Heat Pump Water Heaters in the Northeast and Mid-Atlantic: Costs and Market Trends

Prepared for

Northeast States for Coordinated Air Use Management (NESCAUM)

The Ozone Transport Commission (OTC)

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Report Definitions and Glossary

DOE: U.S. Department of Energy

Equipment Cost: Cost of the water heating equipment, excluding any electrical upgrades.

eTRM: Electronic Technical Reference Manual

HPWH: Heat Pump Water Heater

Installation Cost: Combined cost of labor and equipment costs.

Labor Cost: Cost of labor and materials needed to install the equipment.

Methane Gas: A fuel commonly combusted for gas water heaters; in this report, the term methane gas is used in place of natural gas

NESCAUM: Northeast States for Coordinated Air Use Management

NOx: Nitrogen Oxides

RECS: Residential Energy Consumption Survey from the U.S. Census Bureau

TRM: Technical Reference Manual

TSD: Technical Support Document

About Energy Solutions

Energy Solutions is a mission-driven clean energy implementation firm that specializes in programs that align with the market to deliver significant resource impacts. For 25 years we've been pioneering end-to-end, market-driven solutions that deliver reliable, large-scale and cost-effective savings to our utility, government, and private sector clients across North America. Our passionate, smart employee-owners are committed to excellence and to building long-lasting, trusted relationships with our clients.

Executive Summary

Project Overview

Energy Solutions evaluated the installation and operating costs for heat pump water heaters (HPWH) compared to baseline water heaters of all fuel types across the residential building sector for the Ozone Transport Commission (OTC) and the Northeast States for Coordinated Air Use Management (NESCAUM). The objective of this work is to inform OTC and NESCAUM member states about the potential energy savings, operating cost impacts, and incremental equipment and labor costs associated with replacing fossil fuel and electric resistance water heating systems with high-efficiency electric HPWH systems. The report provides cost analyses for the following Northeast and Mid-Atlantic states: Connecticut, Delaware, the District of Columbia (DC), Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia.

Installation Cost Summary

The installation cost analysis in this report assesses both equipment and labor costs associated with water heater installation, based on publicly available sources. The U.S. Department of Energy (DOE) Technical Support Document (TSD) for proposed energy efficiency standards for consumer water heaters served as the basis for average labor costs for water heater installation, as well as the equipment costs for fuel-fired and electric resistance water heaters. The California Electronic Technical Reference Manual (eTRM) and a recent study by the New Buildings Institute (NBI) were used to establish the average material cost for 240V and 120V HPWHs, respectively. Electric panel upgrade costs, which are sometimes needed when installing a 240V HPWH, especially in homes greater than 50 years old, were also included in the analysis.

After determining appropriate average costs for each equipment type, a population-weighted average of RS Means City Cost Indexes was applied to the averages. These indexes account for differences in material and labor rates across state boundaries. If other sources are used for average installation costs, these indexes, found in Appendix D, can be used to compare costs across the region. Figure **1** depicts equipment and labor costs combined, across the region, for 240V HPWHs not requiring a panel upgrade. Depending on the state where a consumer resides, the combined equipment and labor cost could vary significantly.

Total installation costs for 240V HPWHs not requiring a panel upgrade are 3-4 times higher than electric resistance, methane gas, and propane water heaters and similar to fuel oil storage water heaters. The higher upfront cost of HPWHs can be offset by available federal, state, local, and utility incentives for high-efficiency equipment, as well as HPWHs' lower operating costs under most conditions.

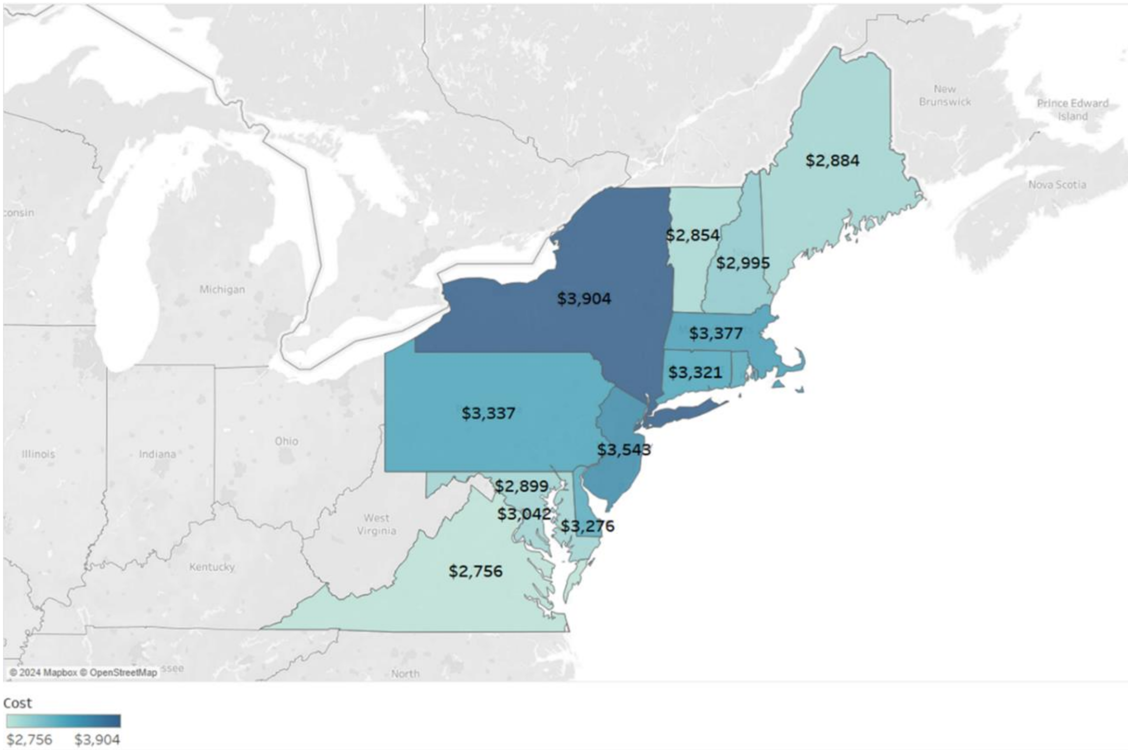

Figure 1: Equipment and Labor Cost of a 240V Heat Pump Water Heater Without a Panel Upgrade Across the Northeast and Mid-Atlantic Region - 2023

Operating Cost Summary

Operating costs for water heaters are significantly impacted by three variables: groundwater temperature, electricity and fuel costs, and equipment efficiency. The operating costs were calculated based on these variables, assuming all other variables such as setpoint temperature or water consumption per year as constants. Table 1 shows the operating cost savings per year for converting from a baseline water heater to a 240V HPWH. Across the region, assuming state-average electricity and fuel prices, consumers will reduce operating costs by switching to HPWHs, due to the high efficiency of heat pump technology compared to baseline equipment. The highest operating cost savings are associated with conversions from lower-efficiency equipment with higher cost fuels to higher-efficiency equipment types, such as a transition from a propane water heater to a 240V HPWH.

TABLE 1: ANNUAL OPERATING COST SAVINGS WHEN REPLACING VARIOUS UNITS WITH A 240V HEAT PUMP WATER HEATER - 2023

240V HPWH	Methane Gas Storage Water Heater	Methane Gas Tankless Water Heater	Electric Resistance Storage Water Heater	Propane Storage Water Heater	Fuel Oil Storage Water Heater
Connecticut	$137	$55	$401	$516	$348
Delaware	$135	$75	$209	$480	$423
District of Columbia	$136	$71	$244	$439	$368
Maine	$236	$132	$342	$532	$415
Maryland	$158	$88	$231	$476	$400
Massachussetts	$167	$74	$424	$483	$359
New Hampshire	$194	$95	$413	$572	$406
New Jersey	$77	$24	$290	$460	$398
New York	$131	$54	$373	$498	$421
Pennsylvania	$154	$86	$220	$447	$414
Rhode Island	$132	$51	$400	$508	$344
Vermont	$120	$43	$394	$530	$402
Virginia	$162	$96	$183	$475	$389

Annual Savings ($)
$24 $572

* Costs calculated at state average fuel prices from open source EIA databases

A more common scenario would be for a consumer to switch from a methane gas[1] storage water heater to a 240V HPWH, since methane gas storage water heaters are the most common fossil fuel-fired equipment type in the region.[2] In this scenario, a consumer could save between $77 and $236 per year, depending on the state where they reside. While conversions from methane gas water heaters to HPWHs will typically reduce energy bills, there may be rare exceptions in situations where a customer is switching from a high-efficiency methane gas water heater and is located in a utility service territory with particularly high electricity rates. Operating costs will also vary based on factors such as installation location, hot water setpoint temperature, and other variables that impact water heater performance.

[1] A fuel commonly combusted for gas water heaters. In this report, the term methane gas is used in place of natural gas or pipeline gas.

[2] See Appendix C, Table 28.

Cost Trends Summary

Two leading HPWH manufacturers were interviewed to discuss anticipated HPWH trends over a five-to-ten-year timeline. These manufacturers have a vast majority of the market share for residential HPWHs. The specific questions asked to each manufacturer are detailed in Appendix A. Answers and insights are anonymized as requested by these organizations. The following are key takeaways on cost and market trends:

- **Market drivers:** Newly adopted federal appliance efficiency standards[3] for consumer water heaters are a major driver of change in the industry, along with state and local policies and programs promoting building electrification. These federal standards would shift much of the electric water heater market from electric resistance to higher-efficiency heat pump technology by 2029. HPWHs are already highly efficient; HPWH efficiency is not expected to increase substantially over time.
- **Production trends:** Manufacturers are currently restructuring manufacturing operations to substantially increase HPWH production to meet growing demand. There is a shift in industry focus to offering a broad range of HPWH products across more sizes and functionalities due to the proposed federal standards. A broader range of products should enable future HPWH installations in buildings where installing HPWHs is not feasible with currently available technology.
- **Cost trends:** Proposed federal standards may lead to value engineering of HPWH technologies as manufacturers seek to reduce equipment cost. However, HPWH costs are also rising due to the cost of steel and HPWH components such as compressors, fans, and microchips. Increasing demand for heat pumps and similar components will compete for supply of component parts, potentially driving costs up or leading to supply chain delays. Fuel-fired water heater costs are also affected by increasing demand for these component parts.
- **Workforce trends:** There is a current shortage of skilled manufacturing laborers, and workforce development will be needed to respond to the increased demand for HPWHs. Installation and service contractor workforce development and training is also needed to handle the increased demand for HPWH.

[3] DOE Energy Conservation Standards for Consumer Water Heaters, Final Rule. https://www.regulations.gov/document/EERE-2017-BT-STD-0019-1426

Introduction

The objective of this study is to inform Ozone Transport Commission (OTC) and Northeast States for Coordinated Air Use Management (NESCAUM) member states about the potential energy savings, operating cost impacts, and incremental equipment and labor costs associated with replacing fossil fuel and electric resistance water heaters with high-efficiency electric heat pump water heaters (HPWH) in residential buildings. This analysis can help inform states' decision-making as they consider policies to address emissions from combustion equipment in buildings. The report provides cost analyses for the following Northeast and Mid-Atlantic states: Connecticut, Delaware, the District of Columbia (DC), Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia.

Energy Solutions conducted this study for OTC and NESCAUM. The following tasks were included in the scope:

1. Installation cost research and analysis: Conduct a literature review of heat pump and HPWH studies to understand existing resources available to support cost analysis. Analyze full and incremental equipment and labor costs, including labor and associated necessary upgrades (e.g., panels, wiring) for HPWH.
2. Operating cost analysis: Analyze baseline and measure efficiency technology operating costs for each defined measure category across each Northeast and Mid-Atlantic state.
3. Cost trend analysis and market interviews: Research and summarize technology trends and innovations over the next 5-10 years by conducting both literature research and primary research through manufacturer interviews.

The report first reviews the methodologies used to estimate installation costs, including both equipment and labor costs, and operating costs for baseline water heaters and HPWHs. It also shares key insights from interviews with market actors about cost trends over time. The report then summarizes the results of the installation and operating cost analyses, with estimated costs provided for each of the 13 states. Finally, the report discusses opportunities for future analyses building on this initial study.

Installation Cost Analysis

Literature Review

The literature review, shown in Appendix B, focused on the equipment and labor costs for HPWHs, with a focus on sources from the Northeast and Mid-Atlantic regions. Reports containing relevant cost values were used to compare the average consumer equipment purchase cost and labor cost of HPWHs (shown in Table 12 and 14, respectively). The average equipment and labor costs developed in this report were within the ranges reported by three other sources that also reported HPWH equipment and labor cost information.

Equipment Cost Analysis Methodology

This report uses publicly available data sources for equipment costs. The TSD for Consumer Water Heaters, published by DOE in July 2023 to support proposed energy efficiency standards, was utilized to extract national average consumer purchase costs for **baseline equipment**, including methane gas storage and tankless water heaters, electric resistance storage water heaters, propane storage water heaters, and fuel oil storage water heaters.[4] The baseline water heaters selected for this analysis have medium draw patterns except for the fuel oil storage water heaters, which were only reported to have a high draw pattern in the TSD. The 240V Heat Pump Water Heaters have a medium or high draw pattern while the 120V Heat Pump Water Heaters have a low draw pattern.

