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Emissions of Greenhouse Gases in the United States 2003

Executive Summary

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Energy Information Administration
Office of Integrated Analysis and Forecasting
U.S. Department of Energy
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The full report is on the WEB at:
www.eia.doe.gov/oiaf/1605/ggrpt/index.html

Preface

Emissions of Greenhouse Gases in the United States 2003 was prepared under the general direction of John Conti, Director, Office of Integrated Analysis and Forecasting, Energy Information Administration (202/586-2222; e-mail, john.conti@eia.doe.gov). General questions concerning the content of this report may be directed to the National Energy Information Center at 202/586-8800.

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Title XVI, Section 1605(a) of the Energy Policy Act of 1992 (enacted October 24, 1992) provides:

> *Not later than one year after the date of the enactment of this Act, the Secretary, through the Energy Information Administration, shall develop, based on data available to, and obtained by, the Energy Information Administration, an inventory of the national aggregate emissions of each greenhouse gas for each calendar year of the baseline period of 1987 through 1990. The Administrator of the Energy Information Administration shall annually update and analyze such inventory using available data. This subsection does not provide any new data collection authority.*

The first report in this series, *Emissions of Greenhouse Gases 1985-1990*, was published in September 1993. This report—the twelfth annual report, as required by law—presents the Energy Information Administration's latest estimates of emissions for carbon dioxide, methane, nitrous oxide, and other greenhouse gases. These estimates are based on activity data and applied emissions factors and not on measured or metered emissions monitoring. The full report can be downloaded from the following web site: www.eia.doe.gov/oiaf/1605/ggrpt.

For this report, data on coal and natural gas consumption and electricity sales and losses by sector were obtained from the Energy Information Administration's (EIA's) November 2004 *Monthly Energy Review*. Additional detailed information on petroleum consumption was obtained from unpublished material in support of EIA's *Annual Energy Review 2003*. Data on electric power sector emissions were obtained from EIA's *Electric Power Annual*. In keeping with current international practice, this report presents data on greenhouse gas emissions in million metric tons carbon dioxide equivalent. The data can be converted to carbon equivalent units by multiplying times 12/44.

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Overview

U.S. Anthropogenic Emissions of Greenhouse Gases, 1990-2003	Carbon Dioxide Equivalent
Estimated 2003 Emissions (Million Metric Tons)	6,935.7
Change Compared to 2002 (Million Metric Tons)	44.8
Change from 2002 *(Percent)*	*0.7%*
Change Compared to 1990 (Million Metric Tons)	820.5
Change from 1990 *(Percent)*	*13.4%*
Average Annual Increase, 1990-2003 *(Percent)*	*1.0%*

U.S. emissions of greenhouse gases in 2003 totaled 6,935.7 million metric tons carbon dioxide equivalent, 0.7 percent more than in 2002 (6,890.9 million metric tons carbon dioxide equivalent). Although emissions of carbon dioxide and emissions of methane grew by 0.8 percent and 0.5 percent, respectively, those increases were partially balanced by reductions in emissions of nitrous oxide (-0.9 percent) and hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (-0.3 percent). U.S. greenhouse gas emissions have averaged 1.0-percent annual growth since 1990.

The U.S. economy grew by 3.0 percent in 2003, which is equivalent to the average annual growth rate that has prevailed during the 1990-2003 period. Consequently, U.S. greenhouse gas intensity (greenhouse gas emissions per unit of real economic output) was 2.3 percent lower in 2003 than in 2002. From 1990 to 2003, U.S. greenhouse gas intensity has declined by 22.3 percent, or by an average of 1.9 percent per year (see box on page 3 for details).

U.S. greenhouse gas emissions in 2003 were 13.4 percent higher than 1990 emissions (6,115.2 million metric tons carbon dioxide equivalent)—an average annual increase of 1.0 percent over the period. 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 (3.0 percent). While the annual growth rate in carbon dioxide emissions since 1990 (1.3 percent) has closely tracked annual growth in population and energy consumption, the average annual rate of growth in total greenhouse gas emissions has been lower (1.0 percent) because of reductions in methane and nitrous oxide emissions since 1990.

