NATIONAL LABORATORY OF THE ROCKIES

ResStock Measure Documentation: Propane Furnace 95% AFUE and Fuel Oil Furnace 88% AFUE

Katelyn Stenger, Philip White, Andrew Parker, Jeff Maguire, Joe Robertson, and Sinoun Phoung

National Laboratory of the Rockies

The National Laboratory of the Rockies is a national laboratory of the U.S. Department of Energy, Office of Critical Minerals and Energy Innovation, operated under Contract No. DE-AC36-08GO28308.

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Technical Report
NLR/TP-5500-96635
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Author contributions: Katelyn Stenger developed the methodology, and performed data acquisition, analysis, interpretation, writing, and revisions of the report. Philip White conducted writing and analysis. Andrew Parker conceptualized the overall design of the research question, applicability of the upgrade, administered the project and resources, and supervised. Jeff Maguire and Joe Robertson conducted data interpretation, methodology refinement, and revisions. Sinoun Phoung conducted data analysis and visualization. Jes Brossman provided detailed technical revisions.

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List of Acronyms

AFUE	annual fuel utilization efficiency
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
DOE	U.S. Department of Energy
HVAC	heating, ventilation, and air conditioning

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Executive Summary

The goal of this work is to develop energy efficiency, demand flexibility, and other retrofit end-use load shapes (electricity, gas, propane, or fuel oil) that cover a majority of the high-impact, market-ready (or nearly market-ready) measures. “Measures” refers to retrofits that can be applied to buildings during modeling.

An “end-use savings shape” is the difference in energy consumption between a baseline building and a building with an energy efficiency, demand flexibility, or other retrofit measure applied. It results in a time-series profile that is broken down by end use and fuel (electricity or on-site gas, propane, or fuel oil use) at each time step.

ResStock™ is a highly granular, physics-based, bottom-up model that uses multiple data sources, statistical sampling methods, and advanced building energy simulations to estimate the annual subhourly energy consumption of the residential building stock across the United States. The baseline model intends to represent the U.S. residential building stock as it existed in 2018. Technical documentation for the inputs and assumptions in the baseline building stock model is available in Reyna et al. (2025). Calibration and validation of the baseline model results are available in the final technical report of the End-Use Load Profiles project (Wilson et al 2022).

This documentation focuses on a single end-use savings shape upgrade—Propane Furnace 95% Annual Fuel Utilization Efficiency (AFUE) and Fuel Oil Furnace 88% AFUE.

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ResStock 2025 Release 1 Measure Documentation: Propane and Fuel Oil Furnace

Accessing Results

This documentation covers the "Propane Furnace 95% Annual Fuel Utilization Efficiency (AFUE) and Fuel Oil Furnace 88% AFUE" upgrade methodology and briefly discusses key results. All results can be accessed on the ResStock™ Open Energy Data Initiative End-Use Load Profiles for the U.S. Building Stock data lake and on the Data Viewer at resstock.nlr.gov.

Upgrade Summary

Measure Title	Propane Furnace 95% AFUE and Fuel Oil Furnace 88% AFUE
Measure Definition	Upgrades existing ducted fuel furnaces to high-efficiency units while retaining the current fuel: • If the dwelling heats with **propane**, replace with **95% AFUE** fuel furnace • If the dwelling heats with **fuel oil**, replace with **88% AFUE** fuel furnace.
Applicability	Applies to dwellings that: • Have ducts, and • Do **not** use wood, "other fuel," or have no primary heating fuel, and • Are **not** serviced by disqualifying shared central systems, and • For **propane upgrade:** Currently have a fuel furnace with efficiency less than 95% AFUE • For **fuel oil upgrade:** Currently have a fuel furnace with efficiency less than 88% AFUE. With these applicability constraints, the measure upgrade applies to **5.8%** of the existing dwelling units.
Not Applicable	This upgrade does not apply to: • Dwellings without ducts • Dwellings with primary heating electricity, natural gas, fuel wood, other fuel, or none • Dwellings served by shared central systems • Dwelling whose existing fuel furnace efficiency falls outside the sets noted in "Applicability". These constraints exclude **94.4%** of the dwelling units from receiving this measure upgrade.
Original Release	2025 Release 1: 2025/resstock_amy2018_release_1; 2025/resstock_amy2012_release_1; 2025/release_tmy2_release1
Project Configuration File	https://github.com/NatLabRockies/resstock/blob/sdr_2025_Release_1/project_national/sdr_upgrades_amy2018.yml

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1 Technology Summary

This work examines the technical potential for replacing existing fuel oil and propane furnaces across the U.S. residential building stock—but only in homes where these types of systems are already installed. Though less widespread than natural gas systems, oil and propane furnaces remain common in areas without pipeline gas service, particularly in older and colder climate dwellings. Oil is most common in older or rural buildings in New England and the mid-Atlantic.

1.1 Introduction to Technology

Fuel-fired furnaces—including propane and fuel oil—are used to heat indoor environments. Fuel ignites in the burner, and the flame heats a metal heat exchanger. A blower fan moves air over the heat exchangers, which warms the air. Most furnaces use ducts to distribute heat, while combustion exhaust is vented outside. In comparison, gravity furnaces do exist but are older and not as common; as such in this study, we only model forced air furnaces.

1.2 Efficiency and System Types

Efficiency, measured by annual fuel utilization efficiency (AFUE) is a key feature of furnaces heated by fuel oil or propane. In this measure upgrade, we include propane in the form of liquified petroleum gas and fuel oil—typically number 2 heating oil.

1.2.1 Annual Fuel Utilization Efficiency

AFUE is the standard rated efficiency for how efficiently a furnace converts fuel into heat at rated conditions. The higher the AFUE rating, the more efficient the system is at converting fuel into usable heat. Energy lost through exhaust gases, radiation, and other components decreases efficiency.

AFUE is the total annual heat output divided by the total annual fuel input—on a scale of 0% to 100%. Note that AFUE does not include the electricity used by the air handler blower, combustion blower, ignition system, or controls. ANSI/ASHRAE 103-2022 provides a procedure for determining AFUE of residential central furnaces and boilers, which is a test cycle structured to simulate ordinary heating conditions throughout the year—including seasons (ANSI/ASHRAE 2022).

“Residential furnaces manufactured and distributed in commerce, as defined by 42 U.S.C. 6291(16) must meet the energy conservation standards specified in the Code of Federal Regulations at 10 CFR 430.32” (DOE 2025). 80% AFUE furnaces are the minimum for non-weatherized gas furnaces (i.e., natural gas and propane) manufactured from 2015 through Dec. 18, 2028. After Dec. 18, 2028, the minimum furnace is 95% AFUE. If an investigator would like to understand equipment standard changes over time, a useful approach could blend data from this study with data from the space heating and cooling (circa 2025) upgrade (Stenger, Liu, Wilson, et al. 2025) as well as the natural gas furnace upgrade (Stenger, Liu, White, et al. 2025), which model fuel oil, propane, and natural gas furnaces.

