AGA
American Gas Association

COMPARISON OF HOME APPLIANCE ENERGY USE, OPERATING COSTS, AND CARBON DIOXIDE EMISSIONS 2022 UPDATE

March 1, 2023

Executive Summary

This AGA study evaluates the critical differences in energy cost and emissions for many common home appliances that use natural gas or rely on other forms of energy. AGA based this study on the characteristics of the average American single-family home and the likely energy consumption for each type of end-use home appliance. The analysis then looks at the current average full-fuel cycle greenhouse gas emissions for each energy source to evaluate the impact on the environment from each appliance in the coming year.

Key Study Conclusions

- The average cost for residential natural gas is the cheapest form of energy, costing homes $12.09 per MMBtu versus $41.79 per MMBtu for electricity, $25.11 per MMBtu for distillate oil, and $24.42 per MMBtu for propane.
- The typical natural gas single-family home with standard efficiency appliances costs less than other fuel sources at just $1,068 per year. Even compared to a home with a cold climate heat pump, the natural gas home on average saved $390.
- Based on 2020 power generation emissions data from the EPA, the use of natural gas can lower household emissions this year by 17% compared with a home using many minimum-efficiency electric appliances including an energy star heat pump for space heating.
- A cold climate heat pump and heat pump water heater showed lower emissions compared to the typical gas home with standard appliances. With the installation of condensing natural gas space and water heaters, natural gas homes can reach 11% lower emissions this year than with the use of many advanced air-source heat pumps.
- The use of natural gas heat pumps can further lower emissions by 22% compared to the cold climate heat pump configuration.

Introduction

Natural gas, electricity, oil, and propane serve as energy sources in the residential sector in various applications—primarily space heating and water heating. Natural gas, electricity, and propane also serve in cooking and clothes-drying applications. Choosing which energy to use has significant implications in terms of efficiency, economics, and the environment. While consumers and builders make the ultimate energy choice, this choice is also influenced by government policies.

Government policies and regulations that influence energy matters must be based on accurate energy efficiency measurements and environmental impacts. Most government policies and regulations that affect energy matters use energy metrics that are "site-based"—that is, metrics only consider the impacts at the location or "site" where the energy is consumed. Site-based regulations, such as appliance efficiency standards and measurement, can lead to higher energy resource consumption as well as higher levels of pollution.

Full-fuel cycle analysis and metrics provide a more comprehensive and accurate approach. This method examines all impacts associated with energy use, including those from extraction/production, conversion/generation, transmission, distribution, and ultimate energy consumption. Site energy analysis only takes into consideration the ultimate consumption stage. Significant energy is consumed, with resulting polluting emissions, during all stages of energy use.[1]

This view is supported by the National Academies report to the Department of Energy (DOE), "Review of Site (Point-of-Use) and Full-Fuel Cycle Measurement Approaches to DOE/EERE Building Appliance Energy Efficiency Standards."[2] The report found that DOE should consider changing its measurement of appliance energy efficiency to one based on the full-fuel cycle. This more accurate measurement would give consumers more complete information on energy use and environmental impacts.

This analysis aims to compare the relative impacts of residential appliances powered by natural gas, electricity, oil, and propane. Consideration is given not only to impacts at the point of ultimate energy consumption—i.e., 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 required for crude oil and natural gas.

This study also presents a cross-comparison of appliances under the same modeled housing structure. The model relies on national average prices and building energy characteristics to conduct a simple "apples to apples" analysis. Other studies based on the market share will differ from this type of analysis for a variety of reasons, including:

- Differences in the age of housing stock, where gas, propane, and fuel oil homes are common in older existing buildings and electric in newer buildings.
- Differences in regional market shares will place natural gas end-users towards northern climates, where heating costs are typically higher and electric users towards southern climates. Propane users are generally found in more rural parts of the country, and fuel oil primarily resides in the Northeast.

[1] For more information, see *Full-Fuel-Cycle Energy and Emissions Factors for Building Energy Consumption—2018 update.* *https://www.aga.org/globalassets/research--insights/reports/22433-ffc-final-report-2019-01-14.pdf*

[2] National Academies, http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12670

- The average natural gas-heated home has 30% more heated square footage than the average electric home. This analysis uses the same-sized home and assumed annual heat loss.
- Not all natural gas residential end users have four unique gas appliances. The average natural gas home has between two and three appliances, with space heating being the most common.

Summary of Results

Using natural gas results in lower consumer energy bills on average compared with electricity, oil, and propane. When evaluated on a full-fuel-cycle basis, natural gas significantly reduces energy consumption, greenhouse gas emissions, and air pollutant emissions compared with electricity, oil, and propane.

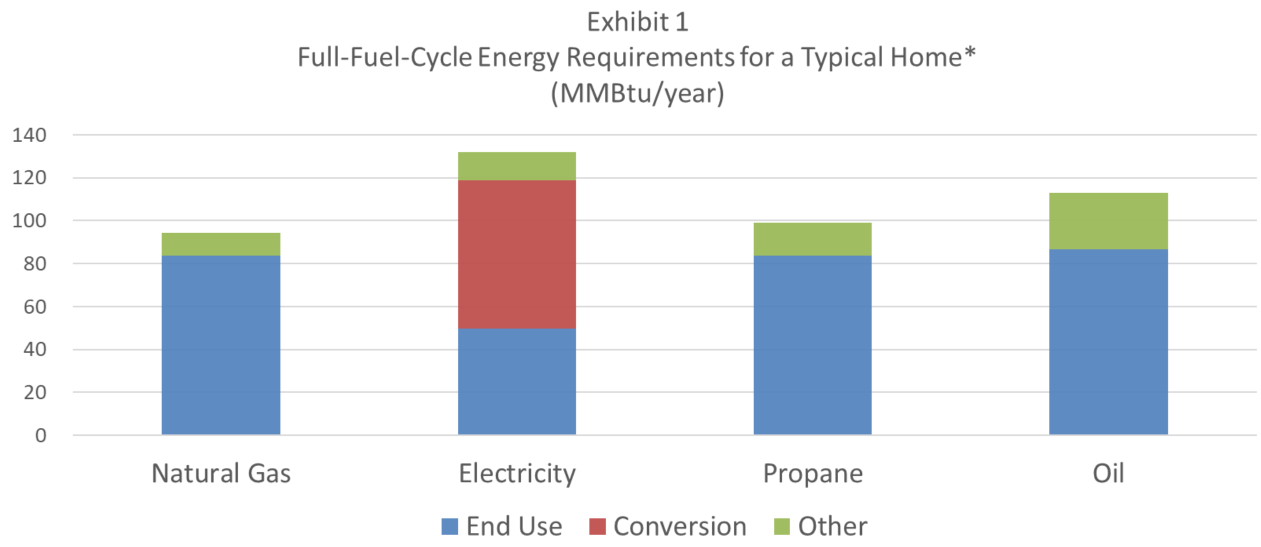
<u>Natural Gas Use Results in Less Total Energy Consumption</u>

