Congressional Budget Office
Nonpartisan Analysis for the U.S. Congress

Emissions of Carbon Dioxide in the Electric Power Sector

DECEMBER | 2022

At a Glance

The electric power sector accounts for about 30 percent of U.S. emissions of carbon dioxide (CO_2), the most common greenhouse gas. Although demand for electricity is projected to increase as the economy grows and as other sectors rely more heavily on it, the amount of CO_2 emitted in producing electricity is likely to decline because that sector has relatively low-cost methods of reducing those emissions.

In this report, the Congressional Budget Office describes recent trends in CO_2 emissions in the electric power sector, changes in how electric power is produced and the reasons for those changes, and expectations for future CO_2 emissions in that sector. In particular:

- In 2021, CO_2 accounted for about 80 percent of greenhouse gas emissions; more than 90 percent of those CO_2 emissions resulted from the burning of fossil fuels to produce energy. In the electric power sector, coal-fired generation accounted for nearly 60 percent of the CO_2 emissions. The rest were almost entirely from the burning of natural gas.
- Emissions of CO_2 in the electric power sector had been growing until about 2005 but have since declined by about 35 percent. Reductions of energy-related CO_2 occurred in each of three broad sectors—electric power, transportation, and a composite of the industrial, residential, and commercial sectors. But the electric power sector alone accounted for more than 75 percent of the overall decrease.
- The downward trend in emissions related to energy is largely attributable to a shift away from coal-fired generation to natural gas–fired generation in the electric power sector. About two-thirds of the decline in CO_2 emissions in that sector has occurred because of the switch from coal to natural gas, and about one-third has come from increased generation from renewable sources, which do not release CO_2. Since 2005, coal-fired generation has declined by 55 percent. About 70 percent of that decline has been offset by increases in natural gas–fired generation, which emits about half as much CO_2 as coal. At the same time, wind and solar generation—which account for nearly all the growth of renewable generation—have together increased from less than 1 percent of all generation to nearly 13 percent. Changes in the average costs of producing power—from lower natural gas prices and cost reductions in renewable generation—have been responsible for the changes in generation shares.
- In the coming decade, emissions of CO_2 from the electric power sector are expected to decrease further, largely because of growth in renewable generation. Emissions of CO_2 in the electric power sector are projected to decline by about three-fifths by 2032, in part because of provisions in the 2022 reconciliation act (Public Law 117-169) that are expected to promote significant investment in renewable generation. The magnitude of that decline will depend on factors such as future technology costs, the price of fuel, the availability of transmission capacity, the siting of new generators and transmission lines, and the use of the financial incentives available under the act.

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Notes

The Congressional Budget Office adapted data from many sources for this report. For a description of CBO's analytic method, see Appendix A. Citations for the figures are listed in Appendix B.

Numbers in the text and figures may not add up to totals because of rounding.

All years referred to in this report are calendar years, and all values are reported in 2020 dollars.

Emissions of Carbon Dioxide in the Electric Power Sector

The accumulation of greenhouse gases in the atmosphere—particularly of carbon dioxide (CO_2) released when fossil fuels are burned—contributes to climate change. Climate change imposes costs on people and countries around the globe, including the United States.

Measured in terms of its aggregate potential to affect global warming, CO_2 is the most common of the greenhouse gases. Over 90 percent of CO_2 emissions occur when fossil fuels—coal, natural gas, oil, and their derivative products, such as gasoline and heating oil—are burned to produce energy. About one-third of energy-related emissions, and thus about 30 percent of CO_2 emissions overall, come from producing electricity. CO_2 emissions in the electric power sector have been declining and are expected to continue declining in the future.

In this report, the Congressional Budget Office provides an overview of CO_2 emissions and the sources of those emissions from the electric power sector. The report also examines the factors underlying recent declines in CO_2 emissions in the sector and the reasons that trend is expected to continue in the years ahead.

Carbon Dioxide Emissions and Fuels Used to Produce Electric Power

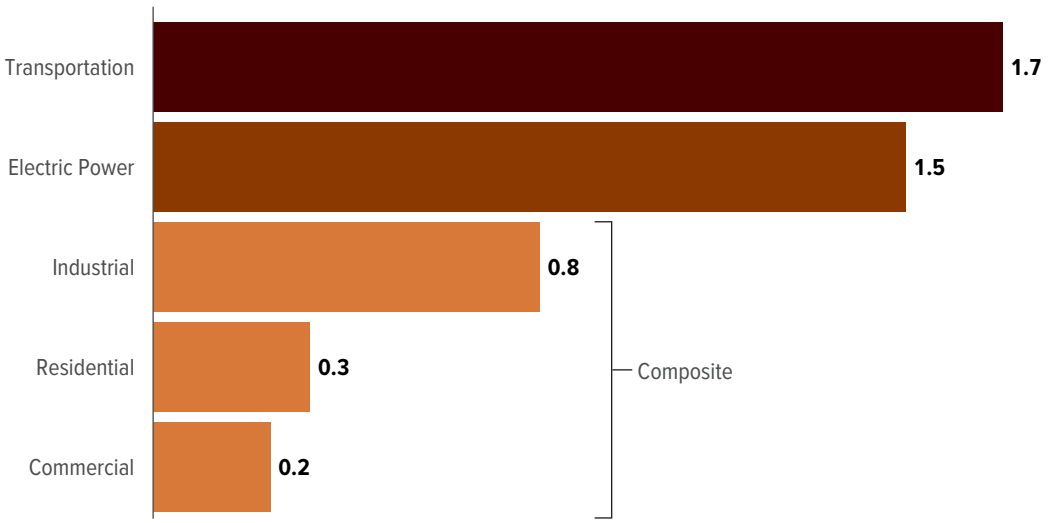
The United States emitted an estimated 6.4 billion metric tons (BMT) of greenhouse gases in 2021.[1] Nearly 80 percent of those emissions were carbon dioxide; the remainder, measured in CO_2 equivalent units, were methane, nitrous oxide, and other (mainly fluorinated) gases.[2] About 92 percent, or 4.6 BMT, of CO_2 emissions occurred when fossil fuels were burned to produce energy. The other 8 percent were released as a by-product of industrial activity or product use rather than from combustion of fossil fuels. The nation's forests and soils absorb carbon and, thus, reduce CO_2 emissions; since 2010, that absorption has offset about 15 percent of CO_2 emissions annually, on average.

Of the 4.6 BMT of energy-related emissions of CO_2 in 2021, about one-third, or 1.5 BMT, came from the electric power sector. The transportation sector accounted for 1.7 BMT of those energy-related emissions, nearly all of which were attributable to the combustion of petroleum fuels.[3] (For more information about CO_2 emissions in the transportation sector, see Congressional Budget Office, *Emissions of Carbon Dioxide in the Transportation Sector* (December 2022), www.cbo.gov/publication/58566.) Energy-related CO_2 emissions from what CBO refers to as the composite sector (industrial, residential, and commercial uses) totaled 1.4 BMT (excluding emissions from producing the electricity used in the sector, which were attributed to the electric power sector).

Unlike the transportation and composite sectors, the electric power sector has relatively low-cost options available to reduce energy-related emissions of CO_2. In particular, electricity is produced using a variety of fuels containing differing amounts of carbon, and there is a high degree of substitutability among them for the sector as a whole. The other sectors are more dependent on specific fossil fuels and have fewer cost-effective alternatives available.[4]

Energy-Related Emissions of Carbon Dioxide, by Economic Sector, 2021

Billions of Metric Tons



CBO estimates that transportation accounted for 38 percent of all energy-related emissions of CO_2 in 2021; 33 percent were from electric power, and the other 29 percent were from the composite sector (industrial, residential, and commercial uses).

