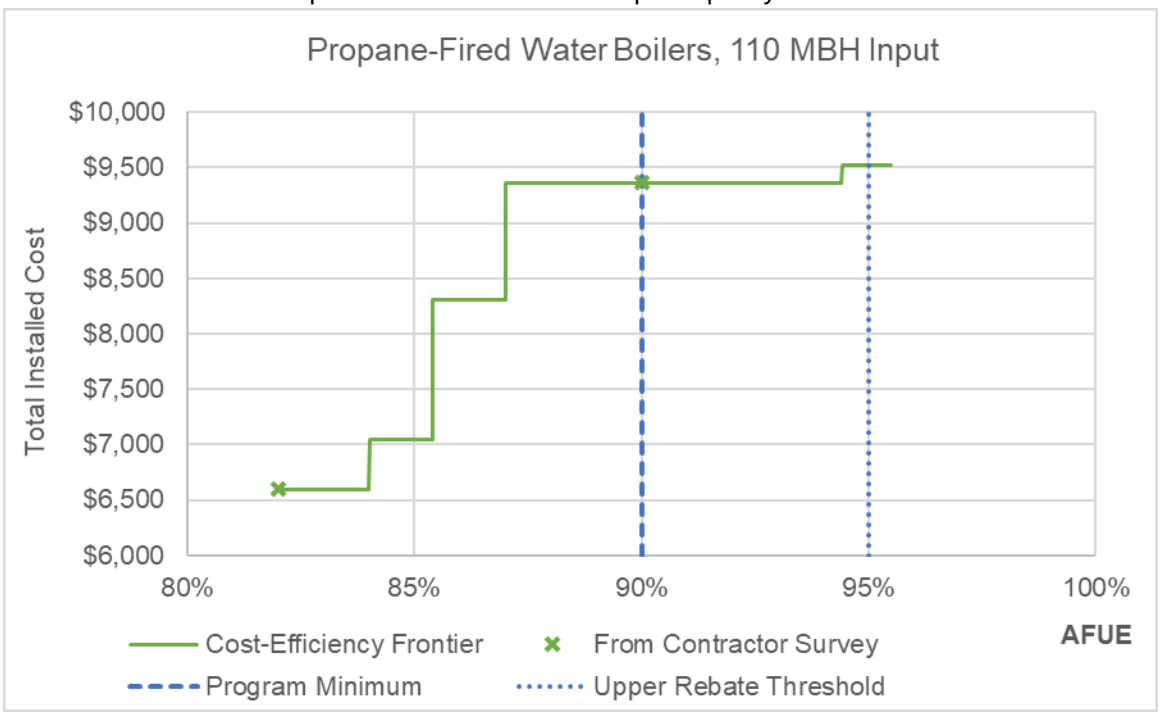


Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Gas-Fired Water Boilers at 110 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 84.0%	$6,042
84.1 – 85.4%	$6,444
85.5 – 87.0%	$7,693
87.1 – 94.4%	$9,210
94.5 – 95.5%	$9,471

3.2.5 Boilers – Propane

Total Installed Cost of Propane Boilers at 110 MBH input capacity

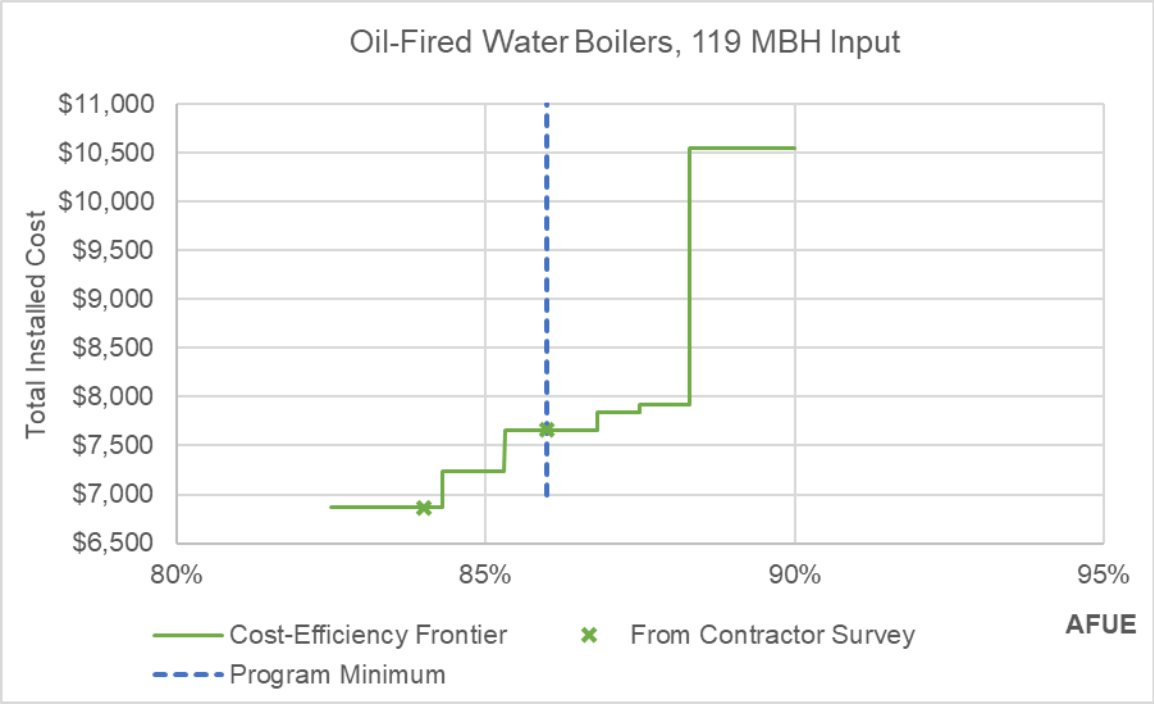


Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Propane-Fired Boilers at 110 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 84.0%	$6,595
84.1 – 85.4%	$7,047
85.5 – 87.0%	$8,301
87.1 – 94.4%	$9,363
94.5 – 95.5%	$9,525

3.2.6 Boilers – Oil

Total Installed Cost of Oil-Fired Boilers at 119 MBH input capacity



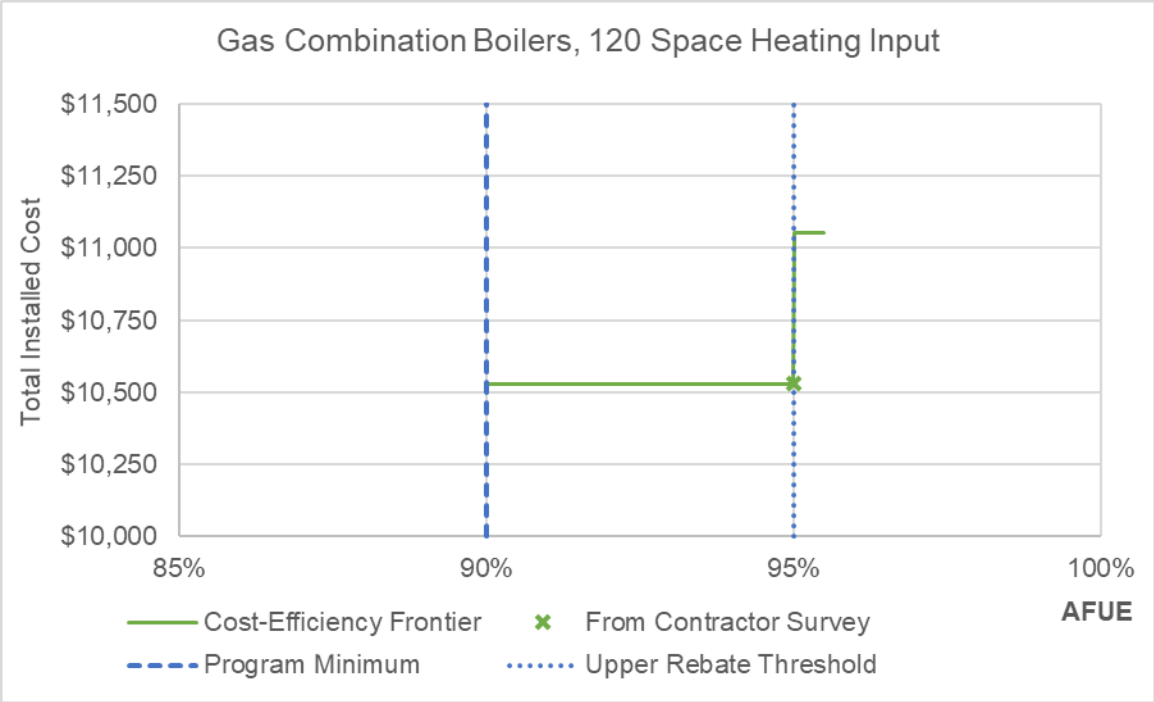
Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Oil-Fired Boilers at 119 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 84.3%	$6,866
84.4 – 85.3%	$7,232
85.4 – 86.8%	$7,664
86.9 – 87.5%	$7,834
87.6 – 88.3%	$7,918
88.4 – 90.0%	$10,552

3.2.7 Combination Boilers – Natural Gas

The evaluation team did not observe any natural gas combination boilers rated below 90% AFUE at the representative capacity of 120 MBH. Additionally, several contractors indicated that there are no gas-fired combination boilers on the market below 90% AFUE.

Total Installed Cost of Gas-Fired Combination Boilers at 120 MBH space heating input capacity



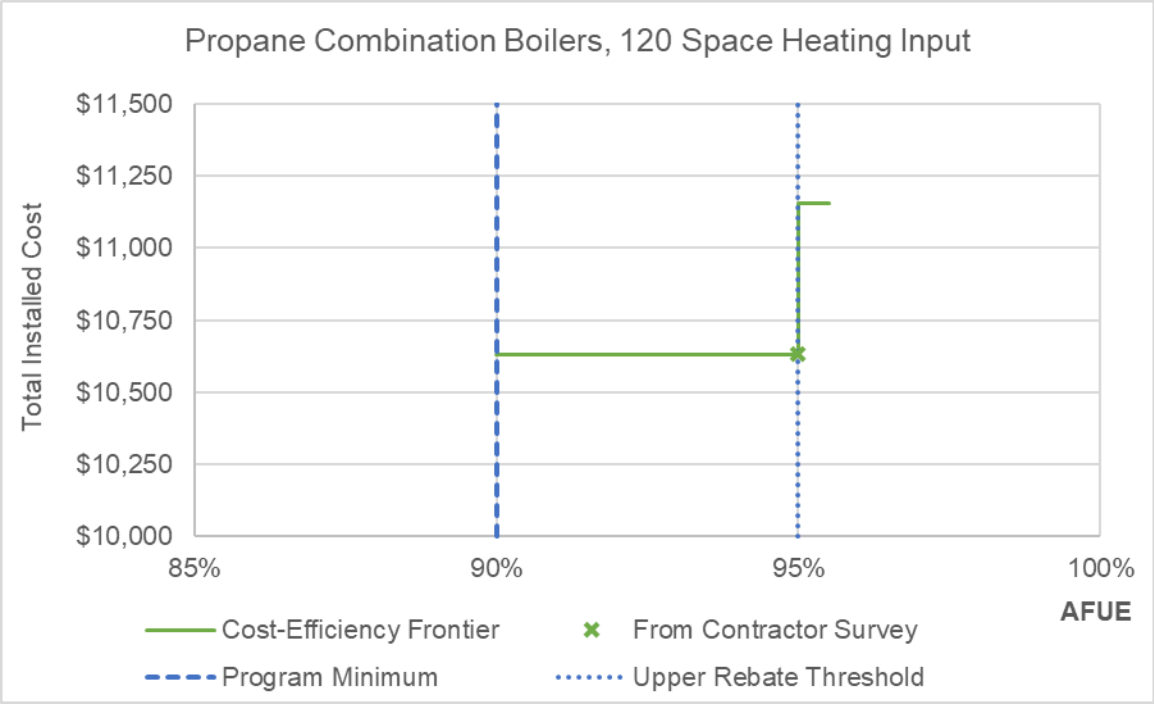
Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Gas-Fired Combination Boilers at 120 MBH Heating Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 95.0%	$10,530
95.1 – 95.5%	$11,054

3.2.8 Combination Boilers – Propane

The evaluation team did not observe any propane combination boilers rated below 90% AFUE at the representative capacity of 120 MBH. Additionally, several contractors indicated that there are no propane-fired combination boilers on the market below 90% AFUE.

Total Installed Cost of Propane-Fired Combination Boilers at 120 MBH space heating input capacity

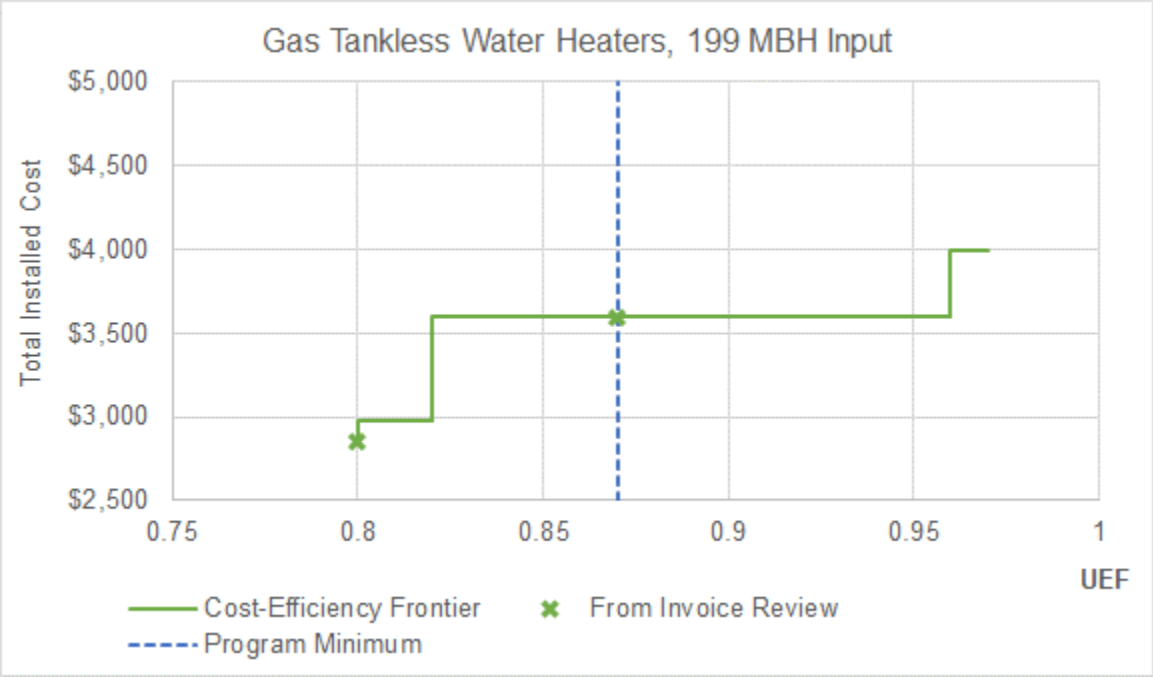


Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Propane-Fired Combination Boilers at 120 MBH Heating Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 95.0%	$10,631
95.1 – 95.5%	$11,155

3.2.9 On-Demand Tankless Water Heaters – Natural Gas

Total Installed Cost of Gas-Fired On-Demand Tankless Water Heaters at 199 MBH input capacity

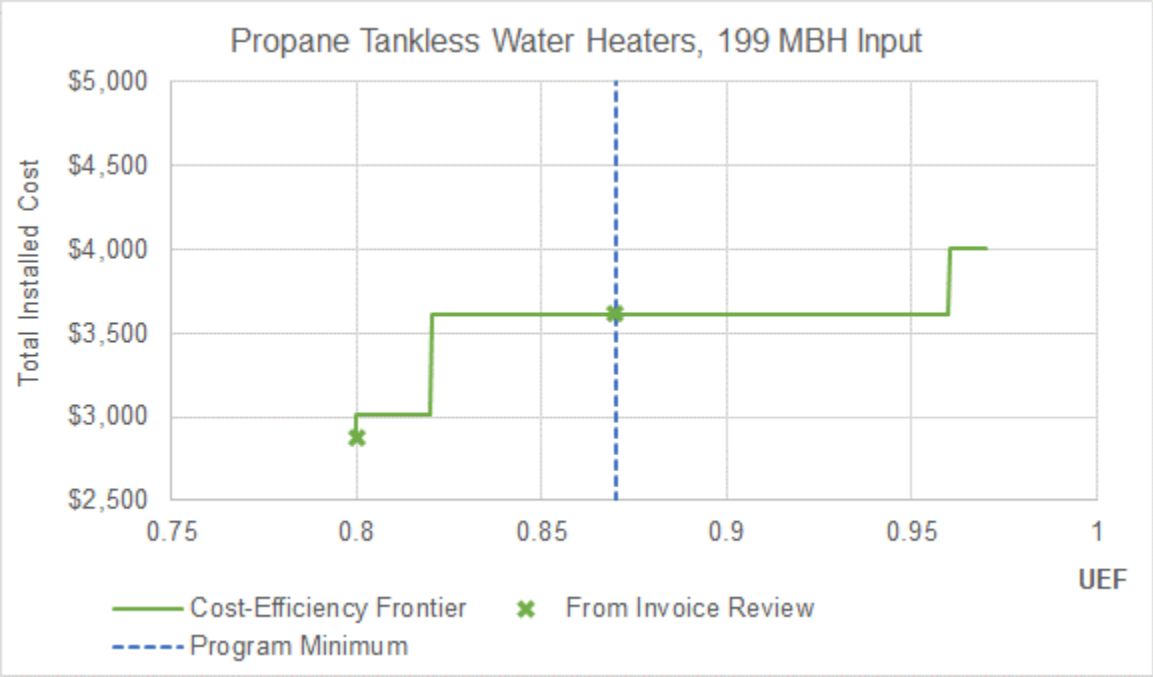


Source: Navigant analysis of product cost data from contractor survey, program invoice review, and webscraping

Total Installed Cost of Gas-Fired On-Demand Tankless Water Heaters at 199 MBH Input Capacity, by Efficiency Level	
UEF	**Total Installed Cost**
Up to 0.80 UEF	$2,853
0.81 – 0.82 UEF	$2,981
0.83 – 0.96 UEF	$3,596
0.97 UEF	$3,990

3.2.10 On-Demand Tankless Water Heaters – Propane

Total Installed Cost of Propane-Fired On-Demand Tankless Water Heaters at 199 MBH input capacity

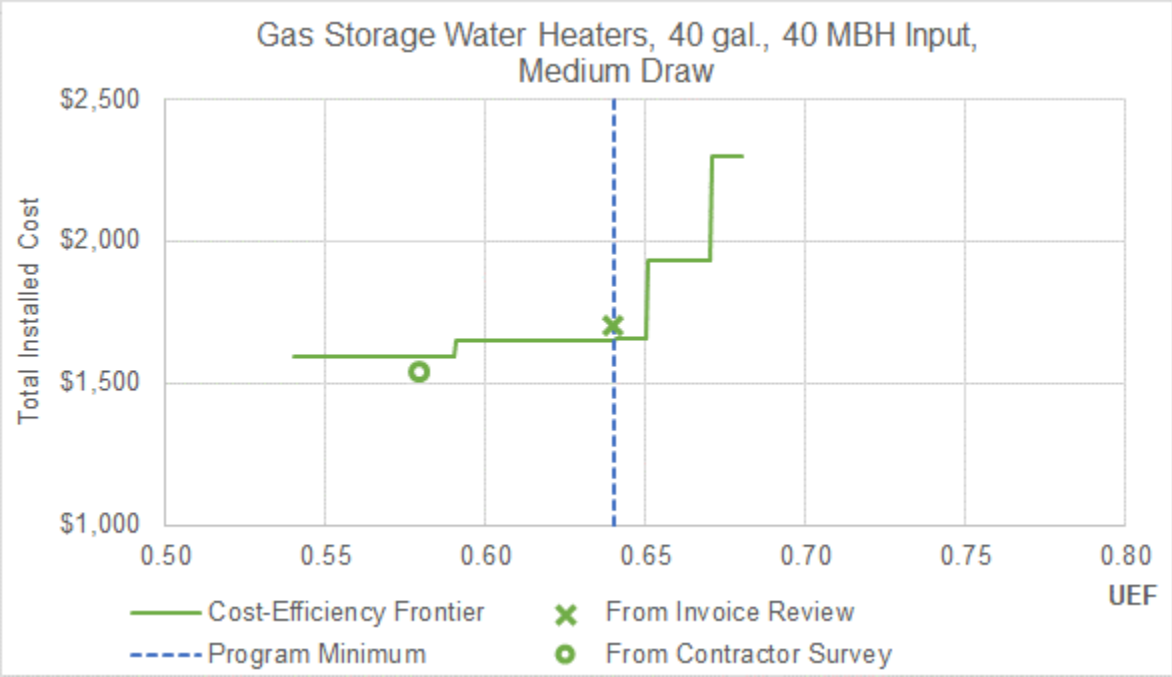


Source: Navigant analysis of product cost data from contractor survey, program invoice review, and webscraping

Total Installed Cost of Propane-Fired On-Demand Tankless Water Heaters at 199 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 0.80 UEF	$2,874
0.81 – 0.82 UEF	$3,011
0.83 – 0.96 UEF	$3,614
0.97 UEF	$4,008

3.2.11 Medium-Draw Gas Storage Water Heaters at 55 Gallons or less – Natural Gas

Total Installed Cost of Gas-Fired Storage Water Heaters at 40 gallons and 40 MBH input capacity

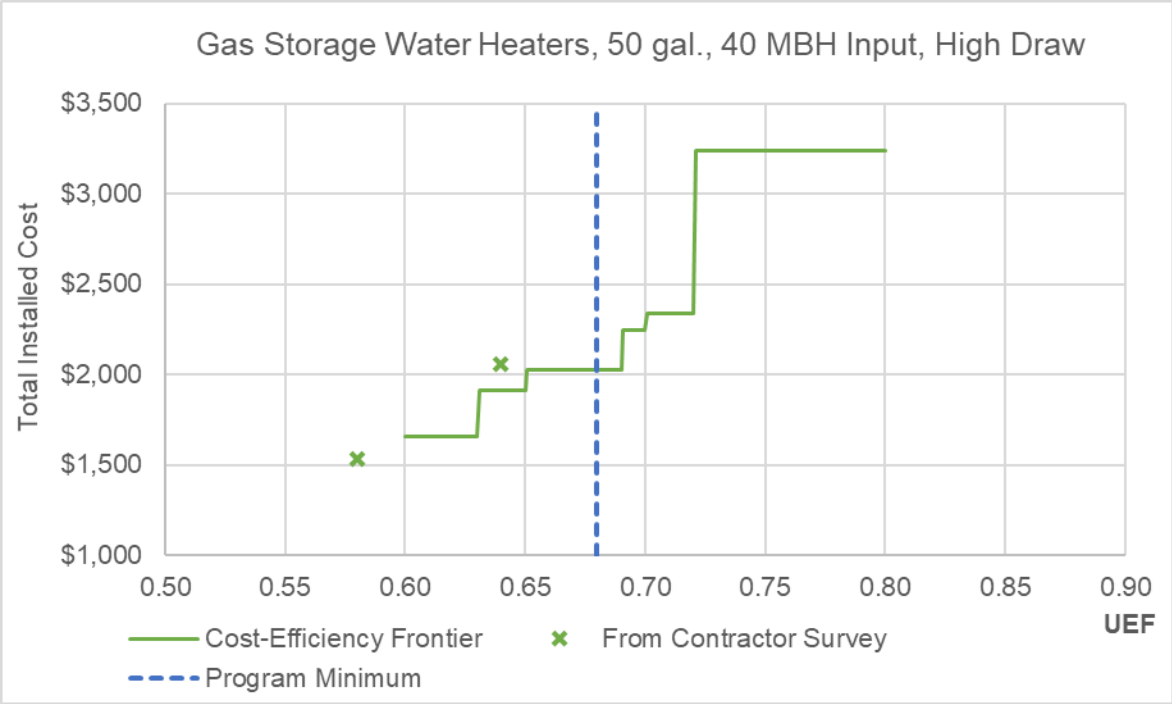


Source: Navigant analysis of product cost data from contractor survey, program invoice review, and webscraping

Total Installed Cost of Gas-Fired Storage Water Heaters at 40 gallons, 40 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 0.59 UEF	$1,591
0.60 – 0.64 UEF	$1,647
0.65 UEF	$1,656
0.66 – 0.67 UEF	$1,933
0.68 UEF	$2,296

3.2.12 High-Draw Gas Storage Water Heaters at 55 Gallons or less – Natural Gas

Total Installed Cost of Gas-Fired Storage Water Heaters at 50 gallons and 40 MBH input capacity

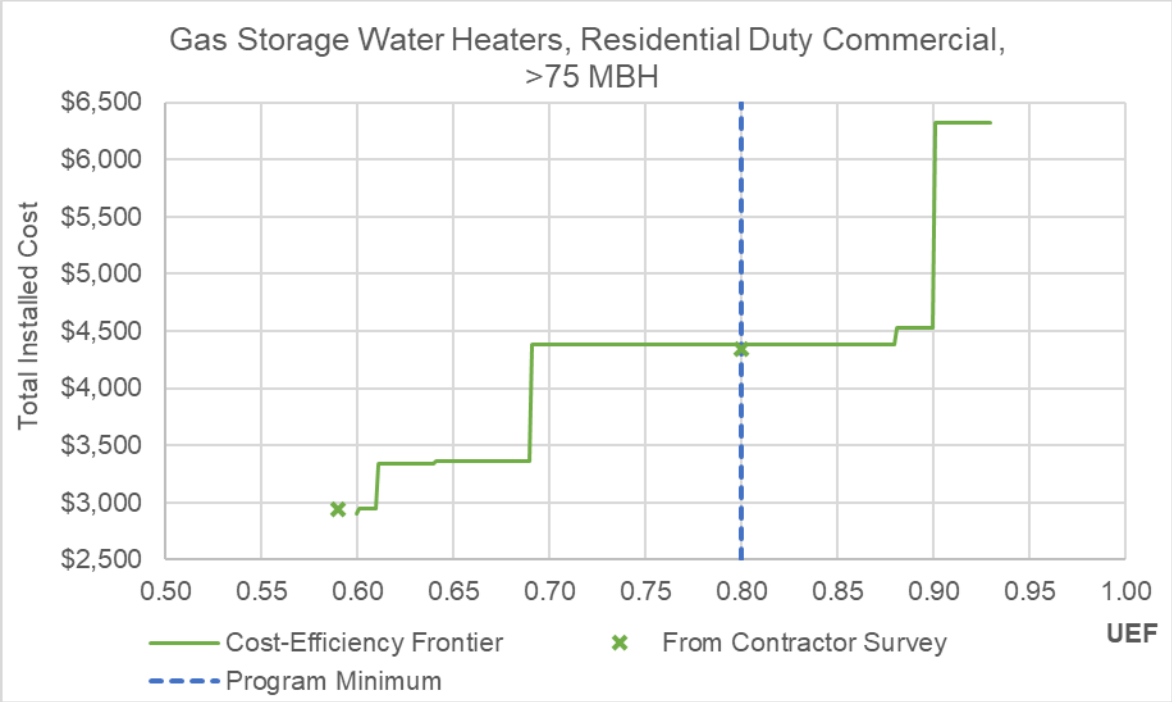


Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Gas-Fired Storage Water Heaters at 50 gallons, 40 MBH Input Capacity, by Efficiency Level	
AFUE	**Total Installed Cost**
Up to 0.63 UEF	$1,653
0.64 – 0.65 UEF	$1,913
0.66 – 0.69 UEF	$2,023
0.70 UEF	$2,243
0.71 – 0.72 UEF	$2,339
0.73 – 0.80 UEF	$3,235

3.2.13 Gas Storage Water Heaters over 55 Gallons and 75 MBH (Residential-Duty Commercial) – Natural Gas

Total Installed Cost of Residential-Duty Commercial Gas-Fired Storage Water Heaters

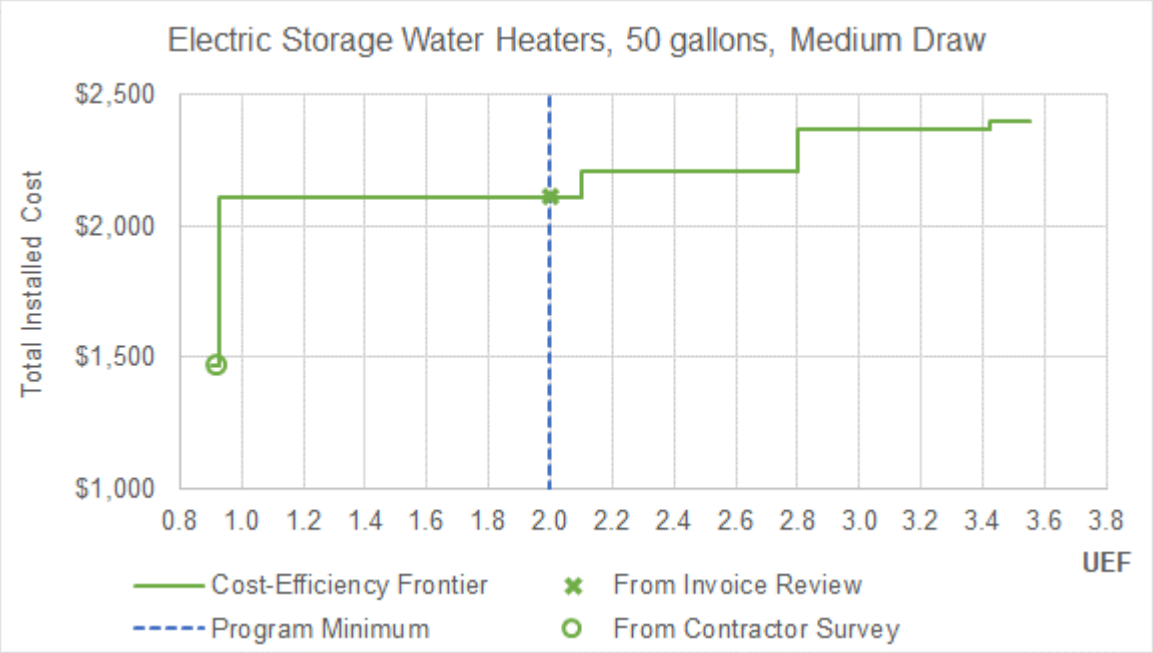


Source: Navigant analysis of product cost data from contractor survey and webscraping

Total Installed Cost of Residential-Duty Commercial Gas-Fired Storage Water Heaters, by Efficiency Level	
UEF	**Total Installed Cost**
Up to 0.60 UEF	$2,900
0.61 UEF	$2,944
0.62 – 0.64 UEF	$3,344
0.65 – 0.69 UEF	$3,358
0.70 – 0.88 UEF	$4,381
0.89 – 0.90 UEF	$4,526
0.91 – 0.93 UEF	$6,326

3.2.14 Electric Storage Water Heaters at 55 Gallons or Less – Electric Resistance and Electric Heat Pump

Total Installed Cost of Electric Storage Water Heaters at 50 Gallons Capacity and Medium Draw

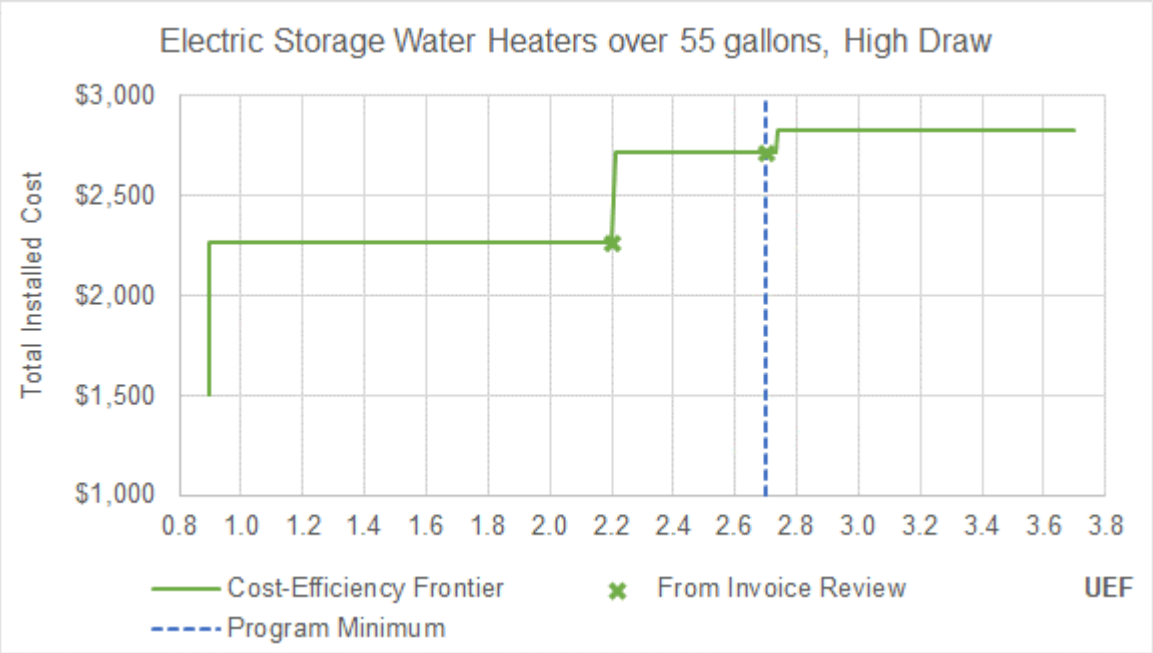


Source: Navigant analysis of product cost data from contractor survey, program invoice review, and webscraping

Total Installed Cost of Electric Storage Water Heaters at 50 gallons, by Efficiency Level	
UEF	**Total Installed Cost**
Up to 0.92 UEF	$1,469
0.93 UEF	$1,473
0.94 – 2.10 UEF	$2,110
2.11 – 2.80 UEF	$2,210
2.81 – 3.42 UEF	$2,370
3.43 – 3.55 UEF	$2,401

3.2.15 Electric Storage Water Heaters over 55 Gallons – Electric Resistance and Electric Heat Pump

Total Installed Cost of Electric Storage Water Heaters at 80 Gallons Capacity



Source: Navigant analysis of product cost data from contractor survey, program invoice review, and webscraping

Total Installed Cost of Electric Storage Water Heaters at 80 gallons, by Efficiency Level	
UEF	**Total Installed Cost**
0.90 UEF (estimated)	$1,502
0.91 – 2.20 UEF	$2,263
2.21 – 2.73 UEF	$2,714
2.74 – 3.70 UEF	$2,823

3.2.16 Indirect Water Heaters

Indirect water heaters may be installed alongside gas-, propane-, or oil-fired hot water boilers. The total installed cost for indirect water heaters was determined using the contractor survey and the review of program rebate invoices. The survey asked contractors to provide the total installed cost of indirect water heaters for an installation with each fuel type. Survey respondents indicated that the total installed cost of indirect water heaters is the same for products attached to natural gas, propane and oil boilers. The review of program invoices provided an average total installation cost for indirect water heaters.