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 marginal radiative efficiency. The GWP concept, developed by the Intergovernmental Panel on Climate Change (IPCC), provides a comparative measure of the impacts of added units 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

[1]See "Units for Measuring Greenhouse Gases" on page 5, and Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

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

appeared in the IPCC's Second Assessment Report.[3] The GWPs published in the Third Assessment Report were used for the calculation of carbon dioxide equivalent emissions for this report. Generally, the level of total U.S. carbon dioxide equivalent emissions is 0.6 percent higher when the GWPs from the Third Assessment Report are used; however, the trends in growth of greenhouse gas emissions are similar for both sets of GWP values.

During 2003, 83.0 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 2003 U.S. greenhouse gas emissions include carbon dioxide from non-combustion sources (1.6 percent of total U.S. greenhouse gas emissions), methane (8.7 percent), nitrous oxide (4.6 percent), and other gases (2.1 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, transmission, 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 (SF_6), used as an insulator in utility-scale electrical equipment.

Table ES1. Summary of Estimated U.S. Emissions of Greenhouse Gases, 1990 and 1995-2003
(Million Metric Tons of Gas)

Gas	1990	1995	1996	1997	1998	1999	2000	2001	2002	P2003
Carbon Dioxide.	4,990.1	5,306.7	5,495.5	5,558.1	5,590.7	5,671.6	5,844.8	5,777.0	5,824.8	5,870.2
Methane	30.8	29.6	28.3	28.2	27.2	26.6	26.7	26.0	26.1	26.2
Nitrous Oxide	1.1	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1
HFCs, PFCs, and SF_6 . .	M	M	M	M	M	M	M	M	M	M

M = mixture of gases. These gases cannot be summed in native units. See Table ES2 for estimated totals in carbon dioxide equivalent.
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 2002*, DOE/EIA-0573(2002) (Washington, DC, October 2003).
Source: EIA, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

Table ES2. U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990 and 1995-2003
(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1995	1996	1997	1998	1999	2000	2001	2002	P2003
Carbon Dioxide	4,990.1	5,306.7	5,495.5	5,558.1	5,590.7	5,671.6	5,844.8	5,777.0	5,824.8	5,870.2
Methane.	707.8	681.6	650.5	647.7	624.6	612.3	614.7	598.3	599.2	601.9
Nitrous Oxide.	328.7	347.9	346.5	337.0	336.4	335.2	331.2	325.6	323.2	320.2
HFCs, PFCs, and SF_6 . .	88.5	94.7	114.7	122.4	138.0	137.8	142.4	134.2	143.7	143.4
Total	**6,115.2**	**6,430.9**	**6,607.1**	**6,665.1**	**6,689.6**	**6,756.9**	**6,933.0**	**6,835.0**	**6,890.9**	**6,935.7**

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 2002*, DOE/EIA-0573(2002) (Washington, DC, October 2003).
Sources: **Emissions:** Estimates in *Emissions of Greenhouse Gases in the United States 2003*. **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.

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

Trends in U.S. Carbon Intensity and Total Greenhouse Gas Intensity

From 2002 to 2003, the greenhouse gas intensity of the U.S. economy fell from 684 to 668 metric tons per million 2000 dollars of GDP (2.3 percent), continuing a trend of decreases in both carbon intensity (see figure at right) and total greenhouse gas intensity. As shown in the table below, declines in carbon intensity by decade have ranged from a low of 3.3 percent in the 1960s to 25.9 percent in the 1980s. From 1990 to 2003, total U.S. greenhouse gas intensity fell by 22.3 percent, at an average rate of 1.9 percent per year.