Dwellings upgraded from lower efficiency furnaces often have atmospheric vents. After the upgrade, these will side vent rather than having an atmospheric vent, meaning some dwellings with propane furnace could changes in their infiltration (HPXML 2025). In this study, we model

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a 95% AFUE furnace consuming propane. For dwellings heated with fuel oil, we model an 88% AFUE furnace as a higher-efficiency furnace (AHRI 2025).

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2 Applicability

This measure applies only to homes that currently use fuel oil or propane for space heating and that have existing ducted systems. It upgrades the heating system to a **95% AFUE propane** furnace or an **88% AFUE fuel oil** furnace (matching the home's existing fuel). When a dwelling's furnace efficiency is greater than the upgrade, the home does not receive the upgrade.

Approximately 5.8% of the U.S. housing stock qualifies. Details in the application logic are in Table 1.

Table 1. Summarized Apply Logic for Fuel Oil or Propane Furnace Upgrade Package

Heating Fuel	HVAC Shared Efficiencies	HVAC Has Ducts	Propane Fuel Furnace	Fuel Oil Furnace	Stock Saturation (%)
Fuel Oil	None	Yes	No	Yes*	3.03%
		No	No	No	1.15%
	Fan Coil Cooling Only; Fan Coil Heating and Cooling, Fuel; Fan Coil Heating and Cooling, Electricity; Boiler Baseboards Heating Only, Fuel; Boiler Baseboards Heating Only, Electricity	Any	No	No	0.50%
Propane	None	Yes	Yes*	No	3.74%
		No	No	No	0.62%
	Fan Coil Cooling Only; Fan Coil Heating and Cooling, Fuel; Fan Coil Heating and Cooling, Electricity; Boiler Baseboards Heating Only, Fuel; Boiler Baseboards Heating Only, Electricity	Any	No	No	0.90%
Electric, Natural Gas, Other Fuel, None	Any	Any	No	No	90.88%

*The upgrade is not applied when the dwelling's existing furnace efficiency is greater than the upgrade's furnace efficiency, accounting for <1% of dwellings.

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3 Modeling Approach

This section outlines how propane and fuel oil furnace upgrades are modeled in ResStock using the OpenStudio-HPXML workflow. ResStock assigns each dwelling unit a set of building characteristics, including heating system type, efficiency, and fuel source, based on probabilistic sampling logic informed by national housing stock data. Furnaces are modeled as forced-air heating systems that distribute heat through ductwork. The primary variable representing an upgrade is AFUE, which characterizes how efficiently the furnace converts fuel to usable heat over a heating season. Ducts remain unchanged when heating systems are upgraded. ResStock models fuel type (e.g., propane or natural gas) explicitly, influencing energy use calculations. The model assumes consistent operation patterns across households, and scales furnace capacity based on heating load requirements determined by building envelope characteristics and climate zone. While equipment brand and installation quality are not modeled explicitly, the total heating energy demand and fuel consumption are recalculated to reflect the standardized furnace and fuel use.

These probability distributions are sampled to create a synthetic stock where each sample has an assigned option for each characteristic for each dwelling unit to be simulated. ResStock utilizes the OpenStudio-HPXML workflow to translate these dwelling characteristics into building models ready to be simulated via OpenStudio® and EnergyPlus® through the use of an HPXML file. For reference, the state of the OpenStudio-HPXML repository when the ResStock 2025 Release 1 dataset was created can be found here. Assumptions about the oil and propane furnace upgrades that are not explicitly defined in ResStock are taken care of in the BuildResidentialHPXML measure.

3.1 Propane and Fuel Oil Furnaces

In ResStock, building characteristics are translated to OpenStudio-HPXML parameters. Measure upgrades, such as converting or replacing furnaces with higher-efficiency propane or fuel oil systems, are modeled as changes to baseline building characteristics. This section outlines the technical details of how propane and fuel oil furnace upgrades are implemented in the ResStock workflow.

3.1.1 ResStock Inputs

Propane and fuel oil furnaces are modeled as forced-air heating systems serving homes with central ducts. Each upgrade replaces the existing heating system with a furnace that uses either propane or fuel oil, with efficiency defined by a target AFUE level: 88% AFUE for fuel oil heated dwellings and 95% AFUE for propane heated dwellings. These furnaces are modeled assuming that the efficiency is constant at the AFUE and that heating is always available if there is a demand for it. This measure assumes the furnaces are always installed correctly, although models exist in OpenStudio-HPXML to account for issues with installation that may degrade performance. The furnaces supply air at a constant temperature to the ducts. Duct losses are then calculated based on the supply temperature, airflow rate, and duct characteristics using a custom routine in EnergyPlus.

For propane furnaces, the AFUE used here requires a condensing furnace, modeled with a side vent. Lower efficiency equipment often uses a vertical atmospheric vent, as it vents at a higher temperature and can rely on buoyancy. In OpenStudio-HPXML, the type of vent affects the

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infiltration in the home, as atmospheric vents can increase infiltration. This means this upgrade can also decrease infiltration in these homes if they don't have another atmospheric vent for the water heater; see references for more details on when atmospheric flues are modeled (HPXML 2025).

In OpenStudio-HPXML, each central furnace is represented under: "/HPXML/Building/BuildingDetails/Systems/HVAC/HVACPlant/HeatingSystem," with type "Furnace," and a federal minimum efficiency or like-for-like efficiency replacement. OpenStudio-HPXML maps these fields to an OpenStudio Furnace object, setting capacity, efficiency, distribution, and fan characteristics. Below is the input schema support, both required and optional fields.

Table 2. ResStock Argument Values for Central Furnaces

ResStock Argument	Value	Units
Heating System Type	Furnace	-
Heating System Pilot Light Capacity	0	Btu/hr
Heating System Fuel	Propane, Fuel Oil	-
Annual Heating Efficiency	0.95 for Propane, 0.88 for Fuel Oil	AFUE
Fraction Heating Load Served	1	Fraction

3.1.2 Housing Stock Characteristics

HVAC heating types and efficiencies are key characteristics of the housing stock for this upgrade; see Table 3.