Total Installed Cost of Indirect Water Heaters at 45 gallons, by Fuel Type

Fuel Type	Total Installed Cost
Natural Gas	$2,919
Propane	$2,919
Oil	$2,919

Source: Navigant analysis of product cost data from contractor survey and a review of program invoices

4. CONCLUSIONS AND CONSIDERATIONS

This study estimated the total installed costs across the range of available efficiencies for water heating, boil, and furnace products rebated by the Residential Heating and Cooling Program. The program may reference these costs in its cost-benefit analysis to refine the rebate efficiency thresholds and the incentive amounts that are offered for these products. There are three strategies the Program Administrators (PAs) could pursue to improve the cost effectiveness of water heater, boiler, and furnace rebate offerings.

- **Consideration 1:** The PAs should consider discontinuing the lower rebate level of 90% AFUE for combination boilers and continue incentivizing the adoption of higher-efficiency 95% AFUE models that appear to be a less expensive option for customers.

    - **Finding 1:** The webscraping of retail product prices found that the least expensive combination boilers (at the representative size of 120 MBH input) are rated at 95% AFUE. Additionally, one of the survey respondents indicated that combination boiler products rated at 95% AFUE often have lower wholesale prices than combination boilers rated between 87% and 94% AFUE.

- **Consideration 2:** The evaluation team does not have access to shipment or sales data that would indicate the number of low-efficiency installations that have been allowed because of this enforcement policy. The evaluation team is reaching out to survey respondents to ask how frequently these large electric resistance water heaters are installed in Massachusetts. However, the number of survey respondents was limited, and any data they provide will be limited. The PAs should consider pursuing additional survey efforts to understand how prevalent these models are in Massachusetts. If the high-volume electric resistance models are found to be prevalent, the PAs should consider reassessing the baseline for the large electric storage water heater product class.

    - **Finding 2:** The evaluation team identified several 80-gallon electric water heater models on the market that meet the definition of residential electric storage water heaters, but do not meet the federal minimum standards for residential electric storage water heaters. The U.S. Dept. of Energy (DOE) published an enforcement policy stating that at least until March 31, 2018, DOE will not seek penalties for the failure to properly certify water heater models that meet certain criteria.[6] It is not clear whether this policy will be extended beyond March 31. In the meantime, these non-compliant models are available for residential customers to purchase and install.

[6] The DOE Enforcement Policy Statement Regarding Testing, Compliance with the Applicable Energy Conservation Standards, and Certification for Certain Consumer Water Heaters is available on DOE's website: https://energy.gov/sites/prod/files/2018/01/f47/Enforcement%20Policy-ConsumerWH_Def_1-2018.pdf

APPENDIX A. CONTRACTOR SURVEY

This appendix contains a hard copy of the web-based cost survey of water heater, boiler, and furnace installation costs that was delivered to a sample of HVAC contractors in Massachusetts between December 2017 and January 2018.

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1. What is your name?
2. To which address should we send your gift card (provided you complete this survey)?
3. What is the best phone number to reach you for a follow up interview (if necessary)?
4. What company do you work for?
5. Where is your company headquartered?

☐ Greater Boston	☐ Central MA
☐ Metro West	☐ Western MA
☐ North of Boston	☐ Cape Cod & Islands
☐ South of Boston	☐ Other._____.

6. In which regions do you operate?

☐ Greater Boston	☐ Central MA
☐ Metro West	☐ Western MA
☐ North of Boston	☐ Cape Cod & Islands
☐ South of Boston	☐ Other._____.

7. Which of the following equipment types do you install?

☐ Furnaces	☐ On-Demand Tankless Water Heaters
☐ Boilers	☐ Storage Water Heaters
☐ Combination Boilers	☐ Indirect Water Heaters

8. How many of each of the equipment types does your company install annually in residential settings?

Product Type	Typical Number of Installations Per Year (Select one range for each type)					
	None	1-10	11-25	26-50	51-100	100+
8A. Furnaces	O	O	O	O	O	O
8B. Boilers	O	O	O	O	O	O
8C. Combination Boilers	O	O	O	O	O	O
8D. Gas Tankless Water Heaters	O	O	O	O	O	O
8E. Gas Storage Water Heaters	O	O	O	O	O	O
8F. Electric Storage Water Heaters	O	O	O	O	O	O
8G. Indirect Water Heaters	O	O	O	O	O	O

9. What percentage of your total sales is to commercial customers? This question is for data-gathering purposes only. The remainder of this survey pertains to residential installations only.

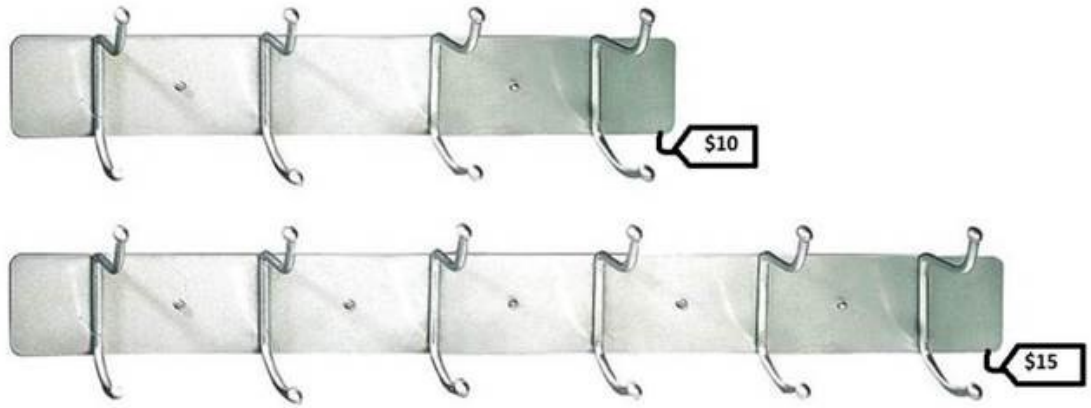
Installation Scenarios

For the following residential installation scenarios, please provide an estimate for the labor, equipment, and other costs. The following prompts ask about the total costs for each installation described and not the incremental price differentials between different models.

We understand that costs in the "Other" category (travel, warranty, insurance, etc.) will vary from customer to customer. Please report what you believe are the typical costs for an average installation in your operating territory.

Example of Cost Inputs

As an example, the table below shows cost estimates for installing two different kinds of coat racks pictured here. The 4-hook rack costs $10 and the 6-hook rack costs $15, and this is reflected in the "Equipment" cost line. The 6-hook rack takes 5 screws, so it has a higher "Supplies" cost than the 4-hook rack which takes 2 screws. The 6-hook rack takes longer to install, so it has "Labor" cost of $30 compared to the $20 to install the 4-hook rack. The "Other" costs are the same for both racks, because they have the same warranty, overhead, and travel time.



Example response for the installation scenario above:

	Install 4-hook plate with 2 screws	Install 6-hook plate with 5 screws
Labor	$20	$30
Equipment	$10	$15
Supplies	$0.50	$1.25
Other	$50	$50

Furnaces

For purposes of this survey, the term "furnace" means a product that:
(A) is the main heating source for a residential living space,
(B) is not contained in the same package as a central air conditioner with a rated cooling capacity above 65kBtu/hr, and
(C) is a forced-air central furnace, or gravity central furnace running on natural gas, propane, or oil.

Installation Note: Assume the furnace will be installed indoors in a home with existing ductwork, easily accessible gas or oil supply piping, and easily accessible electrical hookups (both for thermostats and power). For all condensing equipment, assume that the home does not have existing piping for handling or draining condensate and appropriately venting flue gas.

The prompts below ask about products with different fuel types at different efficiencies. How much would you typically charge to install the products described above at the levels below? Only fill in values that are applicable to your operations.

Equipment Type:	**Natural Gas-fired Furnace (80,000 Btu capacity)**		
Efficiency Level:	**Code minimum, 80% AFUE**	**95%-96% AFUE**	**97% AFUE or higher**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*	*Calculated*

Equipment Type:	**Propane-fired Furnace (80,000 Btu capacity)**	
Efficiency Level:	**Code minimum, 80% AFUE**	**95% AFUE or higher**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

Equipment Type:	**Oil-fired Furnace (91,000 Btu capacity)**	
Efficiency Level:	**Code minimum, 83% AFUE**	**86% AFUE or higher**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

What is the lowest AFUE rating at which a gas-fired furnace installation will require a condensate drain? Please make sure the values you entered above reflect any additional supply and labor costs for handling condensate and flue gas.

Comments/Additional notes

Hot Water Boilers

For purposes of this survey, the term "boiler" means a gas- or oil- burning boiler designed to supply hot water for space heating application. A hot water boiler operates at or below 160 psig water pressure and 250 °F water temperature.

Installation note: Assume the boiler will be installed in a home with existing hydronic piping, easily accessible gas or oil supply piping, and easily accessible electrical hookups (both for thermostats and power). For all condensing equipment, assume that the home does not have existing piping for handling or draining condensate and appropriately venting flue gas.

The prompts below ask about products with different fuel types at different efficiencies. How much would you typically charge to install the products described above at the levels below? Only fill in values that are applicable to your operations.

Equipment Type:	**Natural Gas-fired Hot Water Boiler (110 Btu capacity)**		
Efficiency Level:	**Code Minimum, 82% AFUE**	**90%-94% AFUE**	**≥95% AFUE**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*	*Calculated*

Equipment Type:	**Propane-fired Hot Water Boiler (110 Btu capacity)**	
Efficiency Level:	**Code Minimum, 82% AFUE**	**>90% AFUE**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

Equipment Type:	**Oil-fired Hot Water Boiler (119,000 Btu capacity)**	
Efficiency Level:	**Code Minimum, 84% AFUE**	**≥86% AFUE**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

What is the lowest AFUE rating at which a gas-fired boiler installation will require a condensate drain? Please make sure the values you entered above reflect any additional supply and labor costs for handling condensate and flue gas.

Comments/Additional notes

Combination Boilers

For purposes of this survey, the term "combination boiler" means a gas- or propane-fired boiler combined with an on-demand hot water heater. The product must be considered as one unit by the manufacturer.

Installation note: Assume the boiler will be installed in a home with existing hydronic piping, easily accessible gas supply piping, and an easily accessible electrical hookup (both for thermostats and power). For all condensing equipment, assume that the home does not have existing piping for handling or draining condensate and appropriately venting flue gas.

The prompts below ask about products with different fuel types at different efficiencies. How much would you charge to install the products described above at the levels below? Only fill in values that are applicable to your operations.

Equipment Type:	**Natural Gas-fired Combination Boiler (120,000 Btu capacity)**		
Efficiency Level:	**82% AFUE**	**90%-94% AFUE**	**≥95% AFUE**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*	*Calculated*

Equipment Type:	**Propane-fired Combination Boiler (120,000 Btu capacity)**		
Efficiency Level:	**82% AFUE**	**90%-94% AFUE**	**≥95% AFUE**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*	*Calculated*

Comments/Additional notes

On-Demand Tankless Water Heaters

For purposes of this survey, the term "on-demand tankless water heater" means an instantaneous-type unit which heats water but stores no more than one gallon of water per 4,000 Btu/h of input.

Installation note: Assume the water heater will be installed in a home with existing piping, accessible gas supply piping, and an easily accessible electrical hookup (both for thermostats and power). For all condensing equipment, assume that the home does not have existing piping for handling or draining condensate and appropriately venting flue gas.

Metric note: The Uniform Energy Factor (UEF) is the U.S. Dept. of Energy's newly developed metric for communicating the energy efficiency of water heaters. As of June, 2017, the UEF replaces the Energy Factor (EF) metric. For the sake of clarity, this survey describes efficiency thresholds in terms of both EF and UEF, though we understand there is not a direct correlation between the two metrics.

The prompts below ask about products with different fuel types at different efficiencies. How much would you typically charge to install the products described above at the levels below? Only fill in values that are applicable to your operations.

Equipment Type:	**Natural Gas-fired On-Demand Tankless Water Heater (199,000 Btu)**	
Efficiency Level:	**Code Minimum, 0.82 EF (or 0.80 UEF)**	**ENERGY STAR, ≥0.94 EF (or ≥0.87 UEF)**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

Equipment Type:	**Propane-fired On-Demand Tankless Water Heater (199,000 Btu)**	
Efficiency Level:	**Code Minimum, 0.82 EF (or 0.80 UEF)**	**ENERGY STAR, ≥0.94 EF (or ≥0.87 UEF), with electronic ignition**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

What is the lowest EF or UEF rating at which a gas-fired on-demand tankless water heater installation will require a condensate drain? Please make sure the values you entered above reflect any additional supply and labor costs for handling condensate and flue gas (powered, if applicable).

Comments/Additional notes

Storage Water Heaters

A storage water heater means a product which heats and stores water at a thermostatically controlled temperature.

Installation note: Assume the water heater will be installed in a home with existing hot water piping plumbed for a conventional water heater, easily accessible gas supply piping, and an easily accessible electrical hookup (if necessary, for example, for electronic pilot ignition furnished with the higher efficiency units). For condensing equipment (Large natural-gas fired storage residential-duty commercial water heater), assume that the home does not have existing piping for handling or draining condensate and appropriately venting flue gas (powered, if applicable). For electric water heaters, please consider the additional costs (if any) associated with installing a **heat pump water heater** in a space designed for a conventional storage water heater.

Metric note: The Uniform Energy Factor (UEF) is the U.S. Dept. of Energy's newly developed metric for communicating the energy efficiency of water heaters. As of June, 2017, the UEF replaces the Energy Factor (EF) metric. For the sake of clarity, this survey describes efficiency thresholds in terms of both EF and UEF, though we understand there is not a direct correlation between the two metrics.

The prompts below ask about products with different fuel types at different efficiencies. How much would you typically charge to install the products described above at the levels below? Only fill in values that are applicable to your operations.

Equipment Type:	**Natural Gas-fired Storage Water Heater, 40-gallon, 40,000 Btu.**	
Efficiency Level:	**Code minimum, ≥0.62 EF (or 0.58 UEF)**	**ENERGY STAR, ≥0.67 EF (or 0.64 UEF)**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

Equipment Type:	**Large Natural Gas-fired Storage Residential-Duty Commercial Water Heater, 50-gallon, 100,000 Btu.**	
Efficiency Level:	**Code minimum, ≥0.59 UEF**	**ENERGY STAR, >=0.80 UEF (condensing)**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

Equipment Type:	**Standard-size Electric Storage Water Heater, 50-gallon**	
Efficiency Level:	**Code Minimum, 0.95 EF (or ≥0.92 UEF) Electric Resistance**	**ENERGY STAR, ≥2.30 EF (or ≥2.00 UEF) Heat Pump**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

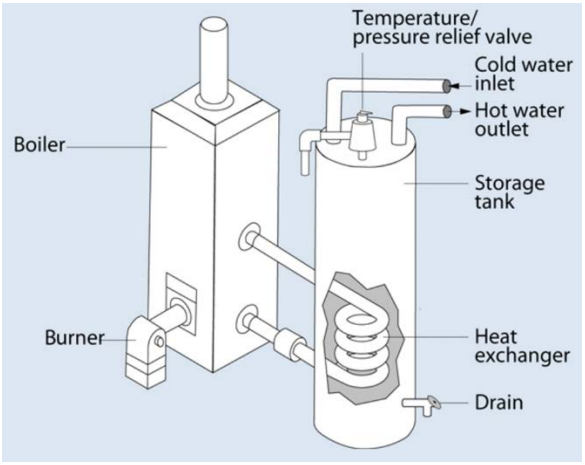
Equipment Type:	**Large Electric Storage Water Heater, 80-gallon**	
Efficiency Level:	**Code Minimum, 2.00 EF (or ≥2.20 UEF) Heat pump**	**≥3.00 EF (or ≥2.70 UEF) Heat pump**
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*

Comments/Additional notes

Indirect Water Heater

Note, an indirect water heater means a product which heats water via a dedicated loop on a natural gas, oil, or propane boiler. The boiler heats a fluid that is circulated through a heat exchanger in the indirect water heater storage tank.

Installation note: Assume the boiler is already installed in the home, and that all piping and equipment is easily accessible.



The prompts below ask about products with different fuel types at different efficiencies. How much would you charge to install the products described above at the levels below? Only fill in values that are applicable to your operations.

Equipment Type:	**Indirect water heater, installed alongside an existing boiler**		
Tank size and boiler fuel type:	45-gallon tank attached to a **natural gas-fired** boiler	45-gallon tank attached to a **propane-fired** boiler	45-gallon tank attached to an **oil-fired** boiler
Labor costs, burdened ($) Equipment costs, including markup ($) Supplies costs (mounting supplies, additional lines, tools, etc.) ($) Other costs (travel, warranty, insurance, etc.) ($) Description of other costs:	_____ _____ _____ _____	_____ _____ _____ _____	_____ _____ _____ _____
Total	*Calculated*	*Calculated*	*Calculated*

Comments/Additional notes

APPENDIX B. REPRESENTATIVE PRODUCT SIZES FOR COST STUDIES (TASK 1 MEMO)

To: Massachusetts Program Administrators and Energy Efficiency Advisory Council

From: Decker Ringo and Danielle Vitoff; Navigant Consulting Inc.

Date: September 19, 2017

Re: RE: Water Heating, Boiler, and Furnace Cost Study (RES 19)
Task 1: Representative Product Sizes for Cost Studies

Summary

The Water Heating, Boiler, and Furnace Cost Study (RES 19) will develop cost-efficiency curves for a variety of heating products to describe the changes in product costs as product efficiency increases. These curves will describe the costs that customers typically face, and the curves should represent the product capacities that are typically rebated by program participants. This memorandum reports the typical capacity of heating products rebated by the Massachusetts Program Administrators (PAs) for the product varieties included in the RES 19 study. With the approval of the PAs, these representative capacities will be used as the basis for contractor surveys and the cost-efficiency curve development.

The PAs provided the evaluation team with participant rebate data assembled by Energy Federation Inc. (EFI) for the period of January 1, 2016 through July 31, 2017. The evaluation team filtered these records by product type, then identified and removed any outlier records which the team believed to contain erroneous data. For each product type, the team selected a metric or metrics that provide an appropriate description of the product's capacity. For several product types, the capacity data contained in the EFI records were incomplete. For product types with incomplete data, the evaluation team used the product model numbers reported in the participant records to reference capacity information from product specification sheets or the AHRI Database of Certified Product Performance. For example, only 39 of the 3,838 participant records for gas-fired indirect water heater reported a tank capacity in gallons. Using product specification sheets available online, the evaluation team located capacity data for 3,785 of the 3,799 gas-fired indirect water heater records that originally lacked capacity data.

For each of product type covered in the RES 19 study, the evaluation team selected a representative capacity value based on an examination of participant data. To select these representative capacities, the evaluation team first calculated summary statistics of the capacity metric over all the relevant participant records. The team then plotted histograms to examine the distribution of rebate claims across the range of product capacities. For most product types, the summary statistics provided a clear indication of the representative capacity. As an example, the natural gas combination boiler product type reports capacity in terms of the heat rating in thousands of British thermal units (Mbtu). The 236 participant records for that product type have mean, median, and mode all equal to 120 Mbtu. This clearly indicates that 120 Mbtu is the representative size for natural gas combination boilers. For some product types, the evaluation team used a combination of statistics and expert judgment to select the most representative capacity. For example, the distribution of natural gas furnace capacities had two peaks: there are large numbers of records both at 60 Mbtu capacity and at 80 Mbtu capacity. The evaluation team selected 80 Mbtu as the

representative size for natural gas furnaces, since that capacity is closest to the mean capacity of 74 Mbtu.

The representative capacities selected through task 1 and identified in this memo will be used as the basis for webscraping product data and for cost surveys of contractors and plumbers. To gather accurate cost data, it will be helpful for the representative capacities selected in this task to match products that exist in the market. To that end, the evaluation team selected capacities that match commonly-available products for all product types covered in this study. In some cases, this required that the team use expert judgment to interpret the summary statistics. As an example, the records of on-demand gas water heaters showed an average capacity of 190 Mbtu, but none of the participant records claim a capacity of exactly 190 Mbtu. In fact, few on-demand gas water heaters are even available at that capacity, and the average value of 190 Mbtu is the result of averaging many records at 199 Mbtu with some records at less than 185 Mbtu. In this case, the evaluation team selected 199 Mbtu as the representative capacity for on-demand gas water heaters, since the 199 Mbtu value matches the mode and the median capacities of the participant records for this product type.

The remainder of this memo includes the key findings of this research, followed by a detailed presentation of the statistics and capacity distributions for each product type.

Key Findings

Table 5 lists the product types included in the RES 19 study, along with the capacity metric and the representative capacity(s) that the evaluation team selected for each product.

Table 5. Capacity Metric and Representative Capacity for RES 19 Product Types

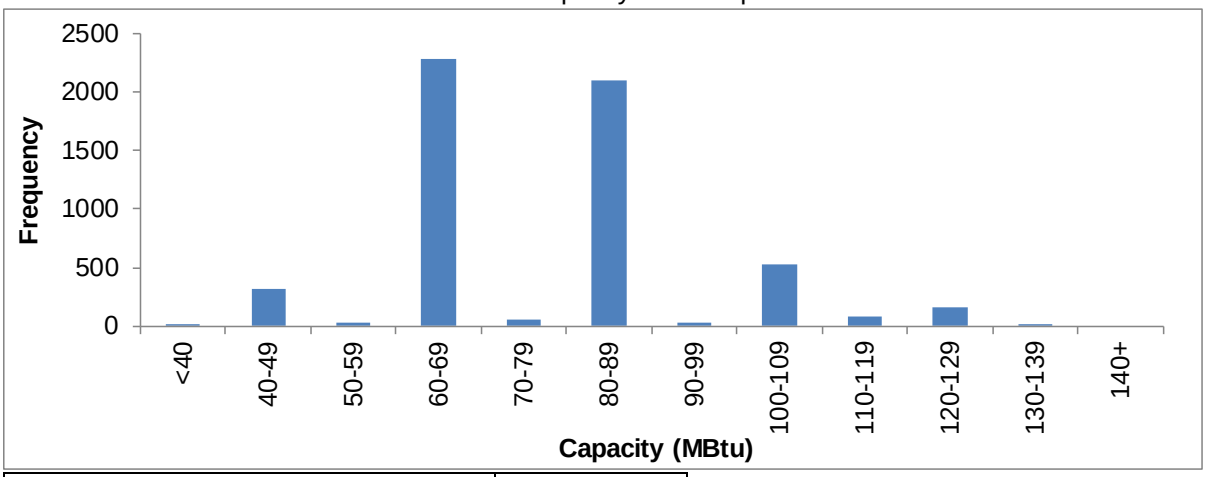
Product Type	Fuel Type	Capacity Metric	Representative Capacity
Furnace	Natural Gas	Heat Rating (Mbtu)	80 Mbtu
Furnace	Propane	Heat Rating (Mbtu)	80 Mbtu
Furnace	Oil	Heat Rating (Mbtu)	91 Mbtu
Hot Water Boiler	Natural Gas	Heat Rating (Mbtu)	110 Mbtu
Hot Water Boiler	Propane	Heat Rating (Mbtu)	110 Mbtu
Hot Water Boiler	Oil	Heat Rating (Mbtu)	119 Mbtu
Combination Boilers	Natural Gas	Space Heating Heat Rating (Mbtu)[7]	120 Mbtu
Combination Boilers	Propane	Space Heating Heat Rating (Mbtu)	120 Mbtu
On-Demand Tankless Water Heaters	Natural Gas	Heat Rating (Mbtu)	199 Mbtu
On-Demand Tankless Water Heaters	Propane	Heat Rating (Mbtu)	199 Mbtu
Storage Water Heaters, <75 MBH	Natural Gas	Storage Volume (gal), Heat Rating (Mbtu)	40 gal., 40 Mbtu
Storage Water Heaters, ≥75 MBH	Natural Gas	Storage Volume (gal), Heat Rating (Mbtu)	50 gal., 100 Mbtu
Storage Water Heaters, ≤55 gal.	Electric	Storage Volume (gal)	50 gal.
Storage Water Heaters, >55 gal.	Electric	Storage Volume (gal)	80 gal.
Indirect Water Heater	Natural Gas	Storage Volume (gal)	45 gal.
Indirect Water Heater	Propane	Storage Volume (gal)	45 gal.
Indirect Water Heater	Oil	Storage Volume (gal)	45 gal.

The charts and tables that follow present the capacity distributions and summary statistics for each product type in the RES 19 study. Each chart is a histogram that illustrates the number of participant records in each capacity bin recorded from January 1, 2016 through July 31, 2017. The tables present the mean (average), median, and mode for the capacity data of each product type, as well as the representative capacity that the evaluation team selected to represent the product type in our analysis.

[7] Because combination boilers perform both a space heating function and a water heating function, combination boilers typically report two different heat ratings: one rating for space heating and one rating for water heating. The evaluation team observed that participant records for combination boilers typically report the space heating heat rating in the "MBTU Input" field. Thus, from the two metrics available, the space heating heat rating is selected here as the capacity metric for combination boilers.

Furnaces – Natural Gas

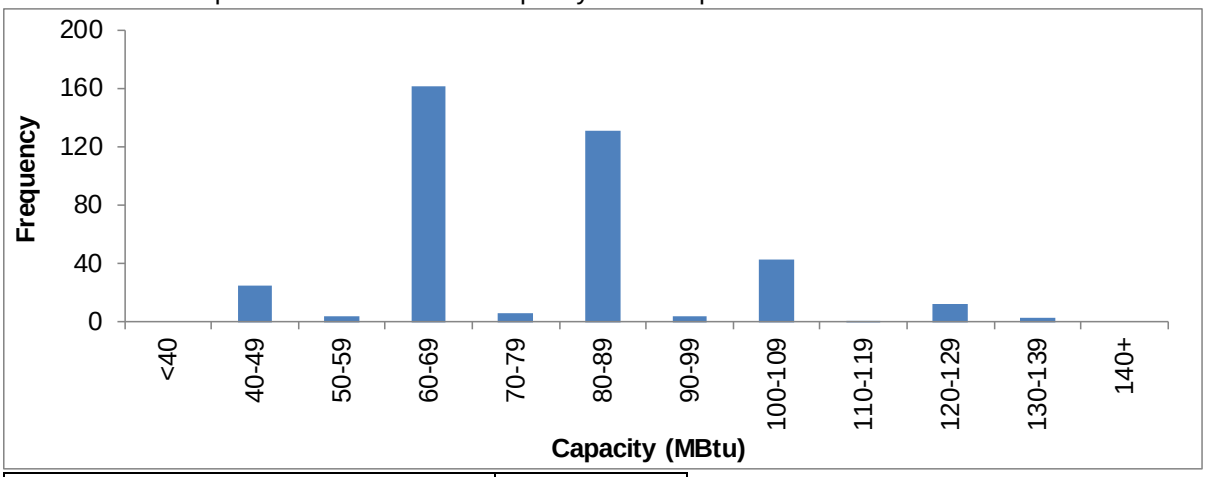
Distribution of Natural Gas Furnace Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	5,606
Mean	74 Mbtu
Median	80 Mbtu
Mode	60 Mbtu
Representative Capacity Selected	**80 Mbtu**

Furnaces - Propane

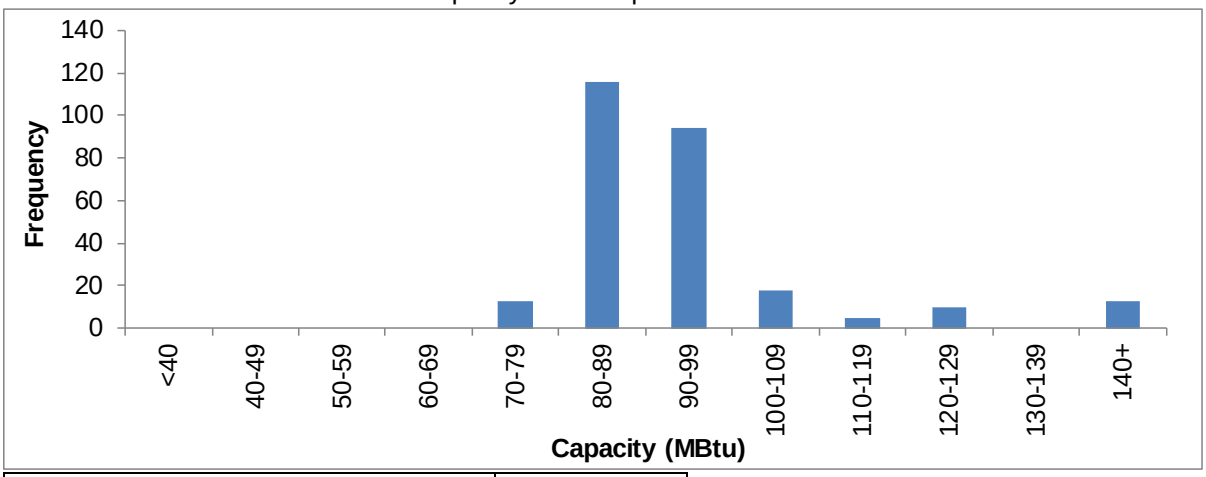
Distribution of Propane Furnace Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	390
Mean	74 Mbtu
Median	75 Mbtu
Mode	60 Mbtu
Representative Capacity Selected	**80 Mbtu**

Furnaces - Oil

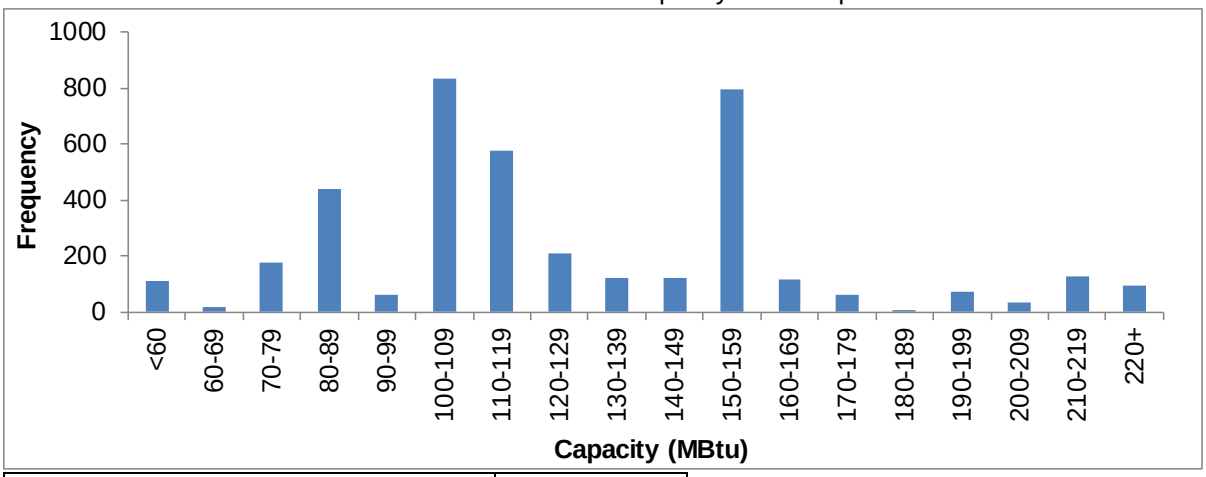
Distribution of Oil Furnace Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	269
Mean	92 Mbtu
Median	91 Mbtu
Mode	91 Mbtu
Representative Capacity Selected	**91 Mbtu**

Hot Water Boiler – Natural Gas

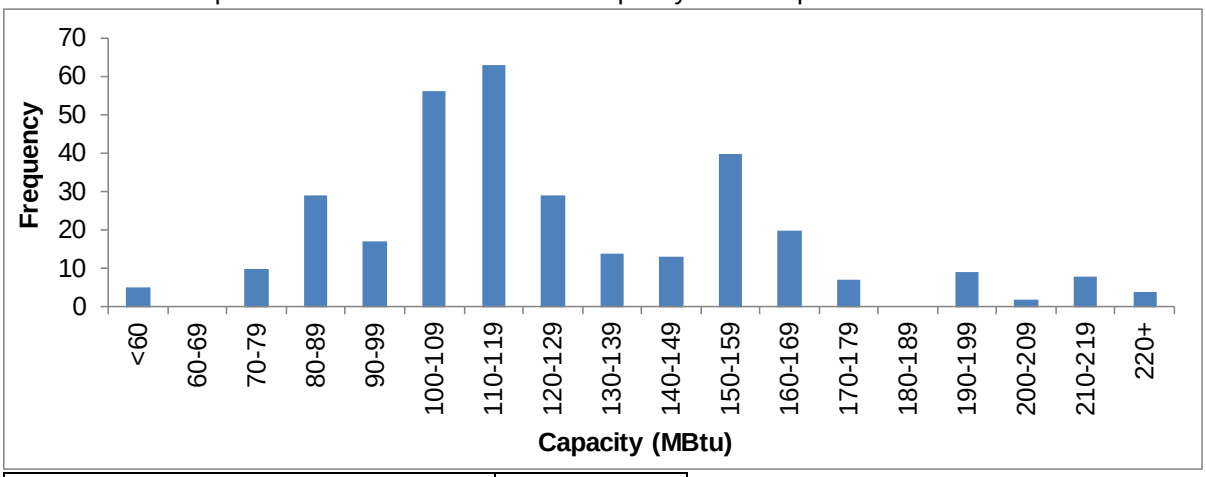
Distribution of Natural Gas Hot Water Boiler Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	3,988
Mean	125 Mbtu
Median	110 Mbtu
Mode	105 Mbtu
Representative Capacity Selected	**110 Mbtu**

