U.S. Energy-Related Carbon Dioxide Emissions, 2022

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Executive Summary

This report highlights notable trends in energy-related carbon dioxide (CO_2) emissions in the United States observed in 2022. Overall, annual U.S. CO_2 emissions increased slightly in 2022 from the year before across all end-use sectors and most fossil fuels. Although numerous factors influence these changes in emissions, this report focuses on:

- The substitution away from coal toward natural gas, solar, and wind in the electric power sector, which reduced CO_2 emissions
- Increasing demand for energy to heat and cool buildings due to more extreme temperatures, which tended to increase direct CO_2 emissions
- The waning impact of the COVID-19 pandemic on the transportation sector, which increased energy use and CO_2 emissions.

The 1% increase in U.S. CO_2 emissions in 2022 was much slower than the previous year's 7% increase. Nevertheless, the United States produced 4% less energy-related CO_2 emissions in 2022 than just before the COVID-19 pandemic in 2019. Less use of coal was the largest contribution to U.S. emissions reductions in 2022.

Annual U.S. CO_2 emissions from coal decreased by 7% in 2022, while coal-fired electricity generation declined by 8%. Changes in electricity generation sources decreased the carbon intensity of electricity by 4% in the United States in 2022, dropping from 392 metric tons of CO_2 per gigawatthour (GWh) in 2021 to 376 metric tons of CO_2 per GWh in 2022. Coal-fired electricity generation was displaced by other generation sources in the United States, primarily natural gas and renewables. Coal supply shortages, driven by underlying production and consumption dynamics that have affected coal markets since 2017, also reduced coal-fired generation.

More natural gas-fired electricity generation increased annual U.S. CO_2 emissions from gas burned for the electric power sector by 8% in 2022, offsetting some of the reduction in coal-related emissions and yielding the slight decrease in U.S. electric power sector emissions for the year. Because coal is the most carbon-dense fuel, switching from coal to other generation sources, even other fossil fuels, reduces the carbon intensity of electricity.

Except for modest decreases in CO_2 emissions in the electric power and industrial sectors, energy-related CO_2 emissions increased in all other U.S. end-use sectors between 2021 and 2022. Notably, heating and cooling demand increased, particularly in the residential and commercial sectors. Winter weather was cooler, increasing the number of heating degree days (HDDs) by 8% between 2021 and 2022. Summer weather was warmer, increasing the number of cooling degree days (CDDs) by 4%.

Increases in CO_2 emissions from the transportation sector, the sector most affected by responses to the COVID-19 pandemic, started to level off in 2022. This slower increase in emissions can be attributed to the slowing economic recovery from COVID-19-related remote work and lifestyle changes; increasing travel; and price dynamics within the oil market. Relatively high crude oil prices reduced on-road vehicle

travel in the second half of 2022. Most CO_2 emissions increases in 2022 resulted from increased air travel, which was less affected by these price increases.

Short-term forecasts and long-term projections of U.S. energy-related CO_2 emissions are available in many EIA products. A short-term forecast of U.S. energy-related CO_2 emissions and key drivers can be found in our *Short-Term Energy Outlook* (STEO), which includes forecasts by fuel source over the next calendar year and the latest estimates of the effects of recent events on energy markets and energy-related CO_2 emissions. We publish long-term U.S. emissions projections in our *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. Projections of international energy-related CO_2 emissions through 2050 are available in our *International Energy Outlook* (IEO).

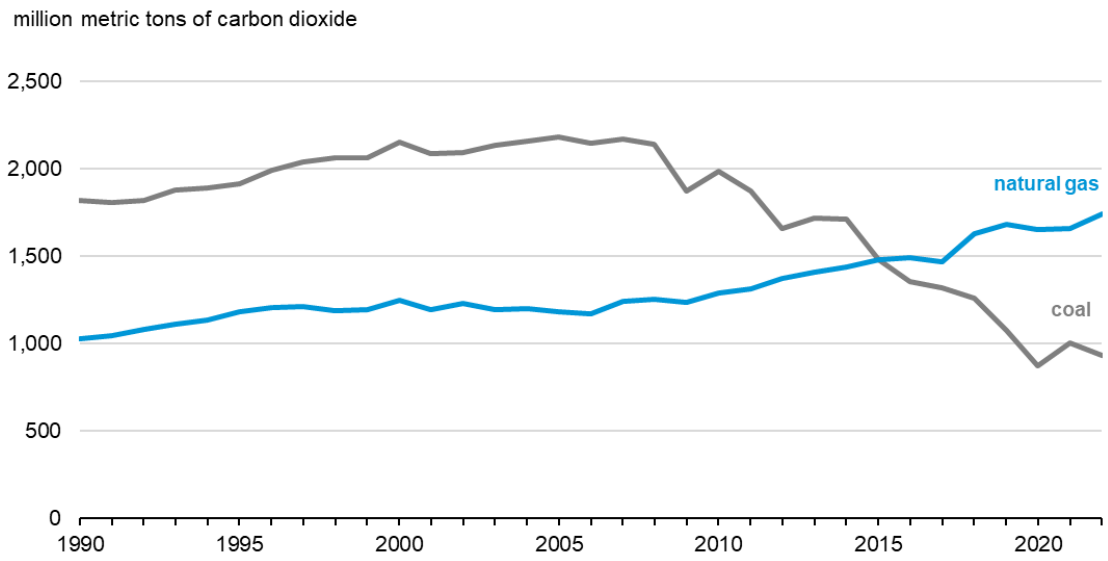
Analysis of U.S. energy-related CO_2 emissions in this report is based on EIA data published in the STEO, *Monthly Energy Review* (MER), *Quarterly Coal Report*, and *Petroleum and Other Liquids* browser. This report also uses external data from the National Oceanic and Atmospheric Association (NOAA) 2022 *National Climate Report*. Note that the emissions values and analysis presented in this report pertain only to CO_2 emissions associated with fossil fuel combustion and non-combustion applications of energy products (for example, as industrial feedstocks). We do not include estimates of CO_2 emissions outside of this scope or other greenhouse gas emissions burned or released in production, extraction, or distribution. This approach may result in discrepancies between our emissions estimates and those of other organizations, including other U.S. government agencies.

