American Gas Association

Building for Efficiency

Home Appliance Cost and Emissions Comparison

Contents

Executive Summary

This study examines the use of natural gas and electricity in new homes, focusing on the costs and greenhouse gas emissions of various home energy options. It addresses the critical intersection between environmental sustainability and economic efficiency in household energy use.

The study analyzes key factors affecting home energy performance, including building envelopes, heating, ventilation and air conditioning systems, climate conditions and energy conservation measures.

Accurate representation of these factors allows for informed decisions by consumers, policymakers and other stakeholders to enhance energy efficiency while maintaining multiple options for households to reduce their carbon impact and control living costs. The findings can influence the incentives and adoption of energy-efficient technologies, shaping the future trajectory of residential energy use.

The study compares natural gas and electric appliances in terms of greenhouse gas emissions and cost, providing valuable insights for homeowners, policymakers and the energy industry. Analyses like this are especially relevant to public efforts to reduce greenhouse gas emissions affordably and sustainably.

The study utilizes publicly available tools and datasets — including the U.S. Department of Energy EnergyPlus model, data from the U.S. Energy Information Administration, and the National Renewable Energy Laboratory Cambium Database — to facilitate transparent and open modeling assumptions.

Key Findings

- **Cost Savings**: Natural gas used in a baseline new home costs $1,132 per year less than an equivalent all-electric household. An advanced natural gas home with more efficient appliances saves an average of $492 annually compared to an electric cold-climate heat pump.
- **Homes Prefer High-Efficiency Gas**: Over 75% of new homes with natural gas install a 90%+ efficient furnace. In moderate to cold climates, customers prefer gas to electric heat pumps by 5 to 1, with 92% of central ducted heat pumps sold before 2020 rated below 9.2 Heating Seasonal Performance Factor (HSPF).
- **Greenhouse Gas Reductions**: An advanced all-gas home with a condensing natural gas furnace can cut lifetime emissions by 17% compared to the typical all-electric household. Compared with an advanced all-electric home with a cold climate heat pump, the advanced natural gas household typically can equal or exceed emissions reductions while cutting lifetime costs by thousands.
- **New Consumer Solutions**: Natural gas heat pumps, hybrid gas-electric systems and renewable natural gas options can reduce costs and emissions more cost-effectively than many electric or most typical natural gas home configurations. A home with a natural gas heat pump would cut costs by $651 per year compared with an electric cold-climate heat pump.

By tailoring policy strategies to existing market trends and supporting both high-efficiency natural gas and renewable natural gas within a broader suite of consumer solutions, policymakers can pave the way for a more sustainable and cost-effective energy future.

Introduction

About this Study

This study compares the relative impacts of residential appliances powered by natural gas and electricity. Consideration is given not only to the impacts at the point of ultimate energy consumption — i.e., the site or the home — but also to those impacts associated with the production, conversion, transmission and distribution of energy to the household. For example, energy is used and lost in generating electricity and the processing and transportation required for natural gas. In 2022, the average efficiency of the U.S. electric grid was 38% from source to site, while natural gas provided 92% of all sourced energy to homes.

Emissions from the use of electric appliances evaluated in this study are based on the assumption that the energy mix used to generate electricity will increasingly incorporate more lower-carbon resources, including natural gas and renewables, over the next few decades. This study's electricity analysis is based on the National Renewable Energy Laboratory's (NREL) Cambium model and database, which includes a forecast influenced by the Inflation Reduction Act, state mandates to reach 100% renewables by a specific date, and many more market incentives to reduce the carbon intensity of the electric system.

The analysis also addresses improvements in the natural gas system. Natural gas utilities have made recent efforts to reduce greenhouse gas emissions from the operations of gas distribution systems and to assist customers with reducing their emissions. The industry works to reduce methane emissions from operations and purchased fuel, has begun to offer renewable natural gas and continues to invest in long-held efficiency programs for households to help lower costs and emissions.

This study also presents a cross-comparison of appliances within the same modeled housing structure. It relies on national average prices and building energy characteristics for a newly constructed home to conduct a straightforward apples-to-apples analysis that meets 2021 International Energy Conservation Code (IECC) requirements for buildings. Other organizations, such as RMI, have conducted similar studies using the same tools. Building upon that prior work, this study identifies several areas for improvement in those earlier methodologies to provide a more comprehensive and accurate representation of home energy costs and emissions for the average new home.

Additionally, this study offers insights into market share advancements in high-efficiency technologies for homes and examines how consumer and builder preferences can impact real-world savings. Topics specifically related to natural gas households are also reviewed, allowing readers to learn various ways consumers can save money and lower emissions, including using hybrid gas-electric or gas heat pump technologies.

The findings of other studies based on the average of all homes, as opposed to newly constructed homes, will differ from this type of study for a variety of reasons, including:

- **Differences in the Age of Housing Stock**
  Older buildings commonly use natural gas, propane and fuel oil, while newer buildings have a larger share of electricity. Nearly 90% of natural gas single-family homes use central HVAC

systems, which will require a split air source heat pump (ASHP) for a fully electric configuration or a hybrid approach where natural gas is used based on cost, emissions or simply backup during peak winter conditions. Models that assume ductless heat pump systems and their associated efficiency and costs are not appropriate based on most natural gas household needs.

- **Regional Market Shares**
  Natural gas heating is more prevalent in northern climates, where heating requirements are higher, while electric heating is more common in southern climates. Propane users are typically located in rural areas, and fuel oil is primarily used in the Northeast and varied Midwestern states.
- **Size of Home**
  The average natural gas-heated home has 30% more heated square footage than the average electric home. This study assumes the same-sized home and annual heat loss for a consistent comparison.
- **Building Envelope Efficiency**
  The efficiency of the building envelope depends on the age of the home and its maintenance over the years. This study focuses on a building efficiency code that represents new homes built in the last few years in select cities.
- **Market Comparisons**
  Simple comparisons of state or city-wide markets often fail to consider the fact that only 40% of all homes with an electric heat pump have access to natural gas. Most electric heat pumps today compete with less efficient electric technologies and fuels, rather than natural gas.
- **Variety of Natural Gas Appliances**
  Not all natural gas residential end users have four unique gas appliances. Some may also have duplicates (stoves and dual-zoned HVAC). Others may have mini split heat pumps as a backup source of heating for attics, basements or ADUs. Based on data from EIA, the average natural gas home has between two and three appliances, with space heating being the most common.

Components of this Report's Analysis

This report is structured to provide a detailed analysis of the use of natural gas and electric appliances in new homes, focusing on cost, efficiency and emissions. It includes:

1. **Market Analysis for Energy-Efficient Appliances:** The study explores the current market dynamics for natural gas and electric homes, highlighting the implications for household costs and emissions. Informed decision-making should consider what builders and households are installing today and the potential for replacing the least efficient options with better alternatives.
2. **Cost Savings for Homeowners**: The study underscores the economic advantages of natural gas, revealing significant cost savings for many homeowners. Natural gas often emerges as the lower-cost option, resulting in potential savings of $1,132 per year for an average single-family new construction home.
3. **The Impact of the Full-Fuel Cycle on Cost and Emissions**: While electric appliances can have lower site energy consumption, the overall efficiency of the natural gas production and delivery system often offset this advantage, making natural gas a more attractive option for reducing overall energy use.

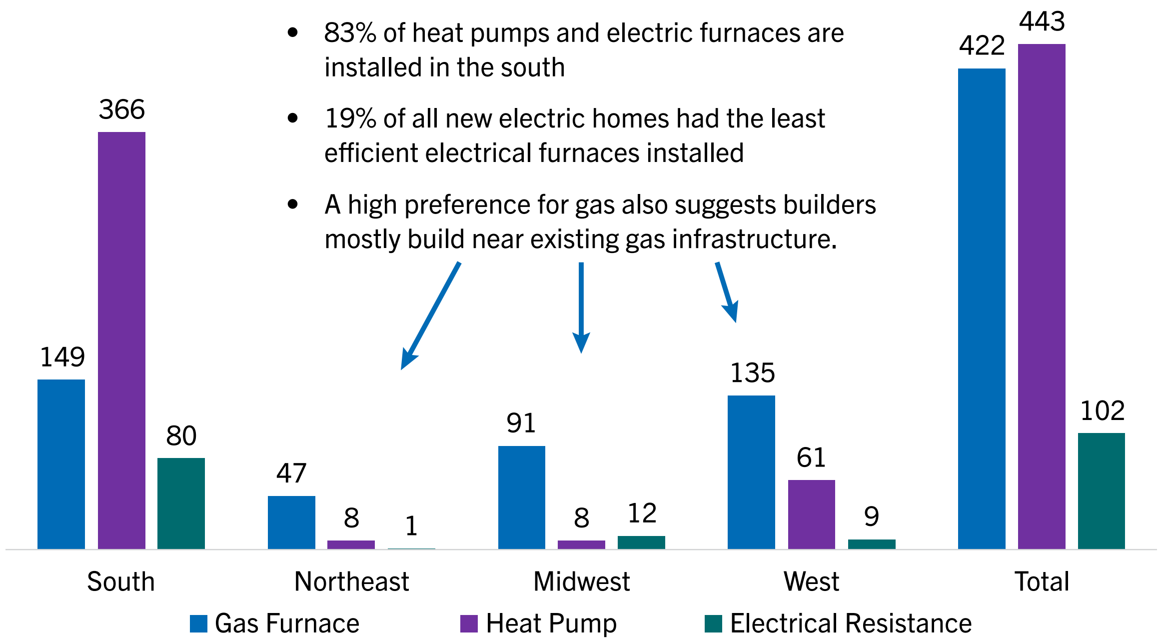
4. **Seasonal Efficiency and Cost Variations**: Seasonal variations impact the energy efficiency and cost-effectiveness of heat pumps. While heat pumps are more cost-effective during spring and fall seasons due to higher coefficient of performance (COP) values when outdoor temperatures are higher, natural gas remains a more economical choice during peak winter months when heating demand is significantly higher due to the decline of electric air-source heat pump efficiency and output capacity as a function of outdoor temperature.
5. **Comparative Emissions Analysis**: The study highlights that the economic benefits of natural gas and emissions reductions are not mutually exclusive. It acknowledges the importance of emission reduction strategies and the evolving role of fuels like renewable natural gas (RNG) as new consumer energy options. Natural gas homes currently exhibit a carbon footprint advantage, with most new all-electric homes installing lower-tier efficiency heat pumps and resistance furnaces powered by electricity that nationally emit more full fuel cycle emissions. The use of RNG and advancements in the electric grid over the next two decades could potentially drive emissions reductions from both natural gas and heat pump technologies. Emission reductions beyond the life of appliances installed today will depend on the rate of carbon intensity reductions in gas and electricity systems.
6. **Policy Considerations**: Policy must be adaptive and responsive to local conditions, recognizing that no one-size-fits-all approach exists for every household. Based on existing market dynamics, heat pump adoption is concentrated in areas that do not have access to natural gas service — areas where 40% of all households are located. This study highlights that emission reduction goals can be better achieved through a strategic combination of RNG integration and improved appliance efficiency.

The Market for New Construction Homes and Advanced Appliances

This section examines recent market data on home heating fuel and appliances to provide an accurate baseline from which to explore specific home energy scenarios.

Natural gas and propane heat continued to lead the new single-family home market in 2023. According to the U.S. Bureau of the Census, new single-family completions heated by gas totaled 422,000 in 2023. Gas furnaces had a plurality market share of 44% of all new completions. Electric heat pumps were installed in 443,000 households, or 46% of all new single-family completions, and most of the remaining 11% are electric resistance furnaces. For homes heating with electricity, 1 in 5 were built with electric resistance furnaces, most in the south.

Figure 1
New Single-Family Home Market by Region
Thousands of Homes Built in 2023

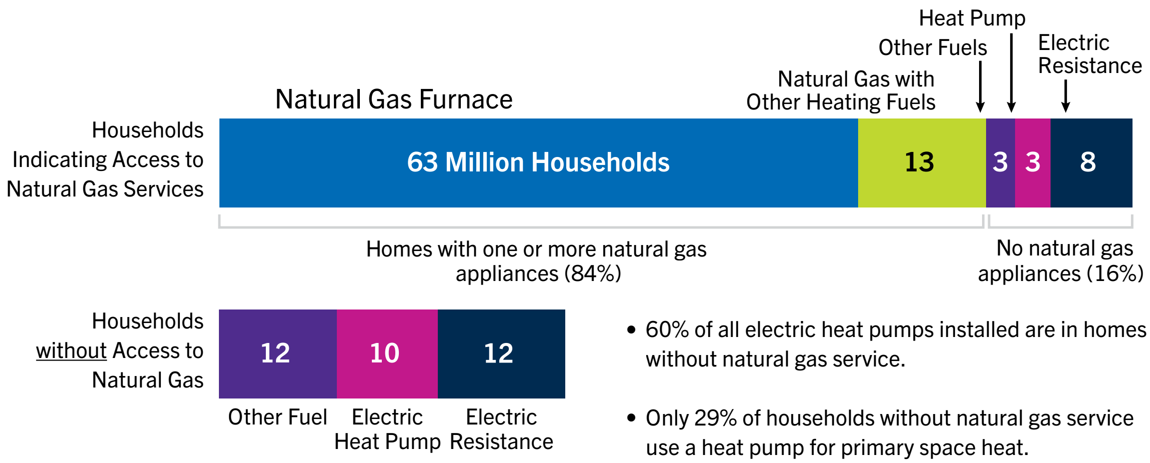


Source: U.S. Census Characteristics of New Construction Survey 2023

Of all new construction electric heat pumps installed in 2023, 83% were installed in the South. By contrast, natural gas accounts for about 82% of all new construction in 2023 in the Northeast and Midwest, where most heating demand is concentrated. The census survey only collects appliance data for primary space heating but also includes some information about other fuels used with heat pumps. In 2023, of the 443 thousand single-family homes built with a heat pump, 34,000 or 8% of all homes with a heat pump also included some other gas heating appliance(s) such as a furnace, fireplace or gas-powered heat pump installed.

The Residential Energy Consumption Survey from the Energy Information Administration (EIA) indicates that only 40% of homes with an electric heat pump have access to natural gas. This suggests that builders and households prefer natural gas over electric heat pumps when given the choice.

