U.S. Energy-Related Carbon Dioxide Emissions, 2024—Report Appendix and Methodology

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Sector Contributions to Changes in U.S. Energy-Related CO_2 Emissions

Annual changes in U.S. energy-related CO_2 emissions in each sector are affected by changes in:

- Electricity consumption
- The fuel mix of electricity generation (which determines the carbon intensity of electricity consumed)
- Direct energy consumption (also known as primary energy)
- The fuel mix of direct consumption of primary energy (which determines the carbon intensity of primary energy consumed)

Table A-1 shows each end-use sector's contribution to the total change in energy-related CO_2 emissions for the U.S. economy in 2024. The table includes CO_2 emissions related to changes in:

- Each sector's electricity consumption, measured in British thermal units (Btu), 2023–24
- The electricity generation fuel mix for electricity consumption and the carbon intensity (CO_2/Btu) of electricity sales to end-use sectors
- Primary energy consumption (Btu) by sector
- Carbon intensity (CO_2/Btu) by sector
- The total of all end-use sectors based on summing the changes for electricity and direct primary energy consumption across the four sectors

Table A-1 also includes the sum of these changes.

Table A-1. Sector contributions by electricity and primary energy changes to the total energy-related CO_2 emissions change

million metric tons of CO_2

	Residential	Commercial	Industrial	Transportation	Total all sectors
Change in electricity-related CO_2 emissions, 2023–24	5	0	1	0	6
Change related to the carbon intensity of electricity-related CO_2 emissions, 2023–24	-8	-8	-6	0	-22
Change in electricity-related CO_2 with no change in carbon intensity, 2023–24	13	8	7	0	28
Change in primary energy-related CO_2 emissions, 2023–24	-10	-2	-14	-2	-29
Change related to the carbon intensity of primary energy-related CO_2 emissions, 2023–24	0	-1	-15	-8	-23
Change in primary energy-related CO_2 emissions with no change in carbon intensity, 2023–24	-9	-2	0	6	-5
Sum of the change in electricity and primary energy CO_2 emissions, 2023–24	-5	-2	-13	-2	-23

Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Tables 11.2−11.5, Carbon Dioxide Emissions from Energy Consumption by Sectors
Note: Totals may not equal sum of components due to independent rounding.

Methodology for Table A-1

We divide total energy-related CO_2 emissions for each U.S. end-use sector into two components: primary (or direct) emissions and indirect emissions. *Primary emissions* are CO_2 emissions resulting from fossil-fuel combustion in each sector (for example, natural gas used for home heating). *Indirect emissions* refers to emissions created by electricity generation, which we attribute to each end-use sector based on its share of total electricity consumption:

- Row 7 shows changes in total energy-related emissions for each end-use sector
- Row 4 shows changes in primary emissions
- Row 1 shows changes in indirect emissions

The first row in Table A-1 represents the total change in electricity-related CO_2 emissions by end-use sector between 2023 and 2024. The change in electricity-related CO_2 emissions is driven by two components: the change in the carbon content of consumed electricity and the change in total electricity demand. In other words, we express the total change in electricity-related CO_2 emissions as

$$\Delta\, CO_2\; electricity_{s,y} \;=\; \Delta\, CO_2\; electricity\; mix_{s,y} + \Delta\, CO_2\; electricity\; demand_{s,y} \quad (1)$$

where
s = an end-use sector; and
y = the year.

We calculate the second term, the change in electricity-related emissions associated with changes in electricity demand, by multiplying the previous year's electricity-related emissions in that sector by that sector's change in electricity consumption.

$$\Delta\, CO_2\; electricity\; demand_{s,y} = CO_2\; electricity_{s,y-1} \cdot \%\,\Delta\;\, electricity\; consumption_{s,y} \quad (2)$$

This value represents the change in total electricity-related CO_2 emissions in the sector, assuming that the electricity generation mix and carbon content are held constant. If this assumption is true, then the change in demand-related electricity CO_2 emissions will be equal to the total change in electricity CO_2 emissions. However, the electricity mix is usually dynamic over time. To account for this potential discrepancy, we define the change in emissions associated with the carbon content of electricity by reordering Equation 1 as

$$\Delta\, CO_2\; electricity\; mix_{s,y} = \Delta\, CO_2\; electricity_{s,y} - \Delta\, CO_2\; electricity\; demand_{s,y} \quad (3)$$

We calculate primary emissions for each end-use sector by subtracting indirect emissions from total emissions, or

$$CO_2\; primary_{s,y} \;= CO_2\; total_{s,y} \;- CO_2\; electricity_{s,y} \quad (4)$$