The format of this year's report differs from that of previous years in its focus on thematic stories pertaining to energy-related CO_2 emissions as opposed to discussions on individual economic sectors and fuels. Supplemental analysis, figures from past reports, and a discussion of the methodology and terminology used in this report are available in the first appendix. The second appendix documents current and ongoing work to harmonize our CO_2 emissions estimates and related data-gathering approaches with those of the Environmental Protection Agency as called for in the Bipartisan Infrastructure Law.

Supply constraints supported a reduction in coal generation and CO_2 emissions

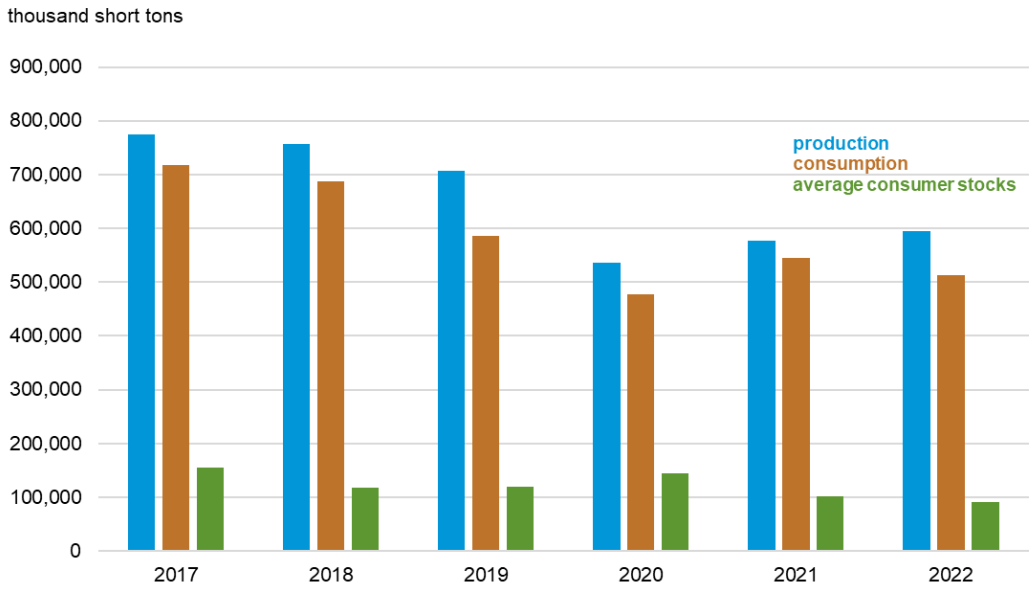
In 2022, U.S. coal-related CO_2 emissions decreased by 7%, or 68 million metric tons (MMmt), as a result of a near 8% decrease in coal-fired power generation from 2021. The reduced output from coal-fired power plants was due to a combination of factors, including a decrease of over 25,000 MW of coal-fired generating capacity between January 2021 and December 2022, along with the increased build-out of new natural gas-fired and renewable energy resources. In addition, concerns over a shortage of coal supply early in 2022 because of international demand, low production, and uncertainty about the winter season resulted in power plant owners conserving coal supplies in anticipation of the possibility of strong winter 2021–2022 demand. Shortages of coal also helped boost prices, making coal less cost-competitive with other energy sources on the grid and reducing its use. Less coal-related emissions were offset by more natural gas emissions, which increased by 5% (87 MMmt) across all economic sectors over this same period (Figure 1). Between January 2021 and December 2022, over 17,000 MW of new and highly efficient natural gas-fired generating capacity had been installed.

