Building for Efficiency: Home Appliance Cost and Emissions Comparison

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Contents

This analysis examines energy, cost, and emissions characteristics of new homes based on appliances and fuels

- This AGA study evaluates energy costs and emissions for typical new single-family homes for different appliances and fuels using a full-fuel-cycle methodology to examine energy use and greenhouse gas emissions.

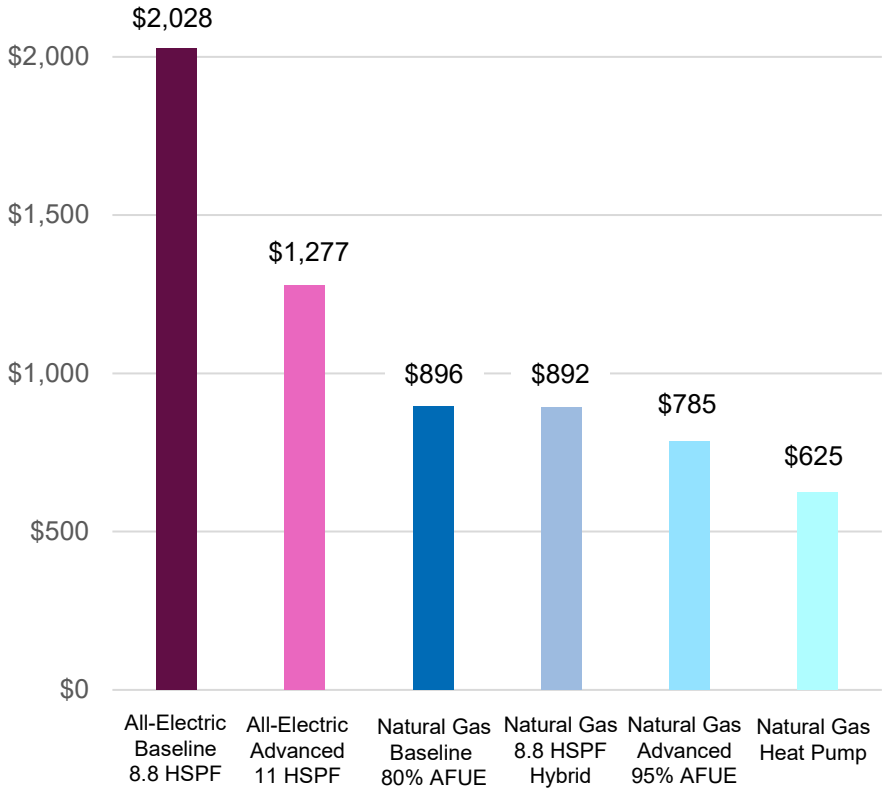
New Construction Household Performance Examined	
Monthly Energy Costs	Greenhouse Gas Emissions

Appliances	Energy Sources
Space Heating	Electricity
Water Heating	Natural Gas
Cooking	Renewable Natural Gas
Clothes Drying	

Key findings: A typical new home with natural gas shows the lowest annual energy costs and often the lowest greenhouse gas emissions for space heating, water heating, cooking, and clothes drying applications.

Cost Comparison of Gas and Equivalent Electric Appliances

Average Annual Cost in Dollars



Cost Savings: A baseline natural gas new home costs $1,132 per year less than an equivalent baseline all-electric household.

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 HSPF.

Greenhouse Gas Reductions: A condensing natural gas furnace installed today in an all-gas home can cut lifetime emissions by 17% compared to the typical all-electric household. Matched to an all-electric home with a cold climate heat pump, natural gas 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.

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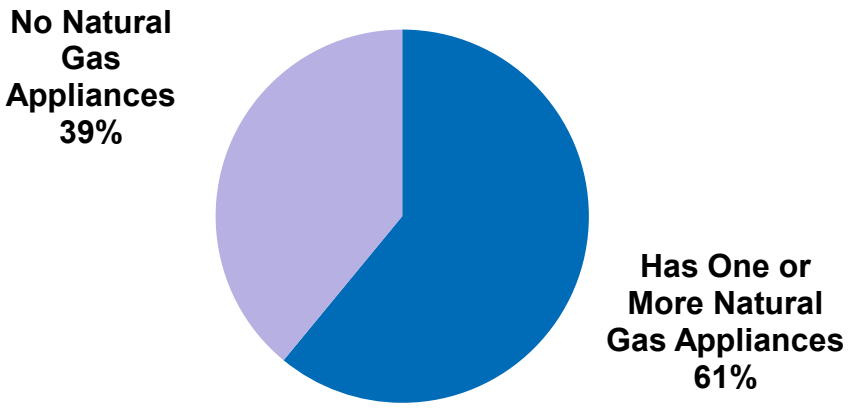
An Introduction to the Residential Natural Gas Marketplace

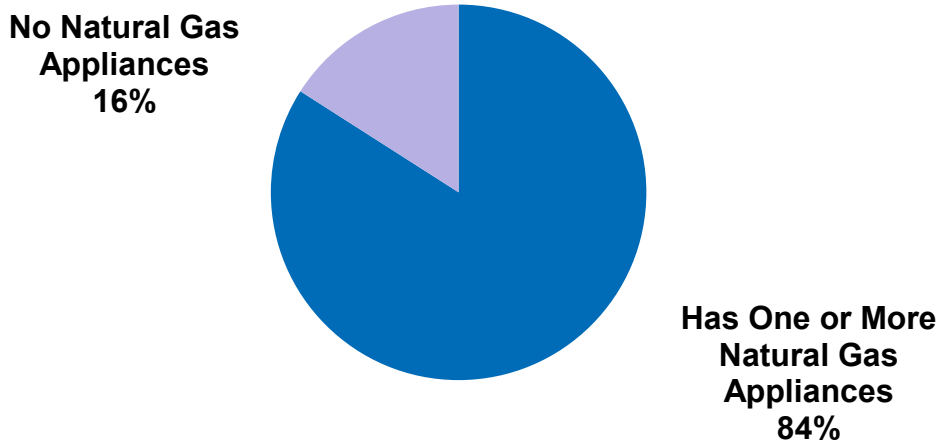
The Critical Role of Infrastructure in Gas vs. Electric Heating Comparisons

All Households



Based on market share alone, 61% of homes use natural gas, and 39% do not. Without exploring the data further, a policy might assume any home is just as likely to use electricity for heating as a natural gas.

Households with Access to Natural Gas



The missing factor is infrastructure and without considering it as a separate geographic boundary, any analysis would miss that wherever gas is available, most homes use it because of the cost benefits.

84% of homes with access to natural gas use it for one or more appliances. Most of the growth in high-efficiency heat pumps has occurred outside this boundary.