Draw pattern is a measure of the throughput the water heater is capable of and was used to inform equipment costs. The draw pattern dictates the frequency and duration of hot water draws during the 24-hour simulated use test and is an indicator of delivery capacity of the water heater. According to the TSD, medium draw patterns are most common for consumer water heaters. For baseline storage water heaters, the reported costs represent models with 40–50 gallons of stored water, which is typical for residential applications. These baseline costs were developed by DOE using manufacturer production and shipping costs, multiplied by average distributor and contractor markups, and where applicable, sales tax.

According to DOE, "economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to "learning" or "experience" curves."[5,6] To convert baseline equipment prices to 2023 prices, the fuel-fired water heaters were multiplied by 0.988 and electric resistance water heaters were multiplied by 0.990, which are the "learning rates" for 2023 developed by DOE based on historical cost trends. It is important to note that the inflation that occurred over the past two years was not factored into

[4] 2023-07 Technical Support Document: Consumer Water Heaters, July 2023. https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0058

[5] Desroches et al., "Incorporating experience curves in appliance standards analysis," January 2013. https://www.sciencedirect.com/science/article/abs/pii/S0301421512008488

[6] Weiss et al., "A review of experience curve analyses for energy demand technologies," March 2010. https://www.sciencedirect.com/science/article/abs/pii/S0040162509001668

the DOE TSD and may result in higher equipment costs than are reflected in this study.[7] The efficiency levels for each baseline product are assumed to match current federal energy conservation standards.

For HPWH equipment costs, referred to as **measure equipment**, values reported in the California eTRM and a recent study published by NBI were used for 240V and 120V HPWHs, respectively.[8,9] The reported prices represent a 45-55 gallon model for the 240V option and a 65 gallon model for the 120V option. Due to the lack of electric resistance back-up elements, the the 120V models have a slower recovery time when the hot water is used, and generally require a larger storage capacity to meet the same demand. The higher reported price of the 120V HPWHs is due to the fact that they are larger in size and contain additional components such as thermostatic mixing valves which are not generally integrated into 240V equipment.

The analysis used the California eTRM and NBI study rather than the DOE TSD as the source for average HPWH costs because the TSD did not contain data on 120V HPWHs, and the 240V HPWH costs in the TSD included storage capacities outside of typical residential applications, which affected the reported average costs. Specifically, the TSD had two categories for 240V HPWHs, above 55 gallons and below 55 gallons. The reported cost from the TSD for the "below 55 gallons" category was approximately $1,100, which included cheaper models below 45 gallons and too small for a typical residential application in cold climates. The 240V HPWH cost reported in the California eTRM better aligned with retail prices found on the Lowes and Home Depot websites as well as the median equipment costs found in the literature reviewed for this report. Additionally, the eTRM was selected because regional Technical Reference Manuals (TRMs), such as Massachusetts and New York TRMs, do not report measure costs. The CA eTRM had a robust set of recent data to derive costs for this capacity range, including 32 models across three manufacturers, from June 2022.

To create state-specific costs for the baseline and measure equipment, the "material" City Cost Indexes provided by RS Means were averaged based on population for each state.[10] RS Means generates these indexes to compare equipment and labor costs from city to city. By averaging all available cities for each state, a state index was created to compare costs from state to state. While a statewide average is instructive for this regional analysis, there will be variations within a given state that will impact costs in specific areas. Each included city was weighted based on U.S. Census population data to derive the state material cost index, detailed in Appendix D. Additionally, Appendix D includes each city's material cost index, which can be used for further analysis within each state. The results of this analysis are shown in

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[7] When this report was developed, there was no known publicly available source of water heater installation costs that reflected recent inflation.

[8] New Buildings Institute, Plug-In Heat Pump Water Heater Field Study Findings & Market Commercialization Recommendations, July 2023. https://newbuildings.org/resource/plug-in-heat-pump-water-heater-field-study-findings-market-commercialization-recommendations/

[9] California Electronic Technical Reference Manual. https://www.caetrm.com

[10] RS Means. 2023. https://www.rsmeans.com

Table 2 and applied to the average equipment costs using the equation below:

$$\frac{Material\ Cost\ Index\ A}{100} x\ Average\ Consumer\ Purchase\ Cost = Equipment\ Cost\ in\ State\ A$$

TABLE 2: STATE MATERIAL CITY COST INDEXES - 2023

States	Material Cost Index	Cities Included
Connecticut	98.9	Bridgeport, Bristol, Hartford, Meriden, New Britain, New Haven, New London, Norwalk, Stamford, Waterbury, & Willimantic
Delaware	101.4	Dover, Newark, & Wilmington
District of Columbia	102.2	
Maine	96.9	Augusta, Bangor, Bath, Houlton, Kittery, Lewiston, Machias, Portland, Rockland, &Waterville
Maryland	99.2	Annapolis, Baltimore, College Park, Cumberland, Easton, Elkton, Hagerstown, Salisbury, Silver Spring, & Waldorf
Massachusetts	98.2	Boston, Brockton, Buzzards Bay, Fall River, Fitchburg, Framingham, Greenfield, Hyannis, Lawrence, Lowell, New Bedford, Pittsfield, Springfield, & Worcester
New Hampshire	98.3	Charleston, Claremont, Concord, Keene, Littleton, Manchester, Nashua, & Portsmouth
New Jersey	97.7	Atlantic City, Camden, Dover, Elizabeth, Hackensack, Jersey City, Long Branch, New Brunswick, Newark, Paterson, Point Pleasant, Summit, Trenton, & Vineland
New York	98.4	Albany, Binghamton, Bronx, Brooklyn, Buffalo, Elmira, Far Rockaway, Flushing, Glens Falls, Hicksville, Jamaica, Jamestown, Kingston, Long Island City, Monticello, Mount Vernon, New Rochelle, New York, Niagara Falls, Plattsburgh, Poughkeepsie, Queens, Riverhead, Rochester, Schenectady, Staten Island, Suffern, Syracuse, Utica, Watertown, White Plains, & Yonkers
Pennsylvania	98.0	Allentown, Altoona, Bedford, Bradford, Butler, Chambersburg, Doylestown, Dubois, Erie, Greensburg, Harrisburg, Hazleton, Indiana, Johnstown, Kittanning, Lancaster, Lehigh, Montrose, New Castle, Norristown, Oil City, Philadelphia, Pittsburgh, Pottsville, Reading, Scranton, State College, Stroudsburg, Sunbury, Uniontown, Washington, Wellsboro, Westchester, Wilkes-Barre, Williamsport, & York
Rhode Island	99.7	Newport & Providence
Vermont	96.7	Bellows Falls, Bennington, Brattleboro, Burlington, Guildhall, Montpelier, Rutland, St. Johnsbury, & White River Jct.
Virginia	99.1	Alexandria, Arlington, Bristol, Charlottesville, Culpeper, Fairfax, Farmville, Fredericksburg, Grundy, Harrisonburg, Lynchburg, Newport News, Norfolk, Petersburg, Portsmouth, Pulaski, Richmond, Roanoke, Staunton, & Winchester

Source: RS Means

Labor Cost Analysis Methodology

The DOE TSD for Consumer Water Heaters also served as the basis for national average consumer labor costs for the baseline equipment and the 240V HPWH measure case. DOE's method separated labor costs into "Basic," "Venting," "Condensate Drainage," and "Other" categories. The focus of this report is replacement scenarios, so the "Venting" costs, which estimated the pricing for new venting materials, were not used. The "Condensate Drainage" costs were only applied to the HPWH installations because condensate drainage is not required for the baseline equipment. Descriptions for each cost category are provided in Table 3, below.

TABLE 3: LABOR COST CATEGORIES

Labor Cost Category	Description

Basic	• Hours and average contractor rates for wholesale equipment purchases
	• Commute to the installation site
	• Removal of the old water heater
	• Installation of the new water heater
	• Additional water heater materials such as
	  ○ Gas/Water piping
	  ○ Drain pan
	  ○ Temperature and pressure valves

Condensate Drainage*	• Condensate drainage system
Other	• Installation of insulation jackets • Permits • Additional labor needed to set up venting or mounting using existing configurations • Minor electrical costs that are commonly required for HPWHs (separate from electric panel upgrades)

* Condensate drainage costs were only applied to HPWH installations

According to the NBI Plug-In Heat Pump Water Heater Field Study Findings and Market Commercialization Recommendations report, as well as the manufacturer interviews conducted for this report, 120V HPWHs have a faster installation time compared to the 240V HPWH counterparts. The NBI report surveyed two installers that took 4-7 hours to complete their installations.[11] Since the TSD estimated that the 240V HPWH requires 6.95 labor hours, the low end of the NBI labor hour range (4 hours) was used to establish the 120V HPWH installation. This reduction in labor hours was applied to the TSD reported labor cost to establish the labor cost for 120V HPWHs. This is intended to reflect an average installation, but each retrofit case will be unique and require a range of interventions to complete the installation; therefore this cost can vary.

[11] New Buildings Institute, Plug-In Heat Pump Water Heater Field Study Findings & Market Commercialization Recommendations, July 2023. https://newbuildings.org/resource/plug-in-heat-pump-water-heater-field-study-findings-market-commercialization-recommendations/

In addition to the labor hours for installing HPWHs, electric panel upgrades may be needed when installing 240V HPWHs, especially in older buildings. The TECH Clean California Program has collected recent data on the cost and frequency of panel upgrades when installing 240V HPWHs. This source was used for our analysis because it contained data on the cost of the panel upgrade when only installing a HPWH, as opposed to other electric-powered technologies such as electric vehicles and heat pumps used for space heating. According to the TECH data, the approximate cost of upgrading an electric panel to accommodate a 240V HPWH is $2,275 and homes greater than 50 years old are twice as likely to incur this cost. This cost is also within the $2,000-4,500 range reported by NV5 for electrical panel upgrades.[12] The cost from the TECH data represents an average cost to accommodate a 240V HPWH, but this cost varies depending on the existing electrical conditions. While only 8% of the single-family homes receiving HPWH incentives from TECH required a panel upgrade, it is believed that the high cost of panel upgrades influenced consumers to install other water heater types.[13] Additionally, it is important to note that the frequency of panel upgrades reported by TECH is specific to California, and areas with older building stock, such as the Northeast, may require panel upgrades more frequently. In this report, the labor cost for 240V HPWHs is presented with and without the cost of the electric panel upgrade.

To create state-specific labor costs, the "Installation" City Cost Indexes provided by RS Means were averaged for each state.[14] Similar to material cost indexes, population weighting was used for each city within each state, detailed in Appendix D, to derive the state labor cost indexes. Installation costs also vary within each state, and the city labor cost indexes included in Appendix D can be used to compare these costs within a given state. The state indexes used for this analysis are found in Table 4 and were applied to the average labor costs using the equation below:

$$\frac{Labor\ Cost\ Index\ A}{100} x\ Average\ Consumer\ Labor\ Cost = Labor\ Cost\ in\ State\ A$$

[12] NV5, Service Upgrades for Electrification Retrofits Study Final Report, May 27, 2022. https://pda.energydataweb.com/api/view/2635/Service%20Upgrades%20for%20Electrification%20Retrofits%20Study%20FINAL.pdf

[13] TECH Clean California Public Reporting Data. https://techcleanca.com/public-data/download-data/

[14] RSMeans. https://www.rsmeans.com/

TABLE 4: STATE LABOR COST INDEXES - 2023

States	Labor Cost Index	Cities Included
Connecticut	114.5	Bridgeport, Bristol, Hartford, Meriden, New Britain, New Haven, New London, Norwalk, Stamford, Waterbury, & Willimantic
Delaware	107.6	Dover, Newark, & Wilmington
District of Columbia	88.6	
Maine	83.9	Augusta, Bangor, Bath, Houlton, Kittery, Lewiston, Machias, Portland, Rockland, & Waterville
Maryland	82.0	Annapolis, Baltimore, College Park, Cumberland, Easton, Elkton, Hagerstown, Salisbury, Silver Spring, & Waldorf
Massachusetts	119.7	Boston, Brockton, Buzzards Bay, Fall River, Fitchburg, Framingham, Greenfield, Hyannis, Lawrence, Lowell, New Bedford, Pittsfield, Springfield, & Worcester
New Hampshire	90.4	Charleston, Claremont, Concord, Keene, Littleton, Manchester, Nashua, & Portsmouth
New Jersey	133.0	Atlantic City, Camden, Dover, Elizabeth, Hackensack, Jersey City, Long Branch, New Brunswick, Newark, Paterson, Point Pleasant, Summit, Trenton, & Vineland
New York	159.5	Albany, Binghamton, Bronx, Brooklyn, Buffalo, Elmira, Far Rockaway, Flushing, Glens Falls, Hicksville, Jamaica, Jamestown, Kingston, Long Island City, Monticello, Mount Vernon, New Rochelle, New York, Niagara Falls, Plattsburgh, Poughkeepsie, Queens, Riverhead, Rochester, Schenectady, Staten Island, Suffern, Syracuse, Utica, Watertown, White Plains, & Yonkers
Pennsylvania	116.9	Allentown, Altoona, Bedford, Bradford, Butler, Chambersburg, Doylestown, Dubois, Erie, Greensburg, Harrisburg, Hazleton, Indiana, Johnstown, Kittanning, Lancaster, Lehigh, Montrose, New Castle, Norristown, Oil City, Philadelphia, Pittsburgh, Pottsville, Reading, Scranton, State College, Stroudsburg, Sunbury, Uniontown, Washington, Wellsboro, Westchester, Wilkes-Barre, Williamsport, & York
Rhode Island	110.5	Newport & Providence
Vermont	82.0	Bellows Falls, Bennington, Brattleboro, Burlington, Guildhall, Montpelier, Rutland, St. Johnsbury, & White River Jct.
Virginia	71.2	Alexandria, Arlington, Bristol, Charlottesville, Culpeper, Fairfax, Farmville, Fredericksburg, Grundy, Harrisonburg, Lynchburg, Newport News, Norfolk, Petersburg, Portsmouth, Pulaski, Richmond, Roanoke, Staunton, & Winchester

Source: RS Means, 2023

Operating Cost Analysis

Methodology

The algorithm for calculating the energy consumption and operating cost impacts for each water heater type was adapted from the Heat Pump Water Heater Measure in the New York State TRM, Version 10.[15] We selected this resource due to the traceability of its methods, alignment with current industry standards, and New York being in the region of interest. This resource is supported and maintained by the New York State (NYS) Joint Utilities Commission and its contents are derived from credible sources such as federal standards, recent efficiency certification standards (e.g., ENERGY STAR), and studies applicable to the technology type.

