Residential Technology and Fuel Switching Costs

March 2026

Independent Statistics and Analysis
U.S. Energy Information Administration

www.eia.gov
U.S. Department of Energy
Washington, DC 20585

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Residential Technology and Fuel Switching Costs

Energy used in the residential sector provides a wide range of services, including heating, cooling, lighting, refrigeration, cooking, and numerous other end uses. The U.S. Energy Information Administration (EIA) conducts a household buildings-sector survey—the *Residential Energy Consumption Survey*—that provides information on the equipment stock and energy consumption within existing buildings. However, this survey does not directly gather other information that we need to project future energy consumption, such as costs associated with switching equipment between different technologies and fuels.

The Residential Demand Module of the National Energy Modeling System uses equipment cost and performance technology menus that represent competing options for most of the major end uses. The contracted report in Appendix A and an associated Microsoft Excel workbook provide incremental switching costs that include all necessary removal and decommissioning activities (such as sealing fuel lines or ducts) and internal connections required for fuel supply and operational needs when replacing major end-use equipment with a different technology or fuel than previously installed. This installation may involve additional ductwork, plumbing, electrical work, etc. Previous editions of the *Annual Energy Outlook* (AEO) used similar contracted reports.

Appendix A's report highlights the objective, assumptions, and methodology used to characterize technology and fuel switching costs for major residential space heating, water heating, cooking, and clothes drying equipment in our AEO Counterfactual Baseline case projections.[1] The associated Microsoft Excel workbook contains all national and census division switching costs and computations in 2022 dollars.

When referencing the contracted report in Appendix A or any related workbook data, you should cite it as a report by Jack Faucett Associates, prepared for the U.S. Energy Information Administration.

[1] In addition to the Counterfactual Baseline case, we also develop sensitivities to explore different assumptions for the cost and performance of future technologies. Unless specified otherwise, Counterfactual Baseline case assumptions apply to side cases.

APPENDIX A

Residential End Uses: Technology and Fuel Switching Costs for a Select Group of Residential Equipment Classes

Task Order#89303024FEI400155 – Milestone 6: Final Report and Workbook

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April 2025 | Bethesda, MD 20814

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Residential Technology and Fuel Switching Cost Data

Executive Summary

- This report summarizes key methods and assumptions for the estimation of residential technology and fuel switching costs for select switching scenarios
- Characterized residential energy end use categories include space heating, water heating, cooking, and clothes drying
- The report includes an Excel workbook file that provides all methods, assumptions, data, sources, computations, aggregations, and other information used in the switching cost estimation process
- The workbook provides switching costs for the national level and by census division, all in 2022 dollars

Objective

EIA's primary objective with this project is to enhance fuel and technology switching costs estimates for some residential equipment

- EIA seeks to identify costs associated with switching fuels and equipment types for residential space heating, water heating, cooking, and clothes drying
- Switching costs are the material and labor expenses — such as ductwork, piping, exhaust, and removal costs — in addition to the equipment itself, but exclude standard installation costs for new equipment
- Costs associated with bringing natural gas service to the home are not included
- Costs may be specific to the installed equipment, such as standard or high-efficiency or special venting for high-temperature applications such as tankless water hearers
- This study uses national-average costs for national estimates and applicable census division detail or other special consideration by census divisions

Categories of Technology and Fuel Switching Cost

- *Appliance Costs* include the equipment or appliance cost itself and delivery of the primary appliance and accessories
- *Standard Installation Costs* include the costs for positioning, foundation/securement, and short-run connections (under 3 feet) to essential apparatus, such as a furnace-to-air handler attachment or adjacent connections. *Standard Installation Costs* are not included in *Switching Costs* in this study
- *Switching Costs* include all necessary removal and decommissioning activities (such as sealing fuel lines or ducts), and internal connections required for fuel supply and operational needs when replacing equipment with a different technology or fuel than previously installed. This may involve additional ductwork, plumbing, electrical work, etc.. Notable exceptions to include in *Switching Costs* will cover connections to exterior storage tanks and ground loops for ground-source heat pumps (GSHPs)
- Generally,

  Switching Costs = *Total Installed Costs* minus *Appliance Costs* minus *Standard Installation Costs*

Methodology

General Methodology for Technology and Fuel Switching Cost Estimation

- Create a technology/fuel switching matrix. This matrix should include current and alternative technologies for various fuel types and should facilitate the exploration of all potential technology/fuel-switching options
- Evaluate technology/fuel-switching options to understand the technological and physical requirements for each
- Identify the activities and costs associated with each switching scenario, which may involve installing new internal fuel lines, setting up new electrical wiring, and decommissioning existing fuel tanks (these are examples and not an exhaustive list). Determine the unit costs for each switching activity
- Match the activities and required materials with their corresponding unit costs and calculate the total switching cost for each fuel/technology switching scenario