Energy Information Administration: Residential Energy Consumption Survey 2020

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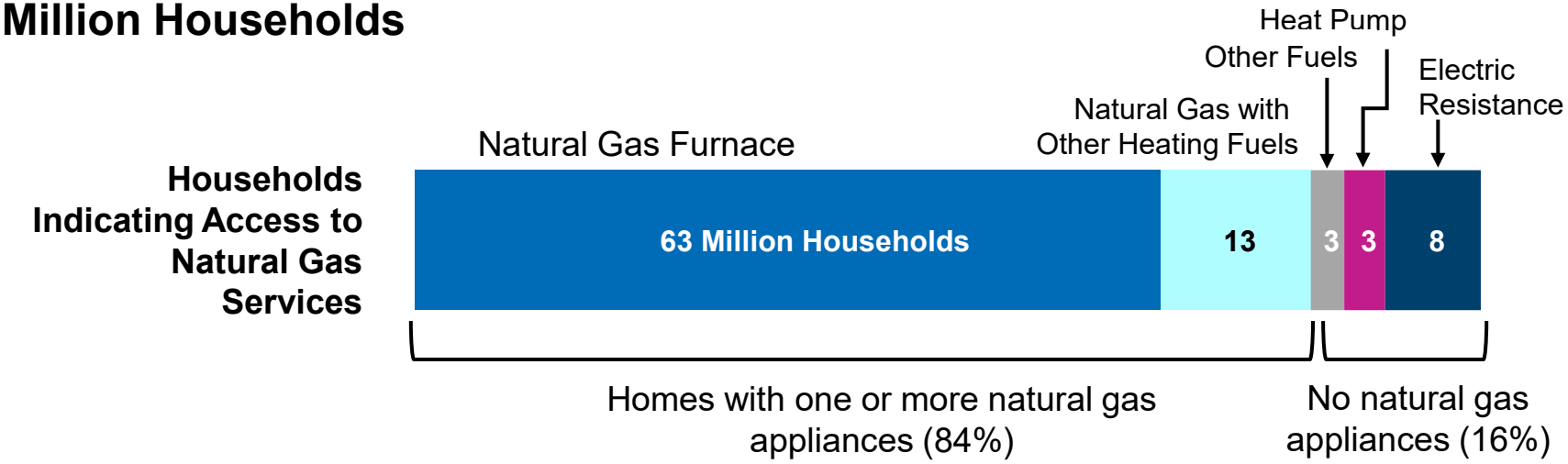
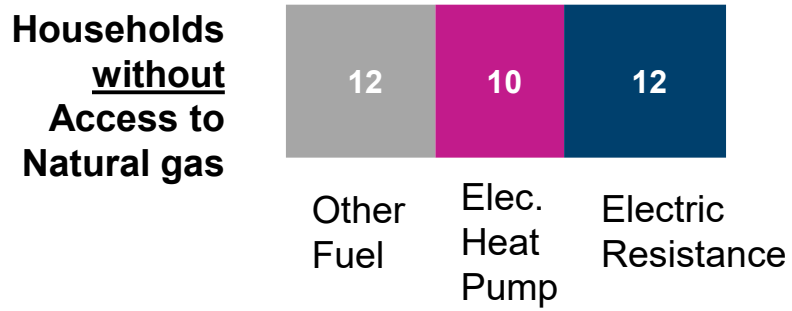
Most consumers use natural gas for space heating when gas service is available. Electric heat pumps are typically installed in homes without access to natural gas.

Primary Space Heating Equipment Installed

Million Households





- 60% of all electric heat pumps installed are in homes without natural gas service.
- Only 29% of households without natural gas service use a heat pump for primary space heat.

Natural gas and electric heat pumps serve as complementary solutions in advancing residential energy efficiency, each catering to diverse consumer needs and preferences.

Energy Information Administration: Residential Energy Consumption Survey 2020

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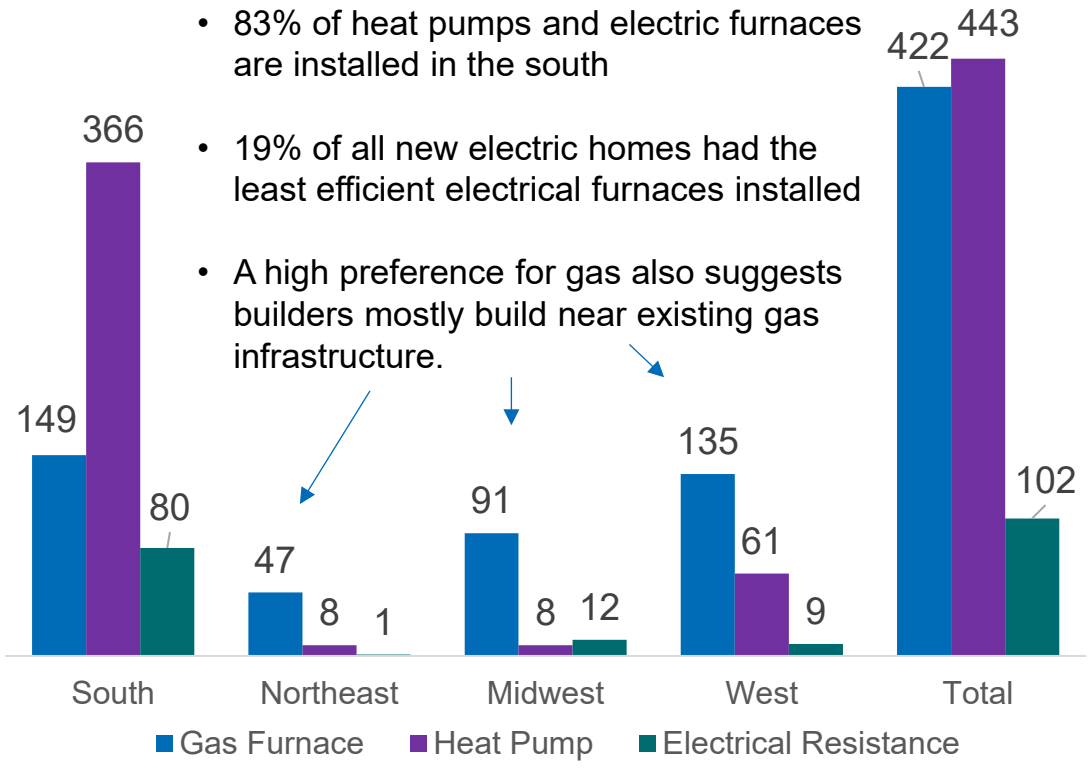
In 2023, 44% of all new single-family homes installed natural gas. Outside of the Southern US, there is generally a high market penetration for natural gas, with 5 to 1 new homes installing natural gas.

New Single-Family Home Market by Region

Thousands of Homes Built in 2023

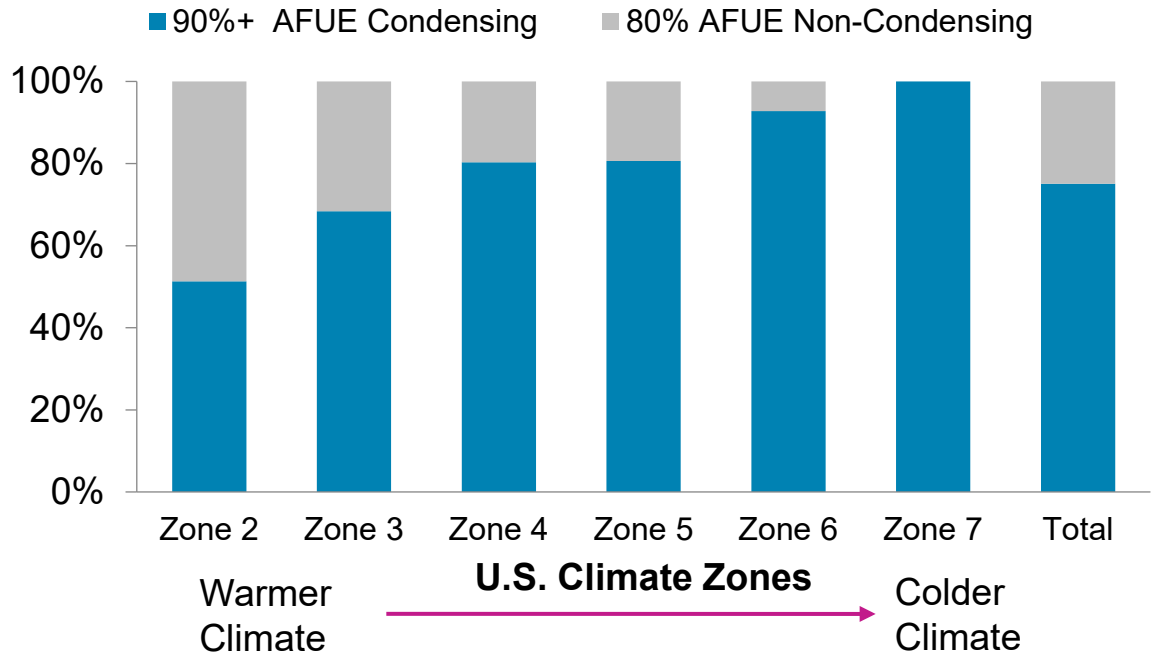
- 83% of heat pumps and electric furnaces are installed in the south
- 19% of all new electric homes had the least efficient electrical furnaces installed
- A high preference for gas also suggests builders mostly build near existing gas infrastructure.



Natural Gas Furnaces

Installed base by efficiency/product class

75% average condensing installation rate for new homes and businesses. 90% or more in the coldest climates.