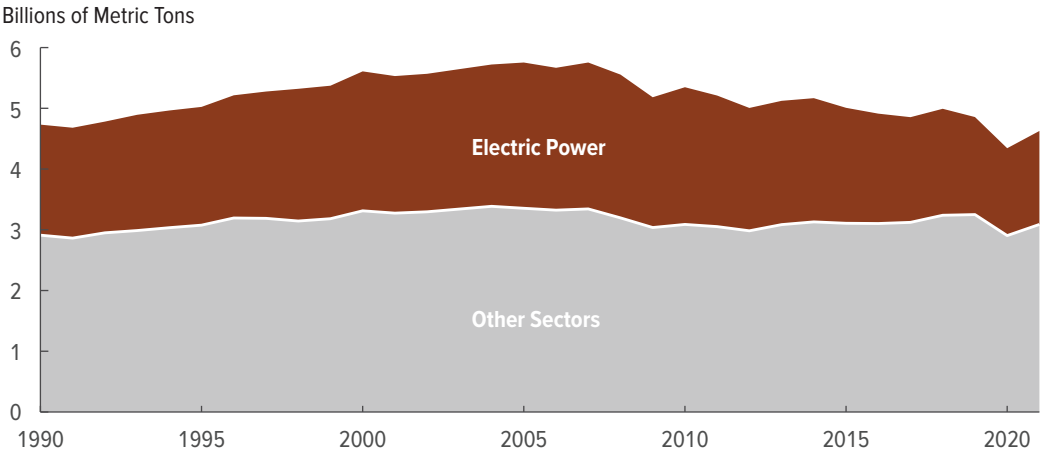
Trends in Emissions of Carbon Dioxide

In the United States, energy-related emissions of CO_2 from all sources and those from the electric power sector peaked around 2005. Since then, emissions of CO_2 from the production of electric power have declined nearly twice as fast as total CO_2 emissions, returning in 2021 to levels of the early 1980s.

Since 2005, emissions in the transportation and the composite sectors have fallen by an estimated 6 percent and 9 percent, respectively. Neither decline was as significant as the 36 percent decline in the electric power sector, which alone accounted for more than 75 percent of the estimated decline in U.S. emissions of energy-related CO_2 since 2005.

That share would have been larger without the lingering effects of the coronavirus pandemic. In the transportation and composite sectors, more than half of the estimated decline in CO_2 emissions since 2005 has occurred since 2019; in the electric power sector, however, less than one-tenth of that decline has occurred since then. Excluding those pandemic years, the electric power sector accounted for nearly 90 percent of the overall reduction in energy-related CO_2 emissions since 2005.

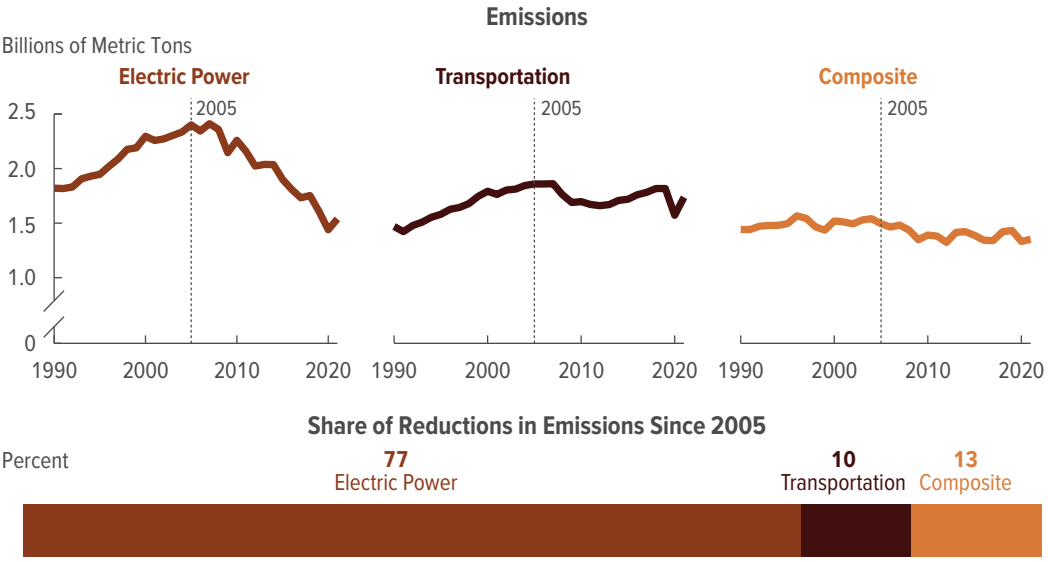
Total Energy-Related Emissions of Carbon Dioxide From the Electric Power and Other Economic Sectors



In 2005, overall energy-related emissions of CO_2 reached 5.8 BMT, and emissions in the electric power sector totaled 2.4 BMT.

Since then, emissions of CO_2 in the production of electric power have declined by 36 percent, accounting for most of the decline in CO_2 emissions overall.

Energy-Related Emissions of Carbon Dioxide and Reductions in Those Emissions, by Economic Sector



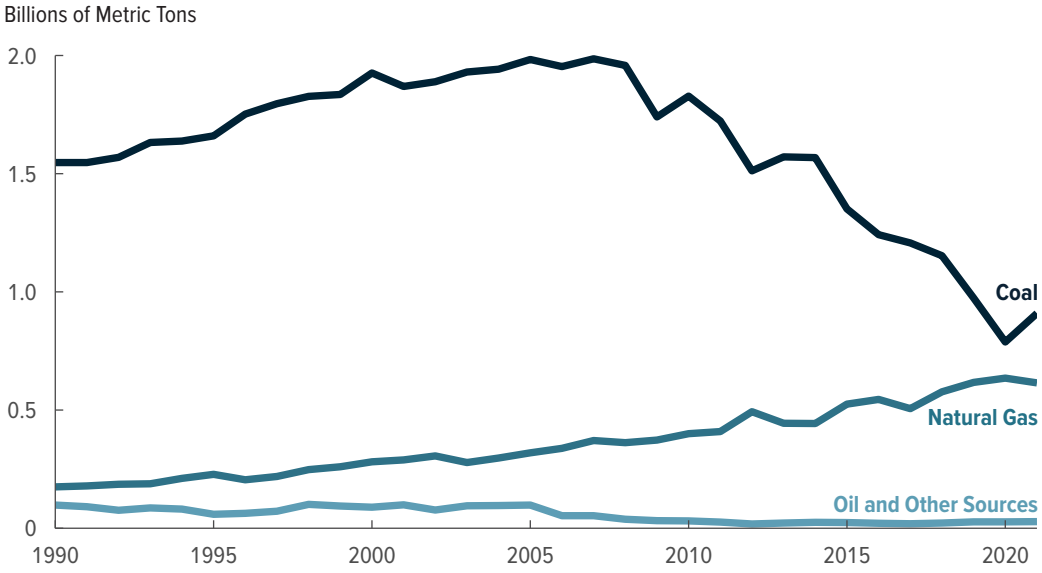
CBO estimates that the electric power sector accounted for 0.9 BMT, and the transportation and composite sectors each accounted for 0.1 BMT, of the 1.1 BMT total decline of energy-related emissions of CO_2 since 2005.

Sources of Emissions in the Electric Power Sector

Coal burned to generate electricity accounts for most of the CO_2 released in the electric power sector.[5] In 2021, coal-fired generation accounted for nearly 60 percent of the CO_2 emissions in the sector, and the rest were almost entirely from the burning of natural gas. Emissions from burning oil and from other sources accounted for about 1 percent of emissions in the sector.