Annual Energy Savings

To determine energy savings, energy consumption for both baseline and measure case equipment must be estimated. The energy demand for each unit depends on the annual water consumption per household, groundwater temperature, and the Uniform Energy Factor (UEF) of the water heater.

Calculating Energy Consumption

Energy consumption per year (MMBTU) was calculated for all equipment types to develop a fuel-neutral energy consumption analysis. Then, for fossil fuel-powered water heaters, consumption was converted to Therms/year. Electric water heater energy consumption was converted to kWh/year.

Below is the algorithm used to determine energy consumption for each unit. Table 5 describes the inputs used in the algorithm.

$$MMBTU_{Baseline\ or\ Measure} = GPD \times 365 \times 8.33 \times (T_{set} - T_{main}) \times \left(\frac{1}{UEF_{Baseline\ or\ Measure}}\right)\left(\frac{1}{10^6}\right)$$

$$kWh = MMBTU \times (293.07\ {}^{kWh}/_{MMBTU})$$

$$Therms = MMBTU \times \left(10\ {}^{Therms}/_{MMBTU}\right)$$

[15] New York Technical Resource Manual V10. https://dps.ny.gov/technical-resource-manual-trm

TABLE 5: SUMMARY OF ENERGY CONSUMPTION VARIABLES AND DATA SOURCES

Variable	Value	Description
GPD	17.2 X # of people; Assumed 45.5 GPD/household	Gallons per day[16]
365		Days per year
8.33		Energy required (BTU) to heat one gallon of water by one degree Fahrenheit[17]
T_{set}	125	Set point, outlet water temperature (°F)[18]
T_{main}	Variable by State (Consult Table 8)	Inlet groundwater temperature (°F). Determined by state outdoor air temperature. More detail is provided in the Groundwater Temperature section.
$UEF_{Baseline}$	Table 6	Baseline Water Heater Uniform Energy Factor
$UEF_{Measure}$	Table 6	Measure (HPWH) Uniform Energy Factor
10^6		Conversion factor, one MMBTU equals 10^6 BTU
$MMBTU$		Annual energy consumption of baseline or measure water heater in MMBTUs. Calculated for all equipment types.
kWh		Annual energy consumption of baseline or measure water heater in kWhs. Only calculated for electric units.
293.07		Conversion factor, one MMBTU equals 293.07 kWh
$Therms$		Annual energy consumption of baseline or measure water heater in Therms. Only calculated for fossil fueled units.
10		Conversion factor, one MMBTU equals 10 Therms

Calculating Energy Savings

Energy savings is determined by subtracting measure case equipment energy consumption (in MMBTU, kWh, or Therms) from the baseline equipment energy consumption.

$$Energy\ Savings_{MMBTU/kWh/Therms} = MMBTU/kWh/Therms_{Baseline} - MMBTU/kWh/Therms_{Measure}$$

Energy savings is dependent on the efficiency of the water heater. Efficiency data (UEF) from the DOE TSD, which included an extensive market analysis of U.S. water heaters, was used for the comparison between the operating costs for baseline and measure equipment. Baseline equipment efficiencies were based on minimally compliant equipment available in the market. 240V HPWH efficiency was classified as efficiency level 2 in the electric storage water heater

[16] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.

[17] New York Technical Resource Manual V10. https://dps.ny.gov/technical-resource-manual-trm

[18] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.

product category of the DOE TSD. 120V HPWH data was derived from NBI's Plug-In Heat Pump Water Heater Field Study[19] and a survey of 120V HPWH efficiencies on the ENERGY STAR Water Heater Qualified Product List (QPL).[20]

Equipment efficiency is driven by equipment type due to federal minimum efficiency requirements. Because federal minimum efficiency is dictated by volume of the water heating tank, instantaneous water heaters are required to have higher efficiency than their storage water heater counterparts. Efficiency requirements are also stricter for electric water heaters than fossil fuel water heaters. Thus, electric water heaters tend to require less energy input than fossil fuel water heaters, which can result in lower costs. See Appendix C, Table 27 for a full breakdown of energy consumption by water heater type. HPWHs have the highest efficiency levels compared to other water heater types and therefore have the lowest energy consumption.

Table 6 provides a summary of equipment specifications utilized in the operating cost analysis, ranked from lowest to highest efficiency.

TABLE 6: EQUIPMENT SPECIFICATION ASSUMPTIONS FROM LOWEST TO HIGHEST UEF

Equipment Type	DOE "Efficiency Level"	Draw Pattern[21]	UEF[22]	Representative Volume
Methane Gas Storage WH	0	Medium	0.58	40-50 Gallons
Propane Storage WH*	0	Medium	0.58	40-50 Gallons
Fuel Oil Storage WH	0	High	0.64	40-50 Gallons
Methane Gas Tankless WH	0	Medium	0.81	n/a
Electric Resistance Storage WH	0	Medium	0.92	40-50 Gallons
Electric 120V HPWH	2	Low	3.2	65 Gallons
Electric 240V HPWH	2	Medium	3.35	45-55 Gallons

* Propane equipment was assumed to be the same specification as methane gas equipment due to availability of water heaters operable via propane or methane gas in the market

[19] New Buildings Institute, Plug-In Heat Pump Water Heater Field Study Findings & Market Commercialization Recommendations, July 12, 2023. https://newbuildings.org/resource/plug-in-heat-pump-water-heater-field-study-findings-market-commercialization-recommendations/

[20] ENERGY STAR Certified Heat Pump Water Heaters. https://www.energystar.gov/productfinder/product/certified-heat-pump-water-heaters/results

[21] Draw pattern is related to the first hour rating of water heaters, as dictated by federal energy conservation standards and test procedures 10 CFR 429.17. For equipment types with multiple draw patterns available, a medium draw pattern was assumed for analysis purposes.

[22] Baseline equipment efficiency levels based on minimum efficiency required by energy conservation standards found at 10 CFR 430.32(d).

Overall, conversions from fossil fuel-powered water heaters to HPWHs result in positive Therm savings and negative kWh savings (i.e., an increase in electricity consumption). Conversions from conventional electric resistance water heaters to HPWHs result in positive kWh savings and zero Therm savings.

Annual Operating Cost Savings

Operating costs are calculated by multiplying the energy consumption for the baseline or measure case equipment by the price of fuel for the designated state. Fuel price data for each fuel type can be found in Table 9 through Table 11.

$$Operating\ Cost\ (\$/yr)_{Baseline\ or\ Measure} = kWh/Therms_{Baseline\ or\ Measure} \times Fuel\ Price_{\$/_{kWh} or \$/_{Therm}}$$

To calculate operating cost impacts, the cost to operate the measure case equipment is subtracted from the cost to operate the baseline equipment.

$$Operating\ Cost\ Savings\ (\$/yr) = Operating\ Cost\ (\$/yr)_{Baseline} - Operating\ Cost\ (\$/yr)_{Measure}$$

Key Assumptions

In order to estimate the operating cost for each equipment type, it was necessary to make assumptions to account for the variability in installations for water heaters in the residential market. Factors such as installation location in the house, weather conditions, and price of fuel are variables that impact the cost to operate a water heater.

A water heater's installation location could be inside a utility closet, a garage, or an attic. Water heaters may perform differently in different parts of the house due to interactions between the HVAC system and the water heater. Since HPWHs draw heat from ambient air, installation location has an impact on their performance. An ideal location for HPWH installation is somewhere in the house with excess heat, such as a furnace room.[23] However, due to uncertainty regarding installation location, this analysis assumes that water heaters perform to rated efficiencies with no improved or declined performance due to location of the water heater.

Storage water heaters incur standby losses when heated water is not used immediately. Standby losses lead to additional energy consumption and costs for the consumer. Standby losses are accounted for in the rated efficiency for water heaters.

The geographic location in which a water heater is installed affects the cost of operation based on the temperature of the main water supply available and the price of fuel necessary to operate the equipment. Colder states have lower inlet water temperatures, for example. Incorporating groundwater temperature into the calculation allows for more customization to compare

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[23] DOE, Heat Pump Water Heaters. https://www.energy.gov/energysaver/heat-pump-water-heaters

performance across water heater types.[24] In the following sections, the methods used to determine both groundwater temperature (T_{main}) and fuel price for each state are provided.

Groundwater Temperature (T_{main})

Groundwater temperature (T_{main}) was calculated using a National Renewable Energy Laboratory (NREL) model[25] that approximates groundwater temperature using average outdoor air temperature data. This model was referenced by the NYS TRM V10, the DOE TSD, and other technical conference papers.[26] While this is currently the best-known method to approximate groundwater temperature, the algorithm may need to be modified for cold climates where ground freeze and snow cover exist in wintertime. Average outdoor air temperature data was collected from the National Centers for Environmental Information[27] website for the years 2003-2023 in the statewide (and city for D.C.) time series format. Then the maximum, minimum, and average temperature for each year were determined. Provided below are the model inputs, in Table 7, and the model equation.

$$\boldsymbol{T_{main}} = (\boldsymbol{T_{amb,avg}} + \boldsymbol{offset}) + \boldsymbol{ratio} \times \left({}^{\Delta \boldsymbol{T_{amb,max}}}/_{\boldsymbol{2}}\right) \times \sin[.\boldsymbol{986} \times (\boldsymbol{day}\,\# - \boldsymbol{15} - \boldsymbol{lag}) - \boldsymbol{90}]$$

TABLE 7: SUMMARY OF TMAIN MODEL INPUTS

Variable	Value	Notes
$\boldsymbol{T_{main}}$		Inlet groundwater temperature (°F)
$\boldsymbol{T_{amb,avg}}$		Annual average ambient air temperature
$\Delta\boldsymbol{T_{amb,max}}$	$T_{max,year} - T_{min,year}$	Maximum difference between monthly average temperatures per year
$\boldsymbol{0.986}$	360/365	Degrees per day
$\boldsymbol{day}\,\#$	1 – 365	Day of the year
$\boldsymbol{offset}$	6 °F	
$\boldsymbol{ratio}$	$0.4 + 0.01 \times (T_{amb,avg} - 44)$	
$\boldsymbol{lag}$	$35 - 1.0 \times (T_{amb,avg} - 44)$	

$T_{amb,avg}$ was determined by averaging the average temperature for each year from 2003-2023. $\Delta T_{amb,max}$ was determined by subtracting the minimum monthly average temperature from the maximum monthly average temperature for each year and taking the average of $\Delta T_{amb,max}$ over

[24] Ambient and groundwater temperatures are assumed according to the test procedure: 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters. Annual energy consumption may differ from generic energy calculations because of this procedure.

[25] Jay Burch and Craig Christensen, "Towards Development Of An Algorithm For Mains Water Temperature." http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf

[26] Harvey et al., "Understanding the Seasonality of Domestic Water Heating Energy," 2019. http://www.newecology.org/wp-content/uploads/2020/01/New-Ecology-2019-PHIUS-conference-paper.pdf

[27] NOAA, Statewide Time Series. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series/44/tavg/all

the 2003-2023 year period. The model was applied for each day # (1-365) and the average of all iterations for each state was implemented as the inlet temperature (T_{main}) for all subsequent calculations.

Groundwater temperature is dictated by the climate of the installation location. Lower temperature results in a higher demand for energy input to heat water and as a result, higher operating costs. For example, a consumer in Maine will spend more on water heating than a consumer in the District of Columbia, because the weather is much colder. The temperatures used to generate operating costs are provided in Table 8.

TABLE 8: STATE SPECIFIC GROUNDWATER TEMPERATURE (TMAIN) - 2023

State	T_{main} (°F)
Connecticut	56.5
Delaware	62.8
District of Columbia	65.5
Maine	48.4
Maryland	61.9
Massachusetts	55.4
New Hampshire	50.6
New Jersey	60.2
New York	52.5
Pennsylvania	55.9
Rhode Island	57.2
Vermont	49.6
Virginia	62.5

Fuel Price

Fuel price data was collected from the U.S. Energy Information Administration (EIA) website and utility websites. In order to account for the wide range in prices and sizes of utilities operating in each state, this analysis incorporated four representative categories of utility rates for electricity[28,29] and methane gas[30,31,]: Largest Utility, Second Largest Utility, Sample "Small" Utility/Co-op, and EIA State Average. Prices from 2022 were used for the matrix. Some states, such as Rhode Island or the District of Columbia, do not have more than one utility for methane gas service. For these scenarios, the EIA State Average values were substituted.