Hot Water Boiler – Propane

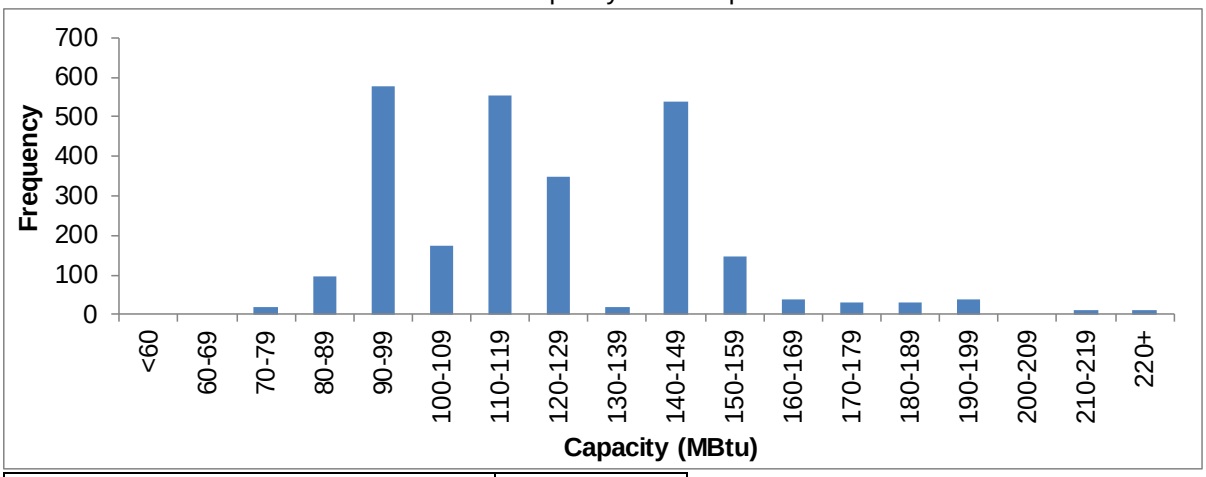
Distribution of Propane Hot Water Boiler Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	330
Mean	125 Mbtu
Median	118 Mbtu
Mode	110 Mbtu
Representative Capacity Selected	**110 Mbtu**

Hot Water Boiler – Oil

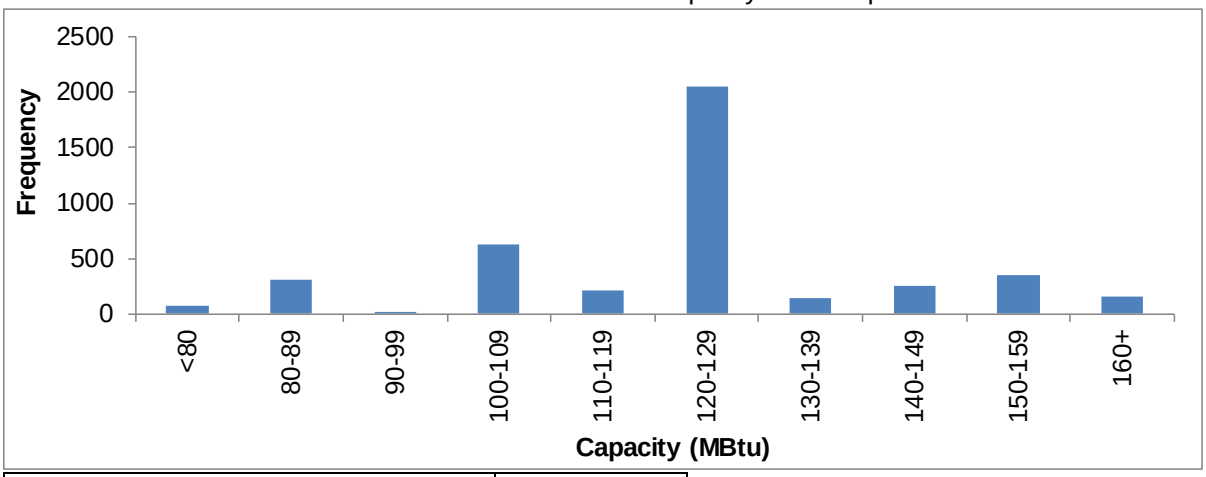
Distribution of Oil Hot Water Boiler Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	2,635
Mean	122 Mbtu
Median	119 Mbtu
Mode	98 Mbtu
Representative Capacity Selected	**119 Mbtu**

Combination Boiler – Natural Gas

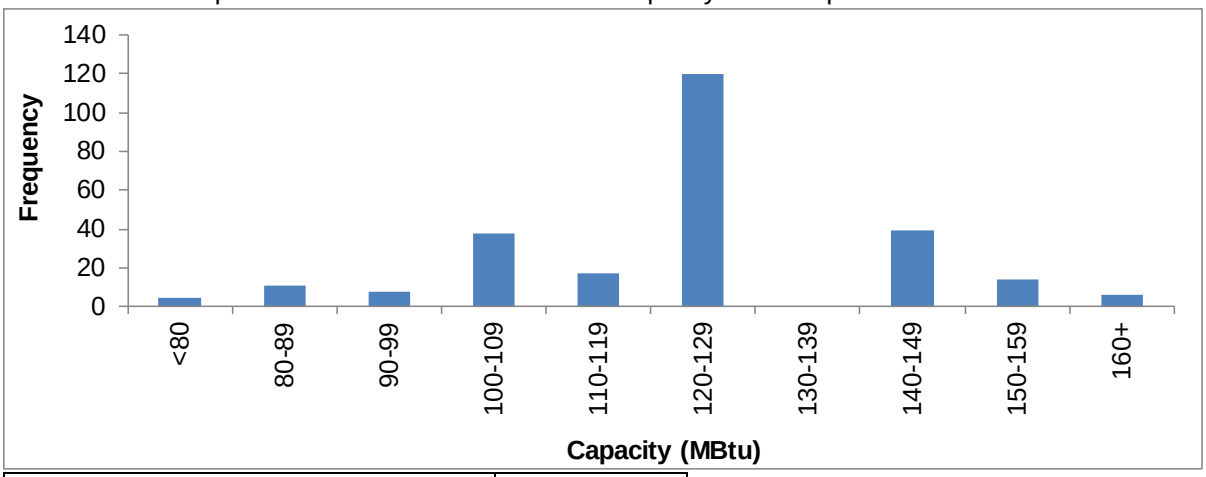
Distribution of Natural Gas Combination Boiler Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	4,222
Mean	120 Mbtu
Median	120 Mbtu
Mode	120 Mbtu
Representative Capacity Selected	**120 Mbtu**

Combination Boiler – Propane

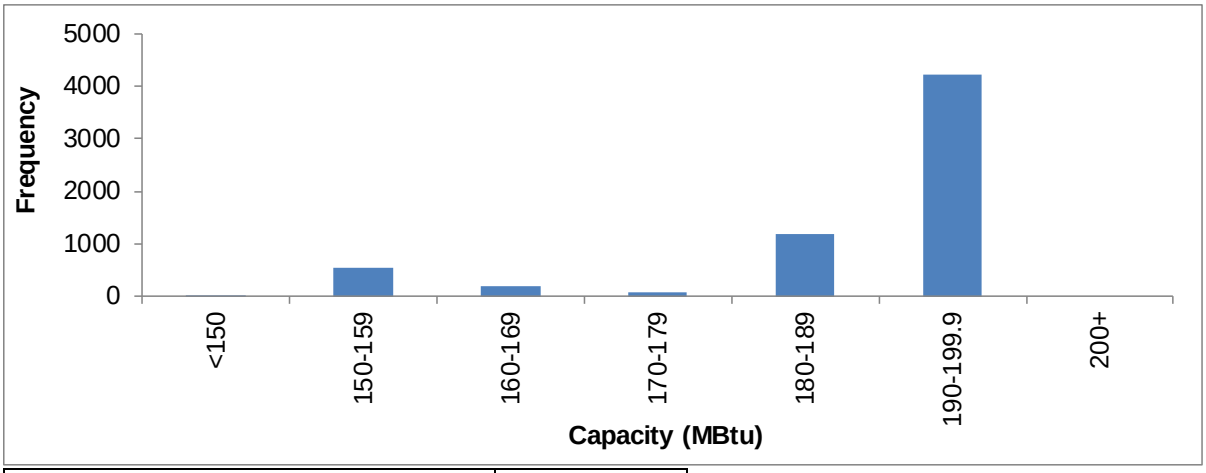
Distribution of Propane Combination Boiler Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	258
Mean	121 Mbtu
Median	120 Mbtu
Mode	120 Mbtu
Representative Capacity Selected	**120 Mbtu**

On-Demand Tankless Water Heaters – Natural Gas

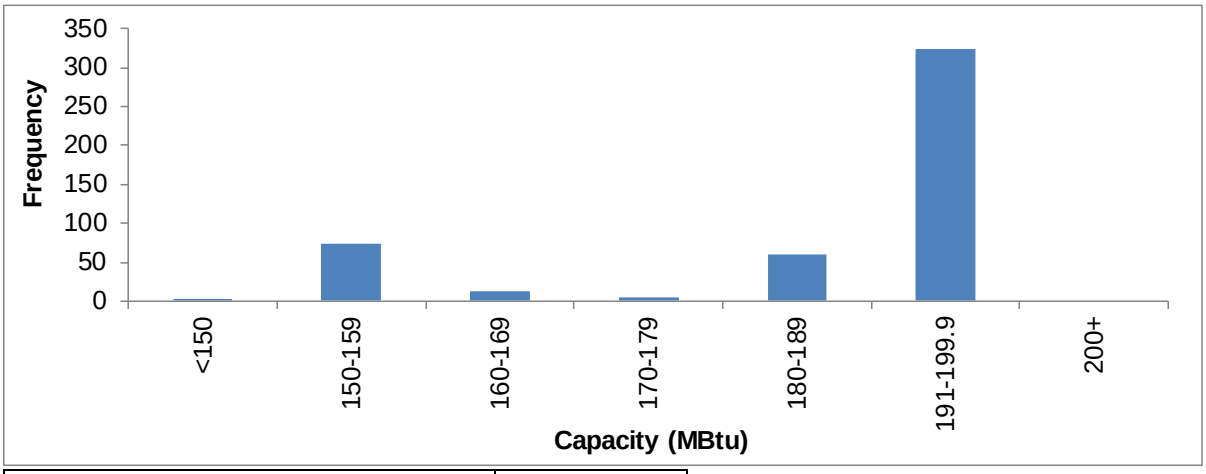
Distribution of Natural Gas On-Demand Tankless Water Heaters Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	6,195
Mean	190 Mbtu
Median	199 Mbtu
Mode	199.9 Mbtu
Representative Capacity Selected	**199 Mbtu**

On-Demand Tankless Water Heaters – Propane

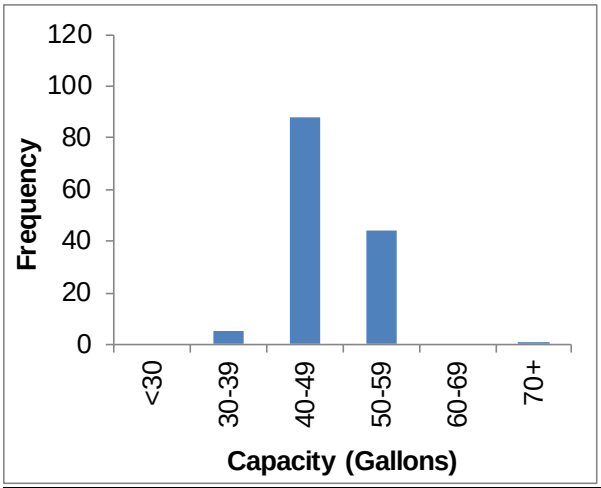
Distribution of Propane On-Demand Tankless Water Heaters Product Capacity in Participant Records 1/1/16–7/31/17

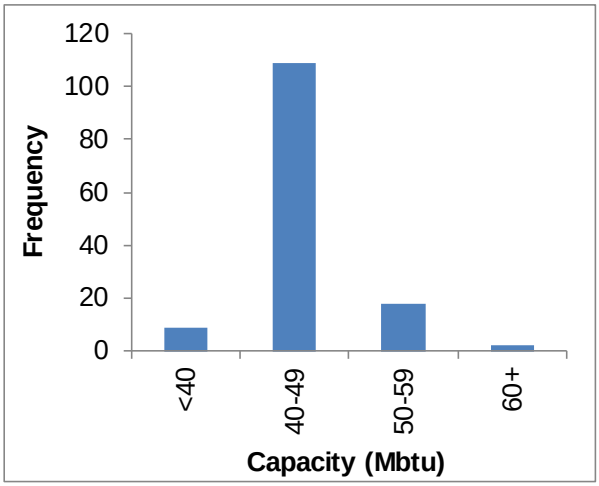


Quantity of Participant Records	476
Mean	188 Mbtu
Median	199 Mbtu
Mode	199 Mbtu
Representative Capacity Selected	**199 Mbtu**

Storage Water Heaters <75 MBH – Natural Gas

Distribution of Natural Gas Storage Water Heaters (<75 MBH) Product Capacity in Participant Records 1/1/16–7/31/17

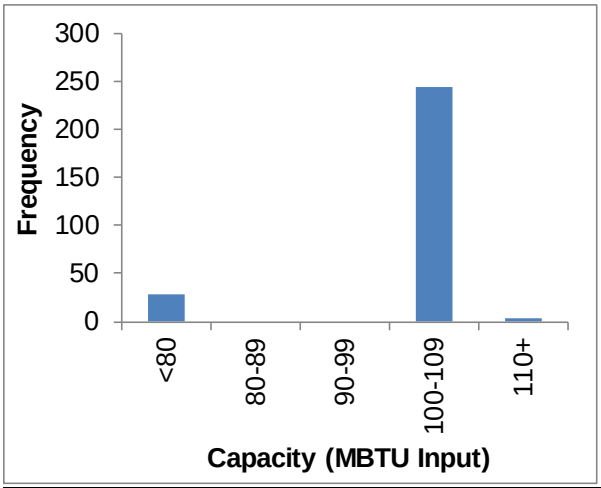


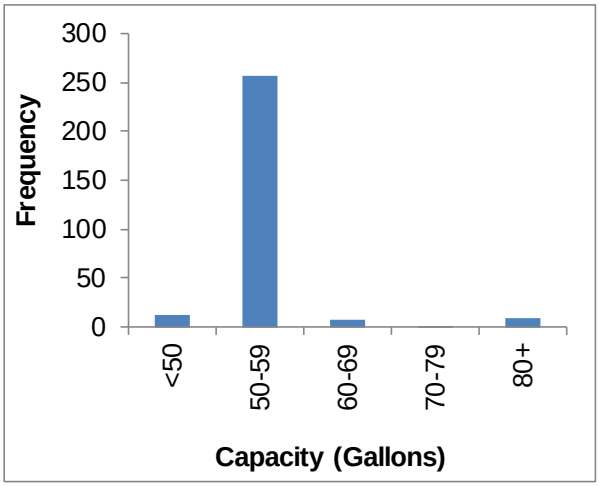


Quantity of Participant Records	840
Mean	45 gal., 42 Mbtu
Median	40 gal., 40 Mbtu
Mode	40 gal., 40 Mbtu
Representative Capacity Selected	**40 gal., 40 Mbtu**

Storage Water Heaters ≥75 MBH – Natural Gas

Distribution of Natural Gas Storage Water Heaters (≥75 MBH) Product Capacity in Participant Records 1/1/16–7/31/17

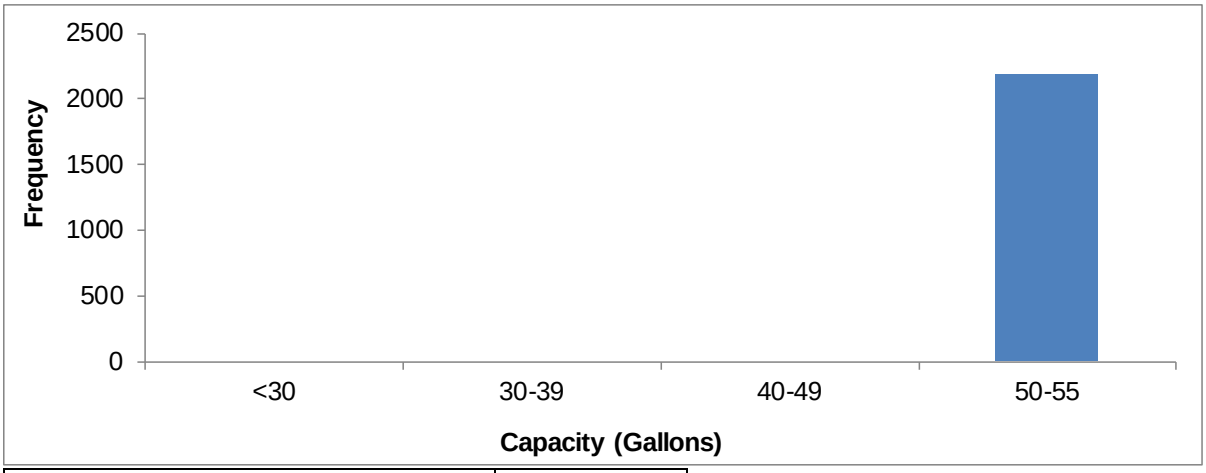




Quantity of Participant Records	286
Mean	50 gal., 103 Mbtu
Median	50 gal., 100 Mbtu
Mode	50 gal., 100 Mbtu
Representative Capacity Selected	**50 gal., 100 Mbtu**

Storage Water Heaters, ≤55 gal. – Electric

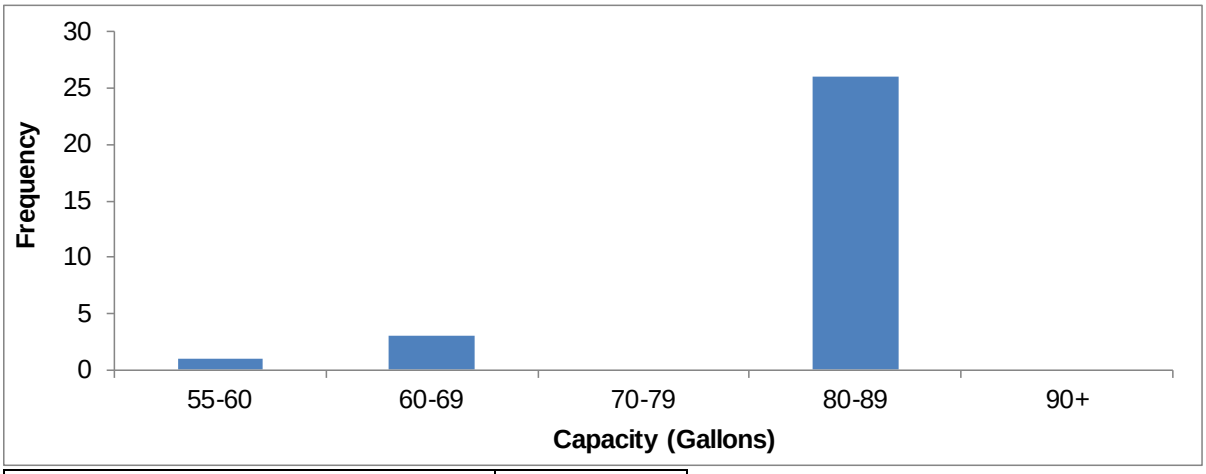
Distribution of Electric Heat Pump Storage Water Heaters (≤55 gal) Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	2,186
Mean	50 gal.
Median	50 gal.
Mode	50 gal.
Representative Capacity Selected	**50 gal.**

Storage Water Heaters, >55 gal. – Electric

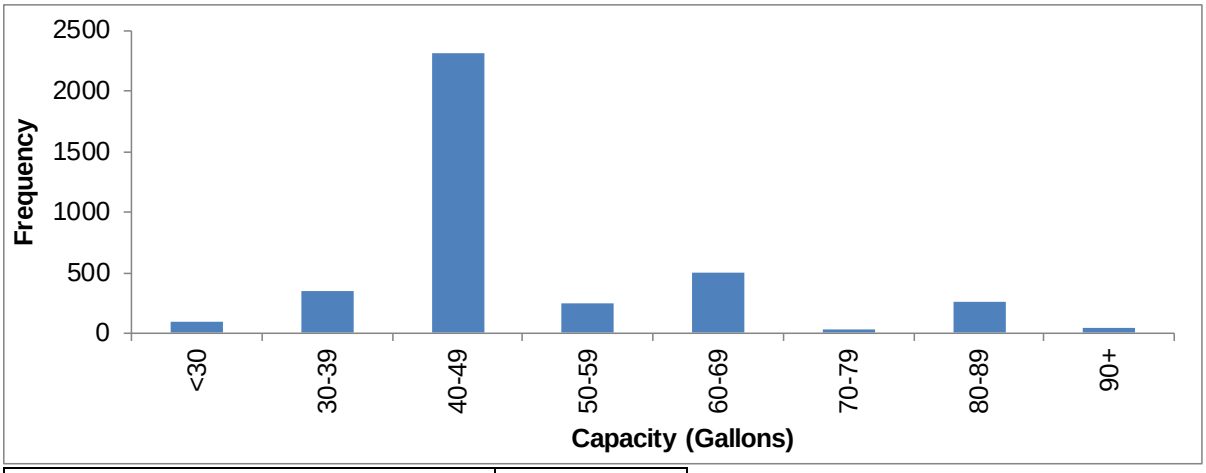
Distribution of Electric Heat Pump Storage Water Heaters (>55 gal) Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	30
Mean	78 gal.
Median	80 gal.
Mode	80 gal.
Representative Capacity Selected	**80 gal.**

Indirect Water Heater – Natural Gas

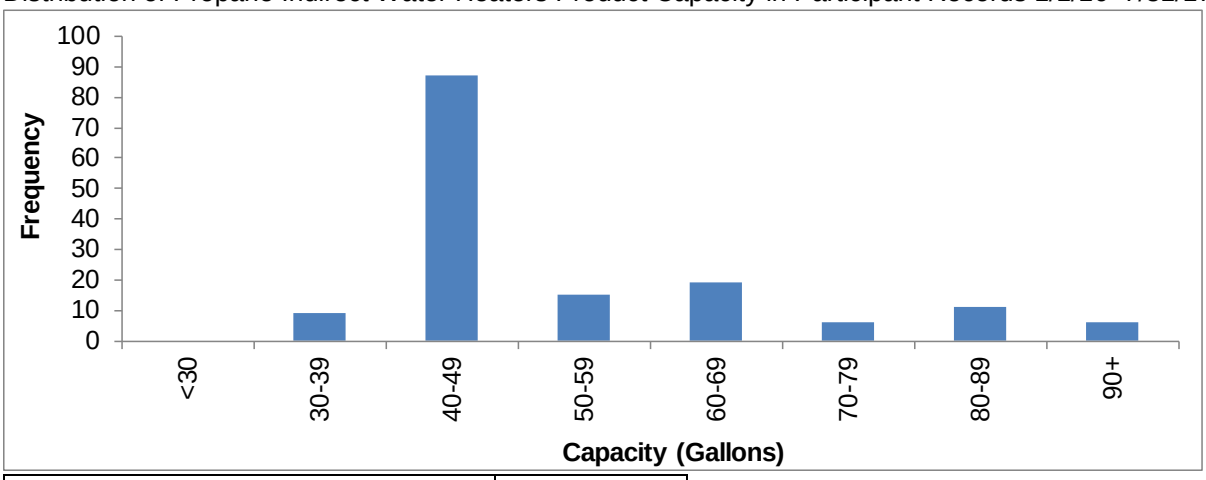
Distribution of Natural Gas Indirect Water Heaters Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	3,823
Mean	49 gal.
Median	45 gal.
Mode	45 gal.
Representative Capacity Selected	**45 gal.**

Indirect Water Heater – Propane

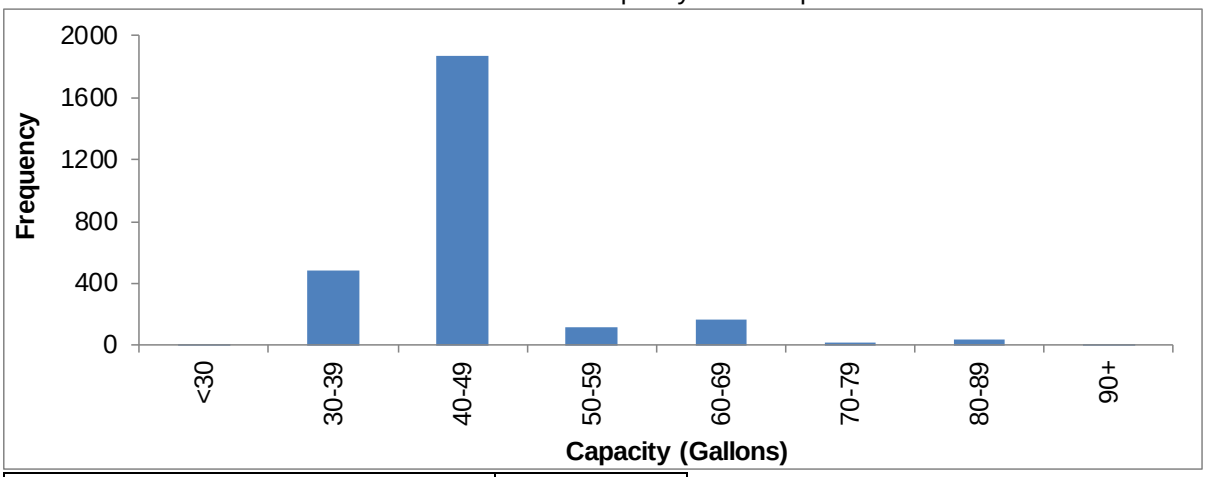
Distribution of Propane Indirect Water Heaters Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	153
Mean	52 gal.
Median	45 gal.
Mode	45 gal.
Representative Capacity Selected	**45 gal.**

Indirect Water Heater – Oil

Distribution of Oil Indirect Water Heaters Product Capacity in Participant Records 1/1/16–7/31/17



Quantity of Participant Records	2,705
Mean	44 gal.
Median	45 gal.
Mode	45 gal.
Representative Capacity Selected	**45 gal.**

APPENDIX C. WEBSCRAPE OF RETAIL WATER HEATER PRICES (TASK 2-3 MEMO)

To: Massachusetts Program Administrators and Energy Efficiency Advisory Council

From: Decker Ringo and David Basak; Navigant Consulting Inc.

Date: January 12, 2018

Re: Water Heating, Boiler, and Furnace Cost Study (RES 19)
Task 2: Adapt DOE Cost-Efficiency Curves, and
Task 3: Webscrape of Retail Water Heater Prices

The purpose of the Water Heating, Boiler, and Furnace Cost Study (RES 19) is to evaluate the changes in product prices and installation costs that result from increased product efficiency. This memo presents the methodology and results of Tasks 2 and 3 of the study, in which the evaluation team studied the retail prices of residential water heaters and heating products. The costs associated with the installation of these products will be examined in Task 4 of this study, which the team will present in a separate memo. The goals for Tasks 2 and 3 of this study are:

- Examine the relationship between retail costs and product efficiency, and document the lowest-cost path to improving efficiency (i.e., the "efficiency frontier") for each product type in this study
- Document any non-efficiency-related features that are present in models on the cost-efficiency frontier, and estimate the retail price associated with those features
- Determine the retail cost of "connected product" capabilities

To address these goals, the evaluation team gathered retail price data for thousands of models and reduced the data to a set of curves that summarize the retail cost of improving efficiency. This memo presents the findings of Tasks 2 and 3.

Summary

The Residential Heating and Cooling program currently offers rebates for several varieties of water heaters, furnaces, and boilers. Residential water heaters and home heating products are available across a range of efficiency levels. Generally, the price of products at a given capacity increases as the efficiency of the product increases.

In Task 1 of this study the evaluation team identified a "representative size" for each product type that represents the product size that is most commonly rebated in the Massachusetts PAs' service areas. In Task 3 the evaluation team used webscraping to gather online retail prices for these representatively-sized models across the full range of available efficiencies for each of the product types covered in this study.

The team organized the webscraped data to determine the lowest-cost models available at each efficiency level from the lowest efficiency to the highest efficiency available in the market. The lowest-cost path from low efficiency to high efficiency is termed the "cost-efficiency frontier." The team examined the

feature sets of product models on the cost-efficiency frontier to determine whether the higher efficiency models include any non-efficiency-related features that may affect the retail cost of the product.

As shown in Figure 3, the evaluation team performed Task 3 using the following steps:

- Identify the representative product capacities from Task 1
- Identify viable data sources for webscraping
- Use webscraping to obtain a large cost-efficiency data set
- Determine the cost-efficiency frontiers for each product type
- Process the data points in the cost-efficiency frontier considering any non-efficiency-related features and cost-efficiency data outliers

Figure 3. Simplified workflow, Task 3

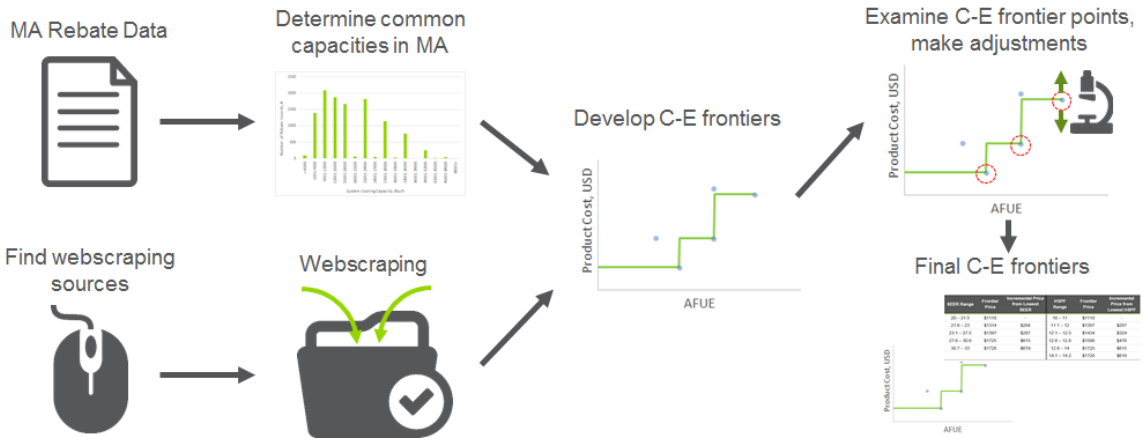


Table 6 presents the summary results, showing the lowest retail cost (not including installation) for a representatively sized model that meets the MassSave rebate threshold level. The Key Findings section of this memo presents the full cost-efficiency frontiers and the feature sets for all the product types covered in this study.

The evaluation team recognizes that the retail prices of heating products advertised online may not match the prices that customers actually pay to have these products installed in their homes. This is because the price of products purchased online is marked up by the online retailer, whereas the price of installed products is marked up once by the wholesale vendor and again by the contractor performing the installation. The retail prices gathered in this task will be used in combination with the results of the Task 4 contractor survey to estimate the costs that customers actually pay to have products installed.

Table 6. Summary of Retail Product Costs at MassSave Rebate Threshold Efficiencies

Product Type	Representative Size, from Task 1	Lowest Adjusted Retail Cost (Installation Not Included)		
Natural Gas Furnaces	80 MBH input	**80% AFUE**	**95%-96% AFUE**	**≥97% AFUE**
		$541	$1,102	$1,416
Propane Furnaces	80 MBH input	**80% AFUE**	**≥95% AFUE**	
		$581	$1,217	
Oil Furnaces	91 MBH input	**83% AFUE**	**≥86% AFUE**	
		$1,439	$1,960	
Natural Gas Boilers	110 MBH input	**82% AFUE**	**90%-94% AFUE**	**≥95% AFUE**
		$1,399	$1,949	$2,210
Propane Boilers	110 MBH input	**82% AFUE**	**≥90% AFUE**	
		$1,399	$2,048	
Oil Boilers	119 MBH input	**84% AFUE**	**≥86% AFUE**	
		$1,850	$2,035	
Natural Gas Combination Boilers	120 MBH input (space heating)	**82% AFUE**	**90%-94% AFUE**	**≥ 95% AFUE**
		Not found	$2,039	$2,039
Propane Combination Boilers	120 MBH input (space heating)	**82% AFUE**	**90%-94% AFUE**	**≥ 95% AFUE**
		Not found	$2,039	$2,039
Natural Gas On-Demand Tankless Water Heaters	199 MBH input	**0.80 UEF (Non-condensing)**	**≥0.87 UEF (Condensing)**	
		$719	$941	
Propane On-Demand Tankless Water Heaters	199 MBH input	**0.80 UEF (Non-condensing)**	**≥0.87 UEF (Condensing)**	
		$710	$941	
Natural Gas Storage Water Heaters, ≤55 gallons	40 gal., 40 MBH, Medium Draw	**0.58 UEF**	**≥0.64 UEF (ENERGY STAR)**	
		$397	$600	
	50 gal., 50 MBH, High Draw	**0.60 UEF**	**≥0.68 UEF**	
		$459	$611	
Natural Gas Storage Water Heaters, ≥75 MBH input	50 gal., 100 MBH, High Draw	**0.59 UEF**	**≥0.80 UEF (ENERGY STAR)**	
		$755	$1,828	
Electric Storage Water Heaters, ≤55 gallons	50 gal., Medium Draw	**0.92 UEF (Elec. Resistance)**	**≥2.00 UEF (Heat Pump)**	
		$384	$899	
Electric Storage Water Heaters, >55 gallons	80 gal., High Draw	**2.20 UEF**	**≥2.70 UEF**	
		$1,703	$1,781	
Indirect Water Heaters, attached to boiler	45 gallons	**Natural Gas, Propane, or Oil**	$1,250	

Background

This section describes several issues and assumptions that affect the results presented in this memo.

Adaptation of DOE Cost Curves – Change in Analysis Approach

The analyses published in support of DOE appliance standards rulemakings typically include a market and technology assessment and an engineering analysis. These analyses establish efficiency levels and estimate the incremental product cost increases associated with each efficiency level. In the Stage 3 Evaluation Plan for this study, the evaluation team planned to estimate the costs of residential furnaces and boilers by adapting the cost-efficiency curves published by DOE for these products. The evaluation team proposed to adjust the DOE-published curves published in 2014 to account for inflation and to account for the differences between DOE regulations, which shift the market via regulatory action, and incentive-based rebate programs, which are voluntary.

The evaluation team proceeded with this plan and retrieved the cost-efficiency curve published by DOE for residential water boilers at 100 MBH input.[8] The cost data published by DOE includes the percentage of product costs that derive from raw materials, purchased components, labor, depreciation, and overhead. The team adjusted these costs for inflation between their publication in 2014 and the current year, 2017. The team then adapted the inflation-adjusted cost curve to account for the fact that DOE's analysis assumes increased production volumes at higher efficiency levels.[9] This adaptation involved two main steps. First, the method accounts for lower production volumes in a non-mandatory regime by increasing the cost of purchased components (but not raw materials[10]) that are used in manufacturing high-efficiency products, to account for the fact that production volumes for high-efficiency products are lower in the absence of mandatory high-efficiency standards. The second step involves adjusting the supply chain markups that are used to estimate the consumer retail product prices. [11]

Figure 4 illustrates how these inflated and adapted cost curves compare to current retail prices for residential hot water boilers. In Figure 4, blue points show current residential boiler retail prices gathered by webscraping of vendors that advertise boilers online. The solid orange line in Figure 4 shows the DOE cost-efficiency curve adjusted for inflation. The dashed green line in Figure 4 shows the inflation-adjusted DOE curve after the team adapted it to account for reduced production volume in a non-mandatory rebate regime. For efficiency levels up to 92% AFUE, the adapted DOE price tracks closely with the published DOE price. This is because the actual 2017 production volumes of lower-efficiency models are similar to the production volumes modeled in DOE's cost analysis. In other words, for efficiencies up to 92% AFUE, the adaptation involved little adjustment to the purchased component portion of the product costs. However, at 96% AFUE, the adapted DOE price diverges sharply from the published DOE price. This is because the actual 2017 production volume of high-efficiency models is much lower than the production

[8] DOE published the estimated consumer costs of residential boilers at different efficiency levels in the Final Rule Technical Support Document for Residential Boilers, p. 8-11, Table 8.2.5. Available at: https://www.regulations.gov/document?D=EERE-2012-BT-STD-0047-0070

[9] DOE estimates the consumer price of products at each efficiency level assuming that the mandatory minimum standard is set at the efficiency level being estimated.