Process to Estimate Technology and Fuel Switching Costs

A – Develop technology and fuel switching cost matrix	B – Identify technology or fuel switching options	C – Identify each scenario's line-item activities	D – Estimate cost of line items required for each scenario	E – Estimate switching cost for each census division
Key Activities: • Identify typical options for mid- and long-term projections for selected residential appliances and fuels • Collect information on infrastructure needed to switch between technologies and fuels • Develop switching scenarios	Key Activities: • Review literature on the activities required beyond standard installation, for switching technology or fuel • Identify census division differences in options or costs	Key Activities: • Identify each activity required beyond standard installation • Identify all non-standard installation materials and trade skills required in each switching scenario	Key Activities: • For each scenario, identify national cost estimates for each activity or build costs through assumptions about the skilled labor required, the necessary materials, and any required removal and disposal of the old equipment	Key Activities: • Collect information on any census division effects that might impact the cost of switching in each state and census division • Collect data on labor rates and sales taxes for required skills to estimate cost differences by state and census division
Planning	***Data Collection***	***Computation***	***Results***	

Several assumptions are made to obtain national and census division switching cost estimates

- Cost estimates assume the previous and new fuel systems are not for one appliance only; however, fuel choices are independent as in NEMS. Cooking, clothes drying, water heating, and space heating fuels will often be switched together
- The high costs of connecting fuels to outdoor storage tanks and removing/ decommissioning those tanks will be incorporated into space heating only. In other cases, the incremental costs of switching the cooking, clothes drying, and water heating fuels will typically be smaller, and those smaller costs are captured
- Existing chimneys or flues that are not remaining in-service are typically abandoned in place
- In most cases, ductwork not reused will be closed off instead of removed

Identifying Technology and Fuel Switching Cost Scenarios

- The cost estimates are driven by a series of technology and fuel choice decisions represented in the end use matrix
- Current literature on advances in energy efficient and cost-effective residential technologies has been reviewed to determine technology or fuel switching scenarios
- Each energy end use—space heating, water heating, cooking, and clothes drying — technology and fuel options are represented in the end-use matrices
- For each switch cell in the matrix, the switching cost line items are identified

Identification of Technology/Fuel Switching Scenarios and Customizability

- Some scenarios are not costed, specifically:
  - Like-to-like (that is, some scenarios of to/from the same technology and/or fuel) are not included as, by definition, they are not switching technology or fuel
  - In census divisions where specific technologies or fuels are not used based on RECS. If the dater user wanted to include these, the matrices are customizable, and the user could adapt them easily
  - A few technology/fuel switching scenarios are eliminated as being extremely unlikely or non-existent, such as an instantaneous solar or distillate fuel oil water heaters.

Technology and Fuel Switching Cost Line-Item Categories Potentially Included in Selected Scenario Cost Estimates

- Electrical Line 240V
- Electrical Line 120V
- Fuel Line
- Decommissioning / Removal
- Permits and Inspections
- Ductwork
- Duct Closure
- Standard Efficiency B-Venting
- High Efficiency Condensing PVC Venting
- Average Venting
- Ventilation Modifications
- Piping and Hydronic System
- Fuel Lines and Pipes to Outdoor Tanks
- Electrical Wiring to Air Handlers
- Refrigerant Distribution System
- Horizontal Loop System
- Air Handler Connections

Switching Scenario Line-Item Cost Category

For each technology or fuel switching scenario, a set of required activities is identified that are not included with the appliance cost or within the standard installation cost. A scenario line-item cost matrix is developed for each end use indicating the line items included, such as those in the example below. *Note: The matrix below is for illustrative purposes only and a complete set of line-item activity matrices are in the Excel workbook*

Residential Space Heating Switching Subcomponents: Standard Fuels and Technologies Including Average Venting Switching Costs					
FROM / TO		Switching From Fuel or Technology			
		Fuel	Natural Gas	Distillate Fuel Oil/Kerosene	Natural Gas
Switching To Fuel or Technology	Fuel	Technology	Furnaces	Furnaces	Boilers
	Natural Gas	Furnaces		OilFiredFurnaceDemo NaturalGasFurnaceVenting GasFiredFurnacesPermit GasLine	GasFiredBoilerDemo GasFiredFurnacesPermit Ductwork NaturalGasFurnaceVenting
	Distillate Fuel Oil/Kerosene	Furnaces	FuelLine OilFiredFurnacesPermit GasFiredFurnaceDemo OilFurnacesVenting		Ductwork OilFiredFurnacesPermit GasFiredBoilerDemo OilFurnacesVenting FuelLine

Census Division Cost Differences

Census division costs vary for labor and materials requirements as well as associated sales taxes and markup for each cost category