The contribution of coal was previously much higher. It accounted for more than 80 percent of CO_2 emissions in the electric power sector in 2005. Emissions from coal-fired generation have since declined by almost 55 percent, or by about 1.1 BMT, although about a quarter of that decline has been offset by a near doubling of emissions from burning natural gas. Emissions from burning coal rose in 2021 as increases in natural gas prices during the postpandemic economic recovery shifted electricity production from natural gas–fired generation toward coal-fired generation.

Emissions of Carbon Dioxide in the Electric Power Sector, by Energy Source



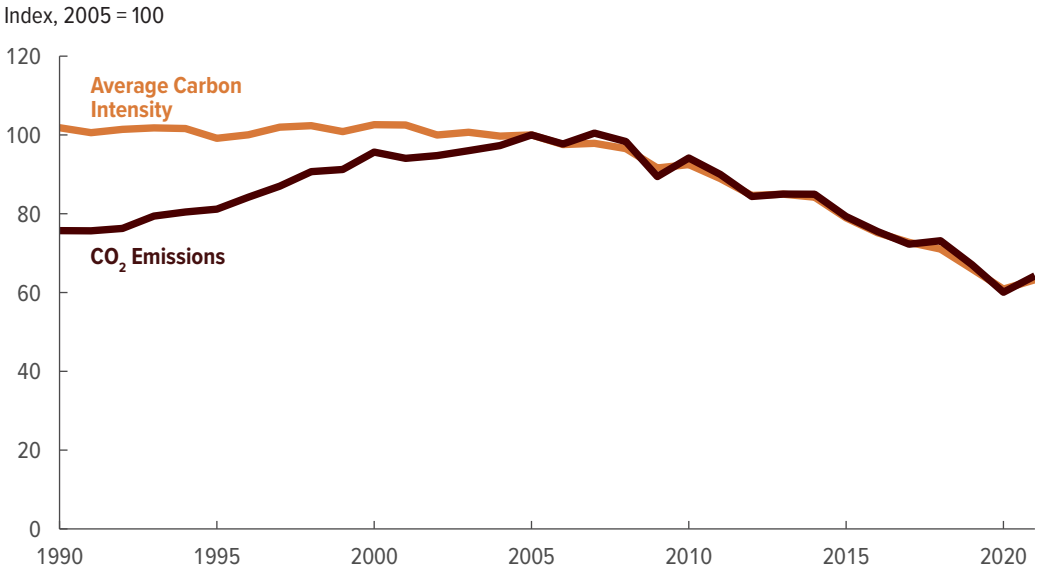
In 2021, CO_2 emissions from coal-fired generation were about 50 percent higher than those from natural gas–fired generation. By comparison, they were more than six times as high in 2005 and nearly nine times as high in 1990.

Carbon Intensity of the Electric Power Sector

The decline in CO_2 emissions in the electric power sector closely reflects the recent decrease in the carbon intensity—the amount of emissions released, on average, for each unit of electricity produced—of the sector. Since 2005, the average carbon intensity for generating electricity has fallen by about 35 percent. Put another way, producing a megawatt-hour of electricity in 2021 released about 35 percent less CO_2, on average, than producing the same amount of electricity did in 2005.[6]

Total emissions of CO_2 in the electric power sector have also declined by about 35 percent since 2005 because the amount of electricity produced has not changed much since then. Thus, the overall decline in sectoral CO_2 emissions since 2005 has stemmed from changes in the composition of fuels used to produce power rather than from a reduction in electricity produced. By contrast, the average carbon intensity of the sector was largely constant before 2005, and CO_2 emissions had increased because the amount of power produced had been increasing.

Emissions of Carbon Dioxide and the Carbon Intensity of the Electric Power Sector



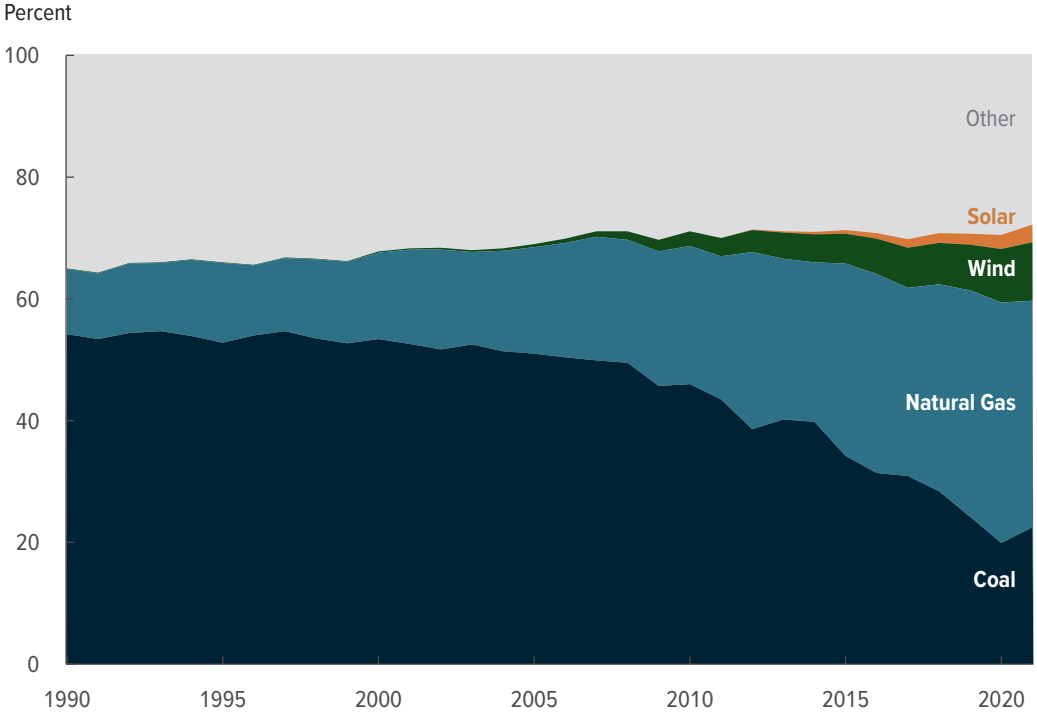
After remaining largely constant, the average carbon intensity of the electric power sector declined from about 0.6 metric tons (MT) of CO_2 per megawatt-hour of electricity produced in 2005 to about 0.4 MT of CO_2 per megawatt-hour in 2021. Because the amount of electricity produced changed little over that time, CO_2 emissions in the electric power sector declined by about the same proportion.

Factors Contributing to the Decline in Emissions in the Electric Power Sector

The decline in CO_2 emissions in the electric power sector reflects two trends: a decline in the amount of fossil fuels used to produce electricity and a change in the mix of the fossil fuels used. Fossil fuels accounted for more than 70 percent of all generation in 2005; that share fell to about 60 percent by 2021. Carbon-free sources of generation accounted for the rest—nuclear, hydroelectric, and wind and solar power, among others.[7] Increases in wind and solar generation have been responsible for nearly all of the growth in carbon-free generation in recent decades.

Because fossil fuels differ in the amount of carbon dioxide they release during combustion, changes in the mix of fuels used to produce power have also affected emissions in the sector. Since 2005, the share of natural gas–fired generation has more than doubled, and the share of coal-fired generation has fallen by more than half. In total, about 70 percent of the reduction in coal-fired generation was offset by an increase in natural gas–fired generation. Because burning natural gas releases about half the CO_2 per megawatt-hour of electricity of combusting coal, that transition from coal-fired to natural gas–fired generation has reduced sectoral emissions even without any change in the amount of fossil fuels used overall.

