Independent Statistics and Analysis
U.S. Energy Information Administration

U.S. Energy-Related Carbon Dioxide Emissions, 2021

December 2022

Independent Statistics & Analysis
www.eia.gov

U.S. Department of Energy
Washington, DC 20585

This report was prepared by the U.S. Energy Information Administration (EIA), the statistical and analytical agency within the U.S. Department of Energy. By law, EIA's data, analyses, and forecasts are independent of approval by any other officer or employee of the U.S. Government. The views in this report should not be construed as representing those of the U.S. Department of Energy or other federal agencies.

Contents

Figures

Executive Summary

In 2020, the COVID-19 pandemic substantially affected the U.S. and world economies, energy markets, and energy-related carbon dioxide (CO_2) emissions. In 2021, economic activity and energy-related CO_2 emissions began to return to pre-pandemic levels. Total U.S. energy-related CO_2 emissions increased by 7%, or 325 million metric tons (MMmt), in 2021 compared with 2020; however, total emissions in 2021 remained 5%, or 242 MMmt, below 2019 levels.

Both short-term and long-term factors contributed to the rise in energy-related CO_2 emissions. Increases in the consumption of petroleum products, particularly in the transportation sector, accounted for over half of the rise in U.S. CO_2 emissions. CO_2 emissions from U.S. motor gasoline increased by 9% and jet fuel increased by 27% as travel demand began to return to pre-pandemic levels.

Changes in the mix of fuels used to generate electricity also affected energy-related CO_2 emissions in the United States. Significant increases in natural gas prices reduced the share of electricity generated by natural gas from 40% in 2020 to 37% in 2021. This decline was largely offset by coal-fired generation, whose share of electricity generation increased from 20% in 2020 to 23% in 2021. These increases in electricity-related CO_2 emissions were tempered by a continued longer-term trend towards non-carbon electricity generation, particularly solar and wind, whose shares of electricity generation continued to increase in 2021.

As a result of these short- and long-term factors, U.S. energy-related CO_2 emissions increased across all sectors, although in each of these sectors, emissions remained below 2019 levels:

- Transportation sector emissions increased by 11%, or 185 MMmt, due to increased travel.
- Commercial sector emissions increased by 7%, or 50 MMmt, resulting from both a change in the electricity fuel mix and an increase in commercial activity.
- Residential sector emissions increased by 4%, or 36 MMmt, mostly from changes in the electricity fuel mix.
- Industrial sector emissions increased by 4%, or 54 MMmt, due to an increase in industrial activity.

The combination of conditions that raised energy-related CO_2 emissions in the United States in 2021 do not necessarily represent future trends. Many changes in energy-related CO_2 emissions between 2020 and 2021 were associated with the economic effects of the pandemic.

Short-term forecasts and long-term projections of U.S. energy-related CO_2 emissions are available in many of our products. You can find a short-term forecast of U.S. energy-related CO_2 emissions and key drivers in our monthly *Short-Term Energy Outlook* (STEO), which includes forecasts by fuel source over the next calendar year and our latest estimates on the effects of recent events on energy markets and energy-related CO_2 emissions.

We publish our long-term U.S. emissions projections in the *Annual Energy Outlook* (AEO), which provides annual projections of energy-related CO_2 emissions by fuel source, sector, and end use, as well as projections of other elements of energy markets, through 2050. We also provide projections of international energy-related CO_2 emissions through 2050 in our *International Energy Outlook* (IEO).

We were directed in the Infrastructure Investment and Jobs Act of 2021 to work with the U.S. Environmental Protection Agency (EPA) to examine how our estimates of energy-related U.S. CO_2 emissions compare to their data. We found that though there are small differences in details arising from scope and estimation method, our estimates are very close to EPA's at aggregate levels.

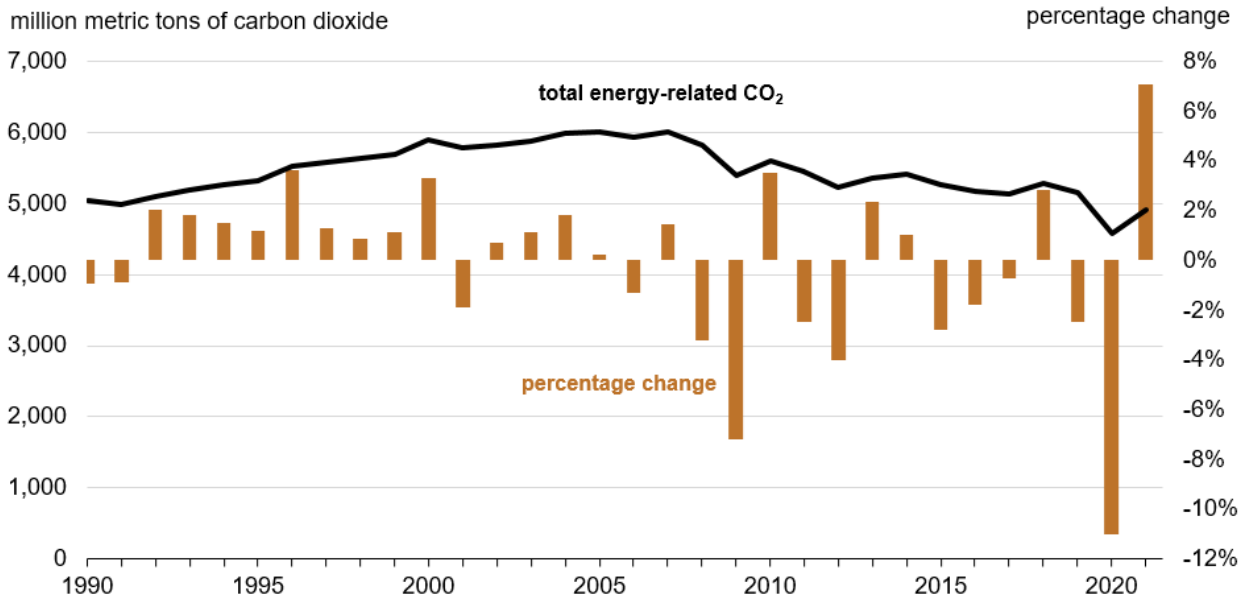
Our analysis of U.S. energy-related CO_2 emissions in this report is based on data published in both the STEO and the *Monthly Energy Review* (MER). Supplemental analysis, as well as a discussion of the methodology and terminology used in this report, is available in the Appendix and methodology.