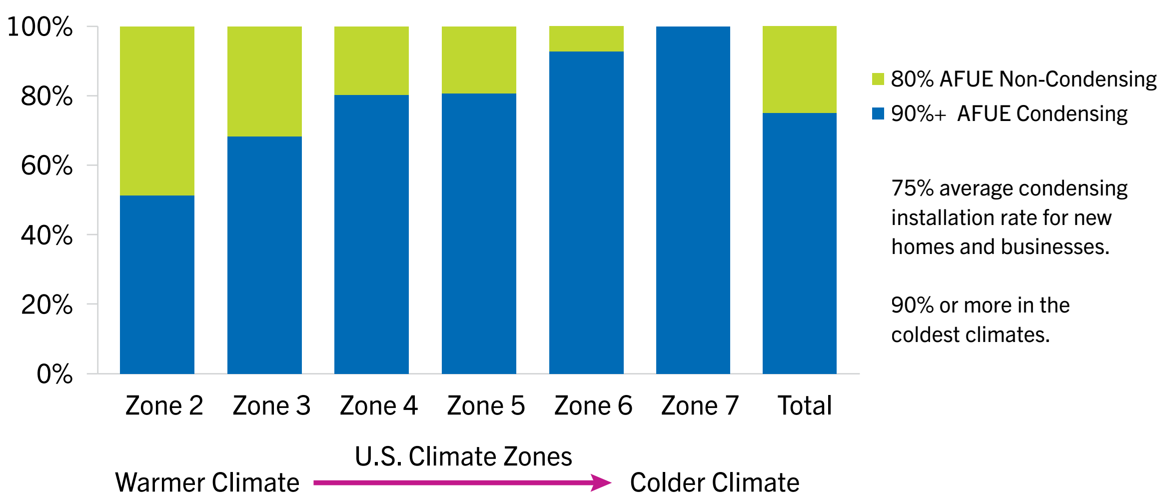
Figure 2
Primary Space Heating Equipment Installed
Million Households



Source: Department of Energy, EIA, Residential Energy Consumption Survey 2020

The majority of new homes that install natural gas furnaces adopt efficient condensing natural gas appliances. Specifically, 75% of builders install 92% or higher condensing furnaces. Existing homes have a lower rate of adoption, with only 50% of the existing market having condensing furnaces installed. This estimate is based on data from the Department of Energy (DOE), sourced from the model used in the minimum efficiency furnace rule. In the South, where homes will have the least space heating demand, 61% of new homes installed a condensing furnace.

Figure 3
Natural Gas Furnaces
Installed base by efficiency/product class



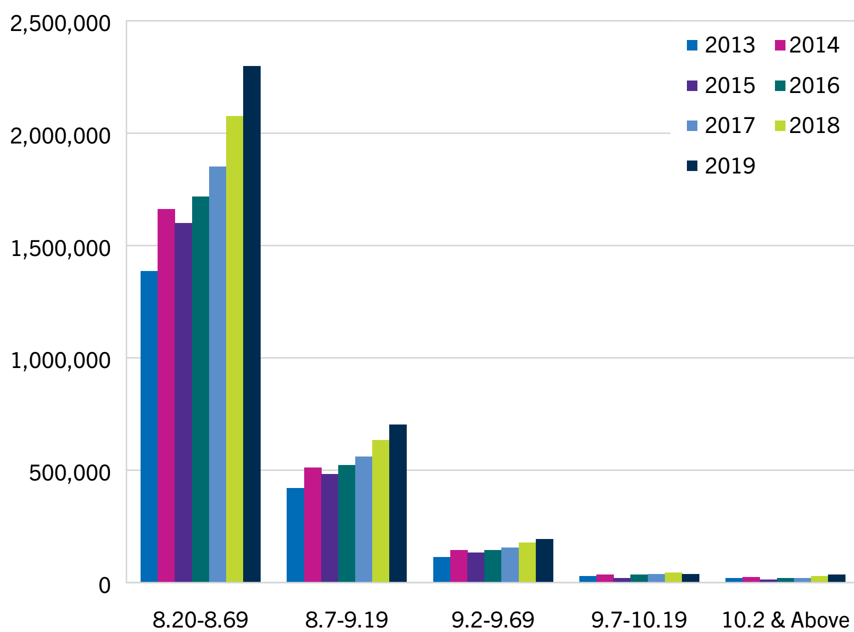
Source: Based on AHRI, DOE, and EIA RECS 2020 data

Although electric heat pump sales saw significant growth between 2013 and 2019, the market is still dominated by lower-efficiency electric heat pump models. According to the U.S. Department of Energy, 92% of all-electric centrally ducted heat pump units sold in 2019 had a Heating Seasonal Performance Factor (HSPF) of 9.2 HSPF or lower. This estimate is based on DOE data cited with a recent report by GTI and reflects recent national trends for heat pumps sold before 2020[1].

Publicly available shipment data does not provide more granular details based on performance ratings and size. Therefore, it is unclear whether the high-efficiency centrally ducted electric heat pump will become more common. Current federal incentives do not require them, and electric heat pumps may not satisfy the cost and heating performance needs of most natural gas homes.

Therefore, it is important to be cautious when concluding that policies that are either intended to drive heat pump adoption or limit access to non-electric fuel sources will result in significant emissions reductions by assuming the uptake of high-efficiency heat pumps. Without a significant increase in sales of high-efficiency heat pumps, policies intended to drive heat pump adoption are unlikely to result in the same emission savings as one might expect from modeling the uptake of higher-efficiency heat pumps. Additionally, because 19% of all new single-family homes are heated by electric resistance, it is reasonable that many builders/households might choose to install heat pumps in these homes without natural gas as an option.

Figure 4
Residential Shipments of Spilt ASHP by HSPF Rating
2013-2019



Vast majority of electric heat pumps sold meet minimum Federal efficiency standards.

In 2019, 92% of electric heat pumps had an HSPF rating of 9.2 or lower.

Sales of higher efficiency electric heat pumps (e.g., HSPF 9.7 or higher) show no signs of higher growth rates.

Source: DOE, based on AHRI data

1 https://www.gti.energy/wp-content/uploads/2021/03/22788-Topical-Report-Fayetteville-AR-Black-Hills-Energy-GHG-Analysis-w-Appx-A_GTI.pdf

Analysis Methodology

This study evaluates the cost and environmental impacts of a newly constructed home equipped with either all-electric or all-natural gas equivalent appliances. It establishes a baseline efficiency level and an advanced version for each home by fuel source. While a mix of fuels and appliances is feasible, the study focuses on a more likely installation scenario.

The overall energy demands are based on the average two-story, single-family detached residence with 2,377 square feet of conditioned space. It focuses on a typical natural gas household operating in an "average" winter climate in the United States, equating to 4,811 heating degree days. Heating and cooling loads are determined using a thermostat setpoint of 72 degrees Fahrenheit in winter and 75 degrees in summer. The home modeled in the study meets 2021 International Energy Conservation Code (IECC) requirements for buildings.

Table 1
Fuel and Appliance Scenarios Analyzed

All-Electric Home	Natural Gas Home
8.8 HSPF2 Heat Pump	80% AFUE Furnace
99% COP Tanked Water Heater	64% AFUE Tanked Water Heater
Electric Stove and Dryer	Gas Stove and Dryer
16 SEER Heat Pump	16 SEER Air Conditioner
Advanced All-Electric	**Advanced Natural Gas**
11 HSPF2 Heat Pump	95% AFUE Furnace
220% COP Tanked Water Heater	95% AFUE Tankless Water Heater
Electric Stove and Dryer	Gas Stove and Dryer
19 SEER Heat Pump	19 SEER Air Conditioner
Natural Gas Heat Pump	**Natural Gas Hybrid**
140% COP Gas Heat Pump	80% AFUE Furnace w/
95% AFUE Tankless Water Heater	8.8 HSPF2 Heat Pump
Gas Stove and Dryer	95% AFUE Tankless Water Heater
19 SEER Air Conditioner	Gas Stove and Dryer
	16 SEER Heat Pump

The selection of individual appliances is based on market penetration and similarities in installation requirements and costs. For instance, a home with a condensing furnace would have a corresponding condensing water heater. Likewise, a home with a minimum-efficiency Energy Star heat pump typically includes a resistance-based water heater.

The selection of resistance water heaters for the baseline electric home is influenced by EPA Energy Star sales data.[2,3] In 2021, Energy Star gas water heaters outsold heat pump water heaters by a ratio of 10 to 1, with only 112 thousand heat pump water heaters sold with the Energy Star label. The advanced appliance set prioritizes optimal operation, installation and environmental benefits while sharing similar system requirements.

For a straightforward comparison, this study examined six different installation scenarios within the same designed new home. Baseline natural gas and electric homes include many appliances commonly found in most existing or new homes today. Advanced versions of each include appliances that are typical in higher-end installations.

Two additional natural gas space heating applications are evaluated: a gas heat pump and a gas-electric hybrid system.

Gas-Electric Hybrid System: This type of space heating system replaces the air conditioner with a heat pump. By using a heat pump alongside a gas furnace, the household can optimize bill savings and emissions through a smart thermostat to utilize whichever appliance best serves the home. It can also alleviate installation costs by sizing the heat pump for primarily cooling needs, which can reduce upfront costs and widen the range of products that fit the home.

Gas Heat Pump: A natural gas-powered absorption heat pump operates by harnessing natural gas to drive a heating cycle, efficiently transferring heat from the outside air or ground into a home. Gas heat pumps can also be used in cooling modes and for providing supplemental water heating from waste heat, though these use cases are not modeled in this analysis.

Both gas heat pumps and gas hybrids are available today for installation. Still, they are not yet common in most installations, especially gas heat pumps, which have only become available for residential homes in recent years. At least for the moment, these types of installations would be unique in a typical new home. However, both options are growing in popularity and commercial availability and offer additional potential savings to households.

Estimating Annual Energy Consumption

This study utilizes the U.S. Department of Energy EnergyPlus V22.2 model, a free software tool for building energy simulations that allows for transparent and open modeling. The model includes thousands of variables and potential outputs, making it a robust tool for analyzing energy consumption. The study employed DOE's prototype models to ensure full transparency in the methods used and to encourage stakeholders to understand better how households can save money and reduce emissions.[4]

AGA adjusted several variables within the DOE *EnergyPlus* prototypes to more accurately reflect the appliances typically installed in new homes. These adjustments encompassed changes to appliance efficiency levels and some auto-sized settings, including the HVAC system's tonnage, to ensure optimal comfort.

2 https://www.aga.org/wp-content/uploads/2023/06/AGA-Energy-Insights-Empowering-Consumer-Choices-Analyzing-the-Impact-of-the-ENERGY-STAR-Program-on-the-Adoption-of-High-Efficiency-Gas-Appliances.pdf

3 DOE Consumer Water Heater rule is set to require electric heat pump water heaters starting in 2029

4 https://energyplus.net/

Energy consumption is modeled using the *EnergyPlus* software and model home files.[5] Outputs are recorded hourly and presented monthly or annually to simplify the evaluation of energy bills and emissions.

All end uses, including lighting and radiant energy from miscellaneous appliances like televisions, are included in the final consumption because the final bill for any household will consist of all appliances, not just the four appliances that can use natural gas. Importantly, the *EnergyPlus* software treats each type of energy use that cannot utilize natural gas (e.g., lighting) consistently, as per the DOE's model design. The approach is crucial because it accounts for the potential impact of different appliances on the heating or cooling load. For example, the radiant heat emitted from lighting can affect overall heating and cooling requirements.

Table 2
Estimated Annual Residential Site Energy Usage for New Homes, MMBtu/year

End Use	Baseline Natural Gas	Baseline Electric	Advanced Natural Gas	Advanced Electric	Natural Gas Heat Pump	Natural Gas Hybrid
Heating	47.5	23.3	40.0	18.1	27.2	23.2
Cooking	4.5	2.1	4.5	2.1	4.5	4.5
Dryer	5.3	2.8	5.3	2.8	5.3	5.3
Water Heater	12.8	8.4	8.8	4.2	8.8	8.8
Sub Total	70.1	36.7	58.6	27.2	45.7	41.8
Fan	5.3	5.9	5.3	5.8	5.3	5.3
Cooling	32.2	31.3	26.0	24.8	26.0	26.0
Other	18.5	20.4	18.5	20.7	18.5	18.5
Total	126.2	94.2	108.4	78.5	95.5	91.5

Table 3
Estimated Annual Residential Full Fuel Cycle Energy Usage for New Homes, MMBtu/year

End Use	Baseline Natural Gas	Baseline Electric	Advanced Natural Gas	Advanced Electric	Natural Gas Heat Pump	Natural Gas Hybrid
Heating	51.8	60.4	43.6	46.8	29.6	48.0
Cooking	4.9	5.3	4.9	5.3	4.9	4.9
Dryer	5.8	7.4	5.8	7.4	5.8	5.8
Water Heater	14.0	21.8	9.6	10.9	9.6	9.6
Sub Total	76.5	95.0	63.9	70.4	49.8	68.3
Fan	13.8	15.2	13.8	15.0	13.8	13.7
Cooling	83.5	81.1	67.3	64.4	67.3	67.3
Other	47.9	52.8	47.9	53.6	47.9	47.9
Total	221.6	244.1	192.8	203.4	178.7	197.3

5 https://www.energycodes.gov/prototype-building-models

Calculating the Annual Energy Cost Estimates

Consumer energy costs are the product of the total end-use energy required and the price of energy. Full-fuel cycle energy efficiencies affect consumer energy costs in that these costs reflect the total volume of fuels necessary to satisfy consumer energy needs.

Each year, the Department of Energy publishes an average unit costs for energy. For 2023, the most recent data available, DOE reports that the cost of electricity to the residential consumer in the U.S. would be 3.3 times higher than natural gas. DOE reports that the representative cost of distillate oil is two times higher than that of natural gas. Finally, DOE estimated that propane would be 2.3 times the price of natural gas. Please note that energy prices and resulting consumer costs vary by region and month. Values for 2024 have yet to be released; however, the current monthly data shows the same price differences amongst fuels.