Total emissions are taken directly from the EIA *Monthly Energy Review* (MER), with the methodology defined in the MER Section 11 Notes. We then break down these primary emissions into carbon content and demand components in much the same way as electricity-related emissions. The demand component of changes in primary emissions is expressed as

$$\Delta\, CO_2\ demand\ primary\ energy_{s,y} = CO_2\ primary_{s,y-1} \cdot \%\ \Delta\ primary\ consumption_{s,y} \quad (5)$$

and the change in emissions associated with the change in carbon content of primary energy is calculated as

$$\Delta\, CO_2\ primary\ energy\ content_{s,y} = \Delta\, CO_2\ primary_{s,y} - \Delta\, CO_2\ demand\ primary\ energy_{s,y} \quad (6)$$

CO_2 Emissions from Electricity Generated Outside of the Electric Power Sector

Not all electricity used in the United States is generated by the electric power sector. In the commercial and industrial sectors, coal, natural gas, petroleum, and biomass are also used to generate power for onsite use (accounting for 4% of total generation). Table A-2 presents our analysis of CO_2 emissions originating from electricity generation outside of the electric power sector.

Table A-2. CO_2 emissions from electricity generated outside of the electric power sector

million metric tons of CO_2

	CO_2 emissions from generation within the commercial sector (excludes CO_2 emissions from the electric power sector)				CO_2 emissions from generation within the industrial sector (excludes CO_2 emissions from the electric power sector)				Total commercial and industrial CO_2 emissions from generation (excludes CO_2 emissions from the electric power sector)
	Coal	Natural gas	Petroleum	Total	Coal	Natural gas	Petroleum	Total	Total
2005	0.81	1.84	0.23	2.88	15.93	28.16	2.45	46.54	49.42
2006	0.73	1.88	0.13	2.75	15.63	29.14	1.92	46.69	49.44
2007	0.76	1.85	0.10	2.72	10.89	30.08	1.89	42.87	45.59
2008	0.82	1.82	0.06	2.69	10.83	28.26	1.36	40.46	43.15
2009	0.69	1.86	0.07	2.63	9.76	28.19	1.22	39.17	41.80
2010	0.68	2.14	0.07	2.88	16.99	30.06	0.88	47.92	50.81
2011	0.74	2.55	0.05	3.34	11.84	30.90	0.78	43.52	46.85
2012	0.63	3.42	0.11	4.16	9.58	34.35	1.70	45.63	49.79
2013	1.05	3.62	0.13	4.79	9.65	34.93	1.38	45.96	50.75
2014	0.41	3.93	0.17	4.52	9.54	34.07	0.92	44.53	49.05
2015	0.32	3.85	0.10	4.27	8.13	34.30	0.67	43.11	47.38
2016	0.21	2.55	0.04	2.80	6.09	29.33	0.60	36.02	38.82

2017	0.18	2.75	0.08	3.00	5.54	29.69	0.54	35.78	38.78
2018	0.16	2.89	0.10	3.16	5.03	31.05	0.49	36.56	39.72
2019	0.14	3.06	0.09	3.29	4.29	34.00	0.46	38.74	42.03
2020	0.13	2.85	0.09	3.06	3.52	34.00	0.40	37.93	40.99
2021	0.15	2.50	0.09	2.75	3.28	32.18	0.36	35.82	38.57
2022	0.15	2.67	0.10	2.92	3.23	32.70	0.43	36.36	39.28
2023	0.12	2.69	0.07	2.88	2.86	33.40	0.34	36.60	39.48
2024	0.11	2.69	0.07	2.87	2.92	32.85	0.29	36.06	38.93

Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Table 7.3c, Consumption of Selected Combustible Fuels for Electricity Generation: Commercial and Industrial Sectors (Subset of Table 7.3a) and Carbon dioxide Emissions Coefficients by Fuel

Methodology for Table A-2

We based the estimates in Table A-2 on our *Monthly Energy Review* (MER), Table 7.3c, Consumption of Selected Combustible Fuels for Electricity Generation: Commercial and Industrial Sectors (Subset of Table 7.3a). To perform this calculation, we used the following CO_2 emissions factors:

- Coal
  - 95.99 million metric tons (MMmt) per quadrillion British thermal units (quad) for the commercial sector
  - 95.70 MMmt per quad for the industrial sector
- Natural gas
  - 52.91 MMmt per quad for both the commercial sector and the industrial sector
- Petroleum
  - 74.15 MMmt per quad for the commercial sector
  - 73.94 MMmt per quad for the industrial sector

Emissions factors for coal and natural gas consumed in the United States are from the detailed factors spreadsheet available on our Environment page. We constructed petroleum factors manually by using each end-use sector's consumption of distillate fuel oil and residual fuel oil and associated CO_2 emissions.

We applied these factors to the amount of each fuel combusted (in British thermal units) to produce electricity in the commercial and industrial sectors. These calculations account for the changes in the carbon intensity (CO_2 per kilowatthour) of electricity generated from all sources. Biomass is excluded from these emissions calculations because we assume biomass to be carbon neutral.