[10] From our work with manufacturers, we have found that the price manufacturers pay for components they purchase (such as motors, gas valves, and control boards) decreases as their purchase volume increases. We have not found a similar relationship between production volume and raw material costs.

[11] DOE has documented how different supply chain markups are applied to baseline-efficiency products compared to high-efficiency products. The application of baseline vs. high-efficiency markups is different between a mandatory standards regime compared to a non-mandatory rebate regime.

volume modeled in DOE's cost analysis. DOE estimates the costs of high-efficiency models on the assumption that mandatory efficiency standards would move manufacturers to increase production of high-efficiency models, and that the cost of high-efficiency models would come down as a result of economies of scale. The adapted cost curve estimates costs in the non-standards case, where production of high-efficiency models remains low in the absence of mandatory standards and economies of scale are not realized.

Figure 4. Consumer Price vs. Efficiency, Gas-Fired Residential Water Boilers, 100 MBH Input

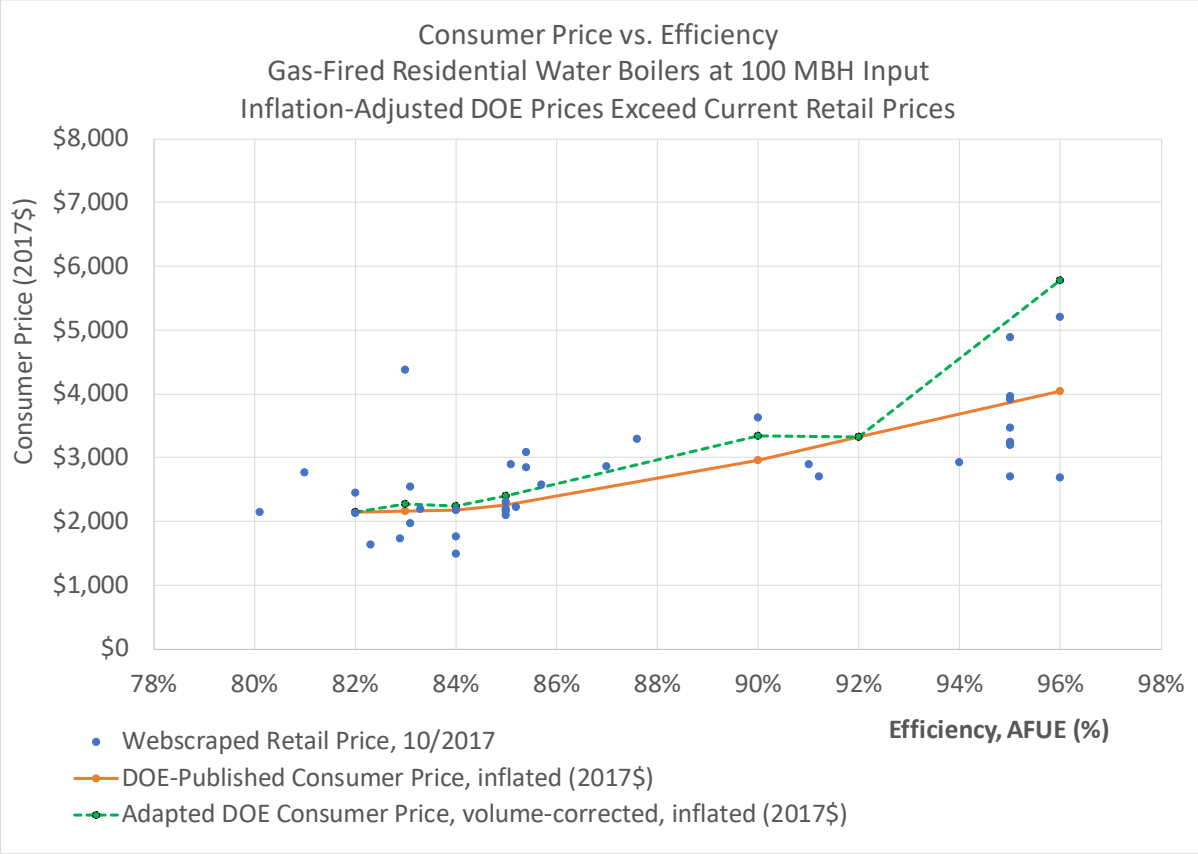


Figure 4 shows many boiler models with retail prices below the inflation-adjusted consumer price estimated by DOE. Several factors could explain this discrepancy:

- The 2014 DOE analysis was influenced by high raw material prices in the preceding 5 years, especially for stainless steel and copper. The 5-year average cost of these raw materials is about 20% lower in 2017 compared to 2014. Similarly, cast-iron (used in baseline boilers) and cold rolled steel (used in furnaces) 5-year raw material cost averages are about 7% lower in 2017 vs. 2014.
- Purchased parts used inside heating equipment have also become less costly on an inflation-adjusted basis thanks to increased competition.
- There have been significant shifts in the market for heating equipment, with some original equipment manufacturers (OEMs) offshoring their production (particularly to Mexico) or shuttering domestic manufacturing operations and switching to private-labeling imported goods. These market shifts tend to reduce customer prices.

- The DOE rulemaking analyses estimate consumer costs for products purchased through a contractor, and contractors may apply different markups compared to online retailers.
- The DOE rulemaking analyses typically estimate the average industry cost to manufacture and sell products, while the analysis in this study focuses on the lowest-cost models at each efficiency level.

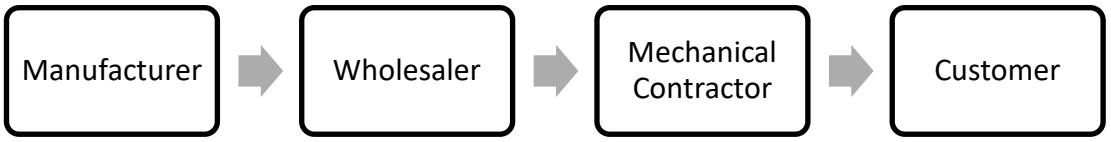
Lower raw material and purchased part costs combined with market shifts and increased competition (reducing margins) have hence enabled vendors to offer products with retail prices below the industry average prices in 2014.

Based on the findings presented above and in Figure 4, the evaluation team concluded that costs developed by adapting DOE cost curves would not accurately represent the costs that Massachusetts customers face today. The evaluation team discussed this issue with the PAs and EEAC in a conference call on October 12, 2017. In that call, the team proposed to use webscraping instead of DOE cost curve adaptation for residential furnaces and boilers, and the PAs and EEAC approved this change in approach. All of the cost results presented in this memo were gathered using webscraping.

Cost Assumptions

When customers purchase heating products to install in their home, they typically purchase them from the contractor that they hire to perform the installation as shown in the distribution channel illustrated in Figure 5. In this distribution channel, the product price is marked up at three stages: by the manufacturer, the wholesaler, and the mechanical contractor. This is the most likely distribution channel that customers would use to purchase rebate-eligible products, since the MassSave program will not provide rebate payments unless the products are installed by a licensed heating contractor or plumber.

Figure 5. Contractor Distribution Channel for Replacement of Residential Heating Equipment



The prices and cost curves presented in this memo represent the retail cost of heating products purchased through online vendors, and the distribution channel for this mode of sale is illustrated in Figure 6. In this channel, the product price is marked up at just two stages, by the manufacturer and the online retailer.

Figure 6. Online Distribution Channel for Replacements of Residential Heating Equipment

The evaluation team recognizes that only a small percentage of customers purchase water heaters or home heating equipment online.[12] This memo does not claim that customers would pay the same price to purchase products through contractors as they would pay to purchase products online. Therefore, the prices presented in this memo should not be interpreted as the final product prices that customers will pay for contractor-installed equipment. The online price data gathered in this task serves as one of several inputs that the evaluation team will consider when estimating the cost of installing products at different efficiency levels. Online price data is especially useful because it indicates the proportional price difference between low- and high-efficiency products.

Energy Metric Changes

For storage water heaters and on-demand water heaters, the 2017 qualifications are described in terms of the energy factor (EF) metric. The Stage 3 Evaluation Plan for this cost study stated that this study would evaluate how the prices of water heating products vary with efficiency as defined by the EF metric. However, the DOE amended its test procedure in June 2017 such that the efficiency of water heaters must now be measured and reported using the new uniform energy factor (UEF) metric. The Massachusetts PAs plan to adopt the UEF metric for water heaters for the 2018 program. Given these developments, the cost and efficiency data presented for water heater products in this memo are presented in terms of the new UEF metric.

Data Sources

The evaluation team used the following publicly-available data sources throughout the analyses conducted for this task.

- **AHRI Directory of Certified Product Performance**
  Link: https://www.ahridirectory.org/
  The AHRI Directory contains product performance data submitted by manufacturers to certify that their products conform to industry standards. Manufacturers typically contract 3rd-party laboratories to conduct performance testing for home heating and water heater products. The evaluation team used the AHRI database to study the population of certified products, to select the baseline efficiency levels, and to select representative models for cost analysis.
- **DOE Energy Conservation Standards for Residential Products**
  Link: https://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title10/10cfr430_main_02.tpl
  The minimum efficiency standards for residential home heating and water heating products are codified in the Code of Federal Regulations at Subpart C of 10 CFR 430. The evaluation team used these standards to determine the minimum efficiency level available for new products sold in different product classes.
- **Retail Merchant and Price Aggregator Websites**
  Many retailers advertise the prices of residential heating products and water heaters online. The evaluation team conducted targeted webscraping to retrieve pricing data from different online retailers. Many of the prices used in this analysis were sourced from Menards.com,

[12] In an analysis of cost markups for residential boilers, the U.S. DOE stated, “The [online sales distribution] channel mainly applies to do-it-yourself (DIY) installation representing around two percent of the total HVAC shipments.” Source: U.S. DOE (2015). “Final Rule Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers.” p.6-3. Available at: https://www.regulations.gov/document?D=EERE-2012-BT-STD-0047-0070

HomeDepot.com, Lowes.com, SupplyHouse.com, and Ecomfort.com. Many other websites were represented as well. The evaluation team used these retail sites to estimate the purchase cost of water heaters at different efficiency levels.

Table 7. Websites Scraped for Data Gathering

Vendors Advertising Products for Sale	
A/C Wholesalers	www.acwholesalers.com
Alpine Home Air Products	www.alpinehomeair.com
DIY Comfort Depot	www.diycomfortdepot.com
eComfort.com	www.ecomfort.com
The Home Depot	www.homedepot.com
HVAC Direct	www.hvacdirect.com
Ingram's Water and Air	www.ingramswaterandair.com
Lowe's Home Improvement	www.lowes.com
Menards	www.menards.com
National Air Warehouse	www.nationalairwarehouse.com
Supply House	www.supplyhouse.com
The A/C Outlet	www.theacoutlet.com
Websites that Aggregate Product Prices	
Furnace Price Guides	www.furnacepriceguides.com
Pick HVAC	www.pickhvac.com

Methodology

This section describes the methodology used to develop the cost-efficiency frontiers for different product types.

Representative Sizes

The cost-efficiency relationships developed in this task should describe the costs that customers in the PAs' service areas typically face when they are choosing between low-efficiency and high-efficiency products. Product costs usually vary with product capacity, and high-capacity products typically cost more than low-capacity products. To ensure that the cost-efficiency curves developed in this analysis represent the costs customers are likely to pay, the evaluation team focused the analysis using one "representative size" for each product type. These representative sizes represent the product size that is most commonly rebated in the PAs' service areas. The representative size is defined by the product's heating capacity and/or the product's volume depending on the product type.

In Task 1 of this study, the evaluation team examined participant records to determine which product sizes are most frequently rebated in the PAs' service areas. The team selected a single representative size for each product type. The Task 1 memo describes how the evaluation team selected the representative sizes used in this analysis.

Webscraping Activities

The evaluation team gathered price data for this task using structured web searches of vendors that advertise products for sale on the internet. When possible, the evaluation team used automated data collection tools to gather pricing info from vendor websites. For the automated data collection, the team first created site maps of vendor web pages using a webscraping tool called WebHarvy,[13] and then retrieved data from individual product pages using a second webscraping tool, Webscraper.io.[14] In cases where vendor websites were not consistently structured and the evaluation team could not efficiently automate the data collection, the team collected data manually.

The evaluation team collected the webscraped data into one file that includes a record of each price quote that the team gathered. The data for each record includes, at a minimum, the following items: vendor name, product type, product brand, product model number, product capacity, product efficiency, sales price, shipping cost, and the web address of the page where the product is advertised. Some product models may have more than one record in the file if they were listed for sale by more than one vendor.

For the oil furnace and gas furnace product types, some major brands (Bryant, Goodman, Rheem) advertise sale prices online. However, several other brands (Carrier, Lennox, Trane, and others) do not advertise product prices online and instead require customers to purchase their furnace products through a licensed contractor, with the contractor dictating the sales price. To circumvent this limitation in the available online data, the evaluation team referenced several price aggregating websites such as FurnacePriceGuides.com and PickHVAC.com. These price aggregators do not sell equipment, but they gather and re-publish the list prices for brands that do not advertise pricing online. These aggregators compile prices from several sources, including annual flat rate price books used by HVAC contractors and industry-related equipment price guides. The charts presented in this memo distinguish between the records obtained from online vendors and the records obtained from price aggregators. The survey work that the evaluation team is conducting in Task 4 will ask contractors to provide the prices they charge for products at different efficiency levels.

Identifying and Removing Cost Outliers

Webscraped data typically contains outlier data points due to variability in suppliers' inventory cycles, price markups and markdowns, etc. The evaluation team examined the webscraped data at each efficiency level to identify any outliers whose price was lower than its peer models. This was done by investigating the systems at the cost-efficiency frontier and evaluating whether their price is consistent with the features provided. The team considered whether the stated AFUE or UEF rating was reasonable relative to the price of the product. The evaluation team considered the price of the system relative to similar systems to determine if the system was an outlier or not.

In total, the team identified only one product listing as an outlier and removed it from the analysis. The plots presented in the Key Findings section distinguish this outlier from other data points.

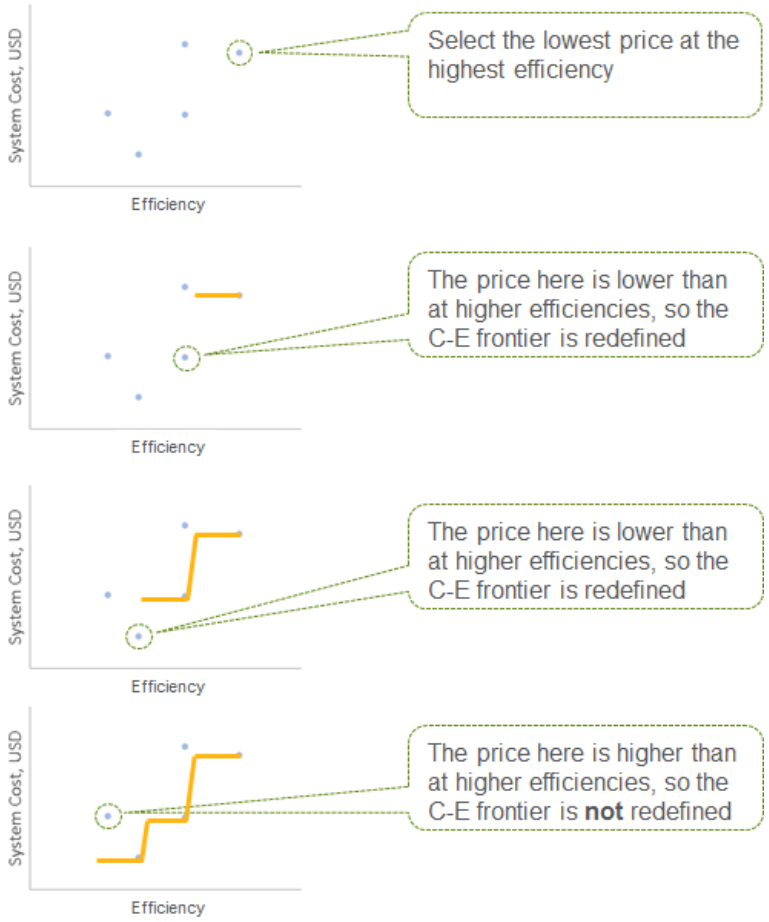
[13] WebHarvy is a visual webscraping software program that automatically identifies patterns of data occurring in web pages. More information is at https://www.webharvy.com/

[14] WebScraper.io is a web browser extension built for data extraction from web pages. Users can input a plan that describes how a web site should be traversed and what should be extracted. More information is at http://webscraper.io/

Plotting the Cost-Efficiency Frontier

The evaluation team determined the cost to achieve a certain efficiency based on the concept of a cost-efficiency frontier. The cost-efficiency frontier is the minimum incremental price required to achieve a given efficiency. To determine the cost-efficiency frontier, the team used a "waterfall" approach: a) the highest efficiency available is determined; b) the least expensive system at the highest efficiency is selected as the cost-efficiency frontier at that efficiency; c) then, for each efficiency lower than the maximum, the cost-efficiency frontier is defined as the lowest price available at that efficiency for the next efficiency level above. With this definition, the cost-efficiency frontier cannot decrease as the efficiency goes up. In other words, the cost-efficiency frontier either remains constant or goes up as the efficiency goes up. The process is illustrated in Figure 7.

Figure 7. "Waterfall" process to determine the cost-efficiency frontier.



Non-Efficiency-Related Features

The features included in residential heating and water heating equipment can be classified into two broad groups:

a) Efficiency-related features are those that provide an improvement in the operating efficiency of the product. Since this analysis is based on cost as a function of AFUE (for heating equipment) or UEF (for water heating equipment), the evaluation team based its classification on whether the

feature improves AFUE or UEF. Common strategies for improving efficiency are: increasing the size and/or thermal conductivity of heat exchangers, increasing the combustion efficiency of fuel burners, decreasing the heat transfer between the product and its surrounding environment, improving the control system, and (for heat pump water heaters) increasing the efficiency of the heat pump compressor.

b) Non-efficiency-related features are any features that do not improve AFUE or UEF. Some features classified as non-efficiency-related may have a tangible effect on energy consumption, but not on AFUE or UEF (as measured by the DOE test procedures that are used to rate heating products and water heaters). Examples of non-efficiency-related features are: features that may improve durability (*e.g.*, dual anode rods or 316Ti stainless heat exchangers), features that reduce customer risk (*e.g.*, longer warranty periods), features that improve product utility (*e.g.*, water leak sensors, built-in recirculation pumps), product connectivity (such as WiFi control and connections that enable demand response), as well as product differentiators (*e.g.* brass vs. plastic drain valves for storage water heaters).

The purpose of this cost study is to determine the cost of increasing the operating efficiency relative to a baseline product. However, the retail prices gathered by webscraping also include the cost of any non-efficiency-related features that may be bundled with higher-efficiency products. That means that the difference in price between two heating products may be driven in part by the different non-efficiency-related features each product has. Consequently, to obtain an accurate measure of the cost of efficiency, it is necessary to correct for price variations that are due to non-efficiency-related features.

The evaluation team took a careful approach to limit the effect of non-efficiency-related features on the incremental cost of efficiency. Basing the analysis on the lowest-priced products at each efficiency level (as opposed to the average-cost product at each level) is a way to mitigate this issue. The lowest-priced products tend to be the simplest and least costly to manufacture, so they are less likely to include non-efficiency-related features. Nevertheless, manufacturers may include advanced non-efficiency-related features even in their least expensive high-efficiency products, thus providing consumer value beyond the efficiency gains.

To mitigate this issue, the evaluation team catalogued the features that are included in the products that define the cost-efficiency frontier for each product type. Where the team identified non-efficiency-related features, the team estimated the consumer cost associated with these features and subtracted it from the retail price of the product. If a non-efficiency-related feature was present in the least efficient product on the cost-efficiency frontier, the team considered it to be a baseline feature and did not subtract its cost from the cost of the products.

Four non-efficiency-related features stood out as potential cost drivers: product warranty period, dual anode rods, external water sensors, and WiFi-enabled remote control. These features are discussed in detail below.

Product Warranty Period

It is often the case that a single water heater model is offered in the market at different price points, corresponding to different warranty periods. For instance, manufacturers may offer a single model with a 6-, 9-, or 12-year warranty. In these cases, a longer warranty period adds to the retail price to cover the manufacturer's financial risk associated with the longer warranty option, but it does not impact the design life of the water heater. In cases where single models were offered with multiple warranty periods, the team selected the lowest price option to mitigate the price effects of different warranty options.

Dual Anode Rods

Most storage water heaters are equipped with a single anode rod to protect the inside of the water heater tank from corrosion. Some storage water heater models include a second anode rod as an extra protective measure. A second anode rod may increase the water heater life and allow the manufacturer to offer longer product warranty, but it does not improve the efficiency of the water heater. The evaluation team estimated the price of a secondary anode rod component to be $18.35 per unit, including the component itself and the marked-up manufacturing cost associated with threading an extra hole in the top of the water heater to accommodate the second rod. The team subtracted that component price from the retail price of units with this feature on the cost-efficiency frontier.

Water Sensor for Leak Detection

Storage water heaters from one manufacturer include a built-in water sensor with an audible alarm to alert the customer of water leakage outside the water heater. This feature enhances customer utility but does not improve efficiency. The evaluation team estimated the price of a water sensor component to be $9.28 per unit, including the component itself and necessary wiring, connectors and electronic components. The team subtracted that component price from the retail price of units with this feature on the cost-efficiency frontier.

Integrated WiFi Remote Control

One manufacturer of storage water heaters (Rheem) produces several models that can connect without any additional components to a WiFi network and be controlled remotely. The ability to remotely control a water heater does not affect the operating efficiency of the water heater as measured by the UEF test metric. Consequently, in determining the cost-efficiency frontiers for water heating products, the evaluation team considered removing the cost of integrated Wi-Fi capability from the models that offer this feature. However, the team observed that the models with integrated Wi-Fi capability have the same retail prices as otherwise-identical models without the integrated Wi-Fi capability. Because the retail prices are the same with and without the integrated capability, the evaluation team did not adjust prices to account for this feature. The PAs expressed interest in the cost of add-on modules (i.e., not integrated) that provide connected product capabilities. Those add-on modules are discussed separately in the following section.

Connected Product Capabilities

Connected products give the customer (or a third party, if user-approved) the ability to control the product remotely via the Internet. This allows the customer to, for example, change the water temperature setting of their equipment while they are away from the home. From a utility's perspective, it allows for the application of demand response programs (that is, utility-consumer agreements in which the utility can control consumers' products to reduce peaks in demand).

The evaluation team found only one mention of demand response in manufacturer marketing materials. The manufacturer specification sheet stated that some of its models should only be used as part of a demand response program.[15] However, no additional information was available online. Thus, the evaluation team could not evaluate the cost of implementing a demand response system for water heating equipment.

On the other hand, the evaluation team found plenty of information on connected capabilities of direct interest to the user (such as the ability to control the equipment remotely). The technology required in the

[15] Demand response programs were mentioned in Rheem literature for electric resistance water heaters. For details, see http://cdn.globalimageserver.com/fetchdocument-rh.aspx?name=specification-sheet&id=d06f901b-4026-46e9-bfb7-d60b139efc23 (accessed on January 3rd, 2018).

equipment is essentially the same in both cases, the difference being mainly in terms of who provides the commands (the customer or an authorized third party). Thus, it is safe to assume that the systems that already have consumer-facing connected capabilities would only require minor changes to enable utility-facing connected capabilities, such that the difference in product price, if any, would be marginal.

Remote control features are more prevalent in electric water heater models, since remote control is often used for demand response and load shaping programs. The team identified 47 electric storage water heater models and 7 gas storage water heater models that either have integrated connectivity or are designed to pair with connectivity-enabling modules. In gas-fired models, the connectivity is often paired with a leak-detection sensor that can remotely alert the customer to water leaks. The evaluation team found that connected capabilities are most commonly implemented using an add-on module.[16] The add-on module can be purchased separately or bundled with the equipment, and must be connected to the equipment with a wired connection through a specific port. Some manufacturers offer this capability across their product lines, while others only offer it for higher end products. The customer's cost to add connected capability to their products is equal to the cost of the add-on module.

The evaluation team obtained 11 online prices for add-on modules from four brands of gas and electric water heating and combination boiler products (Navien, Rheem, Rinnai, and Ruud). The team found that the modules for storage water heaters are generally less expensive than the modules for tankless water heaters and combination boiler-water heaters. For that reason, the evaluation team split the module quotes into those two categories. Then, the team averaged the costs for each category to obtain the consumer cost of an add-on module.[17] Because a different number of data points was obtained for each manufacturer, the manufacturer averages were used to obtain the category averages, thus avoiding undue weight for any given manufacturer. The average costs are shown in Table 8.

Table 8. Average online retail cost per system to add connected capabilities to products that are designed for add-on modules

Product Type	Online Retail Cost (per system)		
	Minimum	Average	Maximum
Gas and electric storage water heaters	$49	$49	$49
Tankless water heaters and combination boiler-WHs	$91	$156	$207

The average cost of add-on modules for storage tank water heaters is significantly lower than for tankless WHs and combination boiler-WHs. This seems to be due to how the manufacturers chose to implement this technology in each case. Modules for storage tank water heaters usually require a single connection to the water heater, which provides power and data exchange. For tankless WHs and combination boiler-

[16] In the on-going cost study of ductless mini-split heat pumps, the evaluation team found several ductless mini-split heat pump models with built-in connected capabilities. Built-in connectivity is much less common for water heating products. The evaluation team found only one model available for purchase online that claimed to have built-in connected capabilities. Given that add-on modules are much more common for water heating products, the evaluation team omitted the single model with built-in connectivity from this analysis.

[17] In developing the cost-efficiency frontiers, the evaluation team determined the least expensive means of increasing efficiency by focusing on the lowest-cost systems available in the market. In the case of add-on control features, consumers do not have a choice of which module to purchase, because modules generally have proprietary manufacturer technology. Thus, the team believes an average-cost approach is a more accurate estimate of what the consumer will pay for the additional connected capability feature.

WHs, the modules tend to also require a separate power supply and additional connection hardware, thus increasing the cost of the module.

However, the biggest marginal cost driver may simply be scale. In other words, not enough residential customers are aware of demand response and its benefits to incentivize manufacturers to offer built-in connectivity features. Hence, demand-response features continue to be marketed mostly as an add-on feature. Widespread revisions to rate plans may be required before enough general interest (and financial benefit) prods manufacturers to make demand-response functionality a standard feature.

Key Findings

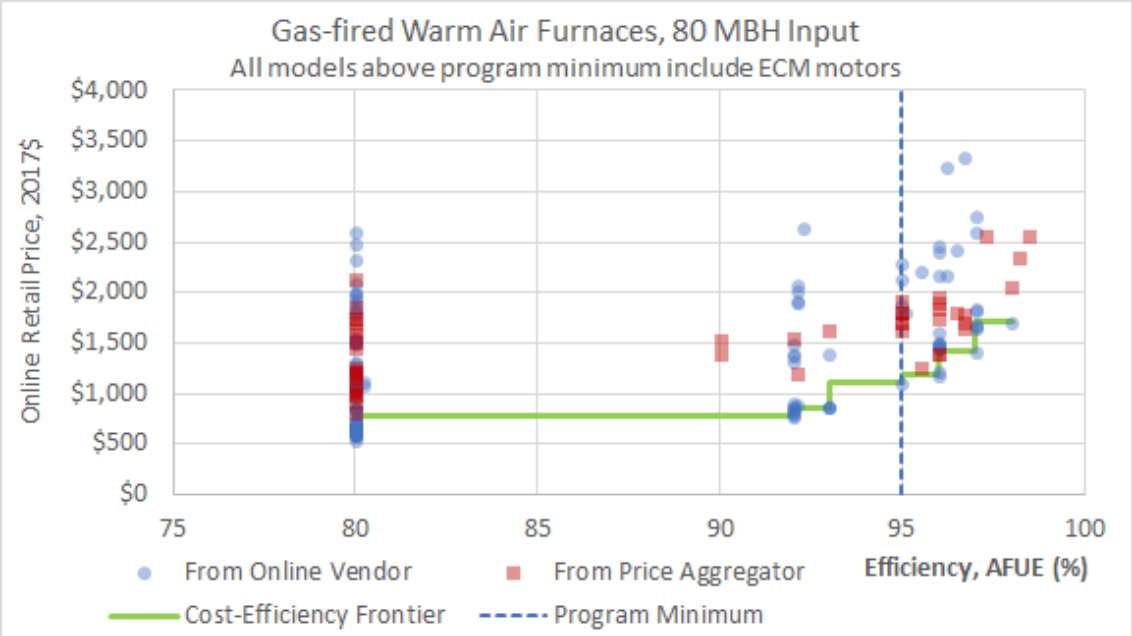
This section reports the key findings from the analysis conducted in this task. Readers should note that the prices reported in this section cover the furnace, boiler, or water heater product and any minor components that may be shipped with the product at no additional cost, such as minor mounting hardware or a gas orifice for conversion to propane fuel. The prices reported here do not include installation-related costs or supplies associated with installing ventilation, drainage, plumbing, or electrical service. These installation-related costs will be gathered via a survey of contractors and plumbers that will be conducted in a separate task of this cost study. The cost-efficiency charts for several product types show a wide variation in prices at each efficiency level. The team observed that product prices are based on many factors, including brand, perceived quality, and other non-efficiency related features. The purpose of this webscraping exercise is to estimate the incremental retail cost of efficiency, with all other factors held constant. For this reason, the cost-efficiency frontier for each product type is based on the lowest product price at each efficiency level.

There is a sub-section here for each product type and each subsection contains the following information:

- **Retail cost versus equipment efficiency plot.** This plot summarizes all the webscraping data that was gathered for the product type. Prices gathered from online vendors who sell the product are indicated by blue circle markers (●). For the product types where the evaluation team consulted price aggregating websites, the prices gathered from aggregators are indicated by red square markers (■). Any models that were removed from the analysis as outliers are indicated by hollow markers (○, □). The cost-efficiency frontier is plotted as a green line that traces the lowest cost models at each efficiency level that are not identified as outliers.
- **Table of prices on cost-efficiency frontier.** Accompanying each plot is a table of prices that define the cost-efficiency frontier. For efficiency levels where the lowest-cost model is priced above the lowest-cost model at a higher efficiency level, the table reports the lower price of the higher-efficiency model. For example, the lowest-cost gas furnace at 95.0 AFUE has a price of $986, but the lowest-cost gas furnace at 96.0 AFUE has a price of $843. The cost-efficiency frontier adopts the $843 price at 95.0 AFUE because this is the lowest price that achieves the 95.0 AFUE threshold.
- **Table of features by efficiency level.** This table presents the features that are advertised for the product models that define the cost-efficiency frontier. The first row in the feature table describes the feature set that exists in the lowest-cost, lowest-efficiency model. Subsequent rows in the table describe features that are added or upgraded at higher efficiency levels. Added features that are not related to the product's energy efficiency are indicated with a double asterisk (**).

Furnaces – Natural Gas

Cost-Efficiency Plot of Natural Gas Furnaces at 80 MBH input capacity



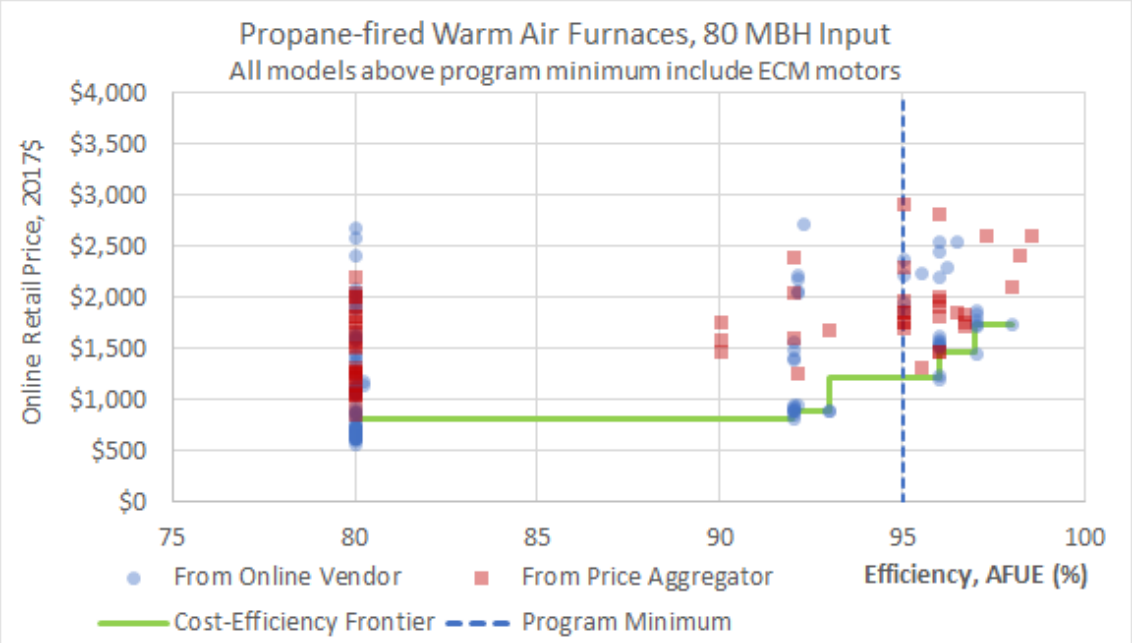
Online Retail Prices of Natural Gas Furnaces at 80 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 80.0%	$541
80.1 – 92.0%	$772
92.1 – 93.0%	$857
93.1 – 95.0%	$1,102
95.1 – 96.0%	$1,180
96.1 – 97.0%	$1,416
97.1 – 98.0%	$1,707

Efficiency Level	Features Included with Natural Gas and Propane Furnaces, by Efficiency Level
80 AFUE	Single-stage gas valve, multi-position installation, electronic hot surface ignition, aluminized-steel primary heat exchanger, reinforced and insulated cabinet with baked enamel finish, multi-speed PSC motor, 10-year warranty on parts, self-diagnostic control board, quiet induced-draft blower
92 AFUE	***Add:*** Stainless steel secondary heat exchanger, Air-tight bottom/side cabinet Certified for direct vent, Low NOx
95 AFUE	***Upgrade from PSC motor:*** ECM Variable-speed motor
97 AFUE	***Upgrade from 1-stage valve:*** Two-stage gas valve
98 AFUE	***Add:*** Communicating, two-stage or single-stage thermostats

Furnaces – Propane

Most residential warm air furnace models on the market are compatible with either natural gas or propane. All the propane-compatible models identified through webscraping require a propane conversion kit that is sold separately from the furnace product. The conversion kit prices vary by brand and model. As part of the webscraping activity, the evaluation team identified and priced the appropriate conversion kit for each furnace model. The retail prices reported here for propane furnaces include the price of the separately-purchased conversion kit. The cost-efficiency frontier for propane-fired furnaces is defined by the same furnace models that define the frontier for gas-fired models. However, the prices at each efficiency level are higher, reflecting the added cost of the propane conversion kit.