Overview

The 2021 increase in U.S. energy-related CO_2 emissions followed an increase in economic activity

In 2021, U.S. energy-related CO_2 emissions increased by 7%, or 325 MMmt (Figure 1). This was the largest annual increase in U.S. energy-related CO_2 emissions on record, both in absolute and percentage terms, and followed the historic decline in U.S. energy-related CO_2 emission that occurred in 2020. Most of this increase resulted from activity across all sectors of the economy returning to pre-pandemic levels. Although record growth in emissions occurred in 2021, total emissions remained lower than peak CO_2 emissions in 2007, as well pre-pandemic emissions in 2019.

Figure 1. Annual emissions of and percentage change in energy-related carbon dioxide



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source

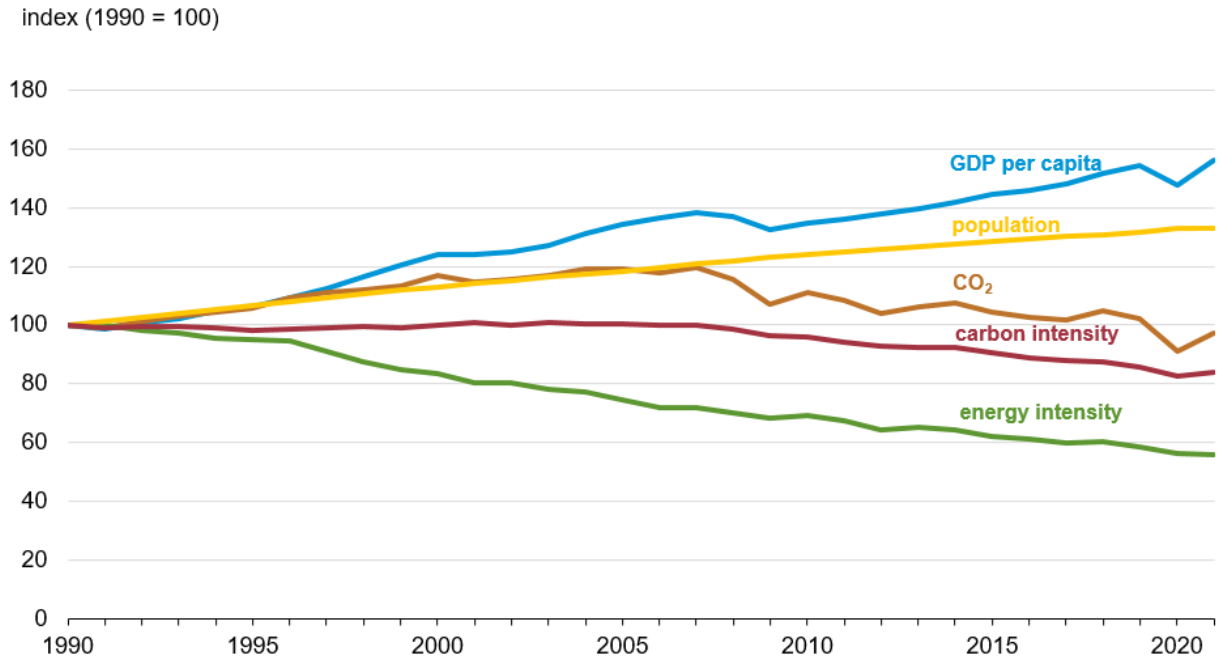
U.S. energy-related CO_2 emissions increased across most components of the Kaya Identity

Percentage changes in energy-related CO_2 emissions can be broken down into changes in four components:

- Energy intensity (energy consumed per unit of GDP)
- Carbon intensity (CO_2 emissions per unit of energy)
- Population
- GDP per capita

These components, when combined to estimate total energy-related CO_2 emissions, are known as the *Kaya identity* (Figure 2).