Historical Growth Rates for U.S. Carbon Intensity

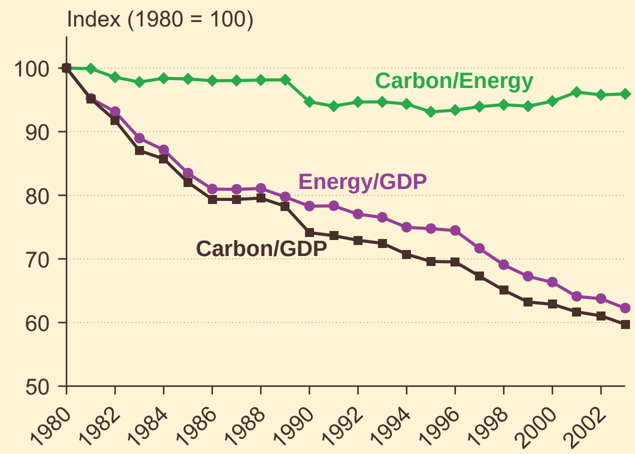
Decade	Overall Change in Intensity (Percent)		Average Annual Change in Intensity (Percent)	
	Carbon Dioxide	Total GHG	Carbon Dioxide	Total GHG
History				
1950-1960	-12.9	—	-1.4	—
1960-1970	-3.3	—	-0.3	—
1970-1980	-17.7	—	-1.9	—
1980-1990	-25.9	—	-2.7	—
1990-2000	-15.2	-17.9	-1.6	-1.9

Source: Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, DC, September 2004), and estimates presented in Appendix B of *Emissions of Greenhouse Gases in the United States 2003*.

The carbon intensity and greenhouse gas intensity of the U.S. economy move in lockstep, because carbon dioxide emissions make up most of the total for U.S. greenhouse gas emissions. Energy-related carbon dioxide emissions represent approximately 83 percent of total U.S. greenhouse gas emissions. As such, trends in energy-related carbon dioxide emissions have a significant impact on trends in total greenhouse gas emissions. Historical trends in U.S. carbon intensity (energy-related carbon dioxide emissions per unit of economic output) are described below.

The carbon intensity of the economy can largely be decomposed into two basic elements: (1) energy intensity, defined as the amount of energy consumed per dollar of economic activity; and (2) carbon intensity of energy supply, defined as the amount of carbon emitted per unit of energy. As illustrated by the formulas below, the multiplication of the two elements produces

Intensity Ratios: Carbon/GDP, Carbon/Energy, and Energy/GDP



Source: EIA, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

a numerical value for U.S. carbon intensity, defined as the amount of carbon dioxide emitted per dollar of economic activity:

Energy Intensity x *Carbon Intensity of Energy Supply = Carbon Intensity of the Economy* ,

or, algebraically,

(Energy/GDP) x *(Carbon Emissions/Energy) = (Carbon Emissions/GDP)* .

Components of Energy Intensity. Since World War II the U.S. economy has been moving away from traditional "smokestack" industries towards more service-based or information-based enterprises. This has meant that over the second half of the 20th century economic growth was less tied to growth in energy demand than it was during the period of industrialization in the 19th and early 20th century. Other factors contributing to decreases in energy intensity include:

- Improvements in the energy efficiency of industrial equipment as new materials and methods improved performance in terms of energy inputs versus outputs

(continued on page 4)

Trends in U.S. Carbon Intensity and Total Greenhouse Gas Intensity (Continued)

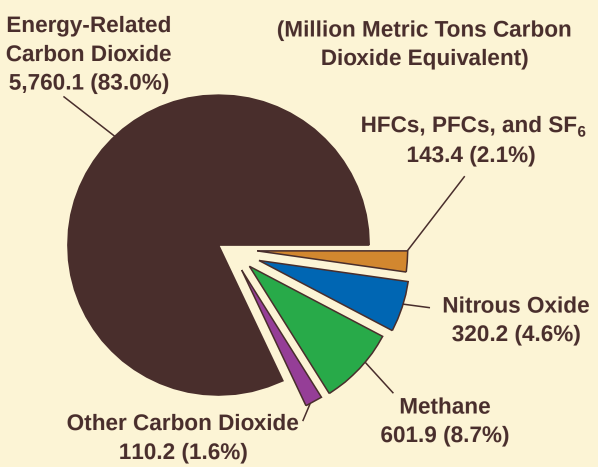
- Increased efficiency of transportation equipment as lighter materials and more efficient engines entered the marketplace
- Improvements in commercial and residential lighting, refrigeration, and heating and cooling equipment
- Developments in new electricity generating technologies, such as combined-cycle turbines.

Further reductions in energy intensity, which are projected to continue, will among other things promote deeper reductions in U.S. carbon intensity.