Table 4
2023 Representative Average Unit Costs for U.S. Residential Energy Prices, $/MMBtu

Natural Gas	Electricity	Distillate Oil	Propane
$13.97	$46.19	$28.36	$32.62

Sources: U.S. Energy Information Administration, Short-Term Energy Outlook (August 8, 2023), Annual Energy Outlook (March 16, 2023), and Monthly Energy Review (July 26, 2023).

This study evaluates appliance energy, cost and emissions on an annual and monthly basis. Households typically receive a monthly energy bill reflecting their consumption over the past 30 days. By focusing on monthly impacts, this study can assess the actual financial impact on households across different seasons.

The *EnergyPlus* model can determine annual and monthly energy consumption, especially for specific appliances such as space heating and cooling. Using the hourly metered outputs from the model, an average expected consumption per month was determined for each scenario.

The structure of utility rates influences the energy cost displayed on a bill. On many electricity and natural gas bills, this structure can include various consumption or seasonal tiers, resulting in different charges based on energy usage levels. While hourly consumption can factor into a “time of use” electricity rate, most residential households operate with a different rate structure.

While natural gas commodity prices can fluctuate daily, retail rates paid by consumers are usually pre-determined, with utilities sourcing most natural gas through fixed contracts or other mechanisms that are not exposed to the daily market. Utilities plan for reliable natural gas deliveries on a daily, weekly, monthly and seasonal basis by matching supply resources to forecasted demand. Gas utilities often employ a diverse set of contractual arrangements to procure their gas supplies, including long-term, mid-term, monthly and daily agreements.

Utility bills can also encompass fixed costs unrelated to energy consumption. These fixed costs, often termed service or customer charges, are fees that households pay for utility access and maintenance, regardless of their energy usage. Such charges assure a fair distribution of costs among customers, foster energy conservation and motivate enhanced energy efficiency. By incorporating marginal prices into the study, the results can more accurately reflect the complete bill impact on households from energy efficiency, encompassing service charges or tiers based on consumption or season.

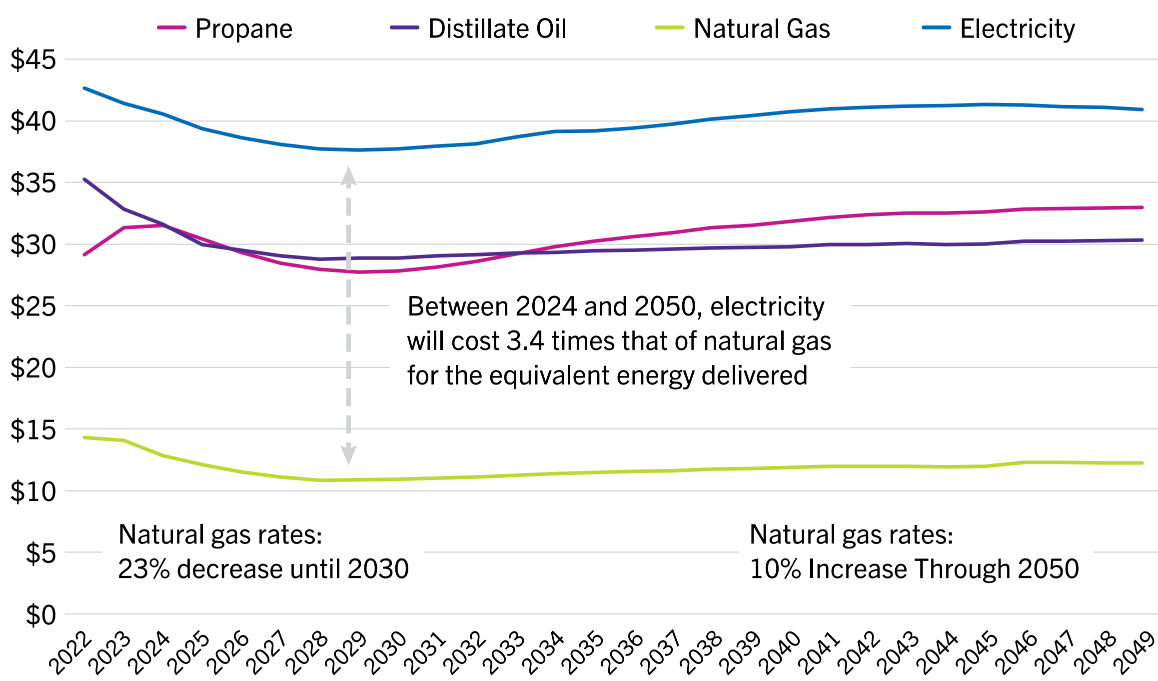
For this study, the average national and state monthly costs for the year 2024 are based on prices reported in the December 2023 EIA *Short-Term Energy Outlook*. A marginal cost factor based on monthly residential energy consumption and price was introduced to evaluate the net savings of advanced homes compared to the baseline.

Forward-Looking Changes in Energy Costs

This study utilizes prices from the EIA Annual Energy Outlook 2023 Reference Case. The average residential energy price for natural gas is forecasted to drop more than any other fuel since 2022 highs. Per unit of energy, natural gas is to remain significantly cheaper than other forms of fuel available to households. By the end of 2030, EIA is forecasting natural gas prices will drop 23% from their 2022 highs before changing direction slightly and increasing by 10% through 2050.

EIA projects that electricity prices will be 3.4 times higher than natural gas for the same unit of energy through 2050. For fuel oil and propane, the price of energy will be closer to 2.5 times that of natural gas. Because propane appliances are like natural gas, this will continue to drive homes to natural gas wherever possible, or electric heat pumps.

Figure 5
Residential Retail Energy Prices
Dollars (2022$) per MMBtu



Source: Department of Energy, EIA, Annual Energy Outlook 2023, Reference Case

Equipment and Installation Costs

When comparing the installation costs of natural gas appliances in new homes with all-electric alternatives, various factors come into play for each type of new single-family home. This analysis utilizes cost data provided by the National Association of Home Builders (NAHB) for a comprehensive and accurate appraisal of the factors that influence the construction of a new home.

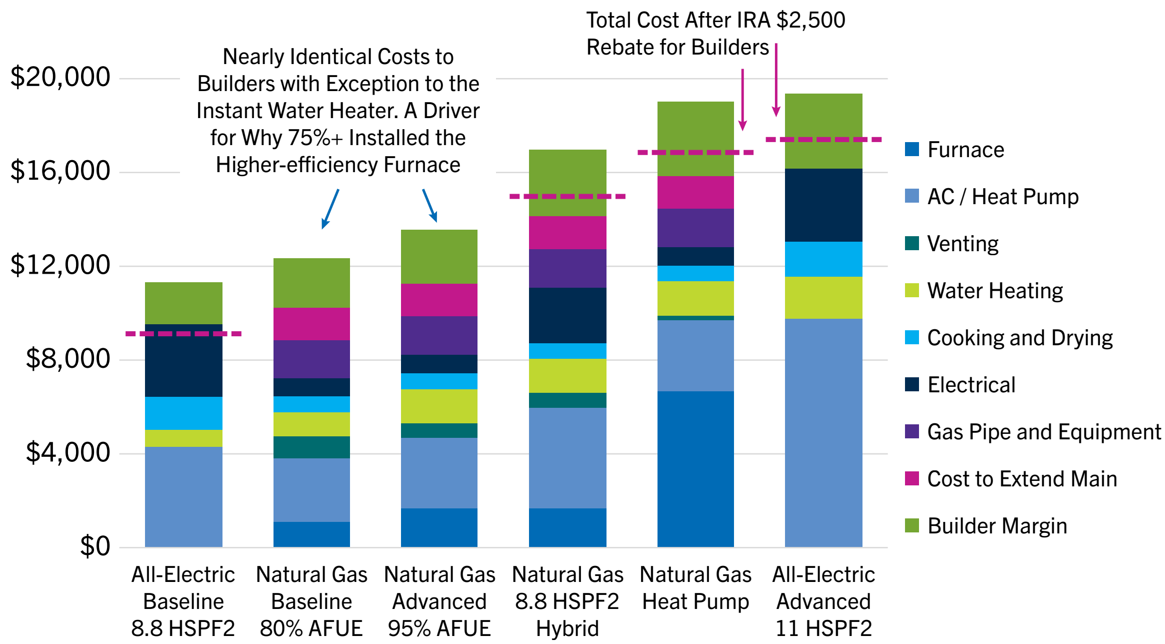
Beyond appliance purchase costs and installation, different homes may have specific infrastructure requirements to accommodate these appliances. For example, natural gas homes require gas piping and metering, which can add to overall construction costs. Conversely, all-electric homes potentially require additional investments in electrical systems, such as additional wiring and compatible plugs.

Generally, these cost differences are relatively modest, highlighting that the overall cost of each option is influenced by multiple factors, with the cost of the appliances being a significant driver.

This analysis does not include the additional costs of requiring car charging and solar pre-wiring. This analysis also does not include additional wiring and plugs for future electric appliances, which would increase builder costs to meet potential “electric ready” requirements without any direct energy savings.

Outside of the home, the cost of extending the utility gas main to the meter is dependent on local conditions and the specific characteristics of a new home or its location. In the South, where suburban communities are growing, the low density of homes can be a barrier to the extension of natural gas services. By contrast, in the North, higher density can lead to lower costs for new homes. In many cases, utilities may cover some or all of the cost of extending gas services to the meter, reducing the average cost cited by the Home Innovation Research Labs study from $1,400 to $0.

Figure 6
New Residential Installation Costs
Dollars (2022$)



Source: Home Innovation Research Labs, Cost Impact of Electrification Strategies on Residential Construction, February 2021

The upfront cost benefits of an advanced condensing natural gas home are evident in the market data. Approximately 75% of new homes opt for higher-efficiency gas models. Condensing natural gas appliances — those rated above 90% AFUE — not only reduce energy expenses but, counterintuitively, typically have lower installation costs compared to non-condensing furnaces (80% AFUE) due to lower ventilation costs. By installing high-efficiency condensing natural gas appliances, builders can save on venting expenses compared to the baseline home.[6]

Federal tax credits exist for electric appliances and some gas appliances, such as the highest-efficiency natural gas furnaces and natural gas heat pumps.

However, the high costs of advanced all-electric homes still pose significant barriers to achieving better energy efficiency. While federal tax credits available in the Inflation Reduction Act (IRA) can offset some of these upfront costs — potentially reducing expenses by up to $2,500 for the type of home modeled in this study — there are still challenges.

Builders are also just as likely — and maybe more likely — to take advantage of electric heat pump tax credits and apply them to homes that were already going to be all-electric. According to the most recent data, 19% of new homes install an electric resistance furnace as the primary electric space heating equipment. The share of resistance electric homes has decreased from 30% the year prior which did not have the same incentives in place. Federal incentives for electric heat pumps may, in this case, induce builders to install an electric air-source heat pump instead.

6 It's important to note that the upfront cost advantage of condensing equipment is often absent in the retrofit market. When upgrading from a non-condensing furnace to a condensing furnace, homeowners may need to modify the ventilation system, which can sometimes incur significant costs. In some cases, existing homes may not be physically able to upgrade the ventilation system to accommodate a condensing furnace. However, these costs and circumstances of this scenario are not relevant to this analysis, which is focused on new construction.

Modeling Greenhouse Gas Emissions from All Forms of Energy

There are several components of greenhouse gas emissions associated with household energy use. This analysis examines the following:

- Emissions from electricity generation using long-term marginal emissions rates using NREL's Cambium 2022 tool.
- Carbon dioxide emissions from natural gas combustion.
- Methane emissions from both the natural gas value chain (from production to distribution) and electricity generation.

This study examines the "monthly-hourly" marginal long-term electric and annualized gas emissions from electric and gas appliances in the near term (2024). The analysis also calculates the cumulative 15-year emissions from equipment by using NREL estimates for marginal long-term emissions in 2040 and then averaging between each year from 2024 to 2040.

While the focus of this report is on a national average, regional data points for various cost and emissions variables are included for comparative purposes. All greenhouse gases evaluated in this study are presented using an equivalent 100-year global warming potential — the same time horizon used by EPA in the Greenhouse Gas Reporting Program (GHGRP) and the Inventory of Greenhouse Gas Emissions and Sinks (GHG Inventory). The analysis also consists of a supplementary output for long-term marginal rates that provides estimates of methane emissions associated with electricity generation. This estimation encompasses the entire fuel cycle, spanning both fuel production and combustion of natural gas and coal.

In addition to the emissions quantified in this study, there are other greenhouse gas emissions to consider. For example, refrigerant leakage from electric heat pumps can contribute significantly to greenhouse gas emissions, as the refrigerants typically used in these systems have a high global warming potential. These leaks — which can occur during regular use, maintenance, accidental release, installation, and retirement — can result in non-trivial emissions. The types of refrigerants used in heat pumps, air conditioning units, and gas heat pumps vary.[7] Electric heat pumps, which operate year-round in both heating and cooling modes, are more prone to refrigerant loss over time compared to central air conditioning units, which only run in cooling mode. In contrast, gas heat pumps use ammonia as a refrigerant, which is not a greenhouse gas. There may also be minor methane emissions from residential gas appliances or uncombusted exhaust, according to EPA's estimates in the GHG Inventory; however, additional studies are needed to quantify these so-called post-meter emissions.[8] It's important to note that the scenarios modeled in this study assume new homes are equipped with new appliances that meet all manufacturer safety design standards.

7 New air conditioners and heat pumps are typically charged with the refrigerant R-410A, a chemical that has a 100-year GWP of 2,088. Future units sold will likely come with other refrigerants like R-32, which has a GWP of 675. Natural gas-powered heat pumps rely on ammonia as a refrigerant. Ammonia is not a greenhouse gas. https://www.epa.gov/sites/default/files/2020-12/documents/fugitiveemissions.pdf

8 The emission factors used to support EPA's post-meter segment emissions estimates in the GHG Inventory are based on limited data from a single focused study—a 2018 study of 75 homes in California. AGA has identified five data gaps and uncertainties within EPA's estimates: 1. There are no consensus standard test methods or standard practices for measuring and determining the flow rate or volume of methane emissions from end-use natural gas appliances.

