

Executive Summary

Overview

U.S. Anthropogenic Greenhouse Gas Emissions, 1990-2001

	Carbon Equivalent
Estimated 2001 Emissions (Million Metric Tons)	1,883.3
Change Compared to 2000 (Million Metric Tons)	-23.7
Change from 2000 (Percent)	-1.2%
Change Compared to 1990 (Million Metric Tons)	200.8
Change from 1990 (Percent)	11.9%
Average Annual Increase, 1990-2001 (Percent)	1.0%

U.S. emissions of greenhouse gases in 2001 totaled 1,883 million metric tons carbon equivalent, 1.2 percent less than in 2000 (1,907 million metric tons carbon equivalent). The 1.2-percent decrease from 2000 to 2001 is the largest percentage annual decline in total U.S. greenhouse gas emissions during the 1990 to 2001 time frame. The only other year since 1990 in which total emissions have declined is 1991, when emissions fell by 0.6 percent. U.S. greenhouse gas emissions have averaged 1.0-percent annual growth since 1990. The decline in

U.S. greenhouse gas emissions can be attributed to the combination of the following factors: a reduction in overall economic growth from 3.8 percent in 2000 to 0.3 percent in 2001; a 4.4-percent reduction in manufacturing output that lowered industrial emissions; warmer winter weather that decreased the demand for heating fuels; and a drop in electricity demand and coal-fired power generation that reduced emissions from electricity generation.

U.S. greenhouse gas emissions in 2001 were 11.9 percent higher than 1990 emissions (1,683 million metric tons carbon equivalent). Since 1990, U.S. emissions have increased more slowly than the average annual growth in population (1.2 percent), primary energy consumption (1.2 percent), electric power generation (1.9 percent), or gross domestic product (2.9 percent).

Table ES1 shows trends in emissions of the principal greenhouse gases, measured in million metric tons of gas. In Table ES2, the value shown for each gas is weighted by its global warming potential (GWP), which is a measure of "radiative forcing." The GWP concept, developed by the Intergovernmental Panel on Climate Change (IPCC), provides a comparative measure of the impacts of different greenhouse gases on global warming relative to the global warming potential of carbon dioxide.¹

In 2001, the IPCC Working Group I released its Third Assessment Report, *Climate Change 2001: The Scientific Basis*.² Among other things, the Third Assessment Report updated a number of the GWP estimates that

Table ES1. Summary of Estimated U.S. Emissions of Greenhouse Gases, 1990-2001
(Million Metric Tons of Gas)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Carbon Dioxide ^R	5,002.8	4,960.6	5,063.9	5,175.4	5,260.2	5,320.9	5,505.0	5,573.0	5,596.4	5,672.8	5,855.1	5,788.5
Methane	31.7	31.9	31.9	31.0	31.1	31.1	29.9	29.5	29.0	28.7	28.3	28.0
Nitrous Oxide	1.2	1.2	1.2	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2
HFCs, PFCs, and SF ₆	*	*	*	*	*	*	*	*	*	*	*	*

^REstimates of energy-related carbon dioxide emissions have been revised as part of an agency-wide adjustment to energy consumption data. See text box on page 27 for detailed explanation.

*Less than 0.05 million metric tons of gas.

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001).

Source: Estimates presented in this report.

¹See "Units for Measuring Greenhouse Gases" on page 2, and Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

²Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

Table ES2. U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990-2001
(Million Metric Tons Carbon Equivalent)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Carbon Dioxide ^R	1,364	1,353	1,381	1,411	1,435	1,451	1,501	1,520	1,526	1,547	1,597	1,579
Methane.	199	200	200	194	195	195	188	185	182	180	178	176
Nitrous Oxide.	94	96	98	99	106	102	101	99	99	100	98	97
HFCs, PFCs, and SF ₆	25	23	24	25	25	27	31	32	35	34	34	31
Total	1,683	1,673	1,703	1,730	1,760	1,775	1,821	1,836	1,842	1,861	1,907	1,883

^REstimates of energy-related carbon dioxide emissions have been revised as part of an agency-wide adjustment to energy consumption data and sectoral allocations.

