Independent Statistics & Analysis
U.S. Energy Information Administration

U.S. Energy-Related Carbon Dioxide Emissions, 2019

September 2020

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Introduction

U.S. energy-related carbon dioxide (CO2) emissions decreased in 2019 by 2.8%, or 150 million metric tons (MMmt) when compared with 2018. Changes in the electricity fuel mix were the most important factors, with coal-related CO2 emissions declining by 184 million metric tons (15%). This led to CO2 emissions declines in the residential and commercial sector of 99 MMmt because these sectors consume relatively large amounts of electricity. Compared to 2018, weather played a lesser role in the 2019 decrease because heating demand remained about the same as in 2018, while cooling requirements decreased by 5% compared with 2018.

This analysis examines economic trends and changes in fuel mix that influence energy-related CO2 emissions in the United States. The CO2 emissions in this report are the result of fossil fuel combustion or their use in the petrochemical and related industries.

In the short term, energy-related CO2 emissions are influenced by factors such as weather, fuel prices, and disruptions in electricity generation. In the long term, CO2 emissions are being influenced by

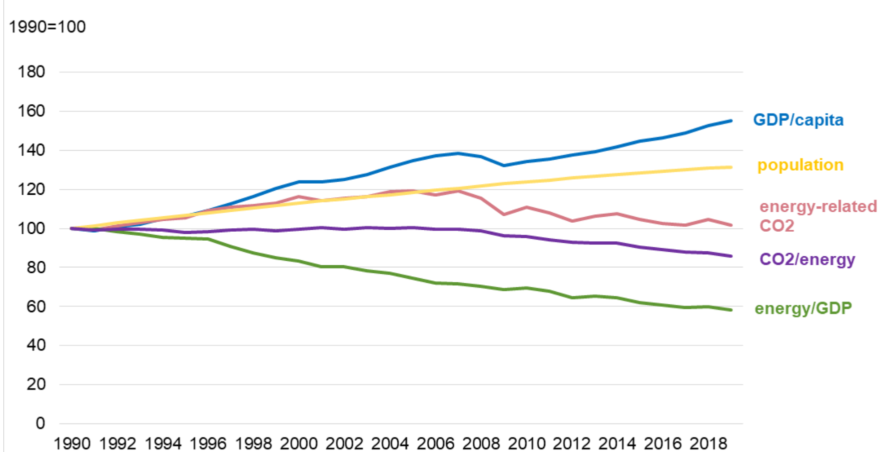
- Policies to encourage low- or no-emitting technologies, such as renewable energy
- New technologies that reduce costs and improved efficiency
- Demand-side efficiency gains, such as increased vehicle miles per gallon or more stringent appliance efficiency standards
- Economic trends, such as the changing profile of U.S. manufacturing industries, GDP, and population

Overview of CO2 Emissions

Thirty years have passed since 1990—a benchmark year used by the United Nations Framework Convention on Climate Change

- Between 1990 and 2007, energy-related CO2 emissions in the United States grew by an average 1.0% per year (Figure 1). Since peaking in 2007, declines have averaged 1.3% per year; however, U.S. energy-related CO2 emissions in 2019 were 1.8% greater than in 1990.
- Through 2007, energy-related CO2 emissions tracked population growth in the United States as decreases in energy intensity (energy/GDP) [1] offset growth in GDP per capita.
- In 2008, as the Great Recession began, U.S. energy-related CO2 emissions began to diverge from population growth.
- After the U.S. economy began to recover in 2010, the divergence of CO2 emissions from population growth continued as a result of decreases in the carbon intensity of energy consumption (CO2/energy) [2]. Decreases in carbon intensity were driven by:
- Increases in natural gas production from shale and tight resources that lowered the cost of natural gas production and made it cost competitive with coal for electric power generation.
- Policies that encouraged the use of renewable energy, such as state-level renewable portfolio standards and federal tax subsidies.
- The decrease in U.S. energy intensity (energy/GDP) has been relatively consistent across the 30-year time frame, largely as a result of demand-side efficiency gains and economic trends, such as the changing profile of U.S. manufacturing industries as well as the shift to greater commercial sector economic activity.

Figure 1. Index of GDP/capita, population, CO2/energy, and energy/GDP that influence energy-related CO2 emissions



Sources: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.1, Carbon Dioxide Emissions from Energy Consumption by Source, and Table 1.1, Primary Energy Overview. U.S. Bureau of Economic Analysis, Current-Dollar and "real" Gross Domestic Product. U.S. Census Bureau, U.S. Population 2019.
Note: CO2 refers to carbon dioxide and GDP refers to gross domestic product.

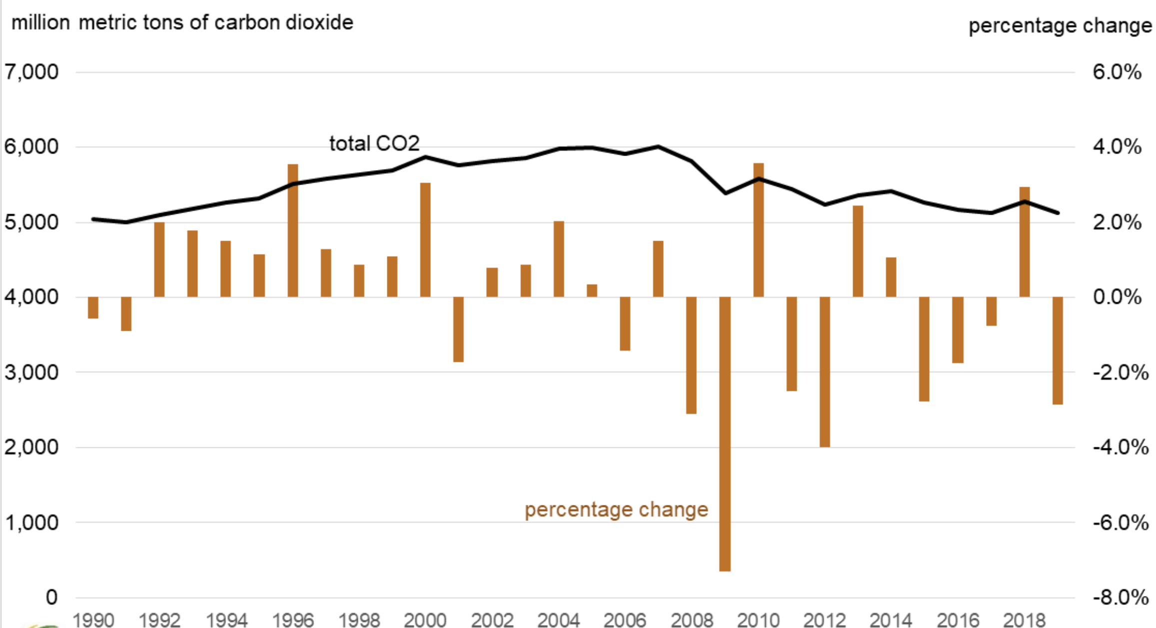
[1] Energy intensity (energy/GDP) definition.