Importance of Full-Fuel-Cycle Accounting

The definition of Full-Fuel-Cycle energy used throughout this report is as follows:

> Full-fuel-cycle energy is the energy consumed by an appliance, system or building as measured at the building site plus the energy consumed in the extraction, processing, and transport of primary energy forms such as coal, oil, natural gas, biomass and nuclear fuel; energy consumed in conversion to electricity in power generation plants; and energy consumed in transmission and distribution to the building site.[9, 10]

Significant amounts of energy can be used or lost in energy extraction, processing, transportation, conversion and distribution of useful energy delivered to consumers. Therefore, greater energy efficiency from the source to the site translates into less overall energy production required for the same amount of delivered useful energy.

The efficiency of end-use equipment also affects the total energy requirement. The full fuel cycle of different energy sources is required to obtain a comprehensive assessment of the full impact of end-use energy applications on energy resources; that is, the efficiency of the energy trajectory in conjunction with that of the end-user device.

Natural gas is delivered to consumers with much less energy wasted compared to electricity. The natural gas system's cumulative efficiency — from the wellhead to the residential meter — is 92%, according to a comprehensive analysis conducted by GTI Energy.[11] This means that for every 100 MMBtu of natural gas energy produced, 92 MMBtu of useful energy is delivered to a natural gas consumer.

Based on the current mix of energy used for electricity generation, electricity provides the consumer with only 38 MMBtu of useful energy for 100 MMBtu of energy produced. For oil, every 100 MMBtu produced results in 84 MMBtu reaching the customer. For propane, every 100 MMBtu produced results in 87 MMBtu reaching the customer.[12]

9 There are considerable data gaps, large uncertainties, and orders of magnitude differences among the other studies EPA reviewed when developing its post-meter emissions estimates.
In any event, the use of a limited set of studies conducted on a small sample of homes is unlikely to be representative of a national estimate for post-meter emissions.
There were no repeated tests conducted to determine the reproducibility of the methods referenced in EPA's post-meter emissions estimates or whether emissions vary with time or environmental conditions, such as seasonal temperature and weather changes.
EPA's estimated time series should reflect the phase-out of pilot lights from many natural gas applications. Due to the Department of Energy's energy efficiency standards for appliances, pilot lights have largely been phased out of U.S.-manufactured natural gas appliances over the past 10 to 30 years.

10 Full-Fuel-Cycle Energy and Emission Factors for Building Energy Consumption – 2018 Update https://www.aga.org/research-policy/resource-library/full-fuel-cycle-energy-and-emission-factors-for-building-energy-consumption-2018-update/

11 Ibid.

12 These results are based on a captured energy efficiency approach that treats non-combustible renewable power generation as if it is 100% efficient. There are several other potential approaches to evaluate conversion efficiencies, which are discussed in the previously linked report on full-fuel-cycle energy and emissions factors.

Table 5
Source-To-Site Efficiency of Energy Delivered to the Home*

Fuel	Extraction	Processing	Transportation†	Conversion	Distribution	Cumulative Efficiency
Natural Gas	96.2%	97.0%	99.3%	--	99.0%	91.5%
Oil	94.9%	89.1%	99.7%	--	99.6%	84.0%
Propane	94.6%	93.6%	99.2%	--	99.2%	87.1%

Fuel	Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency
Electricity - Coal Based	98.00%	98.60%	99.00%	32.00%	95.50%	29.20%
Electricity - Oil Based	96.30%	93.80%	98.80%	31.80%	95.50%	27.10%
Electricity - Natural Gas Based	96.20%	97.00%	99.30%	45.00%	95.50%	39.80%
Electricity - RNG Based	100.00%	80.00%	99.30%	100.00%	95.50%	75.90%
Electricity - Nuclear Based	99.00%	96.20%	99.90%	32.60%	95.50%	29.60%
Electricity - Hydro Based	100.00%	100.00%	100.00%	100.00%	95.50%	95.50%
Electricity - Biomass Based	99.40%	95.00%	97.50%	100.00%	95.50%	87.90%
Electricity - Wind Based	100.00%	100.00%	100.00%	100.00%	95.50%	95.50%
Electricity - Solar Based	100.00%	100.00%	100.00%	100.00%	95.50%	95.50%
Electricity - Geothermal Based	100.00%	100.00%	100.00%	100.00%	95.50%	95.50%
Electricity - Other Based	100.00%	100.00%	100.00%	20.30%	95.50%	19.40%
Electricity Weighted Average§	97.80%	97.50%	99.40%	42.10%	95.50%	38.10%

Source: Gas Technology Institute, Energy Planning Analysis Tool - 2022.
"--" indicates not applicable or no efficiency loss.
*Efficiency of energy delivered to the home refers to the energy used or lost, from the point of extraction to the residence, not including the end-user device.
†Transportation of natural gas from the processing plant to the local distribution system; transportation of fossil fuel to electricity generating plants.
‡Includes renewable energy
§Current national weighted average mix of all power generation sources.

Natural gas often exhibits the highest overall energy efficiency for many applications when considering the full-fuel cycle — the combined source-to-site energy efficiency plus the end-use equipment efficiency. The combined efficiency of the natural gas system and end-uses is often higher than that of the electricity system serving the same end uses. This is primarily because the greatest inefficiency occurs during electricity generation, where approximately two-thirds of the input energy is lost during combustion in turbines/generators. Additionally, approximately 6% of the electricity generated is lost during transmission, further reducing overall efficiency before it reaches a consumer.

These electric "conversion" efficiencies will change over time as coal-fired power plants are retired, as the natural gas generator fleet becomes more efficient, and from the increased use of variable renewables, which this analysis assumes has a conversion efficiency of 100%.[13]

13 There are several approaches to determining the conversion efficiency of non-combustible renewable energy, such as wind and solar. These include Incident Energy, Fossil Fuel Equivalency, Captured Energy Efficiency, and Infinite Energy Efficiency. This analysis uses the Captured Energy approach, which assumes a conversion efficiency of 100%. For more details on the various approaches, see page 27: Full-Fuel-Cycle Energy and Emission Factors for Building Energy Consumption – 2018 Update https://www.aga.org/research-policy/resource-library/full-fuel-cycle-energy-and-emission-factors-for-building-energy-consumption-2018-update/

Table 6
Full Fuel Cycle Impact on Space Heating Efficiency

Natural Gas Heating:	88% for a 95% AFUE condensing furnace and 74% for an 80% AFUE furnace.
Electric Resistance Heating:	39% despite the 99% COP site.
Electric Heat Pumps:	98%, assuming the heat pump operates at 260% COP site efficiency all winter long.
Oil and Propane Furnace:	67% and 70% based on an 80% AFUE furnace.

Average vs. Marginal Energy and Emissions Factors

In discussions surrounding greenhouse gas emissions and strategies for their reduction, both average and marginal emissions offer insights into the emissions and costs linked with various end-use technologies. **Average emissions** provide a general overview of the current state of the electric grid. They are suitable for inventory and benchmarking purposes, including evaluating existing energy requirements or long-term incremental changes to the electric grid. However, average energy and emissions factors can be misleading when comparing technologies that offer the same service, assessing the impacts of an incremental technology change, or making investment decisions.

In contrast, **marginal emission rates** are most appropriate for impact assessments. Marginal approaches account for the energy and emissions associated with the last unit of electricity generated at a specific time. As such, they are most effective when comparing new energy requirements, including new electricity loads, from the adoption of electric appliances. Of course, marginal approaches also have limitations. Relying solely on any marginal rate might not suffice for all energy policy analyses, as the scale of a proposed new demand source can significantly impact the energy source of that final energy unit.

AGA Methods for Estimating Electricity Emissions

Electric grid emissions in this study are modeled using the National Renewable Energy Laboratory (NREL) Cambium database, which provides forecasted hourly average and marginal emissions rates. As the only publicly accessible data source with this level of detail, the Cambium database is invaluable for conducting hourly marginal emission policy analysis.[14]

The Cambium database is developed from the NREL Regional Energy Deployment System (ReEDS), a capacity planning and dispatch model that simulates the U.S. bulk electricity system. ReEDS predicts structural shifts based on factors like fuel costs, technology costs and policies such as renewables mandates. It models supply and demand across the four seasons and different times of the day.

ReEDS alone is not enough to model hourly or marginal emission rates, so NREL also uses a tool called PLEXOS, which simulates optimal hourly generation capacity dispatch. The final output is a comprehensive dataset of hourly average, long-term and short-term greenhouse gas emission rates, which are then presented in the Cambium database. While the ReEDS model is primarily a capacity planning tool, it also provides demand and emissions forecasts, particularly prioritizing zero-carbon sources under new policies.

14 https://scenarioviewer.nrel.gov/

This study integrates hourly consumption data from the EnergyPlus model with the "monthly-hourly" long-term marginal emissions data from the NREL Cambium database. This approach more accurately reflects the conditions of the electric grid, where emissions typically decrease during daylight due to increased solar power generation. These intra-day generation dynamics are crucial for assessing marginal emissions rates.

Long-term marginal rates are useful for predicting permanent demand increases beyond initial estimates. However, their accuracy depends on the assumptions inherent in the original model.[15] In this analysis, AGA utilizes the 2022 Cambium Mid-Case scenario dataset as a baseline, noting that NREL released an updated 2023 model shortly before this report's publication. Both versions reflect similar trends in electricity generation, highlighting how factors like Inflation Reduction Act spending and local or state policies could boost renewable energy implementation. The models predict minimal need for new natural gas generation capacity beyond 2030, indicating a substantial shift from coal to gas with lower carbon emissions from electric generation through 2050.

It's vital to note that all NREL model versions (2020-2023) rely on data from a single weather year for demand forecasting. The year 2012, which recorded the warmest winter in two decades across most of the U.S., serves as a baseline. This year, and therefore NREL's model, is a poor predictor of higher heating demands.

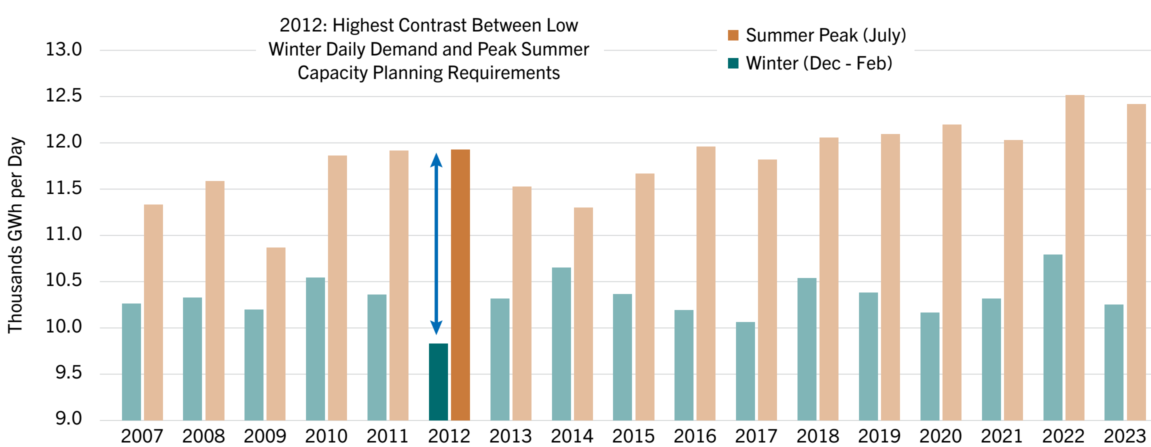
To illustrate, AGA estimated that, using EIA data, the average daily winter electricity demand in 2012 was 9.8 thousand GWh/day. However, the long-term winter average spanning 2007 through 2023, is 5% higher at 10.3 thousand GWh/day, and the peak (set in 2022) of 10.8 thousand GWh/day or 10% higher. However, 2012's warm summer made it a peak year for electric demand for the next eight years, suitable for capacity planning but not for year-round demand testing.

Figure 7

Comparison of Average Seasonal Electricity Daily Demand

Winter Months (Dec-Feb) Compared to Peak Design Month (July)

EIA Electricity Data Browser



15 Additional Note from NREL on the use of Cambium: "This data was created with the ReEDS, dGen, PLEXOS, and Cambium models. The data are modeled projections of the future under a range of possible scenarios. Although we strive to capture relevant phenomena as comprehensively as possible, the models used to create the data are unavoidably imperfect, and the future is highly uncertain. Consequentially, these data should not be used as the sole basis for making decisions. In addition to drawing from multiple scenarios within a single Cambium set, we encourage analysts to draw on projections or perspectives from other sources, to benefit from diverse analytical frameworks when forming their conclusions about the future of the power sector."

NREL's use of 2012 for its electric grid modeling makes it suitable for capacity planning but not for year-round demand testing, especially for winter heating demand.

This contrast between average winter days and peak summer days is stark, suggesting that the NREL model may overbuild for rare scenarios rather than average conditions over a 30-year period.

Additionally, using EIA's Grid Monitor, this study examined how well the NREL model's base year matched actual extremes experienced recently on the electric grid. This study converted the historical data from EIA to match the averaged month-hour dataset provided by NREL. NREL forecast for winter future electric demand tracks at times towards historical lows and may not represent actual future winter electric requirements since this also happens to be when renewables are the most curtailed in the model.

