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

Emissions of Greenhouse Gases in the Manufacturing Sector

FEBRUARY | 2024

At a Glance

When producing goods, the manufacturing sector emits carbon dioxide and other greenhouse gases that cause global warming, both by burning fossil fuels and through certain industrial processes. In this report, the Congressional Budget Office provides an overview of greenhouse gas emissions in the manufacturing sector, describes historical changes in the factors that determine those emissions, presents projections of future emissions, and explains key uncertainties surrounding those projections.

- **CBO estimates that the manufacturing sector was responsible for 12 percent of U.S. greenhouse gas emissions in 2021.** About 75 percent of those emissions came from burning fuel to create heat, and the rest were by-products of industrial processes that transform materials into products.
- **Most emissions in the manufacturing sector come from the chemical and refining industries.** Those two industries accounted for 59 percent of manufacturing's greenhouse gas emissions in 2021.
- **Emissions from manufacturing were 17 percent lower in 2021 than in 2002.** Between 2002 and 2019, the last year before the coronavirus pandemic, the manufacturing sector's output increased, but its emissions intensity—that is, emissions per dollar of output—decreased. The net effect of those changes was a 15 percent decrease in emissions. Emissions then fell further in 2020 in the wake of the pandemic.
- **Emissions from manufacturing are projected to increase by 17 percent between 2024 and 2050.** CBO projects that growth in the output of emissions-intensive industries will lead to an increase in total emissions from manufacturing.
- **Projected levels of emissions reflect projected economic growth, oil and gas supplies, and changes in technology.** Changes in economic growth affect emissions by changing output from manufacturing, and changes in oil and gas supplies affect emissions because oil and gas are important inputs for manufacturing. Changes in technology—including the increased adoption of electrification, carbon capture, and hydrogen fuel—may reduce direct emissions from manufacturing over the long term, but they may also increase indirect emissions from other sectors, such as the electric power sector.

Contents

Notes About This Report

All values are reported in 2021 dollars.

Emissions of greenhouse gases other than carbon dioxide (CO_2) are expressed in amounts of CO_2 equivalent (CO_2e), which is the amount of CO_2 that would result in equivalent warming over a century.

Some subindustries are considered separately from larger industries: Cement and lime manufacturing is separated from the rest of the nonmetallic minerals industry, and iron, steel, and aluminum manufacturing is separated from the rest of the basic metals industry.

Most figures that show values over time start at 2002 instead of 2000 because of data limitations.

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

Emissions of Greenhouse Gases in the Manufacturing Sector

The accumulation of greenhouse gases in the atmosphere contributes to climate change. Greenhouse gases are emitted through the use of energy and the production of goods across various sectors of the economy. This report focuses on greenhouse gas emissions in the manufacturing sector, which comprises industries engaged in the mechanical, physical, or chemical transformation of materials or substances into new products. Those industries were responsible for 12 percent of the United States' total greenhouse gas emissions in 2021, the most recent year for which data are available.[1]

Manufacturing directly creates greenhouse gas emissions in two ways:

- Burning fuel to provide heat releases **combustion emissions**.
- Transforming materials into new products releases **industrial process emissions**.

Manufacturing also indirectly creates greenhouse gas emissions when using electricity that is generated from fossil fuels.[2] Unless otherwise noted, this analysis focuses on direct emissions from the manufacturing sector. However, policies addressing emissions from manufacturing may affect indirect emissions as well as direct emissions.

In this report, the Congressional Budget Office provides an overview of greenhouse gas emissions in the manufacturing sector as a whole and in specific industries. The report discusses historical changes in the factors that determine those emissions, including energy use, technology, and the composition of output. It also provides projections of emissions through 2050 and describes how uncertainty about future economic conditions, fuel prices, and technology affects those projections.

Some industrial processes use fossil fuels not for combustion but as raw materials to create new products (such as natural gas used to create fertilizer). Fossil fuels that are consumed to make products but are not combusted to provide heat are referred to as **energy feedstocks**. Emissions from transforming energy feedstocks are included in estimates of industrial process emissions; however, unless otherwise noted, this report does not include energy feedstocks in its estimates of fuel use.

Greenhouse Gas Emissions and Energy Use in Manufacturing

The United States emitted an estimated 6.4 billion metric tons (BMT) of greenhouse gases in 2021, more than any other country but China. Nearly 80 percent of those emissions were carbon dioxide (CO_2); the rest were methane, nitrous oxide, and other (mainly fluorinated) gases.[3] Non-CO_2 greenhouse gases are measured in CO_2-equivalent (CO_2e) metric tons on the basis of their ability to trap heat.[4]

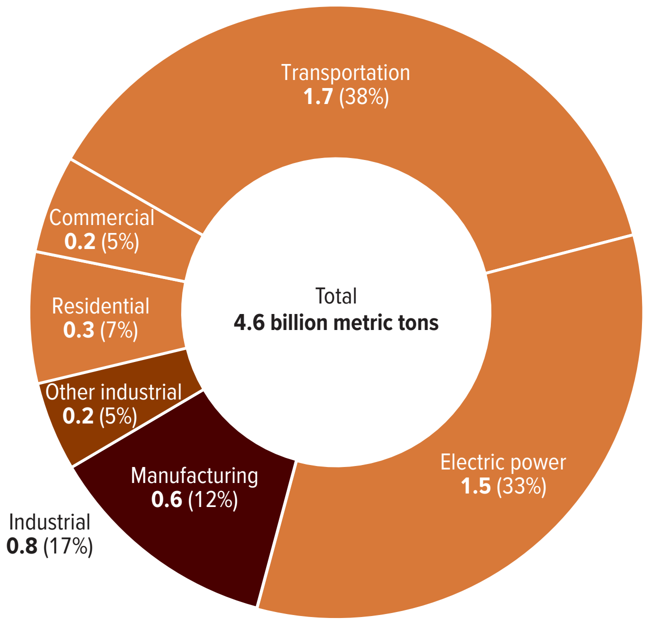
About 92 percent, or 4.6 BMT, of CO_2 emissions occurred when fossil fuels were burned to produce energy; the other 8 percent were released as a by-product of industrial activity or product use (for example, refrigerants that leaked from air conditioning units). The nation's forests and soils absorb carbon, which reduces net CO_2 emissions; since 2010, that absorption has offset about 15 percent of emissions annually, on average.

In this report, CBO separates emissions by economic sector. Manufacturing is the highest-emitting component of the industrial sector, representing 72 percent of industrial sector emissions in 2021. Other industrial sector emissions come from mining and agriculture.

In 2021, combustion emissions from manufacturing totaled 0.6 BMT of CO_2, and other emissions from the industrial sector totaled 0.2 BMT of CO_2. The transportation sector was the largest emitter of CO_2, with a total of 1.7 BMT. The fewest emissions came from the commercial sector, which released 0.2 BMT of CO_2.

Emissions of CO_2 From Fuel Combustion, by Economic Sector, 2021

Billions of metric tons



With a total of 0.6 BMT of CO_2 in combustion emissions, manufacturing industries accounted for 12 percent of all combustion-related emissions in 2021. Those industries emitted about one-third as much as the top-emitting sector of the economy, the transportation sector.

Combustion and Process Emissions

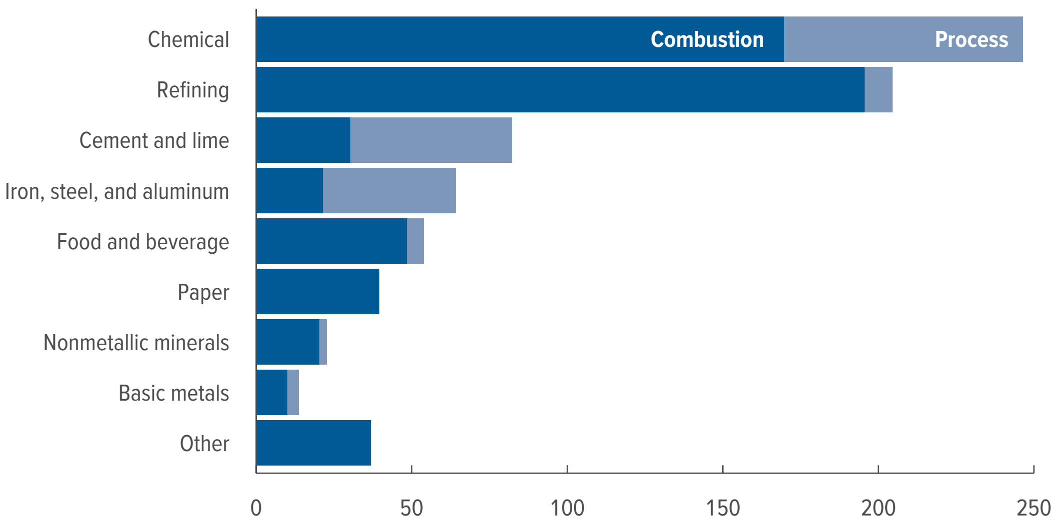
The manufacturing sector's greenhouse gas emissions are heavily concentrated in a handful of industries. The top two emitters—the chemical and refining industries—accounted for 59 percent of emissions from manufacturing in 2021. The top eight industries accounted for 95 percent of emissions from manufacturing in that year. (In the figure below, the "other" category includes the textile, apparel, computer, electrical equipment, transportation equipment, and machinery manufacturing industries.)