Methodology Used in This Analysis

Except figures A-2 and A-3, whose methodologies are described below, we publish the data in this report either as values in our MER or the result of calculations based on published values (for example, CO_2 emissions per unit of energy consumed, or million metric tons of CO_2 per British thermal unit).

Methodology for Figure A-2

Figure A-2 shows how several key factors of energy-related CO_2 emissions change over time and how these changes influence total energy-related CO_2 emissions. These key factors are:

- Population
- GDP per capita
- Energy intensity
- Carbon intensity

At a given point in time, the product of all four factors yields total energy-related CO_2 emissions. Quantifying emissions this way is known as the Kaya identity.

Each of these factors is either directly published in the *Monthly Energy Review* (MER) (for example, population) or is the result of taking the ratio of two published series (for example, GDP per capita). To put the factors' growth or decline into context, we index them to 1990. In Figure A-2, we divide the yearly value of each factor by its value in 1990 and multiply it by 100 to put it into percentage terms. Each point in the series represents the magnitude of each factor relative to 1990, expressed as a percentage.

Methodology for Figure A-3

Figure A-3 shows the change in total energy-related CO_2 between 2022 and 2023 for the key emissions factors that make up the Kaya identity:

- Population
- GDP per capita
- Energy intensity
- Carbon intensity

We calculate the changes in total CO_2 emissions from each factor in the Kaya identity by taking the difference between total energy-related CO_2 emissions in 2024 (that is, the product of each factor's 2024 value) and a hypothetical total emissions value (that is, the product of each factor's 2024 value except for the factor of interest, which uses its 2023 value). For example, the total change in energy-related CO_2 emissions between 2024 and 2023 resulting from changes in GDP per capita is given by:

$$(Pop_{2024} \cdot GDPPC_{2024} \cdot EI_{2024} \cdot CI_{2024}) - (Pop_{2024} \cdot GDPPC_{2023} \cdot EI_{2024} \cdot CI_{2024})$$

where

GDPPC = GDP per capita;
Pop = population;
EI = energy intensity; and
CI = carbon intensity.

These values do not sum to the total change in emissions because of interactions among the changes in each component.

Table A-3. Rates of change in Kaya identity components, 2023–2024

Percentage change

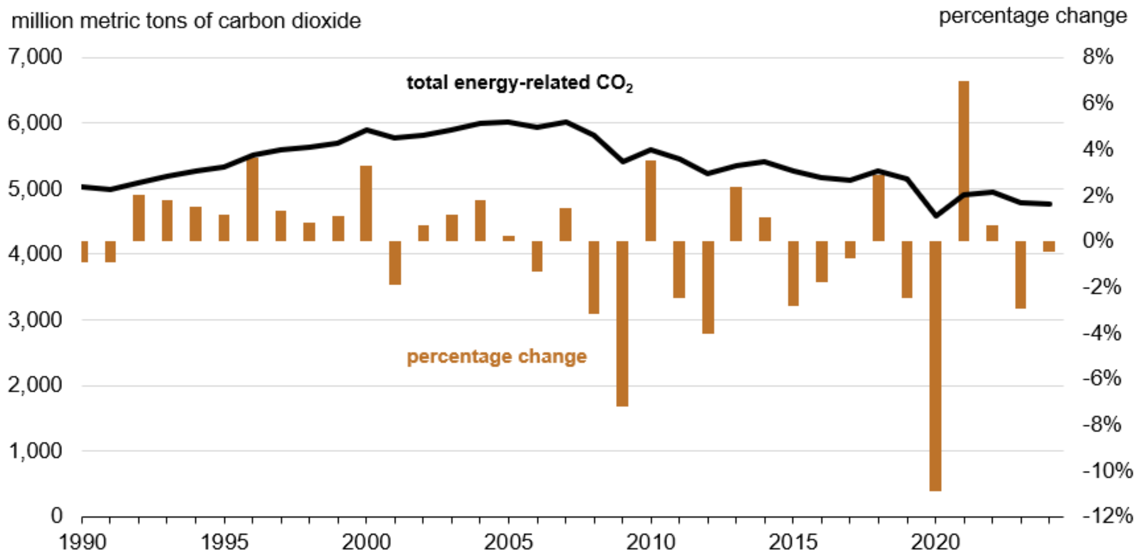
Parameter	2023–2024 percentage change
Population	+ 1.0%
GDP per capita (GDP/population)	+ 1.8%
Energy intensity (Btu/GDP)	- 2.2%
Carbon intensity (CO_2/Btu)	- 1.0%

Data source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*, March 2025; U.S. Bureau of Economic Analysis; U.S. Census Bureau
Note: Btu=British thermal units