Distribution of Electric Power Generation, by Energy Source



Declining amounts of fossil fuels used to produce electricity and a change in the mix of those fossil fuels used have reduced emissions of CO_2 in the electric power sector by about 35 percent since 2005.

The change in the mix of fossil fuels—substituting natural gas for coal—has been responsible for about two-thirds of the decline in sectoral CO_2 emissions, whereas the reduction in the amount of fossil fuels used to produce electricity has accounted for about one-third of the decline.

Composition of Fuels Used to Generate Electric Power

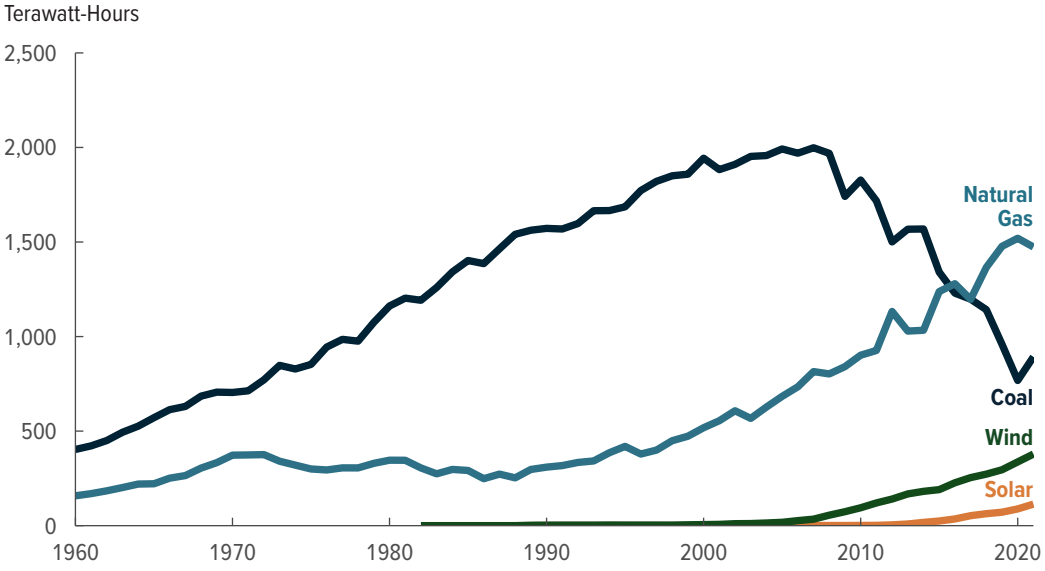
Generation from coal-fired plants increased nearly unabated for decades before peaking in the mid-2000s. Those facilities generated almost 2,000 terawatt-hours of electricity in 2005, about 70 percent more than in 1980 and about five times as much as in 1960.[8] But by 2021, the amount of electricity produced from coal had declined to nearly 50-year lows.

Starting in the late-1980s, coal-fired and natural gas–fired generation grew in tandem with total electricity use. When that growth leveled off starting around 2005, the increase in power produced from natural gas largely displaced that produced from coal; the amount of power produced from other sources—primarily nuclear and hydroelectric—remained largely unchanged.

In 2005, about three times as much electricity was produced from coal as from natural gas; by 2021, the amount of electricity from coal had fallen to nearly half that from natural gas. Although that transition lowered emissions, differences in the carbon intensity of those fossil fuels still meant that, in 2021, coal-fired plants collectively released about 50 percent more emissions of CO_2 than natural gas–fired plants did.[9]

Similarly, wind and solar generation—which accounted for less than 1 percent of the electricity produced in 2005—have grown significantly. Wind power has been responsible for most of that growth, accounting for about 10 percent of the power produced in 2021; solar power accounted for about 3 percent. Despite its comparatively small share, solar power has expanded rapidly since 2015 and is expected to continue to grow. The Energy Information Administration (EIA) projects that solar generation will continue to expand and will exceed wind generation during the next decade.[10]

Generation of Electric Power, by Energy Source



Coal-fired generation peaked around 2005 but by 2021 had declined by 55 percent. Natural gas–fired generation has more than doubled over that period.

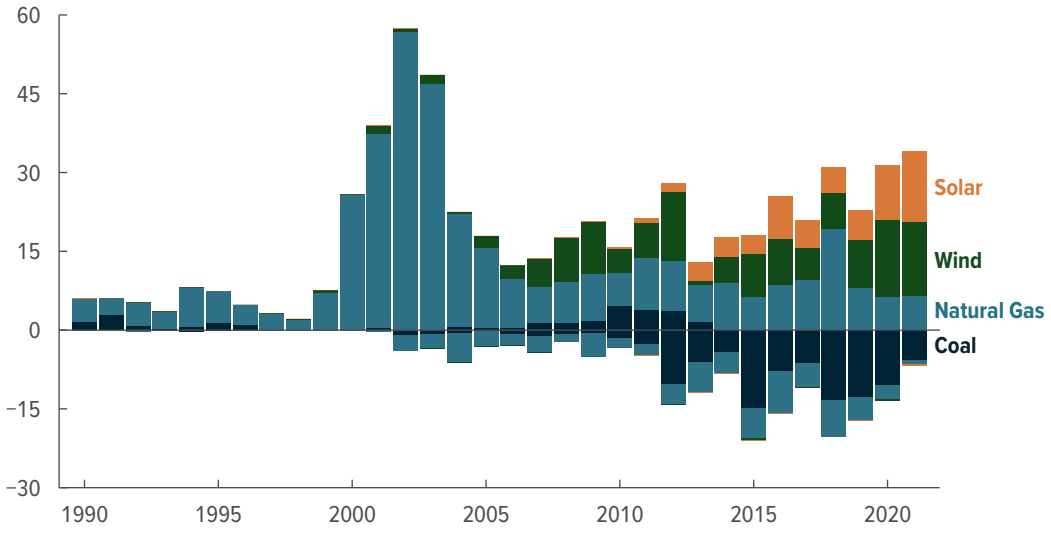
Wind and solar power produced about 0.5 percent of electric power in 2005, but that share had increased to about 13 percent by 2021. Wind production accounted for about 75 percent of that growth.

Changes in Generating Capacity

The increase in electric power generation from natural gas and renewable energy sources and the decline in coal-fired generation reflect the investments in generating capacity in recent years. Since 2005, nearly all of the capacity expansions—new construction or additions to existing power generation facilities—have been in wind, solar, and natural gas–fired generation. By contrast, about half of all capacity contractions—retirements or partial closures of facilities—have occurred in coal-fired generation, and about 30 percent have been in older, less-efficient natural gas–fired generation. Expansions and contractions of capacity for other types of generation have occurred, such as of nuclear plants and hydroelectric facilities, but have been comparatively small.

Those patterns are expected to continue. According to EIA, significant additional capacity from renewable sources and natural gas is expected to come online over the next decade, but no additional capacity is expected from coal. Capacity contractions will consist almost entirely of retirements of coal, oil, and some nuclear facilities.

Capacity Expansions and Contractions of Electric Power Generation, by Energy Source



Since 2005, net capacity expansions have been about 90 gigawatts (GW) for natural gas–fired generation and 190 GW for wind and solar generation. Net capacity contractions have been about 80 GW for coal-fired generation. Total U.S. electric power capacity exceeded 1,000 GW in 2021. (The figure does not include the small changes in capacity for nuclear, hydroelectric, and other types of generation.)