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Table 3. Percentage of Households by HVAC Heating Type and Efficiency, and U.S. Census Division

	U.S. Census Division								
HVAC Heating Type & Fuel	East North Central	East South Central	Middle Atlantic	Mountain	New England	Pacific	South Atlantic	West North Central	West South Central
Electricity ASHP	1%	2%	1%	1%	0%	1%	8%	1%	3%
Electricity Baseboard	1%	<1%	1%	<1%	<1%	2%	1%	<1%	1%
Electricity Electric Boiler	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Electricity Electric Furnace	1%	1%	<1%	1%	<1%	1%	5%	1%	3%
Electricity Electric Wall Furnace	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Electricity MSHP	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Electricity Shared Heating	1%	<1%	1%	<1%	<1%	1%	1%	<1%	1%
Fuel Oil Fuel Boiler	<1%	<1%	1%	<1%	<1%	<1%	<1%	<1%	<1%
Fuel Oil Fuel Furnace	<1%	<1%	1%	<1%	1%	<1%	<1%	<1%	<1%
Fuel Oil Fuel Wall/Floor Furnace	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	-
Fuel Oil Shared Heating	<1%	-	<1%	-	<1%	<1%	<1%	-	<1%
Natural Gas Fuel Boiler	<1%	<1%	1%	<1%	<1%	<1%	<1%	<1%	<1%
Natural Gas Fuel Furnace	9%	2%	4%	4%	1%	6%	4%	4%	4%
Natural Gas Fuel Wall/Floor Furnace	<1%	<1%	1%	<1%	<1%	1%	<1%	<1%	<1%

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	U.S. Census Division								
HVAC Heating Type & Fuel	East North Central	East South Central	Middle Atlantic	Mountain	New England	Pacific	South Atlantic	West North Central	West South Central
Natural Gas Shared Heating	1%	<1%	2%	<1%	1%	1%	<1%	<1%	<1%
Propane Fuel Boiler	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Propane Fuel Furnace	1%	<1%	<1%	<1%	<1%	<1%	1%	1%	<1%
Propane Fuel Wall/Floor Furnace	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Propane Shared Heating	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Other Fuel Boiler	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Other Fuel Furnace	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Other Fuel Wall/Floor Furnace	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Other Fuel Shared Heating	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
None	<1%	<1%	<1%	<1%	<1%	1%	<1%	<1%	<1%
Total % of Housing Stock	**15%**	**6%**	**13%**	**7%**	**5%**	**14%**	**20%**	**7%**	**12%**

Natural gas is common across census divisions. Electricity is most prevalent in the South Atlantic, accounting for nearly 14.5% of the U.S. housing stock. Fuel oil is more prevalent in New England and the Middle Atlantic census divisions, which have historically used fuel oil in older and more rural buildings. Propane is used less frequently but is evenly distributed across the U.S. housing stock, as it is primarily used in more rural areas that don't have access to natural gas service.

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4 Results

This current section describes results from 550,000 simulations, of which only 5.7% are applicable.

4.1 Single Model Results

This section analyzes two example dwellings that received upgrades, both of which are modeled with an 80% AFUE fuel furnace in the baseline. Figure 1 shows the annual energy consumption before and after a fuel oil furnace upgrade in a dwelling in Alaska, and Figure 2 shows the annual energy consumption before and after propane furnace upgrade in a dwelling in Montana.

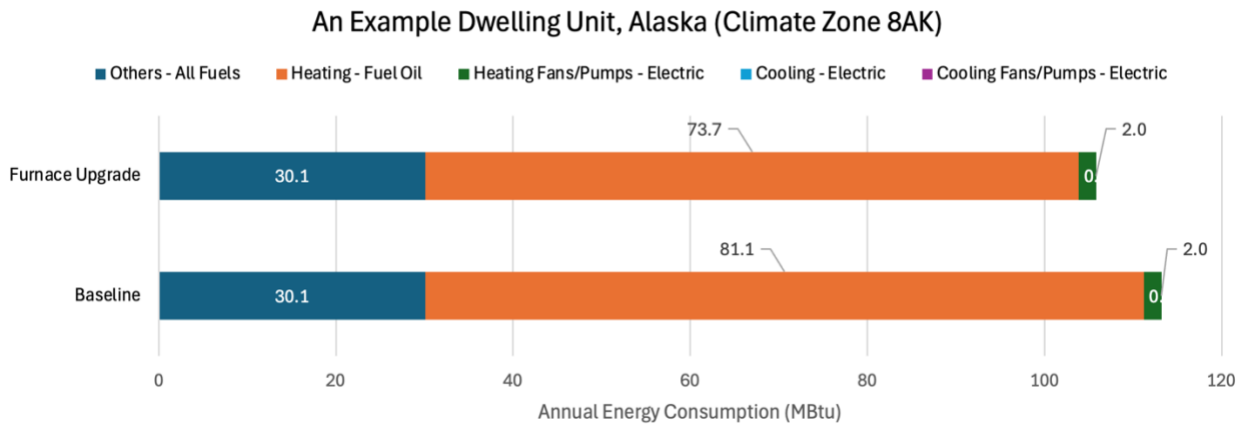

Figure 1. Annual energy consumption for an example dwelling in Alaska before and after the upgrade

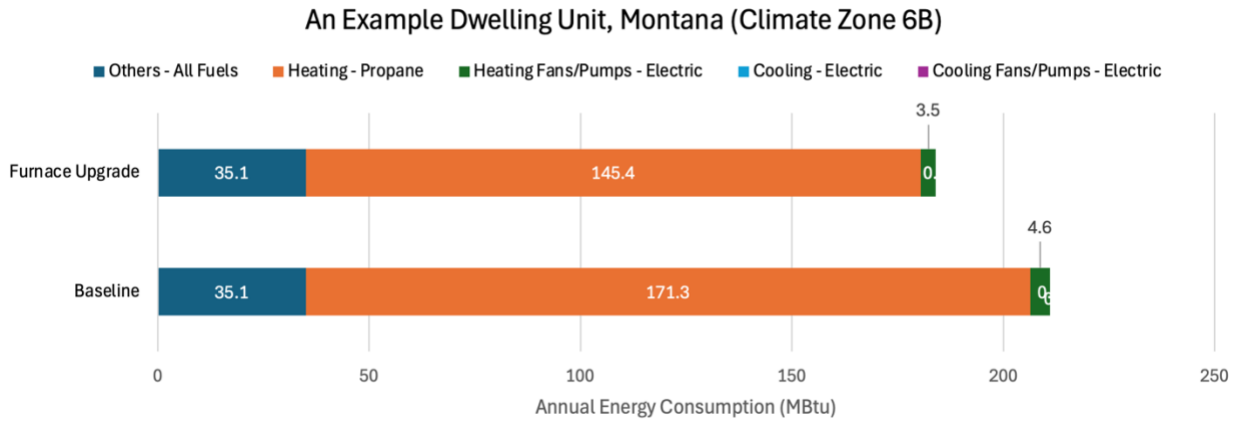

Figure 2. Annual energy consumption for an example dwelling in Montana before and after the upgrade

Figure 1 demonstrates energy savings are sourced from fuel oil heating end uses, where this example dwelling resulted in 7.4 MBtu of energy savings. Figure 2 also demonstrates 27 MBtu total annual energy savings, primarily sourced from propane heating end uses and electricity consumed from heating fans and pumps.

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4.2 Aggregated Building Time Series

Colorado is selected as a case study to analyze the aggregated time-series data. Out of all national dwelling units, 1.7% are in Colorado. Figure 3 presents the aggregated average daily baseline energy consumption in Colorado, with February 20 identified as the day with the highest energy use. To further explore this peak, Figure 4 examines the aggregated average power on February 20 in Colorado, comparing conditions before and after the upgrade.