[2] Carbon intensity of energy consumed (CO2/energy) definition.

U.S. energy-related CO2 emissions decreased 2.8% (150 million metric tons) in 2019 and were close to 2017 levels

- Energy-related CO2 emissions in the United States decreased by 2.8% (150 million metric tons [MMmt]) from 5,281 MMmt in 2018 to 5,130 MMmt in 2019 (Figure 2).
- The overall carbon intensity (CO2/GDP)[3] of the U.S. economy declined 4.9% in 2019. This decline resulted from a 3.0% decrease in energy intensity and a 2.0% decline in the carbon intensity (CO2/energy) of the energy consumed.
- Since 2007 energy-related CO2 emissions have declined eight out of 12 years.
- As indicated in Figure 1 and the related discussion, after the economic recovery from the recession, energy-related CO2 emissions began to diverge from population growth, and on average they began to decline. The year 2019 was typical of the declining years that average about -3.0%.

Figure 2. Energy-related CO2 emissions, 1990-2019



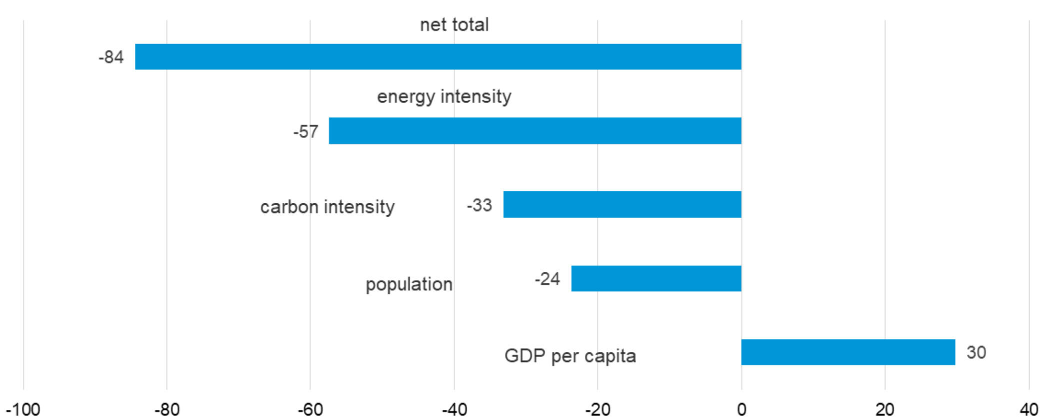
Source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*, August 2020, Table 11.1, Carbon Dioxide Emissions from Energy Consumption by Source.
Note: Unless otherwise indicated, all data in this analysis refer to EIA's August 2020 *Monthly Energy Review*. Nonenergy uses that both emit and capture carbon are included under the term energy-related CO2 because fossil fuels are used primarily as energy inputs. CO2 refers to carbon dioxide.

[3] Carbon intensity of the economy definition.

In 2019, U.S. energy-related CO2 emissions were 84 MMmt lower than the previous 10-year (2008–2018) trend

- The factors that combine to produce total U.S. energy-related CO2 emissions are known as the Kaya identity. The Kaya identity relates percentage changes in energy-related CO2 emissions to changes in four factors: energy intensity, population, carbon intensity, and per capita GDP.
- U.S. CO2 emissions for 2019 appear to be 84 MMmt lower than if components of the Kaya identity (shown in Figure 3) matched their trends over the previous decade (2008–2018).
    - o U.S. energy intensity decreased by 3.0% compared with a 1.9% average decline in the previous decade, which led to 2019 U.S. CO2 emissions that were 57 MMmt lower than if the trend of the previous decade had continued.
    - o The carbon intensity of U.S. energy consumption declined by 2.0% in 2019, a faster decline than the previous decade's average annual rate of 1.3%. As a result, 2019 U.S. CO2 emissions were 33 MMmt below what they would have been if the previous decade's trend had continued.
    - o The U.S. population grew by 0.5%, compared with the previous decade's average of 0.9%, which resulted in 2019 CO2 emissions that were 24 MMmt lower than what would have been projected with the previous decade's trend.
    - o U.S. GDP per capita grew by 1.7% from 2018 to 2019, compared with the previous decade's average annual growth rate of 1.1%. Higher U.S. GDP per capita growth in 2019 added about 30 MMmt of CO2 emissions compared with what the previous decade's average trend would have predicted.

Figure 3. Changes in CO2 emissions attributed to Kaya identity factors from 2018 to 2019 compared with the trend from the previous decade



Sources: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.1, Carbon Dioxide Emissions from Energy Consumption by Source. U.S. Bureau of Economic Analysis, Current-Dollar and "real" Gross Domestic Product. U.S. Census Bureau, U.S. Population 2019. See details of the Kaya identity on page 20.
Note: GDP refers to gross domestic product, and CO2 refers to carbon dioxide.

Fuels

A large decrease in 2019 U.S. coal-related CO2 emissions continued a 15-year trend

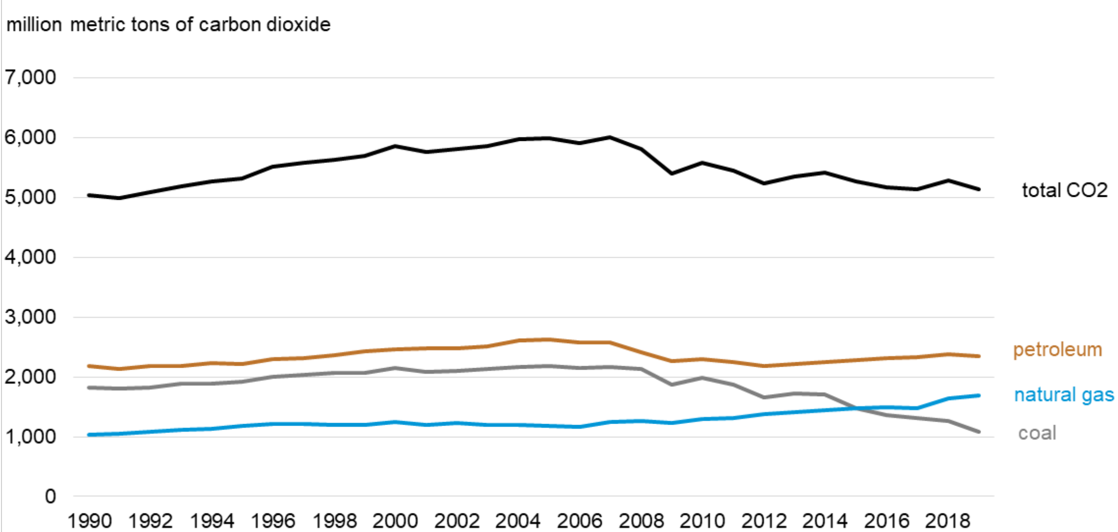
- Since peaking in 2007 at 6,003 MMmt, total U.S. energy-related CO2 emissions have declined by 14.5% (873 MMmt).