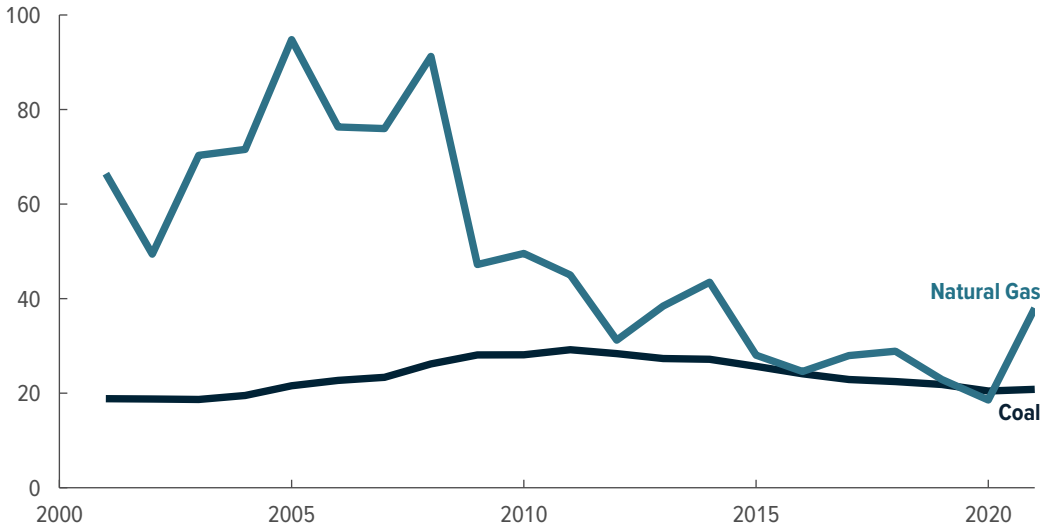
Operating Costs of Existing Plants

The shift from coal to natural gas and renewable energy sources reflects changes in their relative costs to generate power. Total operating costs are the average annual costs incurred to operate a power plant, including the costs of fuel used to produce power and of routine and unexpected maintenance of equipment. Fuel costs, which are the predominant source of operating expenditures, fell by about three-fourths for natural gas between 2008 and 2020, when new mining techniques greatly increased U.S. supplies of natural gas and lowered prices. Although fuel costs for coal-fired generation have remained low, the decline in natural gas prices since 2008 has reduced the average operating costs of natural gas–fired generators below those of coal. Prices for natural gas increased in 2021, but CBO expects that the price increase will be transitory and that natural gas-fired generators will continue to have lower average operating costs than coal-fired generators. Wind and solar generators experience ongoing maintenance costs like other types of generation, but they do not incur fuel costs. The total average operating costs for renewable generation are below those for coal and natural gas.

In addition, federal policies have provided incentives that reduce the costs of renewable power. Federal tax preferences for renewable energy sources include the production tax credit (PTC) for onshore wind and the investment tax credit (ITC) for solar and offshore wind. The PTC offers a credit per kilowatt-hour of electricity produced over the first 10 years of operations, whereas the ITC offers a credit for a fixed portion of the capital cost of new generation. By the end of 2021, the PTC had expired for new generators that were not already under construction, and the ITC had decreased because of a scheduled phaseout. The 2022 reconciliation act (Public Law 117-169), signed into law on August 16, 2022, restored and extended the PTC and ITC to their full values—about $25 per megawatt-hour and 30 percent, respectively—for new construction through 2024.[11] Starting in 2025, any new zero-carbon generators—energy sources such as wind and solar, as well as nuclear power, energy storage, and bioenergy with carbon capture and sequestration, among others—can take either tax credit.

Average Cost of Delivered Fuel, by Energy Source

Dollars per Megawatt-Hour



The average cost to electric utilities for natural gas per megawatt-hour of electricity produced fell by 80 percent between 2005 and 2020. By contrast, the average cost of coal in 2020 was similar to that in 2005. The average cost of natural gas has approached that of coal in recent years because of advances in drilling. The postpandemic economic recovery contributed to the rise in the average cost of natural gas in 2021.

Costs of Producing Electricity at New Plants

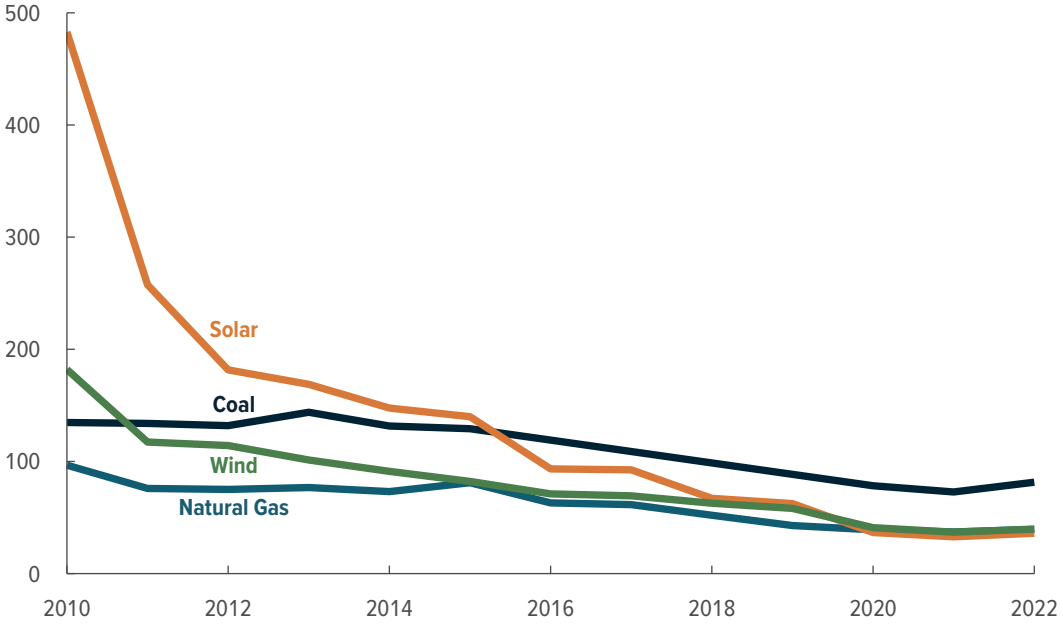
The costs of producing power from natural gas and renewable sources have fallen below that of coal. The levelized cost of electricity (LCOE) is a summary measure of the minimum price of electricity at which a technology generates enough revenue to cover the costs of constructing, financing, and operating a new power plant over an expected operating life. Since 2016, natural gas, wind, and solar have all had lower estimated LCOEs than coal.

One component of the LCOE is the estimated overnight capital cost—the average cost per unit of capacity to build a new facility, excluding the costs to finance its construction. That overnight cost has remained about the same for coal over the past decade and is roughly three times that for natural gas. The estimated overnight capital cost for wind and large solar facilities has declined significantly and is now about 65 percent below that of a coal plant.

Despite the low capital cost, renewable power has two drawbacks. First, unlike coal and natural gas, wind and solar are not dispatchable: Their output cannot be easily increased or decreased in response to changes in demand. Second, generation from those plants is intermittent: A passing cloud might create short-term intermittency for a solar plant, and longer disruptions to generation occur overnight. In the absence of large-scale energy storage, those two factors combine to reduce the availability of renewable sources to generate power during periods of unexpectedly high demand. For example, the Midcontinent Independent System Operator estimates that wind and solar resources in that region can be relied on to provide about 16 percent and 50 percent of capacity, respectively, at any given time.[12] In other words, from a system-planning or reliability perspective, 600 megawatts (MW) of wind capacity or roughly 200 MW of solar capacity are considered to have the same ability to serve peak demand as 100 MW of fossil fuel capacity.