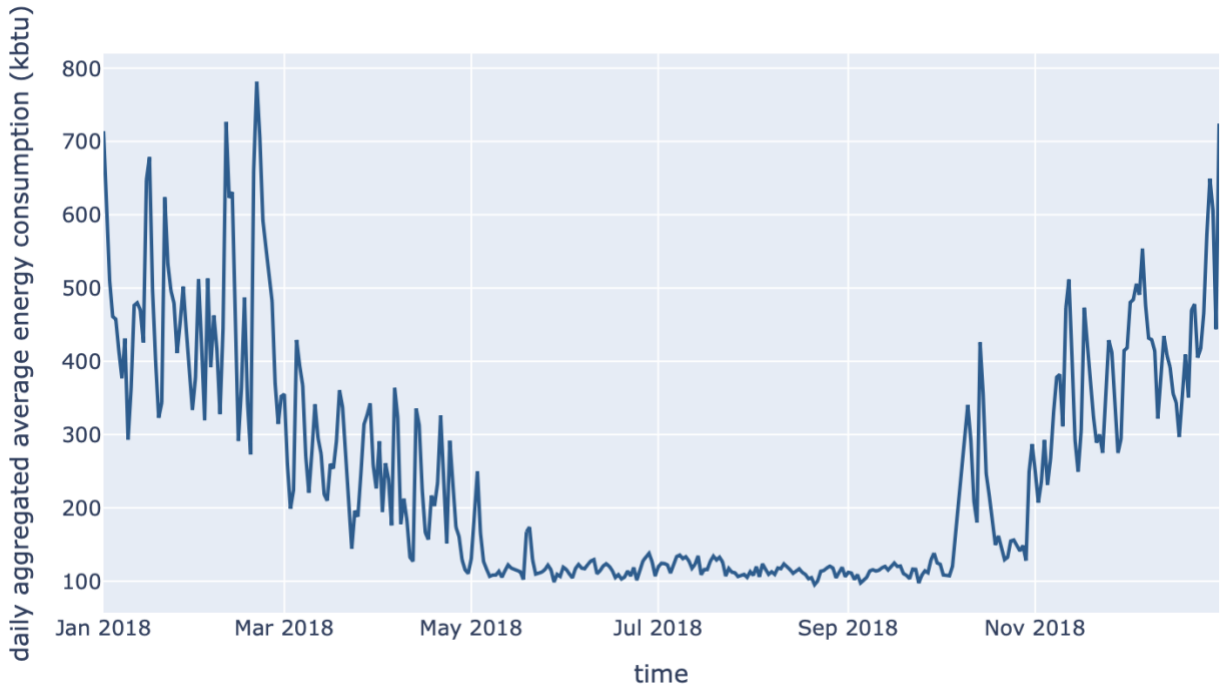

Figure 3. Aggregated daily average energy consumption of baseline in Colorado

Figure 4 shows that the upgrade scenario does not result in drastically different power demand throughout the day compared to the baseline.

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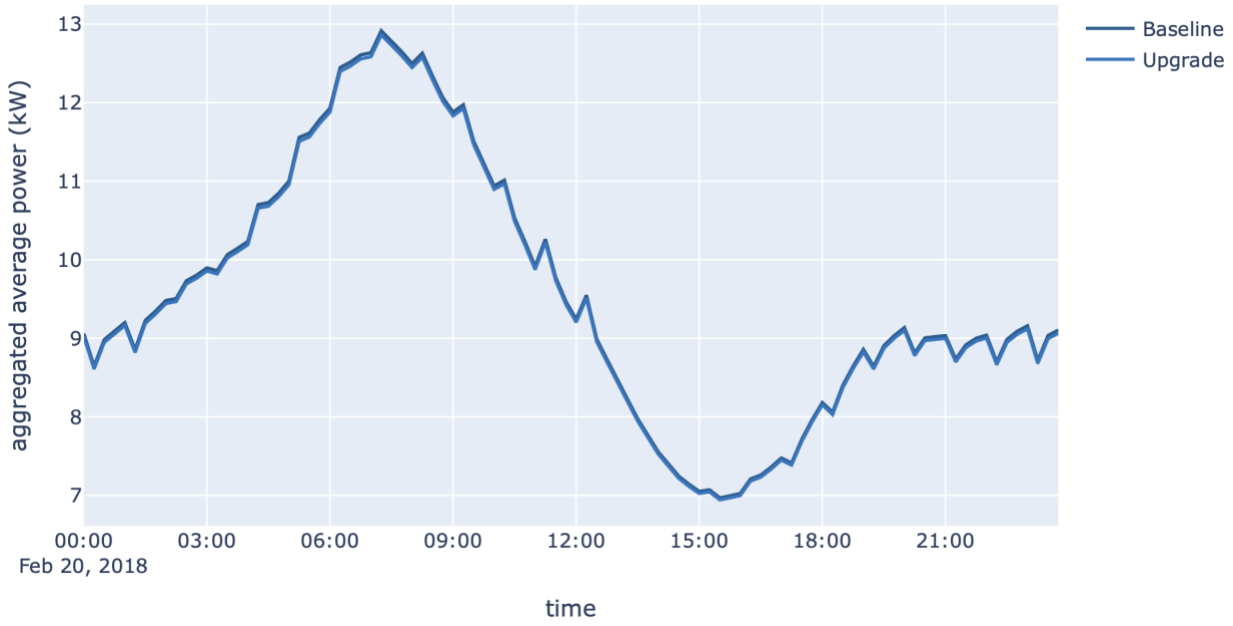

Figure 4. Aggregated average power data in Colorado on peak day

The aggregated average power does not change significantly after the upgrade because it is focused on fuel furnaces. The average power demand shows slight efficiency gains in electricity demand. Figure 5 shows a more granular electricity time series of a dwelling receiving the upgrade, where the propane furnace efficiency increased from 80% AFUE to 95% AFUE, but has little effect on the average electricity demand.

