Residential Energy Use

Identification

1. Indicator Description

This indicator measures changes in residential seasonal energy use in the United States. It includes both residential summer electricity use and residential winter energy use.

Electricity use in the summer is associated with space cooling—particularly air conditioning, which accounts for 19 percent of the average American household's annual electricity use (EIA, 2024), but naturally more in the summer, when outdoor temperatures are warmer. As climate change contributes to an increase in average temperatures and unusually hot days, Americans are expected to use more electricity for air conditioning (Zamuda et al., 2023). This indicator focuses on summer electricity use to provide a sense of how cooling demands have changed over time.

The other component of the indicator considers natural gas use in the winter. This indicator specifically focuses on natural gas because it is the most widely used fuel in the mix for heating in the United States, amounting to about 72 percent of energy used for residential space heating (EIA, 2024). With rising winter temperatures, Americans are expected to use less energy for home heating (Zamuda et al., 2023). Winter natural gas use provides a sense of how heating demands have changed over time.

This indicator also includes heating and cooling degree days (HDD and CDD) as reference metrics. As described in the Heating and Cooling Degree Days indicator, CDD are a measure that reflect the amount of energy needed to cool a building to a comfortable temperature, given how hot it is outside. Heating degree days, conversely, reflect the amount of energy needed to heat a building to a comfortable temperature, given how cold it is outside. A "degree day" indicates that the daily average outdoor temperature was one degree higher or lower than some comfortable baseline temperature on a particular day. In this case, both HDD and CDD use a baseline of 65°F—a typical baseline used by the National Oceanic and Atmospheric Administration (NOAA). HDD are summations of negative differences between the mean daily temperature and the 65°F base; CDD are summations of positive differences from the 65°F base. The sum of the number of CDD over a period of time is roughly proportional to the amount of energy that would be needed to cool a building in that location (Quayle & Diaz, 1980). By the same logic, the sum of the number of HDD over a period of time is roughly proportional to the amount of energy that would be needed to heat a building in that location. Thus, CDD and HDD are rough surrogates for how climate change is likely to affect energy use for cooling and heating, respectively.

Components of this indicator include:

- Time series of residential summer electricity use per capita from 1973 to present, with summer CDD provided for reference (Figure 1).
- Time series of residential winter natural gas use per capita from 1974 to present, with winter HDD provided for reference (Figure 2).

2. Revision History

April 2021: Indicator published.
September 2023: Updated Figures 1 and 2 with data through 2022.
December 2024: Updated Figures 1 and 2 with data through 2024.

Data Sources

3. Data Sources

Residential Electricity and Natural Gas Use

Residential electricity use data for this indicator come from monthly statistics published by the U.S. Energy Information Administration (EIA). EIA collects comprehensive information about power generation, delivery, and sales from electric power utilities across the country. Residential natural gas use data for this indicator also come from monthly statistics published by EIA, based on natural gas delivery/sales data collected from utilities across the country.

Population

EPA calculated electricity and natural gas use per capita using population data provided by the U.S. Bureau of Economic Analysis (BEA). These data originate from official decennial censuses and "intercensal" monthly estimates developed by the U.S. Census Bureau. The U.S. Census Bureau publishes many of these numbers directly, but because the format, resolution, and completeness of electronically available monthly Census Bureau estimates varies by decade, BEA's data product proved to be a more consistent source for this indicator.

Cooling and Heating Degree Days

Data for the CDD and HDD reference metrics were provided by NOAA's National Centers for Environmental Information (NCEI). These data are based on temperature measurements from weather stations overseen by NOAA's National Weather Service (NWS). These underlying data are maintained by NCEI.

4. Data Availability

Residential Electricity Use

This indicator is based on total monthly residential electricity use data that EIA has made available at: www.eia.gov/totalenergy/data/monthly. These historical data records are sourced from Table 7.6 of *Monthly Energy Review* and are available back to January 1973. They are updated monthly. To access the *Monthly Energy Review* for the most recent data and documentation, see: www.eia.gov/totalenergy/data/monthly.

Residential Natural Gas Use

This indicator is based on total monthly residential natural gas use data that EIA has made available at: www.eia.gov/totalenergy/data/monthly. These historical data records, like the electricity use data, are available back to January 1973 and updated monthly.