- Specific Example: Heating detailed costs formula for labor, materials, and other costs are national and census division-specific:
  - Scenario Labor & Material Cost = [(Labor Hours x Labor Category Wage) x (1 + Labor Sales Tax Rate + Benefits Percentage) x (1 + Labor Markup Percent)] + [Material Cost x (1 + Material Sales Tax) x (1 + Material Markup Percent)] + Decommissioning Costs + Permit Fees
    - Wages, sales tax rates, sales tax incidence on labor, and benefits or inspection fees vary by census
    - Different heating types have different decommissioning costs, material, and labor requirements as well as markup rates

This is the breakdown of costs for converting from a typical heating system type to another type of heating system. Other technology and fuel switching scenarios have a similar breakdown.

Census division cost variation can stem from different labor rates, sales tax treatments, and potential equipment requirements

Census Division Trade Labor Rates

Census Division Average Hourly Wages, 2022 $				
Census Division	Plumber Weighted Average Wage	Electrician Weighted Average Wage	HVAC Weighted Average Wage	Total Benefits Percent of Wage
New England	$36.93	$34.35	$31.57	31%
Middle Atlantic	$39.07	$36.97	$30.12	31%
East North Central	$35.37	$33.19	$28.30	31%
West North Central	$32.57	$31.43	$28.35	31%
South Atlantic	$26.22	$26.93	$25.39	28%
East South Central	$26.31	$26.44	$23.52	28%
West South Central	$26.73	$26.08	$24.98	27%
Mountain	$29.32	$28.54	$26.46	29%
Pacific	$36.39	$39.53	$32.52	29%
National	$31.88	$31.43	$27.67	29%
National Wage Index	2.3%	3.7%	3.6%	

Census Division Sales Tax Rates

Weighted Average Sales Tax Rate by Census Division		
Census Division	Labor	Materials
New England	2.02%	5.54%
Middle Atlantic	1.69%	4.96%
East North Central	3.33%	6.76%
West North Central	5.51%	7.35%
South Atlantic	1.46%	6.31%
East South Central	4.83%	7.80%
West South Central	9.49%	9.49%
Mountain	4.32%	7.47%
Pacific	1.36%	8.51%
National Average	3.46%	7.16%

Wage rate shown is average of state wage, weighted by construction trade employment in census division. Sales tax rate is based on average state rate, weighted by state population in the census division. BLS, 2022 $ and various state tax publications.

Example of Line Item and Total Cost for a Technology and Fuel Switching Scenario, National Average Cost 2022 $

Switching from Electric Storage to Natural Gas Instantaneous System					
Average Venting Costs		**Standard to High-Efficiency Venting**		**High-Efficiency to Standard Venting**	
Permit - Gas	$50	Permit - Gas	$50	Permit - Gas	$50
Permit - HVAC	$50	Permit - HVAC	$50	Permit - HVAC	$50
Gas Line Installation	$1,008	Gas Line Installation	$1,008	Gas Line Installation	$1,008
GasInstVentAVE	$1,837	GasInstVentPVC	$2,450	GasInstVentSTD	$1,335
Electrical Line 120V	$659	Electrical Line 120V	$659	Electrical Line 120V	$659
Permit - Electrical	$80	Permit - Electrical	$80	Permit - Electrical	$80
Cost	**$3,684**		**$4,297**		**$3,182**

Note: In this example, switching cost is driven by alternative venting requirements.

Space Heating

Additional Assumptions: Space Heating Technology and Fuel Switching

- Distillate fuel oil/kerosene or propane: the matrix uses costs of above-ground tank removal and decommissioning. Installation of above-ground fuel tanks are considered a standard cost and not calculated here
- Wood stove costs are estimated because they better represent the wood heating market than wood furnaces
- Chosen technologies are characterized based on the report posted here: https://www.eia.gov/analysis/studies/buildings/equipcosts/
- All services that require 120V will need a new dedicated line if there is not one previously, even if there is a 240V connection
- When switching to natural gas, the homeowner would be responsible for the installation of a new meter; often the local gas company will cover it as a one-time convenience waiver
- We assume the electrical service panel is at least 200 amps and does not require an upgrade, when switching to electric heat. If an upgrade to 200 amps is needed (such as some homes in California), there will be an additional cost. This includes electric resistance furnaces, electric resistance unit heaters, and all types of heat pumps. The cost to upgrade has been calculated and can be added (optionally) by the user