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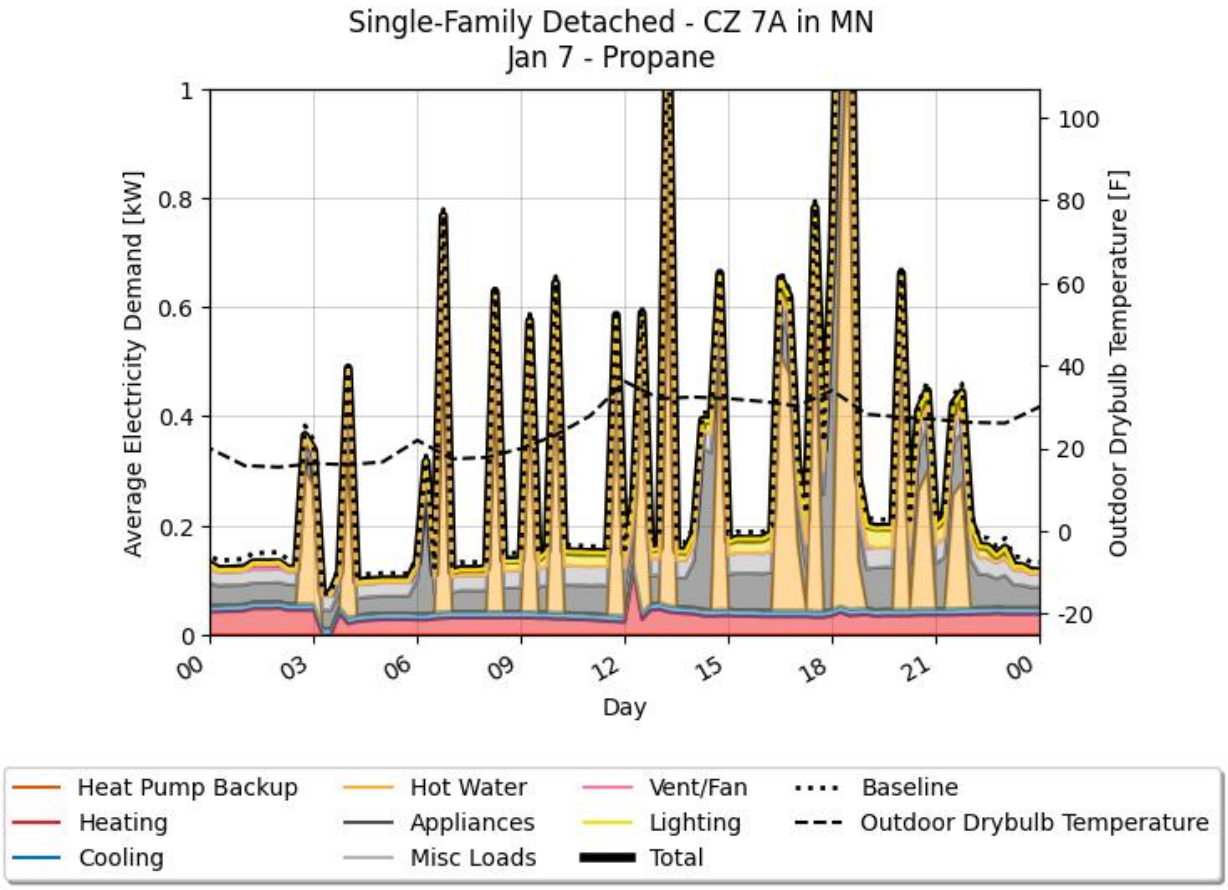

Figure 5. Load shape for propane furnace upgrade in Minnesota, Jan. 7, 2018

4.3 Stock Energy Impacts

Out of 550,000 model building simulations (i.e., models), 31,876 models are applicable for the propane and fuel oil furnace upgrade (5.8%), representing the 139,647,020 dwellings from American Community Survey's 2021, 5-year estimate of U.S. households (not including territories). For the 31,876 applicable units, 13,200 use fuel oil and 18,676 use propane. For the applicable models, the total baseline consumption is 302 billion kWh per year, and after the propane and fuel oil furnace upgrade, the total consumption is 278 billion kWh per year, a 7.9% savings.

Figure 6 shows that energy savings from the propane and fuel oil furnace upgrade mostly come from heating-related end uses.

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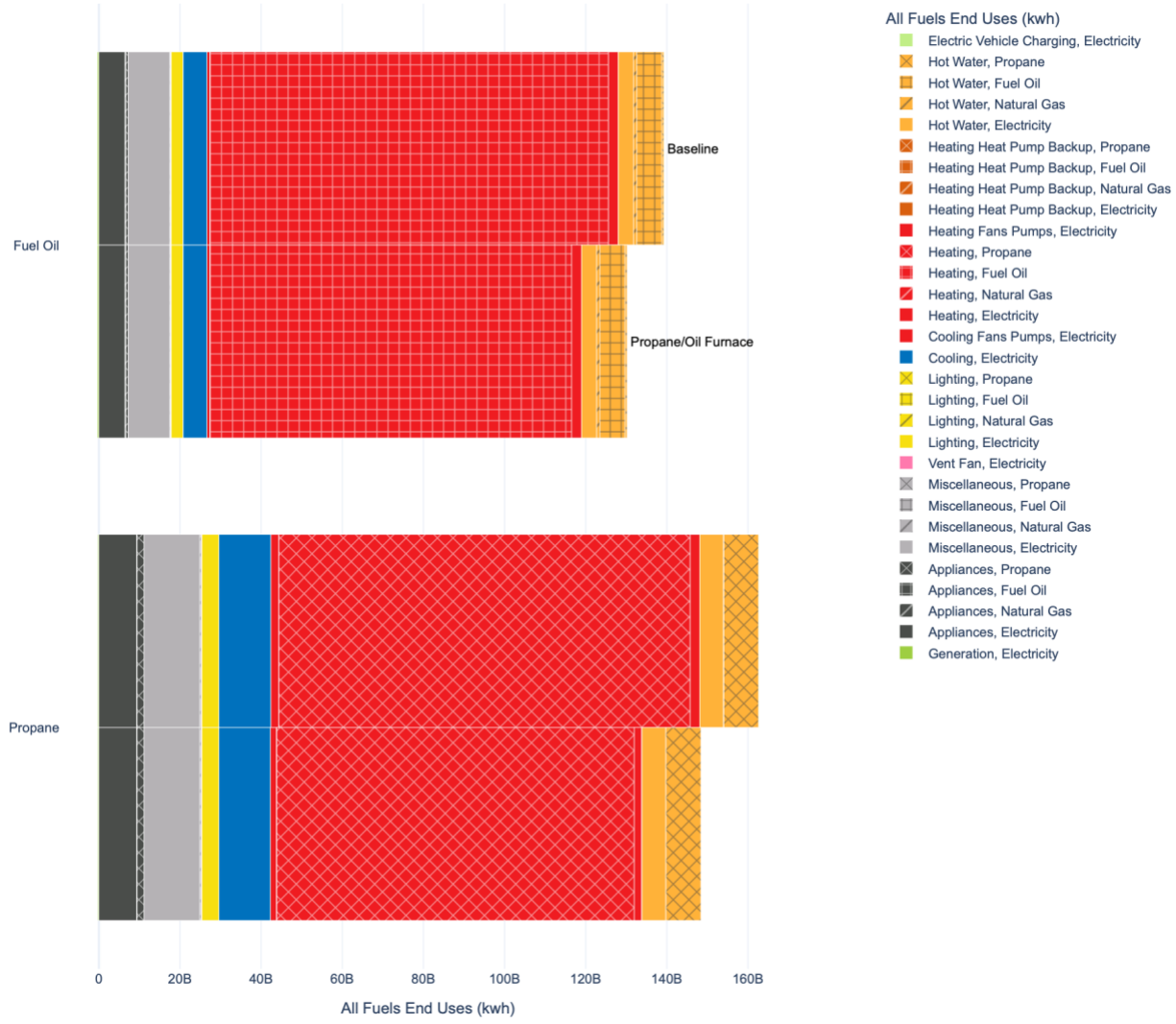

Figure 6. Annual energy consumption by fuel end use and heating fuel

In dwellings heated with fuel oil, energy used for heating from fuel oil reduced 9.3%, from 98.2 billion kWh to 89.1 billion kWh after the upgrade. In dwellings heated with propane, energy used for heating from propane reduced 13.1%, from 101.4 billion kWh to 88.1 billion kWh after the upgrade.