Components of the Carbon Intensity of Energy Supply. Changes in the carbon intensity of energy supply have been less dramatic than changes in energy intensity. There was a slow but steady decline from 1980 until about the mid-1990s, after which it has remained relatively unchanged. The primary reason for the decline has been the development of nuclear power, which is carbon-free and therefore weights the fuel mix toward lower carbon intensity. Other factors that can decrease the carbon intensity of the energy supply include:

- Development of new renewable resources, such as wind power, for electricity generation
- Substitution of natural gas for coal and oil in power generation
- Transportation fuels with a higher biogenic component, such as ethanol.

Figure ES1. U.S. Greenhouse Gas Emissions by Gas, 2003



Source: Table ES2.

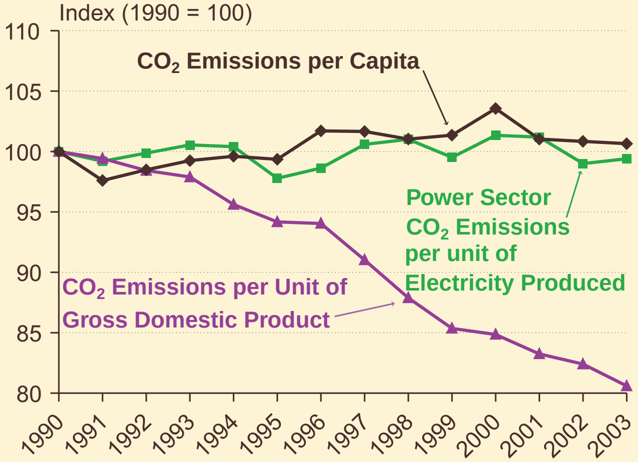
This report, required by Section 1605(a) of the Energy Policy Act of 1992, provides estimates of U.S. emissions of greenhouse gases. The estimates are based on activity data and applied emissions factors, not on measured or metered emissions monitoring.

Carbon Dioxide

The preliminary estimate of U.S. carbon dioxide emissions from both energy consumption and industrial processes in 2003 is 5,870.2 million metric tons, which is 0.8 percent higher than in 2002 (5,824.8 million metric tons) and accounts for 84.6 percent of total U.S. greenhouse gas emissions. U.S. carbon dioxide emissions have 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, growth in carbon dioxide emissions in the longer term results largely from population- and income-driven increases in energy use, as well as consumer choices of energy-using equipment. The "carbon intensity" of energy use (carbon dioxide emissions per unit of energy consumed) can also influence trend growth in energy-related carbon dioxide emissions.

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 gross domestic product (GDP) have continued to fall relative to 1990; by 2003, this measure was 19.4 percent lower than in 1990. Carbon dioxide emissions per capita, however, were 0.6 percent above 1990 levels in 2003. Population growth and other factors resulted in increased aggregate carbon dioxide emissions per year from 1990 through 2003 (a total increase of 17.6 percent).

Figure ES2. Carbon Dioxide Emissions Intensity of U.S. Gross Domestic Product, Population, and Electricity Production, 1990-2003



Source: EIA, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

Carbon dioxide emissions per unit of net electricity generation in 2003 were 0.4 percent higher than in 2002.

EIA divides energy consumption into four general end-use categories: residential, commercial, industrial, and transportation. Emissions from electricity generators, which provide electricity to the end-use sectors, are allocated in proportion to the electricity consumed in, and losses allocated to, each sector. Figure ES3 illustrates trends in carbon dioxide emissions by energy consumption sector. Average annual growth rates in carbon dioxide emissions by sector during the 1990-2003 period were 2.2 percent for the commercial sector, 1.9 percent for the residential sector, and 1.4 percent for the transportation sector. Industrial sector carbon dioxide emissions, after peaking in 1997, are now below their 1990 level.

In the residential sector, total carbon dioxide emissions were up by 1.7 percent, from 1,193.9 million metric tons in 2002 to 1,214.8 million metric tons in 2003. The increase is attributed mainly to a 4.1-percent increase in residential natural gas consumption due largely to colder winter weather that increased heating degree-days by 4.0 percent. Residential sector emissions attributable to purchased electricity also rose by 1.0 percent, and emissions from petroleum products increased by 1.9 percent.