Cost-Efficiency Plot of Propane Furnaces at 80 MBH input capacity

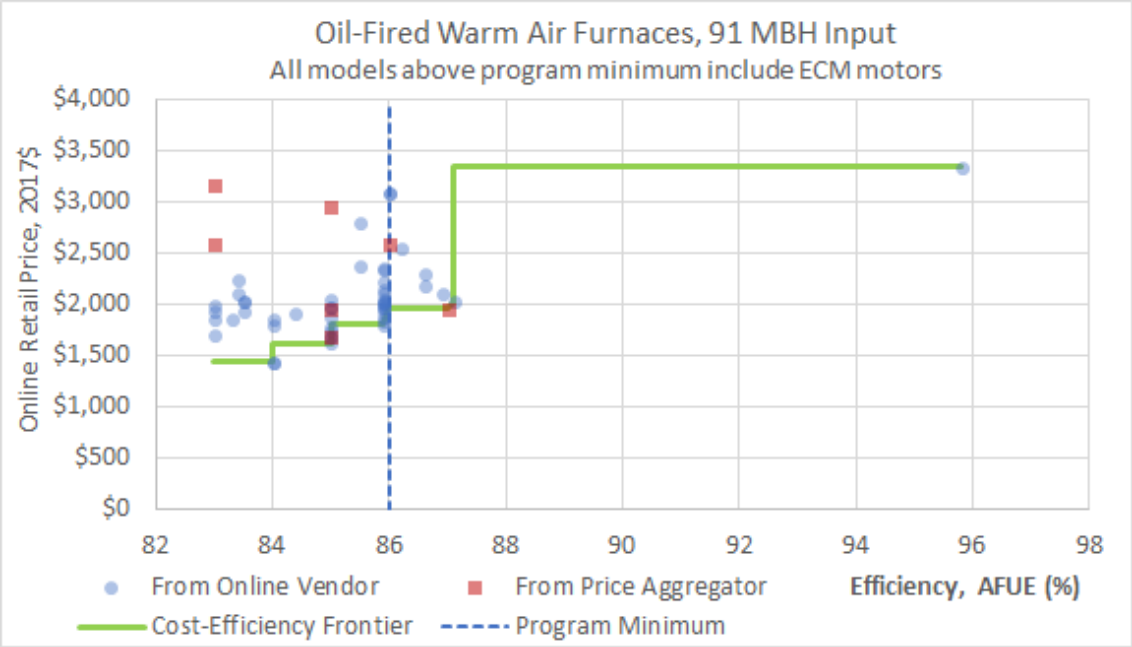


Online Retail Prices of Propane Furnaces at 80 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 80.0%	$581
80.1 – 92.0%	$819
92.1 – 93.0%	$899
93.1 – 96.0%	$1,217
96.1 – 97.0%	$1,466
97.1 – 98.0%	$1,744

Because the cost-efficiency frontier for propane-fired furnaces is defined by the same models as the frontier for gas-fired furnaces, the features included with propane furnaces at each efficiency level are identical to the features included with gas-fired furnaces, which are listed on the previous page.

Furnaces – Oil

Cost-Efficiency Plot of Oil-Fired Furnaces at 91 MBH input capacity

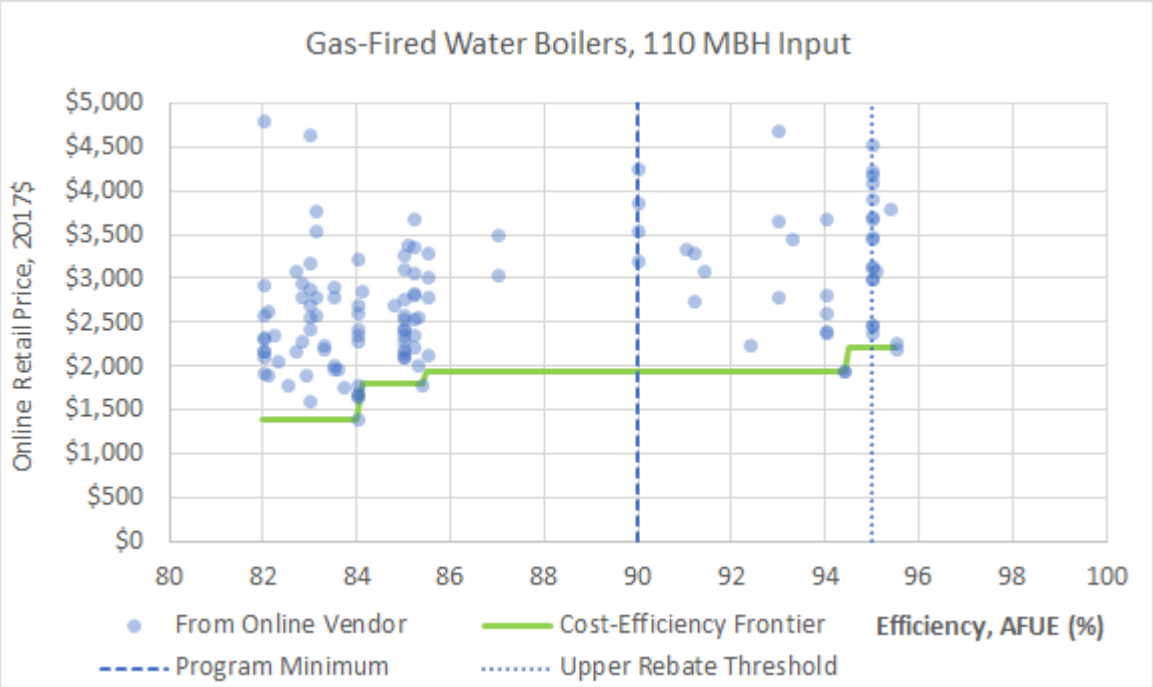


Online Retail Prices of Oil-Fired Furnaces at 91 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 84%	$1,439
84.1 – 85.0%	$1,625
85.1 – 85.9%	$1,809
86.0 – 87.0%	$1,960
87.1%	$2,030
87.2 – 95.8%	$3,346

Efficiency Level	Features Included with Oil-Fired Furnaces, by Efficiency Level
84 AFUE	Multi-position, Includes burner, Heavy-gauge steel primary heat exchanger, Enamel-painted steel cabinet, Foil-faced high-density fiberglass insulation, PSC motor
85 AFUE	***Same features as 84 AFUE***
86 AFUE	***Upgrade burner to:*** High Static Pressure Burner ***Add:*** Stainless Steel secondary heat exchanger, Certified for direct vent
87 AFUE	***Upgrade PSC motor to:*** ECM Variable-speed motor
95.8 AFUE	***Upgrade secondary heat exchanger to:*** High surface area heat exchanger ***Add:*** Condensate neutralizing cartridge

Boilers – Natural Gas

Cost-Efficiency Plot of Gas-Fired Water Boilers at 110 MBH input capacity



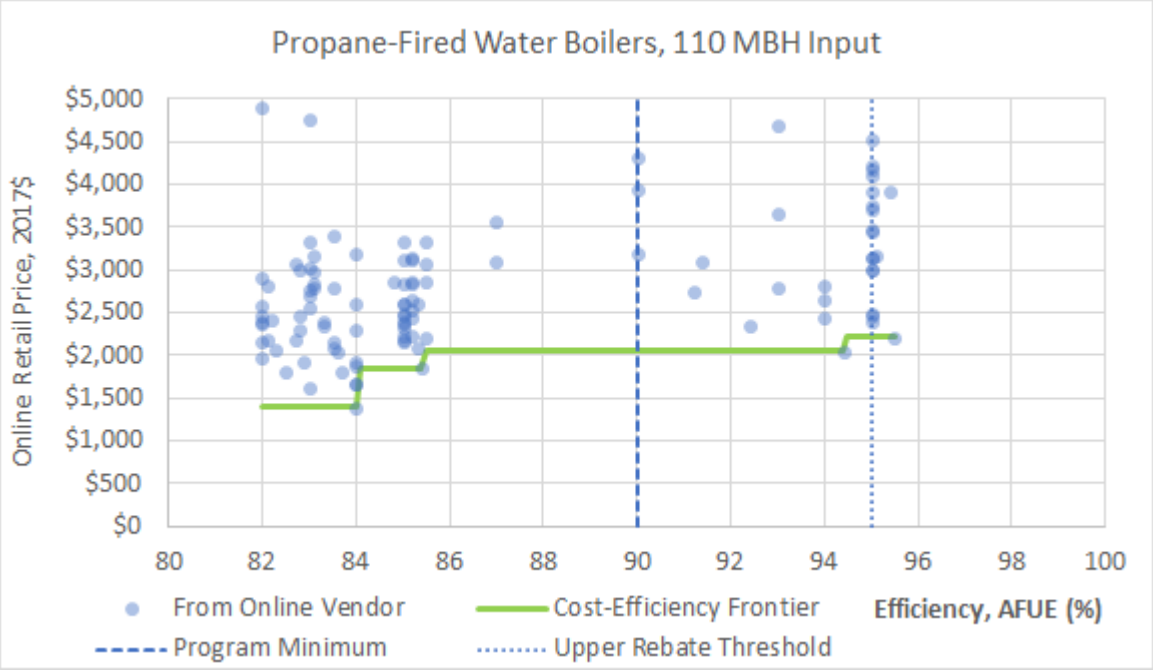
Online Retail Prices of Gas-Fired Water Boilers at 110 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 84.0%	$1,399
84.1 to 85.4%	$1,801
85.5 to 94.4%	$1,949
94.5 to 95.5%	$2,210

Efficiency Level	Features Included with Natural Gas and Propane Boilers, by Efficiency Level
84 AFUE	Floor mounted, 1-stage gas valve, Atmospheric chimney vented, Integrated controls, Cast-iron heat exchanger, Electronic Ignition Control, 1-speed Circulator
85 AFUE	***Upgrade atmospheric chimney vent to:*** Power vent
90-94 AFUE	***Upgrade 1-speed gas valve to:*** Modulating gas valve ***Upgrade 1-speed circulator to:*** 3-speed circulator ***Upgrade heat exchanger to:*** Stainless steel heat exchanger ***Add:*** Low NOx certified, Certified for direct vent
95 AFUE	***Same features as 94 AFUE***

Boilers – Propane

Most of the gas-fired residential boiler models on the market are compatible with either natural gas or propane. Some models do not require conversion to accommodate propane gas, some models require conversion and include a conversion kit at no additional charge, and some models require conversion kits that must be purchased in addition to the boiler product. Conversion kits that must be separately purchased incur an additional cost, ranging from $40 to $215 depending on the model being converted. The retail prices reported here for propane boilers include the price of the separately-purchased conversion kit where applicable. The cost-efficiency frontier for propane-fired boilers is defined by the same boiler models (or their propane-fired equivalents) that define the frontier for gas-fired models. However, the prices at some efficiency levels are higher, reflecting the added cost of the propane conversion kit.

Cost-Efficiency Plot of Propane-Fired Boilers at 110 MBH input capacity

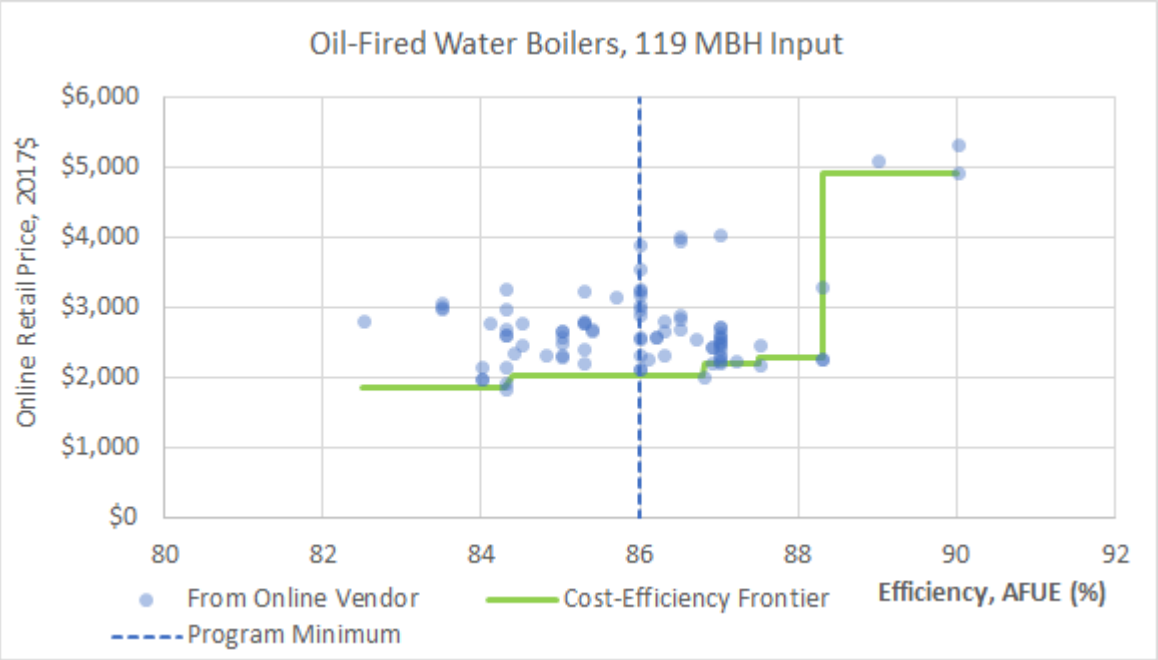


Online Retail Prices of Propane-Fired Boilers at 110 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 84.0%	$1,399
84.1 – 85.4%	$1,851
85.5 – 94.4%	$2,048
94.5 – 95.5%	$2,210

Because the cost-efficiency frontier for propane-fired boilers is defined by the same models as the frontier for gas-fired boilers, the features included with propane boilers at each efficiency level are identical to the features included with gas-fired boilers, which are listed on the previous page.

Boilers – Oil

Cost-Efficiency Plot of Oil-Fired Boilers at 119 MBH input capacity



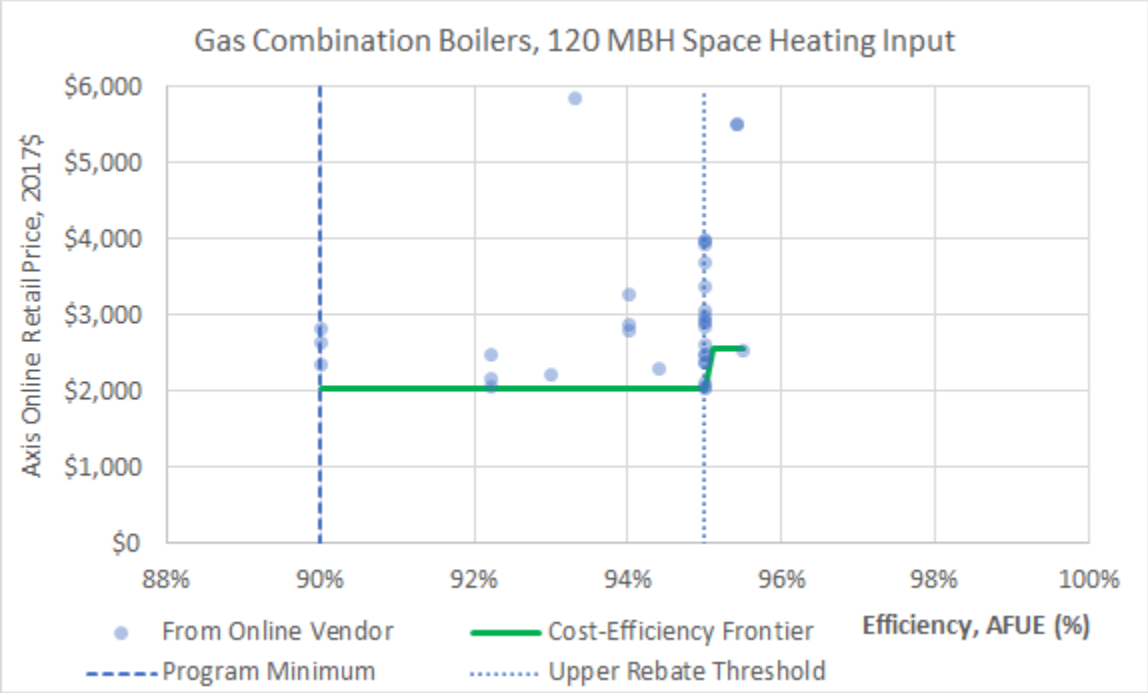
Online Retail Prices of Oil-Fired Boilers at 119 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 84.3%	$1,850
84.4 – 86.8%	$2,035
86.9 – 87.5%	$2,206
87.6 – 88.3%	$2,290
88.4 – 90.0%	$4,923

Efficiency Level	Features Included with Oil-Fired Boilers, by Efficiency Level
84 AFUE	Chimney vented, oil burner, cast iron heat exchanger, lifetime limited warranty, electronic ignitor, circulator pump, integrated boiler control, insulated jacket, swing-away door
86 AFUE	***Upgrade heat exchanger to:*** 3-pass cast iron heat exchanger ***Add:*** Optional direct venting
87 AFUE	***Upgrade burner to:*** High-efficiency oil burner
88 AFUE	***Same features as 87 AFUE***
90 AFUE	***Upgrade high-efficiency oil burner to:*** Two-stage oil burner

Combination Boilers – Natural Gas

The evaluation team did not observe any non-condensing propane-fired combination boilers on the market.

Cost-Efficiency Plot of Gas-Fired Combination Boilers at 120 MBH heating input capacity



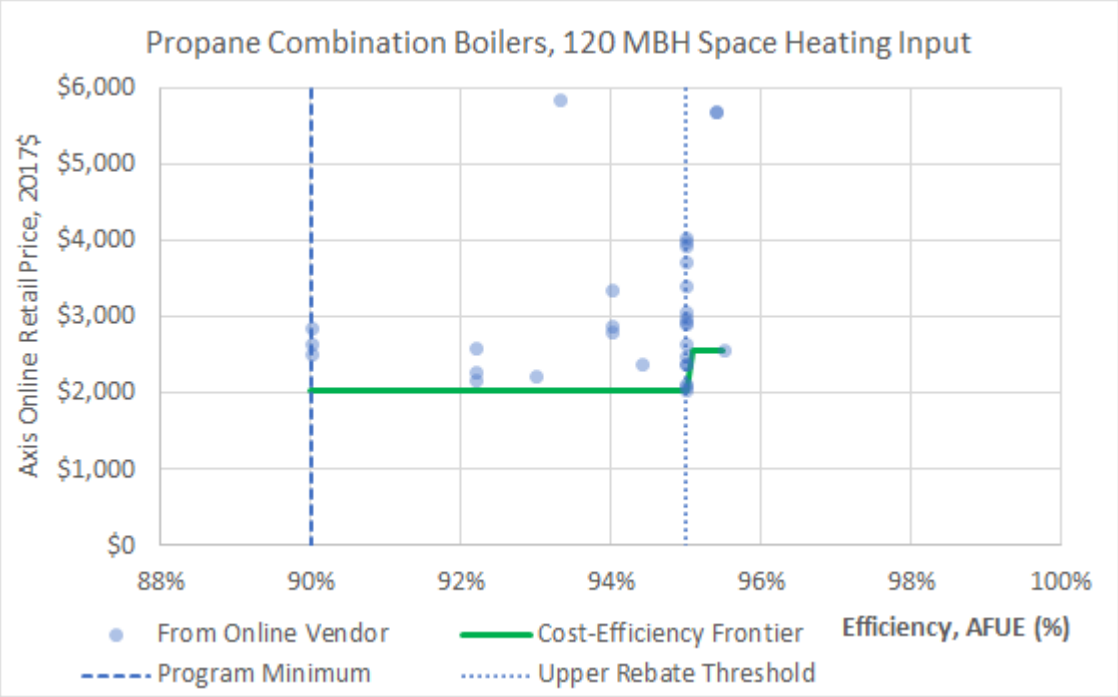
Online Retail Prices of Gas-Fired Combination Boilers at 120 MBH Heating Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 95.0%	$2,039
95.1 – 95.5%	$2,563

Efficiency Level	Features Included with Natural Gas Combination Boilers, by Efficiency Level
95.0% AFUE	Copper tube/aluminum block heat exchanger, digital control, outdoor reset sensor, low water / freeze protection, electronic ignition, variable speed blower, 10-year warranty, pump, parallel venting
95.5% AFUE	***Change tube & block heat exchanger to:*** Brazed plate heat exchanger ***Upgrade parallel venting to:*** Concentric venting

Combination Boilers – Propane

Most of the combination boiler models on the market are compatible with either natural gas or propane. Some models do not require conversion to accommodate propane gas, some models require conversion and include a conversion kit at no additional charge, and some models require conversion kits that must be purchased in addition to the boiler product. Conversion kits that must be separately purchased incur an additional cost, ranging from $20 to $185 depending on the model being converted. Due to these additional costs that apply to some models, some of the points in the chart below are more expensive when compared to the chart for natural gas combination boilers. The models that define the cost-efficiency frontier do not incur any conversion costs, so cost-efficiency frontier and feature sets for propane combination boilers are the same as for natural gas combination boilers. The evaluation team did not observe any non-condensing propane-fired combination boilers on the market.

Cost-Efficiency Plot of Propane-Fired Combination Boilers at 120 MBH heating input capacity

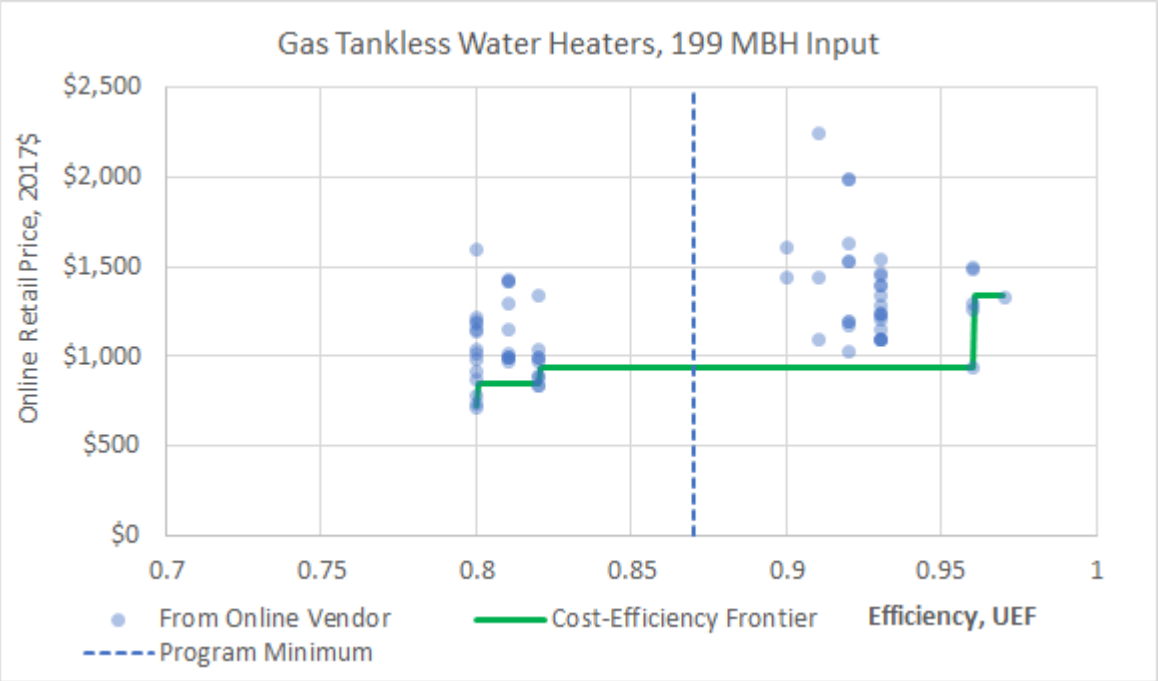


Online Retail Prices of Propane-Fired Combination Boilers at 120 MBH Heating Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 95.0%	$2,039
95.1 – 95.5%	$2,563

The cost-efficiency frontier for propane-fired combination boilers is defined by the same models as the frontier for gas-fired combination boilers. Because of this, the features included with propane combination boilers at each efficiency level are identical to the features included with gas-fired combination boilers, which are listed on the previous page.

On-Demand Tankless Water Heaters – Natural Gas

Cost-Efficiency Plot of Gas-Fired Combination Boilers at 199 MBH input capacity



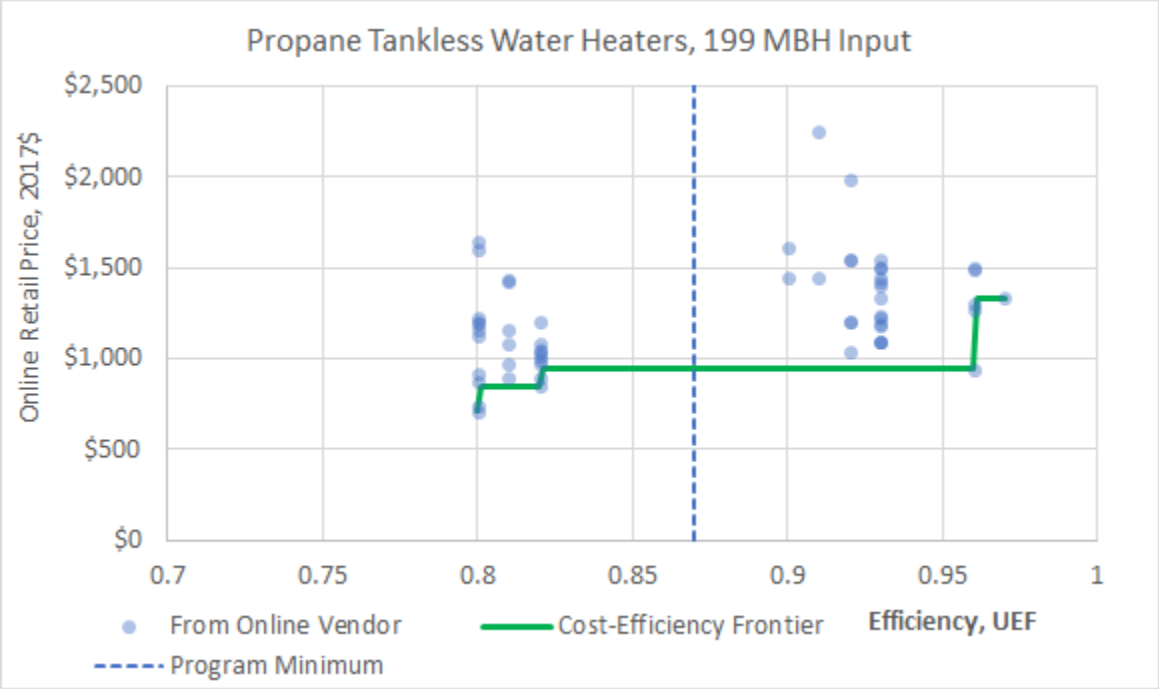
Online Retail Prices of Gas-Fired On-Demand Tankless Water Heaters at 199 MBH Input Capacity, by Efficiency Level	
UEF	**Price**
Up to 0.80 UEF	$719
0.81 – 0.82 UEF	$847
0.83 – 0.96 UEF	$941
0.97 UEF	$1,335

Efficiency Level	Features Included with Natural Gas and Propane On-Demand Water Heaters, by Efficiency Level
0.80 UEF	Copper primary heat exchanger, Digital remote control, 15-year limited warranty, Low NOx emissions, Electronic ignition, Power vent, Freeze protection, Flame sensor, Direct vent capable
0.82 UEF	***Upgrade direct venting to:*** Concentric venting, with power venting
0.90 - 0.96 UEF	***Change copper primary heat exchanger to:*** Stainless steel primary heat exchanger ***Add:*** Stainless steel secondary heat exchanger for condensing flue gas
0.97 UEF	***Same features as 0.96 UEF***

On-Demand Tankless Water Heaters – Propane

Many tankless water heaters on the market are compatible with either natural gas or propane. Some natural gas models do not require conversion to accommodate propane gas, some models require conversion and include a conversion kit at no additional charge. The models that define the cost-efficiency frontier do not incur any conversion costs, so cost-efficiency frontier and feature sets for propane combination boilers are the same as for natural gas combination boilers.

Cost-Efficiency Plot of Propane-Fired Combination Boilers at 199 MBH input capacity

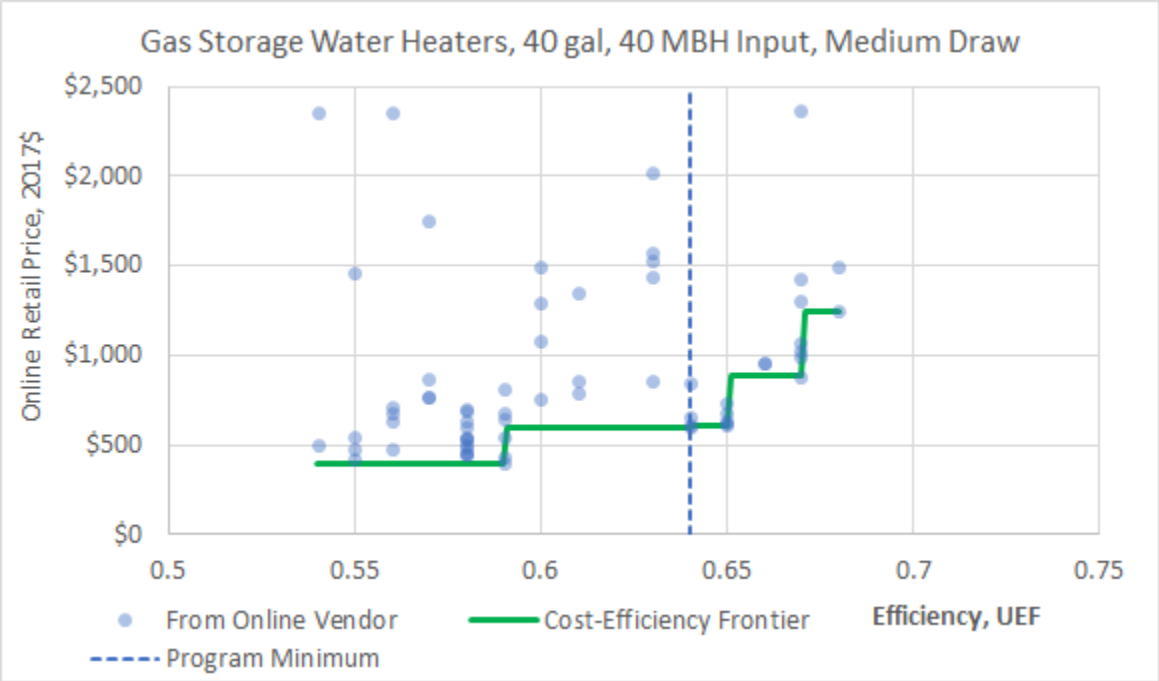


Online Retail Prices of Propane-Fired On-Demand Tankless Water Heaters at 199 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 0.80 UEF	$710
0.81 – 0.82 UEF	$847
0.83 – 0.96 UEF	$941
0.97 UEF	$1,335

The cost-efficiency frontier for propane-fired tankless water heaters is defined by the same basic models as the frontier for gas-fired tankless water heaters. Because of this, the features included with propane tankless water heaters at each efficiency level are identical to the features included with gas-fired tankless water heaters, which are listed on the previous page. Despite having the same basic model, there are slightly different retail prices for the gas-fired and propane-fired tankless water heaters on the cost-efficiency frontier at 0.80 UEF model.