Figure 1. Total CO_2 emissions from coal and natural gas



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2023, Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source

Figure 2. Coal production, stocks, and consumption



Data source: U.S. Energy Information Administration, *Quarterly Coal Report*, October 2023, Table ES-1 U.S. Coal Summary Statistics

The coal supply shortage in 2022 was driven by underlying production and consumption dynamics over the last several years. From 2017 to 2019, coal production steadily declined by 9%, from 775 MMst to 706 MMst (Figure 2). This decrease was largely driven by lower demand in domestic and international markets and increased competition with natural gas and renewable energy sources. Despite this decrease in production, production in 2019 exceeded demand by about 26 MMst, with as much as 134 MMst remaining in storage by the end of the year.

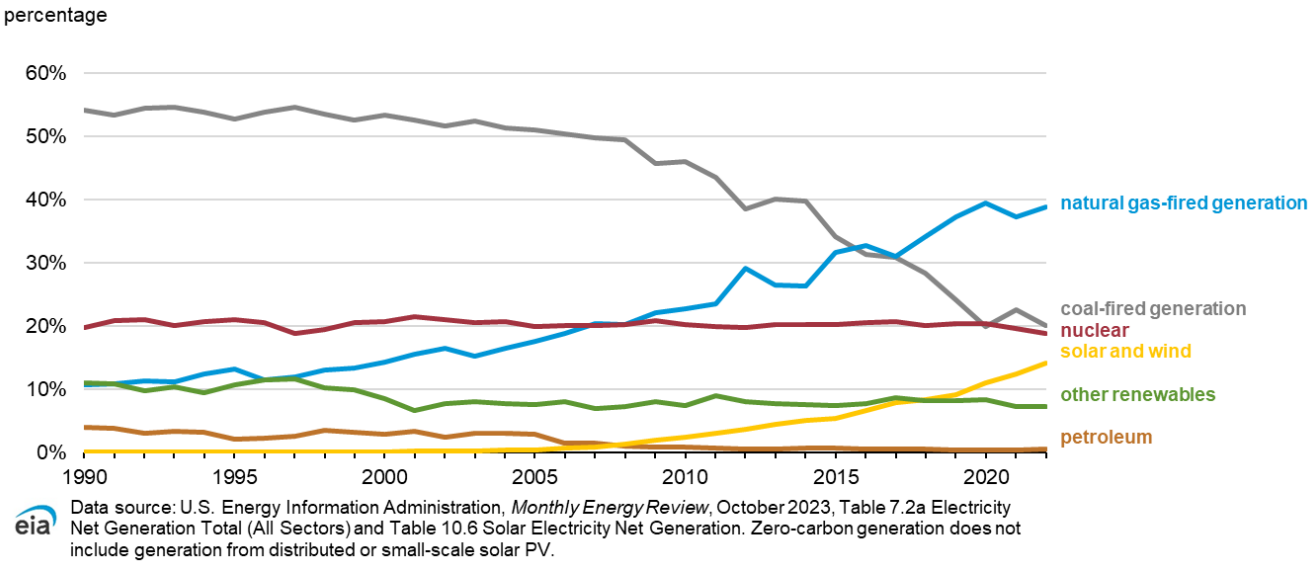
Coal production decreased by a further 24% in 2020 from 706 MMst to 535 MMst because of a 19% decrease in domestic coal demand brought about by a surplus of coal procured in 2019 and COVID-related economic impacts, many of which decreased electricity demand. Demand for coal returned during the second half of 2021 as the economy recovered from the pandemic. Starting in 2021, inventories began to decrease as coal was burned to meet demand.

Despite this rise in 2021 coal demand, coal production was slow to ramp back up due to a combination of labor shortages and a reluctance to commit capital to open new mines or boost output from existing mines. Average consumer coal stocks in 2021 ended up 29% lower than in 2020. Despite coal being more cost competitive in some markets, dwindling inventories and higher demand relative to supply reduced coal-fired electricity generation in 2021 as plant owners wanted to ensure there was sufficient supply to meet winter heating demand.

In late 2021 continuing into 2022, coal production slowly began to rise in response to demand brought about by rising natural gas prices. This increase in production helped balance the coal market during 2022. Russia's full-scale invasion of Ukraine in early 2022 increased demand for all fossil fuels due to a suspension of imports of both coal and natural gas from Russia by many countries throughout the world.