Unlike the transportation and electric power sectors, manufacturing generates emissions not only through fossil fuel combustion but also through industrial processes. The manufacturing sector released 765 million metric tons (MMT) of CO_2e in 2021, in CBO's estimation. Combustion emissions accounted for 573 MMT (or 75 percent), and industrial process emissions accounted for 192 MMT (or 25 percent).

Combustion emissions in the United States are more than 99 percent CO_2. Process emissions are mostly CO_2 but contain a higher proportion of other greenhouse gases. In 2021, 91 percent of industrial process emissions were CO_2; 6 percent were nitrous oxide, mostly related to fertilizer production; and the remaining 3 percent were methane, perfluorinated compounds, sulfur hexafluoride, and nitrogen trifluoride.

Combustion and Process Emissions of CO_2e From Manufacturing, by Industry, 2021

Millions of metric tons



The proportion of emissions from industrial processes varies widely by industry. For example, in 2021, 63 percent of emissions in the cement and lime industry came from the process of breaking down raw materials such as limestone. By contrast, almost all of the refining industry's emissions came from the combustion of fossil fuels to generate heat.

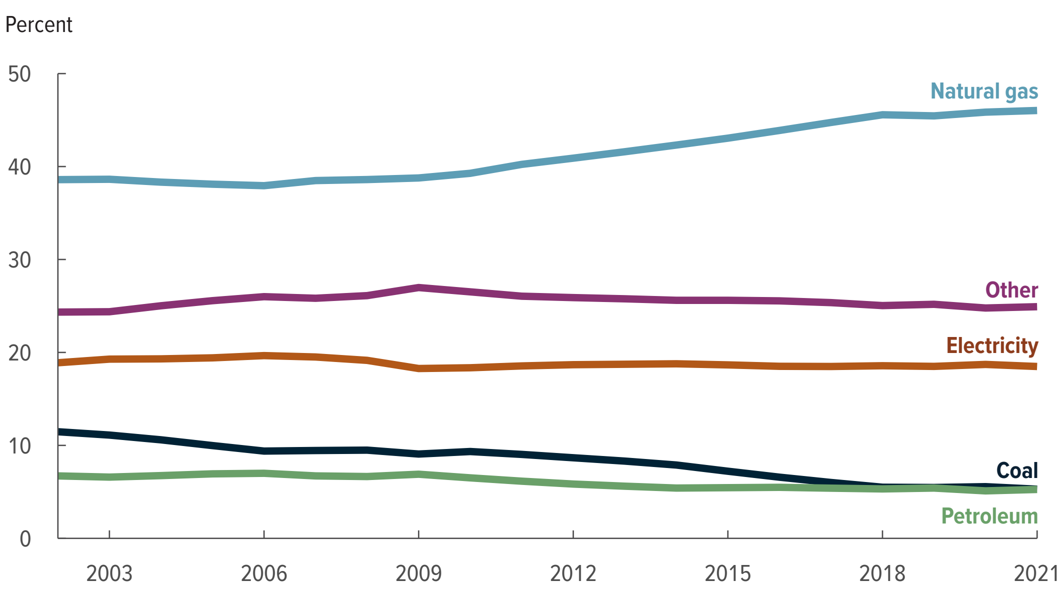
Sources of Energy for the Manufacturing Sector

The manufacturing sector uses several sources of energy. For the past two decades, the largest source of energy has been natural gas, followed by electricity. Coal and petroleum are the least-used fuels for energy, although petroleum is still an important input to production as an energy feedstock for the chemical and refining industries. Other fuel types include biological material, such as wood and paper pulp, as well as waste fuels that would otherwise be disposed of if they were not used as fuel.[5]

Much electricity is generated by burning fossil fuels, and emissions from that process are considered indirect emissions for sectors that use the electricity. In 2021, the manufacturing sector used 713 million megawatt-hours of electricity generated by the electric power sector. Taking into account the amount of emissions released per unit of electricity produced for the entire United States, CBO estimates that indirect emissions from manufacturing totaled 285 MMT of CO_2, equivalent to 37 percent of the sector's direct emissions.

Electrification of manufacturing processes could significantly reduce emissions, but the extent of such reductions would depend on how the electricity was generated. If the electric power sector continued using fewer fossil fuels, and manufacturing firms' demand for electricity did not change, then indirect emissions would fall. But if firms increased their demand for electricity, and the electric power sector met that demand with electricity generated using fossil fuels, emissions would increase. Unless otherwise noted, estimates of emissions in this report include only combustion and process emissions directly released by the manufacturing sector.

Energy Sources in Manufacturing



Coal and petroleum have made up decreasing shares of the fuel used for energy in manufacturing since 2002, while the share of natural gas has increased to account for nearly half of the total.

Electricity continues to be a significant source of energy in the manufacturing sector. Most of that electricity is used for mechanical operations rather than heat production.

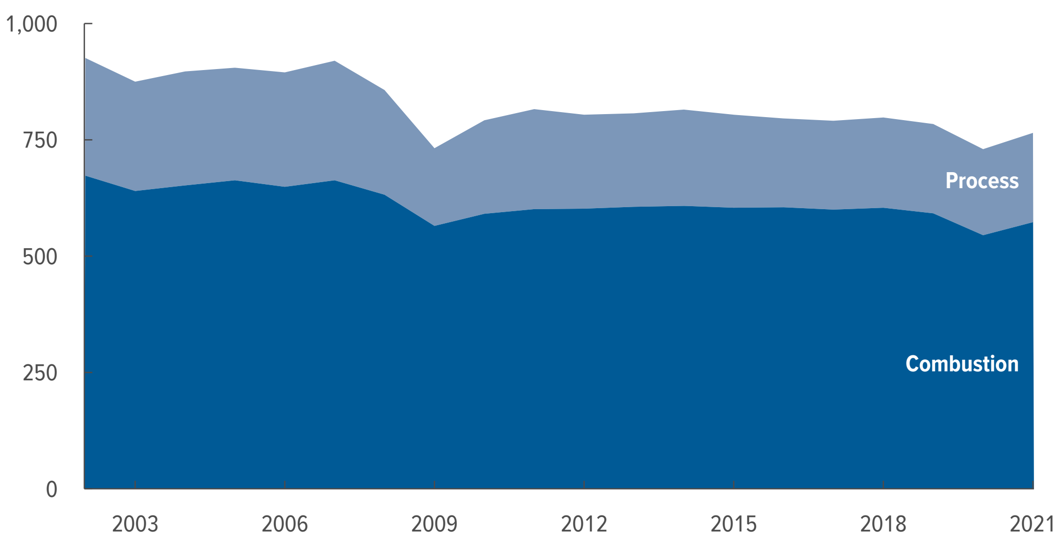
Trends in Total Emissions From Manufacturing

CBO estimates that from 2002 to 2021, manufacturing emissions decreased by 17 percent—from 926 MMT of CO_2e to 765 MMT of CO_2e. Much of that decline happened during the 2007–2009 recession. After that recession, manufacturing emissions rose and then declined slowly from 2012 to 2019, by an average of 0.6 percent per year. Emissions then declined sharply in 2020 in the wake of the pandemic before rising again in 2021.

Historically, fewer policies have targeted greenhouse gas emissions from the manufacturing sector than from the transportation and electric power sectors. Most environmental policies targeting manufacturing are related to controlling local area pollution—for example, the Clean Air Act regulates pollutants such as particulate matter and ozone. The federal government also regulates local area pollution from the transportation and electric power sectors, but additional policies in those sectors reduce greenhouse gas emissions. In the transportation sector, for instance, corporate average fuel economy standards require vehicle manufacturers to increase the distance new light-duty vehicles can travel per gallon of gasoline. And in the electric power sector, policies such as renewable portfolio standards and production and investment tax credits for wind and solar power generation encourage producers to lower their greenhouse gas emissions.[6]

Direct Emissions of CO_2e From Manufacturing

Millions of metric tons



Total direct greenhouse gas emissions from the manufacturing sector declined by 17 percent between 2002 and 2021, CBO estimates.