➢ Although electric appliances (e.g., space heaters, water heaters, stoves, and clothes dryers) may consume less site energy than their natural gas counterparts, this disadvantage is more than offset by the greater energy efficiency of the overall natural gas production and delivery system.

  - In a typical residential application, a natural gas home requires about one-quarter less total energy on a full-fuel-cycle basis than is required for a comparable all-electric home (see Exhibit 1) for those appliances.
  - Less than ten percent of the natural gas energy produced is used or lost from the point of production to the residence. In contrast, almost 63 percent of the energy produced to satisfy the electricity needs of consumers is used or lost in the process of energy production, conversion, transmission, and distribution.

➢ A typical natural gas furnace consumes about the same site energy as a comparable oil furnace. A gas water heater uses slightly less site energy than an oil water heater. Also, since oil is not typically used in cooking and clothes drying, it was assumed that electric appliances would be used for those applications in the oil house. When combined with a slightly higher efficiency for the overall gas production/delivery system relative to oil, these factors result in gas appliances requiring 9 percent less total energy than the oil house.

➢ While natural gas and propane have the same site-based appliance efficiencies, natural gas is more efficient from production through delivery and end-use. This better full-fuel-cycle efficiency results in the natural gas home requiring three percent less total energy than the propane house.



Note: "Other" includes impacts from distribution, transportation, processing, and extraction.
* Energy used for space heating, water heating, cooking, and clothes drying appliances.

Using Natural Gas Can Save Average Homeowners 46 to 53 Percent on Their Energy Bills

- The higher efficiency and lower price of natural gas relative to other energy forms result in annual utility energy bills for the gas home that are roughly 49 percent lower than the comparable all-electric home energy bills, about 53 percent lower than the oil home, and 46 percent lower than the propane home.

  - According to DOE,[3] the 2022 U. S. representative average unit cost for residential gas is $12.09 per million British thermal units (MMBtu) versus $41.79 per MMBtu for electricity, $25.11 per MMBtu for distillate oil, and $24.42 per MMBtu for propane.

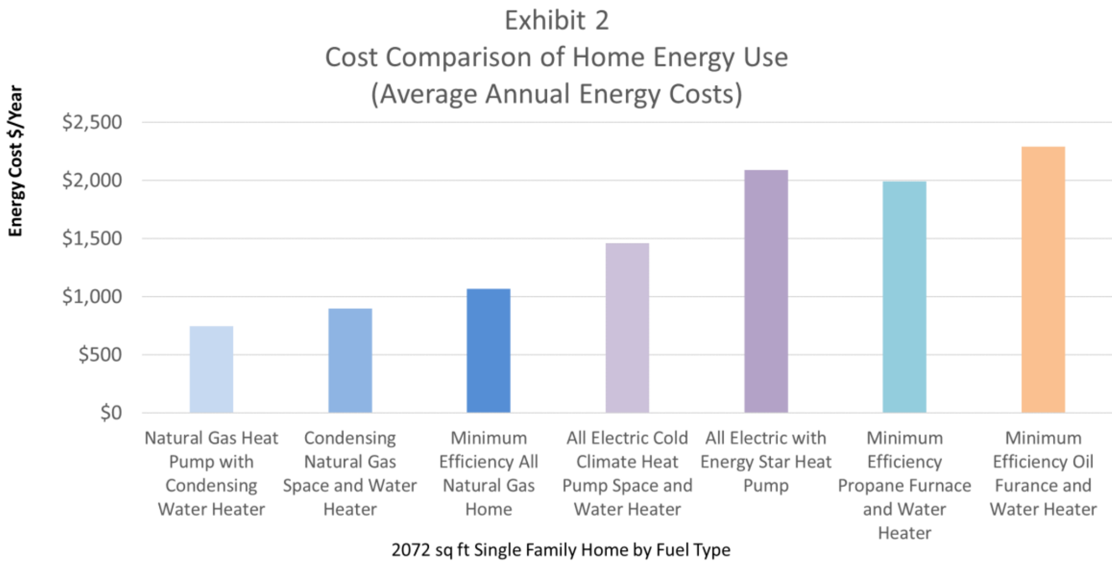
  - Based on these energy prices and the energy consumption levels modeled in this analysis, residential natural gas customers realize annual energy savings of approximately $1,022 compared with all-electric homes, $1,223 with oil homes, and $924 with propane.

Investing in Higher Efficiency Natural Gas Space and Water Heating Technologies Can Save Homeowners an Additional 17 to 30 Percent on Annual Natural Gas Expenditures

- Installing a higher-efficiency condensing natural gas or a natural gas heat pump can further reduce the overall cost of heating a home during the winter. Installing natural gas condensing appliances would save $169 compared to the typical existing natural gas home. Compared to an energy star or a cold climate heat pump, a condensing

[3] *Sources: U.S. Energy Information Administration, Short-Term Energy Outlook (February 8, 2022), Annual Energy Outlook (February 3, 2022), and Monthly Energy Review (January 27, 2022).*

furnace could save homeowners between $560 and $1,191. A natural gas heat pump would prove even more efficient with a total savings of $322 compared to an 80 percent efficiency unit and between $713 and $1,344 compared to an energy star and cold climate heat pump. See Exhibit 2 for a complete cost comparison of annual energy expenditures.