- The decline in CO2 emissions from coal was an important factor in the decline since 2007. U.S. energy-related CO2 emissions from coal declined by more than 50% from 2007 to 2019, more than a billion metric tons. U.S. CO2 emissions from coal declined by 15% (184 MMmt) in 2019 compared with 2018 (Figure 4).

- From 2007 to 2019, U.S. CO2 emissions from petroleum and other liquids declined by 8.5% (219 MMmt). U.S. CO2 emissions from petroleum and other liquids declined by 0.8% (20 MMmt) in 2019 compared with 2018.

- With increased consumption, U.S. natural gas CO2 emissions increased in total 35.6% (443 MMmt) from 2007 to 2019. From 2018 to 2019, natural gas-related CO2 emissions increased by 3.3% (54 MMmt). Natural gas-related CO2 emissions from the residential sector increased only slightly from 2018 to 2019, but the electric power sector saw an increase of 6.9% (72 MMmt).

Figure 4. Energy-related CO2 emissions by fuel, 1990-2019



Source: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.1, Carbon Dioxide Emissions from Energy Consumption by Source.
Note: CO2 refers to carbon dioxide.

End-Use Sectors

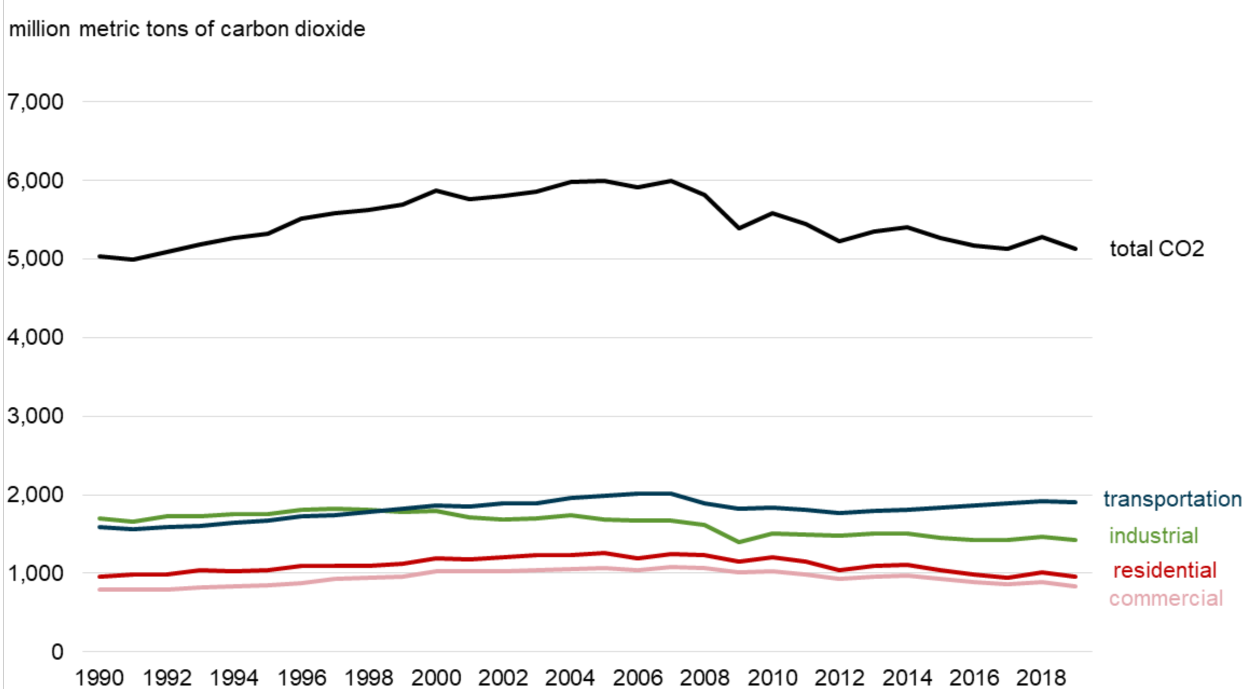
In 2019, CO_2 emissions decreased in all U.S. end-use sectors

- CO_2 emissions from the residential and commercial sectors in the United States declined the most at 99 MMmt or 5.2% in 2019 (Figure 5). This decline was largely the result of the electric power sector's decrease in carbon intensity of generation (CO_2/kilowatthour [kWh]) because electricity is the dominant energy source in residential and commercial sectors. It was also influenced by a 5% decline in cooling requirements.

- Although CO_2 emissions from the U.S. industrial sector increased in 2018, they declined by 2.6% (38 MMmt) from 2018 to 2019 because manufacturing output was flat and CO_2 emissions from purchased electricity declined by 10%.

- Transportation-related CO_2 emissions had been increasing steadily in the United States from 2012 to 2018 because of a recovering economy and moderate fuel prices. However, energy-related CO_2 emissions from the U.S. transportation sector decreased by 0.7% (13 MMmt) in 2019.