During most of that period, manufacturing emissions changed little from year to year; however, emissions fell rapidly with output during recessions.

Determinants of Emissions From Manufacturing

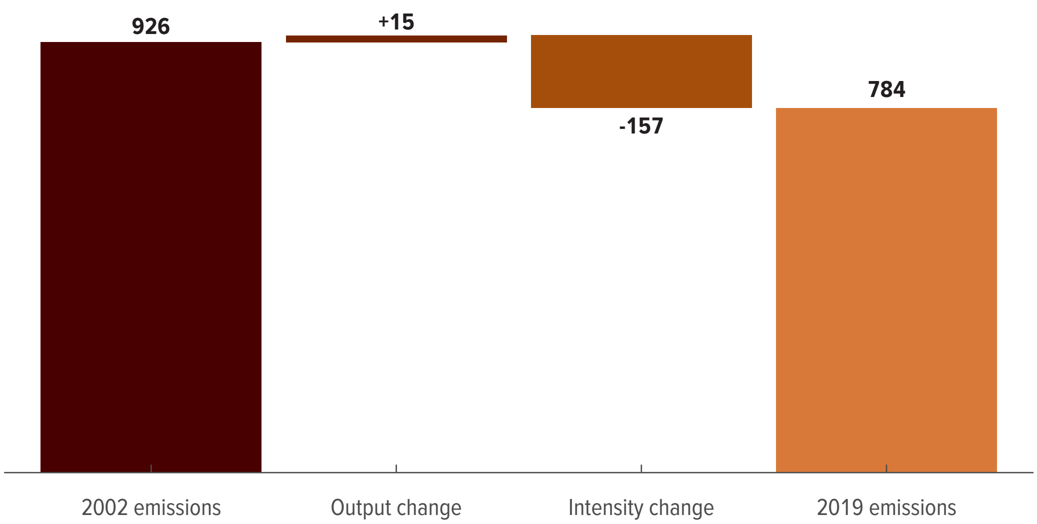
Two primary factors contribute to changes in manufacturing emissions. First, changes in economic output can increase or decrease emissions due to production-related activity. Second, changes in industries' **emissions intensity**, defined as the emissions released per real dollar of output, can increase or decrease emissions. CBO estimates that changes in output between 2002 and 2019 would have increased emissions, but a much larger change in emissions intensity caused total emissions from manufacturing to decrease.

CBO estimates that if emissions intensity had remained constant over that period, growth in output would have increased emissions by 15 MMT of CO_2e. Manufacturing output fell in 2020 and remained lower in 2021 than it was in 2019 because of the effects of the coronavirus pandemic. That decline in output was uncharacteristic of the years preceding it; for that reason, 2019 is used as the comparison year in the figure below.

If output in each industry in the manufacturing sector had remained constant between 2002 and 2019, changes in emissions intensity would have reduced emissions by 157 MMT of CO_2e. Those changes in intensity stemmed from multiple factors, including changes in fuel, technology, and the composition of industries' output. In the following sections, those factors are explained in detail.

Contributions to Changes in CO_2e Emissions From Manufacturing, 2002 to 2019

Millions of metric tons



In the absence of changes in emissions intensity, growth in economic output from 2002 to 2019 would have increased emissions from the manufacturing sector by 2 percent.

In the absence of changes in output, lower intensity would have decreased emissions by 17 percent.

The net effect of those factors was a 15 percent reduction in emissions.

Emissions Intensities of Individual Industries

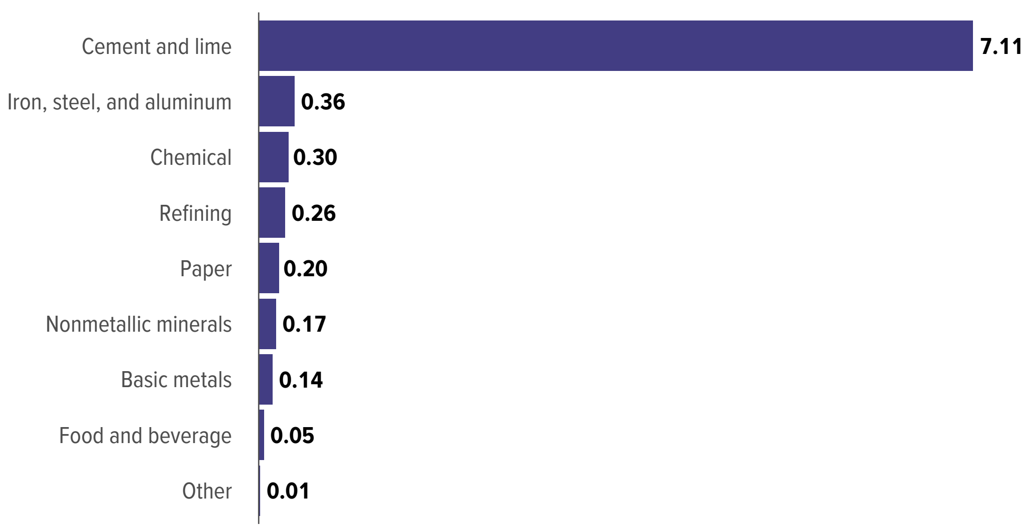
In 2021, the manufacturing sector released 765 MMT of CO_2e in direct emissions and produced goods valued at $6.2 trillion, meaning that, on average, the sector had an emissions intensity of 0.12 metric tons of CO_2e for every $1,000 of output.[7] But emissions intensities vary widely among industries. CBO estimates that the cement and lime industry has the highest emissions intensity, at more than 50 times the average for the sector, though it accounts for only 11 percent of the sector's emissions because of its small share of output.

The two manufacturing industries that produce the most emissions, the chemical and refining industries, have emissions intensities that are more than twice the average for the sector. Industries outside of the sector's top eight emitters include those that manufacture computers, transportation equipment, and heavy machinery. Together, those other industries (labeled "other" in the figure below) represent 47 percent of the output value from manufacturing but only 5 percent of emissions.

An industry's emissions intensity can determine how policies aimed at lowering emissions affect that industry. For example, a policy that imposed a price on emissions (such as a carbon tax) would increase costs for firms, and the higher a firm's emissions intensity, the greater those cost increases would be in percentage terms. Firms, in turn, would pass those increased costs on to consumers by raising the prices for their products.

CO_2e Emissions Intensity, by Manufacturing Industry, 2021

Metric tons per thousand dollars of output



The emissions intensity of an industry is calculated by dividing its emissions by the dollar value of its output.