[28] EIA. https://www.eia.gov/electricity/state/

[29] EIA. https://www.eia.gov/electricity/sales_revenue_price/

[30] EIA. https://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_a.htm

[31] EIA. https://www.eia.gov/naturalgas/ngqs/#?report=RP4&year1=2021&year2=2021&company=Name

For fuel oil and propane price data,[32] weekly prices were available for all territories except the District of Columbia. Weekly fuel oil and propane prices are only recorded during the heating season, which runs from October through March. The price of delivered fuels like fuel oil and propane can fluctuate significantly from year to year based on geopolitics, weather, and other factors. This analysis does not factor in that price volatility; it uses the average weekly price for each fuel type over the most recent heating period from October 2022-March 2023. District of Columbia's fuel oil and propane prices were assumed to be the same as Maryland's.

The price of fuel varies based on fuel type, utility size, and the state in which the fuel is sold. Delivered fuels like propane and fuel oil tend to be more expensive and have greater price volatility than regulated fuels like methane gas or electricity. Utility size also affects prices for methane gas and electricity. Larger electric utilities often charge more than smaller electric utilities in the region, although there are notable exceptions. Conversely, larger methane gas utilities tend to charge less than smaller methane gas utilities. Fuel prices for regulated fuels differ by state due to rate and regulatory variations which were not within the scope of this study. Rate data is provided in Table 9 through Table 11, below.

TABLE 9: ELECTRIC UTILITY RATES ($/KWH) - 2022

State	Largest Utility	Second Largest Utility	Sample "Small" Utility/Co-op	EIA State Average
Connecticut	$0.21	$0.25	$0.14	$0.18
Delaware	$0.12	$0.12	$0.16	$0.11
District of Columbia	$0.12	$0.13*	$0.13*	$0.13
Maine	$0.16	$0.18	$0.17	$0.14
Maryland	$0.12	$0.14	$0.12	$0.11
Massachusetts	$0.25	$0.24	$0.12	$0.19
New Hampshire	$0.20	$0.21	$0.18	$0.17
New Jersey	$0.17	$0.13	$0.17	$0.14
New York	$0.27	$0.15	$0.19	$0.16
Pennsylvania	$0.13	$0.14	$0.12	$0.10
Rhode Island	$0.22	$0.15	$0.42	$0.18
Vermont	$0.20	$0.20	$0.24	$0.16
Virginia	$0.12	$0.11	$0.11	$0.09

* EIA State Average was used for utility categories that were not applicable to the state

[32] EIA. https://www.eia.gov/dnav/pet/pet_pri_wfr_a_EPD2F_PRS_dpgal_w.htm

TABLE 10: METHANE GAS UTILITY RATES ($/THERM) - 2022

State	Largest Utility	Second Largest Utility	Sample "Small" Utility/Co-op	EIA State Average[33]
Connecticut	$1.81	$1.43	$2.17	$1.77
Delaware	$1.17	$1.52	$1.45*	$1.45
District of Columbia	$1.38	$1.61*	$1.61*	$1.61
Maine	$1.66	$1.17	$1.88	$2.00
Maryland	$1.57	$1.25	$1.07	$1.63
Massachusetts	$1.61	$1.37	$2.18	$1.97
New Hampshire	$1.46	$1.92	$1.98*	$1.98
New Jersey	$0.83	$1.22	$0.99	$1.21
New York	$1.42	$2.00	$1.89	$1.57
Pennsylvania	$1.10	$1.01	$0.55	$1.44
Rhode Island	$1.56	$1.75*	$1.75*	$1.75
Vermont	$1.35	$1.49*	$1.49*	$1.49
Virginia	$1.18	$1.43	$0.83	$1.55

* EIA State Average was used for utility categories that were not applicable to the state

[33] EIA defines residential natural gas prices as the average price of natural gas delivered to residential customers. Prices are considered total prices paid by residential end users, inclusive of all tax, delivery, commodity, demand, and other charges.

TABLE 11: PROPANE AND FUEL OIL RATES ($/THERM) - 2022-2023

State	Propane[34]	Fuel Oil[35]
Connecticut	$4.09	$3.37
Delaware	$3.76	$3.73
District of Columbia	$3.75*	$3.58*
Maine	$3.62	$3.28
Maryland	$3.75	$3.58
Massachusetts	$3.87	$3.45
New Hampshire	$4.11	$3.50
New Jersey	$3.69	$3.62
New York	$3.70	$3.59
Pennsylvania	$3.22	$3.33
Rhode Island	$4.08	$3.38
Vermont	$3.78	$3.38
Virginia	$3.65	$3.39

* D.C. propane and fuel oil rates were assumed to be the same as Maryland

[34] EIA defines residential propane price as the price charged for home delivery of consumer grade propane intended for use in space heating, cooking, or hot water heaters in residences.

[35] EIA defines residential heating oil price as the price charged for home delivery of No. 2 heating oil, exclusive of any discounts such as those for prompt cash payment. Prices do not include taxes paid by the consumer.

Cost Trends Over Time

Market Actor Interviews

Energy Solutions contacted three major water heater manufacturers to discuss anticipated HPWH trends over a five-to-ten-year timeline. These three manufacturers make up the vast majority of the market share for residential HPWHs. The specific questions asked to each manufacturer are detailed in Appendix A. As of December 2023, Energy Solutions received responses to these questions. Answers and insights are anonymized as requested by these organizations.

Key Cost Trends Over Time

The key trends from the manufacturers that participated in the interviews for this report are summarized below. While the focus of the manufacturer discussions was HPWHs, some of the trends they identified relate to broader equipment markets and may also apply to other types of water heaters. The team tried to identify which trends were HPWH-specific and which could be applied more generally.

1. Efficiency Trends
    - There are currently HPWH products available that have a rated efficiency of 4.0 UEF, and efficiency is not expected to increase substantially beyond this.
    - Respondents noted the importance of rebate programs to offset the high upfront cost of HPWHs, so manufacturing products that meet increasingly stringent eligibility requirements will impact trends in efficiency.
    - With DOE's increase to minimum UEF for residential electric storage consumer water heaters, essentially mandating heat pump technology, product development will need to shift away from striving for higher UEFs toward creating a broader range of HPWH products catering to a much larger consumer base and wider set of retrofit applications. As a result, it is possible that manufacturers may introduce HPWH products with lower UEFs that fulfill these market needs.
2. Equipment Costs
    - Respondents noted that restructuring production to substantially increase HPWH production is already underway.
    - Respondents remarked that cost reductions due to increasing HPWH production capacity are expected to be relatively modest and may be outweighed by the increasing costs and demand for component parts faced by all water heaters.
    - The DOE consumer water heater standard may also lead manufacturers to remove premium features on HPWHs and reduce evaporator surface area to allow higher production rates and attempt to reduce costs. That said, component parts may limit their ability to accomplish this.
3. Factors Impacting Equipment Costs

- The cost of steel significantly impacts the cost of any water heater, and since HPWHs will likely be sized larger than other water heaters, they will be impacted more by this cost.
- HPWHs require several specialized components such as compressors, evaporators, platform electronics and microprocessors. One respondent noted that given the state of the supply chain and the overlap of these components with the HVAC industry, there are "concerns as to whether the current water heater supply chain can keep up with the components needed in the production of HPWHs at the scale that federal, state, and local policy makers are advancing." This is a challenge faced not only by HPWHs but is more acute in heat pump technologies for HVAC or water heating.
- All respondents mentioned that if supply chain constraints continue, it will inevitably lead to increased costs to consumers. This is likely to be the case across all water heater technologies but to varying degrees, with HPWHs being the most sensitive to supply chain constraints.
- One respondent noted that there is currently a shortage of manufacturing workers with the necessary skills and experience to produce HPWHs. Most manufacturers have vacancies in their current operations, and the expected transition to HPWHs will require retraining and hiring new workers. This will likely lead to an imbalance in supply and demand and cause labor costs associated with manufacturing these products to rise.

4. Current vs. Future Market Size
    - All respondents expect market share of HPWHs to grow. One respondent noted that their organization is in the process of doubling manufacturing capacity for HPWHs.
    - There is uncertainty with the rate of HPWH market growth. One respondent noted that, unlike the usual gradual market expansion that brings about economies of scale benefits, federal, state, and local government policy mandates will necessitate a more rapid and substantial shift to HPWHs. Manufacturers may not only need to supply HPWHs as replacements for the existing electric resistance water heater stock but also for a larger portion of gas storage water heaters.
    - All respondents noted that they anticipate especially significant growth in market share for HPWHs in areas with well-funded incentive programs and electrification policy.
5. Uncertainties
    - The largest source of uncertainty identified by the manufacturers is the unpredictability surrounding the supply chain. They noted that the overall supply chain has not returned to pre-COVID stability. This uncertainty is not unique to HPWHs.
    - Historically, residential water heater shipments have maintained a relatively steady pace, with replacements driving the majority (about 85%) of the market. These replacements have predominantly been "like-for-like," making it relatively

straightforward for manufacturers to anticipate future demand based on past consumer behavior.
    - With the introduction of electrification policies, incentives, and mandated transitions to HPWHs, significant shifts in product mix are anticipated. These changes make it challenging to forecast future demand accurately. Respondents stated their commitment to expanding HPWH production but noted that the industry-wide transition will lead to increased volatility, compounding the extended lead times that exist today due to supply chain delays.
6. Equipment Types
    - For the residential sector, it is anticipated that most homeowners will opt for integrated HPWHs.[36] Presently, they are more cost-effective and, in most cases, easier to install than split HPWHs.[37] However, one respondent noted that approximately 35% of scenarios involving the replacement of electric storage water heaters are projected to face space constraints. In these instances, a split HPWH or alternative may be required.
    - One respondent also noted that their organization is continuing to innovate to address cases where installing an integrated HPWH may not be feasible.
    - The majority of residential HPWH models and corresponding unit shipments are of larger capacities, typically 50 or 66 gallons for 240V models and 66 or 80 gallons for 120V models. One respondent mentioned that 120V units are not always recommended for colder climates given their recovery time and capacity limitations. However, another respondent expressed no concern for installing 120V units in cold climates.
7. Consumer Behavior
    - Most water heaters are replaced during emergency situations, after the existing water heater has failed. Consequently, consumers are inclined to choose units that are both cost-effective and easy to install, focusing on the total installed cost. 120V models, which offer reduced overall installation costs when transitioning from gas, especially when coupled with immediate rebates, have the greatest potential to influence consumer choices because they make it easier to convert to HPWHs.
    - One respondent noted that plumbers are best positioned to influence customer behavior and influence the decision to install a HPWH.
8. Installation Considerations
    - All respondents expressed strong concern over the pace of workforce development keeping up with the market demand for HPWH. As more products are introduced to the market, such as residential split HPWHs that require handling refrigerant, the workforce will need to continuously evolve and learn these specialized skills.

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[36] Integrated HPWHs combine the compressor and storage tank into one unit, usually with the compressor on top of the tank.

[37] Split HPWHs separate the compressor from the storage tank.

- One respondent expressed concern over the age of plumbers, noting that the average is over 55 years old and approaching retirement. This could worsen labor shortages.
- In addition to plumbers, general workforce constraints have the potential to increase lead times for HPWHs.

9. Difficult Installations
    - One respondent identified split HPWHs as a key product for difficult installations, especially in buildings with space constraints.
    - One respondent noted that dual-fuel products might help with challenging installations and also mentioned that innovation will continue to develop new products.

Results

This section presents the results of our analysis of installation and operating costs for conversions from baseline water heating equipment to HPWHs, based on the methodologies previously described. The summary includes results for the following:

- Equipment cost
- Labor cost
- Installation cost (equipment + labor cost)
- Incentives available
- Operating cost

Equipment Cost Results

Average consumer purchase costs and corresponding equipment information are shown in Table 12, below. As previously noted, these average costs are based on publicly available sources that do not account for high inflation in 2021-2023. Actual equipment and labor costs will vary based on local conditions.

TABLE 12: AVERAGE CONSUMER PURCHASE COSTS AND EQUIPMENT INFORMATION - 2023

Water Heater Type	Efficiency (UEF)	Storage Capacity	Average Equipment Cost	Source
Methane Gas Storage WH	0.58	40-50 Gallons	$504	DOE TSD
Methane Gas Tankless WH	0.81	n/a	$639	DOE TSD
Electric Storage WH	0.92	40-50 Gallons	$574	DOE TSD
Propane Storage WH	0.58	40-50 Gallons	$504	DOE TSD (Methane Gas Storage WH Cost)
Fuel Oil Storage WH	0.64	40-50 Gallons	$2,328	DOE TSD
240V Heat Pump Water Heater	3.30	45-55 Gallons	$1,837	California eTRM
120V Heat Pump Water Heater	2.20	65 Gallons	$2,630	NBI Study

State-specific results for equipment costs are provided in Table 13, below. State-specific averages were developed by adjusting the above costs using a state cost index based on RS Means data.