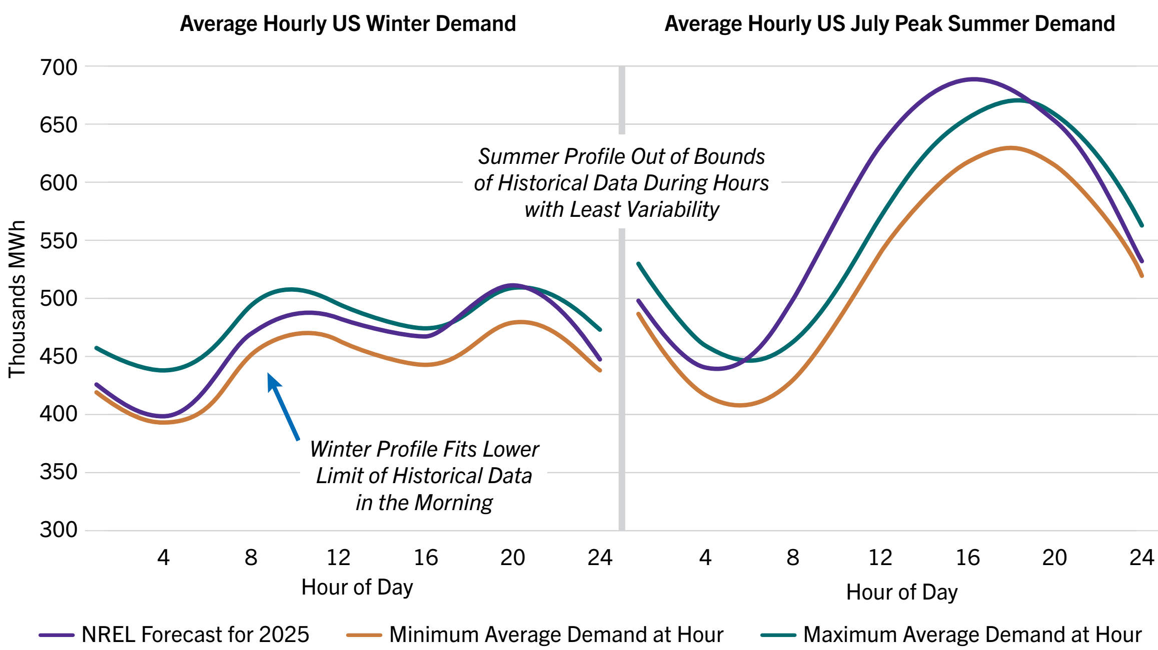
Meanwhile, the summer forecast often exceeds the maximum over this period by as much as 15%. Therefore, the NREL forecast results in an outcome where long-term summer peak conditions are exceeded every day in July, especially during mid-day hours, with very little growth compared to previous years. This forecast makes for a good test for conditions that exceed expectations but also forces the model to add capacity beyond what is likely required and will report significant amounts of renewable generations sitting idle most of the year.

Figure 8

Historical Range vs Forecasted Hourly National End Use Demand

Average Seasonal Hourly Demand for Electricity

Historical Month-Hour 2016-2023 and NREL 2023 Dataset



Source: American Gas Association

Note: NREL forecast for winter future electric demand tracks toward historical lows and may not represent true winter, while summer demand in 2025 exceeds recent averaged peak demand by as much as 15%.

NREL estimates future year-round capacity requirements are primarily based on peak electricity demand during the summer. The model currently uses a demand forecast with high peak summer and low winter conditions, unchanged through 2050. This approach results in an enormous excess of available electric capacity, particularly renewable capacity, that remains largely unutilized, leading to artificially low emissions rates due to lower-than-expected winter electric demand.

By using a warm winter as a baseline, the model forecasts very high levels of seasonal curtailment by 2040, with national average rates as high as 45% in April, indicating that half the U.S. grid's renewable generation could sit idle for much of the month). By contrast, winter renewable curtailment rates are between 6% and 14%. This leads to a scenario where most fossil fuel-based power generation occurs in the summer, with nearly double the demand compared to the winter months. Currently, the U.S. is experiencing growth in natural gas generation during both peak winter and summer conditions, with no trend where winter demand is decreasing relative to the summer.

Through the use of the 2022 Cambium dataset, this analysis includes the same important policy impacts of the Inflation Reduction Act and local or state mandates. However, the model employs a simple curtailment method, resulting in less excess renewable capacity in the winter. Future modifications to Cambium, including the use of a 30-year forecast and other features discussed by NREL, such as virtual powerplants in the summer, may reduce energy by cutting required peak capacity to levels where significant amounts of renewable capacity are not reported idle most of the year.

NREL should also consider incorporating multiple long-term marginal emissions rates to enhance the utility of the database for policy modeling. The current model only tests demand increases by 5% above the current forecast. This is clearly insufficient given the current trend of average and peak electric demand growth. Furthermore, local policies may create circumstances where peak hourly conditions at different times of the year could exceed 10-15%+ of forecasted demand, depending on the assumptions used.

Limitations of Applying NREL's Model for Winter Heating Demand Analysis:

While this analysis relies on the NREL model for its detailed forecasting capabilities, it's important to note some fundamental limitations when applied to a winter heating demand analysis and when estimating actual emissions from electric heating.

1. **Use of an Atypical Baseline Year:** NREL's model relies on the year 2012, which had the warmest winter in two decades, as a baseline for demand forecasting. This year is considered a poor predictor for higher winter heating demands, leading to potentially inaccurate projections for future winter energy needs.
2. **Overemphasis on Summer Peaks:** The NREL model appears to prioritize peak summer demand in its capacity planning, which results in high forecasts for summer electricity demand (exceeding recent averages by up to 15%). This focus may lead to overbuilding capacity for rare peak summer scenarios rather than reflecting average conditions over a 30-year period.
3. **Underrepresentation of Winter Demand:** The model forecasts future winter electric demand tracking towards historical lows, which may not accurately reflect true future winter electric requirements. This could result in an underestimation of the need for winter capacity, particularly when renewable energy sources are most curtailed.
4. **Excess Capacity and Curtailment:** Due to the use of low winter demand and high summer demand scenarios, the model predicts significant excess capacity, particularly for renewable

energy. This leads to large amounts of renewable generation sitting idle, especially in non-peak seasons, creating artificially low emissions rates due to lower-than-expected winter demand.

5. **Inadequate Adaptation for Long-Term Changes:** The current model does not adequately account for the ongoing growth in natural gas generation during peak winter conditions. The use of a single warm winter year in the model may lead to skewed long-term projections, failing to reflect the actual trends and demands seen in recent years.
6. **Need for Model Improvements:** The critique suggests that NREL should consider using a broader range of baseline years and incorporate a more dynamic forecast model that includes multiple long-term marginal emissions rates and better accounts for regional and seasonal demand variations. This would help avoid excessive capacity projections and provide more accurate data for policy modeling.

Natural Gas System Emissions

Natural gas is primarily composed of methane, which is a greenhouse gas. When natural gas is combusted in oxygen, it produces energy and carbon dioxide. It is crucial to account for all emissions, including methane, from the wellhead to the end use to determine the total environmental impact of each appliance. The DOE Argonne National Laboratory GREET model reports GHG emission factors for various end uses and reports a full-fuel-cycle GHG emissions factor for natural gas of 63 kg CO2e/MMBtu. This value includes losses and fugitive emissions from the natural gas system today without potential future improvements to the system or other measures to reduce emissions across the natural gas value chain. The CO2 equivalent from fugitive emissions of methane is estimated to be 10.1% of the 63 kg CO2e/MMBtu.[16]

Renewable Natural Gas

Renewable natural gas (RNG) production captures methane from organic waste, reducing overall emissions and promoting low-carbon fuels. By diverting organic waste from landfills and farms, RNG supports efficient waste management practices and contributes to the local circular economy. Additionally, RNG production generates economic opportunities, particularly in rural areas with abundant organic waste, fostering local development.

RNG can be sourced from diverse organic waste materials, including landfill gas, wastewater treatment plants, agricultural waste, organic municipal solid waste, and industrial and commercial organic waste. Each source has different greenhouse gas emissions and cost characteristics. While RNG is still an emerging and growing market, blending RNG can save significant emissions at a low cost per ton because of the avoided emissions.

AGA's study on the cost and emissions of newly constructed homes includes an alternative cost and emissions outcome for RNG that is achievable today. In 2019, ICF International developed a report for the American Gas Foundation, "The Renewables Sources of Natural Gas: Supply and Emissions Reduction Assessment," which outlines potential RNG sources, costs and emissions.[17]

16 Department of Energy GREET model 2022, the tool used by the Inflation Regulation Act of 2022 to estimate lifecycle greenhouse gas emissions.

17 https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/

Based on the AGF report, this study uses an average cost of RNG of $21.24 per MMBtu. Compared to the average price of natural gas in 2022, the RNG cost is 52% higher. However, this RNG cost is half of the average residential electricity price.

RNG Blending Assumptions

This analysis explores the potential of reducing average natural gas emissions by 20% or more through a blend of renewable natural gas (RNG) sources. The study utilizes RNG production scenarios developed by ICF for the American Gas Foundation. The ICF study presents two RNG production scenarios — low and high resource potential — based on the availability of RNG feedstocks under assumed constraints. This analysis uses the average of both scenarios to estimate RNG production by 2040.

The estimated RNG production is then compared to the total residential and commercial natural gas consumption averaged from 2018 to 2023, to determine the potential RNG blend available for new homes from now through 2040. Although based on detailed technical and economic evaluations, these estimates aim to illustrate the potential of RNG to become a meaningful component of the gas utility supply mix and its role in reducing greenhouse gas emissions from delivered utility gas.

Currently, RNG production accounts for approximately 1% of total residential and commercial natural gas consumption. This study projects that production will grow to the equivalent of 30% of residential and commercial demand by 2040. Accordingly, the analysis assumes a gradual increase in the blend of RNG in the utility mix, resulting in a 20% blend annualized through 2040. In this scenario, the national average annual natural gas bill for a modeled home would increase by only 8.8%, based on 2022 prices. However, regional variations will affect these estimates, and actual costs may differ due to the assumptions and ranges set by ICF in the renewable natural gas resource report.

Emissions from RNG

The greenhouse gas (GHG) emission factors for renewable natural gas (RNG), like those for other energy sources, are often reported as a carbon intensity in units of GHG emissions per unit of fuel energy (e.g., kg CO2e/MMBtu). These values can be referenced using both lifecycle and combustion approaches.

The following tables present lifecycle emissions factors for different renewable natural gas sources. These factors are based on generic pathways in the Argonne National Laboratory GREET model and are presented in an ICF White Paper.[18, 19]

National average CO2e emissions from RNG were based on the forecasted average annual production of each of the eight primary sources of RNG between 2025 and 2040. On average, emissions per MMBtu of RNG delivered to homes are estimated at 2.8 kg CO2e/MMBtu and account for approximately 20% of annualized emissions from natural gas utilities over 15 years. This average will change for specific utilities depending on regional differences in the forecasted source of RNG. The average price per MMBtu presented in the report was $21.24 with a range as low as $14 and as high as $29.70.

18 Argonne National Laboratory, 2019. Available at: https://greet.es.anl.gov/

19 ICF Working paper #1. Greenhouse gas emission accounting principles for RNG - https://bit.ly/38rNhms

Table 7

GHG Emission Factors in the RNG Supply Chain from Anaerobic Digestion of Feedstocks

kgCO2e/MMBtu

RNG Production Process		Dairy Manure	Food Waste	Landfill Gas	WRRFs*	Natural Gas
Collection and Processing	Feedstock Collection	0	1.8	0	0	7.8
	Digestion & Gas Processing	19.4	22.9	19.9	19.6	
	Avoided Emissions	-176.1	-82.1	0	0	
Transmission	Transmission	2.1	2.1	2.1	2.1	2.1
End-Uses	Combustion	<0.1	<0.1	<0.1	<0.1	53.1
Total		-154.6	-55.3	22	21.7	63

*WRRF = Water Resource Recovery Facility

Table 8

GHG Emission Factors in the RNG Supply Chain from Thermal Gasification

kgCO2e/MMBtu

RNG Production Process		Agricultural Residue	Forest Residue	Energy Crops	MSW*	Natural Gas
Collection and Processing	Feedstock Collection	1.7	1.6	3.3	1.8	7.8
	Syngas processing	26	26	26	26	
Transmission	Transmission	2.1	2.1	2.1	2.1	2.1
End Uses	Combustion	<0.1	<0.1	<0.1	<0.1	53.1
Total		29.8	29.7	31.4	29.9	63

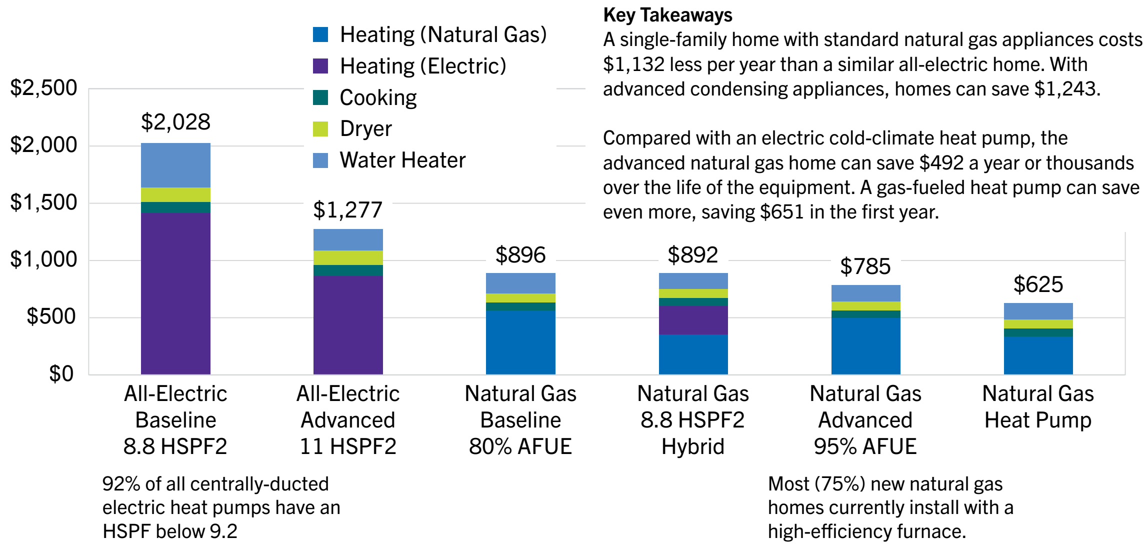
*MSW = Municipal Solid Waste

Results from Examining Costs and Emissions for Homes Modeled

Analysis of Annual Operating Costs

Based on this analysis, the baseline natural gas new construction home would save as much as $1,132 compared to a home that relied on a standard Energy Star heat pump for space heating. The reason for the cost savings, despite the improved site efficiency of the heat pumps, is the cost difference between natural gas and electricity, as well as any seasonal impacts on HVAC performance throughout the winter.

Figure 9
Annual Energy Costs for Gas or Electric Uses
Dollars per Year



Source: American Gas Association

For all-electric homes that rely on the most common heat pumps sold today (units with a heating rating between HSPF 8.4 and 9.2), the outdoor air temperature will impact operational efficiency during the colder winter months. More backup space heating will be necessary, which lowers overall efficiency.