Figure 2. Trends in energy-related carbon dioxide emissions and key indicators



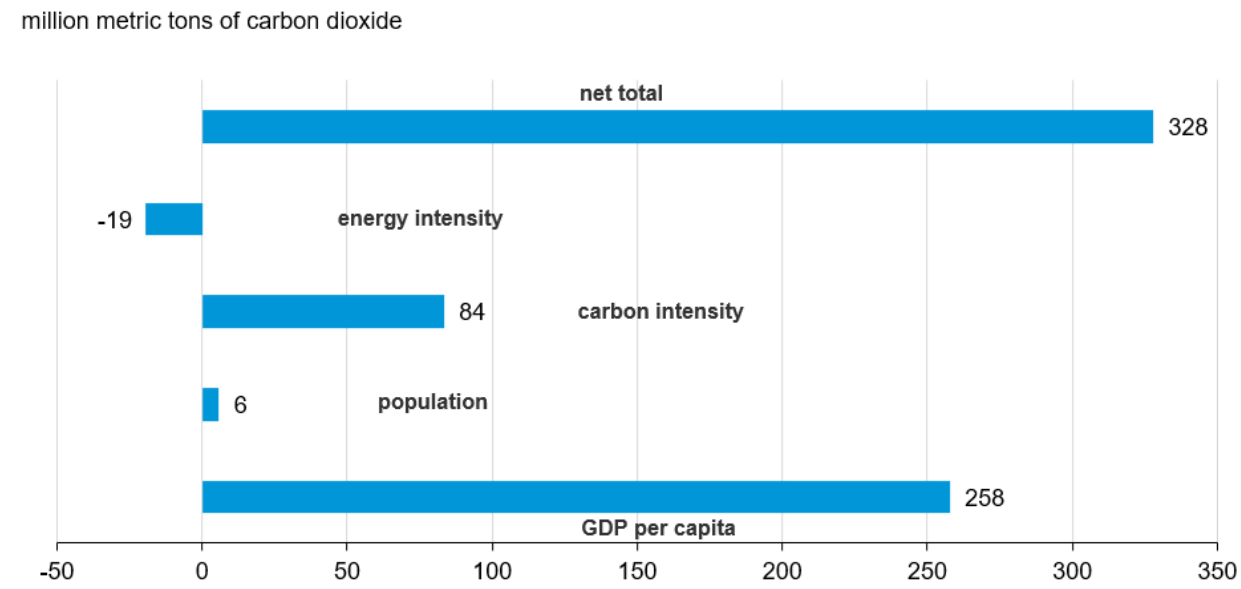
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source; the U.S. Bureau of Economic Analysis; and the U.S. Census Bureau

In 2021, the largest increases in energy-related CO_2 emissions resulted from GDP per capita (258 MMmt), and the carbon intensity of energy (84 MMmt) (Figure 3). The impact of population change on emissions between 2020 and 2021 was positive but marginal. The only factor that caused emissions to decrease in 2021 was energy intensity, which decreased CO_2 emissions by 19 MMmt. With the exception of population, these changes are mostly associated with economic effects of the COVID-19 pandemic.

U.S. GDP per capita increased by 6% in 2021 as economic activity started to return to pre-pandemic levels. U.S. carbon intensity increased by 2% in 2021, mainly because of increases in coal-fired electricity generation and greater transportation demand. Coal has a high carbon content relative to other fossil fuels, which means that it releases more CO_2 into the atmosphere when combusted. High natural gas prices in 2021 resulted in some switching from natural gas- to coal-fired electricity generation, leading to a higher carbon content of electricity. Carbon intensity also rose as a result of increased consumption of high carbon content fuels in the transportation sector, namely motor gasoline and jet fuel.

Although both total U.S. energy consumption and GDP increased in 2021, energy intensity decreased marginally as a result of GDP growth outpacing increases in energy consumption. U.S. energy consumption rose in 2021 by 5%, while GDP rose by 6%. The majority (56%) of the increase in energy consumption came from the transportation sector, which was heavily affected by the COVID-19 pandemic as well as the increased economic activity in 2021.

Figure 3. Change in energy-related CO_2 emissions by Kaya identity component



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source; the U.S. Bureau of Economic Analysis; and the U.S. Census Bureau

Fossil Fuels

Petroleum consumption and its energy-related CO_2 emissions changed the most with a return to pre-pandemic activities

The largest absolute increase in U.S. fossil fuel CO_2 emissions was from petroleum consumption, which rose by 9% (191 MMmt) in 2021. On a percentage basis, coal emissions rose faster—14% (126 MMmt). Natural gas emissions declined by less than 1% (8 MMmt) (Figure 4).

U.S. petroleum emissions increased the most among all fuels in 2021, mainly as a result of increased domestic and international travel demand as the U.S. and other world economies returned to pre-pandemic activities. Travel restrictions as well as an increase in working from home had sharply decreased fuel consumption and related emissions in 2020. As travel restrictions eased and people returned to their workplaces, petroleum consumption increased. In 2021, CO_2 emissions from motor gasoline rose by 9% and jet fuel by 27%, marking their largest annual increases on record in both absolute and percentage terms. Despite growing at record rates in 2021, U.S. petroleum emissions remained below pre-pandemic levels.