Left: U.S. Census Bureau, Characteristics of Residential New Construction
Right: U.S. Department of Energy, Rulemaking on Energy Conservation Standards for Non-Weatherized Gas Furnaces

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Details on Modeling Energy Performance in a New Home

Methodology

This analysis models the typical **single-family newly constructed 2,400 sq ft home**, meeting the 2021 International Energy Conservation Code, using either all natural gas appliances or electric equivalents.

- Modeled consumption based on the EnergyPlus software using sample building files created by DOE with hourly, monthly, and annual outputs. A similar analysis has been performed by RMI.
- EnergyPlus outputs are combined with publicly available cost (EIA and NAHB) and emissions (NREL, EPA, DOE GREET, and ICF) data.
- Outputs: Cost savings are based on natural gas use and equivalent all-electric options. The model uses marginal costs for better bill estimation. Emissions are based on the meter and reflect a lifetime for appliances in the home.

DOE Model Files Available Here

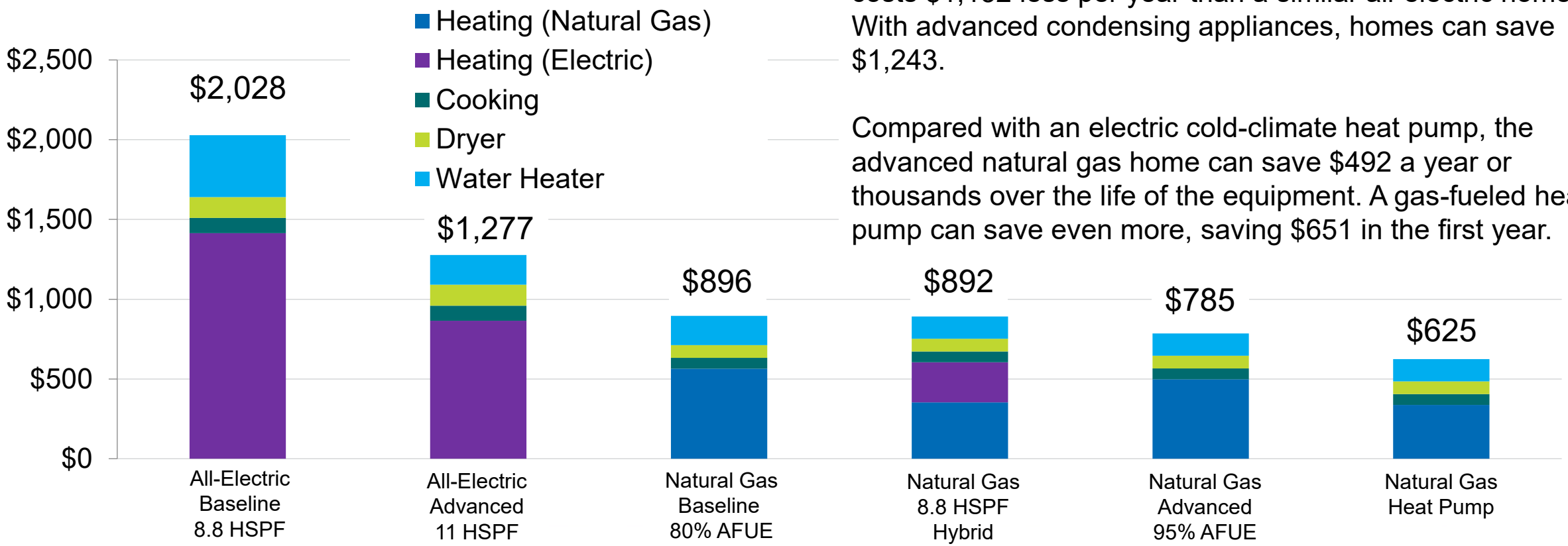
New Household Energy and Appliance Scenarios

	Baseline	Advanced	Emerging
	All-Electric Home	**Advanced All-Electric**	**Natural Gas Hybrid**
Space Heating	8.8 HSPF Heat Pump	11 HSPF Cold Climate Heat Pump	95% AFUE Furnace w/
Water Heating	99% COP Tanked Water Heater	220% COP Tanked Water Heater	8.8 HSPF Heat Pump
Stove / Dryer	Electric Stove and Dryer	Induction Stove and Electric Dryer	95% COP Tankless Water Heater
Space Cooling	16 SEER Heat Pump	19 SEER Heat Pump	Gas Stove and Dryer
			16 SEER Heat Pump
	Natural Gas Home	**Advanced Natural Gas**	**Natural Gas Heat Pump**
	80% AFUE Furnace	95% AFUE Furnace	140% COP Gas Heat Pump
	64% COP Tanked Water Heater	95% COP Tankless Water Heater	95% COP Tankless Water Heater
	Gas Stove and Dryer	Gas Stove and Dryer	Gas Stove and Dryer
	16 SEER Air Conditioner	19 SEER Air Conditioner	19 SEER Air Conditioner

Natural gas households typically have the lowest energy costs compared with similar electric configurations.

Annual Energy Costs for Gas or Electric Uses

Dollars per Year



92% of all centrally-ducted electric heat pumps have an HSPF below 9.2

Key Takeaways

A single-family home with standard natural gas appliances costs $1,132 less per year than a similar all-electric home. With advanced condensing appliances, homes can save $1,243.

Compared with an electric cold-climate heat pump, the advanced natural gas home can save $492 a year or thousands over the life of the equipment. A gas-fueled heat pump can save even more, saving $651 in the first year.

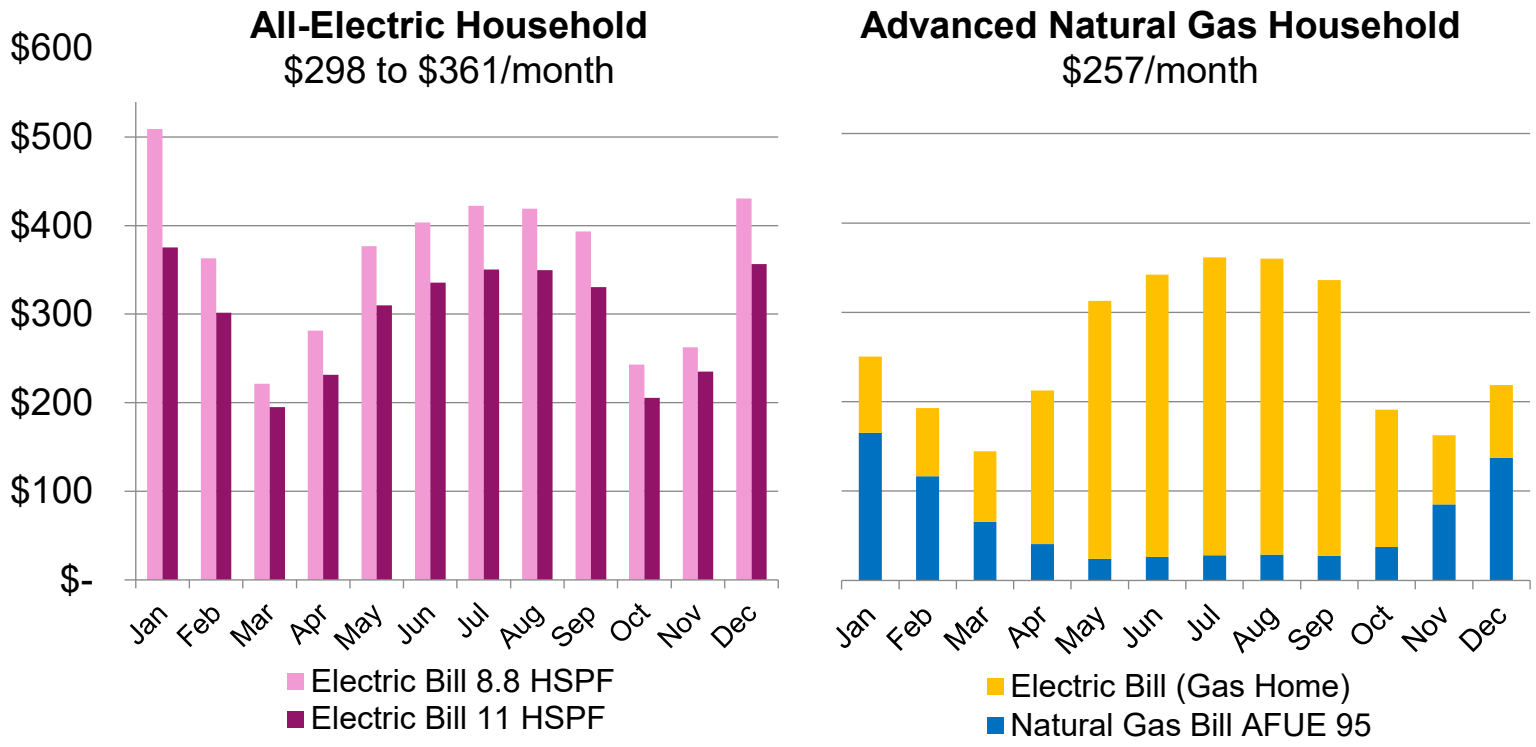
Most (75%) new natural gas homes currently install with a high-efficiency furnace.