For the advanced all-electric home with a rating of 11 HSPF2, the electric heat pump consumed less than 20% or one-fifth of the backup space heating compared to the baseline heat pump.

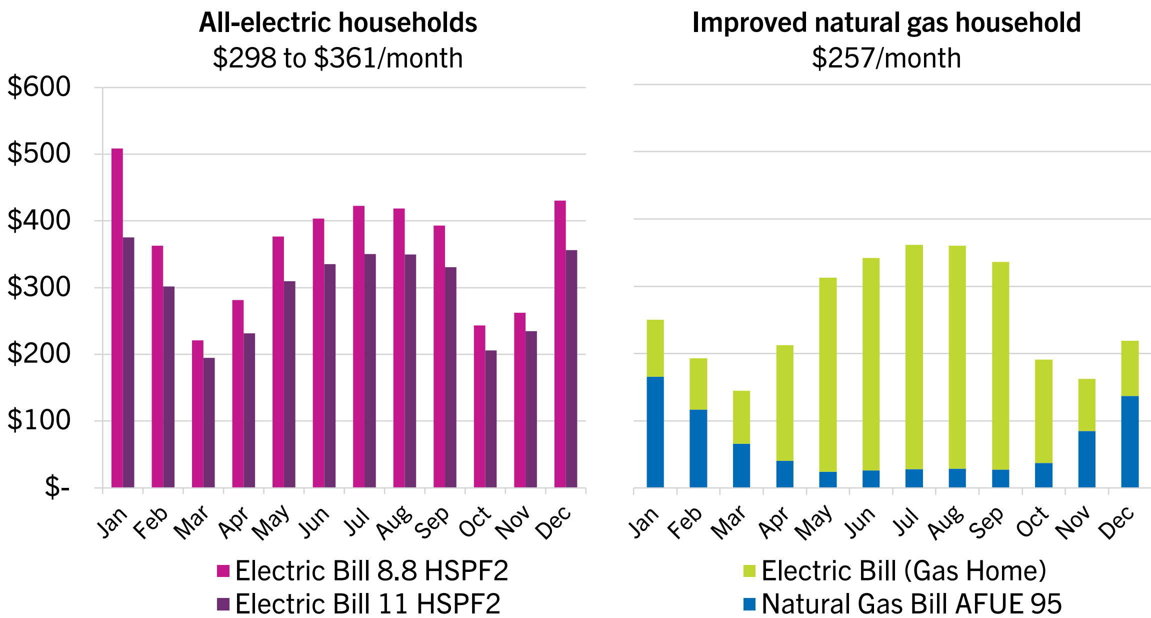
Advanced natural gas and electric homes cut consumer costs due to higher energy efficiency. Both showed value to households.

The heat pump is most cost-effective when the real-world coefficient of performance is high enough to overcome the unit cost of electricity compared to natural gas. The efficiency of heat pumps for space heating most often matches or exceeds the cost advantage of natural gas during the spring and fall seasons when heating demand is lower and air temperatures are higher. Any fixed monthly customer costs, which this study considers, will also be reflected as a higher share of the monthly bill during these months. In contrast to the low demand of "shoulder months," demand is very high during the peak winter months of December, January and February, and monthly bills reflect that need for energy.

This study further illustrates the monthly expenses for both electric and natural gas for all modeled homes. This output mirrors the actual monthly bill fluctuations households may encounter, representing the final bill paid each month. For natural gas customers, it effectively visualizes the added expense from fixed customer charges for service costs, even during months of minimal natural gas consumption.

Monthly bills can be as much as $100 to $300 higher with the all-electric house during the winter, even with the most efficient home model. During the summer, costs are much more similar since space cooling becomes the largest energy user in the home. The fixed cost of service will have a higher share of the total monthly bill, with only cooking, drying and water heating being used. However, the cost savings from these appliances and the significant savings in the winter outweigh the cost of guaranteeing service from a local gas utility.

Figure 10
Monthly Space Heating Costs
Dollars per Month



Source: American Gas Association

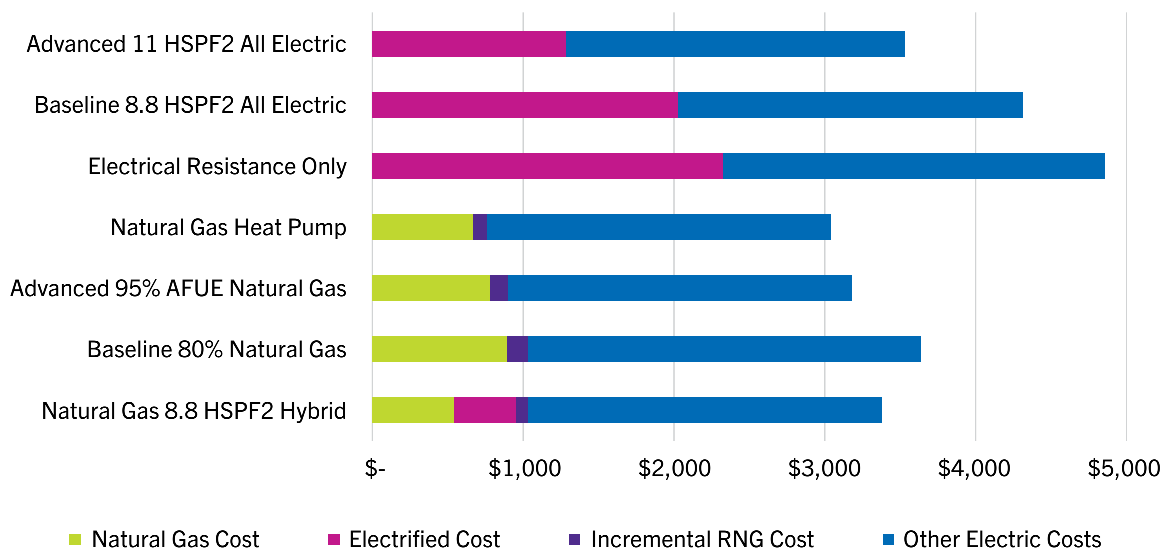
For households or builders seeking the highest amount of cost savings or potential environmental savings through flexible solutions, gas-powered heat pumps and gas hybrid systems can offer both. Gas heat pumps are available today and can be found in larger homes (4,000+ square feet). Gas hybrid systems can be installed in almost any home with the exchange of an A.C. unit with a heat pump. In this analysis, the gas-powered heat pump lowered costs by an additional $160 a year.

The gas-electric hybrid heating system scenario models a home with an advanced condensing gas furnace and water heater and a standard efficiency Energy Star heat pump. The purpose of the hybrid system is to allow for flexibility when weather conditions are worse than normal and to maximize the overall energy efficiency of the space heating system. Households interested in heat pumps could save on operating costs by keeping or installing natural gas appliances along with electric options, providing lower costs and more flexibility in colder than normal weather conditions.

Additionally, renewable natural gas (RNG) was calculated as an incremental cost for natural gas consumers. In this scenario, the analysis assumes that about 20% of the gas supply over 15 years will be sourced by renewable natural gas, with an average forecasted cost for RNG based on the ICF study. The cost range for a mixture of RNG sources per MMBtu could see prices as low as $14 per MMBtu or as high as $29.7 per MMBtu with a mid-range estimate of $21.24 per MMBtu.

Adding the approximate 20% mixture of RNG costs households between $92 and $119 annually. This projection is based on the expected national RNG mixture of feedstocks and is subject to variation based on specific utility sourcing. For gas heat pumps or gas hybrid homes, the inclusion of RNG is based on the net demand for RNG in the advanced condensing natural gas home. Homes that utilize significantly less fuel could consume the same amount of RNG as those with only condensing furnaces.

Figure 11
Total Annual Home Operating Cost
Dollars (2024$)



Source: American Gas Association

Analysis of Annual Full-Fuel-Cycle Emissions

The analysis found that between 2024 and 2026, the baseline natural gas home emits 10.4 metric tons of CO2e annually, while the all-electric baseline heat pump home emits 10.8 metric tons of CO2e. The share of which is from natural gas or potentially electrified appliances is 4.4 and 4.8 metric tons of CO2e in 2024-2026. These estimates are based on current-year emissions from NREL's cambium database and CO2e emissions from natural gas without any use of Renewable Natural Gas "RNG". The assumption of 0% RNG may not align with current market experience, where RNG is already an immediate and growing source of natural gas for local gas utilities and is likely to continue to grow beyond 2040.

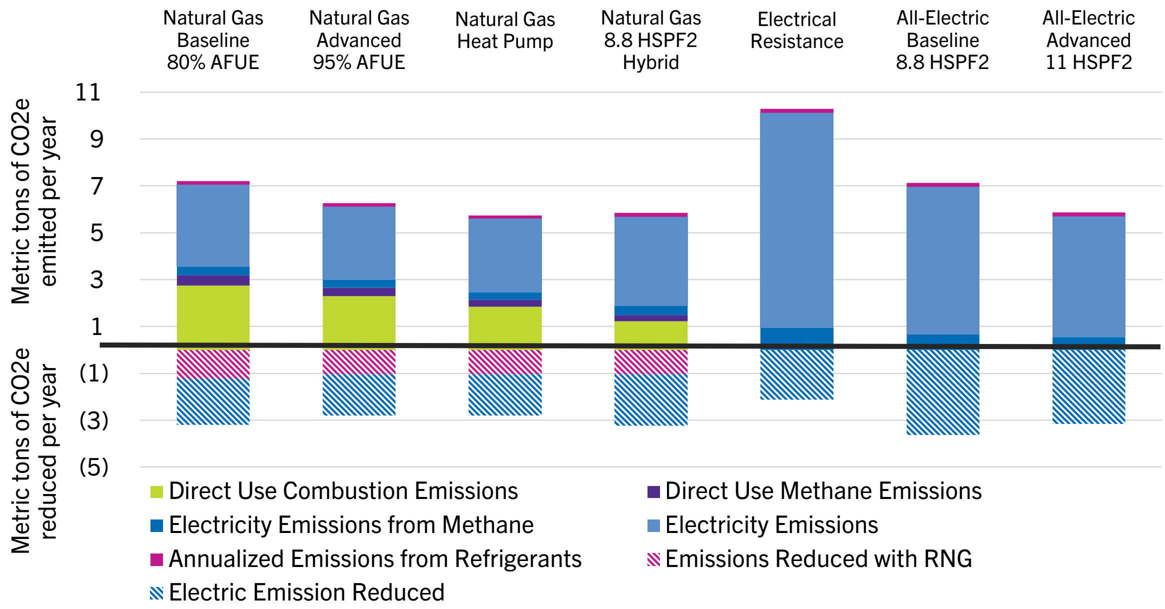
For advanced homes, both all-electric and natural gas emit 8.9 tons of CO2e annually based on today's modeled emissions. Similar to the baseline scenarios, this accounts for all appliances in the home. Emissions from advanced natural gas or advanced electrified appliances are lower than the baseline, both emitting 3.7 metric tons of CO2e in 2024-2026.

This analysis also projects emissions in 2040 based on the methods described previously but includes grid advancements through 2040 and forecasted growth in RNG. By 2040, the advanced natural gas home will continue to have an average annual greenhouse gas emissions nearly equivalent to the advanced cold climate heat pump home. The advanced natural gas home emits 6.0 tons of CO2e, compared with the all-electric home's 5.8 tons of CO2e. This accounts for all appliances used in the home.

Figure 12

Projected Residential Greenhouse Gas Emissions in 2040

Metric tons of CO2e emitted/avoided per year



Source: American Gas Association

A gas hybrid home that utilizes both condensing natural gas appliances and a heat pump would have lower emissions in 2040 than all homes modeled. The ability to reduce emissions would cost less to install or retrofit than an electrified cold climate heat pump home, and have the same annual operating cost as the baseline gas home, all while utilizing commonly available equipment.

A hybrid home can achieve lower emissions than an advanced all-condensing gas home by offering the flexibility to use the most cost-effective and energy-efficient heating appliances as needed. The hybrid system could be sized for cooling and off-peak heating, which can further reduce the total installation costs of the hybrid system compared to an advanced cold-climate heat pump system and lessen peak electricity demand during winter. Compared to an advanced all-electric home, a hybrid system can lower winter peak electricity demand by 6 kW, a significant reduction from the high summer demand seen even in the cold-climate all-electric home modeled. While this approach may not be suitable for all homes or climates, it provides households or builders with a flexible way to reduce emissions while maintaining preferred appliances at a reasonable cost.

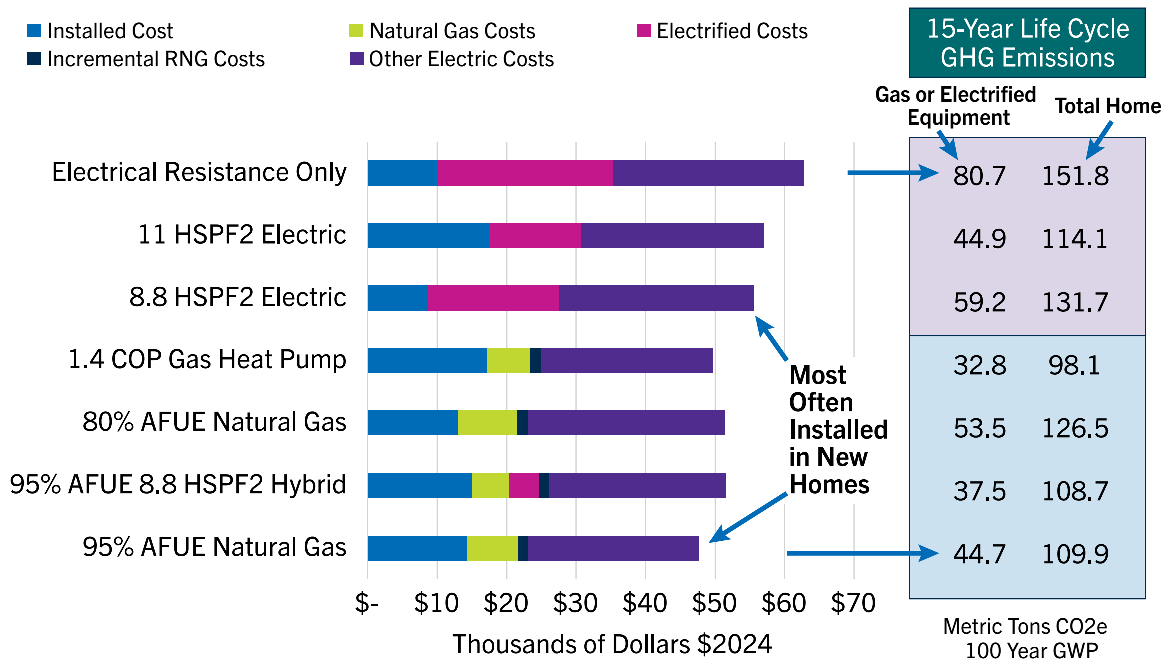
The comparable emissions for natural gas and all-electric homes in 2040 demonstrate that both natural gas and all-electric homes can compete to reduce emissions, even in the long term. It also reinforces that modeled emission reductions are more dependent on general energy efficiency improvements than the substitution of appliance fuel sources through electrification.