TABLE 13: STATE-SPECIFIC EQUIPMENT COSTS - 2023

State	Methane Gas Storage	Methane Gas Tankless	Electric Storage	Propane Storage	Fuel Oil Storage	240V HPWH*	120V HPWH*
Average	$504	$639	$574	$504	$2,328	$1,837	$2,630
Connecticut	$498	$632	$567	$498	$2,301	$1,816	$2,600
Delaware	$511	$648	$581	$511	$2,359	$1,862	$2,666
D.C.	$515	$653	$586	$515	$2,379	$1,878	$2,688
Maine	$489	$620	$556	$489	$2,256	$1,781	$2,549
Maryland	$500	$634	$569	$500	$2,308	$1,822	$2,608
Massachusetts	$495	$628	$563	$495	$2,286	$1,804	$2,583
New Hampshire	$495	$628	$564	$495	$2,288	$1,806	$2,585
New Jersey	$493	$625	$561	$493	$2,275	$1,796	$2,571
New York	$496	$629	$565	$496	$2,290	$1,808	$2,588
Pennsylvania	$494	$626	$562	$494	$2,280	$1,800	$2,576
Rhode Island	$502	$637	$572	$502	$2,320	$1,831	$2,621
Vermont	$487	$618	$555	$487	$2,250	$1,776	$2,543
Virginia	$499	$634	$569	$499	$2,307	$1,821	$2,606

*Without retailer discounts or utility incentives

Labor Cost Results

The average consumer labor costs and corresponding equipment information are shown in Table 14, below.

TABLE 14: AVERAGE CONSUMER LABOR COSTS AND EQUIPMENT INFORMATION - 2023

Water Heater Type	Efficiency (UEF)	Storage Capacity	Ave. Labor Cost	Source
Methane Gas Storage WH	0.58	40-50 Gallons	$361	DOE TSD
Methane Gas Tankless WH	0.81	n/a	$564*	DOE TSD
Electric Storage WH	0.92	40-50 Gallons	$308	DOE TSD
Propane Storage WH	0.58	40-50 Gallons	$564	DOE TSD (Methane Gas Storage WH Cost)
Fuel Oil Storage WH	0.64	40-50 Gallons	$832	DOE TSD
240V Heat Pump Water Heater w/Panel Upgrade	3.30	45-55 Gallons	$3,589	DOE TSD
240V Heat Pump Water Heater w/o Panel Upgrade	3.30	45-55 Gallons	$1,314	DOE TSD
120V Heat Pump Water Heater	2.20	65 Gallons	$762	DOE TSD & NBI Study

* This labor cost would increase if converting from a storage WH to a tankless WH

TABLE 15: STATE-SPECIFIC LABOR COSTS – BASELINE EQUIPMENT - 2023

State	Methane Gas Storage	Methane Gas Tankless	Electric Resistance Storage	Propane Storage	Fuel Oil Storage
Average	$361	$564	$308	$564	$832
Connecticut	$413	$646	$353	$413	$953
Delaware	$388	$607	$331	$388	$895
D.C.	$320	$500	$273	$320	$737
Maine	$303	$474	$258	$303	$698
Maryland	$296	$463	$252	$296	$682
Mass.	$432	$675	$368	$432	$996
New Hampshire	$327	$511	$279	$327	$753
New Jersey	$480	$750	$409	$480	$1,107
New York	$576	$900	$491	$576	$1,327
Pennsylvania	$422	$660	$360	$422	$973
Rhode Island	$399	$624	$340	$399	$920
Vermont	$296	$463	$252	$296	$682
Virginia	$257	$402	$219	$257	$592

TABLE 16: STATE-SPECIFIC LABOR COSTS – MEASURE EQUIPMENT - 2023

State	240V HPWH w/ Panel Upgrade*	240V HPWH w/o Panel Upgrade*	120V HPWH*
Average	$3,589	$1,314	$762
Connecticut	$4,110	$1,505	$873
Delaware	$3,861	$1,414	$820
D.C.	$3,180	$1,165	$675
Maine	$3,012	$1,103	$640
Maryland	$2,943	$1,078	$625
Massachusetts	$4,295	$1,573	$912
New Hampshire	$3,247	$1,189	$690
New Jersey	$4,772	$1,748	$1,014
New York	$5,725	$2,096	$1,216
Pennsylvania	$4,197	$1,537	$891
Rhode Island	$3,967	$1,453	$843
Vermont	$2,943	$1,078	$625
Virginia	$2,554	$935	$542

* Without retailer discounts or utility incentives

Total Installation Cost Results

Since consumers will typically receive an invoice from a contractor that combines the equipment and labor costs, Table 17 and Table 18 show these state-average costs added together for the baseline and measure equipment, respectively. Total installation costs for HPWHs not requiring a panel upgrade are similar to fuel oil storage water heaters and 3-4 times higher than electric resistance, methane gas, and propane water heaters. The higher upfront cost of HPWHs can be offset by available federal, state, local, and utility incentives for high-efficiency equipment, as well as HPWHs' lower operating costs under most conditions, as discussed below.

TABLE 17: STATE SPECIFIC EQUIPMENT & LABOR COSTS – BASELINE EQUIPMENT - 2023

State	Methane Gas Storage	Methane Gas Tankless	Electric Resistance Storage	Propane Storage	Fuel Oil Storage
Average	$865	$1,204	$882	$865	$3,160
Connecticut	$912	$1,278	$920	$912	$3,254
Delaware	$899	$1,255	$913	$899	$3,254
D.C.	$835	$1,154	$859	$835	$3,116
Maine	$791	$1,093	$814	$791	$2,954
Maryland	$796	$1,097	$821	$796	$2,990
Massachusetts	$927	$1,303	$932	$927	$3,282
New Hampshire	$822	$1,139	$842	$822	$3,040
New Jersey	$973	$1,375	$970	$973	$3,382
New York	$1,072	$1,529	$1,056	$1,072	$3,618
Pennsylvania	$916	$1,286	$922	$916	$3,253
Rhode Island	$901	$1,261	$912	$901	$3,240
Vermont	$783	$1,081	$807	$783	$2,933
Virginia	$756	$1,035	$788	$756	$2,899

TABLE 18: STATE SPECIFIC EQUIPMENT & LABOR COSTS – MEASURE EQUIPMENT - 2023

State	240V HPWH w/ Panel Upgrade*	240V HPWH w/o Panel Upgrade*	120V HPWH*
Average	$5,427	$3,152	$3,392
Connecticut	$5,926	$3,321	$3,473
Delaware	$5,723	$3,276	$3,486
D.C.	$5,058	$3,042	$3,363
Maine	$4,793	$2,884	$3,189
Maryland	$4,764	$2,899	$3,233
Mass.	$6,100	$3,377	$3,495
New Hampshire	$5,052	$2,995	$3,274
New Jersey	$6,568	$3,543	$3,584
New York	$7,533	$3,904	$3,804
Pennsylvania	$5,997	$3,337	$3,468
Rhode Island	$5,798	$3,284	$3,464
Vermont	$4,719	$2,854	$3,168
Virginia	$4,375	$2,756	$3,149

* Without retailer discounts or utility incentives

Many consumers in these states can also participate in utility, state, or federal incentive programs and tax credits for HPWH products to lower the overall cost, including new incentives under the Inflation Reduction Act, shown in Table 19. Current statewide rebates as of December 2023 are shown in Table 20. In states where there is not a statewide program, it lists the range of rebates available from the two largest utilities. Together, these incentives can reduce the upfront cost of a HPWH to parity with a gas or electric storage water heater. For example, in New York, a low-income customer receiving a $1,750 federal rebate and a $1,000 utility rebate would pay $1,054-$1,154 for a HPWH without a panel upgrade, on par with the $1,072 cost for a methane gas storage water heater, before any tax credits are applied.

When considering incentive amounts, the goal is often to reduce the incremental cost of installing a HPWH compared to the baseline equipment. Additionally, there are other key components of incentive program design that can impact the success of a program, including the program delivery model (i.e., downstream, midstream wholesale, and midstream retail), the ease of the application submission process, and the outreach and marketing of the program. In terms of program delivery model, a midstream approach, which is a point-of-sale discount offered by the equipment wholesaler or retail store, has been found to be highly effective at driving adoption of HPWHs in this region, as seen in the Efficiency Maine[38] and Efficiency Vermont[39]

[38] Efficiency Maine. https://www.efficiencymaine.com/at-home/heat-pump-water-heater-program/

[39] Efficiency Vermont. https://www.efficiencyvermont.com/rebates/list/heat-pump-water-heaters

programs. Other important best practices include a streamlined application process, strong marketing of the program to residential customers, and active engagement with manufacturers, distributors, retailers, and contractors.

TABLE 19: FEDERAL INFLATION REDUCTION ACT HEAT PUMP WATER HEATER INCENTIVES

Program	Customer Incentives	Notes
Home Electrification Rebates	$1,750	• 100% of cost up to $1,750 for low-income households (under 80 percent of Area Median Income). • 50% of cost up to $1,750 for moderate-income households (between 80 percent and 150 percent of Area Median Income).
25C Tax Credit	$2,000	• 30% of cost for heat pumps and HPWHs, capped at $2,000 per year. The credit resets each year, becoming available for additional projects. • 30% of cost up to $600 for an electrical panel upgrade, in conjunction with another upgrade covered by 25C, such as a HPWH.

TABLE 20: HEAT PUMP WATER HEATER REBATES BY STATE - 2023

State	Customer Rebates[40]	Notes
Connecticut	$750	
Delaware	$700	
D.C.	$700	
Maine	$850	
Maryland	$700	
Massachusetts	$750	
New Hampshire	$750	
New Jersey	$750-$1000	Jersey Central Power & Lt Co - $750 PSE&G - $1000
New York	$700-$1000	National Grid (Upstate NY) - $700 Consolidated Edison - $1000
Pennsylvania	$350-$400	PECO Energy - $350 PPL Electric Utilities - $400
Rhode Island	$150-$600	PPL Rhode Island - $150-$600
Vermont	$300-$800	Incentive for NEEA Tier 1 and 2 HPWHs: $300 Incentive for NEEA Tier 3 and 4 HPWHs: $600 Additional $200 based on household income
Virginia	$400-$750	Dominion Energy - $750 Appalachian Power Co - $400

[40] Customer rebate values broken out by first and second largest utilities came from each utility's website

Operating Cost Results

An "Operating Cost and Savings Calculator.xlsx" was developed using the methodology described above to aid in comparison between equipment types in different states for different utility sizes. This calculator was used to generate all operating costs for this report, and can also be used to generate operating costs for water heaters under different assumptions and scenarios. The state average fuel price was assumed for the operating cost analysis to provide a representative cost for each state. Costs calculated for the other utility price categories, including the two largest electric and gas utilities and a sample small utility or coop in each state, are provided in Table 24 through Table 26 in Appendix C.

These operating costs were determined with the assumption of rated performance (e.g., no decrease in performance over time) and no major HVAC interactive effects between the indoor environment and the water heater. Performance cannot be fully captured by the rated efficiency of a unit since water heaters operate in a wide range of temperatures, not just the test temperature. More in-depth simulations would be required to capture the range of real-world scenarios of HPWH performance. Operating costs will also vary based on factors such as installation location, hot water setpoint temperature, and other variables that impact water heater performance. Table 21 shows annual operating costs at EIA State Average Utility Rates. In every state, assuming EIA average rates, 240V HPWHs are the least expensive type of water heater to operate. 120V HPWHs are slightly more expensive than 240V due to the slight difference in efficiency between the units. These results are consistent across all states considered in this study and demonstrate the value of HPWHs over other water heater types.

Customers who switch from propane, fuel oil, or electric resistance water heaters to HPWHs would significantly reduce their annual operating costs. Propane storage water heaters are the most expensive to operate across all states. The combination of these water heaters being the lowest efficiency of all equipment types and propane being the highest priced fuel for each state leads to this higher cost. In Connecticut, Massachusetts, New Hampshire, and Rhode Island, operating an electric resistance storage water heater is more expensive than a fuel oil water heater. For all other states, the cost of operating an electric resistance storage water heater is cheaper than a fuel oil water heater.

Table 21: Annual Operating Cost of Equipment Types at EIA State Average Fuel Prices – 2022-2023

	Methane Gas Storage Water Heater	Methane Gas Tankless Water Heater	Electric Resistance Storage Water Heater	Propane Storage Water Heater	Fuel Oil Storage Water Heater	240V Heat Pump Storage Water Heater	120V Heat Pump Storage Water Heater
Connecticut	$289	$207	$553	$668	$500	$152	$159
Delaware	$214	$154	$288	$559	$502	$79	$83
District of Columbia	$228	$163	$336	$532	$460	$92	$97
Maine	$365	$261	$471	$662	$544	$129	$136
Maryland	$246	$176	$319	$564	$488	$88	$92
Massachusetts	$327	$234	$585	$643	$519	$161	$168
New Hampshire	$351	$251	$569	$729	$562	$156	$164
New Jersey	$187	$134	$400	$570	$508	$110	$115
New York	$272	$195	$515	$640	$562	$141	$148
Pennsylvania	$237	$170	$304	$531	$497	$83	$87
Rhode Island	$283	$203	$551	$659	$496	$151	$158
Vermont	$269	$192	$543	$679	$551	$149	$156
Virginia	$231	$166	$252	$545	$458	$69	$72

Operating Cost
$69 $729

* Costs calculated at state average fuel prices

Across the region, most customers would save on annual operating costs by switching from methane gas storage and tankless water heaters to HPWHs. However, in less-common scenarios with higher-than-average electricity prices or lower-than-average methane gas prices, or if the gas water heater being replaced is a high-efficiency model, HPWHs could be slightly more expensive to operate than methane gas water heaters.