Estimated Annual Levelized Cost of Electricity, by Energy Source

Dollars per Megawatt-Hour



The estimated levelized cost of electricity has fallen for fossil fuels and renewable sources of energy since 2015. Starting in 2021, new renewable generation is projected to have an LCOE similar to or lower than that of all fossil fuels.

Since 2010, estimated LCOEs for utility-scale solar panels and wind turbines have dropped by 93 percent and 78 percent, respectively, primarily because of lower estimated capital costs for those technologies.

Future Carbon Dioxide Emissions in the Electric Power Sector

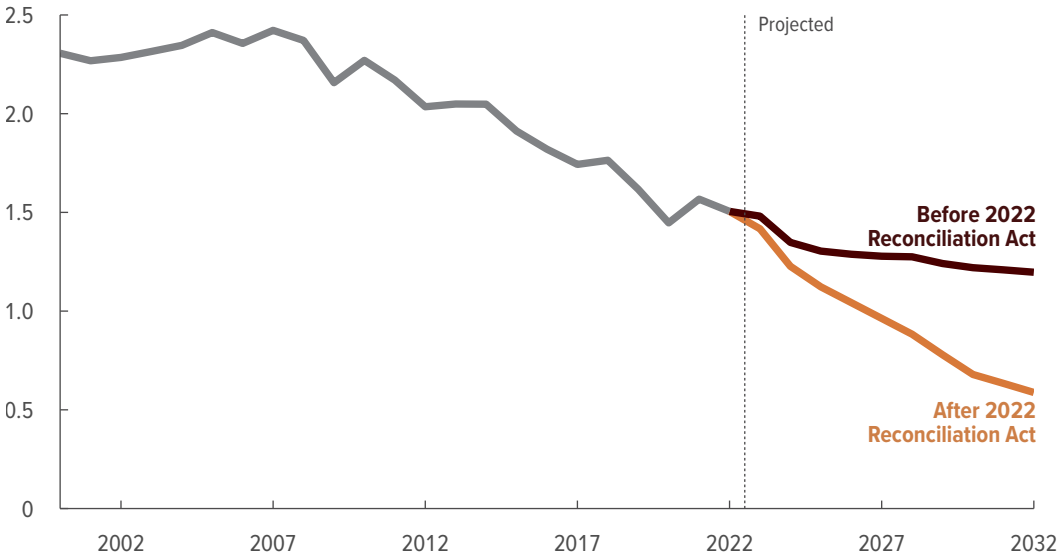
Largely because of anticipated growth of renewable generation, CBO expects CO_2 emissions in the electric power sector to decline by about three-fifths from current levels by 2032, an amount enhanced by recent legislation that provides incentives for the use of wind and solar generation and other zero-carbon energy sources. The amount of that decline is uncertain, however, because it depends on the costs of renewable technologies in the future, the price of natural gas, the availability of transmission capacity, siting for new generators and transmission lines, and the use of financial incentives available under the 2022 reconciliation act, among other factors. Projections indicate a wide range of possibilities for CO_2 emissions in the sector.

Projected Trends

Emissions in the electric power sector are projected to continue their downward trend over the coming years, and the 2022 reconciliation act is expected to accelerate those reductions. The act provides incentives for decarbonization across all sectors of the economy, but most of the projected reductions are expected to occur in the electric power sector. The key provisions affecting the sector are the extensions and expansions of the ITC and PTC to renewable and other zero-carbon generators.

Before the 2022 reconciliation act was enacted, CBO projected that energy-related emissions of CO_2 would decline by nearly 25 percent, from 1.5 BMT to 1.2 BMT between 2021 and 2032, on the basis of information from the Environmental Protection Agency and projections from EIA.[13] With the act's incentives in place, CBO projects that emissions in electric power will instead decline by 62 percent, to about 0.6 BMT in 2032. Those estimates reflect projections from available studies about the effects of the reconciliation act and CBO's assessment of uncertainties about those projections.[14] The reduction is expected to result from greater investment in new wind and solar capacity and the continued operation of nuclear power plants that would otherwise have been expected to be retired.

Annual Emissions of Carbon Dioxide From the Electric Power Sector



Under the 2022 reconciliation act, the supply of electricity from renewable sources is expected to increase significantly over the next 10 years and displace coal-fired and natural gas–fired generation, thereby lowering emissions.

With the act's incentives in place, energy-related emissions of CO_2 are projected to be about 0.6 BMT lower in 2032 than in CBO's previous projection, amounting to a 51 percent reduction in that year.

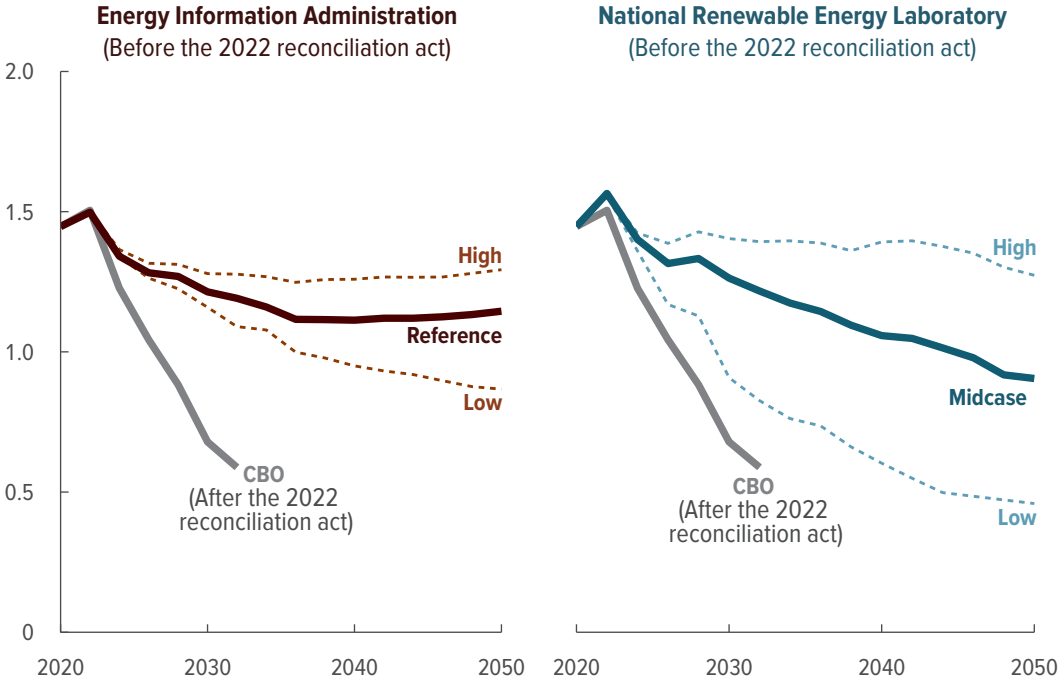
Uncertainty About the Costs of Renewable Energy and Storage

Future emissions could be well above or below the projected trends, depending, for example, on the future cost of renewable energy generators and energy storage technologies. Although the costs of new solar and wind generators have fallen considerably—declining by 56 percent and 33 percent, respectively, in average construction costs since 2013—it is uncertain whether and how much costs to produce power from renewable sources will decline further.[15] Before enactment of the 2022 reconciliation act, EIA and the National Renewable Energy Laboratory (NREL) produced base-case and sensitivity projections that assumed no further policy interventions would occur. CBO's updated projection of CO_2 emissions from the electric power sector is below EIA's and NREL's base-case projections, as well as their low-cost renewable projections, because the expanded tax credits are expected to significantly increase generation from solar, wind, and other zero-carbon sources.