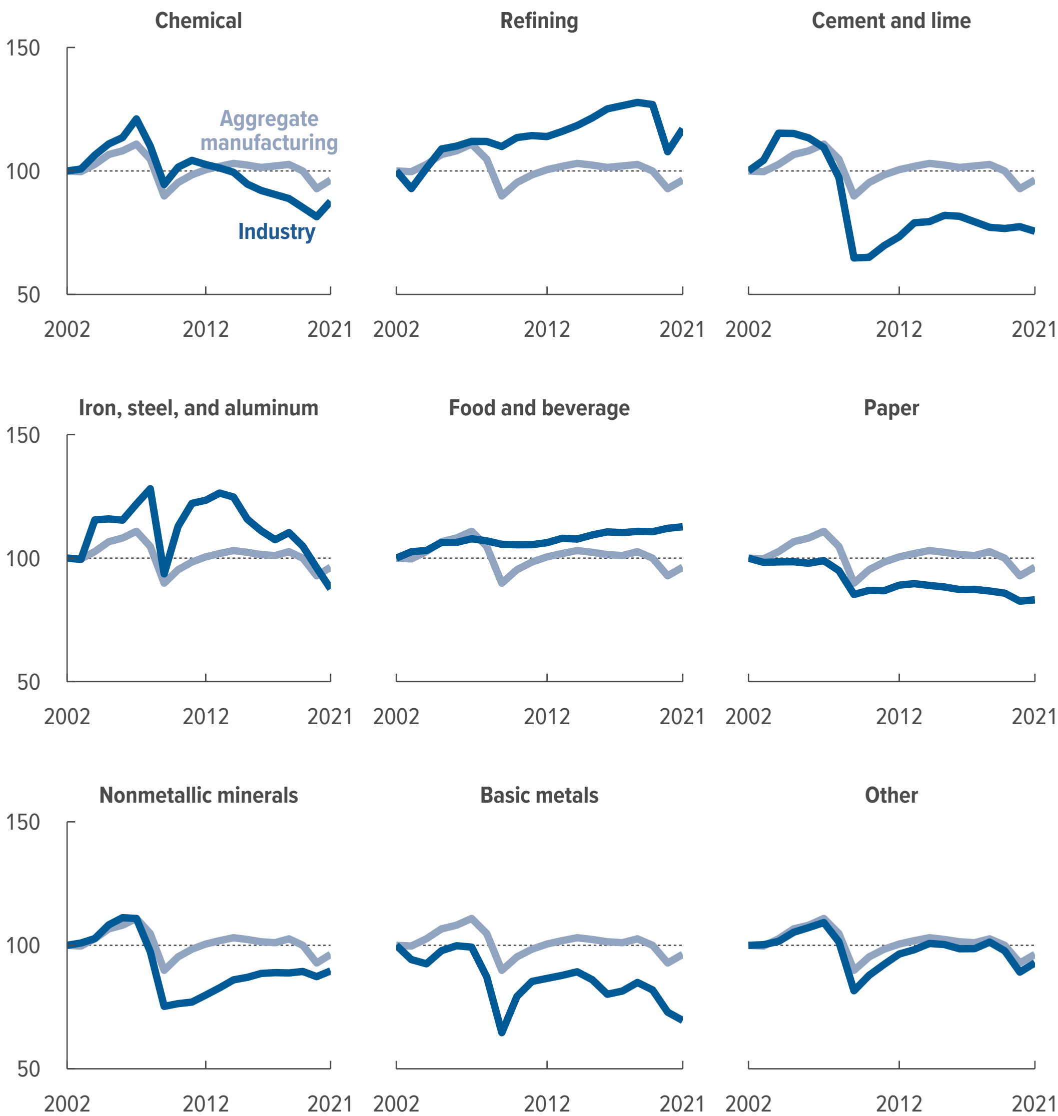
The cement and lime industry has the highest emissions intensity in the manufacturing sector. However, it accounted for only 11 percent of the sector's emissions in 2021.

Trends in Output

Between 2002 and 2021, real (inflation-adjusted) output decreased in all industries except for the refining industry and the food and beverage industry. The largest decline was in the cement and lime industry, which saw real output fall by 25 percent. Most decreases in output occurred during recession years.

Real Output, by Industry, 2002 to 2021

Percent in relation to 2002 value



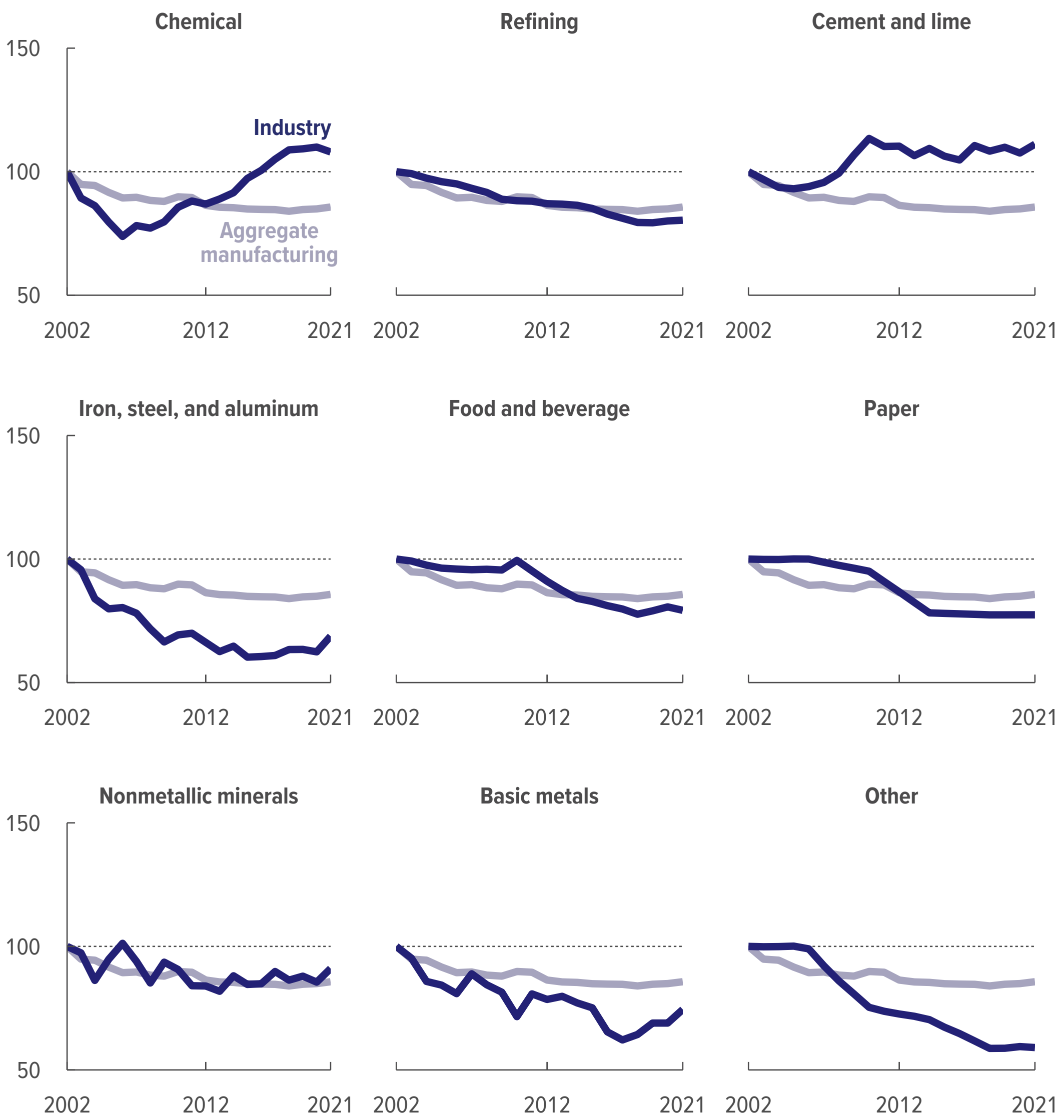
Output in most industries changed modestly between 2002 and 2021. In total, real output in the manufacturing sector declined by about 4 percent between 2002 and 2021.

Trends in Emissions Intensity

Between 2002 and 2021, emissions intensity decreased in all industries except for the chemical industry and the cement and lime industry. Emissions intensity increased in both of those industries because greater shares of their production were devoted to emissions-intensive output over time. The largest decline in emissions intensity among top-emitting industries was in the iron, steel, and aluminum industry.

CO_2e Emissions Intensity, by Industry, 2002 to 2021

Percent in relation to 2002 value



The aggregate emissions intensity of manufacturing decreased by 14 percent between 2002 and 2021.

The emissions intensity of the iron, steel, and aluminum industry decreased by 31 percent. By contrast, the emissions intensity of the chemical industry increased by 8 percent, and that of the cement and lime industry increased by 11 percent.

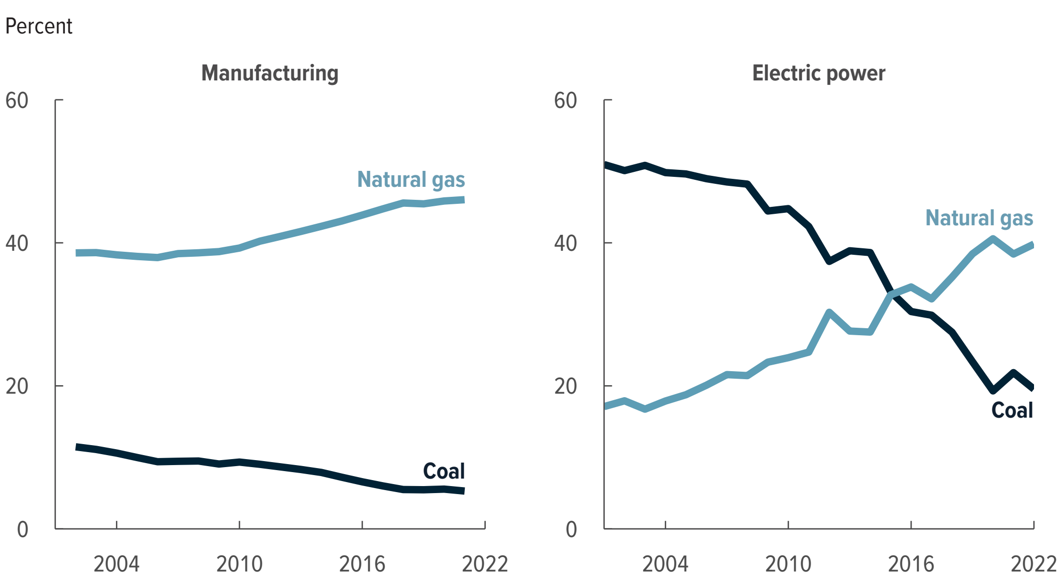
Changes in the Composition of Fuels in the Manufacturing and Electric Power Sectors