Table 22 provides a breakdown of state and utility categories that lead to HPWHs having higher operating costs than methane gas water heaters. Estimated increases in annual operating cost are shown in parentheses.

Table 22: Baseline Equipment with Lower Operating Costs than 240V HPWH and Cost Difference - 2022 – 2023

State	Largest Utility	2nd Largest Utility	Small Utility/Co-op
Maine	N/A	NG Tankless ($11)	N/A
Massachusetts	NG Tankless ($19)	NG Tankless ($41)	N/A
New Jersey	NG Tankless ($45) NG Storage ($9)	N/A	NG Tankless ($20)
New York	NG Tankless ($64)	N/A	N/A
Pennsylvania	N/A	N/A	NG Tankless ($33) NG Storage ($7)
Rhode Island	NG Tankless ($1)	N/A	NG Tankless ($142) NG Storage ($62)
Vermont	NG Tankless ($5)	N/A	NG Tankless ($28)

Half of the scenarios where HPWHs cost more than methane gas water heaters increase operating costs by $20 or less. While these outcomes may not be preferable, operating costs are not starkly different between the baseline option and HPWHs. Other regions have higher cost differences and warrant some concern. For example, the least advantageous scenario is a replacement of a tankless methane gas water heater in a Small Utility Co-op territory in the State of Rhode Island, which could result in an annual operating cost increase of $142. However, this is expected to be an outlier case; across the region, most consumers would experience lower operating costs if they convert to HPWHs.

Future Work

This report provides estimates of the average costs that a typical consumer across the Northeast and Mid-Atlantic region would pay to install and operate a water heater. Users can use the Excel-based Operating Cost and Savings Calculator to analyze operating costs based on different assumptions, such as utility rates that were not included in the study. Users can also use the material and labor adjustments provided in Appendix D to develop alternative installation costs if they have access to other data sources, such as state-specific or proprietary program data.

Future work could explore installation and operating cost impacts under additional scenarios that were beyond the scope of this analysis. For example, a broader discussion and comparison of rate design could explore the impact of electricity and gas rates that encourage electrification, such as new rates in Maine for customers with heat pumps.[41] The results of this study could also be updated and validated with more recent installation cost information based on interviews with installation contractors across the region.

On the technology side, cost comparisons with other water heating technologies could be developed, such as condensing storage and tankless systems, solar water heaters, combination boilers, and indirect water heaters. Future analysis could also consider the potential dehumidification benefits associated with HPWHs, as well as opportunities for HPWHs to be used as a distributed energy resource to support grid flexibility and reliability.

[41] Central Maine Power, Electric Technology Rate. https://www.cmpco.com/account/understandyourbill/newelectrictechnologyrate

Appendix A: Market Questionnaire

NESCAUM/OTC Heat Pump Water Heater Market Study Questionnaire

1. Efficiencies: What trends can we expect in HPWH efficiencies over the next 5-10 years?
2. Equipment costs: How will HPWH equipment costs change in the next 5-10 years?
3. Factors that affect equipment costs: What factors in the industry will affect equipment cost over the next 5-10 years? (Refrigerants, raw materials, microchips, volume produced per year)
4. Current vs Future Market Size: How will increased production volume in the future (due to market adoption of HPWH) affect cost per HPWH?
5. Uncertainties: How confident are you in your predictions for cost trends? What do you see as the largest sources of uncertainty?
6. Equipment types: What product mix do you anticipate over the next 5-10 years? (Integrated units, dual fuel, combination products, split systems, etc.)
7. Under current policy, to what extent do you expect conversions from fossil fuel to electric water heaters by 2030. Will gas water heaters maintain their current market share or will people start to convert to HPWH?
8. Equipment types: What is the most common storage capacity for residential installations (replacing a 40/50 gallon fuel fired WH)?
9. Consumer behavior: Do you anticipate any changes to consumer purchasing decisions or patterns based on the greater prevalence of HPWH and other equipment types (such as combination products)?
10. Installation considerations: Do you anticipate sufficient workforce development and training to support increased adoption of HPWH and other product types (such as combination systems)? Are there any anticipated changes to installation costs associated with trends either in the workforce, or the product mix (for example, might 120V units lower installation costs in some scenarios).
11. Difficult installations: What changes, if any, do you anticipate to the product mix or installation practices that address particularly challenging installations for HPWH?
12. State-level data: States are interested in more granular data on WH sales into their states.
    a. Do you have state-level sales data? If so, would you consider making it available to states?
    b. We are discussing a potential long-term industry solution where states might potentially pay for this data. Would you be interested in a follow up conversation to discuss this?
13. How prepared are you to comply with forthcoming Low-GWP Refrigerants regulations?
14. Thoughts on the proposed federal appliance efficiency standards and what it might do to the WH market?
15. For those that also manufacture HVAC HPs, is there anything significantly different that you anticipate will impact costs in this 5-10 year timeline?

Appendix B: Bibliography

Title	Publisher	Equipment Cost	Install Cost	Notes
NBI Plug-In Heat Pump Water Heater Field Study Findings & Market Commercialization Recommendations, July 2023	NBI	$2,630 – 120-Volt HPWH with Mixing Valve (65 gal) $2,270 – 240-volt HPWH (65 gal)	$200-$700 – 120-Volt HPWH $1,000-$3,200 240-Volt HPWH	Cost data was estimated through invoices from other projects in CA. Labor costs will vary by area. Install cost shows a range based on the typical cost of the intervention needed for complete installation. Noting that Amperage service upgrade for 240V HPWH is not within the scope and was excluded from the cost range
NBI 120V HPWHs Field Validation and Market Efforts, 2022	NBI	N/A	$250-$1,000 – 120-Volt HPWH $950-$3,150 – 240-Volt HPWH	Cost data was estimated through invoices from other projects in CA. Labor costs will vary by area. Install cost shows a range based on the typical cost of the intervention needed for complete installation. Noting that Amperage service upgrade for 240V HPWH is not within the scope and was excluded from the cost range
MA-EEAC Residential New Construction Energy Optimization Cost Study, October 2021	MAEEC	$999-$2,399 (Literature Review Sources) $2,125 (Contractor web Survey results)	$595-$1,087 (HPWH Literature review sources) $1,111 (Contractor web survey results)	Literature review values based on 5 resources, costs include both new construction and retrofits. Contractor web survey results based on 20 HPWH survey submissions and is showing the mean value cost
EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, March 2023	EIA	$630-1,440	$870-$2,230	Residential heat pump water heater values are based on an average of low and medium draw pattern units and ranges represent span of typical values.

Title	Publisher	Equipment Cost	Install Cost	Notes
RI-OER Heating Sector Transformation in Rhode Island, May 2020	RI-OER	N/A	N/A	Report includes a figure that displays HPWH capital cost per year over an average economic lifetime of 10 years
DOE Technical Support Document – Consumer Water Heaters, July 2023	DOE	See Section 2	See Section 2	TSD reported values are represented in the methodologies above
NESCAUM/OTC Residential Building Electrification in the Northeast and Mid-Atlantic, August 2023	NESCAUM/ OTC	N/A	N/A	Report focuses on energy consumption and emissions impacts
EIA Residential Energy Consumption Survey Data, 2020	EIA	N/A	N/A	The data shown in the report was not relevant to the report's methodology
NEEP Market Transformation Progress Report, September 2022	NEEP	N/A	N/A	Report includes some information on rebate dollar ranges for HPWH
ACEEE Equity and Electrification-Driven Rate Policy Options, September 2023	ACEEE	N/A	N/A	Report includes information on HPWH energy costs
BAAQMD Socioeconomic Impact Analysis of Proposed Amendments to Regulation 9, Rule 4, December 2022	BAAQMD	N/A	N/A	Report has project cost data for HPWH which includes both equipment and install cost. Also has panel upgrade cost.
TECH Clean California Public Program Data	TECH	N/A	Used for electric panel upgrade frequency & costs	Report includes public data on Single-Family only showed total project cost and incentive dollars for HPWH
NV5 Service Upgrades for Electrification Retrofits Study Final Report	NV5	N/A	Used for electric panel upgrade costs	Report includes costs for upgrading electrical service capacity when completing residential electrification retrofits

Title	Publisher	Equipment Cost	Install Cost	Notes
ACEEE Analysis of Electric and Gas Decarbonization Options for Homes and Apartments, July 2022	ACEEE	N/A	N/A	Report includes combined equipment and labor costs for HPWH
BDC How Building Decarbonization Has Transformed the US Building Sector In Just Four Years, February 2023	DC	N/A	N/A	Report did not include any HPWH costs
NBI The Building Electrification Technology Road Map, January 2021	NBI	N/A	N/A	Report did not include any HPWH costs
Peninsula Clean Energy Design Guidelines for Electrified Homes (Presentation)	Peninsula Clean Energy	N/A	N/A	Presentation did not include any HPWH costs
NBI Cost Study of the Building Decarbonization Code, April 2022	NBI	N/A	N/A	Report includes incremental first cost per sq-ft for HPWH
NYSERDA Residential Building Stock Assessment, September 2019	NYSERDA	N/A	N/A	Report did not include any HPWH costs
NEEP Northeastern Regional Assessment of Strategic Electrification, July 2017	NEEP	N/A	N/A	Report did not include any HPWH costs
NREL ResStock Literature and Data	NREL	N/A	N/A	The data shown in the report was not relevant to the report's methodology
NRDC/Ecotrope Heat Pump Water Heater Performance Data, November 2016	NRDC/ Ecotrope	N/A	N/A	Data includes values on HPWH performance (COP)
OSTI Towards Development of an Algorithm for Mains	OSTI	N/A	N/A	Used for Operating Cost Analysis

Title	Publisher	Equipment Cost	Install Cost	Notes
Water Temperature, 2007				
Efficiency Maine Trust Heat Pump Water Heater Initiatives Impact Evaluation, December 2019	Efficient Maine Trust	N/A	N/A	Report includes per unit measure cost savings for HPWH

Appendix C: Supporting Data Tables

TABLE 23: OPERATING COST OF EQUIPMENT TYPES AT EIA STATE AVG. ELECTRIC - EIA STATE AVG. GAS - 2022-2023

Equipment Type	Methane Gas Storage WH	Methane Gas Tankless WH	Electric Resistance Storage WH	Propane Storage WH	Fuel Oil Storage WH	Electric 240V HPWH	Electric 120V HPWH
Connecticut	$289	$207	$553	$668	$500	$152	$159
Delaware	$214	$154	$288	$559	$502	$79	$83
District of Columbia	$228	$163	$336	$532	$460	$92	$97
Maine	$365	$261	$471	$662	$544	$129	$136
Maryland	$246	$176	$319	$564	$488	$88	$92
Massachusetts	$327	$234	$585	$643	$519	$161	$168
New Hampshire	$351	$251	$569	$729	$562	$156	$164
New Jersey	$187	$134	$400	$570	$508	$110	$115
New York	$272	$195	$515	$640	$562	$141	$148
Pennsylvania	$237	$170	$304	$531	$497	$83	$87
Rhode Island	$283	$203	$551	$659	$496	$151	$158
Vermont	$269	$192	$543	$679	$551	$149	$156
Virginia	$231	$166	$252	$545	$458	$69	$72

TABLE 24: OPERATING COST OF EQUIPMENT TYPES AT LARGEST UTILITY ELECTRIC - LARGEST UTILITY GAS - 2022-2023

Equipment Type	Methane Gas Storage WH	Methane Gas Tankless WH	Electric Resistance Storage WH	Propane Storage WH	Fuel Oil Storage WH	Electric 240V HPWH	Electric 120V HPWH
Connecticut	$295	$211	$643	$668	$500	$177	$185
Delaware	$173	$124	$340	$559	$502	$93	$98
District of Columbia	$195	$140	$320	$532	$460	$88	$92
Maine	$303	$217	$556	$662	$544	$153	$160
Maryland	$236	$169	$342	$564	$488	$94	$98
Massachusetts	$267	$191	$765	$643	$519	$210	$220
New Hampshire	$260	$186	$640	$729	$562	$176	$184
New Jersey	$128	$92	$497	$570	$508	$137	$143
New York	$246	$176	$873	$640	$562	$240	$251
Pennsylvania	$181	$129	$384	$531	$497	$105	$110
Rhode Island	$252	$180	$661	$659	$496	$181	$190
Vermont	$243	$174	$650	$679	$551	$179	$187
Virginia	$175	$126	$334	$545	$458	$92	$96