Lifecycle Costs and Emissions for Each Home Over 15 Years

This analysis highlights various pathways to reducing emissions over time, each offering different levels of CO2e savings at varying costs. The choice of primary energy sources, installation expenses and the inclusion of alternative fuels like renewable natural gas (RNG) significantly impact the cost-effectiveness of each approach to lowering CO2e emissions. This study evaluated the cost of installing and operating a house from 2025 through 2040 under different scenarios.

The total cost of ownership for a home with natural gas proves to be lower than that of all-electric alternatives in all 15-year scenarios. The high-efficiency gas home results in the lowest life cycle operating costs compared to other options. Notably, homes with a gas-electric hybrid heat pump system, which assumes the use of a baseline efficiency heat pump operating in tandem with condensing gas space and water heating appliances, have lower life cycle costs, installation costs and emissions than all-electric homes using an electric cold climate heat pump. This conclusion demonstrates the role of natural gas in achieving higher cost-effectiveness in homes installed with electric heat pumps.

Figure 13
15-Year Lifecycle Costs, All Appliances
Thousand Dollars (2024$)



Source: American Gas Association
Note: Natural gas and electricity costs are based on EIA Annual Energy Outlook 2023. Renewable natural gas (RNG) costs are fixed at estimates reported by the American Gas Foundation. All operating costs are subject to a 3% discount rate.

Homes that install natural gas heating systems generally show lower emissions than all-electric homes, though some all-electric configurations may show lower emissions relative to a baseline natural gas home. The baseline natural gas homes emit an average of 8.3 tons of CO2e annually, while all-electric homes emit 8.8 tons of CO2e between 2025 and 2040. The share of which is from natural gas or potentially electrified appliances is 3.4 and 3.9 metric tons of CO2e over the next 15 years.

A condensing furnace and water heater, utilizing an annualized average blend of 20% RNG demonstrate lower lifecycle costs in the thousands of dollars and proved to be the most cost-effective option, emitting similar amounts of CO2e over 15 years than the cold-climate electric heat pump home. The cost savings and emissions reductions from the natural gas home include the incremental cost increase from an average annualized 20% mix RNG and the lower fuel emissions. At lower percent mixtures of RNG, the natural gas home would have higher emissions but the consumer would also have an even lower life-cycle cost compared to before.

Based on the modeled forecast for greenhouse gas emissions over 15 years, the advanced natural gas and all-electric homes emit approximately 7.2 tons of CO2e annually between 2025 and 2040. For natural gas or electrified appliances only, the share of emissions is also approximately the same at 3.0 metric tons CO2e annually. When comparing emissions between the most commonly built homes today, the use of high-efficiency condensing gas appliances reduces emissions by 17% compared to the baseline all-electric home. The importance of this specific comparison is that these two scenarios represent the average level of efficiency in new homes today.

One area where electric heat pumps undoubtedly provide more significant and immediate cost and emissions benefits is replacing electric resistance appliances. Currently, twice as many existing homes use electric resistance heat than heat pumps. Even for new construction, 19% of electric homes built in 2023 use resistance heating, making these households prime candidates for electric heat pumps due to existing infrastructure.

Gas heat pumps and hybrid systems also result in the smallest amount of lifecycle emissions and are cheaper than the all-electric options despite higher installation costs than homes with a stand-alone gas furnace. The gas heat pump has an added cost of $2,954 compared to a natural gas furnace, while the hybrid system includes both a furnace and a baseline 8.8 HSPF2 heat pump at an incremental cost of $893 more than the advanced all-condensing home. The low-cost savings for installing a hybrid are due to the $2,500 IRA-funded builder tax credit. Additional savings are possible in some climates by installing a smaller heat pump sized for cooling and off-peak heating season. Compared to the advanced cold climate heat pump home, the all-electric build costs $3,177 more than the advanced condensing home or similar to the gas heat pump home but with higher operating costs.

Effect of Incorporating Renewable Natural Gas

Households and utilities can further reduce emissions by offsetting part or all of their gas usage with RNG. Compared to all-electric alternatives, the inclusion of a forecasted average annualized 20% RNG mix is always more cost-effective when used in any of the natural gas homes modeled. This highlights RNG's potential to reduce emissions while offering an alternative to full building electrification.

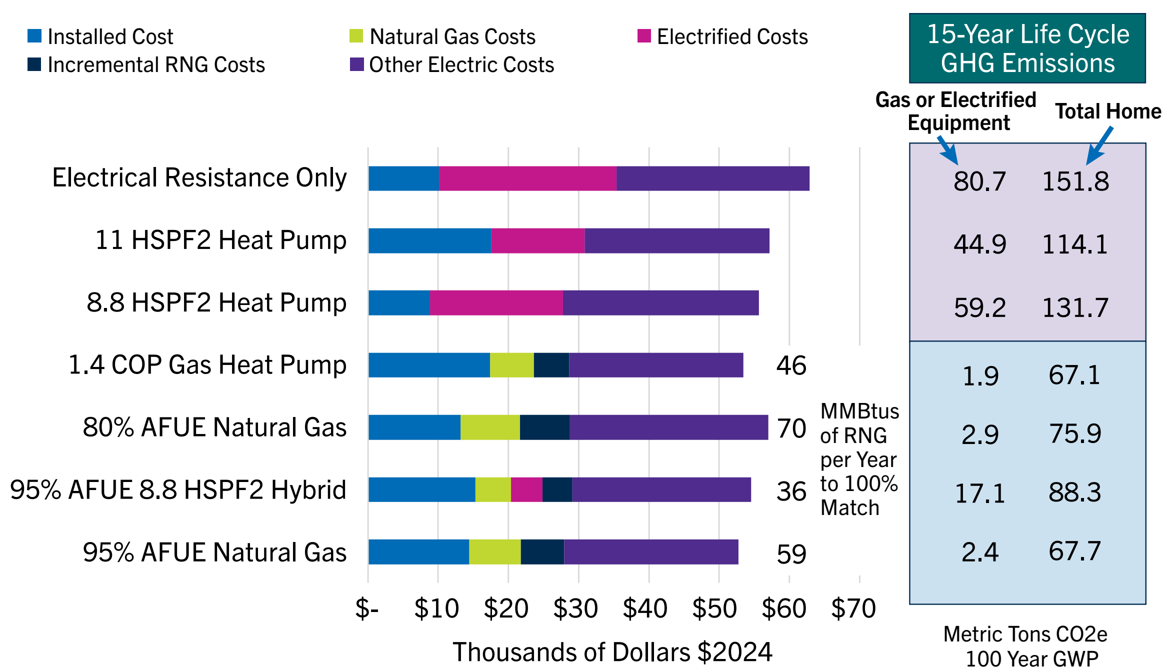
For households using advanced natural gas appliances or the more advanced all-electric home, the average savings in the first year would more than compensate for the increased cost of RNG. The annual incremental cost of RNG would be $92 annually and the average cost savings with RNG comparing both advanced gas and advanced all-electric homes would be $492 in the first year. After accounting for changes in energy prices over the next 15 years, that annualized savings increase to $600 a year with RNG.

Incremental impacts differ by geography. However, for numerous households, the cost savings compared to the all-electric scenarios can outweigh the increased expense of small inclusions of low-carbon fuels while maintaining the winter resilience that natural gas utilities provide.

For both gas heat pumps and hybrid homes, the amount of natural gas used on-site is lower than in homes with furnace-only systems. Assuming flat future total demand for residential and commercial natural gas use, as more buildings install gas heat pumps and hybrid systems, the amount of RNG available to these homes would be the same (or greater) as what is being distributed to the baseline or advanced natural gas homes. Utilizing a natural gas heat pump in this RNG scenario would further lower emissions by 0.5 metric tons of CO2e a year compared to the condensing natural gas furnace scenario, while also reducing annual energy costs by $160.

Scenarios that assume 100% RNG are generally cost-comparable to any of the all-electric options tested and reduce, on average, 96% of emissions attributable to natural gas appliances. This approach can provide a more cost-effective way to reduce emissions and make it easier to reach carbon neutrality when combined with a smaller, less expensive rooftop solar system than otherwise needed.

Figure 14
15-Year Lifecycle Costs, All Appliances
Thousand Dollars (2024$)



Source: American Gas Association
Note: Natural gas and electricity costs are based on EIA Annual Energy Outlook 2023. Renewable natural gas (RNG) costs are fixed at estimates reported by the American Gas Foundation. All operating costs are subject to a 3% discount rate.

Cost-Effectiveness of Emissions Reductions

This study found that in an average new single-family home, the more common all-electric baseline heat pump scenario would emit the highest annual CO2e emissions compared to all other scenarios. By focusing on this baseline home, initially comparing unchanged emissions over time, we can compare various appliance scenarios and fuel sources — such as greenhouse gas emission improvements from grid-sourced electricity, utility natural gas and renewable natural gas — to assess their cost-effectiveness in reducing CO2e per metric ton over the next 15 years. This enables an evaluation of how future emissions-related improvements to grid-sourced electricity might compare in cost-effectiveness and total emissions reductions to renewable natural gas and natural gas appliances.

The cost-effectiveness of emissions reductions is defined here in terms of dollars per metric ton of greenhouse gas emissions reduced, represented in carbon dioxide equivalent terms (CO2e). The GHG reductions are a function of the efficiency of the end-use application and GHG emissions intensity of the fuel source, in this case electricity or natural gas. This study evaluates different scenarios of renewable natural gas blended into the natural gas fuel mix utilized by the appliance.

At present, the electrified appliances in the baseline all-electric home emit 4.8 metric tons of CO2e annually, amounting to 71.5 metric tons of CO2e over 15 years, assuming no improvements to the electric grid. Therefore, when taking into account NREL's projected changes in the electric grid mix and the commensurate reduction in carbon intensity of generated electricity over that same period, total GHG emissions are reduced by 12.4 metric tons of CO2e, bringing the total to 59 metric tons of CO2e over 15 years. The net installation and total operating costs, when compared to the advanced natural gas home, result in a cost of $1,081 per metric ton of CO2e reduced over 15 years. Crucially, these emission reductions for the all-electric home rely entirely on the forecasted improvements to the electric grid.

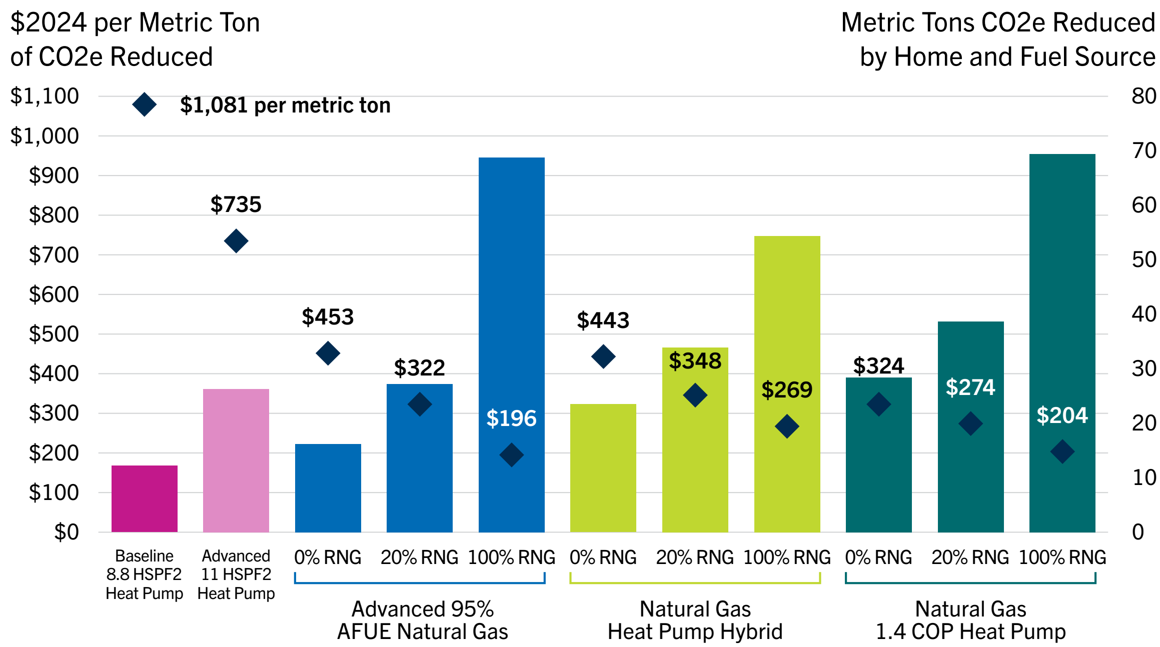
In contrast, the advanced all-condensing natural gas home emits 16.3 metric tons of CO2e less than the baseline "no change to the grid" all-electric scenario, even without incorporating renewable natural gas (RNG). Although RNG is forecasted to constitute an annualized 20% of utility gas use over the next 15 years (per the assumption described earlier in this report), the natural gas home already performs better in emissions and costs less to build and operate. Without RNG, the advanced natural gas home achieves a cost of $453 per metric ton of CO2e reduced.