The manufacturing sector has used more natural gas than coal since at least 1990.[8] Since 2002, the share of coal in manufacturing's fuel use has fallen from 11 percent to 5 percent, while the natural gas share has grown from 39 percent to 46 percent. Because natural gas releases fewer emissions to generate the same amount of heat, the substitution of natural gas for coal has contributed to reductions in emissions. However, coal now makes up such a small share of the fuel used in manufacturing that further switching from coal to natural gas would achieve only minor additional reductions in emissions. Switching to electricity would achieve additional reductions only if the electricity was generated using non-emitting sources of energy, such as wind or solar power.

Reductions in coal use and associated emissions have been much more pronounced in the electric power sector. CO_2 emissions from the electric power sector have decreased by 36 percent since 2005—more than in any other sector. About two-thirds of that decrease in emissions was due to a shift from coal to natural gas. The remaining third was the result of substituting renewable energy sources for fossil fuels.[9]

Within manufacturing, substituting nonfuel inputs to production is another way of reducing emissions, as exemplified by the possibilities in cement production. Most emissions from cement production occur when limestone is heated to create clinker—the main component of cement. When limestone is heated, it releases CO_2. Those emissions can be reduced by replacing the limestone with materials such as fly ash, slag, silica fume, or natural pozzolans. However, the specific requirements for some uses of cement may limit the adoption of input substitutes.

Shares of Energy From Natural Gas and Coal in the Manufacturing and Electric Power Sectors



Because a much smaller share of energy comes from coal in manufacturing than in the electric power sector, the potential to reduce emissions by switching to natural gas is more limited in manufacturing.

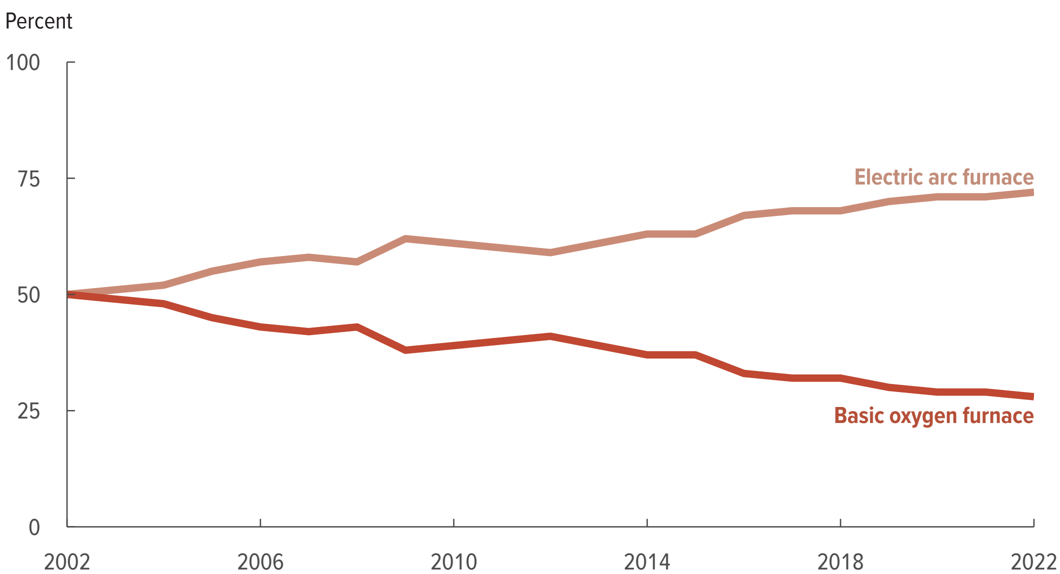
An Example of Technological Change: Iron and Steel Production

The manufacturing sector has reduced its emissions intensity by changing its production technologies. One example of such a change is the increased use of electric arc furnaces (EAFs) in steel production. During the 20th century, most iron and steel in the United States was produced with basic oxygen furnaces (BOFs). That process involves heating coal, iron ore, and coke (a fossil fuel product created from metallurgical coal) in a large furnace to create molten iron.

Over the past two decades, most iron and steel production has shifted to EAFs, which use a high-powered electrical current to melt down and re-form scrap iron and steel. Some EAFs can also create certain types of steel from iron ore through a process known as direct iron reduction; that process is more emissions intensive than using scrap but less emissions intensive than using a BOF. Accounting for the average emissions intensity of electric power generation in the United States, researchers estimate that EAFs emitted about one-third as much CO_2 per ton of steel as BOFs did in 2019.[10]

Some steel produced by EAFs is indistinguishable from that produced by BOFs, but certain applications require steel made by a particular process. Therefore, although EAFs have led to less energy consumption over time, there are limits to their future adoption.

Shares of Iron and Steel Produced With Electric Arc Furnaces and Basic Oxygen Furnaces



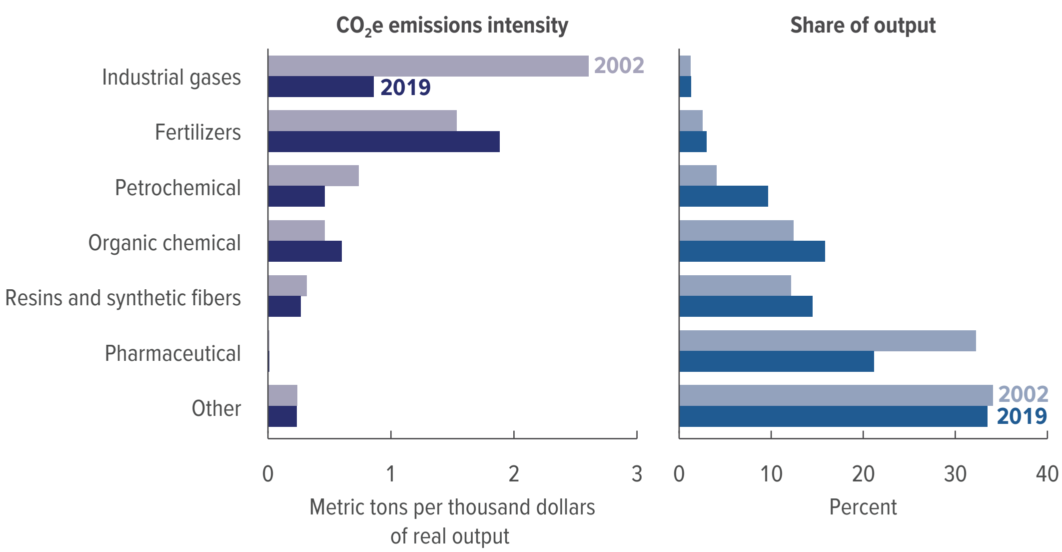
The iron and steel industry has substantially reduced its direct emissions and emissions intensity. Those reductions have primarily come from a shift toward using electric arc furnaces instead of basic oxygen furnaces.

An Example of Change in the Composition of Output: The Chemical Industry

Changes in the emissions intensity of manufacturing industries have also occurred because of changes in the composition of output within those industries. For example, the emissions intensity of the chemical industry increased from 2002 to 2021 because of a shift in output among chemical subindustries: Subindustries with lower-than-average emissions intensities (such as the pharmaceutical industry) decreased production, while subindustries with higher-than-average emissions intensities (such as the petrochemical industry) increased production.[11]

Differences in emissions intensity can exist even among individual plants that produce very similar goods. One study found that, on average, a high-energy-use plant uses nearly six times as much energy as a low-energy-use plant in the same industry to produce the same output.[12] Thus, even within narrowly defined industries, reallocation of output across products, production methods, and facilities can lead to changes in emissions intensities.

CO_2e Emissions Intensity and Share of Output Among Subindustries in the Chemical Industry



The increase in the chemical industry's emissions intensity largely reflected a decrease in the production of pharmaceuticals and an increase in the production of petrochemicals.