Water Heating

Technology and Fuel Switching Cost Coverage for Water Heating

- Not all potential technology and fuel switching cost scenarios are presented
- Traditional hot water tank systems can be replaced with higher efficiency instantaneous delivery water heating systems, but these are more expensive than traditional storage unit replacements and once a tankless system is in place it would be very unusual to go back to a traditional tank system
- Switching cost matrices are broken up by technology, instantaneous and storage as follows:
  - From storage to instantaneous; fuel and technology switch
  - From storage to storage; fuel switch only
  - From instantaneous to instantaneous; fuel switch only
- Unit switching cost for all options varies depending on the venting system requirements: average, high-efficiency (direct), and standard-efficiency (B-Vent)

Additional Assumptions: Water Heating Technology and Fuel Switching (1 of 3)

- Cost estimates assume that both the existing and new fuel systems support water heating and space heating, rather than just water heating. In most scenarios, the transition includes switching fuels for both water heating and space heating simultaneously. As a result, the incremental costs of switching water-heating fuel are lower and accounted for in this analysis
- Costs related to fuel lines for outdoor storage tanks, as well as the decommissioning and removal of fuel tanks, are included in the space heating system costs
- Cost estimates assume that both the existing and new fuel systems support both water heating and space heating, rather than just water heating
- As a result, the incremental costs of switching water-heating fuel are lower and accounted for in this analysis

Additional Assumptions: Water Heating Technology and Fuel Switching (2 of 3)

- Instantaneous water heating systems may offer improved energy efficiency, but may be cost prohibitive as a replacement substitute for a high-efficiency gas or electric tank system
- A backup system for water heating is usually present for solar water heaters. An assumption here is a new 240V line is added to the breaker panel, if switching from other than electric
- Heat pump water heater switching costs are assumed to be the same as electric storage water heating
- Many homes have existing multiple fuel systems for space heating and water heating equipment (for example, a natural gas furnace and heat pump water heater, or a distillate fuel oil furnace and an electric resistance storage water heater)
- A decision to replace a space heating fuel source may include replacement of other end use sources

Additional Assumptions: Water Heating Technology and Fuel Switching (3 of 3)

- A January 27, 2023, Consumer Reports article evaluates the cost and energy efficiency of new highly efficient gas and electric water heaters and of tankless (some may include small tanks of about 5 gallons) instantaneous water heaters: https://www.consumerreports.org/appliances/water-heaters/buying-guide/
  - The article finds homeowners typically replace their old water heater with one of the same type and fuel—natural gas or electricity. Consumer Reports indicates switching from a tank water heater to a tankless unit can be expensive because it could require that the home plumbing or electrical system be retrofit
  - The article reports that tankless units may be the most efficient option for new construction or home expansion
- It is assumed that the replacement tankless unit will include a water filtration system. If it does not, this could increase installation cost

Cooking

Additional Assumptions: Cooking Stoves Technology and Fuel Switching

- The previous and new fuel systems are not for cooking only
- The cooking and space heating fuels are typically switched simultaneously
- In these scenarios, the smaller incremental switching costs are captured here
- Costs of fuel lines to outdoor storage tanks, or decommissioning/removal of fuel tanks are incorporated in space heating costs
- Venting costs for cooking are not included in this project's scope

Clothes Drying

Additional Assumptions: Clothes Dryer Technology and Fuel Switching

- The previous and new fuel systems are not for clothes drying only. Typically, there is simultaneous switching of the clothes dryer and space heating fuels. The smaller incremental costs of clothes drying fuel switching are captured here. Costs of fuel lines to outdoor storage tanks, or decommissioning/removal of fuel tanks, are incorporated in heating
- In most cases, electric, natural gas, and propane dryers can use the same venting system for exhausting moisture and lint. However, there are some key considerations and requirements to ensure safety and proper functionality. For switching costs, it is assumed that they can be reused if switching from a vented system to another vented system

Technology and Fuel Switching Workbook

Technology and Fuel Switching Workbook

- This report includes an unprotected multi-sheet Microsoft Excel workbook containing all national and census division switching costs and computations in 2022 dollars
- Only public source information is used to build the scenarios, to identify the cost component line items, and to estimate the cost of each line item
- References for all data incorporated in cost calculations are provided in the workbook along with a reference identification and link that was operable at the time the workbook was developed

Workbook Table of Contents for Key Tabs

- All workbook tabs are listed in the Table of Contents, a brief description, and a hot link to the tab. Some of the key tabs include:
  - **Methodology** – A brief description of the methods applied to estimate the technology and fuel switching cost for each scenario
  - **National Average Costs** – National switching costs for each scenario for each residential energy end-use area
  - **Census Division Costs** – Separate switching costs for each end use and switching scenario for the nine U.S. census divisions
  - **End use tabs** – Each end use includes multiple tabs walking the user through the scenario development and cost estimation
  - **Supporting tabs** – Numerous tabs provide data, information, and calculations for items such as labor rates, sales taxes, markup rates, decommission rates, and other areas