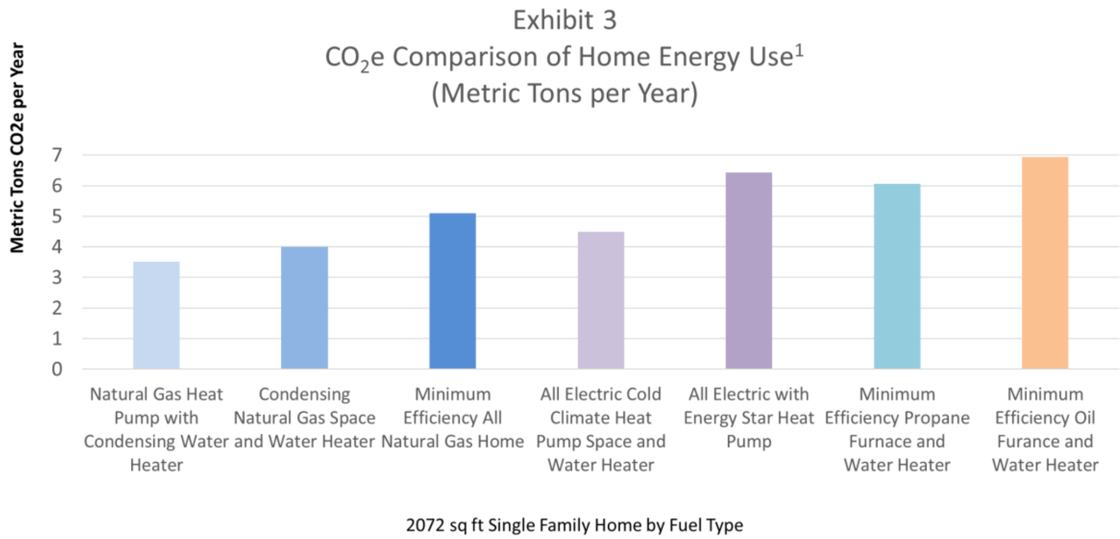
Natural Gas is the Cleaner Fossil Fuel

In conjunction with its high efficiency, the inherent cleanliness of natural gas relative to other fossil fuels results in numerous environmental benefits relative to electric, oil, and propane systems. These include lower emission levels of the criteria pollutants regulated by the Clean Air Act. Natural gas combustion results in a fraction of the nitrogen oxides, sulfur dioxides, and particulate matter compared to oil, coal, and propane combustion.[4] In addition, natural gas use is substantially cleaner than oil, coal, and propane regarding carbon dioxide (CO_2), the principal greenhouse gas. For example, carbon dioxide equivalent (CO_2e) emissions are about 21 percent lower for the typical gas residence than those attributable to an all-electric home, about 27 percent lower than oil homes, and 16 percent lower than propane homes (see Exhibit 3). These results are based on the U.S. national average for 2020 and will vary by region.

Homeowners with higher efficiency appliances like condensing space and water heaters will realize even greater savings in carbon emissions through decreased energy consumption. Using a condensing space and water heater can lower emissions by 17 percent compared to the typical natural gas home. Homeowners using a condensing furnace over other fuels could lower emissions by 40 percent compared to a typical all-electric household, 11 percent lower than a cold climate heat pump home, 30 percent lower than oil homes, and 20 percent lower than propane homes. Homeowners using a

[4] Environmental Protection Agency, AP-42 Emission Factors, http://www.epa.gov/ttn/chief/ap42/ch01/index.html

natural gas heat pump over other fuels could lower emissions by 50 percent compared to a typical all-electric household, 22 percent lower than a cold climate heat pump home, 42 percent lower than oil homes, and 34 percent lower than propane homes.



[1] Emissions from space heating, water heating, cooking, and clothes drying
Note – includes impact on CO_2 equivalent from unburned methane

This analysis is based on newer homes that meet the 2013 International Energy Conservation Code. Electricity is assumed to be generated by all the inputs consumed for generation in the United States, including renewable sources and nuclear energy. The appliances meet the minimum efficiency standards set by the Department of Energy, where applicable, representing the majority of appliances sold. An analysis based on the existing home stock would be even more favorable to natural gas, as older homes require more energy due to their lower thermal integrity and less efficient equipment.

Additional modeling was done for higher natural gas, heat pump space, and water heating standards. This analysis compares a high-efficiency condensing gas furnace and water heater, a cold climate heat pump, and a natural gas heat pump.

The analysis does not consider air conditioning, which is almost always provided by electricity, and the economic comparison focuses on energy costs and does not consider equipment and installation costs. The analysis also does not factor in the potential global warming potential from refrigerants used in electric heat pumps. While both gas and electric heating would require refrigerants of some kind for summer cooling, only heat pumps would have an increased impact on emissions during the winter.

Analysis of Full-Fuel-Cycle Impacts

Background

Significant amounts of energy can be used or lost in energy extraction, processing, transportation, conversion, and distribution. More efficiency from the source to the site translates into less overall energy production required for the same amount of delivered useful energy. In addition, the efficiency of end-use equipment 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.

Compared with electricity, natural gas is delivered to consumers with much less energy wasted. The cumulative efficiency—from the wellhead to the residential meter—of the natural gas system is 92 percent.[5] 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 to the consumer 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 (see Table 1).

In terms of the full-fuel cycle—the combined source-to-site energy efficiency and the end-use equipment efficiency—natural gas retains its superiority. For new residential applications, full-fuel cycle efficiency will be 74 percent for the natural gas space heating option that meets the minimum efficiency rating of 80 percent. For electric heat pumps, whose federal minimum standard for fuel utilization efficiency is about 260 percent, the full-fuel cycle efficiency will be about 98 percent. Less efficient electric resistance heating has a full-fuel-cycle heating efficiency of only 39 percent. The full-fuel cycle efficiency for an oil furnace averages about 67 percent due to an energy trajectory efficiency of 84 percent. The propane furnace full-fuel cycle efficiency measure is also 70 percent. Again, these efficiencies reflect the total losses from extraction, processing, transportation, conversion, distribution, and end use of the natural gas, electric, oil, and propane systems.