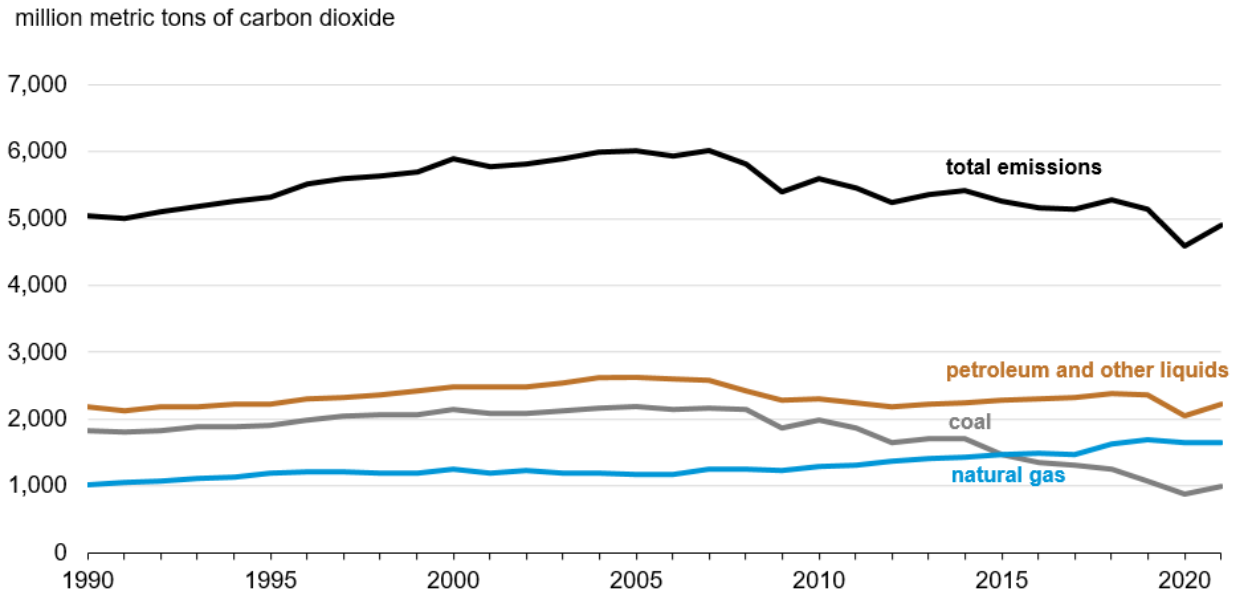
The increase in U.S. coal emissions in 2021 broke a general downward trend in recent years. Since reaching peak CO_2 emissions in 2007, U.S. energy-related CO_2 emissions from coal have declined, on average, by 5% each year. However, the 14% increase in coal emissions in 2021—a notable break from this trend—is the largest annual increase in U.S. coal-related CO_2 emissions on record, in both absolute

and percentage terms, since we began collecting data in 1973. Although increasing, coal emissions remained 7%, or 75 MMmt, below 2019 levels.

Increased demand for electricity, as well as a sharp rise in natural gas prices, contributed to growth in U.S. coal emissions. Natural gas prices for the electric sector more than doubled in 2021, rising by 108% to reach their highest level since 2014, making coal a more competitive resource than natural gas for electricity generation.

The slight decrease in U.S. natural gas emissions in 2021 came primarily from less natural gas-fired generation. Natural gas generation and emissions from the electric power sector decreased by around 3%, driven by significantly higher natural gas prices relative to 2020. Heating demand, which we use heating degree days (HDDs) to quantify, can also influence demand for natural gas. However, 2021 had a similar number of U.S. population-weighted HDDs to 2020.

Figure 4. Energy-related carbon dioxide emissions by fossil fuel



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source

Electricity

CO_2 emissions created in the U.S. electric power sector rose by 7% in 2021 (102 MMmt) as a result of changes in both electricity usage and fuel mix. Electricity use increased in 2021, with total U.S. generation increasing by 3%, or 109 terawatthours, and returning to pre-pandemic levels.

Changes in the mix of fuels used to generate electricity also contributed to some increases in U.S. CO_2 emissions associated with electric power. Although zero-carbon electricity generation continued to grow in 2021, some generation also shifted from lower-carbon natural gas generation to higher-carbon coal (Figure 5 and Figure 6). Coal's share of U.S. electricity generation rose from 20% in 2020 to 23% in 2021,

and natural gas's share decreased from 40% to 37%. The generation share of zero-carbon power in 2021 remained the same as 2020 at 40%. Generation shares of all other sources remained relatively unchanged. This change in generation mix led to a 4% increase in the carbon intensity of electricity, from 0.37 metric tons (mt) per megawatthour in 2020 to 0.39 mt of CO_2 per megawatthour in 2021.