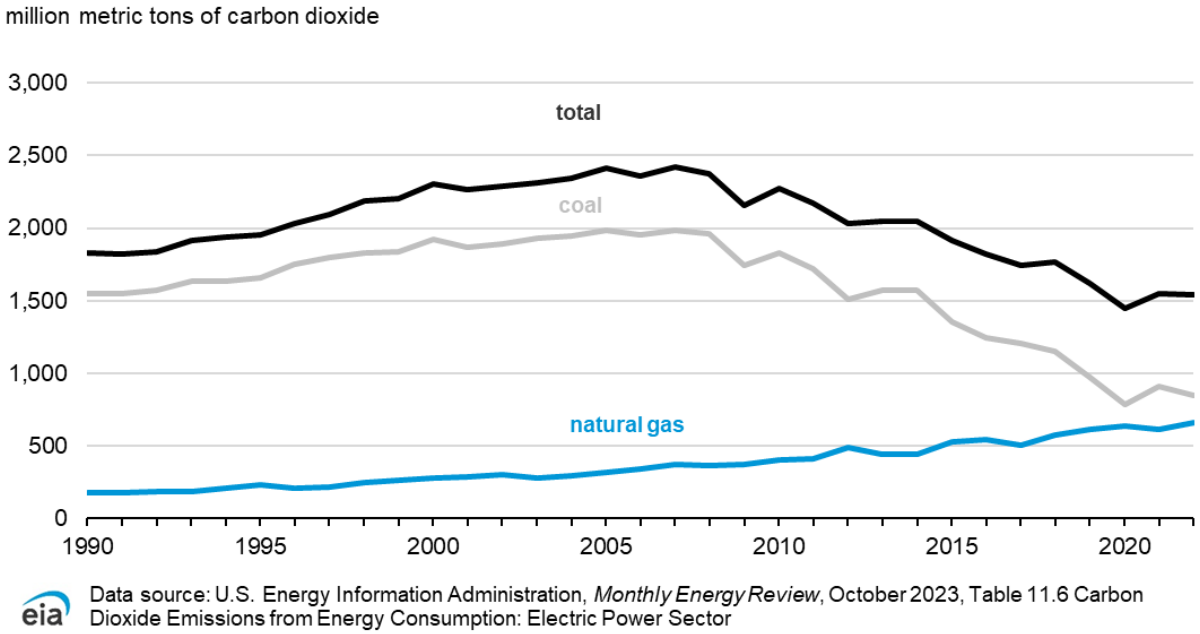
Coal became less economically competitive towards the end of 2022 as natural gas prices began to decrease heading into the 2022–2023 winter season, reducing coal consumption and coal-related CO_2 emissions. Concerns over shortages of fossil fuels in Europe moderated in late 2022 due to increased supply and warmer temperatures. Coal generation in the United States was then replaced by other sources of electricity such as natural gas and zero-carbon options like solar and wind (Figure 3).

Figure 3. Annual percentage of U.S. electricity generation by source



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2023, Table 7.2a Electricity Net Generation Total (All Sectors) and Table 10.6 Solar Electricity Net Generation. Zero-carbon generation does not include generation from distributed or small-scale solar PV.

Figure 4. Electric power sector CO_2 emissions



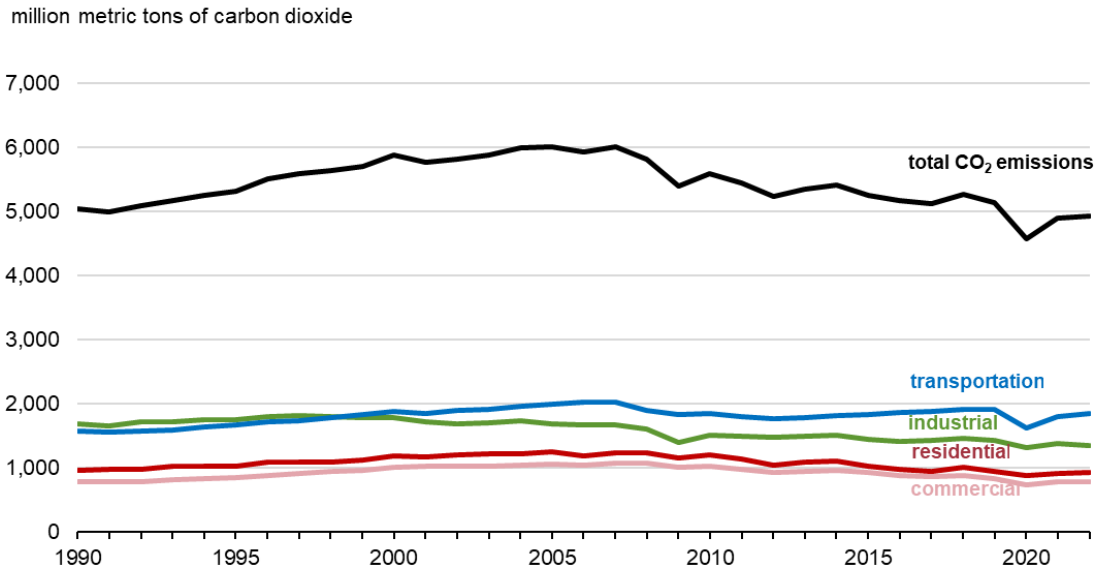
Natural gas acted as a substitute for coal during supply shortages between July 2021 and June 2022, contributing to a 7% (63 MMmt) and a 4% decrease in the carbon intensity of electricity in 2022. Overall U.S. electric power sector emissions remained near 2021 levels due to offsetting increases in natural gas emissions (Figure 4), which rose by 8% (48 MMmt). Although increases in natural gas emissions offset decreases in coal emissions, this shift in generation reduced the carbon intensity of electricity, as natural gas releases around half as much CO_2 as coal per unit of energy consumed.