TABLE 25: OPERATING COST OF EQUIPMENT TYPES AT SECOND LARGEST UTILITY ELECTRIC - SECOND LARGEST UTILITY GAS - 2022-2023

Equipment Type	Methane Gas Storage WH	Methane Gas Tankless WH	Electric Resistance Storage WH	Propane Storage WH	Fuel Oil Storage WH	Electric 240V HPWH	Electric 120V HPWH
Connecticut	$235	$168	$761	$668	$500	$209	$219
Delaware	$225	$161	$316	$559	$502	$87	$91
District of Columbia	$228	$163	$336	$532	$460	$92	$97
Maine	$214	$153	$597	$662	$544	$164	$172
Maryland	$188	$134	$389	$564	$488	$107	$112
Massachusetts	$227	$163	$744	$643	$519	$204	$214
New Hampshire	$341	$244	$673	$729	$562	$185	$193
New Jersey	$189	$135	$377	$570	$508	$104	$108
New York	$347	$248	$476	$640	$562	$131	$137
Pennsylvania	$167	$120	$414	$531	$497	$114	$119
Rhode Island	$283	$203	$447	$659	$496	$123	$129
Vermont	$269	$192	$651	$679	$551	$179	$187
Virginia	$214	$153	$307	$545	$458	$84	$88

TABLE 26: OPERATING COST OF EQUIPMENT TYPES AT SAMPLE "SMALL" UTILITY/CO-OP ELECTRIC - SAMPLE "SMALL" UTILITY/CO-OP GAS – 2022-2023

Equipment Type	Methane Gas Storage WH	Methane Gas Tankless WH	Electric Resistance Storage WH	Propane Storage WH	Fuel Oil Storage WH	Electric 240V HPWH	Electric 120V HPWH
Connecticut	$354	$254	$410	$668	$500	$113	$118
Delaware	$214	$154	$437	$559	$502	$120	$126
District of Columbia	$228	$163	$336	$532	$460	$92	$97
Maine	$344	$247	$562	$662	$544	$154	$162
Maryland	$161	$115	$339	$564	$488	$93	$98
Massachusetts	$362	$260	$359	$643	$519	$99	$103
New Hampshire	$351	$251	$601	$729	$562	$165	$173
New Jersey	$153	$109	$471	$570	$508	$129	$136
New York	$326	$233	$592	$640	$562	$163	$170
Pennsylvania	$90	$64	$354	$531	$497	$97	$102
Rhode Island	$283	$203	$1,255	$659	$496	$345	$361
Vermont	$269	$192	$800	$679	$551	$220	$230
Virginia	$124	$89	$315	$545	$458	$87	$91

TABLE 27: ANNUAL ENERGY CONSUMPTION BY EQUIPMENT TYPE (MMBTU)

Equipment Type	Methane Gas Storage WH	Methane Gas Tankless WH	Electric Resistance Storage WH	Propane Storage WH	Fuel Oil Storage WH	Electric 240V HPWH	Electric 120V HPWH
Connecticut	16.4	11.7	10.3	16.4	14.8	2.8	3.0
Delaware	14.8	10.6	9.4	14.8	13.5	2.6	2.7
District of Columbia	14.2	10.2	8.9	14.2	12.9	2.5	2.6
Maine	18.3	13.1	11.5	18.3	16.6	3.2	3.3
Maryland	15.0	10.8	9.5	15.0	13.6	2.6	2.7
Massachusetts	16.6	11.9	10.5	16.6	15.1	2.9	3.0
New Hampshire	17.7	12.7	11.2	17.7	16.1	3.1	3.2
New Jersey	15.5	11.1	9.7	15.5	14.0	2.7	2.8
New York	17.3	12.4	10.9	17.3	15.7	3.0	3.1
Pennsylvania	16.5	11.8	10.4	16.5	14.9	2.9	3.0
Rhode Island	16.2	11.6	10.2	16.2	14.7	2.8	2.9
Vermont	18.0	12.9	11.3	18.0	16.3	3.1	3.3
Virginia	14.9	10.7	9.4	14.9	13.5	2.6	2.7

TABLE 28: PERCENTAGE OF HOMES USING FUEL TYPE FOR RESIDENTIAL WATER HEATING BY STATE (RECS) - 2020

State	Methane Gas	Electric	Propane	Fuel Oil
All homes	48%	46%	3%	2%
Connecticut	38%	37%	3%	21%
Delaware	29%	57%	10%	Q
District of Columbia	46%	52%	Q	Q
Maine	14%	35%	14%	34%
Maryland	39%	57%	Q	Q
Massachusetts	52%	30%	2%	15%
New Hampshire	22%	38%	17%	22%
New Jersey	70%	26%	Q	3%
New York	57%	28%	4%	11%
Pennsylvania	46%	45%	3%	6%
Rhode Island	51%	26%	Q	19%
Vermont	21%	36%	20%	23%
Virginia	33%	63%	4%	Q

Source: EIA RECS Data (2020), https://www.eia.gov/consumption/residential/data/2020/

TABLE 29: AVERAGE ANNUAL ENERGY CONSUMPTION VIA WATER HEATING PER HOUSEHOLD (MMBTU) BY STATE (RECS) - 2020

State	Methane Gas	Electric	Propane	Fuel Oil
All homes	18.2	9.2	16.7	20.0
Connecticut	20.8	7.1	19.7	19.8
Delaware	16.8	10.4	14.4	Q
District of Columbia	15.6	6.8	Q	Q
Maine	17.9	7.7	13.6	21.3
Maryland	18.1	9.7	Q	Q
Massachusetts	19.1	6.9	18.4	21.1
New Hampshire	17.7	7.9	18.4	20.3
New Jersey	23.3	7.5	Q	20.0
New York	19.5	7.2	17.1	19.8
Pennsylvania	17.5	10.4	20.6	18.4
Rhode Island	21.5	6.8	Q	19.0
Vermont	19.7	9.0	16.7	20.9
Virginia	19.1	10.8	19.1	Q

Source: EIA RECS Data (2020), https://www.eia.gov/consumption/residential/data/2020/

TABLE 30: RESIDENTIAL ENERGY CONSUMPTION SURVEY (RECS): REGION DEFINITIONS

RECS Region	State
New England	Connecticut
	Maine
	Massachusetts
	New Hampshire
	Rhode Island
	Vermont
Middle Atlantic	New Jersey
	New York
	Pennsylvania
South Atlantic	Delaware
	District of Columbia
	Maryland
	Virginia

Source: EIA RECS Data (2020), https://www.eia.gov/consumption/residential/data/2020/

TABLE 31: AVERAGE ANNUAL ENERGY CONSUMPTION VIA WATER HEATING PER HOUSEHOLD (MMBTU) BY REGION (RECS) - 2020

State	Methane Gas	Electric	Propane	Fuel Oil
New England	19.6	7.2	17.3	20.5
Middle Atlantic	20.0	8.6	18.4	19.5
South Atlantic	16.9	9.4	15.2	21.4

Source: RECS Data (2020), Tables CE 4.6 and CE 4.7, https://www.eia.gov/consumption/residential/data/2020/

TABLE 32: PERCENTAGE OF HOMES USING FUEL TYPE FOR RESIDENTIAL WATER HEATING BY REGION (RECS) - 2020

State	Methane Gas	Electric	Propane	Fuel Oil
New England	41.3%	32.9%	6.0%	19.7%
Middle Atlantic	56.3%	32.9%	3.1%	7.7%
South Atlantic	24.1%	73.2%	2.4%	0.3%

Source: RECS Data (2020), Tables HC 8.7 and HC 8.8, https://www.eia.gov/consumption/residential/data/2020/

Appendix D: Population Weighting for RS Means Analysis - 2023

State	City	Population (Most Recent Census Data)	Materials Adjustment	Labor Adjustment	Percent Weighting
CONNECTICUT	BRIDGEPORT	148,377	99.3	114.2	14.9%
CONNECTICUT	BRISTOL	61,330	98.7	114.9	6.2%
CONNECTICUT	HARTFORD	120,686	100.3	115.8	12.2%
CONNECTICUT	MERIDEN	60,242	96.5	113.4	6.1%
CONNECTICUT	NEW BRITAIN	74,396	98.0	114.9	7.5%
CONNECTICUT	NEW HAVEN	138,915	99.4	114.5	14.0%
CONNECTICUT	NEW LONDON	27,980	94.4	113.4	2.8%
CONNECTICUT	NORWALK	91,401	98.9	113.9	9.2%
CONNECTICUT	STAMFORD	136,188	99.0	114.3	13.7%
CONNECTICUT	WATERBURY	115,016	98.9	114.7	11.6%
CONNECTICUT	WILLIMANTIC	18,669	98.8	113.6	1.9%
D.C.	D.C.		102.2	88.6	100.0%
DELAWARE	DOVER	39,421	101.7	107.3	28.0%
DELAWARE	NEWARK	30,622	100.1	107.3	21.7%
DELAWARE	WILMINGTON	70,893	101.7	107.8	50.3%
MAINE	AUGUSTA	18,896	100.7	82.4	9.2%
MAINE	BANGOR	31,740	95.7	83.1	15.4%
MAINE	BATH	8,768	93.5	80.9	4.3%
MAINE	HOULTON	5,763	93.2	80.7	2.8%
MAINE	KITTERY	9,846	92.3	81.2	4.8%
MAINE	LEWISTON	37,127	97.0	84.4	18.1%
MAINE	MACHIAS	2,072	93.1	80.8	1.0%
MAINE	PORTLAND	68,409	99.2	86.6	33.3%
MAINE	ROCKLAND	7,011	92.4	80.9	3.4%
MAINE	WATERVILLE	15,826	93.4	80.8	7.7%
MARYLAND	ANNAPOLIS	40,807	100.2	80.3	4.3%
MARYLAND	BALTIMORE	585,693	100.9	83.8	61.7%
MARYLAND	COLLEGE PARK	34,747	95.6	82.1	3.7%
MARYLAND	CUMBERLAND	19,081	94.8	79.8	2.0%
MARYLAND	EASTON	17,097	96.1	69.1	1.8%
MARYLAND	ELKTON	15,820	94.2	78.8	1.7%

State	City	Population (Most Recent Census Data)	Materials Adjustment	Labor Adjustment	Percent Weighting
MARYLAND	HAGERSTOWN	43,552	96.3	84.3	4.6%
MARYLAND	SALISBURY	33,027	96.7	62.0	3.5%
MARYLAND	SILVER SPRING	81,069	95.5	81.2	8.5%
MARYLAND	WALDORF	77,711	96.3	81.1	8.2%
MASSACHUSETTS	BOSTON	675,632	100.3	133.3	38.9%
MASSACHUSETTS	BROCKTON	105,654	97.5	111.2	6.1%
MASSACHUSETTS	BUZZARDS BAY	3,208	91.1	107.8	0.2%
MASSACHUSETTS	FALL RIVER	93,984	97.2	109.5	5.4%
MASSACHUSETTS	FITCHBURG	41,945	92.7	106.7	2.4%
MASSACHUSETTS	FRAMINGHAM	72,381	92.4	115.5	4.2%
MASSACHUSETTS	GREENFIELD	17,763	94.4	103.4	1.0%
MASSACHUSETTS	HYANNIS	14,089	94.1	110.4	0.8%
MASSACHUSETTS	LAWRENCE	89,153	97.8	117.8	5.1%
MASSACHUSETTS	LOWELL	115,550	97.1	119.2	6.7%
MASSACHUSETTS	NEW BEDFORD	101,089	97.0	109.8	5.8%
MASSACHUSETTS	PITTSFIELD	43,935	96.9	99.3	2.5%
MASSACHUSETTS	SPRINGFIELD	155,931	97.9	104.6	9.0%
MASSACHUSETTS	WORCESTER	206,519	97.9	111.9	11.9%
NEW HAMPSHIRE	CHARLESTON	4,907	93.4	81.5	1.5%
NEW HAMPSHIRE	CLAREMONT	13,149	92.9	81.5	4.1%
NEW HAMPSHIRE	CONCORD	44,503	99.3	91.9	13.9%
NEW HAMPSHIRE	KEENE	22,774	93.8	82.1	7.1%
NEW HAMPSHIRE	LITTLETON	6,092	94.3	74.1	1.9%
NEW HAMPSHIRE	MANCHESTER	115,141	99.8	92.9	35.9%
NEW HAMPSHIRE	NASHUA	91,161	99.0	91.8	28.4%
NEW HAMPSHIRE	PORTSMOUTH	22,713	95.4	89.6	7.1%
NEW JERSEY	ATLANTIC CITY	38,561	96.5	130.3	2.9%
NEW JERSEY	CAMDEN	70,996	98.9	130.4	5.3%
NEW JERSEY	DOVER	18,422	94.9	133.7	1.4%
NEW JERSEY	ELIZABETH	134,283	96.2	133.6	10.0%
NEW JERSEY	HACKENSACK	45,633	94.7	133.5	3.4%
NEW JERSEY	JERSEY CITY	286,670	96.6	133.5	21.4%
NEW JERSEY	LONG BRANCH	32,434	94.5	131.4	2.4%
NEW JERSEY	NEW BRUNSWICK	55,998	97.7	132.9	4.2%