From 2002 to 2019, the share of output from the pharmaceutical industry shrank by 11 percentage points, whereas the share of output from the petrochemical industry grew by 6 percentage points.

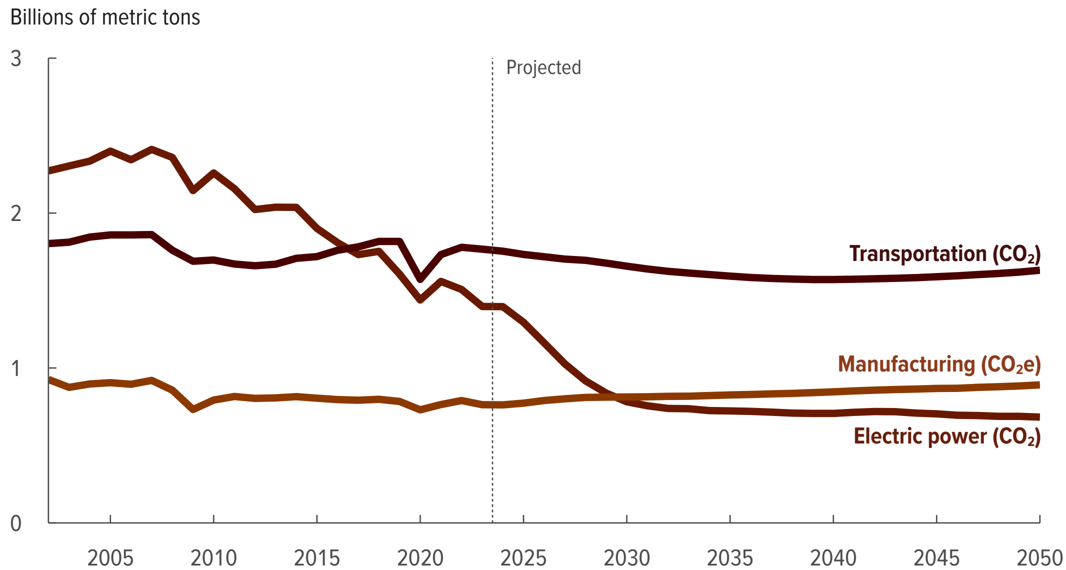
Projections of Emissions From Manufacturing

In CBO's estimation, if energy use followed paths projected by the Energy Information Administration (EIA) in its *Annual Energy Outlook 2023*, direct greenhouse gas emissions from the manufacturing sector would increase by 17 percent between 2024 and 2050.[13] By contrast, EIA projects that CO_2 emissions will decrease by 51 percent in the electric power sector and by 7 percent in the transportation sector over that period. In the figure below, only CO_2 emissions are included for those sectors. Other greenhouse gases accounted for an additional 3 percent of their emissions, in CO_2-equivalent terms, in 2021.

The projected rise in emissions from manufacturing would reverse the historical trend of decreasing emissions in the sector. Although emissions are projected to decline in some industries (such as the iron and steel industry), CBO projects that growth in output from other emissions-intensive industries (such as the chemical and refining industries) will lead to a net increase in emissions from manufacturing.

Projections of emissions reflect the relative cost of and incentives for abatement. Emissions abatement in the manufacturing sector is currently infeasible or cost-prohibitive in many cases. For example, reducing emissions in many industries can require new or costly technology (such as carbon capture) and fuels (such as hydrogen). In the electric power sector, by contrast, solar- and wind-powered electricity generation are relatively mature technologies, and significant financial incentives encourage their adoption. And in the transportation sector, there are financial incentives to encourage the adoption of electric vehicles.[14]

Projected Emissions, by Economic Sector



Direct emissions from manufacturing are projected to increase between 2024 and 2050. By 2030, in CBO's estimation, direct emissions from manufacturing will exceed EIA's projection of emissions from the electric power sector.

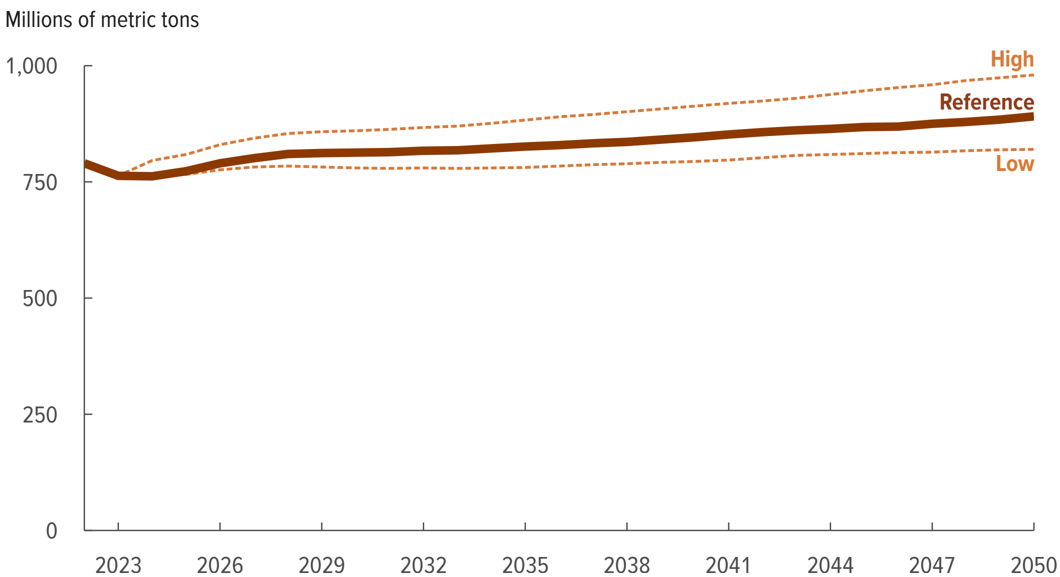
Uncertainty About Economic Growth

Economic growth that is faster or slower than projected could cause emissions to be higher or lower than projected. To show how uncertainty about economic growth affects projections of emissions, CBO has compared the high- and low-economic-growth cases from EIA's *Annual Energy Outlook* with EIA's reference case. The reference case is a baseline scenario of how energy markets would operate through 2050 if current laws and regulations remained unchanged and trends in technological growth persisted. From 2024 to 2050, the reference case reflects average real (inflation-adjusted) growth in gross domestic product (GDP) of 1.9 percent, which is slightly higher than the average rate of 1.7 percent that CBO projects.[15]

The high-economic-growth case from the *Annual Energy Outlook* exhibits faster GDP growth, more capital spending, and faster factor productivity growth than the reference case. (Growth of factor productivity means that firms can make the same amount of output with less labor or capital.) The low-economic-growth case exhibits slower real GDP growth, less capital spending, and slower factor productivity growth than the reference case. By 2050, real GDP in the high- and low-growth cases would be 13 percent higher and 12 percent lower, respectively, than in the reference case.

Those differences would result in more or less output, respectively, from manufacturing. For example, EIA projects that in 2050, output from the iron and steel industry would be $15 billion greater in the high-economic-growth case and $16 billion less in the low-economic-growth case than in the reference case.

Projected CO_2e Emissions From Manufacturing, by Economic Growth Scenario



In CBO's estimation, economic growth consistent with EIA's reference case would lead to a 17 percent increase in emissions from manufacturing from 2024 to 2050.

Those emissions would be 10 percent higher and 8 percent lower in 2050, respectively, if economic growth was consistent with EIA's high- and low-economic-growth cases.