Medium-Draw Gas Storage Water Heaters at 55 Gallons or less – Natural Gas

Cost-Efficiency Plot of Gas-Fired Storage Water Heaters at 40 gallons and 40 MBH input capacity

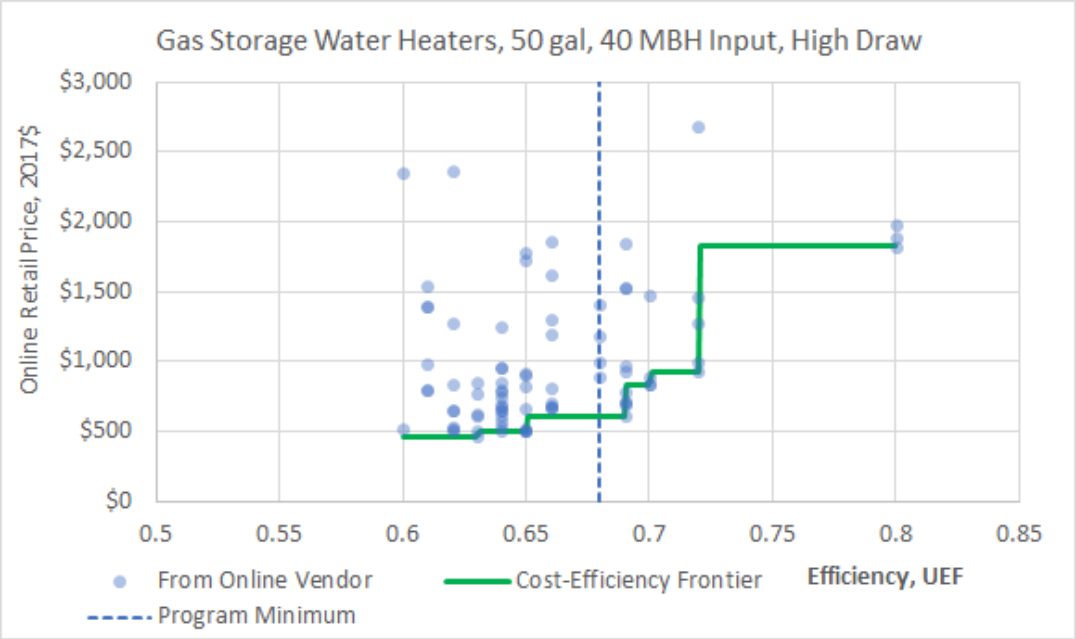


Online Retail Prices of Gas-Fired Storage Water Heaters at 40 gallons, 40 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 0.59 UEF	$397
0.60 – 0.64 UEF	$600
0.65 UEF	$609
0.66 – 0.67 UEF	$886
0.68 UEF	$1,249

Efficiency Level	Features Included with Natural Gas Storage Water Heaters at 40 gallons, 40 MBH Input Capacity, by Efficiency Level
0.59 UEF	Self-powered gas valve, Low NOx, Combustion shut-off system, Temperature and pressure relief valve, 6-year limited warranty, Premium grade anode rod
0.64 UEF	***Same features as 0.59 UEF***
0.65 UEF	***Upgrade gas valve to:*** Electronic gas control and ignition ***Add:*** Flue damper, WiFi-enabled for remote control**
0.67 UEF	***Upgrade flue damper to:*** Power vented
0.68 UEF	***Same features as 0.67 UEF***

High-Draw Gas Storage Water Heaters at 55 Gallons or less – Natural Gas

Cost-Efficiency Plot of Gas-Fired Storage Water Heaters at 50 gallons and 40 MBH input capacity

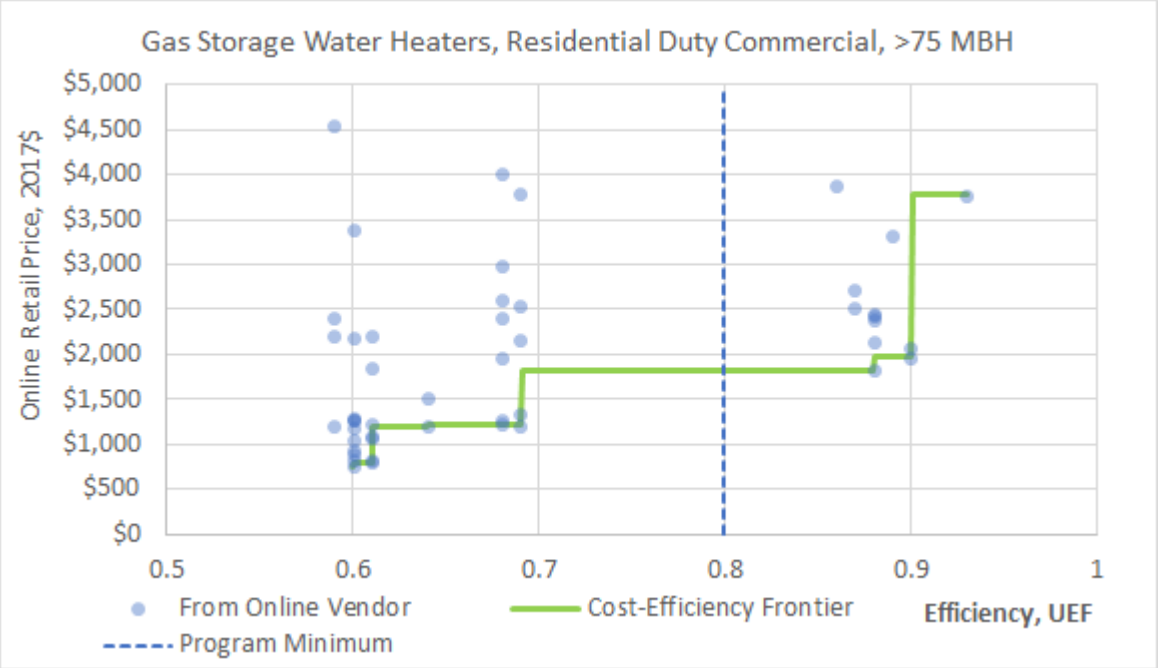


Online Retail Prices of Gas-Fired Storage Water Heaters at 50 gallons, 40 MBH Input Capacity, by Efficiency Level	
AFUE	**Price**
Up to 0.63 UEF	$459
0.64 – 0.65 UEF	$500
0.66 – 0.69 UEF	$611
0.70 UEF	$830
0.71 – 0.72 UEF	$926
0.73 – 0.80 UEF	$1,822

Efficiency Level	Features Included with Natural Gas Storage Water Heaters at 50 gallons, 40 MBH Input Capacity, by Efficiency Level
0.63 UEF	Self-powered gas valve with piezo ignitor and pilot light, Air/fuel safety shutoff system, Atmospheric vent, Low NOx, Temperature & pressure relief valve, 6-year limited warranty, Premium grade anode rod
0.65 UEF	***Same features as 0.63 UEF***
0.69 UEF	***Upgrade piezo ignitor to:*** Electronic ignition ***Add:*** Powered flue damper
0.70 UEF	***Same features as 0.69 UEF***
0.72 UEF	***Upgrade atmospheric vent to:*** Power vented
0.80 UEF	***Upgrade single anode rod to:*** Dual anode rods**

Gas Storage Water Heaters over 55 Gallons and 75 MBH (Residential-Duty Commercial) – Natural Gas

Cost-Efficiency Plot of Residential-Duty Commercial Gas-Fired Storage Water Heaters

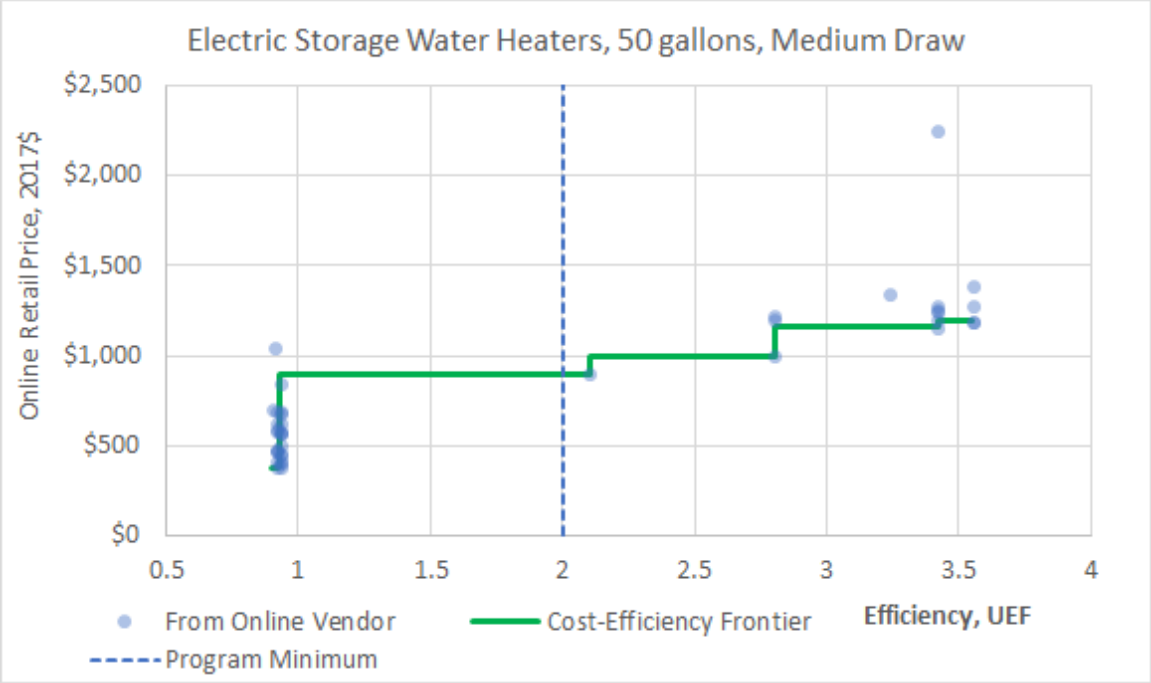


Online Retail Prices of Residential-Duty Commercial Gas-Fired Storage Water Heaters, by Efficiency Level	
UEF	**Price**
Up to 0.60 UEF	$755
0.61 UEF	$799
0.62 – 0.64 UEF	$1,199
0.65 – 0.69 UEF	$1,213
0.70 – 0.88 UEF	$1,828
0.89 – 0.90 UEF	$1,973
0.91 – 0.93 UEF	$3,772

Efficiency Level	Features Included with Natural Gas Storage Water Heaters over 75 MBH, by Efficiency Level
0.60 UEF	Piezo ignitor and pilot light, Temperature and pressure relief valve, Air/fuel safety shutoff system, Atmospheric vent, Low NOx, 6-year limited warranty, Anode rod
0.61 UEF	***Same features as 0.60 UEF***
0.64 UEF	***Same features as 0.60 UEF***
0.69 UEF	***Upgrade push-button ignition to:*** Electronic ignition system ***Upgrade atmospheric venting to:*** Power venting
0.88 UEF	***Upgrade anode rod to:*** Dual anode rod** ***Add:*** Digital user interface, WiFi-enabled for remote control**, condensate drainage
0.90 UEF	***Replace anode rod and glass-lined tank with:*** Stainless steel water tank ***Add:*** Condensate neutralization
0.93 UEF	***Same features as 0.90 UEF***

Electric Storage Water Heaters at 55 Gallons or Less – Electric Resistance and Heat Pump

Cost-Efficiency Plot of Electric Storage Water Heaters at 50 Gallons Capacity and Medium Draw



Online Retail Prices of Electric Storage Water Heaters at 50 gallons, by Efficiency Level	
UEF	**Price**
Up to 0.93 UEF	$384
0.94 – 2.10 UEF	$899
2.11 – 2.80 UEF	$999
2.81 – 3.42 UEF	$1,159
3.43 – 3.55 UEF	$1,190

Efficiency Level	Features Included with Electric Storage Water Heaters at 50 gallons capacity, by Efficiency Level
0.93 UEF	Resistive heating elements, 2x4500W, Premium anode rod, Over-temperature protection, Relief valve, 6-year limited warranty
2.10 UEF	***Add:*** Self-contained heat pump, Electronic user interface, Multiple operating modes, Dry-fire protection, Non-CFC foam insulation *Note: Prices do not include a condensate pump that may be required.*
2.80 UEF	***Same features as 2.10 UEF***
3.42 UEF	***Same features as 2.10 UEF***
3.55 UEF	***Add:*** WiFi-enabled for remote control** ***Add:*** External water sensor for leak detection**

Electric Storage Water Heaters over 55 Gallons – Electric Resistance and Electric Heat Pump

Based on an analysis of rebate records from 1/1/2016-7/31/2017, the evaluation team determined that the representative size of electric water heaters over 55 gallons is 80 gallons nominal capacity. All the residential-class electric storage water heater models available at 80 gallons capacity incorporate heat pump technology and have a rated UEF above 2.0. The product definitions codified at 10 CFR 430.2 stipulate that consumer electric storage water heaters have a nameplate input rating of 12 kW or less, and the definitions codified at 10 CFR 431.102 state that commercial electric storage water heaters have a rated input greater than 12 kW.

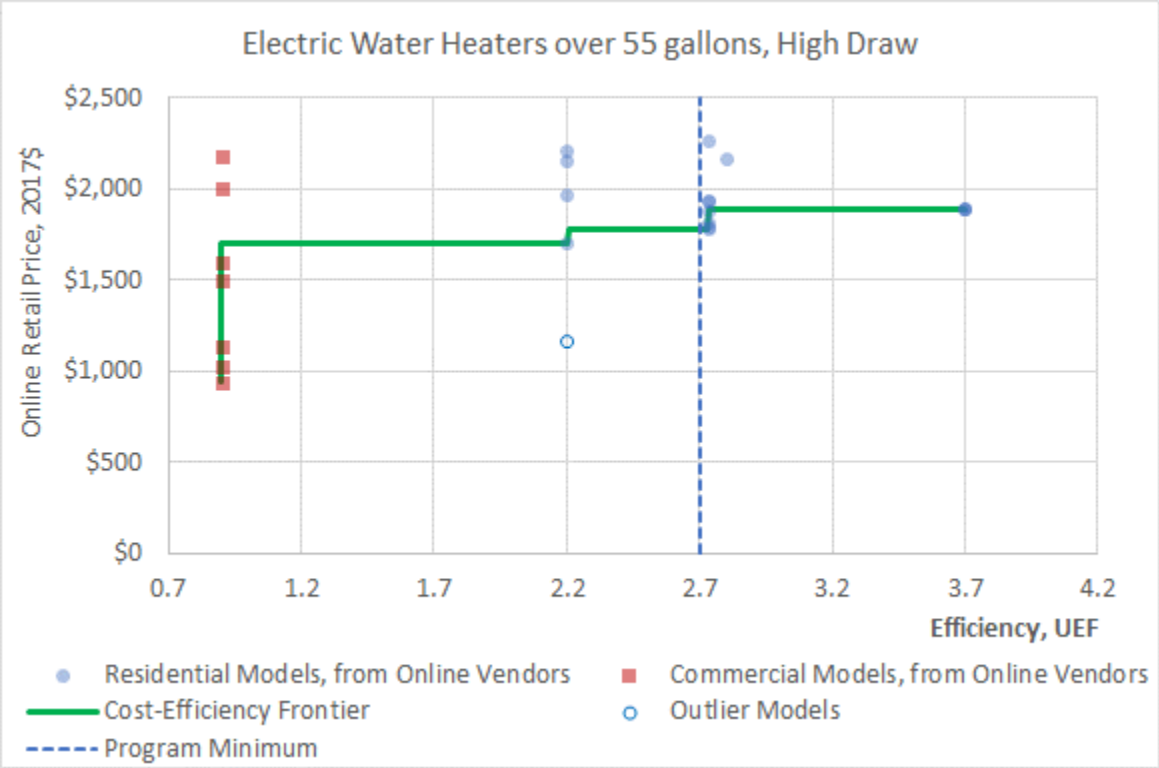
However, on January 26, 2018 DOE published a revised enforcement policy stating that at least until March 31, 2018, DOE will not seek penalties for the failure to properly certify water heater models that meet four criteria.[18] In effect, the policy states that manufacturers will not be penalized for selling individual electric storage water heater models that meet the definition of a consumer water heater but abide by the minimum efficiency standards for commercial water heaters, provided those models meet certain other criteria.

The evaluation team identified several 80-gallon electric water heater models marketed as "commercial water heaters" that are rated below 12 kW input and that heat water using electric resistance elements instead of heat pump technology.[19] These commercial models are not rated using the UEF metric, but the evaluation team estimates that the models would perform at approximately 0.92 UEF. Because these models are available for purchase and residential installation, the PAs may wish to consider these models instead of the code level of 2.16 UEF as a baseline for electric storage water heaters over 55 gallons. The evaluation team does not have shipments or sales data to indicate the volume of installations of water heater products that are subject to this enforcement policy.

[18] The DOE Enforcement Policy Statement Regarding Testing, Compliance with the Applicable Energy Conservation Standards, and Certification for Certain Consumer Water Heaters is available on DOE's website: https://energy.gov/sites/prod/files/2018/01/f47/Enforcement%20Policy-ConsumerWH_Def_1-2018.pdf

[19] Below are three examples of 80-gallon electric storage water heater models that are marketed as "commercial" models, but are rated below 12kW and are available to residential customers.
A.O.Smith model CE3-80H45DV, rated at 9 kW input:
https://www.lowes.com/pd/A-O-Smith-80-Gallon-3-Year-Limited-Tall-Electric-Water-Heater/1000213693
Westinghouse model WEC080C2X045, rated at 4.5 kW input:
https://www.homedepot.com/p/Westinghouse-80-Gal-Lifetime-4500-Watt-Electric-Water-Heater-with-Durable-316l-Stainless-Steel-Tank-WEC080C2X045/206021212
Rheem model MHD85245, rated at 4.5 kW input:
https://www.homedepot.com/p/Rheem-Marathon-85-gal-Tall-4500-Watt-Electric-Non-Metallic-Tank-Water-Heater-MHD85245/205931620

Cost-Efficiency Plot of Electric Storage Water Heaters at 80 Gallons Capacity



Online Retail Prices of Electric Storage Water Heaters at 80 gallons, by Efficiency Level	
UEF	**Price**
0.90 UEF (estimated)	$941
0.91 – 2.20 UEF	$1,703
2.21 – 2.73 UEF	$1,781
2.74 – 3.70 UEF	$1,890

Efficiency Level	Features Included with Electric Storage Water Heaters at 80 gallons capacity, by Efficiency Level
0.90 UEF (estimated)	Copper electric resistance heating elements 2 x 4500W, Fused ceramic shield tank Relief valve, Non-CFC polyurethane foam, 3-year limited warranty
2.20 UEF	***Replace ceramic shield tank with:*** Powered anode rod ***Increase warranty to:*** 10-year limited warranty ***Add:*** Self-contained heat pump unit, Electronic user interface, Dry fire protection, Three operating modes
2.73 UEF	***Same features as 2.20 UEF***
3.70 UEF	***Add:*** WiFi-enabled for remote control** ***Add:*** External water sensor for leak detection**

Indirect Water Heaters

Indirect water heaters may be installed alongside gas-, propane-, or oil-fired hot water boilers. Based on an analysis of rebate records from 1/1/2016-7/31/2017, the evaluation team determined that the representative size of indirect water heaters installed in the PAs' service area is 40 to 45 gallons. The most commonly rebated models in this size are SuperStor model SSU-45 and Heat Flo model HF-40. These models are available from online vendors at a retail price (including shipping) of $1,250. This retail price does not include the piping or circulator pump that would be required to install the indirect water heater.

APPENDIX D. SURVEY OF HVAC CONTRACTORS AND PLUMBERS (TASK 4 MEMO)

To: Massachusetts Program Administrators and Energy Efficiency Advisory Council

From: Decker Ringo and David Basak; Navigant Consulting Inc.

Date: April 2, 2018

Re: Water Heater, Boiler, and Furnace Cost Study (RES 19)
Task 4: Survey of HVAC Contractors and Plumbers

Encl: Residential Heating Products Installation Cost Survey, Final Version

This memo summarizes the evaluation team's findings from a contractor survey covering water heater, boiler, and furnace products rebated through the Residential Heating and Cooling program. The evaluation team obtained data from partipicating contractors via a web survey. The web survey requested labor, equipment, supplies and other costs to the consumer. In the next stage of this study, the evaluation team will combine these survey results with other cost data to characterize the relationship between consumer costs and system efficiency. The sections below describe the sources and methodology used in this task, as well as its key findings.

Summary

The Residential Heating and Cooling program currently offers rebates for several types of water heater, boiler, and furnace products. The purpose of this cost study is to determine the energy-efficiency-related total and incremental costs of installations of each of these product types.

In Task 1 of this study, the evaluation team identified a "representative size" for each product type that represents the product size that is most commonly rebated in the Massachusetts PAs' service areas. Tasks 2 and 3 of this cost study used webscraping to gather retail prices of these different product types at the representative product size, across the complete range of available efficiencies. The evaluation team recognizes that equipment prices only reflect one component of the total cost that customers pay for installing products. There are often additional installation costs associated with high-efficiency equipment. This is particularly true for fuel-burning product types, since high-efficiency products produce flue gas condensate that must be drained and possibly neutralized to avoid corrosion.

In Task 4, the subject of this memo, the evaluation team conducted a web-based survey of HVAC contractors and plumbers to assess how equipment and installation costs change as a function of product efficiency, and to determine the efficiency levels at which flue gas condensate must be accommodated. Over a period of six weeks, the evaluation team contacted a sample of 142 contractors in Massachusetts. The evaluation team emailed survey invitations to 112 of the contractors in that sample, and 11 contractors completed the online survey. The survey asked contractors to provide detailed installation costs for different rebated products that the contractors install, at several different product efficiency levels.

Table 9 presents the summary results of the contractor survey. The results are presented as the average total cost for each case, considering all contractors who participated in the survey. The results for each product type are described in detail under the Key Findings section of this memo.

In the final step of this study, the evaluation team will combine the product cost data collected by webscraping with the data collected by survey to develop complete cost-efficiency curves for each product type.

Table 9. Summary of Contractor Survey Results for Total Installation Costs of RES 19 Product Types

Product Type	Representative Size, from Task 1	Average Total Installation Cost, by Efficiency Level		
Natural Gas Furnaces	80 MBH input	**80% AFUE**	**95%-96% AFUE**	**≥97% AFUE**
		$3,966	$5,566	$6,400
Propane Furnaces	80 MBH input	**80% AFUE**	**≥95% AFUE**	
		$3,589	$5,284	
Oil Furnaces	91 MBH input	**83% AFUE**	**≥86% AFUE**	
		$5,066	$5,801	
Natural Gas Boilers	110 MBH input	**82% AFUE**	**90%-94% AFUE**	**≥95% AFUE**
		$6,042	$9,181	$9,538
Propane Boilers	110 MBH input	**82% AFUE**	**≥90% AFUE**	
		$6,595	$9,393	
Oil Boilers	119 MBH input	**84% AFUE**	**≥86% AFUE**	
		$6,866	$7,664	
Natural Gas Combination Boilers	120 MBH input (space heating)	**82% AFUE**	**90%-94% AFUE**	**≥ 95% AFUE**
		$5,700	$8,600	$10,530
Propane Combination Boilers	120 MBH input (space heating)	**82% AFUE**	**90%-94% AFUE**	**≥ 95% AFUE**
		$6,025	$8,600	$10,631
Natural Gas On-Demand Tankless Water Heaters	199 MBH input	**0.80 UEF (Non-condensing)**	**≥0.87 UEF (Condensing)**	
		$4,137	$5,215	
Propane On-Demand Tankless Water Heaters	199 MBH input	**0.80 UEF (Non-condensing)**	**≥0.87 UEF (Condensing)**	
		$4,177	$5,249	
Natural Gas Storage Water Heaters, ≤55 gallons	40 gal., 40 MBH, Medium Draw	**0.58 UEF**	**≥0.64 UEF (ENERGY STAR)**	
		$1,534	$2,060	
Natural Gas Storage Water Heaters, ≥75 MBH input	50 gal., 100 MBH, High Draw	**0.59 UEF**	**≥0.80 UEF (ENERGY STAR)**	
		$2,941	$4,340	
Electric Storage Water Heaters, ≤55 gallons	50 gal., Medium Draw	**0.92 UEF (Elec. Resistance)**	**≥2.00 UEF (Heat Pump)**	
		$1,469	$2,972	
Electric Storage Water Heaters, >55 gallons	80 gal., High Draw	**2.20 UEF**	**≥2.70 UEF**	
		$2,602	$4,705	
Indirect Water Heaters, attached to boiler	45 gallons	**Boiler Fuel Type**		
		Natural Gas, Propane, or Oil	$3,586	

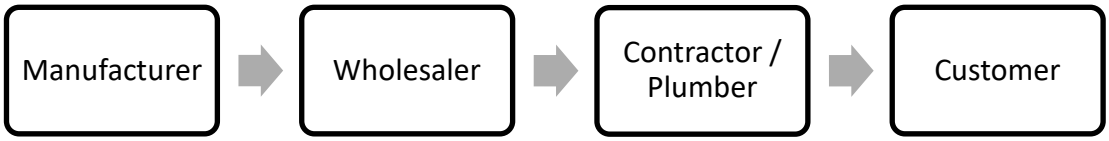
Background

Contractor Survey

The purpose of this task is to estimate the consumer cost of complete installations of water heater, boiler, and furnace products in the Massachusetts PAs' service areas. In particular, the evaluation team is interested in determining the cost of higher efficiency equipment relative to the cost of base case equipment.

When customers purchase products to install in their home, they typically purchase them from the contractor that they hire to perform the installation, as in the distribution channel illustrated in Figure 8.[20] In this channel, the product price is marked up at three stages, by the manufacturer, the wholesaler, and the mechanical contractor. This is the most likely distribution channel that customers would use to purchase rebate-eligible products, since the MassSave program will not provide rebate payments unless the products are installed by a licensed plumber or HVAC contractor.

Figure 8. Contractor Distribution Channel for Replacement of Residential Heating Products.



The contractor or plumber is the last step in the supply chain, so the cost to customers is the price charged by the contractor or plumber. This price includes all equipment markups added along the supply chain, as well as the additional markups and rates charged by the contractor. For that reason, the evaluation team decided to obtain price quotes from contractors and plumbers.

Contractor markups and labor rates vary by geographic location. Thus, national aggregate data for contractor prices would not provide an accurate estimate of the cost paid by consumers in the Massachusetts PAs' service areas. To obtain the most accurate price estimates in the region of interest, the evaluation team developed a web survey and delivered it to plumbers and contractors in the Massachusetts PAs' service areas. Details of the survey sample, design and execution are presented in the Methodology section.

Efficiency Metrics for Water Heaters, Boilers, and Furnaces

The efficiency of heating products is usually expressed in terms of several metrics, specified below.

a) Annual fuel utilization efficiency (AFUE): the AFUE is a measure of how efficient the appliance is in converting the energy in its fuel to heat over the course of a typical year. AFUE is the ratio of annual heat output of the furnace or boiler compared to the total annual fossil fuel energy consumed by a furnace or boiler. As the ratio of two energy values, the AFUE is expressed as a percentage (%).

b) Uniform Energy Factor (UEF): the UEF is a new metric (as of June, 2017) for determining the energy efficiency of water heaters. The UEF metric is a ratio of the amount of heat delivered with

[20] Customers may also purchase equipment from online retailers, but that is less common in the context of the MassSave® program. Nonetheless, the data from online retailers can provide useful insight on the cost to consumers. For details, see the Task 2 memo.

the water divided by the amount of energy consumed by the product. The UEF metric accounts for combustion efficiency and standby losses from the water heater. As a ratio of two energy values, the UEF metric is unitless.

Methodology

This section describes the methodology used in developing and applying the contractor survey. The following points are described:

- The development of the contractor sample
- The survey design – topics covered and inputs requested from the contractors
- The survey delivery and follow-up methods

Contractor Sample

The PAs provided the evaluation team with participant rebate data assembled by Energy Federation Inc. (EFI) for the period of January 1, 2016 through July 31, 2017. The evaluation team selected a survey sample from these records, selecting contractors that had significant experience with water heaters, boilers, and furnaces, based on the number of installation rebate records they submitted. Additionally, the evaluation team considered the geographic location of the contractors so that all the PAs' service areas were represented in the survey sample.

Table 10 shows the number of contractors contacted by the evaluation team in each region, as well as the aggregate number of heating product rebate records filed by those contractors. The evaluation team counted the number of contractors based on the region in which they are based, not the region they serve. This was because the regions served were not available to the evaluation team prior to the survey (and, in fact, the region(s) served is one of the questions on the survey). Contractors often serve regions other than those in which they are based. For example, a contractor based in the South of Boston region may serve the Greater Boston region and parts of Cape Cod and Central Massachusetts. Thus, the number of contractors shown in Table 10 can be considered a conservative estimate of the number of contractors in the sample that serve each region.

Table 10. Number of contractors and rebate records in selected sample per region.

Region	Number of Sampled Contractors Based in the Region ‡		Number of Heating Product Rebate Records	
	Number	% of Sample	Number	% of Records
Cape Cod & Islands	21	15%	1,171	13%
Central MA	18	13%	864	9%
Western MA	21	15%	739	8%
South of Boston	16	11%	1,275	14%
Metro West	52	37%	4,242	46%
North of Boston	11	8%	683	7%
Greater Boston	3	2%	310	3%
TOTAL	142	100%	9,284	100%

‡ Each contractor may serve regions other than the one in which they are based.

The evaluation team believes that this contractor sample is sufficient to represent the geographic distribution of contractors in Massachusetts. The sample contains at least 10 contractors for each region, except for Greater Boston. Greater Boston is the smallest region among those considered, and is also the one with the costliest real estate. Thus, it is not surprising that fewer contractors have offices in that region.

Survey Design

The evaluation team designed the survey to obtain cost information around one cost driver: efficiency. The evaluation team requested cost data at the efficiency levels that are currently rebated through the MassSave program. For an overall perspective on all cases analyzed, see Table 10.

The survey asked contractors to provide cost information in several billing categories: burdened labor costs, equipment costs including markups, supplies costs (plumbing supplies, seals, tools, etc.) and other costs (travel, warranty, insurance, overhead, etc.) for each scenario. By requesting equipment costs as a single line-item cost, the evaluation team can compare the equipment costs provided by contractors with the retail costs retrieved by webscraping in Tasks 2-3 of this study.

The survey thoroughly defined each type of product covered in the survey, with an illustration and description of several assumptions regarding the installation location. All the cost-related survey questions asked contractors to consider costs for installation scenarios that are configured for a baseline product. For instance, because baseline fuel-burning products are not condensing, the survey said, “For all condensing equipment, assume that the home does not have existing piping for handling or draining condensate and appropriately venting flue gas.”

The evaluation team designed the survey with input from the Massachusetts PAs and EEAC and from contractors. The PAs and EEAC reviewed an initial soft-copy draft of the survey and provided preliminary feedback. Then, after the evaluation team programmed the online survey, the PAs tested the survey and provided further comments. The evaluation team provided a digital soft copy of the survey with an initial sample set of 25 contractors. Based on the feedback and questions received from this initial contractor sample, the evaluation team updated the survey to its final form. The final form of the survey is enclosed for reference with this memo deliverable.

Survey Execution

The evaluation team conducted the survey over a six-week period from December 14, 2017 to January 25, 2018. The evaluation team first contacted all the contractors in the survey sample by telephone to request an email address for a point of contact who would be qualified to answer questions regarding installation costs of heating products. During these initial phone calls, the team offered an incentive in the form of a $250 gift card in exchange for completing the survey. Of the 142 contractors sampled, 23 contractors indicated that they did not want to participate, and 10 contractors did not respond to phone calls to provide a valid email address. The evaluation team sent an email invitation to the remaining 112 contractors with a link to participate in the online survey. The online survey allowed respondents to submit their answers via a web browser. The evaluation team followed the responses to the survey and sent follow-up emails to again ask the contractors to fill out the survey.

The evaluation team made several efforts to improve the response rate of the survey. The team conducted pre-screening calls as mentioned above, and the team sent follow-up reminder emails one week after contractors received the survey invitations. Despite these efforts, the survey had a low response rate. Out of 142 contractors sampled, only 11 provided complete survey responses. The evaluation team identified the following obstacles to obtaining a higher response rate:

- The survey was released during the holiday season, when many contractors take time off.
- The survey release coincided with a long cold spell bringing frigid temperatures to Massachusetts, which meant that most contractors were busy answering emergency calls from their customers.
- A particularly large winter storm hit Massachusetts around the same time, leading to work disruptions and power outages. Many contractors were affected and did not have the time or the means to participate.
- The survey collects sensitive data, which may be a concern to certain contractors.

To improve the response rate in future surveys, the evaluation team recommends releasing the survey at times when contractors are less busy with customer calls, such as in the spring or autumn.

Key Findings

This section presents the key findings from the contractor survey for water heaters, boilers, and furnaces. The costs are split between labor, equipment, supplies, and other costs. In their comments on the survey, respondents indicated that costs in the "other costs" category include costs for electrical work, construction permits, travel time, and warranty provision.

All values are presented in U.S. dollars and represent an average of the values provided by the contractors. Consequently, the values provided by any single contractor cannot be derived from the results presented here.

Sales to Commercial Customers

The PAs expressed interest in learning the extent to which residential contractors also serve commercial customers. The survey asked respondents, "What percentage of your total sales is to commercial customers?" The responses to this question are in Table 11. For all eleven survey respondents, commercial sales represent less than 30% of their total sales.

Table 11. Percentage of Sales to Commercial Customers

Percentage of Total Sales to Commercial Customers	Number and Percentage of Survey Responses	
0-10% of sales	6 responses	55%
11-20% of sales	4 responses	36%
21-30% of sales	1 responses	9%
>30% of sales	0 responses	0%

Geographic Variation

The number of responses per region served is shown in Table 12 below. The number of responses in Table 12 is greater than the number of survey respondents who took the survey because some contractors serve more than one region. Figure 9 shows the average costs for the base case scenario in different cost categories for each region.

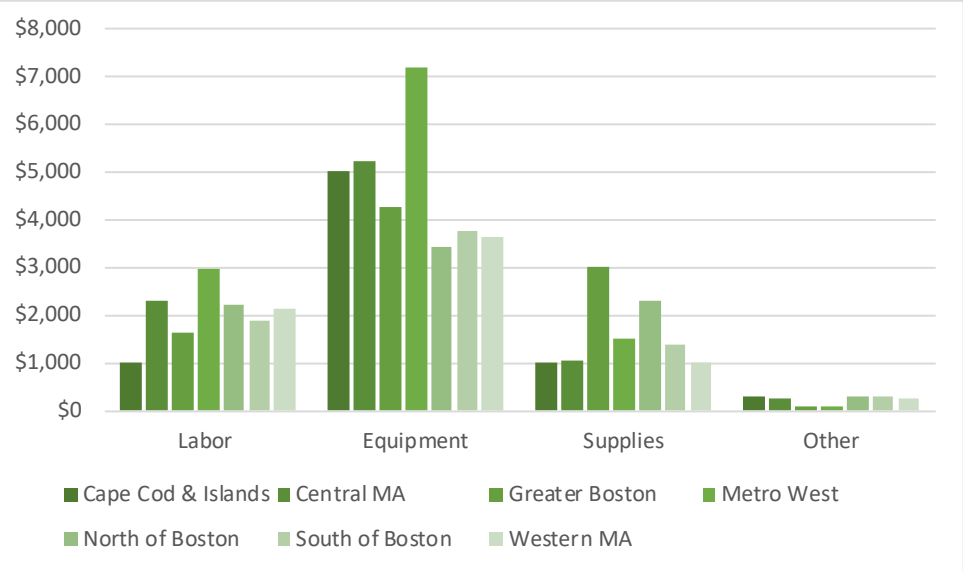
One goal of this study is to assess how installation costs vary across different service areas in Massachusetts. However, the low rate of responses to this survey make it impossible to draw strong conclusions regarding the relationship between cost and geographic region. Instead, the evaluation team focused its efforts on an analysis of Massachusetts as a whole.

Table 12. Number of survey responses per region.