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2000).

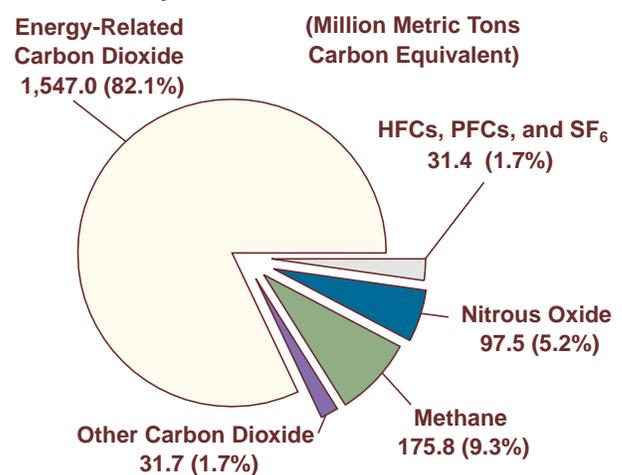
Sources: **Emissions:** Estimates presented in this report. **Global Warming Potentials:** Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), pp. 38 and 388-389.

appeared in the IPCC's Second Assessment Report.³ The GWPs published in the Third Assessment Report were used for the calculation of carbon-equivalent emissions for this report. For a discussion of GWPs and a comparison of U.S. carbon-equivalent emissions calculated using the GWPs from the IPCC's Third and Second Assessment Reports, see Chapter 1, page 12. Generally, total U.S. carbon equivalent emissions are 0.8 percent higher when the GWPs from the Third Assessment Report are used.

During 2001, 82.1 percent of total U.S. greenhouse gas emissions consisted of carbon dioxide from the combustion of fossil fuels such as coal, petroleum, and natural gas (after adjustments for U.S. territories and international bunker fuels). U.S. emissions trends are driven largely by trends in fossil energy consumption. In recent years, national energy consumption, like emissions, has grown relatively slowly, with year-to-year deviations from trend growth caused by weather-related phenomena, fluctuations in business cycles, changes in the fuel mix for electric power generation, and developments in domestic and international energy markets.

Other 2001 U.S. greenhouse gas emissions include carbon dioxide from non-combustion sources (1.7 percent of total U.S. greenhouse gas emissions), methane (9.3 percent), nitrous oxide (5.2 percent), and other gases (1.7 percent) (Figure ES1). Methane and nitrous oxide emissions are caused by the biological decomposition of various waste streams and fertilizer, fugitive emissions from chemical processes, fossil fuel production and combustion, and many smaller sources. The other gases include hydrofluorocarbons (HFCs), used primarily as refrigerants; perfluorocarbons (PFCs), released as fugitive emissions from aluminum smelting and also used in semiconductor manufacture; and sulfur hexafluoride (SF₆), used as an insulator in utility-scale electrical equipment.

Figure ES1. U.S. Greenhouse Gas Emissions by Gas, 2001



Source: Table ES2 and Table 4 in this report.

This report, required by Section 1605(a) of the Energy Policy Act of 1992, provides estimates of U.S. emissions of greenhouse gases, as well as information on the methods used to develop the estimates. The estimates are based on activity data and applied emissions factors, not on measured or metered emissions monitoring.

Carbon Dioxide

The preliminary estimate of U.S. carbon dioxide emissions from both energy consumption and industrial processes in 2001 is 1,579 million metric tons carbon equivalent, which is 1.1 percent lower than in 2000 and accounts for 84 percent of total U.S. greenhouse gas emissions. The 1.1-percent decrease in carbon dioxide emissions in 2001 is the largest annual decline of the 1990 to 2001 period. A 0.8-percent decline in 1991 was the only other annual decrease in carbon dioxide emissions during the period. U.S. carbon dioxide emissions have

³Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996).

grown by an average of 1.3 percent annually since 1990. Although short-term changes in carbon dioxide emissions can result from temporary variations in weather, power generation fuel mixes, and the economy, in the longer term their growth is driven by population, income, and consumer choices of energy-using equipment, as well as the “carbon intensity” of energy use (carbon dioxide emissions per unit of energy consumed).