Less Volatility Each Month & Lower Winter Bills Overall

- The modeled natural gas home (95% furnace) has lower monthly bills than both all-electric configurations.
- For new homes that rely on the baseline efficiency for all-electric appliances, monthly winter bills were more than $200 higher from December through February.
- The cold climate (11 HSPF) all-electric home has slightly lower summer bills ($10-$20) due to the additional customer charges for natural gas service in the gas home. This cost occurs each month and typically ranges between $10 to $25 a month based on the utility.
- Including customer charges for gas service, overall annual operating costs are between $491 and $1,243 lower in the natural gas house.

Monthly Energy Costs for All End Uses

Dollars per Month



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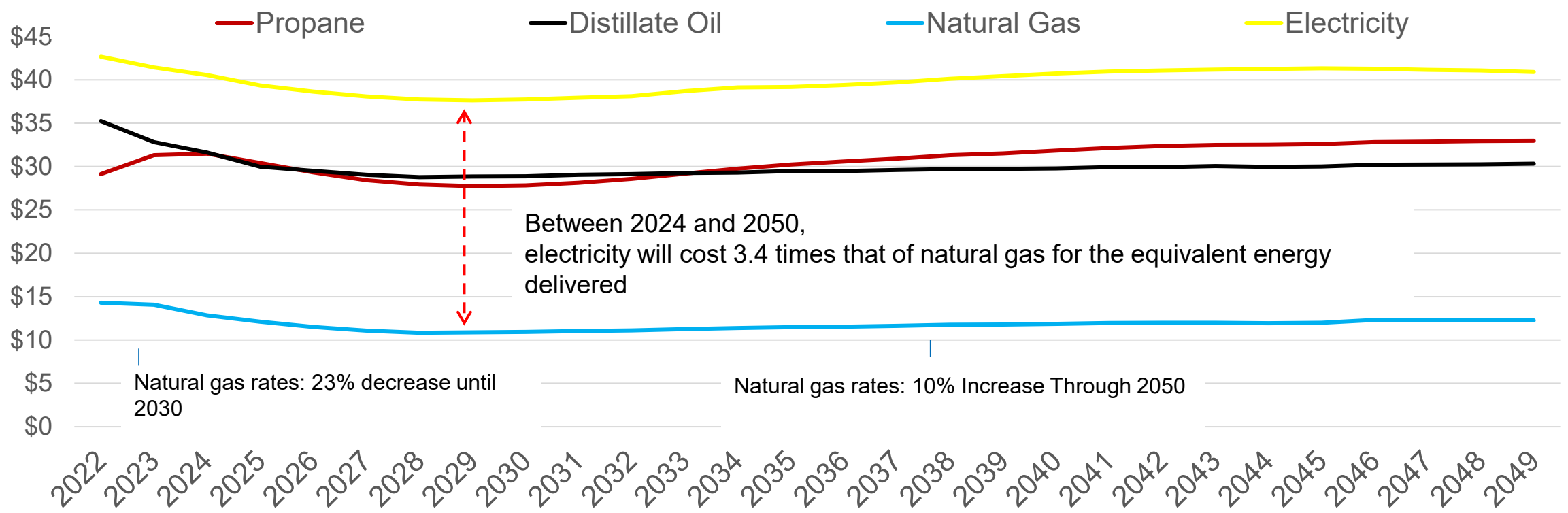
Natural gas retains a long-term price advantage in U.S. government energy outlook

Residential Retail Energy Prices

Dollars (2022$) per MMBtu



U.S. Energy Information Administration, Annual Energy Outlook 2023

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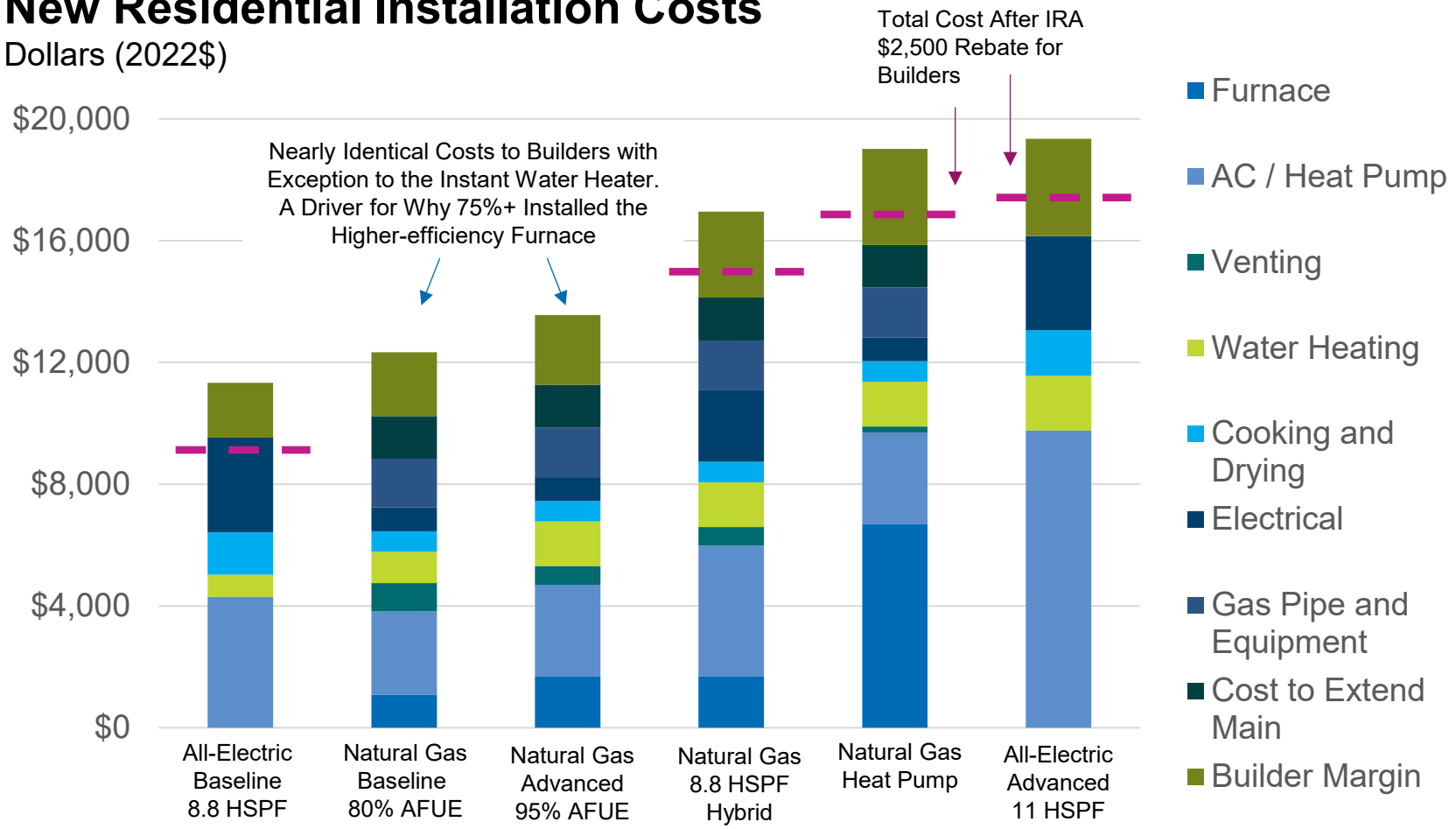
Upfront Costs and Impact on Builders

- **Costs to builders to install non-condensing and condensing gas furnaces are nearly the same**, helping explain why most new households install higher-efficiency condensing equipment.
- **All-electric options can cost less to build but result in higher operating costs.** Based on builder and homeowner preferences, this is only happening in the warmer US climates.
- Cold-climate electric heat pump installation costs are higher than natural gas and may have higher operating costs.
- Gas heat pumps (even in smaller homes) and hybrids can be a more cost-efficient alternative than the advanced all-electric.