Previous Report Charts

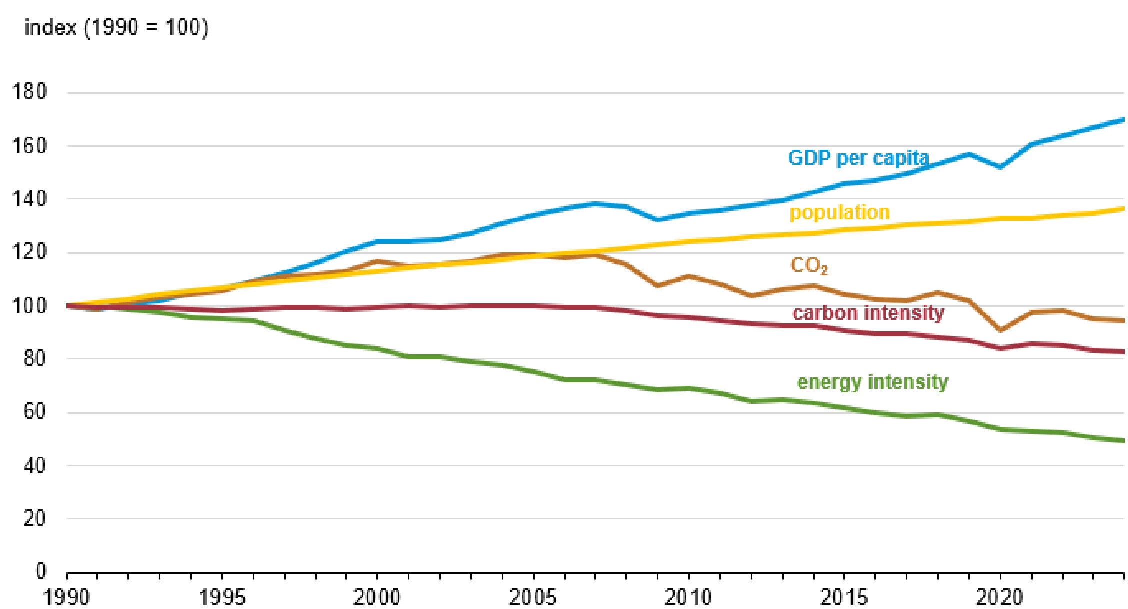
For readers of this report who are searching for specific charts, the library below contains charts shown in previous versions of the report. Each chart uses data from the March 2025 edition of our *Monthly Energy Review* unless otherwise noted in the data sources.

Figure A-1. Annual emissions of and percentage change in energy-related CO_2 emissions



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source

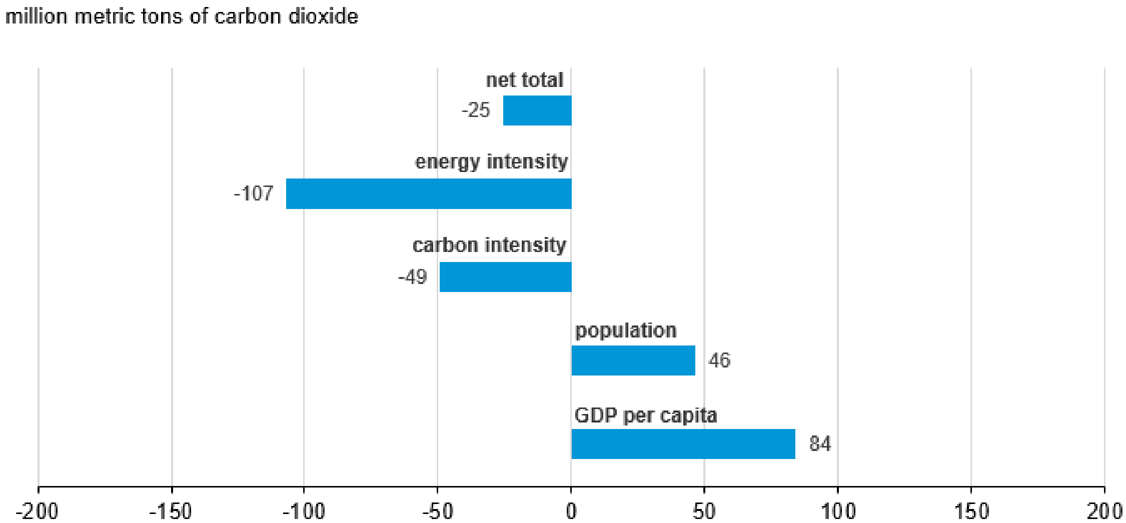
Figure A-2. Trends in energy-related CO_2 emissions and key indicators



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source; the U.S. Bureau of Economic Analysis; and the U.S. Census Bureau