Region	Number of Survey Responses‡	Average Costs for Installation of an 86% AFUE Oil Boiler (2017$)				
		Labor	Equipment	Supplies	Other	Total
Cape Cod & Islands	1	1,000	5,000	1,000	300	7,300
Central MA	2	2,320	5,243	1,038	268	8,869
Greater Boston	1	1,650	4,275	3,000	100	9,025
Metro West	1	2,960	7,200	1,500	100	11,760
North of Boston	2	2,225	3,438	2,300	300	8,263
South of Boston	3	1,883	3,767	1,400	284	7,334
Western MA	4	2,150	3,650	1,000	269	7,069
Average across survey respondents:		2,063	3,999	1,288	297	7,645

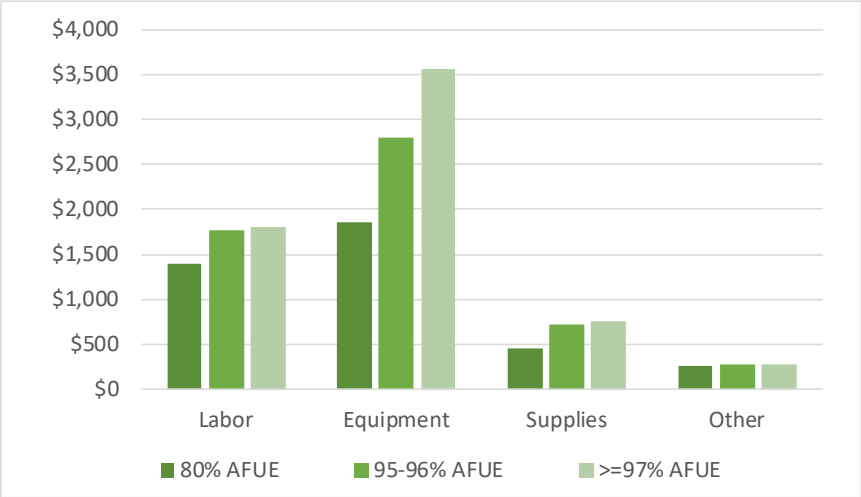
‡ The number of survey responses for each region sums to more than the number of survey completions, because several respondents serve more than one region.

Figure 9. Average base case scenario costs per region served.



Furnaces – Natural Gas

Survey Results for Natural Gas Furnaces at 80 MBH input capacity



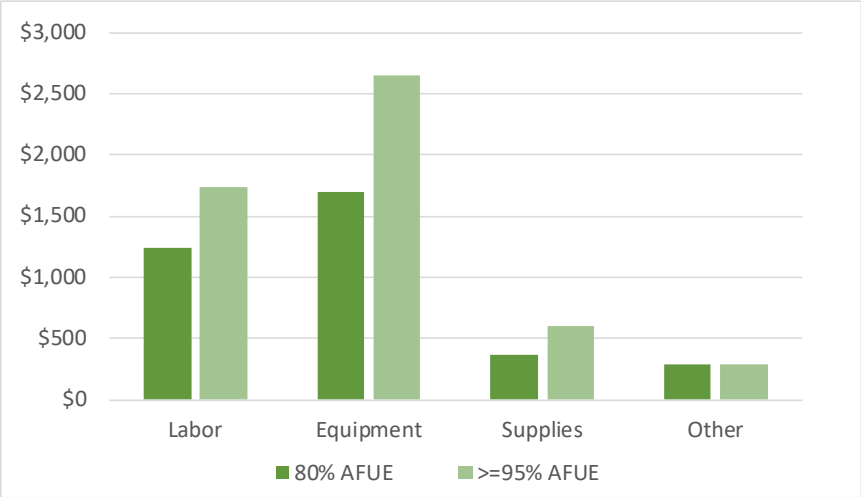
Average Costs by Category in 2017$			
	AFUE (%)		
	80% AFUE	95-96% AFUE	≥97% AFUE
Labor	1,392	1,775	1,805
Equip.	1,855	2,794	3,568
Supplies	463	721	751
Other	256	276	276
Total	**3,966**	**5,566**	**6,400**

Findings related to natural gas furnaces:

- The average incremental total cost between 80% AFUE and 95% AFUE is about $1,600.
- The average incremental total cost between 95% AFUE and 97% AFUE is about $835.
- More than half of the survey respondents indicated that 90% AFUE is the lowest AFUE rating at which a gas-fired furnace installation will require a condensate drain.
- The average labor cost difference between installing a condensing gas furnace and a non-condensing gas furnace installation is about $380.

Furnaces - Propane

Survey Results for Propane Furnaces at 80 MBH input capacity



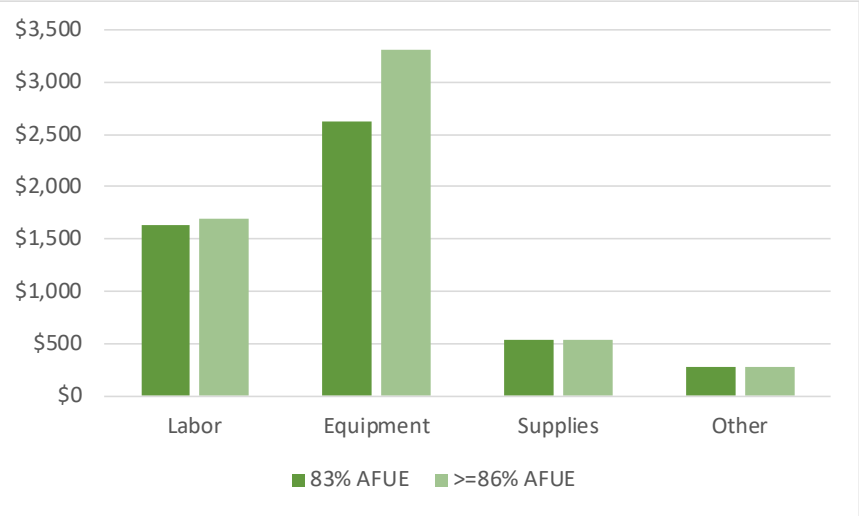
Average Costs by Category in 2017$		
	AFUE (%)	
	80% AFUE	≥95% AFUE
Labor	1,241	1,732
Equip.	1,700	2,649
Supplies	364	607
Other	284	296
Total	**3,589**	**5,284**

Finding related to propane furnaces:

- The average incremental total cost between 80% AFUE and 95% AFUE is about $1,695.
- The average labor cost difference between installing a condensing propane furnace versus a non-condensing propane furnace is about $490.
- The average total cost of installation an 80%-AFUE propane furnace is about $375 less than the cost of installing an 80%-AFUE natural gas furnace.
- The average total cost of installation a 95%-AFUE propane furnace is about $280 less than the cost of installing a 95%-AFUE natural gas furnace.

Furnaces - Oil

Survey Results for Oil-fired Furnaces at 91 MBH input capacity



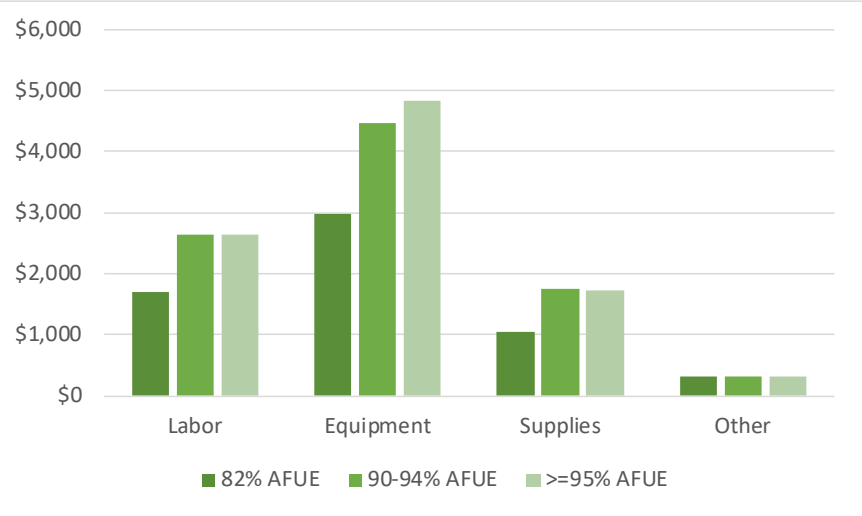
Average Costs by Category in 2017$		
	AFUE (%)	
	83% AFUE	≥86% AFUE
Labor	1,628	1,694
Equip.	2,629	3,302
Supplies	539	535
Other	271	271
Total	**5,066**	**5,801**

Finding related to oil furnaces:

- The average incremental total cost between 83% AFUE and 86% AFUE is about $735. Over 90% of this cost increase is due to changes in equipment costs.
- On average, the total cost of installing a baseline (83% AFUE) oil furnace is $1,100 more than the cost of installing a baseline (80% AFUE) natural gas furnace.

Hot Water Boiler – Natural Gas

Survey Results for Natural Gas Hot Water Boilers at 110 MBH input capacity



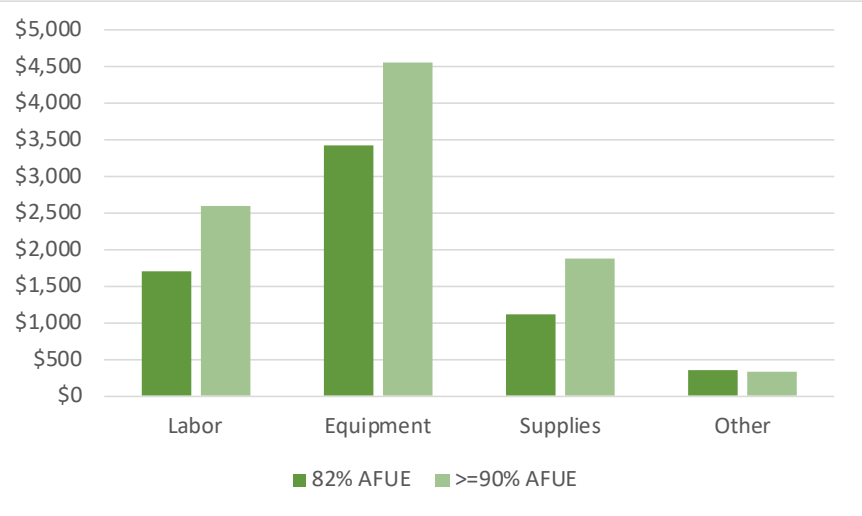
Average Costs by Category in 2017$			
	AFUE (%)		
	82% AFUE	90-94% AFUE	≥95% AFUE
Labor	1,698	2,637	2,643
Equip.	2,971	4,471	4,844
Supplies	1,047	1,764	1,738
Other	326	309	314
Total	**6,042**	**9,181**	**9,538**

Finding related to natural gas hot water boilers:

- The average incremental total cost between 82% AFUE and 90% AFUE is about $3,140.
- The average incremental total cost between 90% AFUE and 95% AFUE is about $360.
- More than half of the survey respondents indicated that 90% AFUE is the lowest AFUE rating at which a gas-fired boiler installation will require a condensate drain. Two respondents noted that there are select few boilers left on the market from previously popular technology that have efficiency of 85% to 87% AFUE, and that these boilers require condensate lines.
- The average labor cost between installing a condensing gas boiler and a non-condensing gas boiler is about $940.
- One respondent noted that boilers in the near-condensing range of 87-64% AFUE may not be cost-effective, since there are boilers currently on the market at 95% AFUE that have lower wholesale prices than boilers rated between 87% and 94% AFUE.

Hot Water Boiler – Propane

Survey Results for Propane Hot Water Boilers 110 MBH input capacity



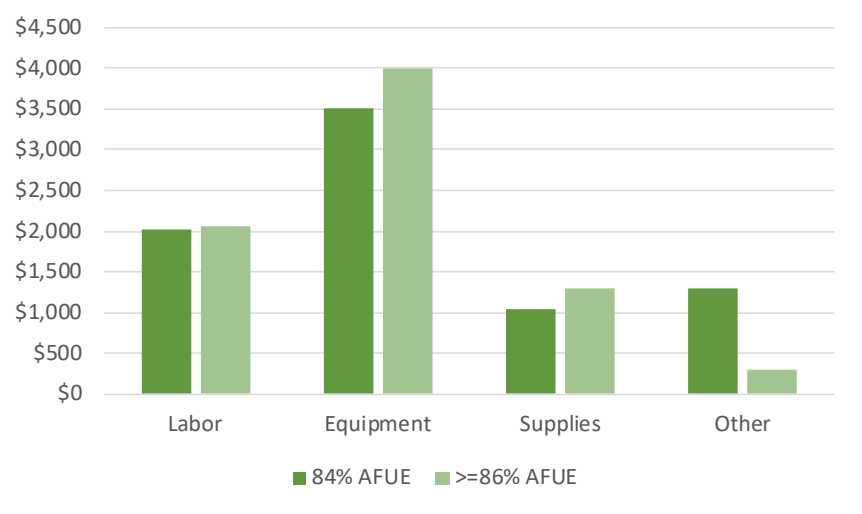
Average Costs by Category in 2017$		
	AFUE (%)	
	82% AFUE	>=90% AFUE
Labor	1,708	2,586
Equip.	3,412	4,560
Supplies	1,122	1,881
Other	354	337
Total	6,595	9,363

Finding related to propane hot water boilers:

- The average incremental total cost between 82% AFUE and 90% AFUE is about $2,770.
- The labor cost difference between installing a condensing propane boiler versus a non-condensing propane boiler is about $880.
- The average total cost of installation an 82% AFUE propane boiler is about $550 more than the cost of installing an 82%-AFUE natural gas boiler.
- The average total cost of installation a 90% AFUE propane boiler is about $180 more than the cost of installing a 90%-AFUE natural gas boiler.

Hot Water Boiler – Oil

Survey Results for Oil-Fired Hot Water Boilers at 119 MBH input capacity



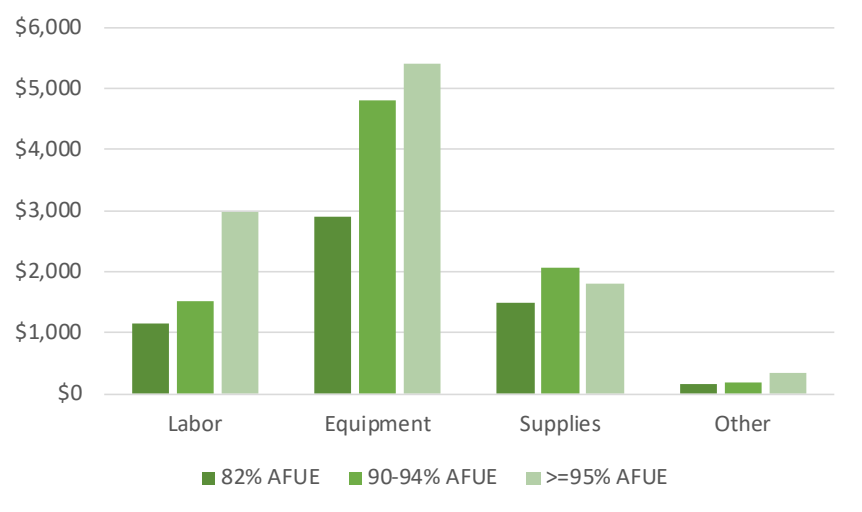
Average Costs by Category in 2017$		
	AFUE (%)	
	84% AFUE	≥86% AFUE
Labor	2,014	2,063
Equip.	3,504	3,999
Supplies	1,048	1,288
Other	301	315
Total	**6,866**	**7,664**

Finding related to oil-fired hot water boilers:

- The average incremental total cost between 84% AFUE and 86% AFUE is about $800.
- Over 90% of this incremental cost is in the cost categories of equipment and supplies.
- Oil-fired boilers at 86% AFUE should not develop flue gas condensate within the boiler heat exchangers, but additional supplies may be needed to manage any condensate that develops in the downstream flue piping.

Combination Boiler – Natural Gas

Survey Results for Natural Gas Combination Boilers at 120 MBH input heating capacity



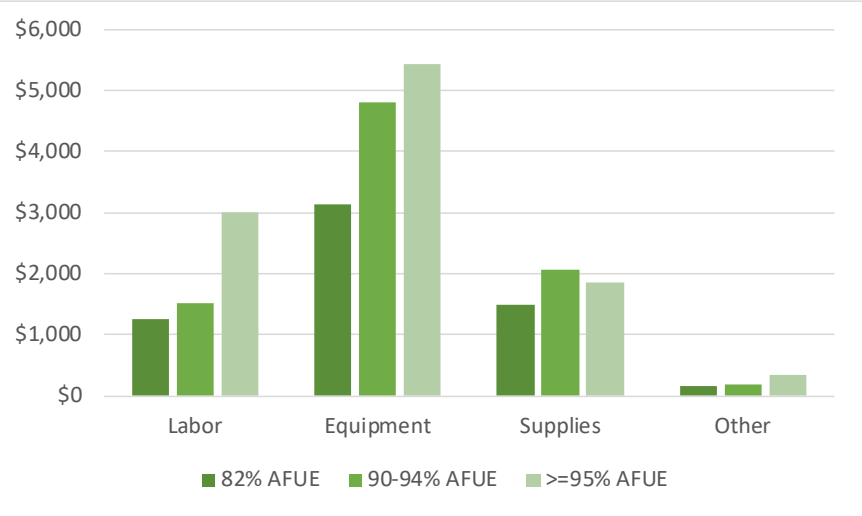
Average Costs by Category in 2017$			
	AFUE (%)		
	82% AFUE	90-94% AFUE	>=95% AFUE
Labor	1,150	1,525	2,974
Equip.	2,900	4,800	5,408
Supplies	1,500	2,075	1,813
Other	150	200	336
Total	**5,700**	**8,600**	**10,530**

Finding related to natural gas combination boilers:

- The average incremental total cost between 82% AFUE and 90% AFUE is about $2,900.
- The average incremental total cost between 90% AFUE and 95% AFUE is about $1,930.
- More than half of the survey respondents indicated that 90% AFUE is the lowest AFUE rating at which a gas-fired boiler installation will require a condensate drain.
- The labor cost difference of installing a condensing gas combination boiler versus a non-condensing gas combination boiler is about $375.
- Two respondents stated they do not believe there are combination boilers on the market that are rated less than 95% AFUE.

Combination Boiler – Propane

Survey Results for Propane Combination Boilers at 120 MBH input capacity



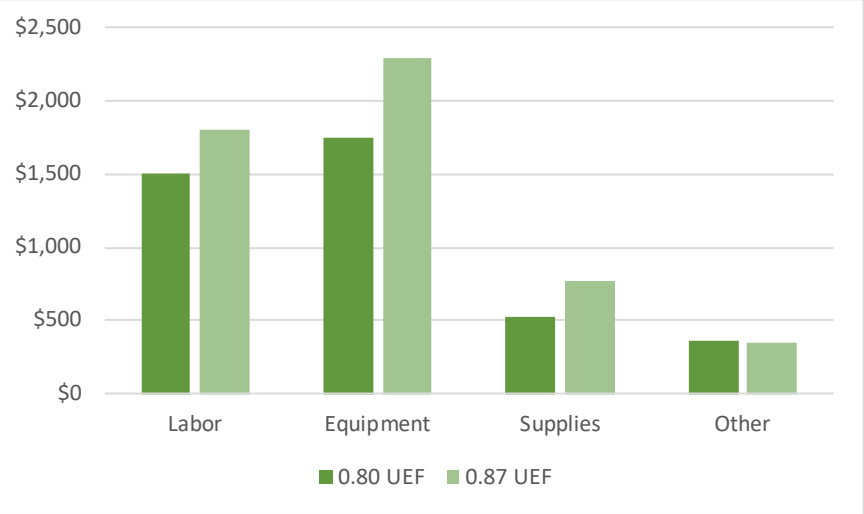
Average Costs by Category in 2017$			
	AFUE (%)		
	82% AFUE	90-94% AFUE	>=95% AFUE
Labor	1,250	1,525	2,999
Equip.	3,125	4,800	5,433
Supplies	1,500	2,075	1,863
Other	150	200	336
Total	**6,025**	**8,600**	**10,631**

Findings related to propane combination boilers:

- The average incremental total cost between 82% AFUE and 90% AFUE is about $2,575.
- The average incremental total cost between 90% AFUE and 95% AFUE is about $2,030.
- The average total cost of installation an 82% AFUE propane combination boiler is about $325 more than the cost of installing an 82%-AFUE natural gas combination boiler.
- The average total cost of installation a 90% AFUE propane combination boiler is about the same as the cost of installing a 90%-AFUE natural gas combination boiler.
- One respondent stated they expect costs to be identical for natural gas combination boilers and propane combination boilers.

On-Demand Tankless Water Heaters – Natural Gas

Survey Results for Natural Gas On-Demand Tankless Water Heaters at 199 MBH input capacity



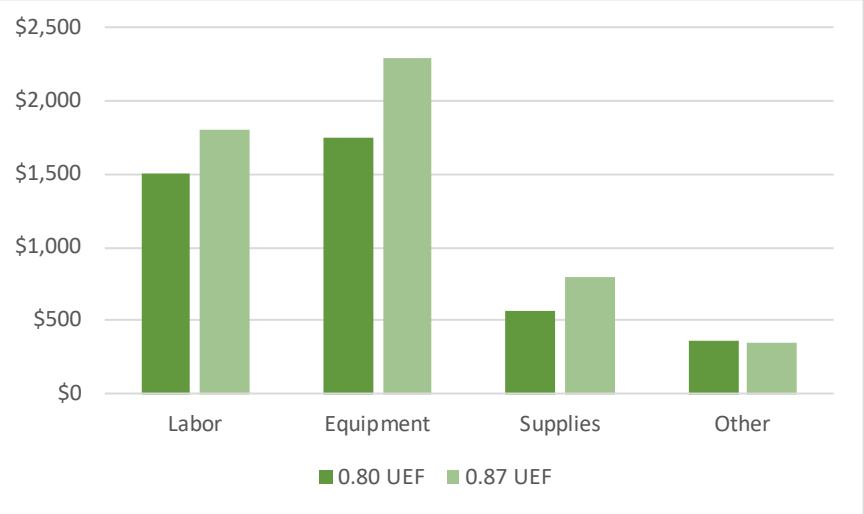
Average Costs by Category in 2017$		
	UEF (unitless)	
	0.80 UEF	0.87 UEF
Labor	1,502	1,807
Equip.	1,749	2,295
Supplies	529	766
Other	357	348
Total	**4,137**	**5,215**

Findings related to natural gas on-demand tankless water heaters:

- The average incremental total cost between 0.80 UEF and 0.87 UEF is about $1,080.
- The survey asked, “What is the lowest EF or UEF rating at which a gas-fired on-demand tankless water heater installation will require a condensate drain?” The responses to this question included values of 0.82, 0.87, 0.90, and 0.94, with no clear majority among the responses. The question was phrased to allow responses in terms of either EF or UEF, so that respondents could use the measure with which they are most familiar. Unfortunately, this caused the results to be meaningless since respondents did not indicate which metric they reported.

On-Demand Tankless Water Heaters – Propane

Survey Results for Propane On-Demand Tankless Water Heaters at 199 MBH input capacity



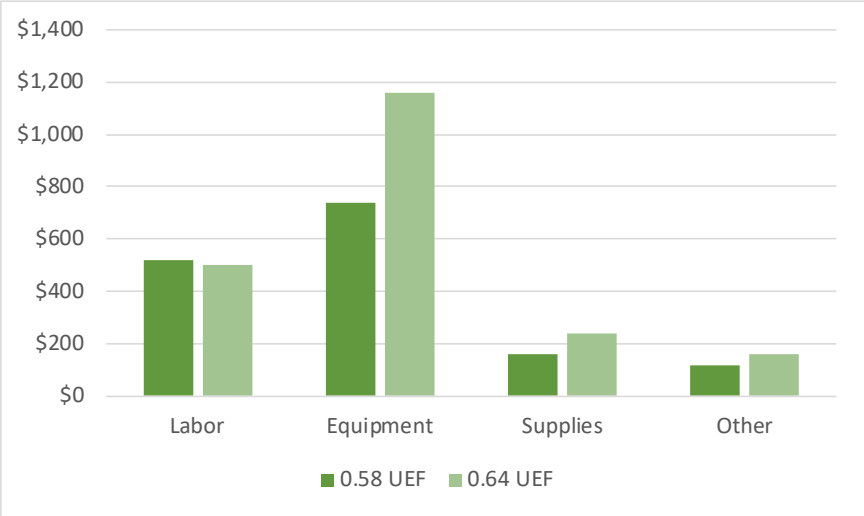
Average Costs by Category in 2017$		
	UEF (unitless)	
	0.80 UEF	0.87 UEF
Labor	1,502	1,807
Equip.	1,749	2,295
Supplies	569	799
Other	357	348
Total	**4,177**	**5,249**

Findings related to propane on-demand tankless water heaters:

- The average incremental total cost between 0.80 UEF and 0.87 UEF is about $1,070.
- The average total cost of installation a 0.80 UEF propane tankless water heater is $40 more than the cost of installing a 0.80 UEF natural gas tankless water heater.
- The average total cost of installation a 0.87 UEF propane tankless water heater is about $30 more than the cost of installing a 0.87 UEF natural gas tankless water heater.

Storage Water Heaters <75 MBH – Natural Gas

Survey Results for Natural Gas Storage Water Heaters at 40-gallons and 40 MBH input capacity



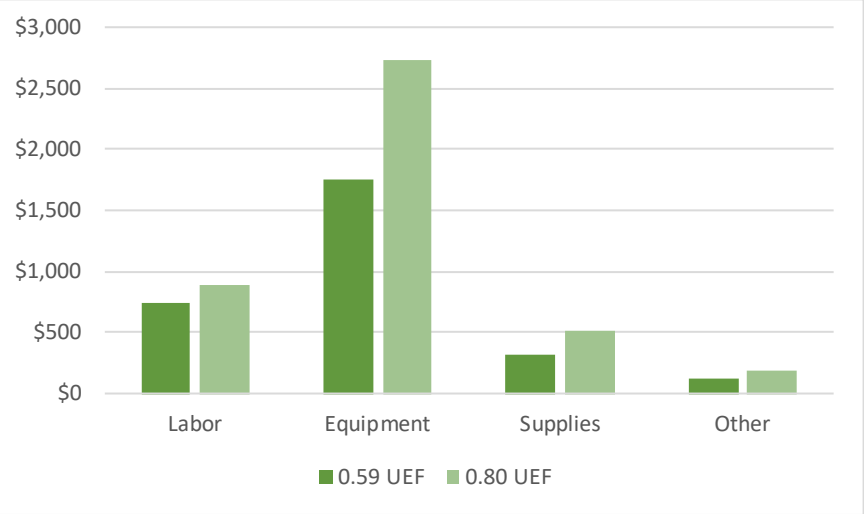
Average Costs by Category in 2017$		
	UEF (unitless)	
	0.58 UEF	0.64 UEF
Labor	518	502
Equip.	736	1,158
Supplies	160	238
Other	120	163
Total	**1,534**	**2,060**

Findings related to natural gas storage water heaters under 75 MBH:

- The average incremental total cost between 0.58 UEF and 0.64 UEF is about $525. The increase in equipment costs makes up 80% of this cost difference.
- Respondents reported labor costs that are on average $15 lower for high-efficiency installations compared to low-efficiency installations. This is the only product type in this study where respondents indicated that labor costs are lower for high-efficiency installations than for low-efficiency installations.

Storage Water Heaters ≥75 MBH – Natural Gas

Survey Results for Natural Gas Storage Water Heaters at 50- to 75-gallons and 100 MBH input capacity



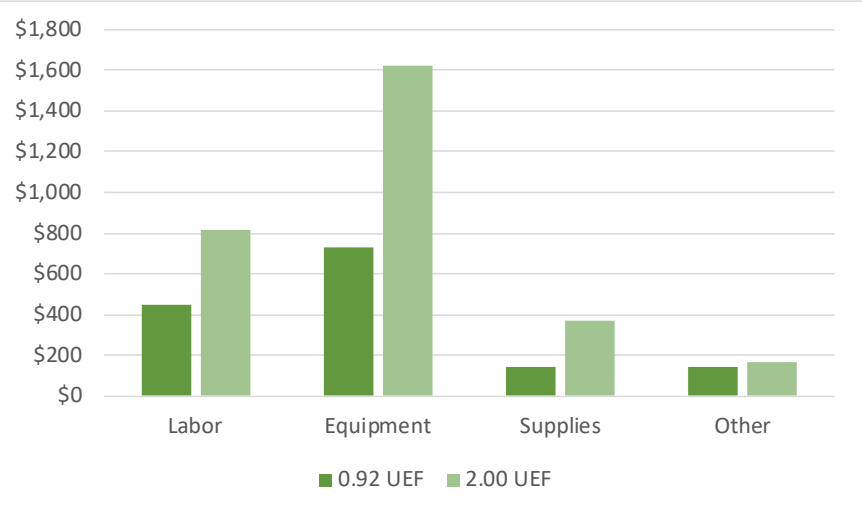
Average Costs by Category in 2017$		
	UEF (unitless)	
	0.59 UEF	**0.80 UEF**
Labor	745	895
Equip.	1,750	2,741
Supplies	317	517
Other	129	188
Total	**2,941**	**4,340**

Findings related to natural gas storage water heaters at or above 75 MBH:

- The average incremental total cost between 0.59 UEF and 0.80 UEF is about $1,400. The increase in equipment costs makes up 70% of this cost difference.
- The increase of $150 in labor costs and $200 in supplies between 0.59 UEF and 0.80 UEF is likely because 0.80 UEF storage water heaters require the installation of additional components to drain and possibly neutralize flue gas condensate.

Storage Water Heaters, ≤55 gal. – Electric

Survey Results for Electric Storage Water Heaters at 50 gallons



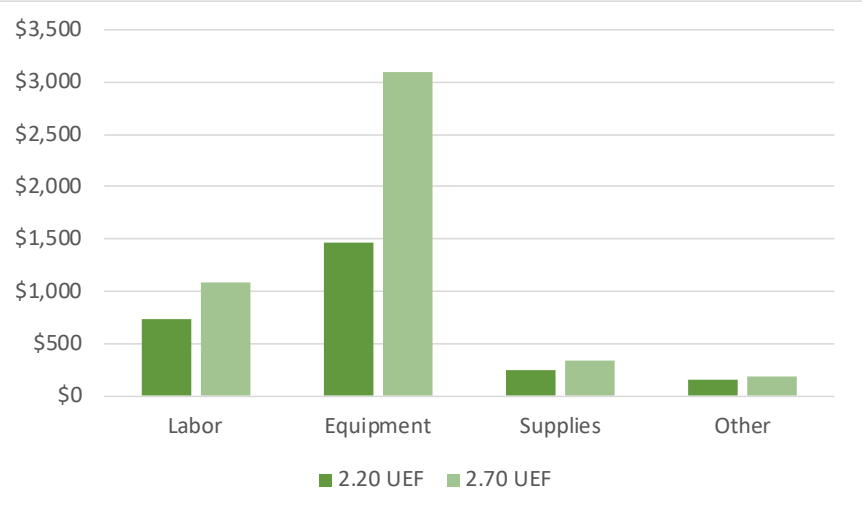
Average Costs by Category in 2017$		
	AFUE (%)	
	0.92 UEF	2.00 UEF
Labor	448	813
Equip.	729	1,625
Supplies	146	371
Other	146	163
Total	**1,469**	**2,972**

Findings related to electric storage water heaters at 50 gallons:

- The average incremental total cost between 0.92 UEF (electric resistance) and 2.00 UEF (heat pump) is about $1,500.
- Before conducting this survey, the evaluation team hypothesized that the labor and supplies installation cost components would not vary for different efficiency levels of electric water heaters. However, the survey responses indicated that on average, the respondents anticipate an increase of $365 in labor and $225 in supplies for high-efficiency electric water heaters over the base case at 50 gallons capacity. These costs could relate to the installation of ventilation grates that are often needed to allow air flow to the heat pump water heater unit.

Storage Water Heaters, >55 gal. – Electric

Survey Results for Electric Storage Water Heaters at 80 gallons



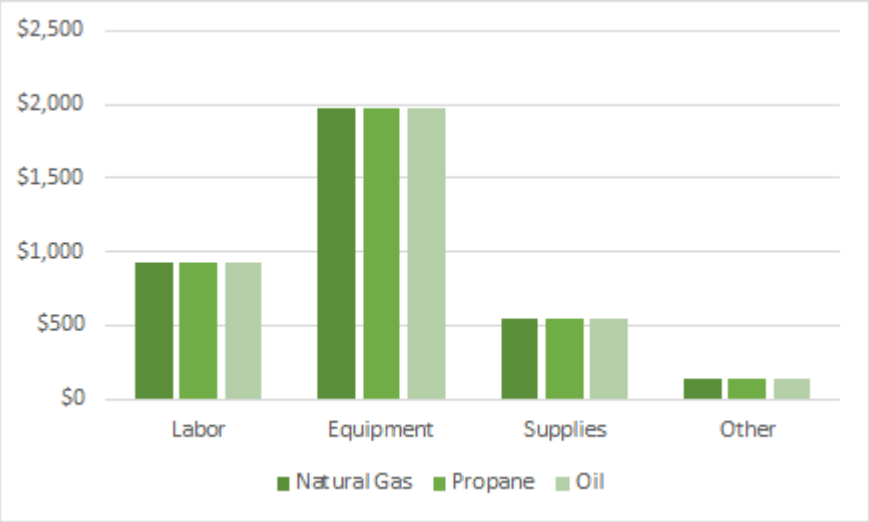
Average Costs by Category in 2017$		
	AFUE (%)	
	2.20 UEF	2.70 UEF
Labor	730	1,090
Equip.	1,461	3,090
Supplies	251	345
Other	160	180
Total	**2,602**	**4,705**

Findings related to electric storage water heaters at 80 gallons:

- The average incremental total cost between 2.20 UEF and 2.70 UEF is about $2,100.
- Before conducting this survey, the evaluation team hypothesized that the labor and supplies installation cost components would not vary for different efficiency levels of electric water heaters. However, the survey responses indicated that on average, the respondents anticipate an additional $360 in labor and $94 in supplies for high-efficiency electric water heaters at 80 gallons capacity. These costs could relate to the installation of ventilation grates that are often needed to allow air flow to the heat pump water heater unit.

Indirect Water Heaters – Natural Gas, Propane, and Oil

Survey Results for 45-gallon Indirect Water Heaters Attached to Gas-, Propane-, and Oil-Fired Boilers



Average Costs by Category in 2017$			
	Fuel Type		
	Natural Gas	**Propane**	**Oil**
Labor	922	922	922
Equip.	1,975	1,975	1,975
Supplies	553	553	553
Other	136	136	136
Total	**3,586**	**3,586**	**3,586**

Findings related to 45-gallon indirect water heaters:

- One respondent noted that the cost of installing an indirect water heater is lower if the indirect unit is installed at the same time as the boiler that provides its heat.
- Nine respondents provided installation costs for all three fuel options (gas, propane, and oil) for indirect water heater. Respondents indicated that installation costs of indirect water heaters are the same regardless of the boiler fuel type.

NAVIGANT

APPENDIX E. RESIDENTIAL WATER HEATER ANALYSIS (TASK 7 MEMO)

To: Massachusetts Program Administrators and Energy Efficiency Advisory Council

From: Decker Ringo and David Basak; Navigant Consulting Inc.