State	City	Population (Most Recent Census Data)	Materials Adjustment	Labor Adjustment	Percent Weighting
NEW JERSEY	NEWARK	305,344	100.4	134.5	22.8%
NEW JERSEY	PATERSON	156,661	97.5	133.7	11.7%
NEW JERSEY	POINT PLEASANT	19,382	97.1	124.5	1.4%
NEW JERSEY	SUMMIT	22,342	95.1	132.7	1.7%
NEW JERSEY	TRENTON	89,661	100.2	130.6	6.7%
NEW JERSEY	VINELAND	60,491	95.7	130.4	4.5%
NEW YORK	ALBANY	100,826	98.8	107.5	1.0%
NEW YORK	BINGHAMTON	47,115	97.5	97.8	0.4%
NEW YORK	BRONX	1,379,946	91.8	165.6	13.0%
NEW YORK	BROOKLYN	2,590,516	101.4	168.1	24.4%
NEW YORK	BUFFALO	276,486	102.4	105.4	2.6%
NEW YORK	ELMIRA	25,852	95.6	98.2	0.2%
NEW YORK	FAR ROCKAWAY	135,919	99.8	169.0	1.3%
NEW YORK	FLUSHING	180,381	99.8	169.0	1.7%
NEW YORK	GLENS FALLS	14,603	92.3	99.2	0.1%
NEW YORK	HICKSVILLE	42,468	99.4	145.1	0.4%
NEW YORK	JAMAICA	133,356	98.6	169.0	1.3%
NEW YORK	JAMESTOWN	28,243	95.5	87.5	0.3%
NEW YORK	KINGSTON	23,916	99.3	121.3	0.2%
NEW YORK	LONG ISLAND CITY	52,075	100.8	169.0	0.5%
NEW YORK	MONTICELLO	7,285	98.3	122.0	0.1%
NEW YORK	MOUNT VERNON	71,714	90.3	140.7	0.7%
NEW YORK	NEW ROCHELLE	82,288	90.9	135.5	0.8%
NEW YORK	NEW YORK	1,694,251	99.6	167.2	16.0%
NEW YORK	NIAGARA FALLS	47,993	96.5	98.0	0.5%
NEW YORK	PLATTSBURGH	19,904	96.1	87.7	0.2%
NEW YORK	POUGHKEEPSIE	32,010	98.7	125.3	0.3%
NEW YORK	QUEENS	2,309,431	99.4	169.0	21.8%
NEW YORK	RIVERHEAD	35,834	100.2	149.7	0.3%
NEW YORK	ROCHESTER	209,352	101.4	98.6	2.0%
NEW YORK	SCHENECTADY	68,809	98.2	107.0	0.6%
NEW YORK	STATEN ISLAND	475,596	92.7	165.5	4.5%
NEW YORK	SUFFERN	11,338	90.3	118.0	0.1%

State	City	Population (Most Recent Census Data)	Materials Adjustment	Labor Adjustment	Percent Weighting
NEW YORK	SYRACUSE	144,451	98.1	99.0	1.4%
NEW YORK	UTICA	64,081	96.2	99.9	0.6%
NEW YORK	WATERTOWN	24,451	97.5	95.9	0.2%
NEW YORK	WHITE PLAINS	59,316	91.7	143.7	0.6%
NEW YORK	YONKERS	208,121	96.3	145.1	2.0%
PENNSYLVANIA	ALLENTOWN	125,094	96.8	104.4	3.8%
PENNSYLVANIA	ALTOONA	43,071	93.5	93.3	1.3%
PENNSYLVANIA	BEDFORD	47,418	95.4	86.0	1.4%
PENNSYLVANIA	BRADFORD	59,866	94.0	90.4	1.8%
PENNSYLVANIA	BUTLER	13,176	90.8	94.5	0.4%
PENNSYLVANIA	CHAMBERSBURG	22,172	93.6	81.5	0.7%
PENNSYLVANIA	DOYLESTOWN	8,352	93.0	115.6	0.3%
PENNSYLVANIA	DUBOIS	7,399	95.7	89.9	0.2%
PENNSYLVANIA	ERIE	93,511	93.6	94.3	2.8%
PENNSYLVANIA	GREENSBURG	14,715	95.4	92.4	0.4%
PENNSYLVANIA	HARRISBURG	50,183	98.8	98.0	1.5%
PENNSYLVANIA	HAZLETON	29,993	93.7	87.5	0.9%
PENNSYLVANIA	INDIANA	14,205	94.6	94.4	0.4%
PENNSYLVANIA	JOHNSTOWN	18,091	95.5	93.4	0.5%
PENNSYLVANIA	KITTANNING	3,923	91.2	94.7	0.1%
PENNSYLVANIA	LANCASTER	57,453	92.6	95.7	1.7%
PENNSYLVANIA	LEHIGH VALLEY	376,317	94.2	101.6	11.3%
PENNSYLVANIA	MONTROSE	1,276	93.2	88.3	0.0%
PENNSYLVANIA	NEW CASTLE	21,532	90.9	95.0	0.6%
PENNSYLVANIA	NORRISTOWN	35,795	95.4	117.6	1.1%
PENNSYLVANIA	OIL CITY	9,459	90.8	89.7	0.3%
PENNSYLVANIA	PHILADELPHIA	1,567,258	100.5	137.6	47.1%
PENNSYLVANIA	PITTSBURGH	302,898	100.1	103.2	9.1%
PENNSYLVANIA	POTTSVILLE	13,338	92.4	88.0	0.4%
PENNSYLVANIA	READING	94,858	97.9	99.3	2.9%
PENNSYLVANIA	SCRANTON	75,848	97.7	94.3	2.3%
PENNSYLVANIA	STATE COLLEGE	40,745	93.5	95.6	1.2%
PENNSYLVANIA	STROUDSBURG	5,888	93.7	95.4	0.2%
PENNSYLVANIA	SUNBURY	9,587	93.2	84.6	0.3%

State	City	Population (Most Recent Census Data)	Materials Adjustment	Labor Adjustment	Percent Weighting
PENNSYLVANIA	UNIONTOWN	9,689	94.6	95.7	0.3%
PENNSYLVANIA	WASHINGTON	13,483	94.5	98.3	0.4%
PENNSYLVANIA	WELLSBORO	3,441	94.4	84.6	0.1%
PENNSYLVANIA	WESTCHESTER	19,531	96.3	116.1	0.6%
PENNSYLVANIA	WILKES-BARRE	44,261	93.4	93.5	1.3%
PENNSYLVANIA	WILLIAMSPORT	27,403	91.6	91.0	0.8%
PENNSYLVANIA	YORK	44,845	94.8	93.7	1.3%
RHODE ISLAND	NEWPORT	24,684	96.3	109.9	11.5%
RHODE ISLAND	PROVIDENCE	189,563	100.1	110.6	88.5%
VERMONT	BELLOWS FALLS	2,770	92.6	86.7	2.5%
VERMONT	BENNINGTON	15,312	92.9	83.5	14.1%
VERMONT	BRATTLEBORO	12,106	93.2	86.7	11.1%
VERMONT	BURLINGTON	44,595	99.7	81.3	41.0%
VERMONT	GUILDHALL	256	92.9	76.4	0.2%
VERMONT	MONTPELIER	8,023	97.1	83.7	7.4%
VERMONT	RUTLAND	15,695	96.7	80.7	14.4%
VERMONT	ST. JOHNSBURY	7,388	94.0	76.3	6.8%
VERMONT	WHITE RIVER JCT.	2,528	93.9	76.7	2.3%
VIRGINIA	ALEXANDRIA	155,525	99.7	81.2	9.7%
VIRGINIA	ARLINGTON	234,000	100.1	79.9	14.6%
VIRGINIA	BRISTOL	16,975	97.1	57.2	1.1%
VIRGINIA	CHARLOTTESVILLE	45,373	98.1	68.2	2.8%
VIRGINIA	CULPEPER	20,764	97.6	78.3	1.3%
VIRGINIA	FAIRFAX	24,835	98.0	80.9	1.5%
VIRGINIA	FARMVILLE	7,473	96.4	63.1	0.5%
VIRGINIA	FREDERICKSBURG	28,757	97.4	76.2	1.8%
VIRGINIA	GRUNDY	849	97.1	60.5	0.1%
VIRGINIA	HARRISONBURG	51,158	97.7	72.3	3.2%
VIRGINIA	LYNCHBURG	79,287	97.5	66.9	4.9%
VIRGINIA	NEWPORT NEWS	184,306	98.7	67.2	11.5%
VIRGINIA	NORFOLK	232,995	100.7	66.9	14.5%
VIRGINIA	PETERSBURG	33,394	96.8	68.7	2.1%
VIRGINIA	PORTSMOUTH	97,029	97.9	65.2	6.1%
VIRGINIA	PULASKI	8,904	96.8	66.5	0.6%

State	City	Population (Most Recent Census Data)	Materials Adjustment	Labor Adjustment	Percent Weighting
VIRGINIA	RICHMOND	229,395	98.8	69.4	14.3%
VIRGINIA	ROANOKE	97,847	100.5	66.2	6.1%
VIRGINIA	STAUNTON	25,904	97.6	65.2	1.6%
VIRGINIA	WINCHESTER	27,936	97.6	72.6	1.7%

Appendix E: Summary Cost Table

Below is a cost summary for each state for HPWHs with and without a panel upgrade, and for a baseline efficiency methane gas water heater. Operating costs were calculated at EIA state average rates. The total first year cost for each unit is provided as well.

Summary Table

		120V Heat Pump Storage Water Heater	240V Heat Pump Storage Water Heater		Methane Gas Storage Water Heater
				With Panel Upgrade	
Connecticut	Equipment Cost	$2,600	$1,816	$1,816	$498
	Install Cost	$873	$1,505	$4,110	$413
	Panel Upgrade Cost			$2,605	
	Operating Cost - EIA Avg.	$159	$152	$152	$289
	Total First Year Cost	$3,632	$3,473	$6,078	$1,201
Delaware	Equipment Cost	$2,666	$1,862	$1,862	$511
	Install Cost	$820	$1,414	$3,861	$388
	Panel Upgrade Cost			$2,447	
	Operating Cost - EIA Avg.	$83	$79	$79	$214
	Total First Year Cost	$3,568	$3,355	$5,802	$1,114
District of Columbia	Equipment Cost	$2,688	$1,878	$1,878	$515
	Install Cost	$675	$1,165	$3,180	$320
	Panel Upgrade Cost			$2,016	
	Operating Cost - EIA Avg.	$97	$92	$92	$228
	Total First Year Cost	$3,460	$3,135	$5,150	$1,063
Maine	Equipment Cost	$2,549	$1,781	$1,781	$489
	Install Cost	$640	$1,103	$3,012	$303
	Panel Upgrade Cost			$1,909	
	Operating Cost - EIA Avg.	$136	$129	$129	$365
	Total First Year Cost	$3,324	$3,013	$4,922	$1,156
Maryland	Equipment Cost	$2,608	$1,822	$1,822	$500
	Install Cost	$625	$1,078	$2,943	$296
	Panel Upgrade Cost			$1,865	
	Operating Cost - EIA Avg.	$92	$88	$88	$246
	Total First Year Cost	$3,325	$2,987	$4,852	$1,042
Massachusetts	Equipment Cost	$2,583	$1,804	$1,804	$495
	Install Cost	$912	$1,573	$4,295	$432
	Panel Upgrade Cost			$2,722	
	Operating Cost - EIA Avg.	$168	$161	$161	$327
	Total First Year Cost	$3,663	$3,538	$6,260	$1,254
New Hampshire	Equipment Cost	$2,585	$1,806	$1,806	$495
	Install Cost	$690	$1,189	$3,247	$327
	Panel Upgrade Cost			$2,058	
	Operating Cost - EIA Avg.	$164	$156	$156	$351
	Total First Year Cost	$3,438	$3,151	$5,209	$1,172
New Jersey	Equipment Cost	$2,571	$1,796	$1,796	$493
	Install Cost	$1,014	$1,748	$4,772	$480
	Panel Upgrade Cost			$3,025	
	Operating Cost - EIA Avg.	$115	$110	$110	$187
	Total First Year Cost	$3,699	$3,653	$6,678	$1,159
New York	Equipment Cost	$2,588	$1,808	$1,808	$496
	Install Cost	$1,216	$2,096	$5,725	$576
	Panel Upgrade Cost			$3,628	
	Operating Cost - EIA Avg.	$148	$141	$141	$272
	Total First Year Cost	$3,952	$4,046	$7,674	$1,344
Pennsylvania	Equipment Cost	$2,576	$1,800	$1,800	$494
	Install Cost	$891	$1,537	$4,197	$422
	Panel Upgrade Cost			$2,660	
	Operating Cost - EIA Avg.	$87	$83	$83	$237
	Total First Year Cost	$3,555	$3,420	$6,080	$1,153
Rhode Island	Equipment Cost	$2,621	$1,831	$1,831	$502
	Install Cost	$843	$1,453	$3,967	$399
	Panel Upgrade Cost			$2,514	
	Operating Cost - EIA Avg.	$158	$151	$151	$283
	Total First Year Cost	$3,622	$3,435	$5,949	$1,184
Vermont	Equipment Cost	$2,543	$1,776	$1,776	$487
	Install Cost	$625	$1,078	$2,943	$296
	Panel Upgrade Cost			$1,865	
	Operating Cost - EIA Avg.	$156	$149	$149	$269
	Total First Year Cost	$3,324	$3,003	$4,868	$1,052
Virginia	Equipment Cost	$2,606	$1,821	$1,821	$499
	Install Cost	$542	$935	$2,554	$257
	Panel Upgrade Cost			$1,619	
	Operating Cost - EIA Avg.	$72	$69	$69	$231
	Total First Year Cost	$3,221	$2,825	$4,444	$988