Units for Measuring Greenhouse Gases

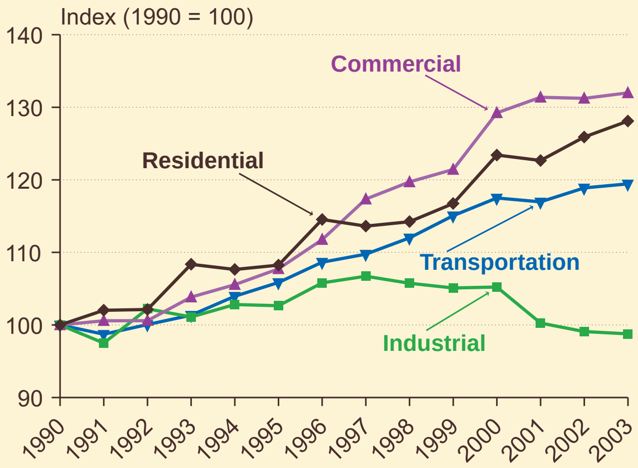
Emissions data are reported here in metric units, as favored by the international scientific community. Metric tons are relatively intuitive for users of English units, because 1 metric ton is only about 10 percent heavier than 1 English short ton.

Emissions of most greenhouse gases are reported here in terms of the full molecular weight of the gas (as in Table ES1). In Table ES2, however, carbon dioxide and other greenhouse gases are reported in carbon dioxide equivalents. In the case of carbon dioxide, emissions denominated in the molecular weight of the gas or in carbon dioxide equivalents are the same. Carbon dioxide equivalent data can be converted to carbon equivalents by multiplying by 12/44.

Emissions of other greenhouse gases (such as methane) can also be measured in "carbon dioxide equivalent" units by multiplying their emissions (in metric tons) by their global warming potentials (GWPs). Carbon dioxide equivalents are the amount of carbon dioxide by weight emitted into the atmosphere that would produce the same estimated radiative forcing as a given weight of another radiatively active gas.

Carbon dioxide equivalents are computed by multiplying the weight of the gas being measured (for example, methane) by its estimated GWP (which is 23 for methane).

Figure ES3. U.S. Carbon Dioxide Emissions by Sector, 1990-2003



Note: Sectoral emissions include both direct emissions and emissions attributable to purchased electricity.

Source: EIA, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

Carbon dioxide emissions in the commercial sector increased by 0.6 percent, from 1,019.8 million metric tons in 2002 to 1,025.7 million metric tons in 2003. Emissions attributable to purchased electricity increased by 0.4 percent, from 793.9 million metric tons in 2002 to 796.7 million metric tons in 2003. Carbon dioxide emissions from the direct combustion of fossil fuels, primarily natural gas, in the commercial sector rose from 225.9 million metric tons in 2002 to 229.0 million metric tons in 2003, a 1.3-percent increase.

Energy-related carbon dioxide emissions in the industrial sector in 2003 are estimated at 1,666.2 million metric tons, which is slightly less than the level of emissions in 1990. After peaking in 1997 at 1,800.1 million metric tons, industrial emissions have generally fallen, with the exception of a slight upturn in 2000.

Industrial energy consumption and carbon dioxide emissions are concentrated in a few energy-intensive industries, and the output of the energy-intensive industries tends to be closely correlated with the industrial sector's total carbon dioxide emissions. Among the six 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, changes in output were mixed in 2003, with production increases in three and decreases in the other three. Declines in output were seen in 2003 for primary metals (-2.3 percent), chemicals (-1.5 percent), and food (-3.6 percent), while increases in output were seen for paper (5.1 percent), nonmetallic minerals (0.9 percent), and petroleum refining (1.5 percent). Although the paper industry showed robust growth in 2003, the manufacture of paper produces relatively small amounts of carbon per energy consumed, because much of the energy used is supplied by wood waste, and the resulting emissions are part of the natural carbon cycle. By fuel type, industrial sector carbon dioxide emissions rose for purchased electricity (1.9 percent), coal (1.2 percent), and petroleum (2.2 percent), while emissions from natural gas fell by 6.3 percent. Because of the large decrease in emissions from natural gas use, total industrial emissions fell despite increases in emissions from the other three energy sources.

Carbon dioxide emissions in the transportation sector, at 1,874.7 million metric tons, were 0.5 percent higher in 2003 than in 2002 (1,866.0 million metric tons). Emissions of carbon dioxide from gasoline consumption (61.0 percent of transportation sector emissions) grew by 0.4 percent, while emissions from jet fuel use for air travel fell by 2.5 percent. Carbon dioxide emissions from distillate fuel use grew by 3.6 percent in 2003. Transportation sector carbon dioxide emissions have grown by an average of 1.4 percent annually since 1990.