However, developments affecting the future costs of renewable energy sources could significantly decrease or increase the projected reduction in emissions under current law. In NREL's scenario with low-cost renewable generation before the 2022 reconciliation act, lower costs of renewable generators and energy storage would increase the share of wind and solar generation to 60 percent and substantially decrease the share of coal-fired generation to 2 percent by 2050, whereas the shares were 45 percent for wind and solar and 6 percent for coal in NREL's midcase scenario. Differences in the projected cost of utility-scale storage are a key factor in the changes in renewable generation and emissions: The capital cost for utility-scale batteries in 2050 is about 40 percent lower and 70 percent higher in NREL's low- and high-cost scenarios for renewable generation, respectively, than in NREL's midcase scenario.

Projected Carbon Dioxide Emissions From the Electric Power Sector With High- and Low-Cost Renewable Generation

Billions of Metric Tons



Costs of renewable generation that are higher (or lower) than the reference or midcase scenario would increase (or reduce) coal and natural gas generation and their associated CO_2 emissions.

Under EIA's scenario with high-cost renewable generation, CO_2 emissions would be 13 percent higher than the reference case by 2050; under its low-cost scenario, emissions would be 24 percent lower. In NREL's similar scenarios, CO_2 emissions would be 41 percent higher and 49 percent lower than in the midcase scenario.

Additional Areas of Uncertainty

Additional factors that would affect future emissions include fuel prices, the availability of transmission capacity, the siting of transmission lines and generators, and the use of financial incentives made available by the 2022 reconciliation act, among others.

The future path of natural gas prices could have strong implications for emissions. High natural gas prices could lead to reductions in natural gas–fired generation and increased renewable generation because natural gas–fired generation would become relatively less competitive. High natural gas prices could also increase coal-fired generation, particularly because some power plants can switch fuels and generate power from either coal or natural gas. Alternatively, low natural gas prices could lead to an increased reliance on natural gas–fired power plants, further displacing coal-fired generation but also reducing investment in new renewable generation. According to EIA's and NREL's projections from before the passage of the 2022 reconciliation act, low natural gas prices would increase emissions by about 10 percent in 2050; high prices would decrease emissions by about 15 percent to 30 percent.

The availability of transmission capacity for electric power generators is another source of uncertainty about future emissions. Continued increases in renewable and total generation will require upgrades to the existing transmission network and construction of new transmission lines because some future renewable generation may be located in areas far from existing lines. In NREL's scenario with high availability of transmission, long-distance transmission lines could be built to allow for more renewable generation, mostly from onshore wind. The scenario with low availability of transmission reflected a higher capital cost of transmission and a limited number of new transmission lines between regions. NREL intends the higher cost to reflect increased challenges for new transmission lines, such as additional barriers to siting or the added expense of putting some or all of a new transmission line underground. In NREL's projection, low availability of transmission would lead to more generation from coal and natural gas, and thus more emissions, primarily at the expense of solar generation, than would occur with high availability of transmission.

Siting of facilities represents an uncertainty for both transmission and new renewable energy generators. Siting concerns, such as local opposition to the building of new transmission lines, could delay or make it more costly to interconnect new zero-carbon generators with the electric grid and deliver power to customers. In addition, siting concerns could also restrict the locations available to new solar and wind resources if those generators were forced to locate to less favorable locations. Such outcomes would probably increase future emissions relative to current projections.

Finally, uncertainty about the uptake of bonus credit provisions in the 2022 reconciliation act may further affect future emissions. Several additional credits are available in the act that can increase the value of the PTC or ITC for new zero-carbon generators. For example, entities could qualify for those bonus credits by manufacturing a generator with a specified share of domestically produced components or locating the new facility at a specific location, such as at the site of a closed coal plant. Future eligibility for those bonus credits is uncertain, but greater uptake of the bonuses would probably increase the expansion of zero-carbon generation and further reduce emissions.

1. CBO estimated energy-related emissions of CO_2 and other greenhouse gases for 2021 using information from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9; Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php; and Energy Information Administration, *Annual Energy Outlook 2018* (February 2018), www.eia.gov/outlooks/archive/aeo18. EIA's February 2018 report is the most recent long-term outlook from which CBO could make projections of non-energy-related emissions.

2. Greenhouse gases differ in their contribution to warming per physical unit of gas. For simplicity, they are often measured in metric tons of carbon dioxide equivalent, or MT CO_2e—quantities of emissions that, over a period of years (usually a century), contribute to the greenhouse effect by as much as a metric ton of CO_2. See Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9.

3. Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

4. Ron Gecan, *How Carbon Dioxide Emissions Would Respond to a Tax or Allowance Price: An Update*, Working Paper 2021-16 (Congressional Budget Office, December 2021), www.cbo.gov/publication/57580.

5. This report considers only emissions resulting directly from the operation of the generating plant. All technologies create additional emissions from the construction and decommissioning of a power plant, as well as from the production of fuel.

6. A megawatt-hour is approximately the average amount of power consumed in the United States by about 750 households during a typical hour.

7. The aggregate "other" includes a small amount of CO_2 emissions from gases other than natural gas and emissions from the incineration of waste for producing power. It also includes emissions from burning wood for power production, but those are considered carbon-free since growing wood absorbs carbon from the atmosphere.

8. A terawatt-hour is a million megawatt-hours.

9. Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

10. Energy Information Administration, *Annual Energy Outlook 2022* (March 2022), www.eia.gov/outlooks/aeo.

11. The base values of the PTC and ITC are 0.5 cents per kilowatt-hour and 6 percent, respectively. The value of the credits is multiplied by five if the requesting entity meets requirements related to prevailing wages and apprenticeships. Those requirements are expected to be met because of the magnitude of the incentive. The values listed in the report—$25 per megawatt-hour and 30 percent—reflect that assumption. Additional bonuses are available that could further increase the value of those credits.

12. Midcontinent Independent System Operator, *Planning Year 2022–2023 Wind and Solar Capacity Credit* (January 2022), https://tinyurl.com/565u8b5k.

13. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9; and Energy Information Administration, *Annual Energy Outlook 2022* (March 2022), www.eia.gov/outlooks/aeo.

14. Megan Mahajan and others, *Updated Inflation Reduction Act Modeling Using the Energy Policy Simulator* (Energy Innovation, August 2022), https://tinyurl.com/yhcrc4n5; John Larsen and others, *A Turning Point for U.S. Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act* (Rhodium Group, August 2022), https://tinyurl.com/2yddcr26; and Kevin Rennert, Nicholas Roy, and Dallas Burtraw, "Modeled Effects of Inflation Reduction Act of 2022" (presentation at the Resources for the Future webinar, August 10, 2022), www.rff.org/events/rff-live/inflation-reduction-act.

15. Energy Information Administration, "Construction Cost Data for Electric Generators Installed in 2019" (July 14, 2021), www.eia.gov/electricity/generatorcosts/archive/2019.

Appendix A: Analytic Method

This appendix provides information about the method that the Congressional Budget Office used to analyze trends in energy-related emissions of carbon dioxide (CO_2).

The Environmental Protection Agency (EPA) provides information about the amount and sources of emissions of greenhouse gases in the United States.[1] In its annual inventory, EPA catalogs emissions of carbon dioxide, methane, nitrous oxide, and other greenhouse gases. Because EPA's 2022 inventory reports emissions through 2020, information about 2021 is not directly available. Although the Energy Information Administration (EIA) reports energy-related emissions of CO_2 on a sectoral basis through 2021, the agency does not publicly report non-energy-related emissions of CO_2 or emissions of other greenhouse gases. Furthermore, EIA's estimates of annual energy-related emissions of CO_2 for 2020 differ from those of EPA by about 5 percent; much of the difference is attributable to the estimates of emissions in the industrial sector.[2]

To describe trends in energy-related emissions of CO_2 through 2021, CBO began with EPA's estimates of emissions through 2020 for each energy-using sector of the economy—electric power, transportation, and industrial, commercial, and residential (the composite sector). Using EIA's estimates of emissions, CBO then calculated the percentage increase or decrease in the estimate of emissions in each of those sectors from 2020 to 2021.[3] To project emissions for 2021, CBO applied the percentage changes in EIA's estimates to EPA's estimates for 2020.