100% of energy savings for dwellings heated with fuel oil is sourced from fuel oil heating end uses. While 93% of average annual energy savings in dwellings heated with propane come from propane heating, cooling fans pumps using electricity composes 3%, heating fans pumps using electricity compose 3%, and cooling using electricity compose 1% of annual average energy savings, as shown in Figure 7. As mentioned in the Modeling Approach section, installation of the propane furnace can improve infiltration, which explains these energy savings. Because of this slight improvement in performance in propane furnace households, an annual average of 8.8 hours of unmet cooling hours are saved.

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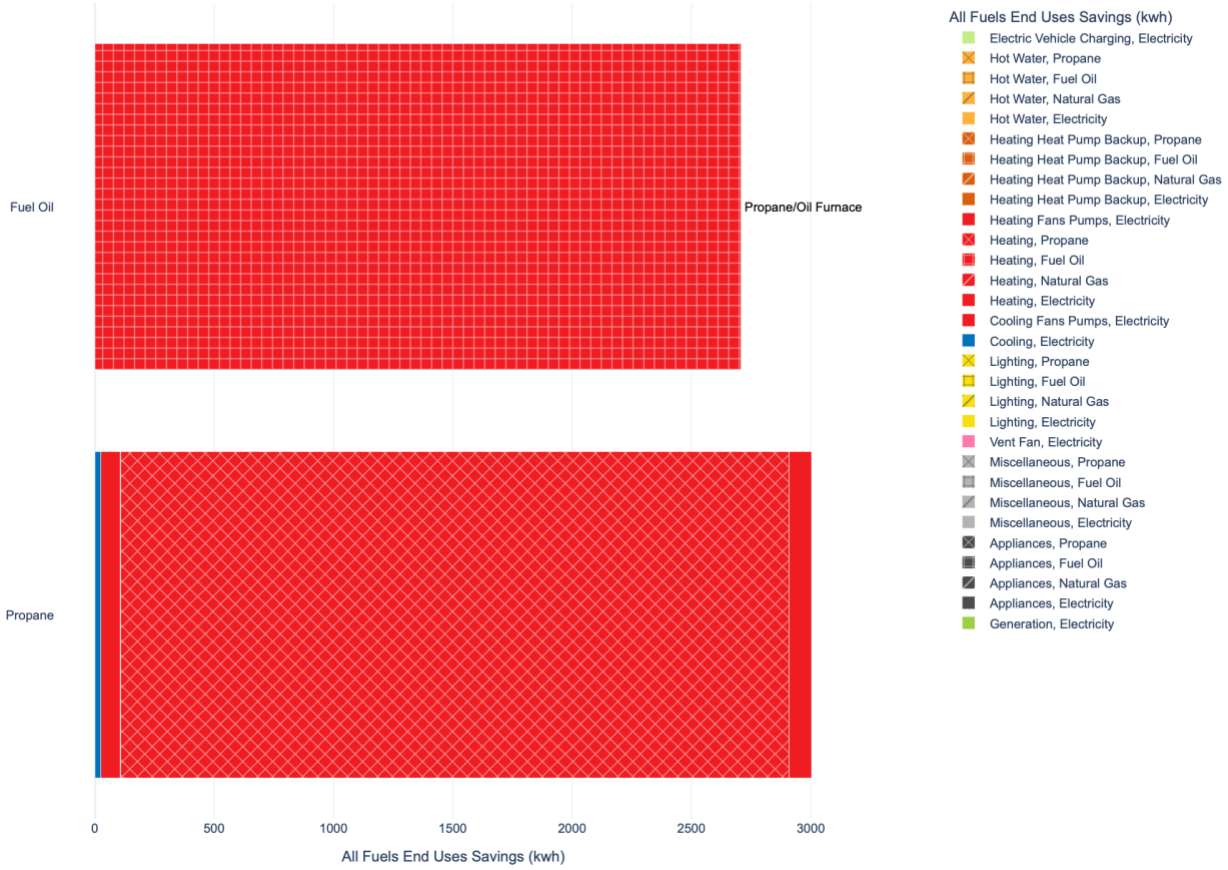

Figure 7. Average annual energy savings by heating fuel

To gain a better understanding of the range for energy savings, Figure 8 shows the distribution of annual energy savings by HVAC heating efficiency.

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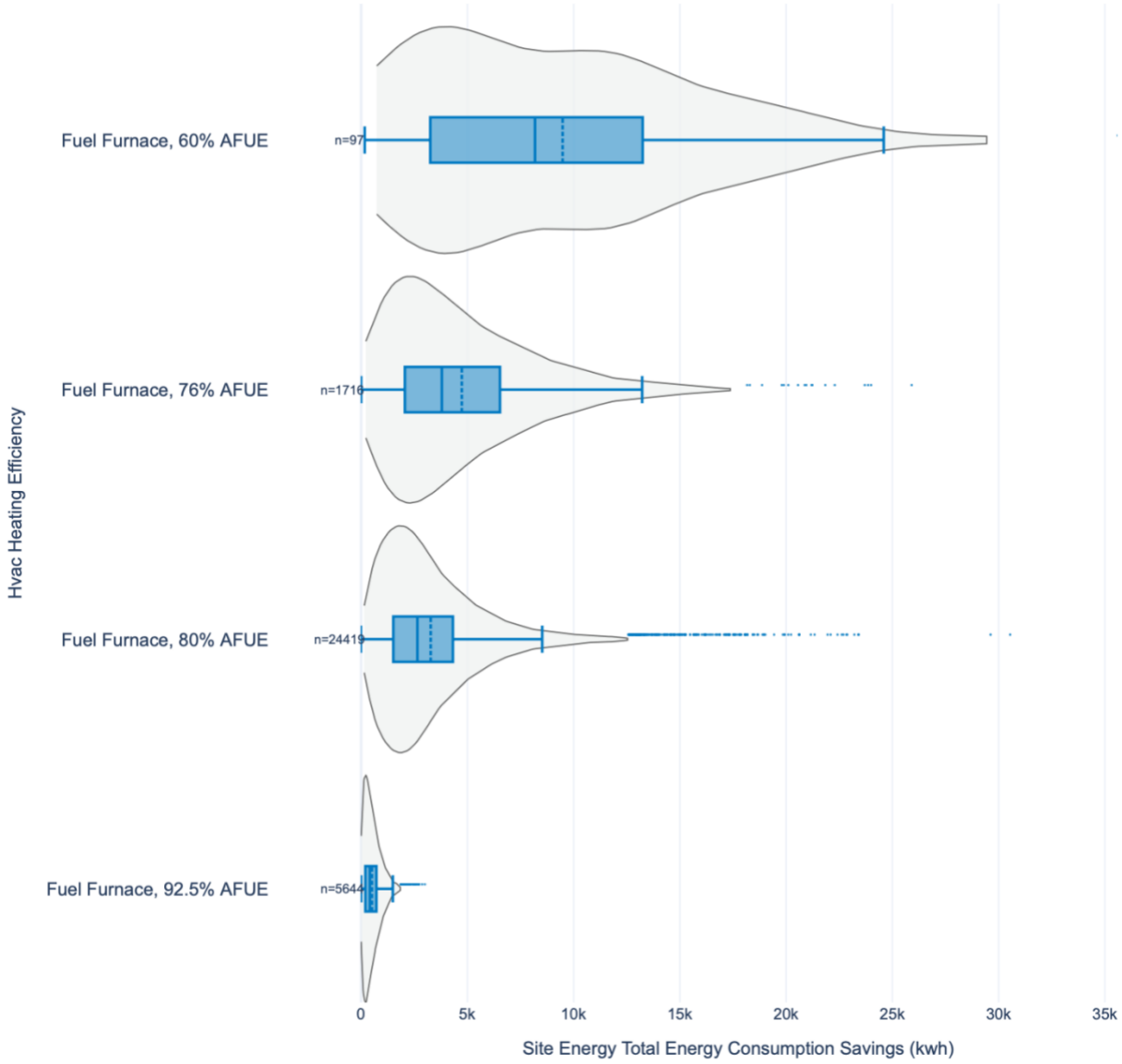