[5] 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 1
SOURCE-TO-SITE EFFICIENCY OF ENERGY DELIVERED TO THE HOME[1]

Energy Efficiency of Fuels Delivered to Building

Fuel	Extraction	Processing	Transportation[2]	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%

Energy Efficiency of Electricity Delivered to Building

Fuel	Extraction	Processing	Transportation[2]	Conversion	Distribution	Cumulative Efficiency
Coal Based	98.0%	98.6%	99.0%	32.2%	94.7%	29.3%
Oil Based	96.3%	93.8%	98.8%	32.9%	94.7%	40.4%
Natural Gas Based	96.2%	97.0%	99.3%	45.3%	94.7%	40.7%
Nuclear Based	99.0%	96.2%	99.9%	32.6%	94.7%	29.7%
Other[3] Based	100.0%	100.0%	100.0%	100.0%	94.7%	92.2%
Electricity Weighted Average[4]	97.7%	97.4%	99.4%	42.9%	94.7%	38.4%

Source: Gas Technology Institute, Energy Planning Analysis Tool - 2020.

"--"indicates not applicable or no efficiency loss.
[1]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-use device.
[2]Transportation of natural gas from processing plant to the local distribution system; transportation of fossil
fuel to electricity generating plants.
[3]Includes renewable energy
[4]Current national weighted average mix of all power generation sources.

The combined efficiency of the natural gas system and end-uses is often higher than the electricity system serving the same end uses. This result may be counter-intuitive since the electricity end-uses can feature equipment with higher end-use efficiency (e.g., an electric air-source heat pump). The reason is that the point of greatest inefficiency along the electricity trajectory is at generation, where roughly two-thirds of the input energy is lost as heat in the production of steam to turn large turbines/generators. Additionally, approximately six percent of the electricity generated does not reach the ultimate consumer due to transmission line losses.

For this study, emissions are estimated based on the national average generating mix in 2020, which is a conservative assumption. For local analyses, marginal impact methodologies are more accurate than national or regional averages for evaluating the impacts of changes in electricity consumption. This study also limited commodity costs and emissions to current conditions this year. Future emissions from electricity are likely to change over time but the same can be said about natural gas and propane. Low-carbon fuels such as renewable natural gas and hydrogen, are currently making an appearance within some local utility's gas mix.

Methodology

<u>Energy Efficiency Trajectories (Table 1)</u>

Data for full-fuel cycle energy efficiency factors were taken from the Gas Technology Institute (GTI) Energy Planning Analysis Tool featuring grid data from 2020. The conversion and cumulative efficiency factors for "Other" energy inputs for electricity generation were calculated based on the weighted average of the other factors as listed in the report.

<u>Energy Use</u>

The analysis examines the total energy requirements for space heating, water heating, cooking, and drying of a one-story, single-family detached residence (2,072 square feet of conditioned space) in an average climate in the United States (4,811 heating degree days). Only natural gas, electricity, oil, and propane appliances were examined. The home in the analysis was assumed to meet 2013 International Energy Conservation Code (IECC) standards for end-use appliances that at least meet the minimum efficiency requirements set by the U.S. Department of Energy.

In the natural gas and propane-heated homes, the analysis assumed the furnace had an efficiency of 80 percent. The energy requirement for the system's fan was also included in the system's energy requirement calculation. The electric home used a heat pump with a heating seasonal performance factor (HSPF) of 8.5. For the oil home, a furnace with an efficiency of 80 percent was used. All units produced approximately 58 MMBtu per year of useable heat annually.

For heating water, the home was assumed to use a 50-gallon electric water heater with an efficiency/energy factor of 95 percent, a 32-gallon oil model with an efficiency of 51 percent, and a 40-gallon model with an efficiency of 82 percent in the natural gas and propane homes. All units meet the minimum efficiency set by DOE and can produce the number of gallons of hot water required by the home—about 15 MMBtu of useful water heating output per year. Such sizing variations are common. Electric units must be sized somewhat larger to provide adequate quantities of hot water due to the units' lower recovery rates compared with natural gas units, and the oil units are relatively smaller due to their larger burner size. All water heaters have a first-hour rating above 60 gallons.

For cooking, the natural gas and propane units have an energy factor of 5.8, and the electric stove has an energy factor of 10.9, and all units produce 0.2 MMBtu of useful cooking energy. Clothes dryers have energy factors of 2.55 for natural gas and propane and 2.33 for electricity, and all units meet a drying energy output of 0.1 MMBtu per year. Since oil is not commonly used for cooking or clothes drying, it was assumed that electric appliances for these applications were used in oil homes.

Results

High-efficiency condensing gas furnaces modeled has a nameplate efficiency of 95 percent, the cold climate heat pump modeled has an HSPF of 10.5, and the natural gas heat pump has a COP of 1.4. Any advanced natural gas home includes a 95 percent efficiency instantaneous condensing water heater, and a cold climate heat pump home includes a heat pump water heater with a COP of 2.2.

On a full-fuel-cycle basis, natural gas use in primary residential appliance applications is far more efficient than electricity, oil, and propane. The full-fuel-cycle energy requirement for an average home using natural gas is 30 percent less than for a similar home using electricity, 16 percent less than a similar oil home, and five percent less than a similar propane home. End-use (site-based) energy requirements for this home would be 83.7 MMBtu per year of natural gas and propane, 50.6 MMBtu per year of electricity, and 86.8 MMBtu for oil. Total energy requirements (full-fuel-cycle), however, would be 94.3, 134.1, 99.0, and 112.8 MMBtu annually of natural gas, electricity, propane, and oil, respectively (see Table 2).