Zero-carbon generation also grew in 2022. The share of zero-carbon generation increased from 39% of the total generation mix in 2021 to 40% in 2022. This growth was predominantly caused by increased generation from solar and wind. Between 2021 and 2022, utility-scale solar generation grew by 26% and wind generation by 15%. All other zero-carbon generation sources remained relatively flat during this time. Growth in solar and wind generation, coupled with a 3% increase in total electricity generation, also contributed to the decrease in the carbon intensity of electricity. Fuel switching also decreased the carbon intensity of electricity from 392 metric tons of CO_2 per GWh in 2021 to 376 metric tons of CO_2 per GWh in 2022.

Transportation CO_2 emissions increases associated with recovery from COVID-19 begin to level off, with most increases in 2022 coming from air travel

Increases in transportation sector CO2 emissions outpaced those of all other end-use sectors. In the transportation sector, direct emissions rose by 2% (43 MMmt). Most of this increase stemmed from higher jet fuel usage, primarily associated with air travel (Figure 5).

Figure 5. Energy-related CO_2 emissions by end-use sector

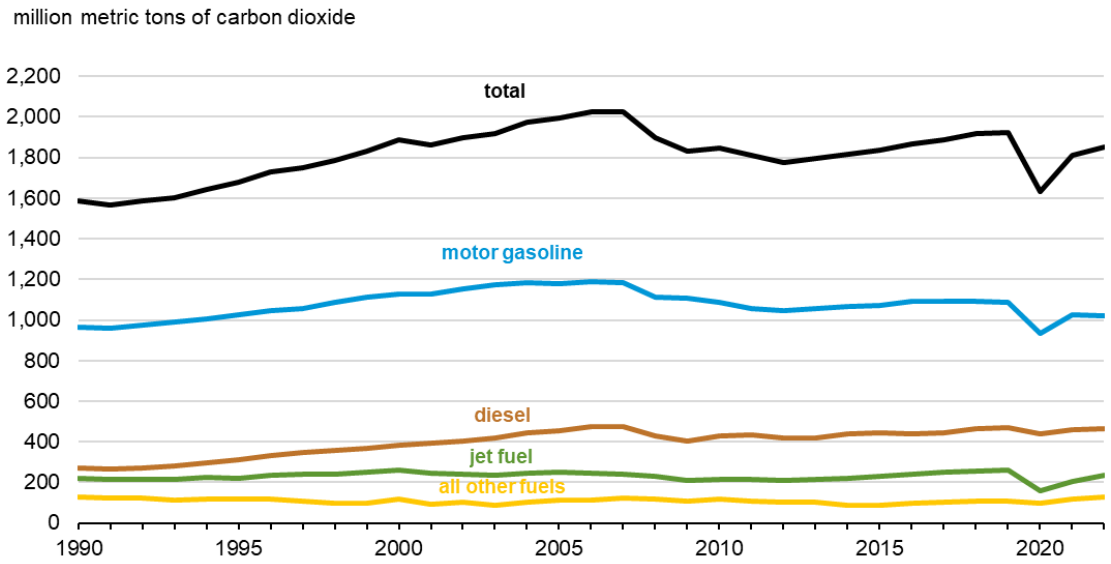


Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2023, Tables 11.1–11.5

U.S. transportation sector CO_2 emissions continued to increase towards pre-pandemic levels in 2022, after declining significantly in 2020 because of the economic effects of the COVID-19 pandemic, though the rate of increase slowed from 2021. Although transportation sector CO_2 emissions increased by 11% in 2021, from 1,633 MMmt to 1,809 MMmt, emissions grew by only 2% in 2022, from 1,809 MMmt to 1,852 MMmt. Although responses to the COVID-19 pandemic affected emissions in all sectors, the largest changes were observed in the transportation sector, mostly because of lower travel demand.

In early 2020, COVID-19 emerged as a global pandemic, prompting significant behavioral changes and limitations relative to travel, movement, work, and leisure time. These factors decreased transportation sector CO_2 emissions which fell 15% between 2019 and 2020. This was the largest year-over-year change in transportation CO_2 emissions in the last 30 years (Figure 6).