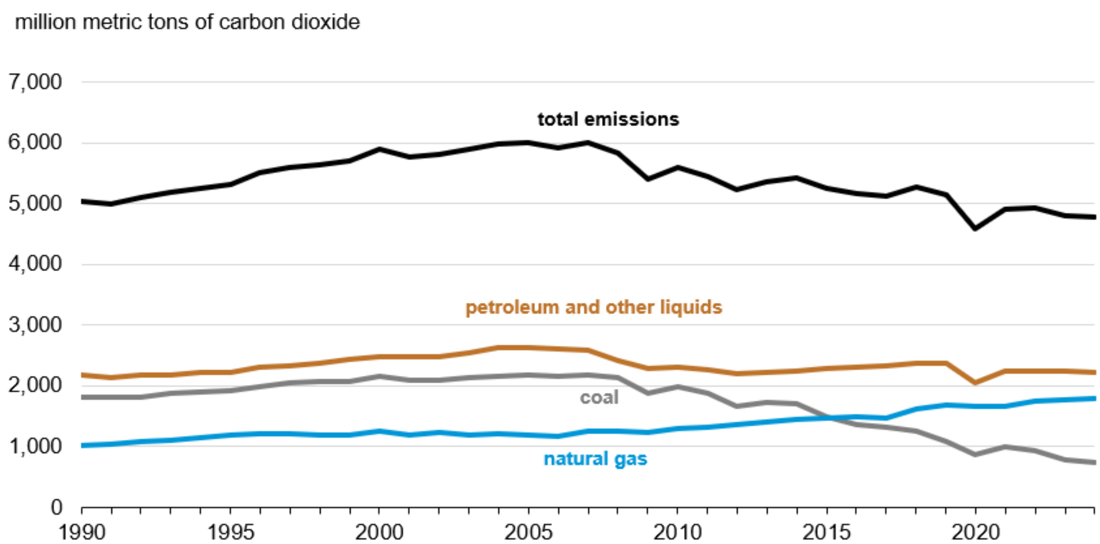
Note: GDP per capita uses chained 2017 dollars.

Figure A-3. Change in energy-related CO_2 emissions by Kaya identity component, 2023–2024



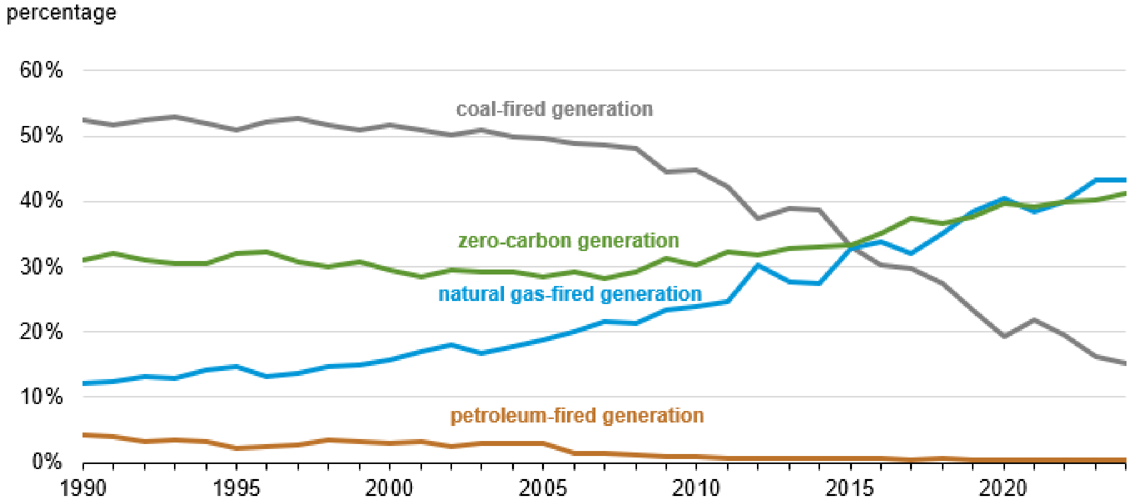
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source; the U.S. Bureau of Economic Analysis; and the U.S. Census Bureau
Note: GDP per capita uses chained 2017 dollars.