New Residential Installation Costs

Dollars (2022$)



Row houses, mixed-use, and multi-family buildings can affect installation costs, particularly with condensing equipment.

Source: Home Innovation Research Labs - Cost and Other Implications of Electrification Policies on Residential Construction 2021

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The Value of Natural Gas and Emissions Reduction

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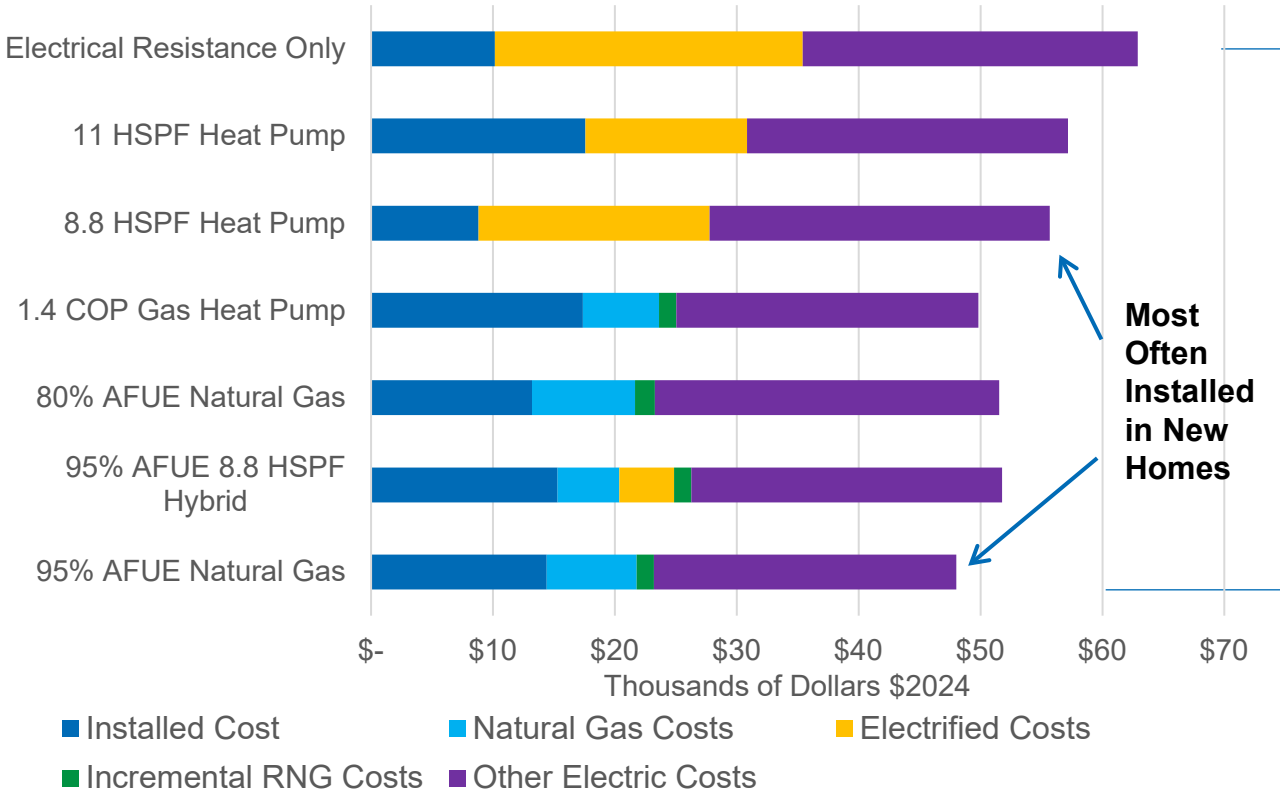
Natural gas is the most affordable option while contributing to lower carbon emissions

15-Year Lifecycle Costs, All Appliances

Thousand Dollars (2024$)



Most Often Installed in New Homes

15-Year Life Cycle GHG Emissions

Gas or Electrified Equipment	Total Home
80.7	151.8
44.9	114.1
59.2	131.7
32.8	98.1
53.5	126.5
37.5	108.7
44.7	109.9

Metric Tons CO2e
100 Year GWP

- **Natural gas typically has the lowest lifecycle cost compared to any all-electric solution.** A home with all condensing appliances would save the most while lowering emissions by 17% compared to the most popular baseline heat pump efficiency.
- Advanced gas homes produce comparable emissions as advanced cold climate heat pumps, but consumer costs are thousands less over 15 years.
- Renewable natural gas costs contribute a small fraction of annual energy costs but can have a big impact on emissions.
- A natural gas heat pump or a hybrid system costs about the same over 15 years and emits the least amount of carbon. Both have cheaper lifecycle costs than 100% electrification.

Natural gas and electricity costs based on EIA Annual Energy Outlook 2023. Renewable Natural gas "RNG" costs are fixed at current estimates made by ICF. All operating costs are subject to a 3% discount rate. Electric power emissions based on NREL Cambium database.

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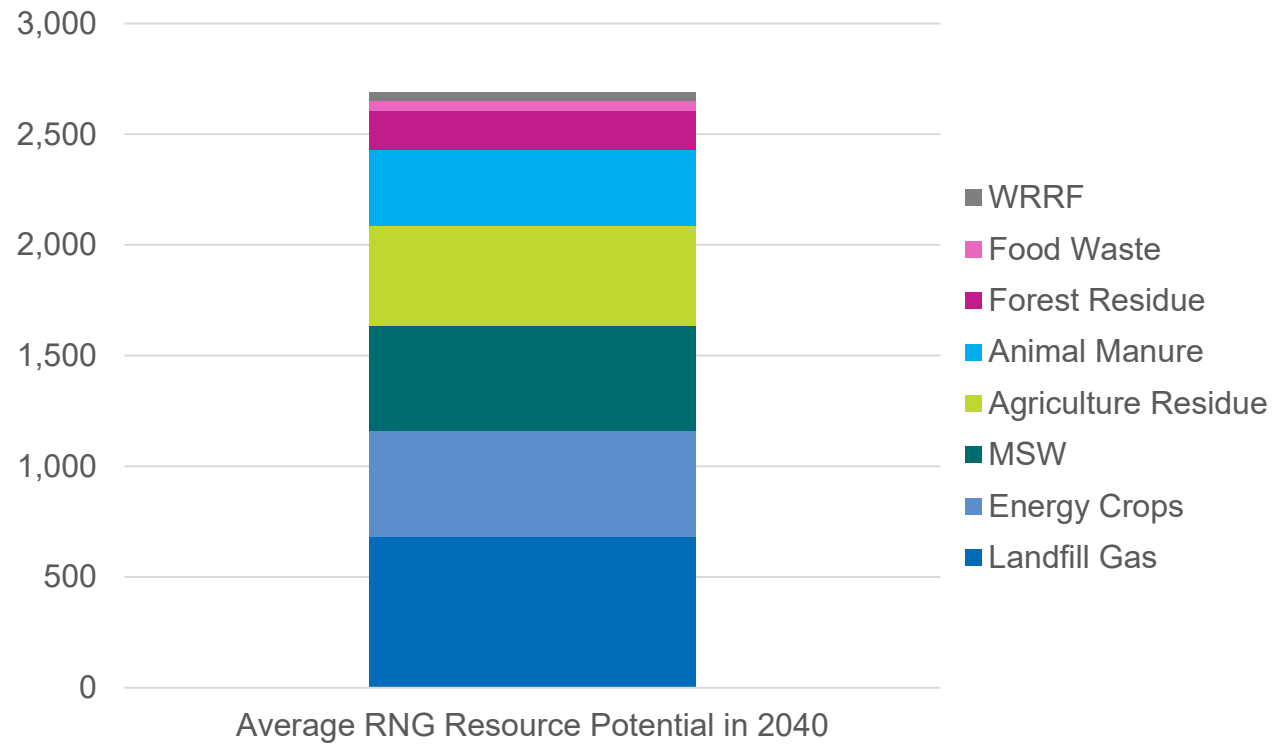
Cost and Resource Potential for Renewable Natural Gas to Offset Residential Natural Gas Emissions