Population

EPA obtained U.S. monthly population data used to derive per capita residential electricity and natural gas use from the Federal Reserve Bank of St. Louis, which made BEA's monthly time series readily available online at: https://fred.stlouisfed.org/series/POPTHM. Underlying U.S. Census Bureau estimates and methodological documentation can be found at: www.census.gov/data/tables/time-series/demo/popest/1980s-national.html, www.census.gov/data/datasets/time-series/demo/popest/intercensal-1990-2000-national.html, www.census.gov/data/datasets/time-series/demo/popest/intercensal-2000-2010-national.html, www.census.gov/data/tables/time-series/demo/popest/2010s-national-total.html, www.census.gov/data/tables/time-series/demo/popest/2020s-national-total.html, and other webpages linked from: www.census.gov.

Cooling and Heating Degree Days

EPA obtained data for the CDD and HDD reference metrics from NCEI at: www.ncdc.noaa.gov/cag. These data are a part of NOAA's Climate Divisional Database (*n*ClimDiv) and replace the previous Time Bias Corrected Divisional Temperature-Precipitation Drought Index. The *n*ClimDiv product incorporates data from the daily version of NOAA's Global Historical Climatology Network (GHCN-Daily) and is updated once a month. For access to *n*ClimDiv data and documentation, see: www.ncei.noaa.gov/access/monitoring/reference-maps/conus-climate-divisions.

Individual weather station data are maintained at NOAA's NCEI, and the data are distributed on various computer media (e.g., anonymous FTP sites), with no confidentiality issues limiting accessibility. Individual station measurements and metadata are available through NCEI's website (www.ncei.noaa.gov/products/land-based-station).

Methodology

5. Data Collection

Residential Electricity Use

EIA collects data from electric power generators, utilities, and other parts of the energy sector using a variety of forms. Some of these forms are essentially mandatory; others are voluntary or part of a sampling program.

This indicator tracks residential summer electricity use based on monthly residential electricity retail sales data reported by a statistically chosen sample of electric utilities and, beginning in 1996, other energy service providers. Retail residential sales data published by EIA are compiled from survey forms that have included:

- EIA Form EIA-861M, "Monthly Electric Power Industry Report."
- EIA Form EIA-826, ''Monthly Electric Utility Sales and Revenue Report with State Distributions,'' which has been merged into EIA-861M in recent years.
- Other predecessor forms that collected the same key data points.

These EIA forms and their descriptions and instructions can be found at: www.eia.gov/survey.

EIA uses regression prediction to estimate state and national retail electricity sales for utilities not in the monthly sample and for any non-respondents. The resulting estimates cover all 50 states plus D.C. For more information about EIA's data collection methods and estimation procedures, see: www.eia.gov/electricity/monthly/pdf/technotes.pdf.

Residential Natural Gas Use

This indicator tracks residential winter natural gas use based on monthly natural gas surveys filled out by companies that deliver natural gas to consumers. Retail residential sales data published by EIA are compiled from survey forms that have included:

- EIA Form EIA-857, "Monthly Report of Natural Gas Purchases and Deliveries to Consumers."
- EIA Form EIA-910, "Monthly Natural Gas Marketer Survey."

These EIA forms and their descriptions and instructions can be found at: www.eia.gov/survey.

Population

Monthly population estimates are used to derive monthly per capita residential electricity and natural gas use data. The most readily available estimates that are consistent over the entire period of interest come from BEA, and they include resident population plus armed forces overseas. Each monthly population estimate from BEA is the average of U.S. Census Bureau estimates for the first of the month and the first of the following month. For consistency, EPA used estimates for the 50 states plus D.C.

The U.S. Census Bureau annually produces and publishes national monthly and annual population estimates. Population estimates for each month since the most recent decennial census are developed by using measures of population change (births, deaths, and domestic and international migration). After each official decennial census, the Census Bureau revises all monthly estimates for the preceding decade. For a description of the input data, methodology, and processes for the creation of population estimates for the time periods following the last three decennial censuses, see: www2.census.gov/programs-surveys/popest/technical-documentation/methodology/2010-2020/v2020-est-relnotes.pdf, www2.census.gov/programs-surveys/popest/technical-documentation/methodology/2000-2010/2010-relnotes.pdf, and: www2.census.gov/programs-surveys/popest/technical-documentation/methodology/1990-2000/90s-nat-meth.txt.