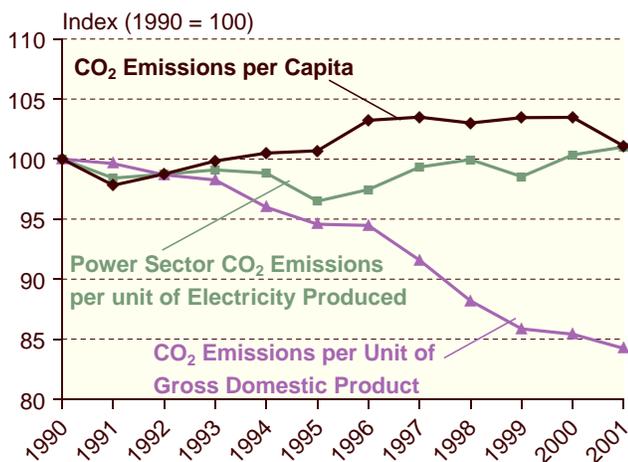
Figure ES2 shows recent trends in some common indexes used to measure the carbon intensity of the U.S. economy. Carbon dioxide emissions per unit of GDP have continued to fall relative to 1990; this measure is now 15.8 percent lower than in 1990. Carbon dioxide emissions per capita, after rising to 3.5 percent above the 1990 level in 1999 and 2000, fell in 2001 to 1.1 percent above the 1990 level. The combination of increasing population growth and rising carbon dioxide emissions per capita resulted in increased aggregate carbon dioxide emissions per year from 1990 through 2000 (a total increase of 17.0 percent). The drop in per capita emissions in 2001 brought the increase since 1990 down to 15.7 percent. Carbon dioxide emissions per unit of net electricity generation increased by 0.6 percent in 2001 from the 2000 level. Although coal-fired generation fell more than other sources of fossil-fuel-generated electric power, increases in emissions from oil- and natural-gas-fired generators offset the decrease. Because oil-fired generators often are less efficient than those that use other fuels, they produce more emissions per unit of

electricity produced. Declines in two of these indexes reflect an economy that was less carbon-intensive in 2001 than in 2000.

Carbon dioxide emissions from the U.S. electric power sector (which includes utilities, independent power producers, and combined heat and power facilities whose primary business is the production and sale of electricity) in 2001 are estimated at 611.7 million metric tons carbon equivalent, 1.5 percent lower than the 2000 level of 621.2 million metric tons carbon equivalent.⁴ The 2001 decrease can be attributed largely to a 2.2-percent drop in total electricity generation. A 2.6-percent decline in carbon dioxide emissions from coal combustion indicates that the most carbon-intensive form of power generation fell even more than total generation. Also contributing to the decline was a 2.0-percent increase in generation from nuclear fuel, which produces no carbon dioxide emissions.

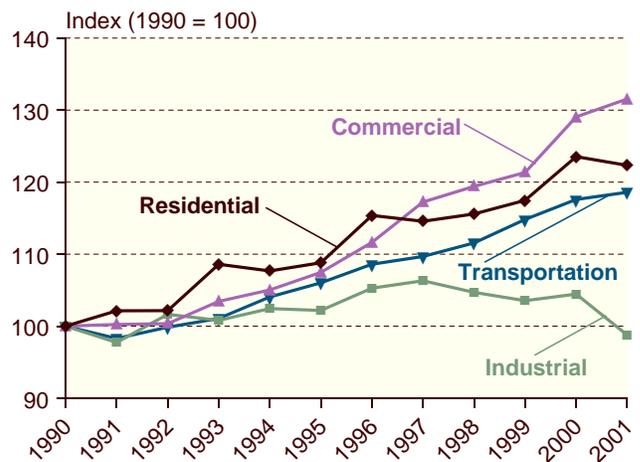
Figure ES3 illustrates trends in carbon dioxide emissions by energy consumption sector. In general, with the exception of the industrial sector, emissions have increased steadily at the sectoral level since 1990. An exception to the general upward trend was 1990-1991, when economic recession and higher oil prices following the Iraqi invasion of Kuwait led to downturns in both the transportation and industrial sectors that were enough to produce a 0.9-percent decrease in national energy-related carbon dioxide emissions in 1991. Average annual growth rates in carbon dioxide emissions by sector during the 1990-2001 period were 2.5 percent for the commercial sector, 1.8 percent for the residential