- By 2040, the **production of RNG is expected to offset one-third of total residential and commercial natural gas** demand, with an average annualized mix of 20% over the next 15 years.
- From an emissions standpoint, using **1 unit of RNG offsets 96% of the emissions** from conventional natural gas, which has an average carbon footprint of 63 kg CO2e per MMBtu
- The **projected average cost of renewable natural gas (RNG) for residential homes is $21.24 per MMBtu**, about 50% higher than the average residential price of natural gas in 2023.
- The annual gas bill of an all-condensing home was $784, and the **incremental cost of 20% RNG was $92 or $458 for 100%.**

Estimated Average Annual RNG Production in 2040

Based on AGF Renewable Sources of Natural Gas 2019 Study
tBtu/year



Source: American Gas Foundation Study: Renewable Sources of Natural Gas 2019

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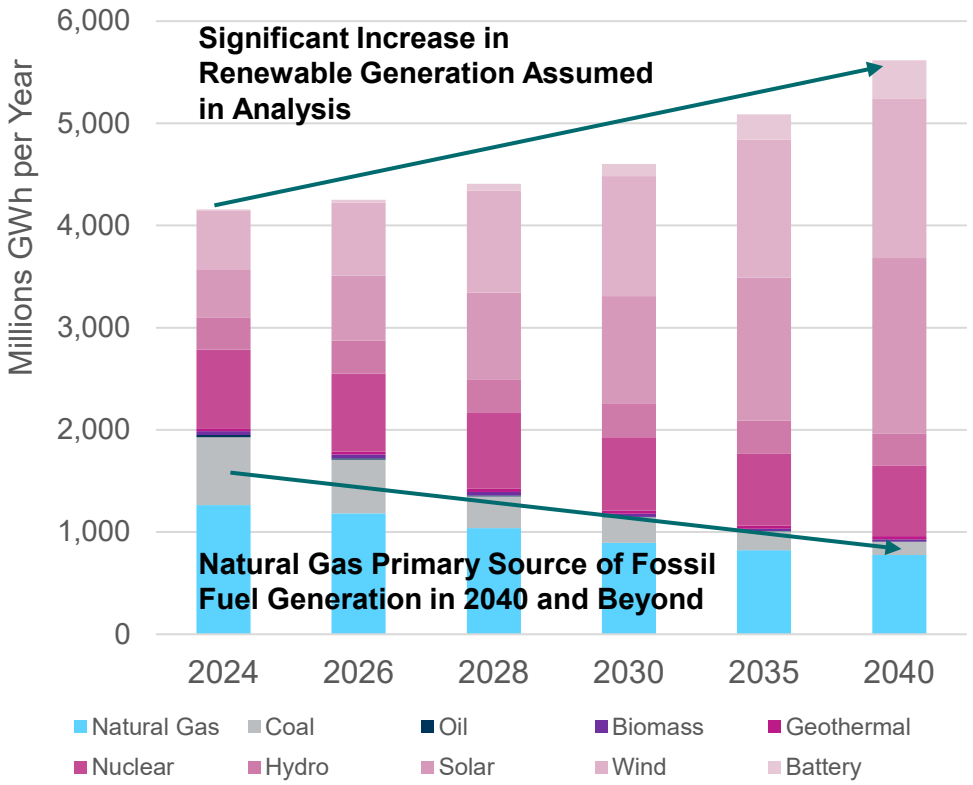
NREL Cambium Database Used to Model Long Term Electric Emissions

NREL Total Projected US Generation

Millions of GWh/year

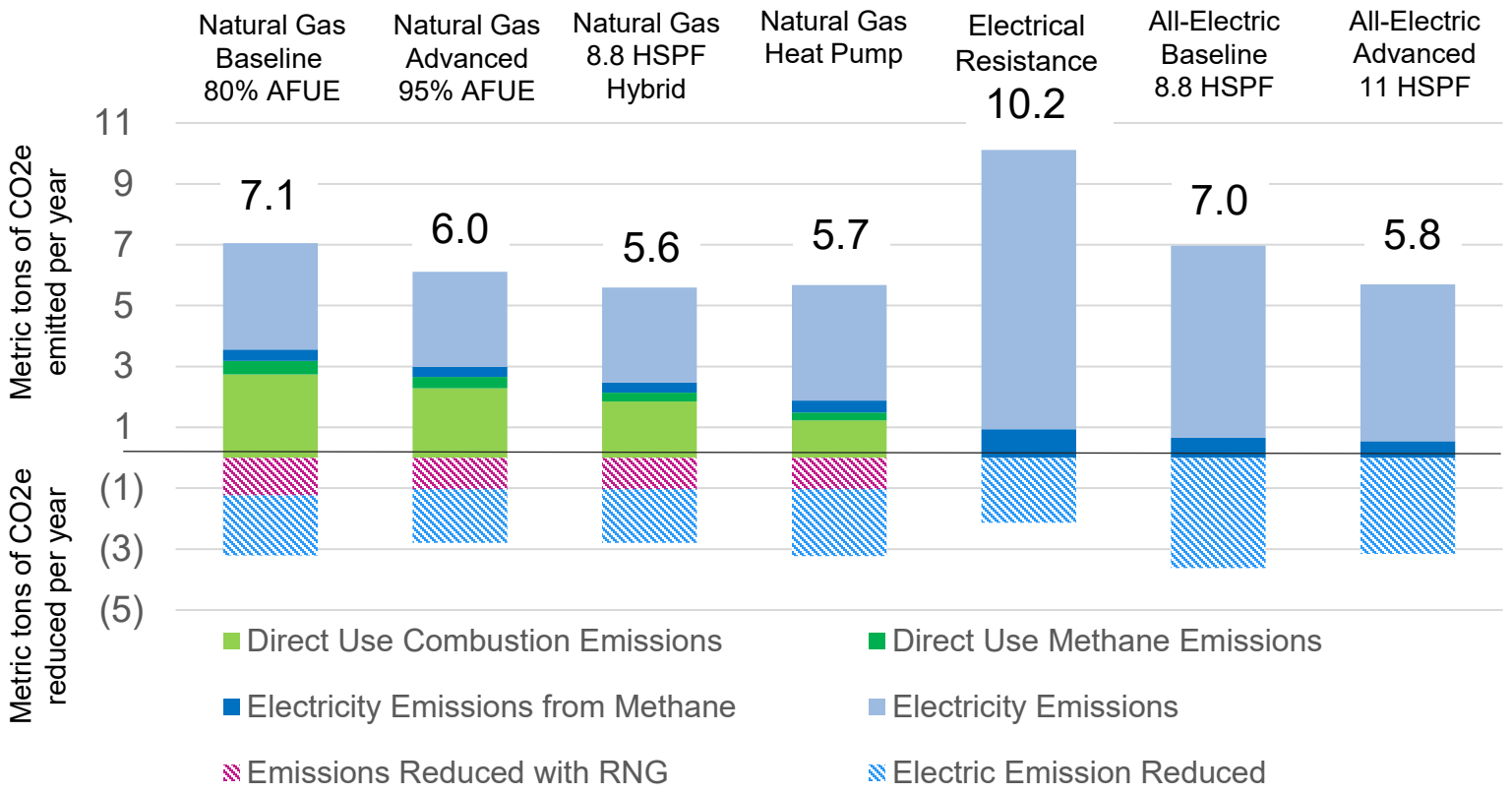


- NREL's model outputs projections on hourly average and marginal emissions rates. Hourly long-term marginal emissions rates are critical for evaluating policies that can impact changes to current trends.
- The database is the only source of electric grid emissions data that is free and publicly accessible and contains this level of detail.
- Incorporates current federal (IRA) and local policies (Renewables Only Mandates) that encourage or require new renewable power generation.
- Not unlike any other projected forecast, estimates on emissions beyond a short time can be very uncertain. Within this analysis, the use of the data out to 2040 projects meaningful emissions reductions from the electric power sector but net zero from electricity is not met nationwide by 2050 based on NREL's analysis.