Figure 5. Annual share of electricity generation by source

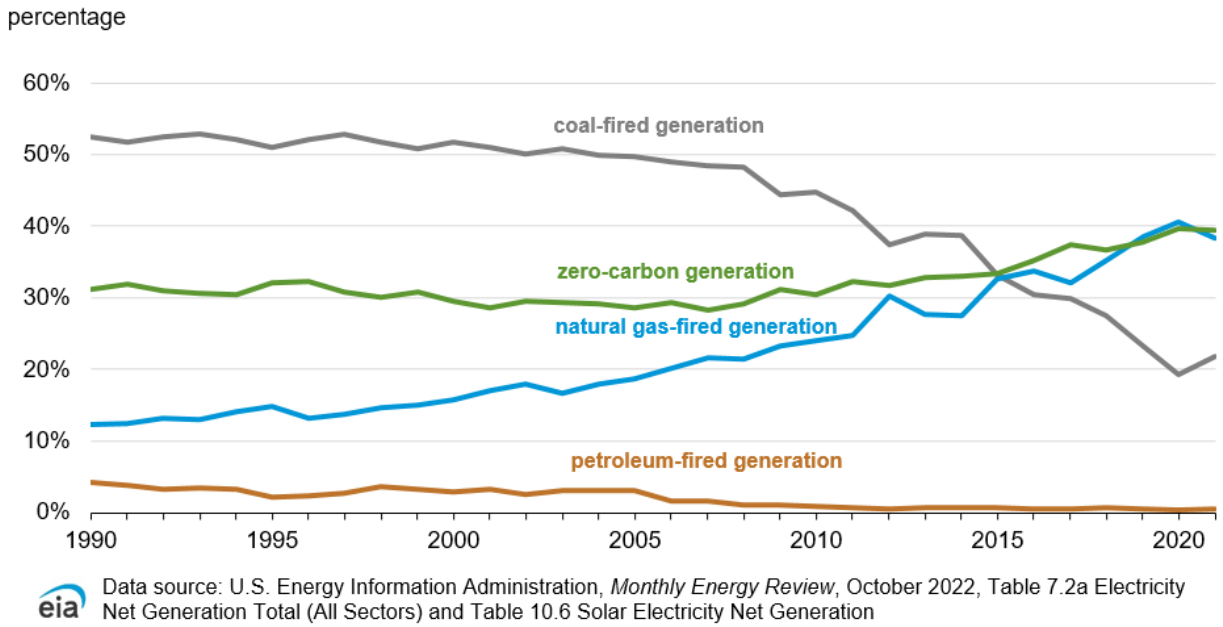
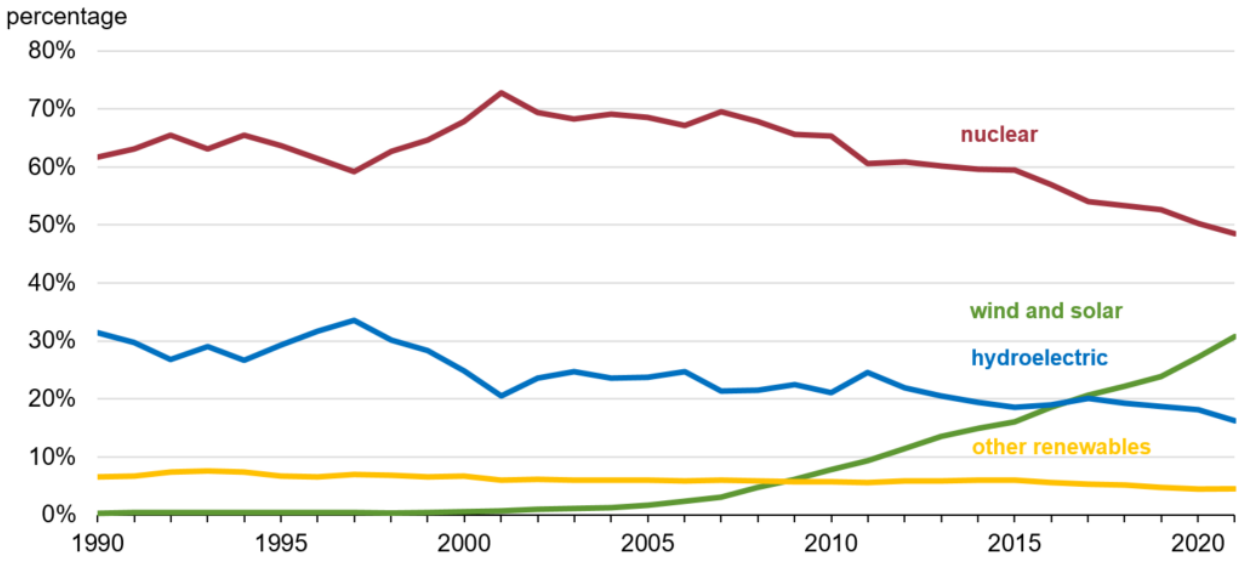