When RNG is blended into natural gas at 20%, it reduces greenhouse gas emissions by 28.4 metric tons of CO2e over 15 years at a cost of $322 per metric ton of CO2e reduced. At a 100% RNG blend, emissions reductions equal 69.1 metric tons of CO2e at $196 per metric ton of CO2e reduced.

Across all natural gas scenarios, including RNG blends, the cost-effectiveness of CO2e reductions is consistently better than both baseline and advanced all-electric heat pump homes. Even with future grid improvements, the advanced all-electric home incurs a cost of $735 per metric ton of CO2e avoided.

These results also provide a surprising conclusion: **Increasing RNG blends increases the overall cost-effectiveness of natural gas emissions reductions.** Therefore, renewable natural gas stands out as an immediate and cost-effective solution for reducing household greenhouse gas emissions relative to all-electric households.

Figure 15
Cost of GHG Emissions Reduction
Total Modeled Home, Natural Gas or Electrified End Uses Only



Source: American Gas Association
Note: Greenhouse gas reductions are based on the modeled 2024-2026 emissions for the electric appliances within the baseline all-electric home, assuming no improvements to the electric grid for 15 years; total baseline greenhouse gas emissions are 71.5 metric tons CO2e.

The ability to achieve 100% RNG blends for 75 million or more households with natural gas requires further demonstration. Furthermore, there are considerations related to consumer cost-effectiveness related to higher blends of RNG as well as all-electric household scenarios that rely on significant reductions of electric grid emissions. However, as described elsewhere in this report and other studies, there is a substantial potential for renewable natural gas resources in the United States to meet a variety of end-use sector needs, including residential building applications. Many jurisdictions are developing supportive regulatory frameworks to enable the expansion of RNG supply and demand. Furthermore, incorporating accounting methods to track the supply and disposition of RNG supplies, including their environmental attributes, can further enable consumer adoption of RNG.[20]

The projected growth of RNG and improvements in gas appliance efficiency presents a viable, cost-effective method for reducing emissions today. Considering current market trends in furnaces and heat pumps, as well as the associated costs of building and operating both gas and electric homes, new homes with natural gas appliances currently offer the most cost-effective pathway to greenhouse emissions reduction for households.

20 *Regulatory Pathways for Advancing Low-Carbon Gas Resources for Gas Distribution Companies*. American Gas Foundation (2023). https://gasfoundation.org/wp-content/uploads/2023/02/AGF-LCR-Study-Full-Report-Final-Final-2.6.23.pdf

Discussion and Policy Considerations

The findings of this study have significant implications for energy policy decisions affecting household energy choices, particularly in the context of emissions mitigation. The study underscores the importance of considering flexible routes and a diverse array of household energy choices.

This study found that:

- High-efficiency natural gas products are already featured prominently in the market today, and consumers prefer these advanced gas heating appliances in new construction.
- Three-quarters of the new construction market installs high-efficiency condensing gas furnaces compared to only 8% of all compatible central split unit heat pumps shipped with a rating over 9.2 HSPF and less than 1% over 11 HSPF2 (i.e., cold climate heat pumps).
- All-electric households are typically found in areas where there is no access to natural gas. More than 60% of homes with heat pumps exist beyond the natural gas system. In other words, when consumers have access to natural gas, they will typically select it. Nearly 20% of new electric space heating is still met with inefficient electric resistance applications.
- The adoption of renewable natural gas (RNG), high-energy efficiency gas appliances, hybrid gas-electric heating systems and natural gas heat pumps can contribute to substantial consumer cost savings and emission reductions, especially compared with all-electric households.
- Natural gas appliance solutions can also offer flexible and lower-cost alternatives to emissions reduction policies that emphasize all-electric households as the primary policy pathway.

These findings underscore a crucial observation: Policy strategies aimed at lowering household energy costs, improving efficiency and reducing emissions should recognize and align with existing market dynamics.

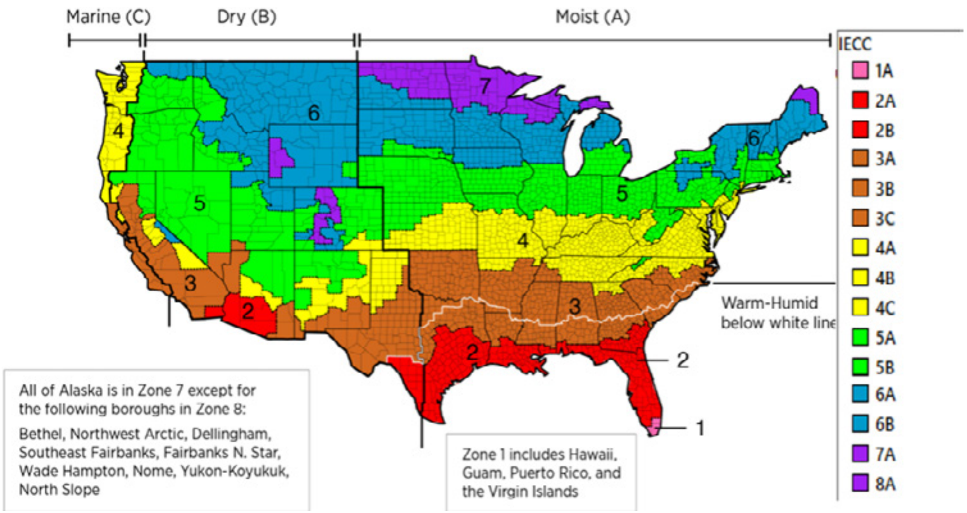
Policymakers may want to consider market trends and consumer choices when devising effective strategies to encourage the use of the most efficient energy choices on the market today. Furthermore, the policy landscape can be adaptive. No one-size-fits-all approach for all consumers exists. Households need flexibility to meet their financial and environmental goals.

This study highlights that emission reduction goals can be better achieved through a strategic combination of high-efficiency natural gas and renewable natural gas integration. These measures can be paired with other approaches to improve efficiency in the natural gas system and within buildings, as well as approaches to reduce emissions along the natural gas value chain.

By tailoring policies to capitalize on the strengths of both the electricity and natural gas systems while acknowledging market realities, policymakers and stakeholders can pave the way for a more sustainable energy future that reduces emissions quickly and cost-effectively.

Appendix A: Changes made to DOE's EnergyPlus Prototype Model Home

1. Replaced design day, location, and water main temperature with 2021 ASHRAE Handbook 99% conditions for St Louis MO. Modeled weather based on the *EnergyPlus* St Louis TMY3 file available on the program website.
2. Removed undefined miscellaneous natural gas and adjusted electric usage.
3. Matched miscellaneous electric usage for both natural gas and electric homes (previously the electric home was higher than natural gas).
4. Removed exterior lights.
5. Limited space heating to be turned on from October 15 through April 15. Cooling is limited to April 15 through October 15. The reason for this change is that most households do not set the thermostat to allow for heating or cooling year-round based on the average climate for the U.S.
6. Changed sizing of all furnaces and heat pump space heating from auto-sized to 8800 W (2.5 ton). Backup electrical resistance heating was set to 20,000 W.
7. Changed coefficient of performance "COP" for Cooling to 3.45 for SEER 16 and 4.15 for SEER 19 (for advanced homes).
8. The heat pump heating COP for the baseline house is 2.6 and COP for the advance house is 3.2. These are both equal to HSPF 8.8 and 11 heat pumps.
9. The heat pump compressor was set to the model default of negative 8 degrees Celsius for the baseline home and negative 18 degrees Celsius for the advanced home.
10. Gas furnace COP was set to 80% for the baseline house and 95% for the advanced house.
11. Changed the efficiency of the natural gas water heater to 65% for the baseline house and 95% for the advanced house. The electric baseline house was changed to a tanked resistance unit for the baseline house, which matches most water heaters sold today. The advanced electric home received a tanked heat pump water heater with a capacity of 0.196841372 m3 and a COP of 2.3.
12. For natural gas and electric water heaters the temperature set point was set at different temperatures with the heat pump 8 degrees F lower. This was changed so that the natural gas and resistance units would match the heat pump.
13. DOE model file used was for IECC Climate Zone 4A



Appendix B: Regional Monthly Residential Prices and Marginal Rates

Average Monthly Residential Natural Gas Prices for 2024 $/MMBtu

	National Average	Northeast	Middle Atlantic	South Atlantic	East South Central	West South Central	East North Central	West North Central	Mountain	Pacific
January	$11.81	$16.90	$12.36	$13.52	$8.86	$9.52	$10.97	$11.48	$11.50	$17.46
February	$11.53	$16.70	$12.14	$13.81	$8.90	$9.75	$10.29	$10.18	$11.36	$16.22
March	$12.01	$16.73	$12.31	$14.86	$9.32	$10.21	$11.21	$10.80	$11.50	$15.75
April	$12.64	$17.35	$12.67	$16.02	$10.12	$10.57	$12.37	$13.52	$12.40	$15.53
May	$14.91	$17.78	$14.03	$19.57	$12.95	$13.85	$15.97	$17.19	$14.15	$15.83
June	$18.36	$18.75	$16.63	$24.06	$19.37	$18.43	$19.99	$19.86	$16.42	$16.35
July	$20.14	$20.58	$18.92	$26.79	$21.29	$20.25	$21.49	$21.87	$18.53	$16.66
August	$20.89	$22.00	$19.66	$26.62	$22.00	$21.13	$22.85	$24.11	$19.04	$16.77
September	$19.67	$20.68	$18.86	$25.94	$19.39	$19.58	$21.30	$23.28	$17.89	$16.40
October	$14.98	$17.65	$15.45	$22.64	$12.01	$13.41	$16.93	$19.87	$14.04	$15.38
November	$12.31	$16.24	$13.23	$14.68	$9.87	$10.19	$12.23	$13.79	$12.02	$14.69
December	$11.61	$16.48	$12.00	$13.20	$8.94	$9.91	$10.74	$11.11	$11.25	$15.89
Marginal Rate Factor*	75%	86%	82%	67%	78%	68%	76%	75%	79%	99%

*Pacific Region does not include HI and AK in order to improve estimating costs for CA. OR, and WA

Average Monthly Residential Electricity Prices for 2024 $/MMBtu

	National Average	Northeast	Middle Atlantic	South Atlantic	East South Central	West South Central	East North Central	West North Central	Mountain	Pacific
January	$51.33	$101.80	$67.44	$45.01	$51.01	$37.92	$42.73	$45.03	$44.33	$66.56
February	$52.95	$105.10	$68.75	$46.77	$52.53	$40.53	$44.57	$47.49	$45.00	$66.00
March	$53.25	$104.16	$66.38	$46.04	$53.60	$41.49	$45.21	$47.35	$44.86	$68.13
April	$54.51	$103.33	$65.22	$47.87	$54.29	$43.46	$45.74	$46.85	$45.67	$75.35
May	$54.53	$96.89	$66.24	$47.90	$55.55	$46.15	$46.30	$47.68	$47.00	$76.76
June	$54.52	$93.05	$68.46	$48.26	$54.10	$48.79	$45.66	$47.21	$47.83	$83.39
July	$54.10	$88.84	$69.18	$47.25	$53.63	$48.59	$44.81	$46.35	$47.33	$82.84
August	$54.79	$89.48	$69.72	$47.78	$52.81	$48.43	$44.17	$47.26	$46.69	$85.90
September	$55.12	$96.06	$73.10	$47.73	$53.45	$46.43	$43.32	$48.47	$46.79	$81.05
October	$53.86	$89.46	$71.10	$46.49	$54.73	$43.20	$44.66	$49.00	$47.15	$70.22
November	$52.70	$91.76	$69.94	$44.46	$53.47	$40.98	$45.18	$48.40	$45.68	$67.62
December	$50.58	$94.57	$68.69	$42.85	$51.35	$37.92	$42.23	$45.96	$44.18	$65.23
Marginal Rate Factor*	104%	85%	96%	105%	99%	107%	95%	97%	108%	109%

*Pacific Region does not include HI and AK in order to improve estimating marginal costs for CA, OR, and WA.

Appendix C: Regional Sources of RNG and Range of Costs

Summarized Emissions and Cost Impact of RNG by Source

	kg CO2e/MMBtu	Average $/MMBtu	Low $/MMBtu	High $/MMBtu
Landfill Gas	22	$13.00	$7.00	$19.00
Animal Manure	-154.6	$25.50	$18.40	$32.60
WRRF	21.7	$16.75	$7.40	$26.10
Food Waste	-55.3	$23.85	$19.40	$28.30
Agriculture Residue	29.8	$22.85	$18.30	$27.40
Forest Residue	29.7	$23.25	$17.30	$29.20
Energy Crops	31.4	$24.75	$18.30	$31.20
MSW	29.9	$30.75	$17.30	$44.20

Source: American Gas Foundation

Source and Cost of RNG based on a Forecasted Resource Availability (tBtu/yr)

	National	Northeast	Middle Atlantic	South Atlantic	East South Central	West South Central	East North Central	West North Central	Mountain	Pacific
Landfill Gas	682	18	76	131	42	105	83	67	36	125
Animal Manure	347	$12.00	$18.00	$46.00	54	50	34	58	43	32
WRRF	40	$3.00	$6.00	$4.00	2	3	1	3	3	15
Food Waste	47	$2.00	$7.00	$8.00	2	7	5	5	2	8
Agriculture Residue	448	$0.00	$6.00	$76.00	182	19	32	87	19	26
Forest Residue	172	$5.00	$7.00	$28.00	17	46	26	22	11	10
Energy Crops	481	$0.00	$6.00	$41.00	135	67	47	183	2	0
MSW	476	$23.00	$66.00	$80.00	29	76	45	50	29	77
Total	2691	$64.00	$192.00	$415.00	462	373	272	476	145	292
Average kg CO2e/MMBtu	2.8	-10.4	6.1	5.3	7.6	1.6	3	5.8	-28.1	3.9
Low $ / MMBtu	$14.00	$13.62	$12.60	$13.92	$13.82	$14.46	$13.41	$16.96	$13.18	$11.81
Average $ / MMBtu	$21.24	$22.42	$21.05	$21.70	$20.89	$21.28	$20.53	$22.95	$20.17	$19.74
High $/ MMBtu	$29.70	$32.35	$30.52	$29.08	$29.47	$30.05	$29.08	$30.17	$30.47	$28.81

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