Figure 8. Annual energy savings by HVAC heating efficiency

In Figure 8, the less efficient furnaces—60% AFUE fuel furnaces—show a wider range and higher median of energy saving (8,182 kWh) than higher-efficiency furnaces like 92.5% AFUE furnaces (411 kWh). By totals, opportunities for energy savings are greatest in the Middle Atlantic, East North Central, and New England Census Divisions, as shown in Figure 9.

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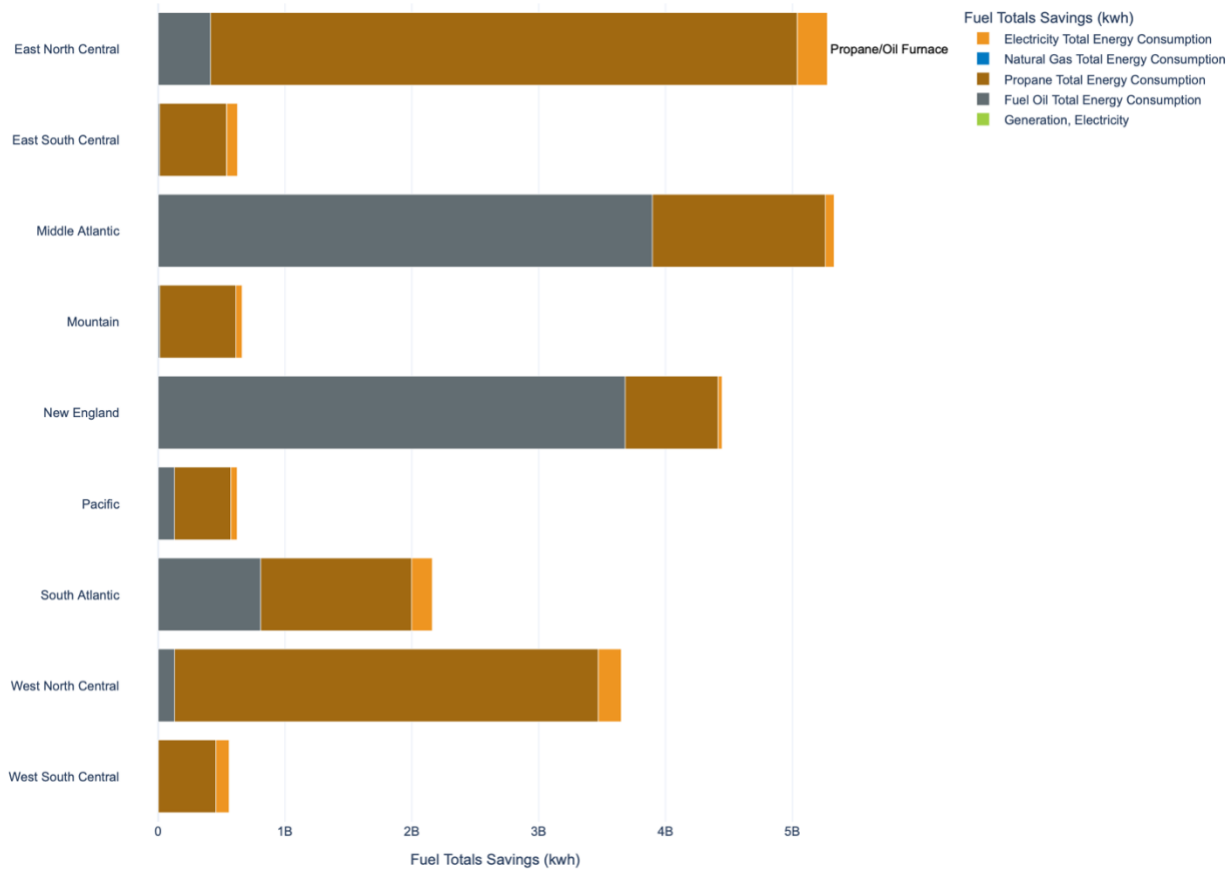

Figure 9. Total annual energy savings by census division and fuel totals savings

After the upgrade, the Middle Atlantic region could save up to 5.33 billion kWh, the East North Central region could save up to 5.27 billion kWh, and the New England area could save up to 4.45 billion kWh.

4.4 Stock Utility Bill Impacts

After the upgrade, the housing stock shows a reduction in energy bill costs, as shown in Figure 10, where dwellings heated with fuel oil show a 4.7% average percentage savings and dwellings heated with propane show a 7.4% average percentage savings.