Cooling and Heating Degree Days

These reference metrics measure the total CDD and HDD nationwide per summer and winter, respectively. For more detail on the underlying data and methods of these two metrics, see the Heating and Cooling Degree Days indicator and associated technical documentation. The CDD and HDD data are based on time-bias-adjusted temperature data from weather stations throughout the contiguous 48 states. For example, NOAA adjusted raw station temperature data to remove bias due to variation in the time of day at which temperature measurements were reported (Arguez et al., 2011; Karl et al., 1986; Vose et al., 2014). Some of these stations are automated stations operated by NOAA's NWS. The remainder are Cooperative Observer Program (COOP) stations operated by other organizations using trained observers and equipment and procedures prescribed by NOAA.

Systematic collection of weather data in the United States began in the 1800s. Since then, observations have been recorded from 23,000 stations. At any given time, observations are recorded from approximately 8,000 stations. COOP stations generally measure temperature at least hourly, and they record the maximum and minimum temperature for each 24-hour time span. Cooperative observers include state universities, state and federal agencies, and private individuals whose stations are managed and maintained by the NWS. Observers are trained to collect data following NWS protocols, and the NWS provides and maintains standard equipment to gather these data. For an inventory of U.S. weather stations and information about data collection methods, see: www.ncei.noaa.gov/products/land-based-station, the technical reports and peer-reviewed papers cited therein, and the NWS technical manuals at: www.weather.gov/coop.

This indicator is based on a specific quality-controlled set of long-term stations that NCEI has designated as its *n*ClimDiv data set. Variables that are relevant to this indicator include observations of daily maximum and minimum temperatures.

6. Indicator Derivation

Residential Electricity Use per Capita

EPA derived residential summer electricity use per capita using the following steps. First, monthly U.S. residential electricity use was divided by monthly population to calculate monthly U.S. residential electricity use per capita. Second, monthly residential electricity use per capita was summed for the months of June, July, and August of each year to calculate U.S. residential electricity use per capita for the summer.

Residential Natural Gas Use per Capita

In a similar process, EPA derived residential natural gas use per capita using the following steps. First, monthly U.S. residential natural gas use was divided by monthly population to calculate monthly U.S. residential electricity use per capita. Second, monthly residential natural gas use per capita was summed for the months of December, January, and February. Note that for each listed year, the December data were from the previous year, while January and February data were from the listed year (e.g., winter 1974 comprised December 1973, January 1974, and February 1974). From this sum, EPA could calculate U.S. residential natural gas use per capita for the winter. EPA choose to use summer and winter months that correspond to meteorological seasons and that easily facilitate comparisons with CDD and HDD.

Cooling and Heating Degree Days

NCEI used several steps to calculate monthly national CDD and HDD data for each month of each year (Arguez et al., 2011; Vose et al., 2014).

First, the raw station temperature data were adjusted to remove bias due to variation in the time of day at which temperature measurements were reported (Arguez et al., 2011; Karl et al., 1986; Vose et al., 2014). This bias arises from the fact that, historically, some COOP stations have reported temperatures over climatological days ending at different times of day (e.g., over the 24-hour period ending at midnight versus the 24-hour period ending at 7:00 p.m.). This variation leads to different reported daily minimum and maximum temperatures, as well as inconsistencies in mean temperature (which historically has often been calculated as [*minimum temperature* + *maximum temperature*] ÷ 2). To address this problem, NCEI used the statistical adjustment procedure from Karl et al. (1986) to remove bias due to differences in time-of-day definitions.

Second, daily bias-adjusted data were used to calculate mean temperatures in each month and year (Arguez et al., 2011; Vose et al., 2014). Additionally, the data were used to calculate the standard deviation of daily temperatures in each location for each month (pooling across all years) over the entire period for which temperature data were available.