Figure 6. Annual share of zero-carbon generation by source

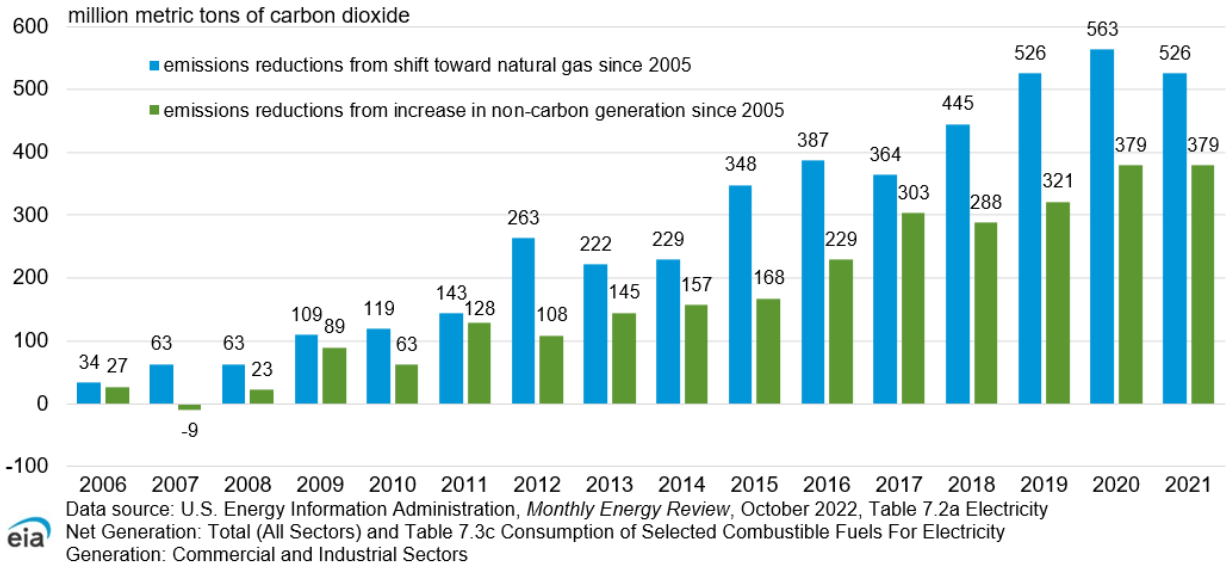


Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Table 7.2a Electricity Net Generation: Total (All Sectors) and Table 10.6 Solar Electricity Net Generation

Although the emissions intensity of U.S. electricity generation increased in 2021 on account of a switch toward more carbon-intensive fossil fuels, the carbon content of electricity has generally been decreasing over time. These reductions in the carbon content of electricity are a result of two overall trends in electricity generation: growth in the share of renewable and zero-carbon generation and a shift from higher- to lower-carbon fossil fuels.

Relative to 2005, the benchmark year for the U.S. Nationally Determined Contribution (NDC) to greenhouse gas reductions under the Paris Agreement, declines in carbon intensity of electricity led to significant reductions in energy-related CO_2 emissions. Between 2005 and 2021, the carbon intensity of electricity has fallen from 0.61 mt per megawatthour to 0.39 mt per megawatthour. Had carbon intensity remained the same as in 2005, an additional 905 MMmt of CO_2 would have been emitted in 2021(Figure 7). Of these avoided emissions, 58% (526 MMmt) were due to a switch from higher-carbon fossil generation to natural gas generation, and 42% (379 MMmt) from growth in zero-carbon generation.