Figure ES2. Carbon Dioxide Emissions Intensity of U.S. Gross Domestic Product, Population, and Electricity Production, 1990-2001



Sources: Estimates presented in this report.

Figure ES3. U.S. Carbon Dioxide Emissions by Sector, 1990-2001



Sources: Estimates presented in this report.

⁴As described in detail in Chapter 2, the Energy Information Administration (EIA) has recently completed a reorganization of its electric power data systems to provide better accounting of fuel use, electricity generation, emissions, and other information from the U.S. electric power industry, which has undergone significant structural changes over the past decade. The data reorganization has led to revisions in EIA’s historical data on fuel use for electricity generation, with corresponding revisions in the 1990-2000 estimates of energy-related carbon dioxide emissions, total greenhouse gas emissions, sector-specific emissions, and emissions by fuel type.

sector, and 1.6 percent for the transportation sector. For the industrial sector, however, carbon dioxide emissions have dipped below their 1990 level. Industrial sector carbon dioxide emissions, which are relatively sensitive to economic fluctuations, declined by 2.3 percent in 1991 during the economic recession, dipped again in 1998 in the wake of the Asian economic slowdown, and once again fell in 2001 as industrial output fell by 4.4 percent.

In the residential sector, total carbon dioxide emissions were down by 1.0 percent, from 318.1 million metric tons carbon equivalent in 2000 to 314.9 million metric tons in 2001. The decrease is attributed mainly to a 3.5-percent drop in natural gas use due to warmer weather that reduced heating degree-days by 5.9 percent. Emissions attributable to purchased electricity also fell by 0.1 percent, which also contributed to the overall decline in residential carbon dioxide emissions. Since 1990, residential carbon dioxide emissions have grown by an average of 1.8 percent annually.

Carbon dioxide emissions in the commercial sector increased by 1.9 percent, from 274.4 million metric tons carbon equivalent in 2000 to 279.7 million metric tons in 2001. Emissions attributable to purchased electricity increased by 2.3 percent, from 210.5 million metric tons in 2000 to 215.4 million metric tons in 2001. Carbon dioxide emissions from the combustion of fossil fuels in the commercial sector, primarily natural gas, rose from 63.9 million metric tons in 2000 to 64.3 million metric tons in 2001, a 0.7-percent increase. The commercial sector increase in emissions was driven by strong commercial development in 2001; however, the 1.9-percent growth in emissions during 2001 was less than the 2.5-percent average annual growth in emissions from the commercial sector since 1990.

Energy-related carbon dioxide emissions in the industrial sector in 2001 are estimated at 452.4 million metric tons carbon equivalent, which is approximately equal to the level of emissions in 1991 and 1992. After peaking in 1997, industrial emissions have generally fallen with the exception of a slight upturn in 2000. Historically, industrial energy consumption and carbon dioxide emissions have been more sensitive to economic growth than to the weather. The most recent decline in 2001 is a case in point: industrial emissions fell by 5.4 percent, from 478.4 million metric tons in 2000 to 452.4 million metric tons in 2001, coinciding with a 4.4-percent decrease in manufacturing output.