Figure 6. Transportation CO_2 emissions by fuel source



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2023, Tables 11.5, Carbon Dioxide Emissions from Energy Consumption: Transportation Sector

COVID-19's effects remain unique in that they were heavily influenced by travel restrictions, social distancing measures, and behavioral changes. As restrictions lifted and people resumed travel, emissions increased and stabilized near pre-pandemic levels. U.S. transportation motor gasoline emissions increased by 10% (89 MMmt) and transportation jet fuel emissions by 27% (43 MMmt) in 2021. U.S. transportation sector emissions increased more slowly in 2022, with jet fuel emissions making up most of the increase and motor gasoline emissions not changing.

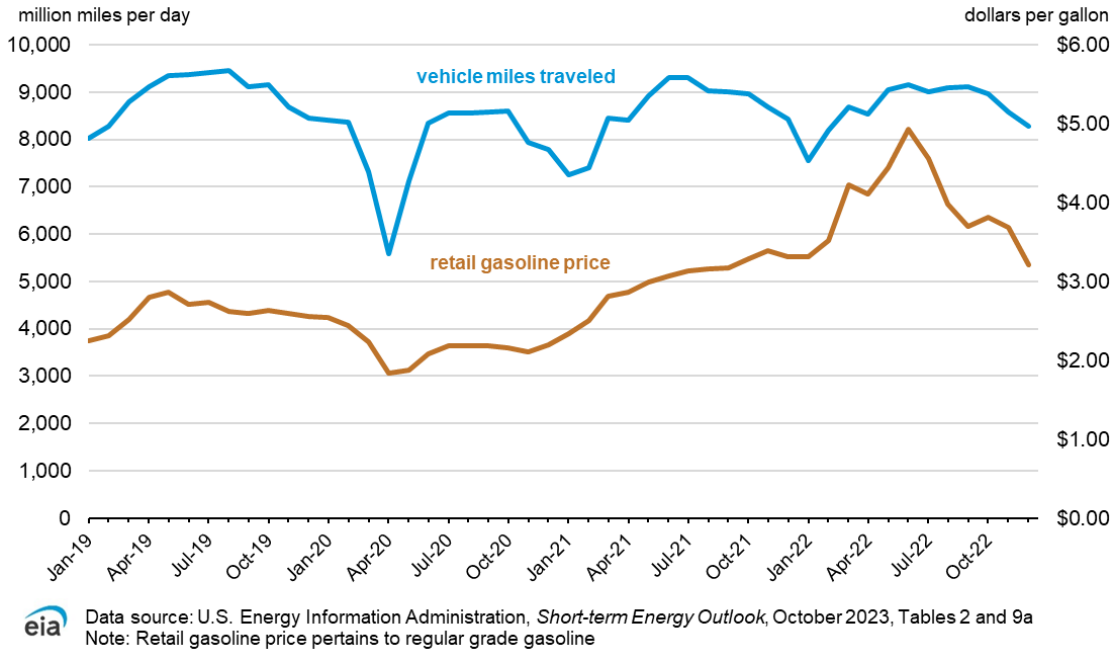
The majority of increases to the U.S. transportation sector CO_2 emissions in 2022 were from increased use of jet fuel. Jet fuel emissions increased by 14% (28 MMmt). Motor gasoline emissions decreased by less than 1% (2 MMmt), and diesel emissions increased by 2% (7 MMmt).

Motor gasoline emissions did not change much in 2022 in large part because of relatively high crude oil prices. A significant contributing factor to these high prices was international pressure, particularly Russia's full-scale invasion of Ukraine in February 2022 and the economic implications of this event on oil markets. Crude oil prices began to increase following the start of this event, with the spot price of Brent crude oil reaching a peak of $123 per barrel (b) in June, an increase of 68% (or around $50/b) relative to the price in June 2021.

These increases in the price of crude oil carried over into retail motor gasoline prices, which increased by a comparable 61% ($1.87 per gallon [gal]) between June 2021 and June 2022. In addition to this notable increase in price, the timing of the price increase also dampened on-road travel. Particularly high oil and gasoline prices occurred during the summer, which often has the highest travel demand relative to other seasons (Figure 7). Overall, these factors led a much smaller increase in travel as measured in vehicle miles traveled (VMT), with average annual VMT increasing by less than 1% relative

to 2021. This relative stability in vehicle travel also stabilized CO_2 emissions from motor gasoline and diesel relative to 2021.