For projections of energy-related emissions of CO_2 from 2022 to 2032, CBO also applied the percentage change of sectoral emissions between 2020 and each of those years in EIA's most recent long-term projections to EPA's 2020 estimate.[4] CBO then adjusted the projections to account for the provisions in the 2022 reconciliation act, which was enacted after EIA released its projections. To estimate the effects of the law's provisions, CBO relied on a set of studies that estimated the effects of the reconciliation act on sectoral emissions in 2030.[5] Relative to their emissions projections before the reconciliation act, those studies concluded that CO_2 emissions in the electric power sector would be 50 percent lower in 2030, on average. To account for various uncertainties that could result in smaller-than-projected reductions in emissions, CBO reduced that 2030 average reduction by 10 percent, so that emissions would be about 45 percent lower in 2030 with the incentives from the 2022 reconciliation act than they would be without them. CBO interpolated the percentage reductions for the years 2023 to 2029 on the basis of the 2030 estimate. For years 2031 and 2032, CBO projected that CO_2 emissions would change at the same annual rates as in EIA's most recent long-term projections for those years. Thus, the year-to-year change in emissions in CBO's postreconciliation projections follows EIA's projections but with the reductions estimated from the 2022 reconciliation.

1. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9.

2. Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

3. Ibid.

4. Energy Information Administration, *Annual Energy Outlook 2022* (March 2022), www.eia.gov/outlooks/aeo.

5. John Larsen and others, *A Turning Point for U.S. Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act* (Rhodium Group, August 2022), https://tinyurl.com/2yddcr26; Megan Mahajan and others, *Updated Inflation Reduction Act Modeling Using the Energy Policy Simulator* (Energy Innovation, August 2022) https://tinyurl.com/yhcrc4n5; and Kevin Rennert, Nicholas Roy, and Dallas Burtraw, "Modeled Effects of Inflation Reduction Act of 2022" (presentation at the Resources for the Future webinar, August 10, 2022), www.rff.org/events/rff-live/inflation-reduction-act.

Appendix B: Data Sources for Figures

Energy-Related Emissions of Carbon Dioxide, by Economic Sector, 2021

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9; and Energy Information Administration, *Monthly Energy Revie*w (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

Total Energy-Related Emissions of Carbon Dioxide From the Electric Power and Other Economic Sectors

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9; and Energy Information Administration, *Monthly Energy Revie*w (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

Energy-Related Emissions of Carbon Dioxide and Reductions in Those Emissions, by Economic Sector

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9; and Energy Information Administration, *Monthly Energy Revie*w (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

Emissions of Carbon Dioxide in the Electric Power Sector, by Energy Source

Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

Emissions of Carbon Dioxide and the Carbon Intensity of the Electric Power Sector

Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

Distribution of Electric Power Generation, by Energy Source

Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

Generation of Electric Power, by Energy Source

Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

Capacity Expansions and Contractions of Electric Power Generation, by Energy Source Source

Energy Information Administration, "Preliminary Monthly Electric Generator Inventory" (EIA-860M) (February 2022 and February 2017) www.eia.gov/electricity/data/eia860m.

Average Cost of Delivered Fuel, by Energy Source

Congressional Budget Office, using data from Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php.

Estimated Annual Levelized Cost of Electricity, by Energy Source

Congressional Budget Office, using data from Energy Information Administration, *Levelized Cost of New Generation Resources in the Annual Energy Outlook* (various years), www.eia.gov/outlooks/archive/aeo10/electricity_generation.html (2010), www.eia.gov/outlooks/archive/aeo11/electricity_generation.php (2011), www.eia.gov/outlooks/archive/aeo12/electricity_generation.php (2012), www.eia.gov/outlooks/archive/aeo13/electricity_generation.php (2013), and www.eia.gov/outlooks/aeo/electricity_generation.php (2014–2022). Linear interpolation is used for advanced coal plants from 2016 to 2019 because of a lack of available data on the levelized costs of electricity for advanced coal plants without carbon capture and sequestration in those years.

Annual Emissions of Carbon Dioxide From the Electric Power Sector

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9; Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php; Energy Information Administration, *Annual Energy Outlook 2022* (March 2022), www.eia.gov/outlooks/aeo/; Megan Mahajan and others, *Updated Inflation Reduction Act Modeling Using the Energy Policy Simulator* (Energy Innovation, August 2022) https://tinyurl.com/yhcrc4n5; John Larsen and others, *A Turning Point for U.S. Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act* (Rhodium Group, August 2022), https://tinyurl.com/2yddcr26; and Kevin Rennert, Nicholas Roy, and Dallas Burtraw, "Modeled Effects of Inflation Reduction Act of 2022" (presentation at the Resources for the Future webinar, August 10, 2022), www.rff.org/events/rff-live/inflation-reduction-act.

Projected Carbon Dioxide Emissions From the Electric Power Sector With High- and Low-Cost Renewable Generation

For NREL's and EIA's base-case and sensitivity projections, Congressional Budget Office, using data from Wesley Cole and others, *2021 Standard Scenarios Report: A U.S. Electricity Sector Outlook*, NREL/TP-6A40-80641 (National Renewable Energy Laboratory, November 2021), www.nrel.gov/analysis/standard-scenarios.html; and Energy Information Administration, *Annual Energy Outlook 2022* (March 2022), www.eia.gov/outlooks/aeo. For CBO's projection, Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, EPA 430-R-22-003 (April 2022), https://tinyurl.com/2p8mhpe9; Energy Information Administration, *Monthly Energy Review* (September 2022), www.eia.gov/totalenergy/data/monthly/previous.php; Energy Information Administration, *Annual Energy Outlook 2022* (March 2022), www.eia.gov/outlooks/aeo; Megan Mahajan and others, *Updated Inflation Reduction Act Modeling Using the Energy Policy Simulator* (Energy Innovation, August 2022) https://tinyurl.com/yhcrc4n5; John Larsen and others, *A Turning Point for U.S. Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act* (Rhodium Group, August 2022), https://tinyurl.com/2yddcr26; and Kevin Rennert, Nicholas Roy, and Dallas Burtraw, "Modeled Effects of Inflation Reduction Act of 2022" (presentation at the Resources for the Future webinar, August 10, 2022), www.rff.org/events/rff-live/inflation-reduction-act.

About This Document

This report was prepared at the request of the Chairman of the House Committee on the Budget. In keeping with the Congressional Budget Office's mandate to provide objective, impartial analysis, the report makes no recommendations.

David Adler and Ron Gecan prepared the report with guidance from Nicholas Chase and Joseph Kile. Kathleen Gramp, Aaron Krupkin, David Mosher, Robert Reese, and Chad Shirley offered comments.

Max Brown of the National Renewable Energy Laboratory and Laura Martin of the Energy Information Administration commented on an earlier draft. The assistance of external reviewers implies no responsibility for the final product; that responsibility rests solely with CBO.

Mark Doms, Jeffrey Kling, and Robert Sunshine reviewed the report. Rebecca Lanning edited it, and R. L. Rebach created the graphics, illustrated the cover, and prepared the text for publication. The report is available at www.cbo.gov/publication/58419.

CBO seeks feedback to make its work as useful as possible. Please send comments to communications@cbo.gov.

Phillip L. Swagel
Director
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