Additionally, some of the site energy consumption from the natural gas, propane, and fuel oil furnaces uses electrical energy. For the gas and propane units, approximately 485 kWh per year or 1.66 MMBtu per year was consumed operating the unit, and fuel oil furnaces consumed 725 kWh per year or 2.47 MMBtu per year. The total site and full-fuel cycle totals reported in table 2 include these values with each furnace.

For many areas of the country, space heating represents the greatest energy use in residences. The site energy required for heating the natural gas and propane homes of about 2,000 square feet is 59.6 MMBtu per year. A comparable home with an electric heat pump requires 29.8 MMBtu of site energy annually for space heating, while the oil home requires 58.8 MMBtu annually. When measured on a full-fuel cycle basis, the annual energy requirements for heating these homes would be 67.7 MMBtu for the natural gas furnace, 79.1 MMBtu for the electric heat pump, 73.4 MMBtu for the oil furnace, and 71.2 MMBtu for the propane furnace.

The annual site energy requirement for water heating would be 18.3 MMBtu for the natural gas and propane appliances, 15.8 MMBtu for the electric option, and 24.0 MMBtu for oil. When calculated on a full-fuel cycle basis, the annual energy requirement would be 20.0 MMBtu for natural gas, 41.9 MMBtu for electricity, 28.6 MMBtu for oil, and 28.0 MMBtu for propane.

The energy requirements for residential cooking and clothes drying are typically lower than those for space and water heating. On a site basis, the combined energy consumption by both appliances would be 5.9 MMBtu for natural gas and propane compared to 4.1 MMBtu for electricity. On a full-fuel cycle basis, the energy requirements would be 6.7 MMBtu for the natural gas appliances, 11.0 MMBtu for the electric appliances, and 7.1 MMBtu for the propane appliances (see Appendix for additional data on appliances).

Not unlike the gas and propane furnaces, some electrical site energy consumption was included in the total site and full-fuel-cycle calculations for dryers and stoves. For gas and propane dryers, the total annual electric energy consumption was 29.8 kWh per year or 0.1 MMBtu per year; for the gas and propane stoves, the total annual electric energy consumption was 33 kWh per year or 0.11 MMBtu per year. The site and full-fuel-cycle totals reported in table 2 include these values with each gas and propane dryer or stove.

TABLE 2
TYPICAL SITE-USE AND FULL-FUEL-CYCLE ENERGY REQUIREMENTS FOR A HOME
(MMBtu per year)

End Use	Natural Gas	Electricity	Oil	Propane
Space Heating	59.6	29.8	58.8	59.6
Water Heating	18.3	15.8	23.8	18.3
Cooking	3.3	1.8	1.8	3.1
Clothes Drying	2.9	6.2	6.2	3.1
Total Site Use	83.8	49.8	86.8	83.8
Energy Losses [2]	10.7	82.2	26.2	15.5
Full-Fuel-Cycle Use [3]	94.5	132	113	99.2

[1]Electric appliances for these applications are used in oil homes.
[2]Includes energy used or lost in extraction, processing, conversion, transportation, and distribution of energy.
[3] Sum of Site Use and Energy Losses

Additionally, higher efficiency space and water heating appliances will further reduce a home's total energy use. The annual site energy requirement for high-efficiency condensing furnace is 46.5 MMBtu, 23.0 MMBtu for the cold climate heat pump, and 35.5 MMBtu for a natural gas heat pump. When measured on a full-fuel cycle basis, the annual energy requirements for heating a typical home would be 55.2 MMBtu for the condensing natural gas furnace and 61.1 MMBtu for the cold climate electric heat pump, and 41.4 MMBtu for the gas-powered heat pump.

For the gas units, approximately 485 kWh per year or 1.66 MMBtu per year was consumed operating the unit. The total site and full-fuel cycle totals reported in table 2 include these values with each furnace.

The annual site energy requirement for high-efficiency water heating would be 15.8 MMBtu for the natural gas and 7.5 MMBtu for the electric heat pump option. When calculated on a full-fuel cycle basis, the annual energy requirement would be 17.2 MMBtu for natural gas and 20 MMBtu for an electric heat pump.

Analysis of Consumer Cost

Background

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 fossil fuels necessary to satisfy consumer energy needs.

Methodology

The end-use (site) energy requirements calculated in the preceding section can be multiplied by national average prices for natural gas, electricity, oil, and propane to calculate the relative energy cost impacts on consumers. Each year the Department of Energy estimates representative average unit costs for energy (see Table 3). For 2022, DOE reports that the cost of electricity to the residential consumer in the U.S. would be

3.5 times higher than natural gas. DOE reports the representative cost of distillate oil is 2.1 times higher than natural gas. Finally, DOE estimated that propane would be two times the price of natural gas. Please note that energy prices, and resulting consumer costs, vary by region.

TABLE 3
2022 REPRESENTATIVE AVERAGE UNIT COSTS FOR U.S. RESIDENTIAL ENERGY PRICES ($MMBtu)

Natural Gas	Electricity	Distillate Oil	Propane
$12.09	$41.79	$25.11	$24.42

Sources: U.S. Energy Information Administration, Short-Term Energy Outlook (February 8, 2022), Annual Energy Outlook (February 3, 2022), and Monthly Energy Review (January 27, 2022).

Results

The total annual residential energy cost for the four appliances in a typical newer natural gas home is $1,022 lower than the electric home, $1,223 lower than the oil home, and $924 lower than the propane home. For space heat alone, residential consumers of natural gas can save $446 a year relative to electricity consumers, $618 a year compared to oil customers, and $585 a year compared to propane customers.

For other baseload applications, energy cost savings can also be realized for natural gas customers. Overall, newer homes can save $536 per year in energy costs by using natural gas instead of electricity for water heating, cooking, and clothes drying. The natural gas house can save $473 per year in energy costs relative to the oil house for these applications. The natural gas costs for operating these baseload appliances would be $213 lower than those of the propane home.