Because of Current Efforts of Gas and Electric Utilities, Most New Homes Built Today Could Produce 40% Fewer Emissions by 2040

- The adoption of efficient natural gas equipment is expected to cut individual household greenhouse gas emissions by 40% by 2040. A large share of a home's total remaining carbon footprint, even in 2040, comes from electricity usage regardless of space and water heating fuel.
- Sources of methane from electricity generation in all-electric homes are forecasted to similarly match emissions from natural gas homes assuming zero improvements are made to gas infrastructure by 2040.
- Noting that both all-electric and natural gas homes can reach similar carbon footprints by 2040, homes that use natural gas have additional options for lower emissions. Access to RNG is a cost-effective way to reduce emissions and add additional flexibility to low or net-neutral carbon policies.
- Additional focus on installing gas heat pumps and hybrids can further free up more RNG to be delivered to homes than modeled.

Projected Residential Greenhouse Gas Emissions in 2040
Metric tons of CO2e emitted/avoided per year



Annual emissions for 2040 are based solely on the projected greenhouse gas emissions for that year and do not reflect the 15-year average. While all homes modeled exhibit significantly lower emissions by 2040, relying on grid-sourced electricity alone does not achieve nationwide carbon neutrality. To reach net-zero emissions beyond 2040, households will need to adopt multiple strategies, such as rooftop solar, renewable natural gas, and more energy-efficient appliances as a baseline.

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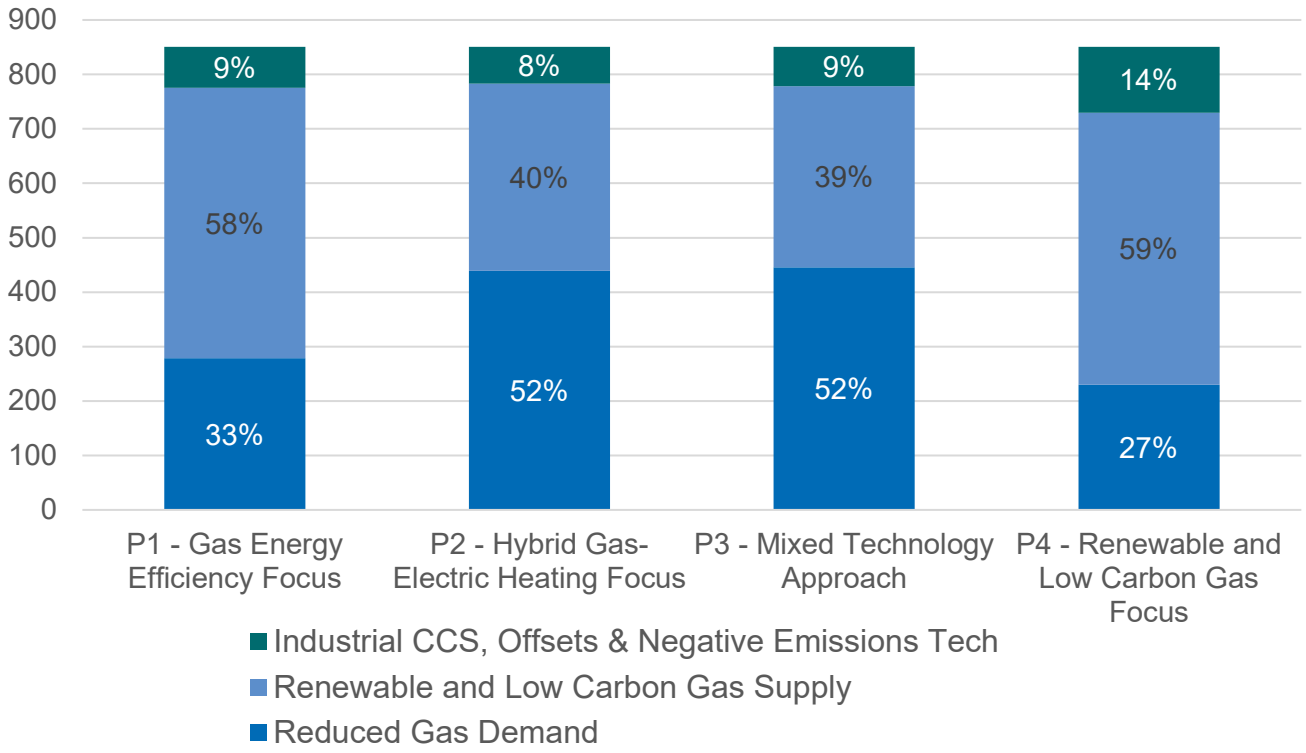
How natural gas is achieving emission reductions through 2040 and beyond

Composition of Emissions Reductions for Natural Gas Appliances in this Study (Market Status)

1. High-efficiency natural gas wherever physically installable is the standard, for new construction in all climates. Mature
2. A cumulative reduction in emissions from RNG through 2040 that results in an average cut of 20% a year for traditional furnaces. Early
3. Gas heat pumps and hybrids are the new target for consumers to consume less and utilize higher shares of RNG per building. Early/ Growth
4. Assumes the same deep decarbonization goals set for electric usage for all scenarios studied. Growth

Summary of Types of 2050 Emission Reductions
ICF Net-Zero Emissions Opportunities for Gas Utilities
Million Metric Tons of CO2e



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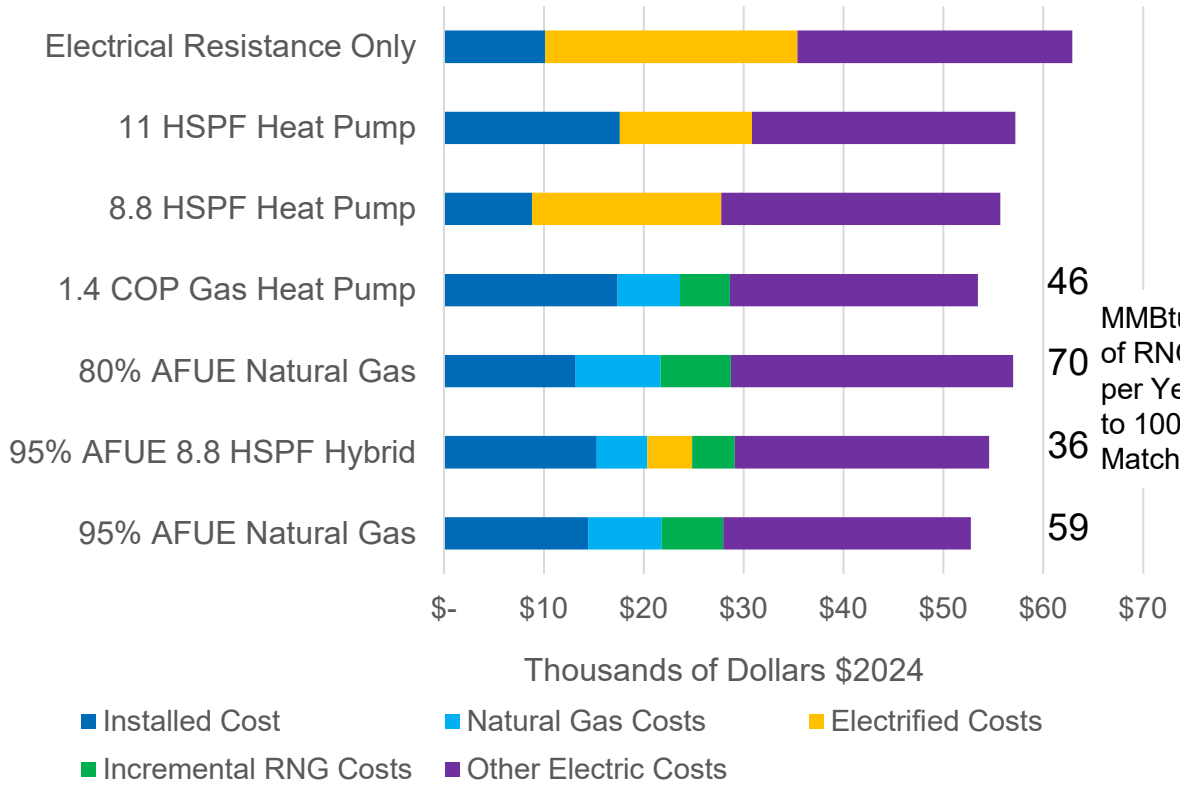
Households Maximizing RNG Can Cost-Effectively **Eliminate** Greenhouse Gas Emissions From Natural Gas Appliances