Industrial energy consumption and emissions are concentrated in a few energy-intensive industries, and their performance is more closely correlated with carbon dioxide emissions than is the performance of the industrial sector as a whole. In all six of the energy-intensive industry groups, which traditionally account for about 65 to 70 percent of total industrial carbon dioxide

emissions and 80 percent of carbon dioxide emissions from manufacturing, output declined in 2001. The greatest declines were in Primary Metals (-11.4 percent), followed by Pulp and Paper (-5.1 percent) and Stone, Clay and Glass Products (-2.4 percent). Smaller declines in output were seen for the other energy-intensive industries: Food (-0.8 percent), Chemicals (-0.8 percent), and Petroleum (-0.6 percent). By fuel type, industrial sector carbon dioxide emissions from purchased electricity fell by 7.4 percent, emissions from natural gas by 7.4 percent, and emissions from coal by 5.7 percent. Emissions from petroleum use in the industrial sector increased by 2.0 percent in 2001 (a net increase of 1.9 million metric tons carbon equivalent); although carbon dioxide emissions from industrial petroleum consumption were lower by 5.5 million metric tons carbon equivalent, an offsetting increase of 7.4 million metric tons carbon equivalent resulted from a 7-percent decline in nonfuel uses of petroleum in the sector.

Carbon dioxide emissions in the transportation sector, at 512.0 million metric tons carbon equivalent, were 0.8 percent higher in 2001 than in 2000. Emissions of carbon dioxide from gasoline consumption (60.2 percent of transportation sector emissions) grew by 2.1 percent, but emissions from jet fuel use for air travel and residual fuel consumption by ships fell by 4.3 percent and 5.8 percent, respectively, as air travel disruptions and an economic downturn at the end of the year affected both airlines and shipping. Transportation sector carbon dioxide emissions have grown by an average of 1.6 percent annually since 1990.

Methane

U.S. emissions of methane in 2001 were 1.1 percent lower than in 2000, at 28.0 million metric tons of methane or 175.8 million metric tons carbon equivalent (9.3 percent of total U.S. greenhouse gas emissions). Total U.S. methane emissions in 2000 were 28.3 million metric tons of methane. The 2001 decline resulted primarily from decreases in methane emissions from natural gas systems and coal mining, which more than offset small increases in emissions from waste management (primarily landfills) and agricultural sources.

Methane emissions come from four categories of sources, three major and one minor. The major sources are energy, agriculture, and waste management, and the minor source is industrial processes. The three major sources accounted for 37.8, 32.8, and 29.0 percent, respectively, of total 2001 U.S. emissions of methane, or approximately 9.3 percent of the Nation's total carbon-equivalent greenhouse gas emissions. Trends in the major sources of anthropogenic methane emissions since 1990 are illustrated in Figure ES4.

Methane emissions from energy sources (coal mining, natural gas systems, petroleum systems, stationary combustion, and mobile source combustion) declined from 11.1 million metric tons of methane in 2000 to 10.6 million metric tons of methane in 2001, representing a 4.3-percent reduction in emissions from energy sources. Methane emissions from energy sources have fallen by 11.3 percent since 1990. The drop in 2001 was the result of reductions in emissions associated with withdrawals of natural gas from underground storage and in emissions from gassy underground coal mines.

Methane emissions from agricultural sources increased by 0.7 percent, from 9.1 million metric tons in 2000 to 9.2 million metric tons in 2001. Agricultural methane emissions have several sources but are dominated by emissions from domestic livestock, including the animals themselves (enteric fermentation) and the anaerobic decomposition of their waste. In 2001, methane emissions from enteric fermentation and animal waste increased by 0.5 and 0.3 percent, respectively. Agricultural emissions have increased by 11.3 percent since 1990.

Methane emissions from waste management sources include two subcategories: emissions from the anaerobic decomposition of municipal solid waste in landfills and emissions from wastewater treatment facilities. Methane emissions from waste management increased by 1.4 percent, from 8.0 million metric tons in 2000 to 8.1 million metric tons in 2001. Contributing to the increase was a 1.4-percent increase in emissions from landfills that resulted from an increase in the amount of municipal solid waste landfilled and a leveling off of methane recovery for energy use and flaring. Emissions of methane from waste management have declined by 28.4 percent since 1990 as a result of an increase in the amount of methane recovered (3.9 million metric tons more in 2001

than in 1990) that would otherwise have been emitted to the atmosphere.