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

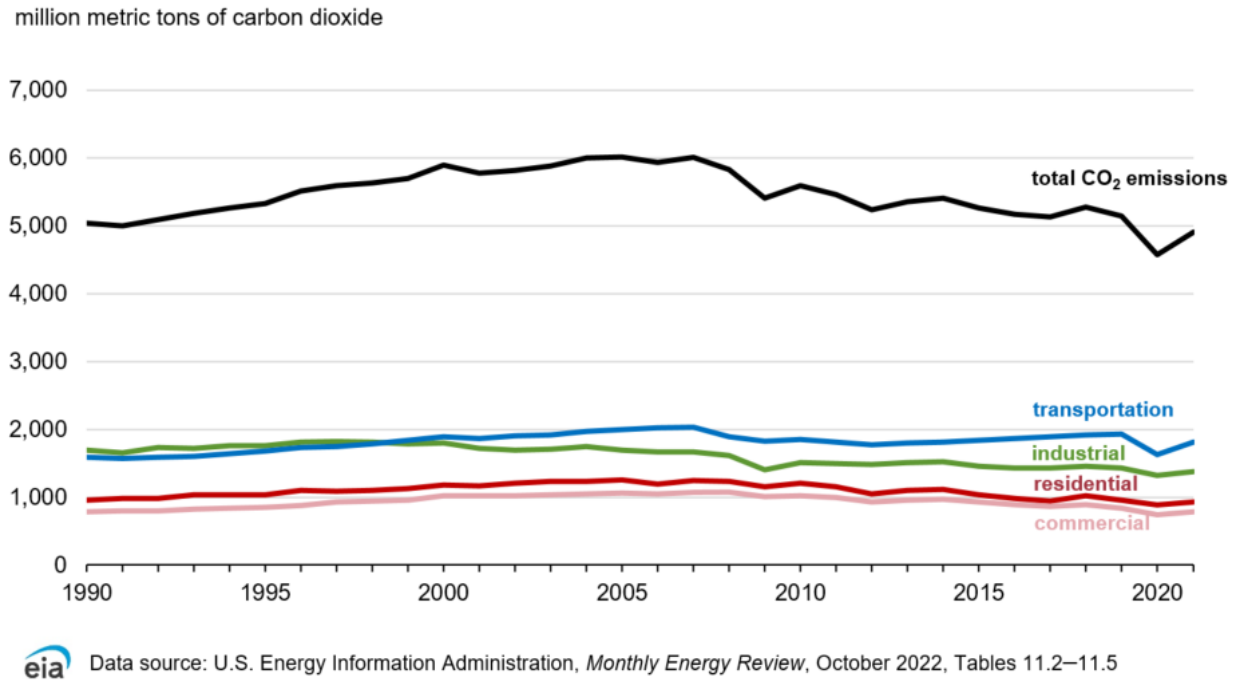


End-Use Sectors

U.S. energy-related CO_2 emissions increased in all end-use sectors in 2021, though they remain below 2019 levels in each sector (Figure 8). These increases take into account both direct and indirect emissions from each sector. Direct emissions are each sector's emissions from the direct consumption of fossil fuels, such as natural gas for heating or gasoline in cars. Indirect emissions are emissions from electricity generation, attributed to each end-use sector based on its share of U.S. electricity consumption.

The U.S. transportation and commercial sectors saw the largest increases in emissions in percentage terms, mainly because these sectors had been the most affected by the COVID-19 pandemic. Emissions from the residential and industrial sectors rose at a slightly lower rate.

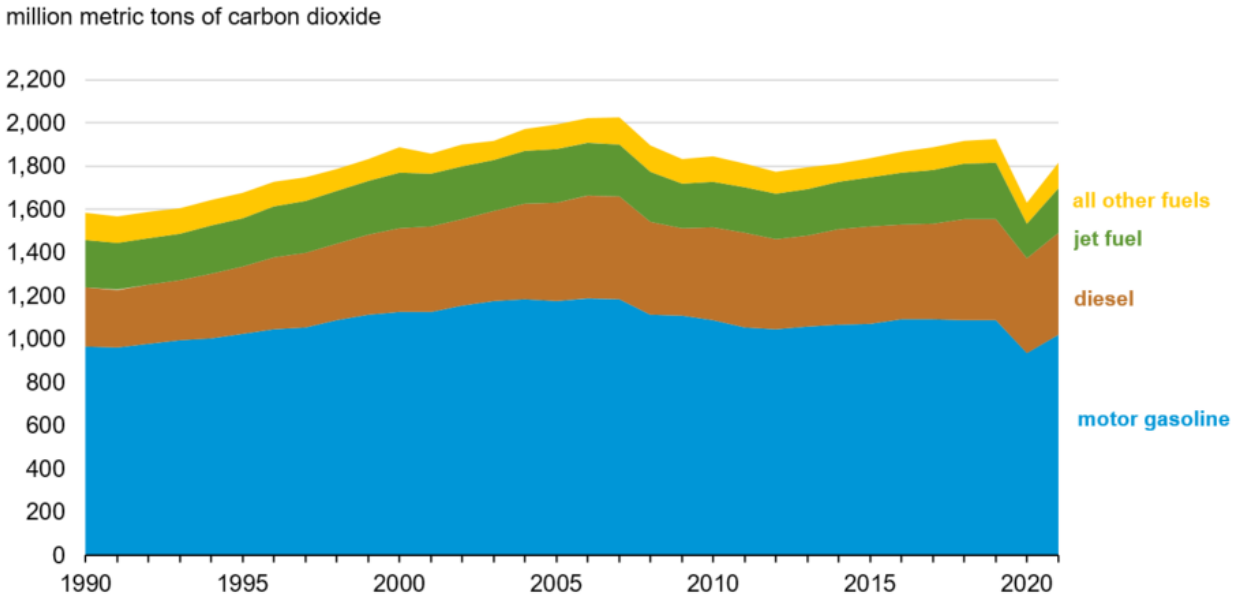
Figure 8. Energy-related carbon dioxide emissions by end-use sector



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Tables 11.2–11.5

The U.S. transportation sector had the largest increase in CO_2 emissions of all sectors in 2021 (11%, or 185 MMmt), mainly because of increased travel as the COVID-19 pandemic eased. Returning to the workplace, reopening businesses and venues, and easing domestic and international travel restrictions led to a 9% increase in emissions from motor gasoline, a 27% increase in emissions from jet fuel, and a 7% increase in emissions from diesel fuel (Figure 9).