Figure A-4. Energy-related CO_2 emissions by fossil fuel



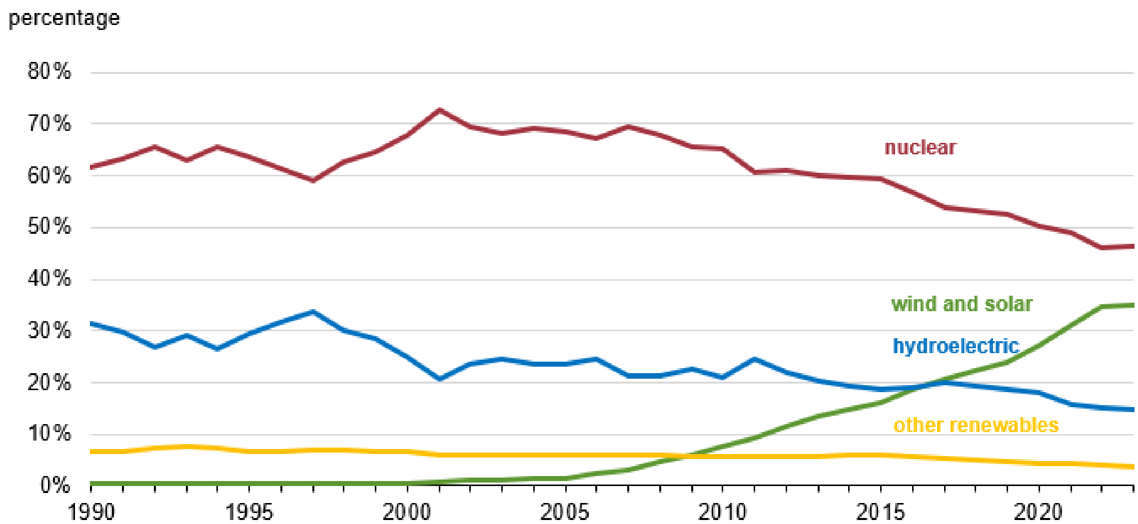
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source

Figure A-5. Annual percentage of electricity generation by source



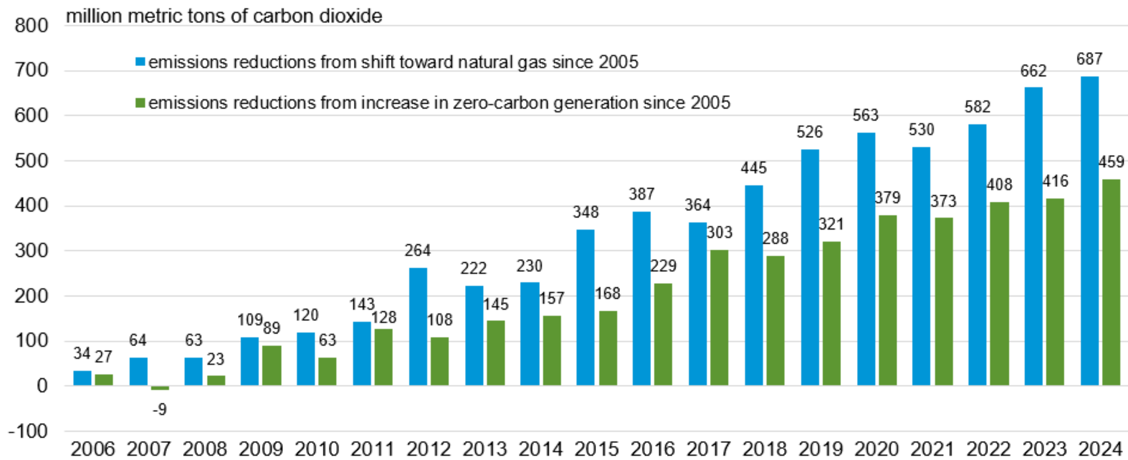
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Table 7.2a Electricity Net Generation Total (All Sectors) and Table 10.6 Solar Electricity Net Generation
Note: Zero-carbon generation excludes small-scale solar generation.

Figure A-6. Annual percentage of zero-carbon generation by source



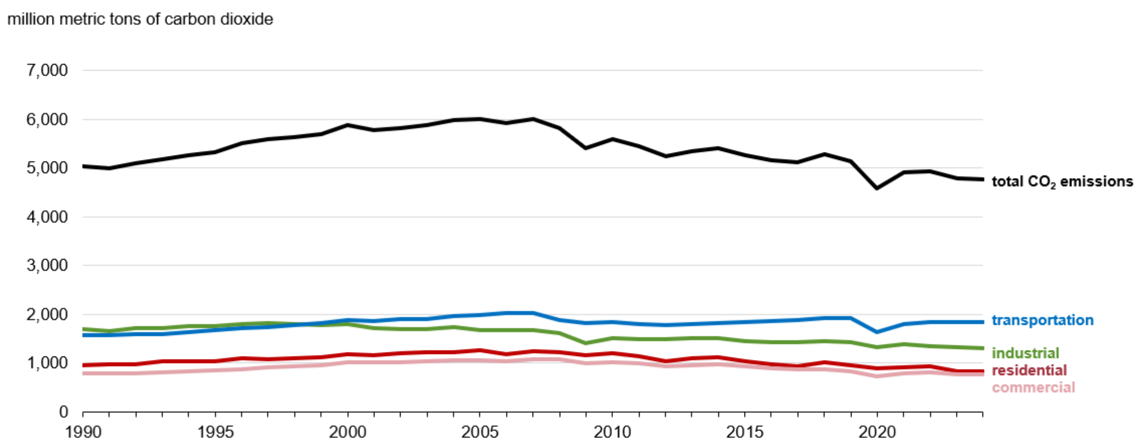
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Table 7.2a Electricity Net Generation: Total (All Sectors) and Table 10.6 Solar Electricity Net Generation.
Note: Wind and solar excludes small-scale solar generation.