Date: September 19, 2018

Re: Water Heating, Boiler, and Furnace Cost Study (RES 19)
Add-On Task 7: Residential Water Heater Analysis

This memo summarizes Navigant's findings from a comprehensive review of Water Heaters incentivized through the Residential Heating and Cooling program. This add-on task looks at potential program changes based on the Massachusetts Program Administrators (PAs) plan to adopt the Uniform Energy Factor (UEF) metric for water heaters. The goals for this task are:

- Determine the baseline UEF and the program UEF
- Estimate the corresponding incremental costs and the energy/demand savings of the new program levels

The research team synthesized its findings from a wide range of sources and distilled key findings to inform the program administrators' (PAs') decision for likely program changes. This memo presents the high-level findings which are further detailed in an accompanied spreadsheet.

Summary

The Residential Heating and Cooling program specifies rebate qualifications that products must meet to be eligible for a rebate. For storage water heaters and on-demand water heaters, the 2017 qualifications are described in terms of the energy factor (EF) metric. These 2017 levels became less applicable since the U.S. Department of Energy (DOE) amended its test procedure to measure the efficiency of water heaters using the UEF metric in June 2017. The Massachusetts PAs adopted the UEF metric for water heaters for the 2018 program. To evaluate the cost-effectiveness of rebates for different water heater varieties, the program managers requested that the evaluation team determine the baseline-, code-, and high-efficiency UEF levels, and estimate the corresponding product costs and the energy and demand savings of the new program levels.

Table 13 provides a summary of the findings from this task. For each of the seven product classes examined, the table provides the UEF, installation and product costs (after contractor markups), and energy consumption at the baseline, code, and efficient levels. Following Table 13, this memo provides more discussion regarding the change in DOE performance metric, the data sources used in this analysis and the methodology for gathering or calculating the data presented in this memo and the accompanying spreadsheet.

Table 13. Summary of UEF, Costs, and Consumption at Different Efficiency Levels for Residential Water Heaters*

Shading in the UEF Level columns indicates the UEF value used to calculate the product cost and consumption at the Base level.

Product Class	UEF Level			Product Costs (incl. supplies & markup)		Incremental Labor Cost	Incremental Total Cost	Consumption			
	Code*	Market Baseline**	High***	Base	High			Base	High	Savings	Units
Gas On-Demand/ Tankless WH	0.63 (from Gas Storage WH, ≤55 gal., High Draw)		0.87	$1,107	$2,406	$644	$1,943	22.0	15.4	6.6	MMBtu/yr
Propane On-Demand/ Tankless WH	0.63 (adapted from Gas Storage WH, ≤55 gal., High Draw)		0.87	$1,207	$2,424	$644	$1,861	17.9	12.5	5.4	MMBtu/yr
Gas Storage WH, ≤55 gallons, Medium Draw Pattern	0.58	0.54	0.64	$1,045	$1,101	$0	$56	23.9†	21.7	2.2	MMBtu/yr
Gas Storage WH, ≤55 gallons, High Draw Pattern	0.63	0.60	0.68	$1,107†	$1,477	$0	$370	22.0†	20.1	1.9	MMBtu/yr
Gas Storage Residential-Duty Commercial WH, >75 MBtu/h	0.59	0.60 (75-gal, 76 MBtu/h)	0.80	$2,155	$3,486	$150	$1,481	23.1	16.1	7.0	MMBtu/yr
Electric Heat Pump Storage WH, ≤55 gallons	0.92 (Electric Resistance Storage, 50-gal., Medium Draw)	0.90	2.00	$1,021†	$1,535	$127	$641	2,550†	958	1,592††	kWh/yr
Electric Heat Pump Storage WH, >55 gallons	2.16	2.20	2.70	$1,721	$2,074	$98	$451	1,066	869	197	kWh/yr

* The “Code” level represents the Federal minimum efficiency requirements.

** The “Market Baseline” level describes models that are available on the market, which do not necessarily match the Federal minimum efficiency requirements. Where the Market Baseline-level models are rated below the Code level, it is because these models previously met the minimum

EF requirements of the previous Federal standard, and they have been grandfathered in to the new UEF standards. In these cases, particularly for Gas Storage WHs ≤55 gallons and HPWHs ≤55 gallons, the evaluation team identified available water heater models with efficiency ratings below the Federal minimum UEF standard (with models rated as low as 0.54 UEF for medium-draw gas storage, 0.60 UEF for high-draw gas storage, and 0.90 UEF for HPWHs). However, all the models we identified on the market that rated below the Federal standard were priced equal to or higher than other models that met the Federal minimum UEF standard of 0.58 UEF, 0.63 UEF, and 0.92 UEF, respectively. In these cases, we used the Code-level UEF values to calculate the cost and consumption at the Base level, to more conservatively estimate the energy savings associated with these water heaters in the PAs' rebate program over the long term.

For product classes where the Market Baseline-level models are rated higher than code (Gas Storage Residential-Duty Commercial WH and Electric HPWH, >55 gal), the Market Baseline level reflects the least efficient code-compliant models available in the market. In these cases, the evaluation team used the Market Baseline-level UEF values to calculate the cost and consumption at the Base level.

*** For all but one class (Electric Heat Pump Storage WH, >55 gallons), the evaluation team used a "High-Efficiency" UEF Level equal to the UEF level required for ENERGY STAR certification. For the purposes of estimating costs and energy consumption, our analysis assumes the least efficient high-efficiency model available in the marketplace (0.90 UEF for tankless WHs; 0.64 UEF for gas storage WHs ≤55 gallons, medium draw; 0.69 UEF for gas storage WHs ≤55 gallons, high draw; 0.86 UEF for gas storage residential-duty commercial WHs, and 2.45 UEF for HPWHs ≤55 gallons). For Electric Heat Pump Storage WHs, >55 gallons, the evaluation team recommends a high-efficiency UEF level of 2.70 as opposed to ENERGY STAR's 2.20 UEF, because the ENERGY STAR requirement is not much more stringent than the Code-level 2.16 UEF.

† For these classes, Market Baseline models are available with UEF ratings lower than the Code-level UEF. However, all the models we identified on the market that rated below the Federal standard were priced equal to or higher than other models that met the Federal minimum UEF standard. For these classes, the evaluation team used the Code-level UEF values to calculate the cost and consumption at the Base level.

†† Heat pump water heaters remove heat from a household's conditioned space. An impact study of heat pump water heaters prepared for the Electric PAs of Massachusetts in 2017 estimated that 4.8% of the electric savings from HPWH would be lost due to increased electric consumption for heating.[21] For the savings calculated in this analysis, that amounts to a savings reduction of 76.4 kWh/year, which is not accounted for in the figures reported in Table 13. The HPWH impact study also estimated a penalty of 0.10 MMBtu/year for natural gas customers due to the additional heating required when a HPWH is in use.

[21] 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

Background

In July 2014, DOE updated the water heater test metric from EF to UEF.[22] In December 2016, DOE provided a methodology for manufacturers to convert older unit ratings from EF to UEF, and DOE updated the minimum efficiency standards for water heaters to use UEF instead of EF.[23] When DOE published the converted UEF standards, DOE concluded that the converted UEF standards are not more stringent than the previous EF standards. Because of this conclusion, they made an allowance for manufacturers: If manufacturers sold models that met the old EF standards before the conversion to UEF, the manufacturers could continue selling those exact same models after the conversion even if the models do not meet the converted UEF minimum standard. In other words, models that were allowed under the old EF standards would be grandfathered in to the converted UEF standards. However, if manufacturers change the design of their old models, they must re-certify them, and the recertification must meet the new UEF standards. Also, if DOE issues a new rule that makes the UEF standards more stringent, then manufacturers will need to certify performance to the new standard and the older models that do not meet the more-stringent standard would be no longer be allowed.

This allowance for grandfathering is relevant to this analysis because it means there are three efficiency levels available on the market:

1. **Baseline efficiency** representing the least efficient model available in the market, which may not meet the minimum UEF standard but may be legally purchased because it was grandfathered
2. **Code efficiency** representing models that just meet the Federal minimum UEF efficiency standard
3. **High efficiency** level under consideration for the PAs' water heater rebate program, which is defined for the different product classes in this analysis

Data Sources

The evaluation team used the following publicly-available data sources throughout the analyses conducted for this task.

- **AHRI Directory of Certified Product Performance**
  Link: https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx
  The AHRI Directory contains product performance data submitted by manufacturers to certify that their products conform to industry standards. Manufacturers typically contract 3rd-party laboratories to conduct performance testing for water heater products. For water heater products, AHRI Directory records report the brand name, manufacturer, model number, energy source, heater type (storage or instantaneous), usage bin (corresponding to the draw pattern), UEF, nominal capacity, DOE rated storage volume, input capacity (in MBtu/h or kWh). The evaluation team used the AHRI database to study the population of certified water heaters, to select the baseline UEF levels, and to select representative models for cost analysis.

[22] DOE-EERE. "Test Procedures for Residential and Commercial Water Heaters; Final Rule." 79 FR 40542. Available at: https://www.regulations.gov/document?D=EERE-2011-BT-TP-0042-0082
[23] DOE-EERE. "Test Procedures for Consumer and Commercial Water Heaters; Final rule." 81 FR 96204. Available at: https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042

- **DOE Compliance Certification Database**
  Link: https://www.regulations.doe.gov/certification-data/products.html
  The Compliance Certification Database (CCD) houses certification reports and compliance statements submitted by manufacturers for covered products subject to Federal energy conservation standards. It contains performance data certified to DOE by manufacturers and their 3rd-party representatives. For water heater products, CCD records report the brand name, model number, heater type, rated storage volume, draw pattern, UEF, and other measurements. The evaluation team used the CCD to study the population of certified water heaters and to select representative models for cost analysis.

- **California Energy Commission (CEC) Appliance Efficiency Database**
  Link: https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx
  In California, manufacturers of federally and State-regulated appliances are required to certify their appliance efficiency data and other information to the CEC. The CEC Appliance Efficiency Database contains publicly-accessible lists of appliances that have been certified to the Energy Commission such as energy performance and efficiency data and information regarding product features and design. The CEC database houses similar data to the AHRI and DOE databases, but the advantage of the CEC database is that it retains historical records and it includes records that were certified over 10 years ago. The Evaluation Team used this data to estimate the UEF-based energy consumption equivalent of an existing low-efficiency 0.55 EF gas storage water heater.

- **DOE Energy Conservation Standards for Residential Water Heaters**
  Link: https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042
  On December 29, 2016, DOE published a final rule that established mathematical conversion factors to estimate UEF based on values determined using the EF, thermal efficiency (TE), and standby loss (SL) test procedures. This rule applied the conversion factors to establish minimum efficiency levels in terms of UEF for water heaters. The evaluation team used these standards to determine the code-level UEF for all product classes.

- **ENERGY STAR® Water Heater Product Criteria**
  Link:https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria
  The ENERGY STAR program reports the criteria that water heater models must to be labeled as ENERGY STAR. The evaluation team used these criteria to determine the efficient-level UEF for several product classes.

- **RES 1 Baseline Load Shape Study**
  Link: http://ma-eeac.org/wordpress/wp-content/uploads/RES-1-FINAL-Comprehensive-Report-2018-07-27.pdf
  The RES 1 Baseline Load Shape Study collected saturation, penetration, and usage behavior data for all major electric and gas appliances, mechanical equipment, and electronics in Massachusetts homes. The evaluation team used electricity consumption data for gas and electric water heaters reported in this study. The team also referenced coincidence factors and peak demand ratios developed in this study for gas and electric water heaters.

- **DOE Test Procedure for Water Heater Products**
  Link: https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.430#ap10.3.430_127.e
  The DOE test procedure (TP) for residential water heaters is codified in the U.S. Code of Federal Regulations, at chapter 10, part 430, subpart B, appendix E. Sections 6.3 and 6.4 of appendix E describe how to calculate the annual energy consumption of water heaters based on their UEF

rating. The evaluation team used the DOE TP to estimate the UEF rating of water heaters at the early replacement baseline of 0.55 EF.

- **Energy Information Administration (EIA) 2015 Residential Energy Consumption Survey (RECS)**
  Link: https://www.eia.gov/consumption/residential/data/2015/index.php
  The EIA RECS reports energy consumption by end use, fuel type, and geographic region. The evaluation team estimated the gas and propane water heating loads for Massachusetts households using RECS data for gas- and propane-fired water heater energy consumption for the New England region.
- **Retail Merchant Websites**
  Many retailers advertise the prices of water heater products online. The evaluation team conducted targeted webscraping to retrieve pricing data from different online retailers. Many of the prices used in this analysis were sourced from Menards.com, HomeDepot.com, Lowes.com, SupplyHouse.com, and Ecomfort.com. Many other websites were represented as well. The evaluation team used these retail sites to estimate the purchase cost of water heaters at different efficiency levels.
- **Survey of HVAC Contractors and Plumbers Operating in Massachusetts**
  In Task 4 of this study, the evaluation team obtained data from Massachusetts contractors via a web survey. The evaluation team designed the survey to obtain cost information around one cost driver: efficiency. The evaluation team requested cost data at the efficiency levels that are currently rebated through the MassSave program. The survey asked contractors to provide cost information in several billing categories: burdened labor costs, equipment costs including markups, supplies costs (plumbing supplies, seals, tools, etc.) and other costs (travel, warranty, insurance, overhead, etc.) for each scenario. By requesting equipment costs as a single line-item cost, the evaluation team can compare the equipment costs provided by contractors with the retail costs retrieved from merchant websites.
- **Review of Program Invoices for Residential Water Heater Installations**
  In Task 8 of this study, the evaluation team sampled 30 rebate records for each of the eight water heater product types in the RES19 study. The team reviewed these records to estimate the total installation costs for different water heater types.

During this analysis, the evaluation team also consulted industry reports and other publicly available sources, and these sources are cited in the spreadsheet that accompanies this memo.

Methodology

This section describes the methodology used to determine or calculate the various data points that are presented in this analysis. The methodology for each data point is described separately in a sub-section below. The attached spreadsheet “RES19_Task7_WaterHeater_Characterization_v8.xlsx” describes how this methodology was applied to each of the product classes considered in this analysis. The attached spreadsheet also includes detailed data sources and calculations.

Code UEF Level

The evaluation team identified the Federal minimum energy conservation standard set by DOE for each product class in this analysis.

Market Baseline UEF Level

The evaluation team selected an appropriate baseline UEF level for each product class. For some classes in this analysis, particularly gas storage and electric heat pump water heaters ≤55 gallons nominal volume, there were products available below the Federal minimum efficiency levels set by DOE. These products are allowed in the market because they were grandfathered in during the transition to the new UEF efficiency metric. In those cases, the evaluation team identified the least efficient models available for the representative size[24], and set the Baseline UEF level equal to the UEF of those least-efficient models. However, given that the baseline models we identified on the market were priced equal to or higher than other models that meet the Federal minimum UEF standard, we assumed the "higher" Code-level UEF for purposes of more conservatively estimating the energy savings associated with these water heaters in the PAs' rebate program over the long term.[25]

There were several product classes where the least efficient models available on the market are rated higher than the code-level efficiency (Gas Storage Residential-Duty Commercial WH and Electric HPWH, >55 gal). For these classes, we assume the baseline efficiency level is equal to the least efficiency model available for purposes of estimating costs and consumption.

Efficient UEF Level

The evaluation team used the ENERGY STAR® qualification as the basis for identifying the efficient UEF level for each of the product classes in this analysis. For all but one class, the evaluation team adopted the UEF level required for ENERGY STAR as the High-Efficiency UEF Level. In the case of electric heat pump water heaters >55 gallons, the ENERGY STAR qualification (2.20 UEF) is nearly equivalent to the DOE minimum efficiency standard (2.16 UEF) for the representative volume of 80 gallons. For that product class, the evaluation team selected a High-Efficiency UEF Level that is above the ENERGY STAR qualification level and is functionally equivalent to the 3.0 EF threshold value currently incentivized in the Massachusetts PAs' 2017 rebate program. The team examined the EF and UEF performance ratings of all models in the AHRI Database and selected a threshold value of 2.70 UEF. At this threshold value of 2.70 UEF, all the models that qualified for rebates in 2017 will continue to qualify, and no models will qualify for rebate if they did not qualify in 2017.

Measure Lifetime and Coincident Factors

The evaluation team retrieved the product lifetime estimates from the Massachusetts TRM submitted with the 2016 PY Report. For each product variety, the team examined the source documents cited by the TRM and conducted a brief literature search to determine whether lifetime and coincident factor estimates should be updated based on newly-published information. The team gathered coincident factors from the load shape analysis conducted for the RES 1 Baseline Load Shape Study.

[24] The evaluation team determined representative sizes and capacities for the product classes in this analysis based on an examination of program rebate data for the period 1/1/2016-7/31/2017.

[25] The evaluation team assumes that it is likely that retailers will ultimately sell these "below-code" but compliant water heaters at a discount to clear inventory.

Baseline, Code, and Efficient Costs

The costs of all the measures considered in this task were estimated using retail price data gathered by webscraping water heater price data (Task 3 of this study), by conducting a survey of HVAC contractors and plumbers operating in Massachusetts (Task 4 of this study), and by reviewing a sample of program invoices for water heater installations (Task 8 of this study). The team used contractor survey data to determine the typical installation costs of baseline water heater models, and the team used a combination of survey results and program invoice review to determine the typical installation costs of efficient products incentivized by program rebates.

Incremental Labor Cost

For some product classes, the high-efficiency models would require additional labor at the time of installation compared to code-level models. For instance, in the Residential-Duty Commercial Gas-Fired Water Heater class, models at the high-efficiency level use condensing heat exchangers, which have special drainage and venting requirements. In these cases, the evaluation team referenced installation cost information gathered from the survey of HVAC contractors and plumbers. The team's reviewed of program invoices also provided data on labor costs, though this data was limited because contractor invoices do not usually provide labor cost details.

Electricity and Fuel Consumption

To estimate the consumption of different water heating products, the evaluation team first estimated the household water heating loads for different water heater fuel types. For households with electric water heating, the evaluation team began with the metered electricity consumption of electric resistance water heaters reported in the RES 1 Baseline Load Shape Study. The team used RES 1 onsite characterization results to estimate the average efficiency of electric resistance water heaters in the installed base. The team estimated the water heating load for households with electric water heaters by multiplying the electric consumption by the average installed base efficiency of electric water heaters.

To estimate the consumption of gas- and propane-fired water heater models, the evaluation team began with the 2015 RECS estimates of fuel consumption for water heating in New England households with gas- or propane-fired water heaters. The team used RES 1 onsite characterization results to estimate the average efficiency of gas water heaters in the installed base (the team assumed that the average installed base efficiency for propane-fired water heaters is the same as the average installed base efficiency for gas-fired water heaters). The team estimated the water heating load for households with gas or propane water heaters by multiplying the gas or propane consumption by the average installed base efficiency of gas water heaters.

The factors used to calculate the household water heating loads for each water heater fuel type are presented in Table 14. One key assumption in this characterization is that the computed household water heating load is assumed to differ by the water heater fuel type (13.9 MMBtu/yr for gas, 11.3 MMBtu/yr for propane, and 8.0 MMBtu/yr for electric), but that the water heating load for each fuel type does not vary based on the size or configuration (medium draw or high draw, storage or tankless) of the existing water heater or its replacement. The evaluation team formulated this assumption after extensive analysis of water heating consumption data at the household level provided by RES1 Baseline Study and RECS microdata. It may be possible that a household water heating loads are correlated with the capacity and configuration of the household water heater, but there was insufficient data available for the team to quantify this correlation if it exists.

After estimating the household water heating loads for different fuel types, the team estimated the electric and/or fuel consumption of each product class and efficiency level by dividing the water heating load by the efficiency of the water heater. For gas and propane water heater models with electricity-consuming components (such as electronic power ignition, power dampers, and power venting fans), the evaluation team used the metered electricity consumption of gas water heaters (43 kWh/year) reported in the RES 1 Baseline Load Shape Study.

Table 14. Factors Used to Compute Household Water Heating Loads, by Fuel

Factor	Natural Gas Water Heaters	Propane Water Heaters	Electric Resistance Water Heaters	Source
Water heating consumption per household (MMBtu/yr)	21.0	17.1	8.7*	***Gas and Propane:*** RECS 2015 Table CE4.7, for households in New England ***Electric Resistance:*** RES 1 Baseline Load Shape Study, 7/27/18 Report, p.19
Average installed base water heater efficiency	0.66 EF	0.66 EF	0.92 EF	RES 1 Onsite Characterization Results
Water heating load (MMBtu/yr)	13.9	11.3	8.0	Calculated, Load = Consumption x Efficiency

* Converted from the value of 2,550 kWh/yr reported in RES 1.

Electric Demand

To calculate the peak electrical demand savings for gas- and propane-fired water heaters and electric resistance water heaters, the evaluation team began with the metered electrical consumption values reported in the RES 1 Baseline Load Shape Study. For electric heat pump water heaters, the team used the annual consumption estimates calculated using household water heating loads and water heater efficiencies, as described in the previous section. The team referenced the Demand Impact Model Update (as of 2018-08-15) developed as part of the RES 1 Baseline Load Shape Study. The Demand Impact Model Update estimated the ratio of average kW in the summer peak period to the total annual kWh for gas, electric resistance, and electric heat pump water heaters. For each water heater type, the team multiplied the annual electric consumption by the appropriate ratio of kW Demand/Annual kWh. The factors used to calculate peak electric demand savings are presented in Table 15.

Table 15. Factors Used to Compute Electric Demand Savings, by Product Class

Factor	Product Classes					Source
	Natural Gas & Propane, High Efficiency	Electric Resistance	Electric Heat Pump			
			2.20 UEF	2.45 UEF	2.70 UEF	
Annual electric consumption (kWh/yr)	43 (metered)	2,550 (metered)	1,066 (estimate)	958 (estimate)	869 (estimate)	***Gas & Elec. Resistance:*** RES 1 Baseline Load Shape Study, 7/27/18, p.19 ***Electric Heat Pump:*** Estimated based on household WH loads
Summer on-peak demand ratio (kW / annual kWh)	0.000077	0.000076	0.000091			Demand Impact Model, 2018-08-15 Update, "Summary Data" tab
Peak demand (kW)	0.003	0.194	0.097	0.087	0.079	Calculated, Peak Demand = Annual Consumption * Summer On-Peak Ratio

Secondary Impacts

Heat pump water heaters remove heat from a household's conditioned space. Operation of electric HPWHs has an impact on space-conditioning loads because heat generated by the heating system is transferred from the conditioned space to the water tank. This impact is dependent on the HPWH's location (fully conditioned or semi-conditioned spaces), home insulation and sealing, thermostat location and set point, hot-water usage, and efficiency of home heating system. An impact study of heat pump water heaters prepared for the Electric PAs of Massachusetts in 2017 estimated that 4.8% of the electric savings from an HPWH would be lost due to increased electric consumption for heating.[26]

For the product class of HPWH ≤55 gallons, this amounts to a savings reduction of 76.4 kWh/year, which is not accounted for in the figures reported in Table 13. The HPWH impact study also estimated a penalty of 0.10 MMBtu/year for natural gas customers due to the additional heating required when a HPWH is in use.

The evaluation team determined that these secondary impacts do not apply to the product class of HPWH >55 gallons. Heat pump technology is already in use at the baseline level of the HPWH >55 gallons product class. Relative to a baseline of a less-efficient HPWH (i.e., not a baseline of an electric resistance water heater), these incremental impacts are expected to be minimal.

Gas Consumption of Existing Low-Efficiency Gas Storage Water Heaters

The program managers integrate early retirement (ER) savings for gas tankless water heaters and gas storage water heater measures into their screening analyses. The program managers requested that the evaluation team estimate the equivalent UEF rating of a representatively-sized low-efficiency 0.55 EF gas storage water heater at ≤55 gallons volume, for medium-draw units and high-draw units. The program

[26] 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

managers also requested that the evaluation team estimate the annual gas consumption of such low-efficiency water heaters based on the equivalent UEF rating.

To convert a water heater's efficiency from the EF metric to the UEF metric using the DOE test procedure, additional performance data are needed. Specifically, the conversion methodology requires information about the water heater's first-hour rating (FHR) and recovery efficiency (RE). The AHRI Database and the CCD database do not contain records for gas storage water heater models ≤55 gallons rated at 0.55 EF, because the AHRI and CCD databases purge certification records for models that are discontinued after Federal standards are updated. However, the CEC Appliance Efficiency Database retains historical certification data after models are discontinued, and the team queried the CEC database to identify typical FHR and RE for older low-efficiency water heater models.

The evaluation team retrieved historical certification records from the CEC Appliance Efficiency Database for many representatively-sized models with efficiency ratings as low as 0.58 EF. However, the CEC database did not contain records for representative models rated at 0.55 EF. As a result, the team could not directly reference the first hour rating (FHR) or recovery efficiency (RE) for a 0.55 EF model, and so the team could not convert directly from 0.55 EF to a UEF value. As an alternative, the team used regression analysis to estimate the typical FHR and RE values of a 0.55 EF model based on performance data of models rated between 0.59 EF and 0.65 EF. The team regressed FHR versus EF and RE versus EF, using representatively-sized models reported in the CEC database. The team retrieved a batch of records for medium draw units (40 gal. +/- 2 gal., and 40 MBtu/h +/- 2 MBtu/h) and a batch of records for high draw units (50 gal. +/- 2 gal., and 40 MBtu/h +/- 2 MBtu/h). The team used these regressions to estimate FHR and RE for a medium- and high-draw water heaters rated at 0.55 EF. Then, the team followed the DOE test procedure methodology to calculate the "New UEF" value based on the EF, FHR, RE, and input rating.

The evaluation team then used the formulas presented in the DOE test procedure to calculate the annual energy consumption for a medium-draw model rated at 0.52 UEF and a high-draw model rated at 0.58 UEF.

Key Findings

In addition to Table 13 in the summary section, the key findings are reported in the spreadsheet attached to this memo and titled, "RES19_Task7_WaterHeater_Characterization_v8.xlsx"

Regarding the gas consumption of existing low-efficiency gas storage water heaters, the team estimated that a 40-gallon 40-MBtu/h medium-draw gas storage water heater rated at 0.55 EF would have a converted "New UEF" value of 0.52 UEF. The team calculated that a medium-draw water heater rated at 0.52 UEF would consume 26.7 MMBtu of gas annually. Separately, the team estimated that a 50-gallon 40-MBtu/h high-draw gas storage water heater rated at 0.55 EF would have a converted "New UEF" value of 0.58 UEF. The team calculated that a high-draw water heater rated at 0.58 UEF would consume 23.9 MMBtu of gas annually.

APPENDIX F. RESIDENTIAL WATER HEATER INVOICE REVIEW (TASK 8 MEMO)

To: Massachusetts Program Administrators and Energy Efficiency Advisory Council

From: Decker Ringo; Navigant Consulting Inc.

Date: September 26, 2018

Re: Water Heating, Boiler, and Furnace Cost Study (RES 19)
Add-On Task 8: Residential Water Heater Invoice Review

This memo summarizes Navigant's findings from a review of customer invoices that were submitted with rebate applications for residential water heater installations. In Task 4 of this study, the evaluation team surveyed HVAC contractors and plumbers in Massachusetts with questions regarding the typical installation costs for residential heating and cooling equipment. For questions related to residential water heaters, the response rate on the contractor survey was low (n=5) and there was high variability in the survey responses. Additionally, the equipment and labor costs that contractors reported in the survey were higher than the evaluation team expected, based on the team's prior review of retail prices and the PA study lead's conversations with the implementation team. At the suggestion of the lead study PA, the evaluation team reviewed a sample of program rebate invoices for eight different water heater classes to provide an additional data source for developing estimates of water heater installation costs.

In this add-on task, the team developed a sample frame of 30 rebate records for each of the eight water heater product types in this study. The team selected these sample frames to proportionally represent the number of rebates in different geographic regions in the PAs' service areas. The team received scanned invoice images for each of the records in the sample frame. For each record, the team verified that the record contains useful information such that the record (1) is legible, (2) is a record that the team requested, and (3) contains cost information for a water heater installation. For each record with useful information, the team recorded the total installed cost for the water heater installation and, if available, the itemized costs for equipment, labor, supplies, and other costs.

The team compiled the cost data collected from invoice records and compared them to the cost results from the contractor survey. This comparison is presented in Figure 10 in the form of a box-and-whisker plot. For the invoice sample data, the blue boxes show the 25%-75% range, the dark blue horizontal line inside the box shows the median, the "x" mark indicates shows the average, and the whiskers show the range from minimum to maximum. Outlier points are not plotted. The contractor survey results are single points illustrated in red. For each water heater product class, Table 16 presents the average total installed cost from the contractor survey alongside the average, 25th percentile, and 75th percentile total installed costs from the program invoice samples.

Figure 10. Comparison of Total Installed Costs from the Contractor Survey and the Program Invoice Review, for Water Heater Classes Only

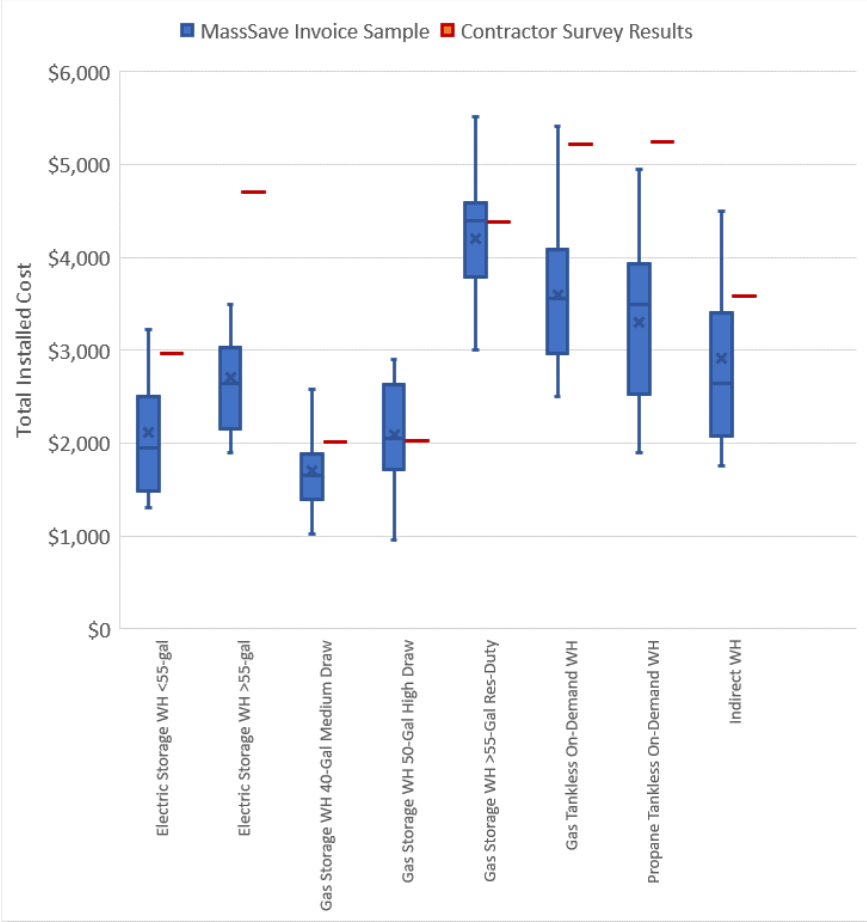


Table 16. Comparison of Total Installed Costs from the Contractor Survey and the Program Invoice Review, for Water Heater Classes Only

Product Class	Total Installed Cost			
	Contractor Survey	Program Invoices		
		25 %tile	Average	75 %tile
Electric Storage WH ≤55 gal.	$2,972	$1,489	$2,110	$2,500
Electric Storage WH >55 gal.	$4,705	$2,158	$2,714	$3,035
Gas Storage WH 40-Gal Medium Draw	$2,013	$1,390	$1,701	$1,878
Gas Storage WH 50-Gal High Draw	$2,023	$1,715	$2,086	$2,634
Gas Storage WH >55-Gal Res-Duty	$4,381	$3,796	$4,197	$4,585
Natural Gas Tankless On-Demand WH	$5,215	$2,962	$3,596	$4,083
Propane Tankless On-Demand WH	$5,249	$2,531	$3,301	$3,926
Indirect WH	$3,586	$2,076	$2,919	$3,405

From this comparison, the evaluation team observed the following:

- For two of the classes (Gas Storage WH at 50-gal and Gas Storage WH >55-gal Residential-Duty), the contractor survey results match the invoice results.
- For the remaining six classes (Gas On-Demand WH, Propane On-Demand WH, and Electric Storage WH ≤55-gal, Electric Storage WH >55-gal, Gas Storage WH at 40-gal, and Indirect WH), the contractor survey results show costs that are above the 75% quartile of the costs observed in the invoice results. For four of these six classes, (Gas On-Demand WH, Propane On-Demand WH, and Electric Storage WH ≤55-gal, and Electric Storage WH >55-gal), the contractor survey results are very high compared to the average invoice costs.

For the third observation above, the evaluation team identified two reasons for the discrepancy between contractor survey data and program invoice data:

(1) **For electric storage water heater classes, customers are more likely to purchase equipment separately and pay contractors for installation only.**
The contractor survey asked contractors to estimate installation costs assuming that the contractor is providing the equipment to be installed. Purchasing equipment through a contractor adds to the retail cost of the delivered unit, since the customer is effectively paying the contractor to source, purchase, and deliver the equipment to their residence. For several specfic classes of equipment, the team found that it is fairly common for customers to reduce their total installed cost by independently purchasing the water heater and hiring a contractor for the installation only. Our invoice review showed that for both Electric Storage classes, 25% of the records in our sample frame were from customers who supplied the unit themselves. This approach can reduce the total installed cost because the customer is not paying the contractor to select, purchase, and deliver the unit. This could explain why contractor-reported costs are higher than invoiced costs for the electric storage classes. This approach was less prevalent in other classes: The samples for the Gas Storage 40-gal class showed 20% of customers supplied their own unit, and other classes showed <5% of records having customer-supplied units.

(2) **Survey respondents overestimated equipment costs.** On average, the contractor survey respondents reported equipment costs for on-demand WH that are about $550 higher than the equipment costs observed in the program invoice review. The contractor survey results showed an average equipment cost of $2,295. From the gas and propane on-demand WH invoices where equipment costs were itemized, the team observed an average equipment cost of $1,743. The lead study PA reported that the lower equipment costs WHs shown in the invoice data is more consistent with the costs that the implementation team is observing in the field.

Based on the results of this program invoice review, the evaluation team recommends that the cost efficiency curves for RES19 be calibrated to fit the average total installed costs from this program invoice review instead of calibrating curves to the contractor survey results for six water heater product classes: (1) Gas On-Demand WH, (2) Propane On-Demand WH, (3) Electric Storage WH ≤55-gal, (4) Electric Storage WH >55-gal, (5) Gas Storage WH at 40-gal, and (6) Indirect WH.