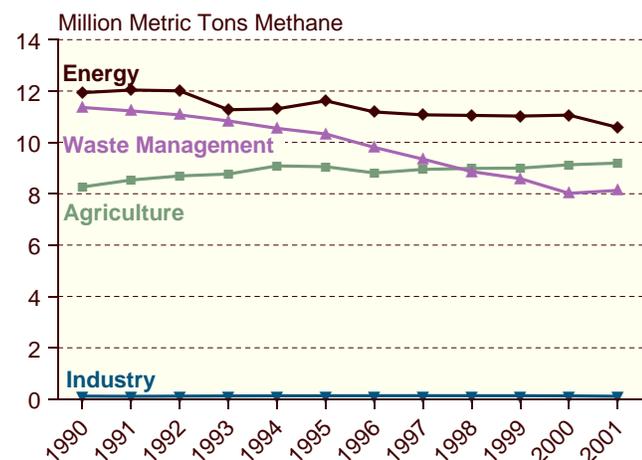
The estimates for methane emissions are more uncertain than those for carbon dioxide. U.S. methane emissions do not necessarily increase with growth in energy consumption or the economy. Energy-related methane emissions are strongly influenced by coal production from a relatively restricted number of mines; agricultural emissions are influenced in part by the public's consumption of milk and beef and in part by animal husbandry practices; and waste management emissions are influenced by the volume of municipal waste generated and recycled, as well as the amount of methane recaptured at landfills.

Nitrous Oxide

U.S. nitrous oxide emissions decreased by 1.0 percent from 2000 to 2001, to 1.2 million metric tons of nitrous oxide or 97.5 million metric tons carbon equivalent (5.2 percent of total U.S. greenhouse gas emissions). The 2001 decline in nitrous oxide emissions resulted primarily from decreases in emissions from agricultural sources and industrial processes. Since 1990, U.S. nitrous oxide emissions have grown by 3.2 percent. Emissions estimates for nitrous oxide are more uncertain than those for either carbon dioxide or methane. Nitrous oxide is not systematically measured, and for many sources of nitrous oxide emissions, including nitrogen fertilization of soils and motor vehicles, a significant number of assumptions are required for the derivation of emissions estimates.

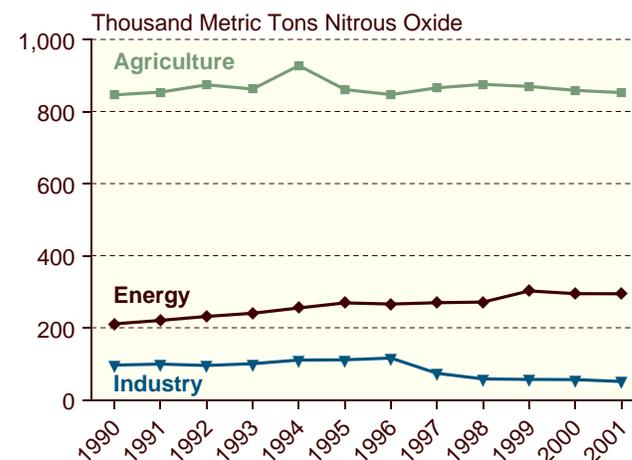
U.S. nitrous oxide emissions include two large categories of sources, agriculture and energy use, and two smaller categories, industrial processes and waste management (Figure ES5). Agricultural sources, at 852.5

Figure ES4. U.S. Emissions of Methane by Source, 1990-2001



Source: Estimates presented in this report.

Figure ES5. U.S. Emissions of Nitrous Oxide by Source, 1990-2001



Source: Estimates presented in this chapter.

thousand metric tons of nitrous oxide, account for about 70.6 percent of total U.S. nitrous oxide emissions. Emissions associated with nitrogen fertilization of soils, at 620.5 thousand metric tons, account for 72.8 percent of nitrous oxide emissions from agriculture. Emissions from the solid waste of animals, at 230.1 thousand metric tons, make up 27.0 percent of agricultural nitrous oxide emissions. Nitrous oxide emissions from agriculture have increased by 0.7 percent since 1990.