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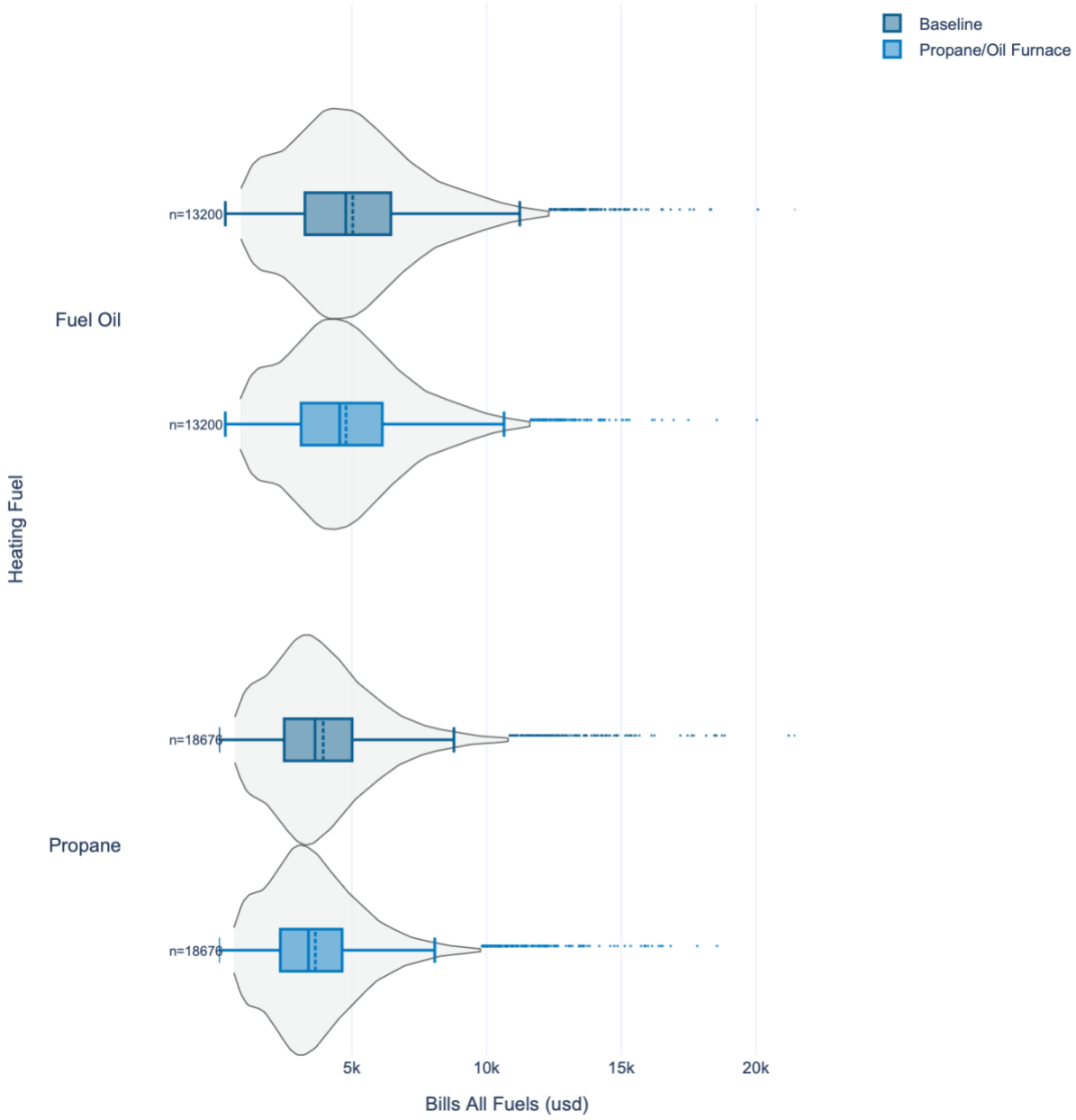

Figure 10. Annual energy bills by heating fuel in baseline and upgrade

Figure 11 shows the average annual bill savings by HVAC heating efficiency and the energy source of the bill.

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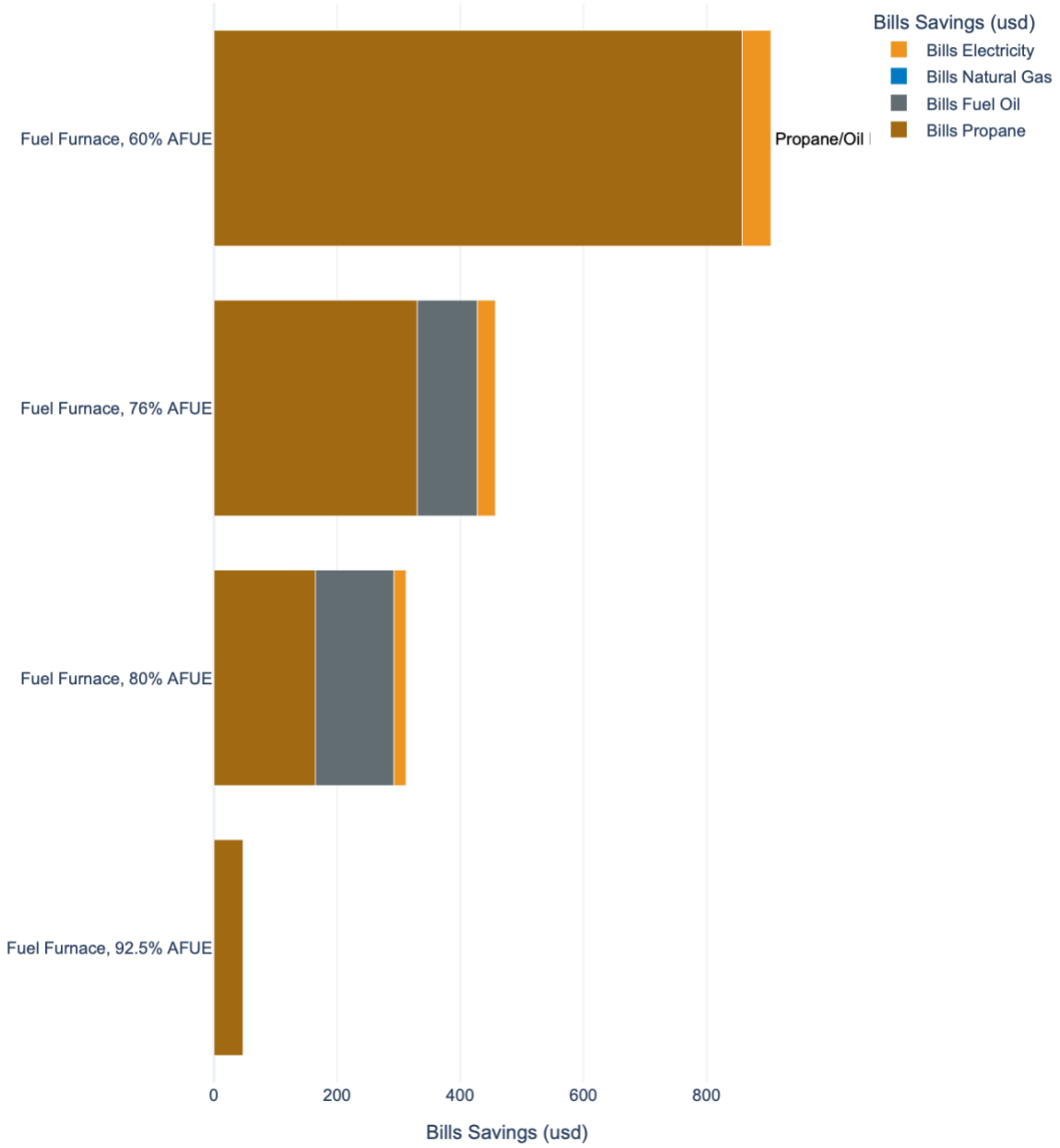

Figure 11. Average annual bill savings by HVAC heating efficiency

Aligning with increasing energy performance shown in the previous section, lower efficiency furnaces show the greatest average annual bill savings after the upgrade. Dwellings receiving the upgrade and heated with fuel oil yield an average annual bill savings of $248, and dwellings heated with propane yield $293. Improving furnaces' efficiency saves on both energy and bills.

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