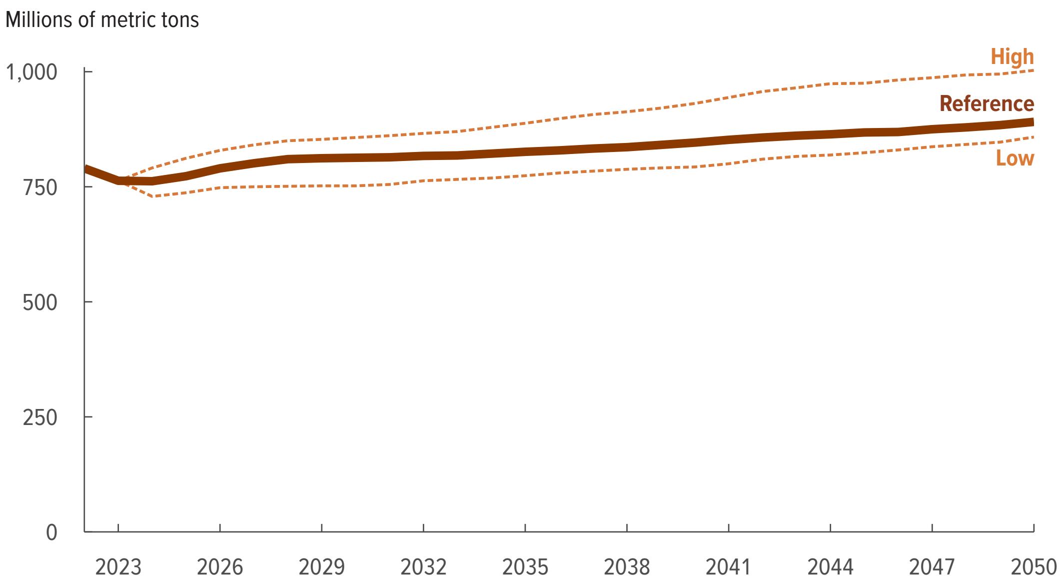
Uncertainty About Supplies of Oil and Gas

Emissions from manufacturing reflect supplies of oil and natural gas because those fuels are important feedstocks for the chemical and refining industries and because their supply affects overall economic growth. If oil and gas are more abundant, their prices will be lower, and firms will consume more of them—both as fuels for combustion and as feedstocks for production.

To demonstrate how uncertainty about oil and gas supplies affects projections of emissions, CBO uses the high- and low-supply cases from EIA's *Annual Energy Outlook*. In the high-supply case, U.S. production from certain types of oil and gas wells is 50 percent higher than in the reference case, newly discovered resources offshore and in Alaska are 50 percent greater, and the rate of technological growth in the oil and gas industry is 50 percent higher. In the low-supply case, those variables are 50 percent lower than in the reference case. As a result, by 2050, oil and gas supplies would be 25 percent higher in the high-supply case and 37 percent lower in the low-supply case than they are in the reference case.

Those differences lead to differences in economic growth. By 2050, GDP is 3.5 percent higher in the high-supply case, and 0.5 percent lower in the low-supply case, than in the reference case.

Projected CO_2e Emissions From Manufacturing, by Oil and Gas Supply Scenario



Using EIA's illustrative scenarios of higher and lower future supplies of oil and gas, CBO projects that emissions from manufacturing in 2050 would be about 13 percent higher in the high-supply case and 4 percent lower in the low-supply case than in EIA's reference case.

Uncertainty About Changes in Technology

Technological changes could affect future emissions from the manufacturing sector. Three technologies in particular may have large effects on those emissions: electrification, carbon capture, and hydrogen fuel production.

Electrification. Electrification of manufacturing processes can reduce combustion emissions. The ability of producers to electrify production depends on the physical properties of the raw materials, the production process, and the availability of electricity. Engineering studies have shown that electrical processes can supply the high temperatures required for most production processes. However, those processes require large amounts of electricity that are not available to all plants, and building and operating plants with an adequate supply of electricity may be prohibitively costly.[16] Moreover, because electrification shifts emissions to the electric power sector, it can increase indirect emissions even as it reduces direct emissions.

Carbon Capture. Carbon capture and storage (CCS) has existed for decades. The technology is expensive: For example, the estimated capital cost of building a new power plant with carbon capture capabilities is 40 percent to almost 100 percent higher, per kilowatt of plant capacity, than the capital cost of a representative conventional power plant. In the United States, CCS at commercial scale is essentially limited to chemical manufacturing and natural gas processing, for which the cost of using the technology is relatively low. The current annual capacity for carbon capture at manufacturing facilities is 7 million metric tons of CO_2, which is less than 1 percent of total direct emissions from the sector.

Another challenge to greater deployment of CCS in manufacturing is the expense of building infrastructure to transport and store the captured CO_2. Since 2008, the federal government has supported the use of CCS through the 45Q tax credit, which gives firms a tax rebate based on the amount of CO_2 they successfully capture and store. The maximum amount of that rebate was increased by 70 percent in the 2022 reconciliation act.[17]

Hydrogen Fuel Production. Hydrogen combustion could provide the high heat needed for many industrial processes, and hydrogen has properties similar to those of natural gas, which is currently in wide use. Hydrogen's effect on economywide emissions would depend on how the hydrogen was produced. Currently, most hydrogen is produced from fossil fuel feedstocks, and CO_2 is released as a by-product during production. It is possible to create hydrogen without fossil fuel feedstocks through electrolysis, which uses electricity to split water molecules into hydrogen and oxygen. However, that process is expensive and requires large amounts of electricity. When the electricity for electrolysis is generated using fossil fuels, producing hydrogen with water can create more emissions than using fossil fuel feedstocks.

Hydrogen is still more expensive than other, similar fuels. Increases in infrastructure for transporting hydrogen and decreases in its production costs will be needed for hydrogen to be cost-competitive with fossil fuels.

1. "Total greenhouse gas emissions" refers to gross emissions, or the total amount of greenhouse gases emitted into the atmosphere from sources in the United States. Some of those carbon emissions are absorbed by forests and soil. In 2021, gross greenhouse gas emissions from the United States totaled 6,340 million metric tons (MMT) of carbon dioxide equivalent (CO_2e), whereas net greenhouse gas emissions totaled 5,586 MMT of CO_2e. Manufacturing accounted for 14 percent of net emissions.

2. For more information on emissions in the electric power sector, see Congressional Budget Office, *Emissions of Carbon Dioxide in the Electric Power Sector* (December 2022), www.cbo.gov/publication/58419. For more information on emissions in the transportation sector, see Congressional Budget Office, *Emissions of Carbon Dioxide in the Transportation Sector* (December 2022), www.cbo.gov/publication/58566.

3. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc.

4. Greenhouse gases differ in their contribution to warming per physical unit of gas. For simplicity, they are often measured in metric tons of CO_2e—quantities of emissions that, over a period of years, contribute to the greenhouse effect by as much as a metric ton of CO_2. For that period, the Environmental Protection Agency typically uses a century, so this report does as well. See Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc.

5. The "other" category in the figure comprises waste gases, waste oils, wood products, hydrocarbon gas liquids (such as propane or butane), and black liquor, which is a combustible residue from making paper pulp.

6. Renewable portfolio standards are regulatory policies implemented by governments at the state and national level to promote the use of renewable energy sources in the production of electricity. Those standards mandate that a certain percentage of energy generated within a specified jurisdiction must come from renewable sources such as wind or solar power.

7. To calculate the emissions intensity of the manufacturing sector, CBO used the total value of shipments as the measure of output. When calculating the contribution of output from manufacturing to gross domestic product, CBO used a value-added measure that removes intermediate consumption to eliminate double counting. The value added from the manufacturing sector in 2021 was $2.4 trillion, according to the Bureau of Economic Analysis. See Bureau of Economic Analysis, "Value Added by Industry" (September 28, 2023), https://tinyurl.com/2ys3txzh.

8. Sharat Ganapati, Joseph S. Shapiro, and Reed Walker, "Energy Cost Pass-Through in U.S. Manufacturing: Estimates and Implications for Carbon Taxes," *American Economic Journal: Applied Economics*, vol. 12, no. 2 (April 2020), pp. 303–342, https://doi.org/10.1257/app.20180474.

9. See Congressional Budget Office, *Emissions of Carbon Dioxide in the Electric Power Sector* (December 2022), www.cbo.gov/publication/58419.

10. Ali Hasanbeigi, *Steel Climate Impact: An International Benchmarking of Energy and CO_2 Intensities* (Global Efficiency Intelligence, April 2022), https://tinyurl.com/5n83rjm7.

11. Examples of petrochemical products include ethylene, propylene, and butylene.

12. Eva Lyubich, Joseph Shapiro, and Reed Walker, "Regulating Mismeasured Pollution: Implications of Firm Heterogeneity for Environmental Policy," *AEA Papers and Proceedings*, vol. 108 (May 2018), pp. 136–142, https://doi.org/10.1257/pandp.20181089.

13. Energy Information Administration, *Annual Energy Outlook 2023* (March 2023), www.eia.gov/outlooks/aeo.

14. CBO projects greater growth in the sales of electric vehicles than EIA does in its 2023 *Annual Energy Outlook*. That difference could result in a different emissions pathway for the transportation sector than the one shown here. See David Austin, *Modeling the Demand for Electric Vehicles and the Supply of Charging Stations in the United States,* Working Paper 2023-06 (Congressional Budget Office, September 2023), www.cbo.gov/publication/58964.

15. Congressional Budget Office, "Data Underlying Figures and Tables" (supplemental material for *The 2023 Long-Term Budget Outlook,* June 2023), www.cbo.gov/publication/59014.