Figure A-7. CO_2 emissions reductions relative to 2005 caused by changed in the fuel mix of electricity generation



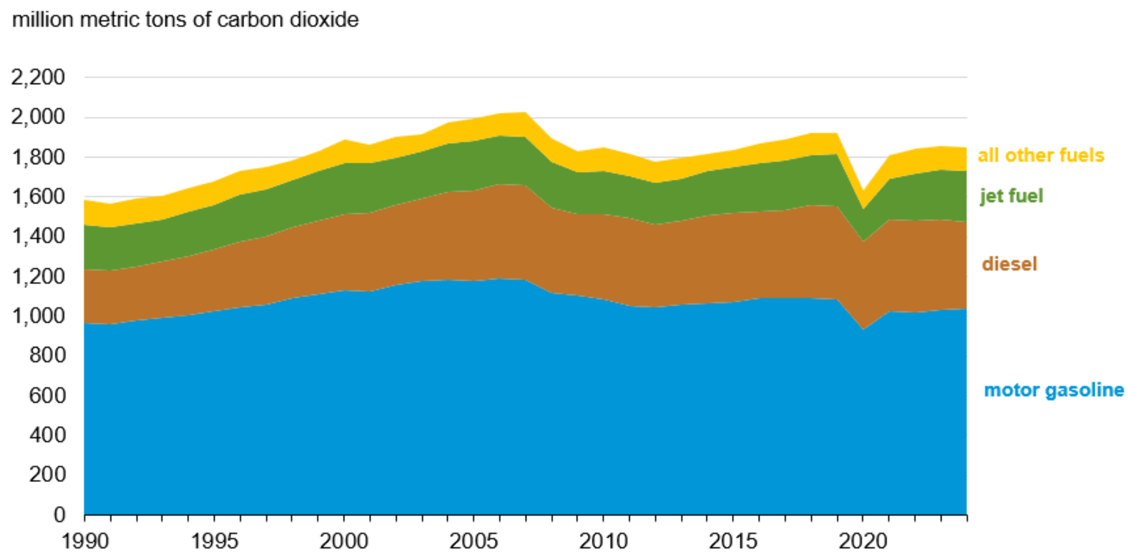
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Table 7.2a Electricity Net Generation: Total (All Sectors) and Table 7.3c Consumption of Selected Combustible Fuels For Electricity Generation: Commercial and Industrial Sectors

Figure A-8. Energy-related CO_2 emissions by end-use sector



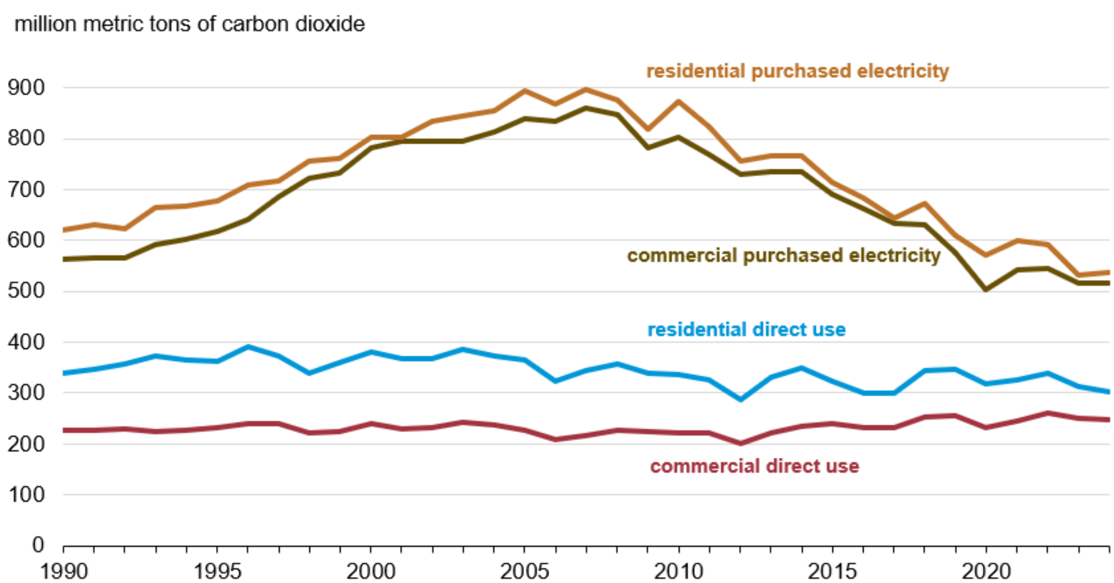
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Tables 11.2–11.5