Third, NCEI estimated the total monthly CDD and HDD at each location. A crude way to find monthly totals would be to simply add all the daily CDD or HDD values over the course of the month. For reasons related to data quality, however, NCEI used a modified version of the procedure presented in Thom (1954a, 1954b, 1966), which assumes that daily temperatures within a month are distributed normally. The expected number of CDD or HDD per month can then be expressed as a simple function of the actual monthly mean daily temperature and the long-term standard deviation of daily temperatures. The logic behind this approach is that CDD and HDD are measures that reflect both the mean (the "absolute value") and standard deviation (the "spread") of daily temperatures—and thus can be estimated from them. Although predictions based on this formula may be inaccurate for any particular day or week, on average across large time periods the predictions will be reasonably good. The rationale for using this approach is that daily COOP station data contain many "inhomogeneities" and missing data points that may add noise or bias to CDD or HDD estimates calculated directly from daily data. By estimating CDD and HDD following the Thom procedure, NCEI was able to generate estimates in a consistent way for all months of the data.

State and national averages for each year were calculated as follows:

1. NCEI calculated a monthly average CDD and HDD for each climate division (each state within the contiguous 48 has up to 10 climate divisions; see: www.ncei.noaa.gov/access/monitoring/reference-maps/conus-climate-divisions) using climatologically aided interpolation to address topographic and network variability. This step is part of NCEI's *n*ClimDiv analysis, in which NCEI uses station data and interpolation between stations to create a 5-kilometer grid across the contiguous 48 states for each variable in the data set. Divisional averages are derived by averaging the grid cells within each climate division. This approach ensures that divisional standardized precipitation index values are not biased toward areas that happen to have more stations clustered close together.

2. NCEI calculated monthly averages for each state by weighting the climate divisions by their population. With this approach, state CDD and HDD values more closely reflect the conditions that the average resident of the state would experience, as both temperature and population are incorporated at the climate division (sub-state) scale.

3. NCEI calculated monthly averages for the contiguous 48 states by weighting the divisions or states according to their population. All population-based weighting was performed using population data from the 2020 U.S. Census.

4. EPA added each year's monthly averages together for the months of June, July, and August to arrive at summer CDD totals for the contiguous 48 states. EPA added each year's monthly averages together for December (of the previous year), January, and February to arrive at winter HDD totals for the contiguous 48 states.

5. Figures 1 and 2 show the national HDD and CDD averages each year for the two seasonal periods as described above.

7. Quality Assurance and Quality Control

Residential Electricity and Natural Gas Use

EIA has in place numerous quality assurance and quality control (QA/QC) procedures, including computerized verification of keyed input, review by subject matter specialists, and follow-up with non-respondents to assure quality statistics. Additionally, to ensure the quality standards established by EIA, formulas based on historic data values are used to check data input for errors automatically. Data values outside the ranges prescribed in the formulas are verified by EIA staff by telephoning respondents to resolve any discrepancies. All survey non-respondents are identified and contacted by EIA staff.

Population

The U.S. Census Bureau has developed comprehensive standards to promote quality in its processes and information products. View the standards at: www.census.gov/content/dam/Census/about/about-the-bureau/policies_and_notices/quality/statistical-quality-standards/Quality_Standards.pdf. In developing population estimates, one of the key principles the Census Bureau hopes to achieve is that all estimates are consistent across geography and demographic characteristics. To do so, the Census uses a number of controlling procedures that ensure consistency given that various estimates products and processes use slightly different input data and methodology. To learn more about the Census Bureau's controlling procedures for population estimates, see: www2.census.gov/programs-surveys/popest/technical-documentation/methodology/2010-2020/methods-statement-v2020-final.pdf.

Cooling and Heating Degree Days

NOAA follows extensive QA/QC procedures for collecting and compiling weather station data. For documentation of COOP methods, including training manuals and maintenance of equipment, see: www.weather.gov/coop. These training materials also discuss QC of the underlying data set. QC procedures are discussed in Kunkel et al. (2005).

NOAA's *n*ClimDiv data set follows strict QA/QC procedures to identify errors and biases in the data and then either remove these stations from the time series or apply correction factors. Procedures for *n*ClimDiv are summarized at: www.ncei.noaa.gov/access/monitoring/reference-maps/conus-climate-divisions.