Figure 5. Energy-related CO2 emissions by end-use sectors, 1990-2019

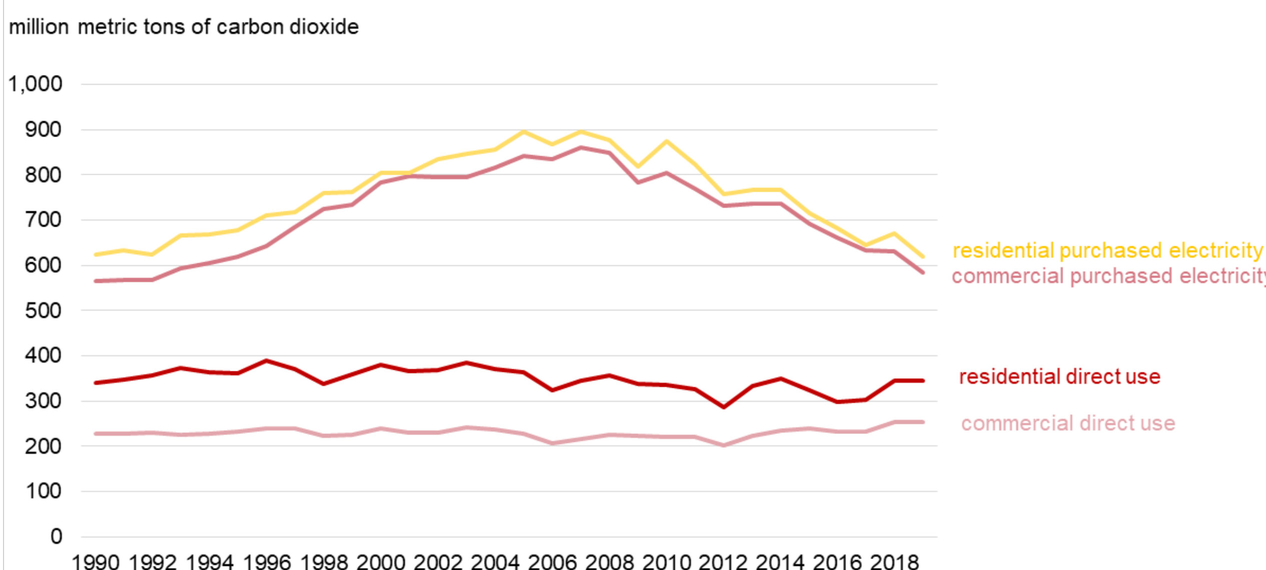


Sources: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.2, Carbon Dioxide Emissions from Energy Consumption: Residential Sector; Table 11.3, Carbon Dioxide Emissions from Energy Consumption: Commercial Sector; Table 11.4, Carbon Dioxide Emissions from Energy Consumption: Industrial Sector; and Table 11.5, Carbon Dioxide Emissions from Energy Consumption: Transportation Sector.
Note: CO2 refers to carbon dioxide.

Total residential and commercial energy-related CO2 emissions had the largest sector decrease in 2019

- The U.S. residential and commercial sectors—or buildings sector—accounted for 66% of the decrease in 2019 total energy-related U.S. CO2 emissions: 35% from the residential sector, and 31% from the commercial sector (Figure 6).
- Buildings-related CO2 emissions are from the direct consumption of fuels for heating, cooking (for example, natural gas or fuel oil heating equipment) and the indirect burn of fuels (for example, electricity consumed by the end-use consumer). Although electricity-related CO2 emissions correspond most closely to cooling demand, parts of the country also heat with electricity.
- CO2 emissions related to direct use in the residential and commercial sectors were unchanged in 2019. CO2 emissions related to purchased electricity declined by 7.7% in the residential sector and by 7.4% in the commercial sector. This decline was related to both a decrease in electricity demand and—more importantly—a decrease in the CO2 emissions per kilowatthour of electricity consumed.

Figure 6. U.S. buildings sector energy-related CO2 emissions, 1990-2019

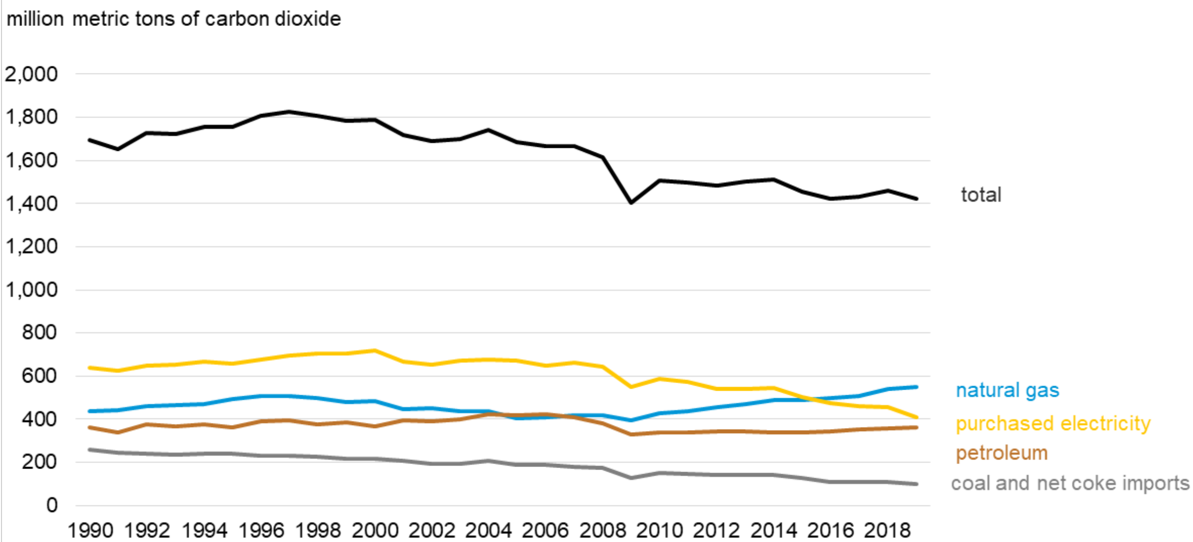


Source: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.3, Carbon Dioxide Emissions from Energy Consumption: Commercial Sector.
Note: CO2 refers to carbon dioxide.

Total industrial sector-related CO2 emissions decreased in 2019

- The U.S. industrial sector's CO2 emissions, which decreased by 2.6% (38 MMmt) in 2019, have remained relatively flat in recent years despite increasing industrial output. Decreasing CO2 emissions from purchased electricity and coal/coke have offset growth in natural gas-related CO2 emissions (Figure 7).
- Industrial natural gas CO2 emissions in the United States have risen most in years since 2009. In 2016, industrial CO2 emissions from natural gas exceeded those from electricity generation. However, increasing use of natural gas has helped reduce overall U.S. CO2 emissions growth because it is the least carbon-intensive of the fossil fuels used in electricity generation and industrial process heat.
- Petroleum CO2 emissions in the U.S. industrial sector have been relatively flat in recent years.
- Coal and net coke imports-related industrial CO2 emissions declined by 61% (157 MMmt) in the United States from 1990 to 2019.