15-Year Lifecycle Costs, All Appliances

Thousand Dollars (2024$)



15-Year Life Cycle GHG Emissions	
Gas or Electrified Equipment	Total Home
80.7	151.8
44.9	114.1
59.2	131.7
2.7	77.6
1.9	73.3
18.9	86.9
2.2	74.9

Metric Tons CO2e
100 Year GWP

- **RNG is an emissions reduction solution for households.** A new home today could completely reduce emissions from natural gas by matching 100% of the fuel used with RNG.
- **RNG use is expected to grow.** Based on the AGF study's projections for RNG production, available RNG volumes by 2040 could be equivalent to more than 30% of current residential and commercial natural gas. Greater energy efficiency and policies aimed at growing RNG resources can bolster RNG availability to consumers.
- **More efficient equipment reduces overall demand.** Compared to the baseline natural gas home, a gas heat pump could reduce site gas consumption by 35%. With condensing natural gas appliances and a hybrid heat pump, site gas consumption could be reduced by 49%. Combined with RNG, this can enable net neutral emissions for residential gas customers by 2050.

Natural gas and electricity costs based on EIA Annual Energy Outlook 2023. Renewable Natural gas "RNG" costs are fixed at current estimates reported by American Gas Foundation 2019. All operating costs subject to a 3% discount rate. Normalizing for weather, the average US household consumed 67 MMBtu in 2023 (compared to the modeled baseline of 70 MMBtu). Electric power emissions based on NREL Cambium database.

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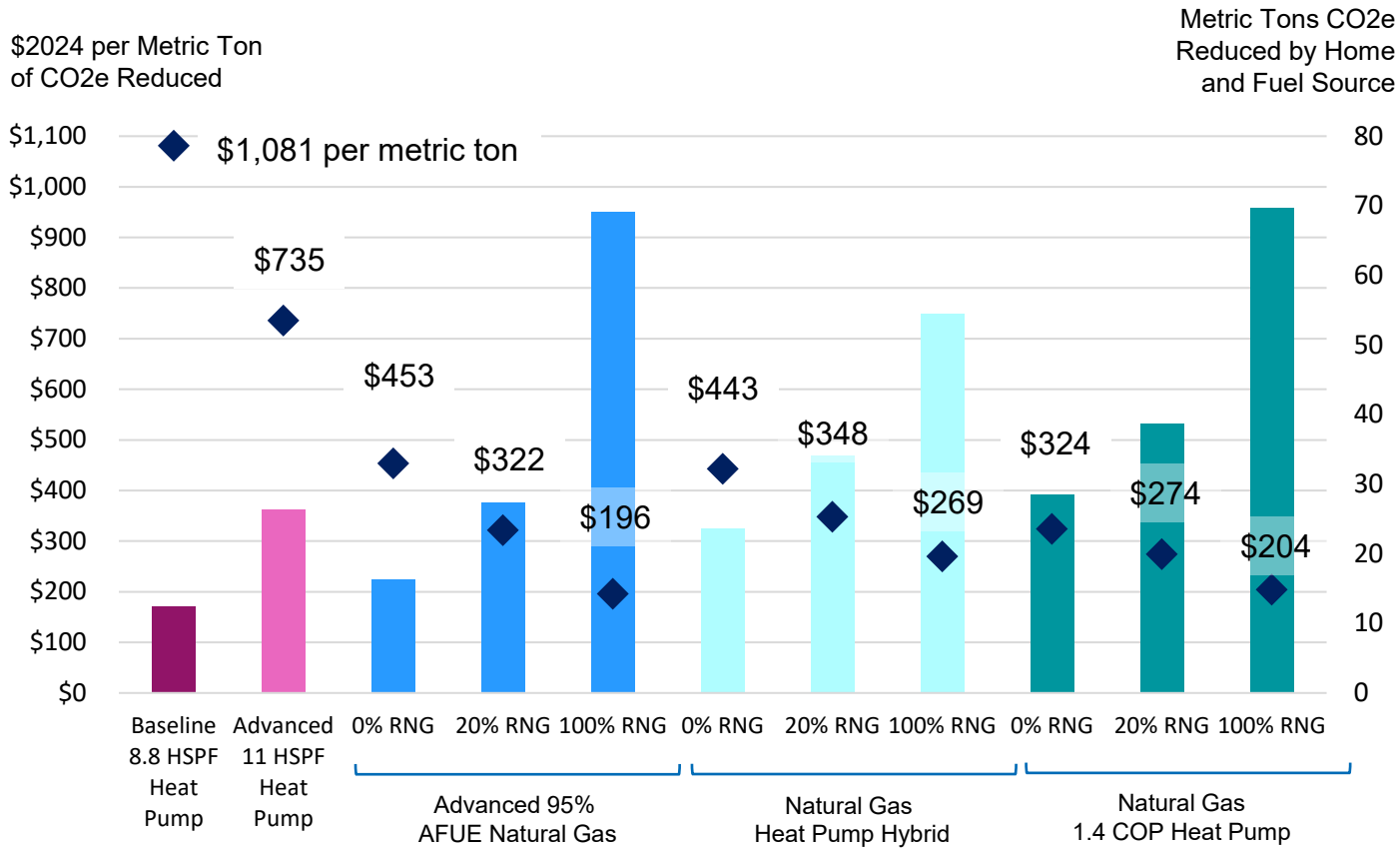
Advanced Gas Homes Are More Cost-Effective for Greenhouse Gas Emissions Reductions Compared to All-Electric. Using RNG Improves Cost-Effectiveness While Achieving Steeper Emissions Reductions.

- The baseline 8.8 HSPF all-electric heat pump scenario has the highest average carbon footprint among all scenarios, based on estimated 2024 CO2e emissions. Therefore, this scenario serves as the reference point for emissions and cost comparisons.
- According to NREL's electric grid forecast, relying on grid decarbonization will reduce total emissions by 17% over 15 years, at a cost of $1,081 per metric ton of CO2e reduced.
- The high adoption rate of advanced condensing gas appliances in new single-family homes demonstrates that natural gas can achieve lower emissions than the more commonly installed baseline heat pump home at a significantly lower cost per ton of CO2e reduced.
- Assuming an 20% blend of RNG annualized through 2040, the advanced gas home will result in similar amount of greenhouse gas emissions as a 11 HSPF heat pump home, but the heat pump will result in 130% higher costs per metric ton of CO2e reduced.

Cost of GHG Emissions Reduction

Total Modeled Home, Natural Gas or Electrified End Uses Only



The cost-effectiveness of emissions reductions is defined in terms of dollars per metric ton of greenhouse gas emissions reduced. The reference point for emissions reduction is the Baseline 8.8 HSPF Heat Pump, which could emit 71.5 metric tons of CO2e over 15 years, assuming no reductions in emissions from electric grid-sourced energy. The cost was calculated based on the net installation cost compared to gas and the total cost to operate over 15 years.

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Discussion and Policy Considerations

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Discussion and Policy Considerations

1. New natural gas homes outnumber electric 5 to 1 in moderate to cold climates and are commonly built with high-efficiency gas furnaces in 75% or more of homes.
2. The baseline natural gas home saves $1,132 annually in energy costs compared to the equivalent all-electric home. A natural gas home with high-efficiency appliances saves $492 per year compared to a home with an electric cold-climate heat pump.
3. 60% of homes with a heat pump exist beyond access to natural gas. Natural gas and electric heat pumps serve as complementary solutions helping individual households improve energy efficiency based on the best options available to them.
4. Renewable natural gas (RNG), hybrid heating, natural gas heat pumps, and high-efficiency gas appliances can reduce costs and emissions compared to all-electric homes.
5. An all-gas home with a condensing natural gas furnace and a mix of RNG can reduce lifetime emissions by 17% compared to a typical all-electric build and match the lifecycle GHG emissions of a cold-climate heat pump while remaining more cost-effective.

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