Figure 9. Transportation carbon dioxide emissions by fuel source

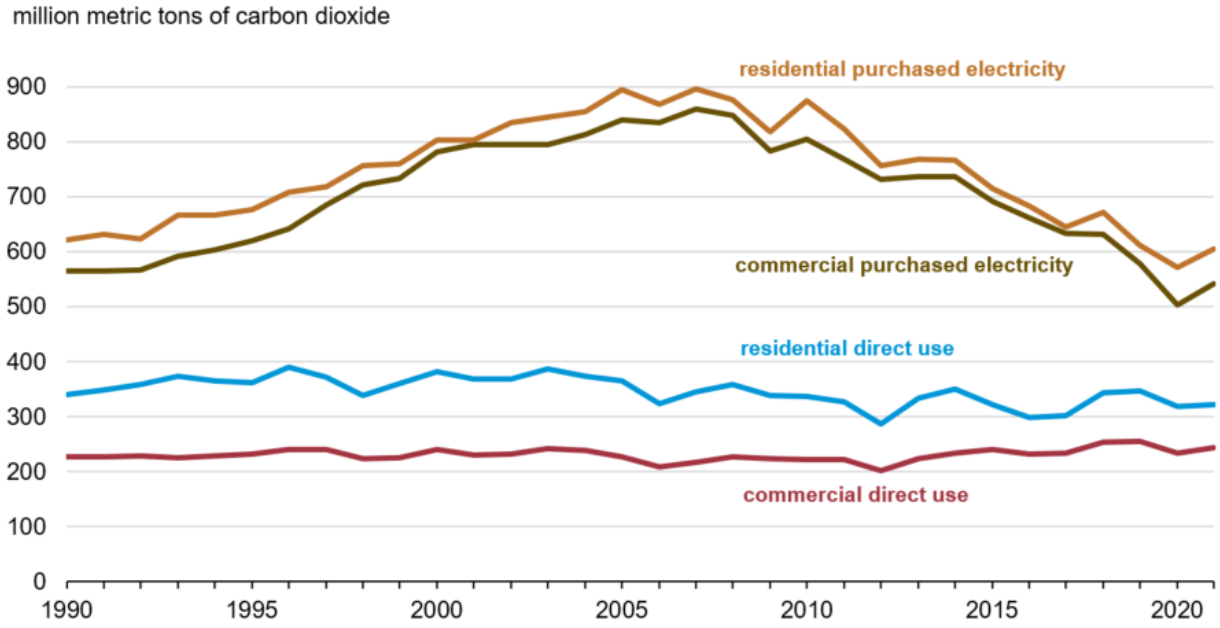


Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Tables 11.5, Carbon Dioxide Emissions from Energy Consumption: Transportation Sector

The commercial sector experienced the second-largest percentage increase in emissions at 7% (50 MMmt), as commercial activity increased following the initial impacts of the pandemic and the carbon content of electricity increased. Emissions from commercial electricity consumption increased by 7% (40 MMmt) (Figure 10). Emissions from direct fuel consumption—such as use of natural gas for space heating—increased by 4% (10 MMmt).

U.S. residential CO_2 emissions rose by 4% (36 MMmt) relative to 2020 mostly due to an increase in the carbon intensity of electricity. Emissions from residential electricity consumption increased by 6% (33 MMmt), with emissions from direct fuel consumption increasing by 1% (3 MMmt).

Figure 10. Energy-related carbon dioxide emissions from the residential and commercial sectors

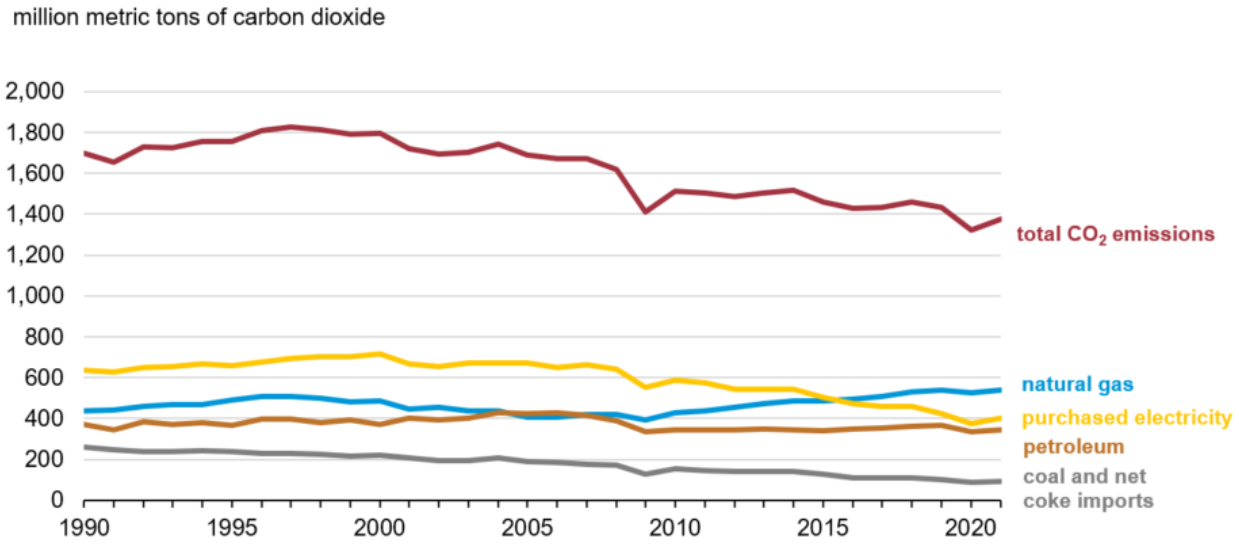


Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Tables 11.2 and 11.3

Emissions from the U.S. industrial sector increased in 2021 as industrial activity began to increase following the initial shocks caused by the pandemic. U.S. manufacturing output rose by 6% in 2021, which led to a 4% increase (54 MMmt) in industrial CO_2 emissions (Figure 11). Output increased across most industries, with the largest increases in petroleum and coal products (15%) and primary metals (12%).[1]

[1] U.S. Bureau of Labor Statistics, accessed via S&P Global (September 2022).

Figure 11. Industrial energy-related carbon dioxide emissions by source



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Tables 11.4, Carbon Dioxide Emissions from Energy Consumption: Industrial Sector