Figure 7. U.S. CO2 emissions from industrial fuels, 1990-2019

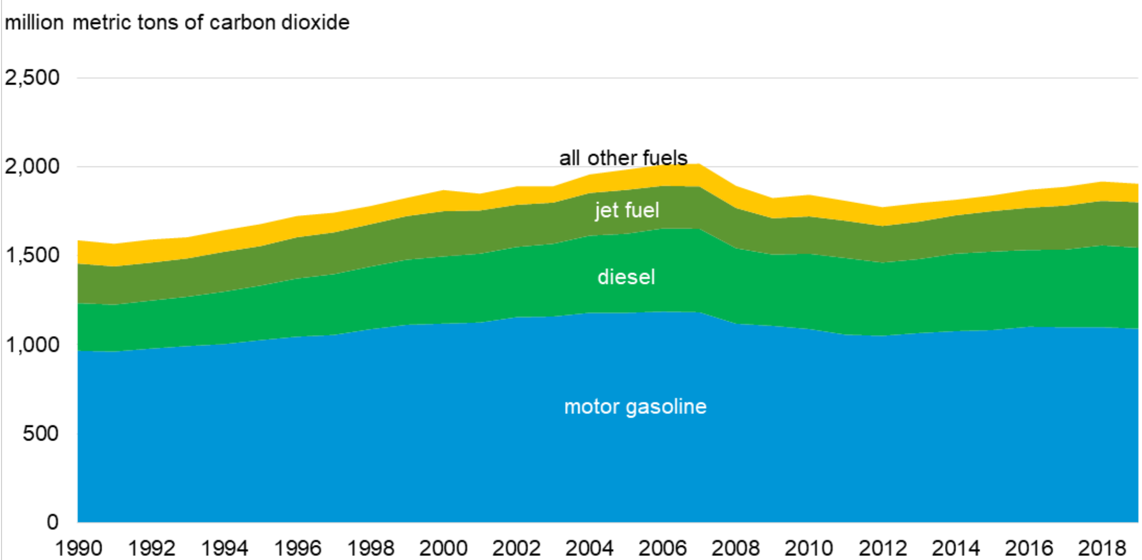


Source: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.4, Carbon Dioxide Emissions from Energy Consumption: Industrial Sector.
Note: CO2 refers to carbon dioxide.

After a period of growth from 2012 to 2018, U.S. transportation sector CO2 emissions declined in 2019

- From 2018 to 2019, U.S. transportation sector CO2 emissions declined by 0.7% (13 MMmt). This is the same percentage decline as motor gasoline-related CO2 emissions, which led to a decrease of 8 MMmt. Diesel fuel-related CO2 emissions declined by 1.1% (5 MMmt). Residual fuel-related CO2 declined by 12.8% (6 MMmt)—included in all other fuels. These declines offset an increase in jet fuel-related CO2 emissions of 1.9% (5 MMmt) (Figure 8).
- From 1990 to 2007, transportation-related CO2 emissions generally increased at an average rate of 1.4%. From 2007 to 2019 there were periods of both decreasing and increasing transportation-related CO2 emissions, but the net result was that CO2 emissions declined at an average rate of 0.5%.

Figure 8. U.S. transportation fuel CO2 emissions by type, 1990–2019



Source: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.5, Carbon Dioxide Emissions from Energy Consumption: Transportation Sector.
Note: CO2 refers to carbon dioxide.

Electricity Generation

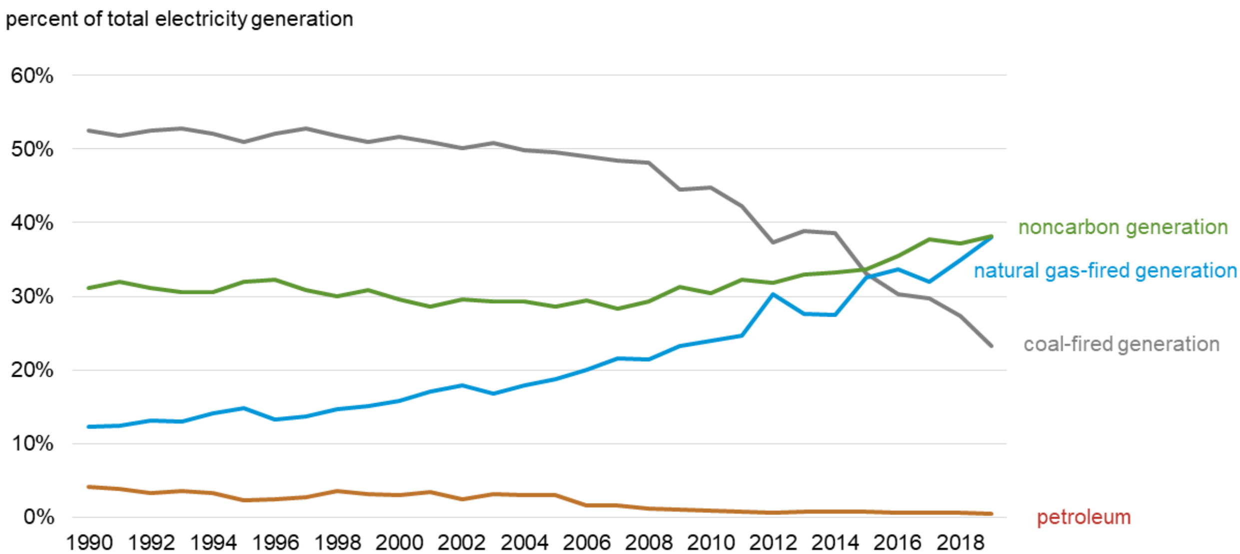
In 2019, non-carbon electricity generation and natural gas generation increased while coal continued to decline

- The changing fuel mix for electricity generation is the main driver for the decline in energy-related CO2 emissions from 2018 to 2019 (Figure 9). From 2018 to 2019 the share of natural gas generation rose from 35% to 38%, and non-carbon generation rose from 37% to 38%. Coal generation declined from 27% to 23%.

- In 1990, coal's share of electricity generation was 52%, and remained about 50% through the mid-2000s. After 2010 it began a consistent decline to 23% in 2019.

- In total, coal, natural gas, and petroleum generation contributed 0.851 CO2 metric tons (mt) per megawatthour (MWh) in 2005, compared with 0.646 CO2 mt/MWh in 2019. This 24% decrease in the carbon intensity of fossil fuel generation played a large role in the energy-related CO2 emissions decline in the past 15 years.

Figure 9. U.S. electricity generation share of three fossil fuels and of non-carbon generation, 1990–2019



Source: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 7.2a, Electricity Net Generation: Total (All Sectors), and Table 10.6, Solar Electricity Net Generation.