16. Innovation for Cool Earth Forum, *ICEF Industrial Heat Decarbonization Roadmap* (December 2019), www.icef.go.jp/roadmap.

17. For more information on carbon capture, see Congressional Budget Office, *Carbon Capture and Storage in the United States* (December 2023), www.cbo.gov/publication/59345.

Appendix A: Analytical Methods

Unless otherwise noted, all the data in this report come from a database that was constructed by CBO. To construct that database, CBO used publicly available data from several sources.

Estimating Energy Use

CBO obtained data on energy use from the Manufacturing Energy Consumption Survey (MECS), which is managed by the Energy Information Administration (EIA). The MECS is administered to about 15,000 establishments drawn from a nationally representative sample that covers about 98 percent of the manufacturing payroll. The MECS is collected every four years, and EIA makes the data publicly available two to three years after the collection year. The energy use data from the MECS are reported in British thermal units (Btus) and categorized in many ways, including by fuel type, region, and industry code according to the North American Industry Classification System (NAICS).

CBO used NAICS codes to connect data between years and create a longitudinal dataset. The MECS started using NAICS codes in 2002, which served as the first year of CBO's dataset. The MECS data across all periods contain 94 industries; after CBO removed industries that were not covered by all years of the survey, 53 remained. Data on energy use for each year of the survey were drawn from Tables 3-2 and 3-5 of the publicly released version of the MECS.[1]

Estimating Emissions

To estimate combustion emissions, CBO used carbon coefficients from EIA, which measure the amount of carbon dioxide released per Btu upon the combustion of a specific fuel.[2] For fuel types that were not covered by EIA's carbon coefficients, CBO used information from the Department of Energy's reports and the Environmental Protection Agency's (EPA's) Inventory of Greenhouse Gas Emissions and Sinks (GHGI).

CBO used Table 4-2 of the GHGI to estimate process emissions for each industry. The GHGI contains descriptions of industrial processes, but those descriptions are not directly linked to NAICS codes. CBO used plant-level data from EPA's Facility Level Information on Greenhouse Gases Tool (FLIGHT) to link most of those processes to NAICS codes. Industrial processes in the GHGI that had no corresponding information in FLIGHT were manually assigned NAICS codes on the basis of their descriptions in the GHGI.

CBO merged those emissions data with economic data categorized by NAICS codes. To estimate real (inflation-adjusted) output, CBO used shipment data from the Annual Survey of Manufacturers (ASM), managed by the Census Bureau, and deflated those nominal values using price indexes from the Bureau of Labor Statistics. The only data not available annually were the MECS data, which contained information on fuel use. The matched energy and output data constituted the historical data for the years 2002, 2006, 2010, 2014, and 2018. CBO used estimates of output from the ASM to impute fuel use for the years between those available in the MECS.

CBO calculated the energy intensity of each fuel—that is, its energy use in Btus per dollar of real output—for each year of the MECS and filled in missing years by linearly connecting the available values for each fuel. For example, if a fuel's energy intensity was 1 in 2006 and 5 in 2010, its imputed energy intensity for 2008 would be 3. For years after 2018, the last year of the MECS data, energy intensities were held constant.

After energy intensities were imputed for each fuel, industry, and year, CBO multiplied energy intensity by total output to obtain total energy use for each fuel, industry, and year. CBO then used EIA's carbon coefficients to estimate combustion emissions from fuel use.

1. See Energy Information Administration, "2018 MECS Survey Data" (December 2021), www.eia.gov/consumption/manufacturing/data/2018.

2. Specifically, CBO used the "Detailed Factors" spreadsheet from EIA's Carbon Dioxide Emissions Coefficients, available at www.eia.gov/environment/emissions/co2_vol_mass.php.

Projecting Emissions

To form projections of emissions, CBO used data from EIA's *Annual Energy Outlook 2023* (*AEO*) and matched projections of energy use to the MECS data by fuel type for each industry. That information came from Tables 24 through 34, which present projections of industrial energy consumption for 10 industry groups.[3] Because the industry groups in the *AEO* did not match those in the MECS, CBO used growth rates projected in the *AEO* for each fuel type in each industry group. Those growth rates were then used to forecast growth in energy use from 2021, the last year covered by the dataset. After energy consumption was adjusted according to rates projected in the *AEO*, estimates of combustion emissions were calculated using the same carbon coefficients used to estimate historical emissions.

CBO created projections of process emissions using growth rates of those emissions from the *AEO* when such rates were available; when they were not, process emissions were projected to have the same growth rate as real output for each industry.

3. See Energy Information Administration, "Reference Case Projections Tables" (March 16, 2023), www.eia.gov/outlooks/aeo/tables_ref.php.

Appendix B: Data Sources for Figures

Emissions of CO_2 From Fuel Combustion, by Economic Sector, 2021

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Combustion and Process Emissions of CO_2e From Manufacturing, by Industry, 2021

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Energy Sources in Manufacturing

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Direct Emissions of CO_2e From Manufacturing

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Contributions to Changes in CO_2e Emissions From Manufacturing, 2002 to 2019

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

CO_2e Emissions Intensity, by Manufacturing Industry, 2021

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Real Output, by Industry, 2002 to 2021

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

CO_2e Emissions Intensity, by Industry, 2002 to 2021

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions*

Coefficients (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Shares of Energy From Natural Gas and Coal in the Manufacturing and Electric Power Sectors

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Congressional Budget Office, *Emissions of Carbon Dioxide in the Electric Power Sector* (December 2022), p. 6, www.cbo.gov/publication/58419; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Shares of Iron and Steel Produced With Electric Arc Furnaces and Basic Oxygen Furnaces

U.S. Geological Survey, *Mineral Commodity Summaries for Iron and Steel* (2002–2021), https://tinyurl.com/bdhhmshs.

CO_2e Emissions Intensity and Share of Output Among Subindustries in the Chemical Industry

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Projected Emissions, by Economic Sector

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Annual Energy Outlook 2023* (March 2023), www.eia.gov/outlooks/aeo; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing*

Energy and Carbon Footprints (2018 MECS) (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Projected CO_2e Emissions From Manufacturing, by Economic Growth Scenario

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Annual Energy Outlook 2023* (March 2023), www.eia.gov/outlooks/aeo; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

Projected CO_2e Emissions From Manufacturing, by Oil and Gas Supply Scenario

Congressional Budget Office, using data from Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*, EPA 430-R-23-002 (April 2023), https://tinyurl.com/485j9nbc; Energy Information Administration, *Annual Energy Outlook 2023* (March 2023), www.eia.gov/outlooks/aeo; Energy Information Administration, *Carbon Dioxide Emissions Coefficients* (October 2022), www.eia.gov/environment/emissions/co2_vol_mass.php; Department of Energy, *Manufacturing Energy and Carbon Footprints (2018 MECS)* (December 2021), https://tinyurl.com/msupeay2; Census Bureau, *Annual Survey of Manufactures* (2002–2016, 2018–2021), www.census.gov/programs-surveys/asm.html; Bureau of Labor Statistics, *Producer Price Index by Industry* (2002–2021), www.bls.gov/pPI; Environmental Protection Agency, *Facility Level Information on Greenhouse Gases Tool* (2010–2020), www.epa.gov/ghgreporting; and Energy Information Administration, *Manufacturing Energy Consumption Survey* (2002, 2010, 2014, 2018), www.eia.gov/consumption/manufacturing.

About This Document

This report was prepared to enhance the transparency of the work of the Congressional Budget Office. In keeping with the CBO's mandate to provide objective, impartial analysis, the report makes no recommendations.

Austin Castellanos and Evan Herrnstadt prepared the report with guidance from Nicholas Chase and Joseph Kile. Jared Jageler fact-checked the report. David Adler, David Austin, Ann Futrell, Ron Gecan, Aaron Krupkin, and Nathan Musick provided comments. Eva Lyubich of the Census Bureau and Tom Lorenz and Nicholas Skarzynski, both of the Energy Information Administration, also commented on earlier drafts. Tom Lorenz, Nicholas Skarzynski, and Kevin Nakolan of the Energy Information Administration provided guidance on the data. The assistance of external reviewers implies no responsibility for the final product; that responsibility rests solely with CBO.

Jeffrey Kling and Robert Sunshine reviewed the report. Christine Browne edited it, and R. L. Rebach created the graphics, designed the cover, and prepared the text for publication. The report is available at www.cbo.gov/publication/59695.

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

Phillip L. Swagel
Director
February 2024