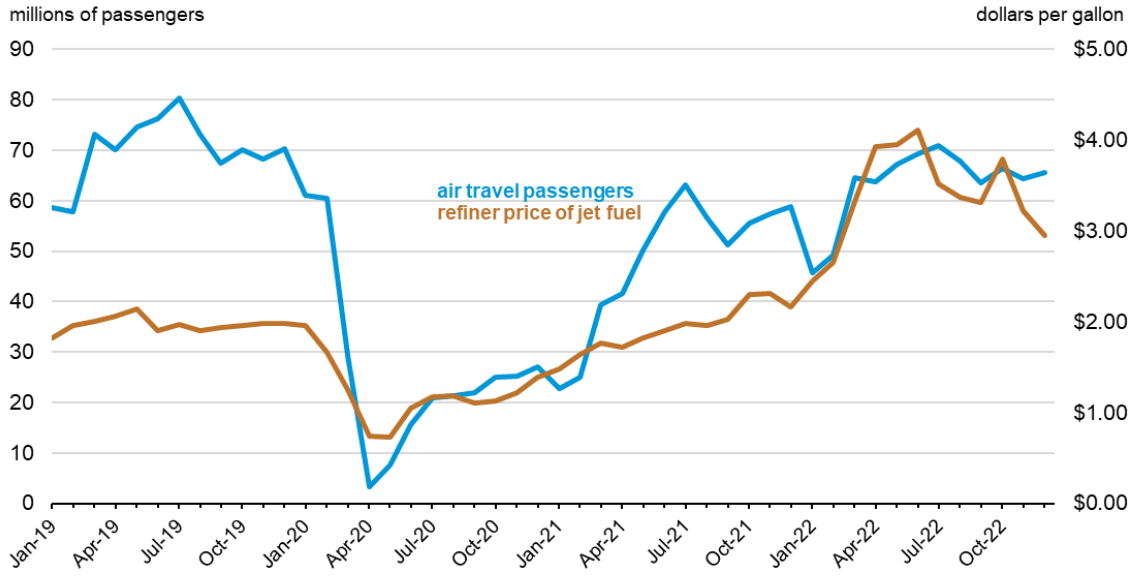
Figure 7. U.S. vehicle miles traveled and retail gasoline prices, 2019–2022



Data source: U.S. Energy Information Administration, *Short-term Energy Outlook*, October 2023, Tables 2 and 9a
Note: Retail gasoline price pertains to regular grade gasoline

Transportation emissions associated with jet fuel continued to increase in 2022 as demand for air travel continued to increase towards pre-pandemic levels. Total air traveler passenger count within the U.S. increased by 31% (179 million passengers) between 2021 and 2022 (Figure 8). This increase occurred despite a notably higher price of jet fuel, which was also affected by crude oil prices. Average annual jet fuel prices increased by 74% ($1.45/gal) between 2021 and 2022. However, several other factors besides the price of jet fuel, such as seasonality of demand and popularity of travel destinations, influenced the overall cost of air travel. As a result, air travel demand and CO_2 emissions associated with higher jet fuel consumption continued to increase in 2022.

Figure 8. U.S. air travel passenger volume and retail jet fuel price, 2019-2022

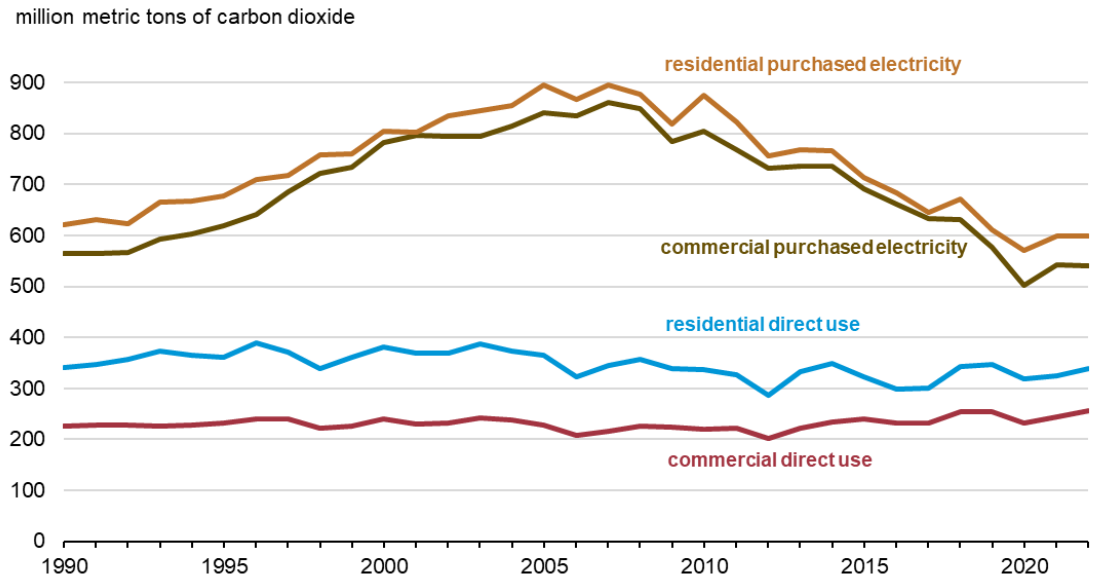


Data source: U.S. Energy Information Administration, *Short-term Energy Outlook*, October 2023, Table 2; U.S. Transportation Security Administration, *TSA Passenger Volumes*

CO_2 emissions increased in the residential and commercial sectors, offsetting declines in industry

The industrial sector experienced a 2% (22 MMmt) decrease in direct emissions, which can be attributed to a 3% overall decrease in industrial activity compared to 2021. By contrast, emissions from the residential and commercial sectors – much of which is attributable to heating and cooling demand – increased by a combined 24 MMmt from 2021 (Figure 9). Total CO_2 emissions in these sectors consists of emissions associated with direct energy use, as well as indirect emissions, attributed to the sector based on its share of total purchased electricity. Total emissions from the residential sector rose by 1% (13 MMmt). Almost all of this increase was a result of direct fuel use, with less than 1 MMmt associated with electricity consumption. Total emissions from commercial buildings increased by 1% (11 MMmt), with 12 MMmt coming from direct fuel use and emissions associated with electricity use decreasing by 1 MMmt.