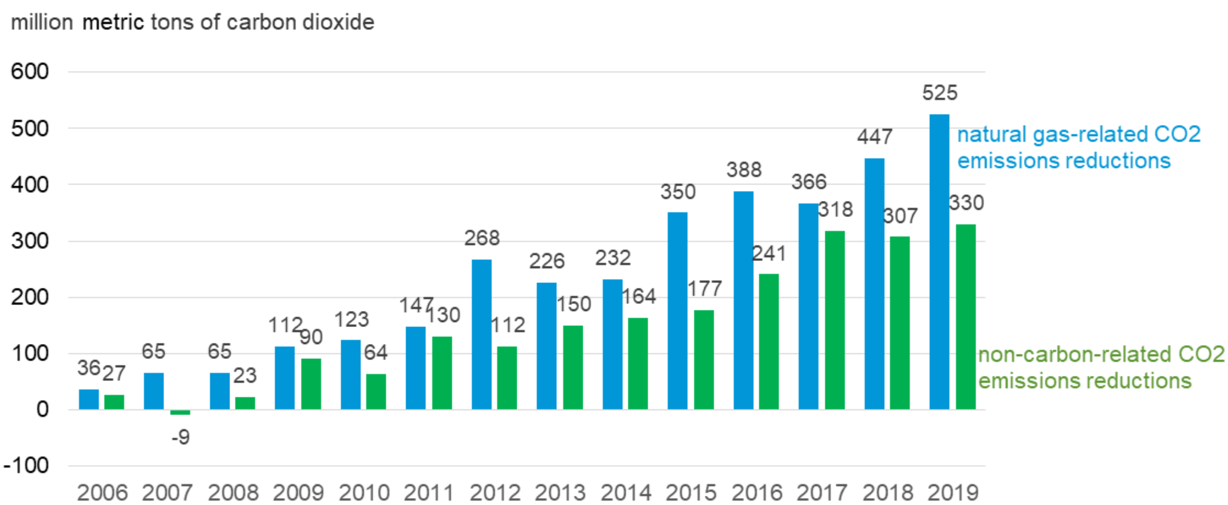
Changing fuel mix has reduced the carbon intensity of U.S. electricity generation

- A major factor in recent reductions in the carbon intensity of electric generation in the United States is the reduced generation of electricity using coal. At the same time, generation has increased from natural gas (which emits less CO2 for the same amount of electricity generated) and from non-carbon generation (including renewables), which emit no direct CO2 (Figure 10).

- EIA calculated that between 2005 and 2019 cumulative U.S. CO2 emissions reductions from shifts in electricity generation from coal to natural gas and to non-carbon generation totaled 5,475 MMmt. This amounts to 19% of total electricity CO2 emissions and 7% of total energy-related CO2 emissions (see methodology on page 18). Of this total, 3,351 MMmt resulted from decreased use of coal and increased use of natural gas, and 2,125 MMmt resulted from decreased use of coal and increased use of non-carbon generation sources.

- Between 2005 and 2019, total U.S. electricity generation increased by almost 2% while related CO2 emissions fell by 33%. During that period, fossil fuel electricity generation declined by about 11%, and non-carbon electricity generation rose by 35%.

Figure 10. CO2 emissions reductions in electricity generation from changes in the fuel mix since 2005



Sources: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.6, Carbon Dioxide Emissions From Energy Consumption: Electric Power Sector, and calculations made for this analysis based on Table 7.3c, Consumption of Selected Combustible Fuels for Electricity Generation: Commercial and Industrial Sectors (Subset of Table 7.3a). Distributed solar generation from Table 10.6, Solar Electricity Net Generation, is added to generation values from Table 7.2a, Electricity Net Generation: Total (All Sectors). See Table 2 on page 18 for carbon dioxide values for the commercial and industrial sectors.
Note: This analysis includes estimated CO2 emissions from electricity generated in all sectors. Non-carbon electricity generation includes small-scale solar. CO2 refers to carbon dioxide.

Growth in U.S. wind and solar electricity generation continued in 2019 and contributed to a decline in the carbon intensity of U.S. electricity generation

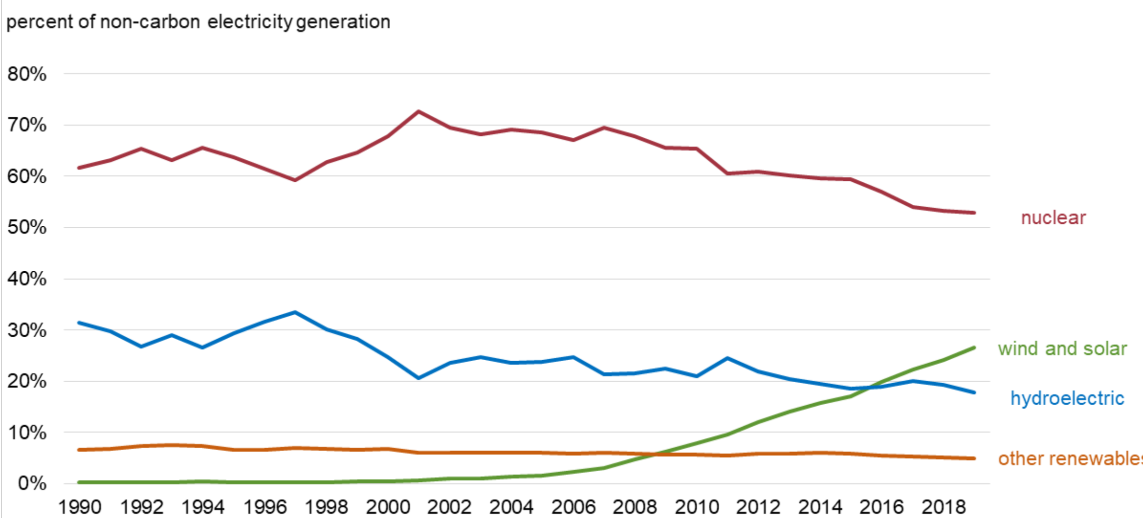
- Wind and solar accounted for about 27% of U.S. non-carbon electricity generation in 2019 (Figure 11).

- Historically, hydropower had the largest share of renewable electricity generation in the United States. With the growth of other renewables, its share has declined from 34% in 1997 to 18% in 2019.

- Although nuclear power remains the dominant source of non-carbon electricity generation in the United States, growth in wind and solar generation has contributed to the decline in its share.

- Other renewables, such as biomass, have grown at a modest rate causing their relative share to remain relatively flat at about 5% of U.S. electricity generation since 2001.

Figure 11. Share of non-carbon electricity generation by source, 1990–2019



Source: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 7.2a, Electricity Net Generation: Total (All Sectors), and Table 10.6, Solar Electricity Net Generation.

Future Implications of the 2019 Decrease in U.S. CO2 Emissions

The combinations of conditions in 2019 that lowered CO2 emissions in the United States relative to 2018 may not necessarily reflect future trends. The EIA products mentioned below contain the most recent forecasts for the short term (2020 and 2021) and projections for the longer term through 2050.

For EIA's short-term forecast of U.S. CO2 emissions and their key drivers, see the *Short-Term Energy Outlook* (STEO), with monthly forecasts through 2021. The STEO is the most appropriate source for EIA's latest estimate for the effect of recent market developments and events on energy markets and related CO2 emissions.

EIA's long-term projections are detailed in the *Annual Energy Outlook* (AEO), with annual projections of domestic energy markets and CO2 emissions through 2050, and the *International Energy Outlook* (IEO), with annual projections of international energy consumption and CO2 emissions through 2050.

The analysis of energy-related CO2 emissions in the United States presented here is based on data published in the *Monthly Energy Review* (MER) reports. Monthly U.S. energy-related CO2 emissions are derived from EIA's monthly energy data. For the full range of EIA's CO2 emissions products, see EIA's Environment analysis.