Analysis

8. Comparability Over Time and Space

Electricity and natural gas use per capita are calculated for the 50 states plus D.C., whereas the CDD and HDD reference time series are only available for the contiguous 48 states. Additional considerations for the individual components of this indicator are described below.

Residential Electricity and Natural Gas Use

EIA has used a number of different survey data collection sources to derive historical monthly U.S. residential electricity and natural gas use, so there may be differences in how the sample set of utilities was determined, how utilities reported sales data, and the types of regression prediction techniques used. For example, in 2001, Form EIA-826 was modified to include all investor-owned electric utilities and a sample of companies from other ownership classes, and a new method of estimation was implemented. EIA noted in its April 2001 *Electric Power Monthly* that: "These changes may affect comparisons of current and historical data within the individual data collection sources as well as across the data collection sources." That said, EIA does periodically update its previous estimates to improve consistency over time. EIA's methods have been applied consistently across the country.

Population

National monthly population estimates developed by the U.S. Census Bureau have been calculated using consistent methods across the country and throughout the period of interest, using a cohort component method derived from the Bureau's demographic balancing equation. In addition, with each annual release of population estimates, the Census Bureau revises and updates the entire time series of monthly estimates from the last decennial census (April 1, 2020) to July 1 of the current year. The Census Bureau also updates its previous monthly estimates after each decennial census. The decennial censuses that inform these estimates are based on rigorous data collection procedures that are designed for optimal accuracy and consistency over time and space.

Cooling and Heating Degree Days

The CDD and HDD reference metrics have been calculated using the same methods for all locations and throughout the period of record. Each climate division contributes to the state and national averages in proportion to its population. All population-based weighting was performed using population data from the 2010 U.S. Census to avoid ending up with a CDD or HDD trend line that reflects the influence of shifting populations (e.g., more people moving to areas with warmer climates).

9. Data Limitations

Factors that may impact the confidence, application, or conclusions drawn from this indicator are as follows:

1. Monthly residential electricity and natural gas use and population data are based on estimates. When these estimates were developed, particularly for electricity and natural gas use, discrepancies may have occurred as a result of changes over time in survey forms and estimation procedures.

2. This indicator is based on residential retail electricity and natural gas sales. In the case of electricity, sales are not exactly the same as total residential electricity use because sales data do not count electricity that people generate and consume onsite—for example, using rooftop solar photovoltaic (PV) panels. Residential solar generation at present represents a small percentage of overall electricity consumed in the United States: EIA estimated 38,900 gigawatts of net residential solar PV generation in 2022 (see Table 21 of EIA [2023]), compared with 1.51 million gigawatts of total residential retail sales during the 12 months of 2022 used in creating Figure 1 of this indicator. That makes residential solar generation equivalent to 2.6 percent of retail sales. As more homeowners produce their own power (e.g., as incentives for solar PV increase and the cost decreases), and this distributed generation displaces electricity that they otherwise would have purchased from a utility, sales data could increasingly underestimate the actual amount of electricity used. However, retail sales data are still the best available approximation for energy use nationwide.

3. Many factors besides temperature influence residential summer electricity and winter heating fuel use and how they might change over time. Possible factors include increasing electrification of American homes; changes in end use equipment (for example, what other electrical or electronic devices people use); prevalence, type, energy source, and efficiency of air conditioning equipment (window-mounted units versus central air, ground source heat pumps, more efficient devices over time, etc.); similar considerations for heating equipment; changes in size and thermal attributes of housing units (for example, a trend toward larger but better-insulated homes); changes in behavioral patterns; changes in average household size; geographic shifts in population (e.g., as more people move to warmer climate zones); and differences in energy prices (which could encourage or discourage power consumption). Some of these influences may tend to balance each other out (for example, people heat and cool larger spaces but have more energy-efficient equipment and homes), but the net result is that temperature is still not the only driver of changes in summer electricity and winter heating fuel use.