Figure 9. Energy-related CO_2 emissions from the residential and commercial sectors

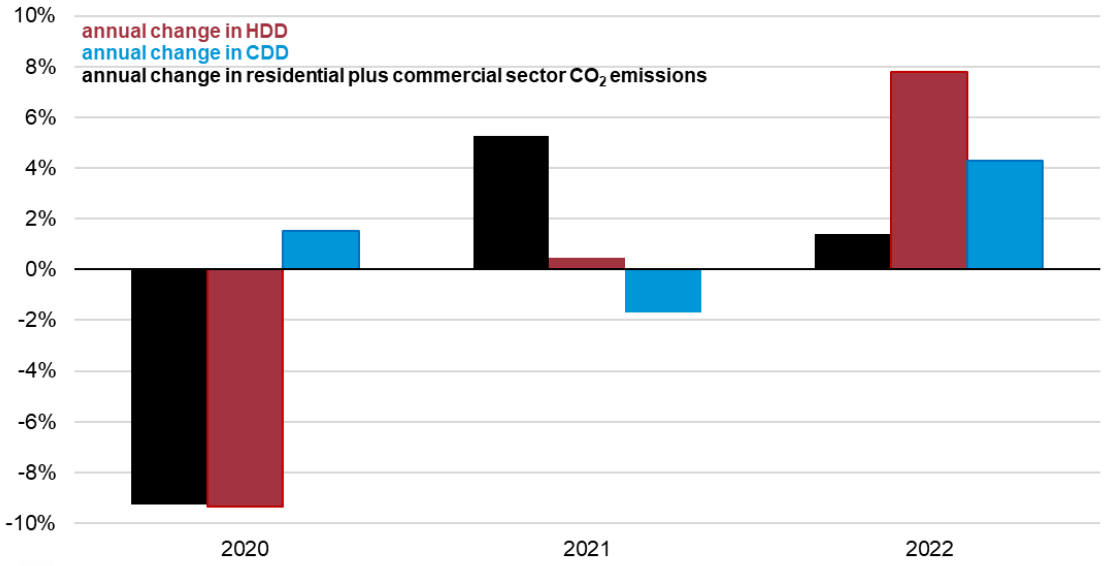


Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2023, Tables 11.2 and 11.3

Heating and cooling are some of the most energy-intensive activities occurring in residential and commercial spaces and have a large influence on sectoral CO_2 emissions. Heating and cooling demand can be measured through heating and cooling degree days; higher degree days generally mean greater energy use for heating or cooling. In 2022, annual U.S. population-weighted heating degree days (HDD) increased 8% and population-weighted cooling degree days (CDD) increased 4% relative to 2021, leading to an increase in both heating and cooling demand as well as CO_2 emissions associated with increased energy use (Figure 10).

Although heating and cooling demand both influence CO_2 emissions, they do so in different ways. CO_2 emissions from heating are mostly captured in direct emissions from natural gas, propane, or heating oil. Emissions associated with cooling, however, are mostly indirect, as most space cooling is done through electricity. These emissions are principally accounted for in the electric power sector, but they can be approximately shared out to the residential and commercial sectors based on the sector's share of total purchased electricity.

Figure 10. Annual change in U.S. average population-weighted heating and cooling degree days



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2023, Tables 1.10, 1.11, 11.2, and 11.3
Note: HDD = heating degree days; CDD = cooling degree days

The National Oceanic and Atmospheric Administration (NOAA) ranked 2022 as the third warmest year in the 128-year record with the average annual temperature being 1.4°F above the 20th century average[1]. Despite 2022 being one of the warmest years on record, heating increased more than cooling demand. A notable event that contributed to the increase in heating demand, and direct emissions, was the late December arctic front that affected almost 240 million people. This weather system brought wind, rain, snow, and ice across much of the nation. Severe snowstorms in New York in November and December also affected heating demand, but the effect was more localized.

While cooling did not greatly affect direct emissions in the residential and commercial sectors, it is an influential factor in electricity demand and CO_2 emissions. The overall warming trend in 2022 is in line with the increase of CDDs and the corresponding increase in energy-related CO_2 emissions.

[1] *Annual 2022 National Climate Report*, National Centers for Environmental Information (NCEI) (noaa.gov).