TABLE 4
ESTIMATED ANNUAL RESIDENTIAL ENERGY BILLS FOR TYPICAL HOMES (2022$)

End Use	Natural Gas	Electricity	Oil	Propane
Space Heating	$770	$1,256	$1,519	$1,485
Other[1]	$298	$834	$771	$507
Total	$1,068	$2,090	$2,290	$1,992

[1] Includes water heating, cooking, and clothes drying

The total annual residential energy cost for the four appliances in a high-efficiency newer natural gas home is $1,191 lower than the electric home and $560 lower than the cold climate heat pump home. For space heat alone, residential consumers of natural gas with a condensing furnace can save $625 a year relative to electricity consumers and $389 a year compared to cold climate heat pump consumers.

Gas heat pumps can provide even more space heating savings than the more available condensing furnace option. For space heat alone, residential consumers of natural gas with a natural gas heat pump can save $292 a year relative to the average natural gas consumer, $153 compared to a higher efficiency natural gas consumer, $778 compared to electricity consumers, and $492 compared to cold climate heat pump consumers.

TABLE 5
ESTIMATED ANNUAL RESIDENTIAL ENERGY BILLS FOR ADVANCED HOMES
(2022$)

End Use	Natural Gas	Electricity	Natural Gas Condensing	Natural Gas Heat Pump	Cold Climate Heat Pump
Space Heating	$770	$1,256	$632	$478	$971
Other[1]	$298	$834	$268	$268	$487
Total	$1,068	$2,090	$899	$746	$1,458

[1] Includes water heating, cooking, and clothes drying

Analysis of Environmental Impacts

Methodology

This analysis examines the emissions of CO_2 resulting from full-fuel cycle energy consumption. In addition, the CO_2 equivalent (CO_2e) of unburned methane released into the atmosphere during this energy process was calculated. The emission factors used to calculate greenhouse gas impacts for both combustion (site) and pre-combustion (source) came from the GTI tool on source energy and emission factors.[6] These emission factors, presented in pounds per MMBtu consumed and per kWh generated, were applied to the energy consumed by the appliances.

The GTI tool also provided methane emission factors for pre-combustion (source) and combustion (site). The factors are presented as pounds per MMBtu and per kWh, and these factors are then applied to the appliance energy consumption numbers. To convert the methane output into carbon dioxide-equivalent (CO_2e), the methane emissions were increased by a factor of 25 to account for methane's global warming potential relative to CO_2.[7]

[6] Gas Technology Institute, Energy Planning Analysis Tool - 2020. http://epat.gastechnology.org/Default.aspx
[7] Energy Information Administration, U.S. Department of Energy, http://www.eia.doe.gov/oiaf/1605/ggrpt/

Results

On a full-fuel-cycle basis, natural gas use in residential applications generates significantly less CO_2e than electricity, oil, and propane. The full-fuel-cycle CO_2e emissions resulting from appliance use in a typical newer home are presented in Table 6.

The efficiency advantage of natural gas, coupled with the fact that natural gas combustion emits approximately 44 percent, 27 percent, and 16 percent of the CO_2e emissions of coal, oil, and propane per MMBtu consumed, respectively, results in significantly lower emissions for natural gas. For the natural gas appliances, annual CO_2e emissions were 5.1 metric tons. In comparison, the all-electric option was 6.4 metric tons of CO_2e annually, the oil home produced 6.9 metric tons, and the propane home produced 6.1 metric tons.

TABLE 6

FULL-FUEL-CYCLE CARBON DIOXIDE EQUIVALENT EMISSIONS FOR TYPICAL HOMES[1]
(Metric Tons of CO_2e[2] per Average Household Energy Use)

Natural Gas	5.1
Electricity[3]	6.4
Oil	6.9
Propane	6.1

[1] Space heating, water heating, cooking, and clothes drying only
[2] Includes impact of unburned methane
[3] Based on the national average generating mix in 2020

With more efficient natural gas space and water heating options, the advanced natural gas home emits approximately 16 percent, 40 percent, and 14 percent less CO_2e emissions compared to a typical natural gas home, all-electric home, and all-electric cold climate heat pump home. For the condensing and natural gas heat pump appliances, annual CO_2e emissions were 4.0 and 3.5 metric tons. In comparison, the all-electric option was 6.4 metric tons CO_2e annually, and the cold climate heat pump home was 4.6 metric tons.

TABLE 7

FULL-FUEL-CYCLE CARBON DIOXIDE EQUIVALENT EMISSIONS FOR ADVANCED HOMES[1]
(Metric Tons of CO_2e[2] per Average Household Energy Use)

Condensing Natural Gas	4.0
Natural Gas Heat Pump	3.5
Cold Climate Heat Pump[3]	4.5

[1] Space heating, water heating, cooking, and clothes drying only
[2] Includes impact of unburned methane
[3] Based on the national average generating mix in 2020

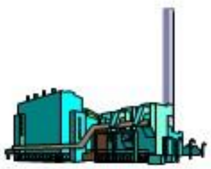
Conclusion

Analyzing energy and environmental impacts on a full-fuel cycle basis is vital to ensure that policymakers and consumers have a complete accounting of the energy efficiency and emissions implications of different fuel options. Full-cycle-cycle accounting shows that natural gas use in primary residential applications (space heating, water heating, cooking, and clothes drying) can result in increased energy efficiency, substantial consumer energy cost savings, and reduced environmental impacts when compared with electricity, oil, and propane use. Direct use of natural gas in the residential sector offers an efficient, cost-competitive alternative to electricity, oil, and propane with fewer adverse environmental impacts.