   Variables such as humidity and dew point are another important influence on energy demand that temperature-based CDD and HDD do not capture. Much like the heat index, which incorporates humidity with temperature, these variables affect what the environment "feels like" and can drive the energy use both in the summer and the winter. In fact, recent research studies have established that mean dewpoint temperature may be a stronger predictor of energy consumption than simple degree days (Pielke et al., 2004).

   This indicator does not attempt to adjust for any of the factors described above. It is simply acknowledged that outdoor air temperature is not the only factor that could drive changes in summer residential electricity use per capita. That said, there is certainly a direct relationship between outdoor air temperatures and summer residential electricity use, as well as winter residential heating fuel use. Figure 1 of this indicator offers visual confirmation of the relationship between outdoor air temperature and summer electricity use, as the two time series (electricity use and CDD) move up and down largely in sync. Figure TD-1 below offers statistical confirmation of this relationship, plotting each summer month (three observations per year) over the entire period of record and showing a correlation between per capita residential electricity use and CDD. Analogously, Figure 2 offers visual confirmation of the relationship between air temperatures and natural gas use, as its two time series (natural gas use and HDD) move up and down largely in sync. Figure TD-2 below offers statistical confirmation of this relationship, plotting each winter month (three observations per year) over the entire period of record and showing a correlation between per capita natural gas use and HDD.

Figure TD-1. Comparison of Residential Electricity Use per Capita and Cooling Degree Days (June, July, August), 1973–2024