Further Analysis of Sector Contributions to the 2019 Energy-Related CO2 Emissions Decline in the United States

When analyzing year-to-year changes in energy-related CO2 emissions, it is helpful to understand the role different sectors have on the overall change in CO2 emissions. A particular sector's share of the total change in CO2 emissions can be calculated by dividing the change in CO2 emissions for a sector over the total change in CO2 emissions for all sectors. For example, as shown in Figures 5 and 6, the residential sector's CO2 emissions decrease of 52 MMmt and the commercial sector's 47 MMmt decrease in 2019 accounted for about 66% of the total CO2 emissions decrease of 150 MMmt in that year.

However, additional analysis on CO2 emissions by sector shows how the annual change in CO2 emissions is affected by changes in:

1. Electricity consumption levels
2. The fuel mix of electricity generation (which determines the carbon intensity of electricity consumed)
3. Primary energy consumption levels
4. The fuel mix of primary energy (which determines the carbon intensity of primary energy consumed)

Table 1 shows the contribution that each sector made to the total change in energy-related CO2 emissions for the U.S. economy in 2019. The table includes the following:

- The amount of CO_2 emissions resulting from the change in each sector's electricity consumption (Btu) from 2018 to 2019
- The amount of CO_2 emissions resulting from the change in the electricity generation fuel mix for electricity consumption and the consequent change in carbon intensity (CO_2/Btu) of electricity sales to sectors
- The amount of CO_2 emissions resulting from the change in primary energy consumption (Btu) by sector
- The amount of CO_2 emissions related to carbon intensities (CO_2/Btu) by sector
- The CO_2 emissions changes in each sector based on the sum total of the changes for electricity and primary energy consumption
- These sector totals summed equal the overall change in CO_2 emissions from 2018 to 2019

For example, in the residential sector, the 52 MMmt decrease in CO_2 emissions related to electricity consumption between 2018 and 2019 would have been a decrease of 15 MMmt had it not been enhanced by a decline in carbon intensity of the electricity supply that reduced CO_2 emissions by an additional 36 MMmt. The change in carbon intensity contributed more than twice as much as the decline in electricity consumed. When the values for CO_2 emissions from electricity and primary energy use are summed, the total change for the residential sector equals -52 MMmt.

Table 1. Sector contributions by electricity and primary energy changes to the total energy-related carbon dioxide (CO_2) emissions change from 2018 to 2019

million metric tons of carbon dioxide

	Residential	Commercial	Industrial	Transportation	Total all sectors
Actual change in electricity-related CO2 emissions, 2018–19	-52	-47	-46	0	-145
Change because of the carbon intensity of electricity-related CO2 emissions, 2018–19	-36	-34	-24	0	-95
Electricity-related CO2 with no change in carbon intensity, 2018–19	-15	-12	-22	0	-50
Actual change in primary energy-related CO2 emissions, 2018–19	0	0	8	-13	-6
Change because of the carbon intensity of primary energy-related CO2 emissions, 2018–19	-2	-1	-5	-1	-9
Primary energy-related CO2 emissions with no change in carbon intensity, 2018–19	2	0	12	-11	3
Sum of actual change in electricity and primary energy CO2 emissions, 2018–19	-52	-47	-38	-13	-150

Source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*, June 2020, Tables 11.2–5, Carbon Dioxide Emissions from Energy Consumption by Sectors (as indicated above).

Method for Including CO2 Emissions from Electricity Generated Outside the Electric Power Sector

Not all electricity used in the United States is generated by the electric power sector. In particular, in the commercial and industrial sectors, coal, natural gas, and petroleum are also used on-site to generate power for use on-site (4% of total generation). To estimate CO2 emissions from electricity generation for sectors outside of the electric power sector, EIA made additional calculations. Table 2 presents the results of calculations made for this analysis based on 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, EIA used the following CO2 emissions factors:

- Coal: 95.35 million metric tons per quadrillion Btu for both sectors
- Natural gas: 53.07 million metric tons per quadrillion Btu for both sectors
- Petroleum: 78.8 million metric tons per quadrillion Btu for the commercial sector and 72.62 million metric tons per quadrillion Btu for the industrial sector

These factors are applied to the Btu values of the fuels combusted to produce electricity in the commercial and industrial sectors. These calculations account for the changes in the carbon intensity (CO2/kWh) of electricity generated from all sources as presented in Figure 9.

Table 2. CO2 emissions from electricity generation within the U.S. commercial and industrial sectors

million metric tons of carbon dioxide

	CO2 emissions from generation within the commercial sector (excludes CO2 emissions from electric power sector)				CO2 emissions from generation within the industrial sector (excludes CO2 emissions from electric power sector)				Total commercial and industrial CO2 emissions
	Coal	**Natural gas**	**Petroleum**	**Total**	**Coal**	**Natural gas**	**Petroleum**	**Total**	**Total**
2005	0.80	1.84	0.25	2.89	15.87	28.25	2.41	46.52	49.42
2006	0.73	1.89	0.14	2.76	15.57	29.23	1.88	46.69	49.44
2007	0.76	1.86	0.11	2.72	10.85	30.18	1.86	42.89	45.61
2008	0.81	1.82	0.07	2.70	10.79	28.35	1.34	40.48	43.18
2009	0.69	1.86	0.08	2.63	9.73	28.28	1.20	39.20	41.83
2010	0.68	2.14	0.07	2.89	16.92	30.15	0.87	47.94	50.83
2011	0.73	2.56	0.06	3.35	11.79	31.00	0.76	43.55	46.90
2012	0.62	3.43	0.11	4.17	9.54	34.46	1.67	45.67	49.84
2013	1.04	3.63	0.13	4.80	9.62	35.03	1.36	46.01	50.81
2014	0.41	3.94	0.18	4.54	9.50	34.18	0.90	44.58	49.12
2015	0.32	3.86	0.10	4.29	8.10	34.40	0.66	43.17	47.46
2016	0.21	2.55	0.05	2.81	6.06	29.42	0.59	36.08	38.89
2017	0.18	2.75	0.08	3.01	5.52	29.78	0.53	35.84	38.85
2018	0.16	2.90	0.11	3.17	5.01	31.14	0.48	36.63	39.80
2019	0.14	2.96	0.10	3.20	4.46	31.95	0.46	36.87	40.06

Sources: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 7.3c, Consumption of Selected Combustible Fuels for Electricity Generation: Commercial and Industrial Sectors (Subset of Table 7.3a). *Carbon dioxide factors source.*

Terms Used in This Analysis

British thermal unit(s) (Btu): The quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (about 39 degrees Fahrenheit).

Carbon intensity (economy): The amount of carbon by weight emitted per unit of economic activity—most commonly gross domestic product (GDP) (CO2/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. Note: this value is currently expressed as the full weight of the carbon dioxide emitted.