Appendix

Efficiency and Appliance Chart

2.4 Times More Energy Reaches the Customer with Natural Gas

	Extraction, Processing, & Transportation	Conversion[1]	Distribution	Delivered To Customer	
Electricity **38% Efficient**	100 MMBtu Energy Source	95	39	38	
					**Total CO_2e**
CO_2 equivalent[2] emissions from typical household use[3] (metric tons)	0.4	4.4	0.1	2.7	**6.4**
Natural Gas **92% Efficient**	100 MMBTU Energy Source	Not Applicable	93	92	
					**Total CO_2e**
CO_2 equivalent[2] emissions from typical household use[3] (metric tons)	0.4		0.1	4.6	**5.1**

1 Includes all energy inputs, including renewable sources – based on actual fuel mix in 2020
2 Includes greenhouse gas impact from unburned methane
3 Energy consumed in space and water heating, clothes drying, and cooking.
NOTE: This full-fuel-cycle examines all impacts from the energy source through consumption

Direct Use of Natural Gas Results in 21% Less CO_2e

Annual CO_2 equivalent* emissions from typical home heating, water heating, cooking, and clothes drying energy uses during the full-fuel-cycle

One Million Homes

Natural Gas

Total CO_2e

5.1 Million Metric Tons/Year

Electricity

Total CO_2e

6.4 Million Metric Tons/Year

NOTES:

1. Fuels used in electricity generation based on 2020 actual generation mix of fossil fuels, nuclear, and renewable energy

* Includes greenhouse gas impact from unburned methane

Full-Fuel-Cycle Impacts from Energy Consumption in a Typical Home

Electric Home

*6.4 metric tons CO_2e**

Full-Fuel-Cycle Energy Consumption: 132 MMBtu/yr
Site Energy Consumption: 49.8 MMBtu/yr
Total Annual Energy Cost: $2,090

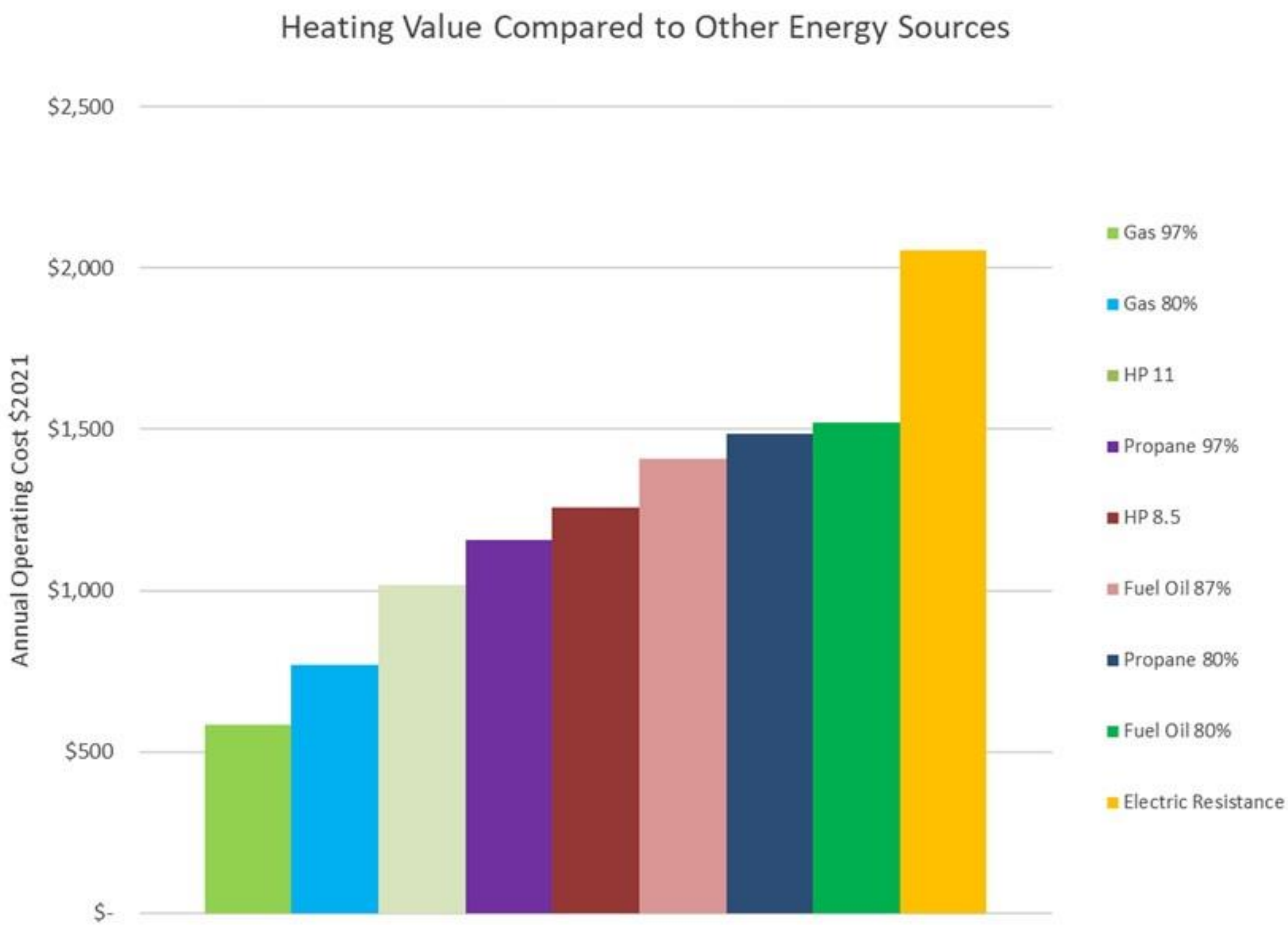
Natural Gas Home

*5.1 metric tons CO_2e**

Full-Fuel-Cycle Energy Consumption: 94.5 MMBtu/yr
Site Energy Consumption: 83.8 MMBtu/yr
Total Annual Energy Cost: $1,068

•Based on a 2,000 square foot home in an average climate, using national average energy prices. Analysis includes the following only: space heating, water heating, cooking, and clothes drying. Home meets 2013 International Energy Conservation Code standards.

* Includes greenhouse gas impact from unburned methane


Heating Value Compared to Other Energy Sources
Annual Operating Cost $2021
$2,500
$2,000
$1,500
$1,000
$500
$-
Gas 97%
Gas 80%
HP 11
Propane 97%
HP 8.5
Fuel Oil 87%
Propane 80%
Fuel Oil 80%
Electric Resistance

Residential Energy Efficiency Ratings
Water Heaters

DOE site-specific energy ratings are misleading.
While DOE rates an electric appliance with a more efficient energy rating than a similar gas appliance, in reality that electric appliance consumes more source energy, pollutes more, and costs the consumer more to operate.