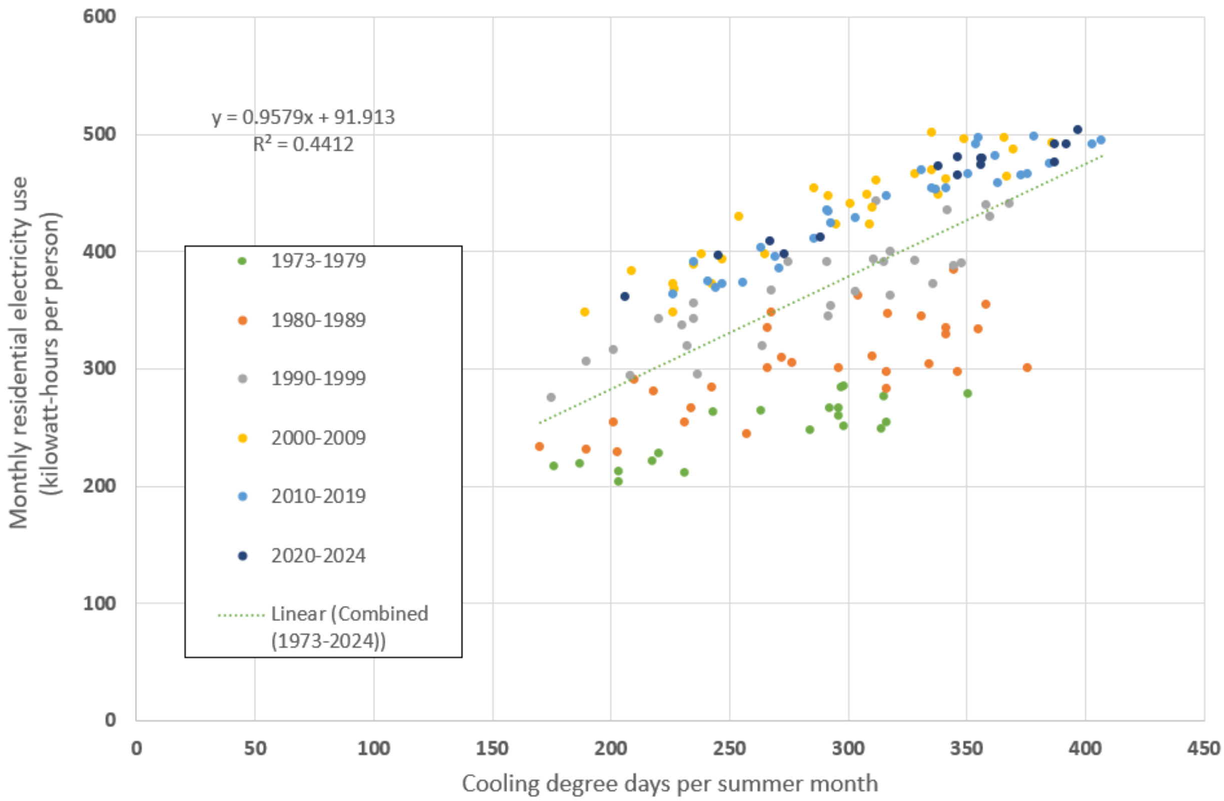
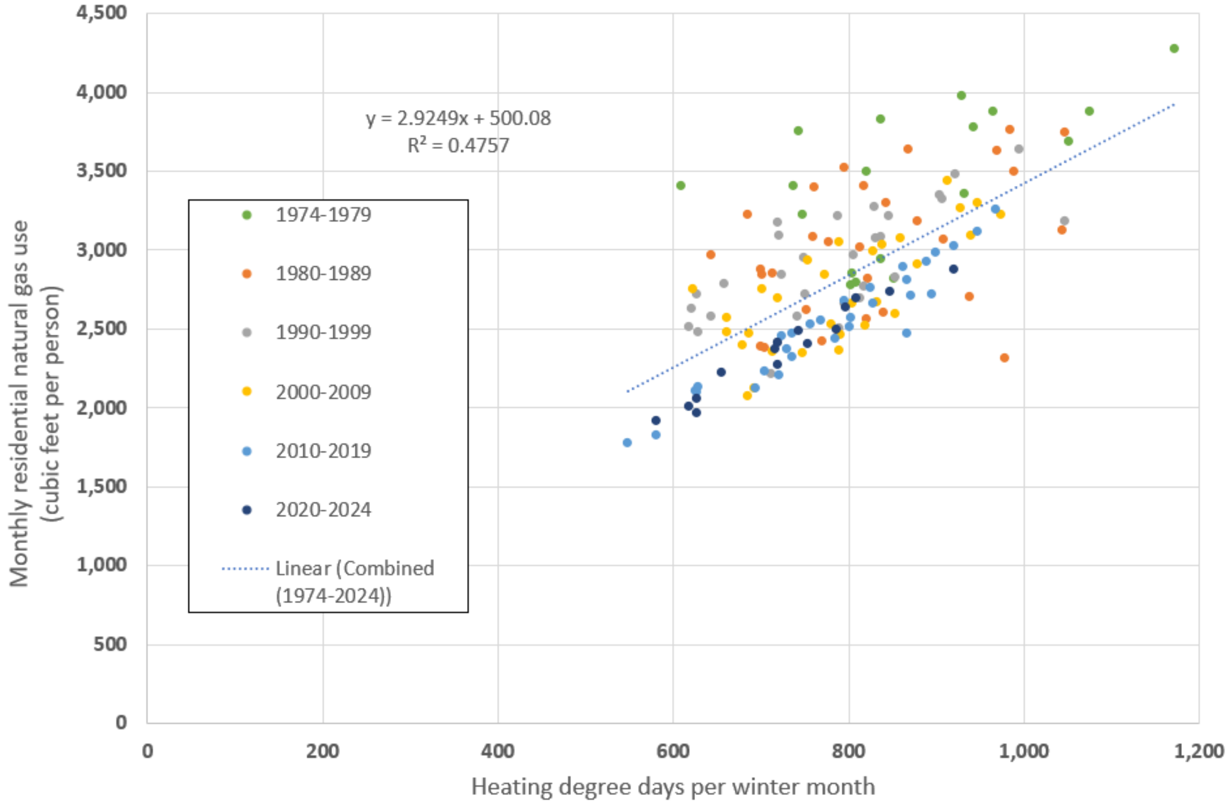


Figure TD-2. Comparison of Residential Natural Gas Use per Capita and Heating Degree Days (December, January, February), 1974–2024



10. Sources of Uncertainty

Residential Electricity and Natural Gas Use Per Capita

The main sources of uncertainty in the residential summer electricity and winter natural gas use per capita metrics come from sampling errors, which could occur because EIA observations are made only on a sample, not on the entire population of utilities. Non-sampling errors can be attributed to many sources in the collection and processing of data, such as response errors and data input errors. The accuracy of overall estimates is determined by the combined effects of sampling and non-sampling errors. EIA has not quantified the uncertainty in its estimates.