Carbon intensity (energy supply): The amount of carbon by weight emitted per unit of energy consumed (CO2/energy, or CO2/Btu). A common measure of carbon intensity is weight of carbon per Btu of energy. When only one fossil fuel is under consideration, the carbon intensity and the CO2 emissions coefficient are identical. When several fuels are under consideration, carbon intensity is based on their combined CO2 emissions coefficients weighted by their energy consumption levels. Note: This value is currently measured as the full weight of the CO2 emitted.

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

Energy intensity: A measure relating the output of an activity to the energy input to that activity. Energy intensity is most commonly applied to the economy as a whole, where output is measured as GDP and energy is measured in Btu to allow for the addition of all energy forms (Btu/GDP). On an economy-wide level, energy intensity is reflective of both energy efficiency and the structure of the economy. Economies in the process of industrializing tend to have higher energy intensities than economies in their post-industrial phase. The term *energy intensity* can also be used on a smaller scale to relate, for example, 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 specified as 65 degrees Fahrenheit. The measure is computed for each day by subtracting the average of the day's high and low temperatures from the base temperature (65 degrees), and negative values are set equal to zero. Each day's HDD are added to create an HDD measure for a specified reference period. HDD are used in energy analysis as an indicator of space heating energy requirements or use.

See EIA's Glossary for other definitions.

Methodology Used in This Analysis

With the exceptions of Figures 3 and 10 (whose methodologies are described below), the data in this report are either published values in EIA's *Monthly Energy Review* (MER) or are calculations based on published values (such as CO2/Btu).

Methodology for Figure 3

Figure 3. *Changes in CO2 emissions attributed to Kaya identity factors from 2018 to 2019 compared with the trend from the previous decade (2008–2018)*: This figure gives context to the most recent year-to-year change by comparing it with the average change for key parameters during the previous decade. The key parameters are

- Population
- Per capita GDP (GDP/population)
- Energy intensity (Btu/GDP)
- Carbon intensity of the energy supply (CO2/Btu)

The changes in these key parameters determine changes in energy-related CO2 emissions. By comparing the rate of change for each parameter from 2018 to 2019 with the average rate of change for that parameter for the previous decade, the contribution of each parameter to the overall deviation from trend can be calculated. The table below summarizes the rates of change used in the calculations. The larger the positive value, the greater the increase in energy-related CO2 emissions measured in MMmt. The larger the negative value, the lesser the increase in MMmt of CO2 emissions.

Table 3. Rates of change for 2018–2019 compared with 2008–2018

Parameter	Previous decade (2008–2018) annual percentage change	2018–2019 percentage change
Population	+0.9	+0.5
Carbon intensity (CO2/Btu)	-1.3	-2.0
Per capita GDP (GDP/population)	+1.1	+1.7
Energy intensity (Btu/GDP)	-1.9	-3.0
Change in energy-related CO2 emissions	-1.2	-2.8

Sources: Population, U.S. Census Bureau; Carbon intensity, EIA; Per capita GDP, U.S. Bureau of Economic Analysis and U.S. Census Bureau; Energy intensity, EIA.

Methodology for Figure 10

Figure 10. *CO2 emissions reductions in electricity generation from changes in the fuel mix since 2005*: This figure shows the CO2 emissions savings from two factors that have resulted in decreased CO2 emissions intensity from 2005 to 2019. The first factor is the shift within fossil fuel generation from coal (and some petroleum) to natural gas. The second factor is the increase in non-carbon electricity generation.

To capture this CO2 emissions savings from the shift to natural gas, the fossil fuel carbon factor (fossil fuel CO2/fossil fuel generation) remains constant at the 2005 level. This factor is then multiplied by the actual fossil fuel generation for subsequent years. The difference between that value and the actual value for fossil fuel-generated CO2 emissions is the savings in that year. For example, the carbon factor in 2005 for fossil fuel generation was 2,465 MMmt divided by 2,896,058 million kilowatthours (kWh) times 10^3 to yield 0.851 metric tons per megawatthour (mt/MWh). By 2019, the carbon intensity had declined to 0.646 mt/MWh. Multiplying the 2005 carbon factor (0.851) by the 2019 level of fossil generation (2,566,530) yields 2,185 million metric tons (MMmt) of CO2 emissions, versus the actual value of 1,659 MMmt. Therefore, the savings from the shift to natural gas from coal and petroleum are estimated to have been 2,185 MMmt minus 1,659 MMmt, or 525 MMmt of CO2 emissions, in 2019.

Because non-carbon generation (the second factor) has a zero-carbon factor for direct CO2 emissions, the overall reduction in total carbon intensity was applied to total generation, in other words, multiplying total generation in 2019 (4,136,519 million kWh) by the 2005 value of 0.608 mt/MWh for total generation. The savings in fossil fuel generation were subtracted from the total, and the difference was credited to non-carbon electricity generation. For example, the total savings in 2019 was 855 MMmt, so the amount allocated to non-carbon generation (855 MMmt minus 525 MMmt) equals 330 MMmt of CO2 emissions.

Table 4. Factors used to estimate CO2 emissions savings from the shift to natural gas and the increase in non-carbon electricity generation since 2005

	2005	2019
Data from the *Monthly Energy Review*		
Carbon dioxide from electricity generation all sectors (MMmt of CO2)	2,465	1,659
Fossil fuel electricity generation from all sectors (million kWh)	2,896,058	2,566,530
Total electricity generation from all sectors (million kWh)	4,055,766	4,136,519
Calculations made for this analysis		
Carbon dioxide intensity for fossil fuel generation for all sectors (mt/MWh)	0.851	0.646
Carbon dioxide intensity for total generation for all sectors (mt/MWh)	0.608	0.401
Counter-factual using 2005 carbon factors		
Counter-factual 2018 fossil-fuel generation with 2005 carbon factor (million kWh)		2,185
Counter-factual 2018 total generation with 2005 carbon factor (million kWh)		2,514
Calculated savings comparing actual to counter-factual CO2 emissions		
Savings with actual (MMmt CO2)		525
Savings with actual—total generation minus fossil generation equals non-carbon savings (MMmt CO2)		330
Savings with actual from total generation (MMmt CO2)		855

Sources: U.S. Energy Information Administration, *Monthly Energy Review*, August 2020, Table 11.6, Carbon Dioxide Emissions from Energy Consumption: Electric Power Sector, and calculations made for this analysis based on Table 7.3c, Consumption of Selected Combustible Fuels for Electricity Generation: Commercial and Industrial Sectors (Subset of Table 7.3a). Distributed solar generation from Table 10.6, Solar Electricity Net Generation, is added to generation values from Table 7.2a, Electricity Net Generation: Total (All Sectors).