Environmental Impact: 1.3 million tons of CO_2e
A 10% market shift in shipments/sales would reduce CO_2e emissions by 1.3 million metric tons per year.

Electric Resistance

Natural Gas

	Electric Resistance	Natural Gas
DOE NAECA Efficiency Rating [1]:	**.95 EF**	**.82 EF**
Full-Fuel-Cycle Energy Consumption (MMBtu/yr):	**41.9**	**20**
Energy Cost[2]/yr :	**$661**	**$221**
CO_2e* Emissions (metric tons/unit/yr):	**2.0**	**1.1**

[1]Energy factors (EF) based on a 40-50 gallon storage water heaters of equivalent first hour rating
[1]Energy Cost is based on 2022 DOE representative average unit costs for energy where electric rate is 14.26 cents/kWh; gas rate is $12.09/MMBtu
EF=Energy Factor

* Includes greenhouse gas impact from unburned methane

Residential Energy Efficiency Ratings

Advance Water Heaters

	Electric Heat Pump	Natural Gas Tankless
		
DOE NAECA Efficiency Rating [1]:	**2.0 EF**	**.95 EF**
Full-Fuel-Cycle Energy Consumption (MMBtu/yr):	**20.0**	**17.2**
Energy Cost[2]/yr :	**$315**	**$191**
CO_2e* Emissions (metric tons/unit/yr):	**0.97**	**0.94**

[1]Energy factors (EF) based on a 40-50 gallon storage water heaters of equivalent first hour rating
[1]Energy Cost is based on 2022 DOE representative average unit costs for energy where electric rate is 14.26 cents/kWh; gas rate is $12.09/MMBtu
EF=Energy Factor

* Includes greenhouse gas impact from unburned methane

Residential Energy Efficiency Ratings
Space Heating

DOE site-specific energy ratings are misleading. *While DOE rates an electric appliance with a more efficient energy rating than a similar gas appliance, in reality that electric appliance consumes more source energy, pollutes more, and costs the consumer more to operate.*

	Electric Heat Pump	Electric Resistance Furnace	Natural Gas Furnace
			
DOE NAECA Efficiency Rating:	**8.5 HSPF**	**99 AFUE**	**80 AFUE**
Full-Fuel-Cycle Energy Consumption (MMBtu/yr):	**79.1**	**130.6**	**67.6**
Energy Cost[1]/year	**$1,256**	**$2,057**	**$770**
CO_2e* Emissions (metric tons/unit/yr):	**3.85**	**6.3**	**3.66**

[1]Energy Cost is based on 2022 DOE representative average unit costs for energy where electric rate is 14.26 cents/kWh; gas rate is $12.09/MMBtu
HSPF=Heating Seasonal Performance Factor, AFUE=Annual Fuel Utilization Efficiency

* Includes greenhouse gas impact from unburned methane

Comparison of Residential Space Heating Appliances

	Electric Heat Pump		Electric Resistance Furnace	Natural Gas Furnace	
DOE/NAECA Efficiency	8.5 HSPF	10.5 HSPF	99 AFUE	80 AFUE	96 AFUE
Full-Fuel-Cycle Energy Use per Year*	79 MMBtu	61 MMBtu	131 MMBtu	68 MMBtu	52 MMBtu
CO_2e** Emissions/Yr*	3.9 Metric Tons	3.0 Metric Tons	6.3 Metric Tons	3.7 Metric Tons	2.6 Metric Tons
Annual Cost***	$1,256	$971	$2,057	$770	$584

* Excludes A/C operations
** Includes greenhouse gas impact from unburned methane
*** Energy Cost is based on 2022 DOE representative average unit costs for energy where electric rate is 14.26 cents/kWh; gas rate is $12.09/MMBtu

Residential Energy Efficiency Ratings

Clothes Drying

DOE site-specific energy ratings are misleading.
While DOE rates an electric appliance with a more efficient energy rating than a similar gas appliance, in reality that electric appliance consumes more source energy, pollutes more, and costs the consumer more to operate.

Environmental impact: 240,000 tons of CO_2e
A 10% market shift on shipments/sales would reduce CO_2e emissions by 240,000 tons per year.

Electric

Natural Gas

	Electric	Natural Gas
DOE NAECA Efficiency Rating:	**3.01 EF**	**2.67 EF**
Full-Fuel-Cycle Energy Consumption (MMBtu/yr):	**6.2**	**2.9**
Energy Cost[1]/yr:	**$98**	**$34**
CO_2e* Emissions (metric tons/unit/yr):	**0.30**	**0.15**

[1]Energy Cost is based on 2022 DOE representative average unit costs for energy where electric rate is 14.26 cents/kWh; gas rate is $12.09/MMBtu
EF = Energy Factor

* Includes greenhouse gas impact from unburned methane

Residential Energy Efficiency Ratings
Cooking Equipment

DOE site-specific energy ratings are misleading.
While DOE rates an electric appliance with a more efficient energy rating than a similar gas appliance, in reality that electric appliance consumes more source energy, pollutes more, and costs the consumer more to operate.

Environmental Impact: 131,000 tons of CO_2e
A 10% market shift on shipments/sales would reduce CO_2e emissions by 131,000 tons per year.

Electric

Natural Gas

	Electric	Natural Gas
Energy Factor	**10.9 EF**	**5.8 EF**
Full-Fuel-Cycle Energy Consumption (MMBtu/yr):	**4.8**	**3.8**
Energy Cost[1]/yr:	**\$76**	**\$43**
CO_2e* Emissions (metric tons/unit/yr):	**0.24**	**0.21**

[1]Energy Cost is based on 2022 DOE representative average unit costs for energy where electric rate is 14.26 cents/kWh; gas rate is $12.09/MMBtu

* Includes greenhouse gas impact from unburned methane