Cooling and Heating Degree Days

Uncertainty in the CDD and HDD metric relates to the quality of the underlying weather station records. Uncertainty may be introduced into this data set when hard copies of historical data are digitized—although this is more of an issue for the early part of the 20th century, before the start of this particular indicator. As a result of these and other reasons, uncertainties in the temperature data increase as one goes back in time, particularly given that there are fewer stations early in the record. However, NOAA does not believe these uncertainties are sufficient to undermine the fundamental trends in the data. Vose and Menne (2004) suggest that the station density in the U.S. climate network is sufficient to produce robust spatial averages.

NCEI has taken a variety of steps to reduce uncertainties, including correcting the data for time-of-day reporting biases and using the Thom (1954a, 1954b, 1966) methodology to estimate degree days. The value of this approach is that it allows estimation of degree days based on monthly average temperatures, even when the daily data may include some inaccuracies. However, this methodology for estimating CDD and HDD from mean monthly temperatures and the long-term standard deviation of monthly temperatures also introduces some uncertainty. Although this peer-reviewed technique is considered reliable, it could produce inaccurate results if the standard deviation of temperatures has changed over time, for example due to an increasing trend of local variability in daily temperatures.

11. Sources of Variability

Residential Electricity Use per Capita

Residential summer electricity use per capita is influenced by temperature, as electricity is the main energy source used for air conditioning in the United States. Consequently, residential summer electricity use per capita will vary with changes in summer CDD. Residential summer electricity use per capita can also be expected to change as a result of other factors described in Section 9. These include the size and thermal characteristics of American homes; prevalence, type, and efficiency of air conditioning equipment; population factors (household size; where people live); other uses of electricity; and energy sources and prices. Some of these factors, like energy prices, could introduce month-to-month or year-to-year variability. Others could influence longer-term trends.

Residential Natural Gas Use per Capita

Residential natural gas use per capita is influenced by temperature, as natural gas is the predominant energy source used for heating in the United States. Consequently, residential winter natural gas use per capita will vary with changes in winter HDD. Residential winter natural gas use per capita can also be expected to change as a result of other factors described in Section 9. These include changes in size and thermal attributes of housing units (for example, a trend toward larger but better-insulated homes); changes in behavioral patterns; population factors (household size; where people live); and energy prices. Again, some of these factors, like energy prices, could introduce month-to-month or year-to-year variability. Others could influence longer-term trends.

Cooling and Heating Degree Days

The reference CDD and HDD metrics are likely to display the same types of variability as the temperature record on which they are based. Temperatures naturally vary as a result of normal variation in weather patterns, multi-year climate cycles such as the El Niño–Southern Oscillation and Pacific Decadal Oscillation, and other factors.

12. Statistical/Trend Analysis

To test for the presence of long-term national-level changes, the residential summer electricity use per capita and residential winter natural gas use per capita data series in Figures 1 and 2, respectively, were analyzed with an ordinary least squares linear regression of annual data points. For electricity, this results in a trend of +13.9 kilowatt-hours per year. This trend is statistically significant ($p < 0.001$). For natural gas, this results in a trend of -61.7 cubic feet per year. This trend, too, is statistically significant ($p < 0.001$).

EPA has also tested these trends using a Sen's slope regression, which is a non-parametric approach that finds the median of all possible pairwise slopes in a temporal data set (Sen, 1968; Theil, 1950). The results are similar: +14.4 kilowatt-hours per year for summer electricity use and -59.7 cubic feet per year for winter natural gas use. Both results are statistically significant, with Mann-Kendall p-values < 0.001.

For reference, the ordinary least squares linear trend in summer CDD is also positive and significant: +3.7 degree days per year (p < 0.001). The trend in winter HDD is negative and significant: -6.9 degree days per year (p < 0.001).

Previous research studies (e.g., Alipour et al., 2019; Mukherjee et al., 2019; Nateghi & Mukherjee, 2017) have shown that linear models may not fully capture the complex relationships between energy and climate. EPA recognizes this limitation and notes that ordinary least-squares and Sen's slope linear regression have been used here for first-order screening purposes only.

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