Figure A-9. Transportation CO_2 emissions by fuel source



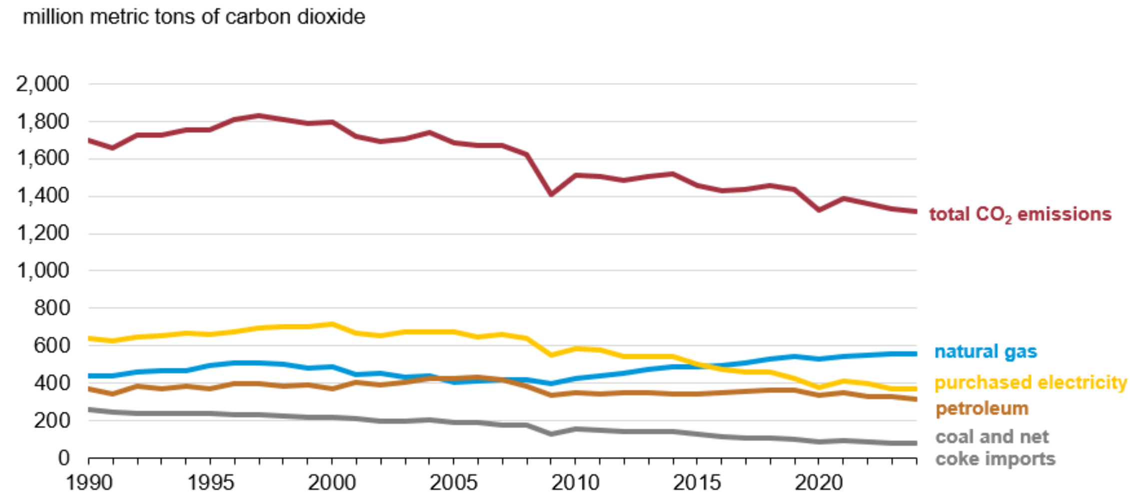
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Tables 11.5, Carbon Dioxide Emissions from Energy Consumption: Transportation Sector

Figure A-10. Energy-related CO_2 emissions from the residential and commercial sectors



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Tables 11.2 and 11.3

Figure A-11. Industrial energy-related CO_2 emissions by source



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, March 2025, Tables 11.4, Carbon Dioxide Emissions from Energy Consumption: Industrial Sector

Terms Used in This Analysis

British thermal units (Btu): A measure of energy, defined as the quantity of heat required to raise the temperature of one pound of liquid water by 1°F at the temperature at which water has its greatest density (approximately 39°F).

Carbon intensity (economy): The amount of carbon by weight emitted per unit of economic activity—most commonly GDP (CO_2 emissions/GDP). The carbon intensity of the economy is the product of the energy intensity of the economy and the carbon intensity of the energy supply. We express this value as the full weight of the CO_2 emitted rather than the weight of just carbon.

Carbon intensity (energy supply): The amount of carbon by weight emitted per unit of energy consumed (CO_2 emissions/energy). A common measure of carbon intensity is the weight of CO_2 per Btu of energy. When considering only one fossil fuel, the carbon intensity and the emissions coefficient are identical. When considering several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption. We measure this value as the full weight of the CO_2 emitted rather than the weight of just carbon.

Cooling degree days (CDD): A measure of how warm a location is during a period of time relative to a base temperature of 65°F. CDDs are used in energy analysis as an indicator of air-conditioning energy requirements or use. The measure is computed for each day by subtracting the base temperature (65°F) from the average of the day's high and low temperatures, and negative values are set equal to zero. Each day's CDDs are added to create a CDD measure for a specific time period.

Energy intensity: A measure relating the output of an activity to its energy input. Energy intensity is most commonly applied to the economy as a whole, where we measure output as GDP and primary energy in Btus so all energy forms (energy/GDP) can be included. On an economy-wide level, energy intensity reflects both energy efficiency and the structure of the economy. Economies in the process of industrializing tend to have higher energy intensities than economies in a post-industrial phase. On a smaller scale, for example, energy intensity can relate the amount of energy consumed in buildings to the amount of residential or commercial floorspace.

Gross domestic product (GDP): The total value of goods and services produced by labor and property located in the United States. As long as the labor and property are located in the United States, the supplier (that is, the workers, or for property, the owners) may be either U.S. residents or residents of foreign countries.

Heating degree days (HDD): A measure of how cold a location is during a period of time relative to a base temperature, most commonly 65°F. HDDs are used in energy analysis as an indicator of space heating energy requirements or use. We compute this measure for each day by subtracting the average of the day's high and low temperatures from the base temperature (65°F), and negative values are set equal to zero. We sum each day's HDD to create an HDD measure for a specific time period.

You can find more definitions in our Glossary.