U.S. nitrous oxide emissions associated with fossil fuel combustion in 2001 were about 0.3 million metric tons of nitrous oxide, or 23.5 percent of total nitrous oxide emissions. Of these energy-related emissions, 82.7 percent comes from mobile sources, principally motor vehicles equipped with catalytic converters. The remainder comes from stationary source combustion of fossil fuels. Nitrous oxide emissions from energy sources have increased by 34.7 percent since 1990.

Industrial processes and wastewater treatment facilities are responsible for 5.8 percent of total nitrous oxide emissions. Industrial process emissions fell from 56.2 thousand metric tons in 2000 to 51.0 thousand metric tons in 2001. This continues a trend that since 1996 has produced a 56.0-percent decrease as a result of reductions in emissions from the production of adipic acid. Emissions from wastewater treatment facilities were unchanged from 2000 at 19.8 thousand metric tons in 2001.

Other Gases: Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride

HFCs, PFCs, and SF₆ are three classes of engineered gases that account for 1.7 percent of U.S. GWP-weighted emissions of greenhouse gases. At 31.4 million metric tons carbon equivalent in 2001, their emissions were 7.7 percent lower than in 2000. The 2000 to 2001 decrease in emissions of the engineered gases was caused by across-the-board reductions in emissions of HFCs (5.0 percent), PFCs (36.1 percent), and SF₆ (6.7 percent). At 21.0 million metric tons carbon equivalent, emissions of HFCs make up the majority of this category, followed by SF₆ at 4.7 million metric tons and PFCs at 2.4 million metric tons. Another group of engineered gases, consisting of other HFCs, other PFCs, and perfluoropolyethers (PFPEs), includes HFC-152a, HFC-227ea, HFC-4310mee, and a variety of PFCs and PFPEs. They are grouped

together in this report to protect confidential data. In 2001, their combined emissions totaled 3.3 million metric tons carbon equivalent. Emissions in this “other” group in 2001 were 6.0 percent higher than in 2000 and orders of magnitude higher than in 1990, when emissions were miniscule (less than 50,000 metric tons carbon equivalent). Since 1990, HFC emissions from U.S. sources have increased by 109.4 percent, PFC emissions have decreased by 53.9 percent, and SF₆ emissions have decreased by 50.8 percent.

Emissions of the high-GWP gases specified in the Kyoto Protocol are very small (at most a few thousand metric tons). On the other hand, some of the gases (including PFCs and SF₆) have atmospheric lifetimes measured in the thousands of years, and consequently they are potent greenhouse gases with GWPs thousands of times higher than that of carbon dioxide per unit of molecular weight. Some of the commercially produced HFCs (134a, 152a, 4310, 227ea), which are used as replacements for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), have shorter atmospheric lifetimes, ranging from 1 to 33 years.

Land Use and Forestry

Forest lands in the United States are net absorbers of carbon dioxide from the atmosphere. According to U.S. Forest Service researchers, U.S. forest land absorbs about 246 million metric tons of carbon annually, equivalent to 15.6 percent of U.S. carbon dioxide emissions. Absorption is enabled by the reversal of the extensive deforestation of the United States that occurred in the late 19th and early 20th centuries. Since then, millions of acres of formerly cultivated land have been abandoned and have returned to forest, with the regrowth of forests sequestering carbon on a large scale. The process is steadily diminishing, however, because the rate at which forests absorb carbon slows as the trees mature, and because the rate of reforestation has slowed.

Over the past several years there has been increasing interest in the United States regarding carbon sequestration in agricultural soils through changes in agricultural practices. Proponents suggest that changes in tillage practices can cause agricultural soils to move from being net sources to net sinks of carbon dioxide, and that the amounts of carbon that might be absorbed by these changes could be significant at the national level. Although EIA's previous emissions inventory reports did not include estimates of carbon sequestration in agricultural soils, they are included in this year's inventory (see Chapter 6, “Land Use Issues”).