Carbon dioxide emissions from the U.S. electric power sector increased by 1.0 percent (22.9 million metric tons), from 2,256.4 million metric tons in 2002 to 2,279.3 million metric tons in 2003. Carbon dioxide emissions from the electric power sector have grown by 27.5 percent since 1990, while total carbon dioxide emissions from all energy-related sources have grown by 16.0 percent. Carbon dioxide emissions from the electric power sector represented 39.4 percent of total U.S. energy-related carbon dioxide emissions in 2003; however, as noted above, in calculating emissions from the end-use sectors EIA distributes electric power sector emissions to the four sectors in proportion to their respective shares of total electricity purchases. Therefore, electric power emissions are already included in the sectoral totals.

By fuel, emissions from natural gas use for electricity generation in 2003 were down by 10.1 percent from 2002, emissions from coal use were up by 1.8 percent, and emissions from petroleum use were up by 25.8 percent. The increases in coal- and petroleum-fired generation, at the expense of natural-gas-fired generation, reflect the rapid rise in natural gas prices in 2003 (52.2 percent), while coal and petroleum prices increased by 1.6 and 29.0 percent, respectively. Petroleum-fired generation is a small component of total electricity generation in the United States.

Methane

U.S. emissions of methane in 2003 were 0.5 percent higher than in 2002, at 26.2 million metric tons of methane or 601.9 million metric tons carbon dioxide equivalent (8.7 percent of total U.S. greenhouse gas emissions). Total U.S. methane emissions in 2002 were 26.1 million metric tons of methane. The 2003 increase resulted primarily from small increases in methane emissions from landfills, coal mines, animal waste, and natural gas systems. Despite the 0.5-percent increase from 2002, methane emissions in 2003 were 4.6 million metric tons (15 percent) below the 1990 level.

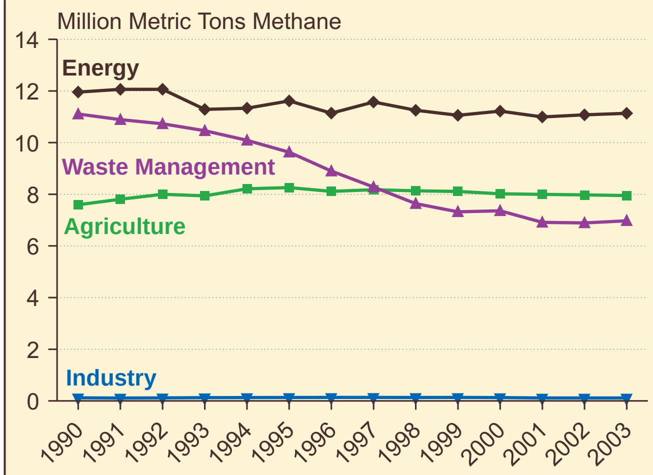
Methane emissions come from four categories of sources, three major and one minor. The major sources are energy, agriculture, and waste management, and the minor source is industrial processes. The three major sources accounted for 42.5, 30.4, and 26.6 percent, respectively, of total 2003 U.S. emissions of methane. 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) increased from 254.7 million metric tons carbon dioxide equivalent in 2002 to 256.1 million metric tons carbon dioxide equivalent in 2003, representing a 0.5-percent increase in emissions from energy sources. Methane emissions from energy sources have fallen by 6.9 percent since 1990. The rise in 2003 was the result of increases in emissions from coal mines and natural gas systems.

Methane emissions from agricultural sources (182.8 million metric tons carbon dioxide equivalent) decreased by 0.3 percent in 2003. 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. Methane emissions from enteric fermentation in 2003 were 0.3 percent lower than in 2002, whereas methane emissions from animal waste were 0.6 percent higher than in 2002. The overall decline in agricultural methane emissions resulted mainly from one of the smallest sources, emissions from rice cultivation, which fell by 0.7 million metric tons carbon dioxide equivalent or 6.8 percent. Agricultural emissions have increased by 4.7 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 rose by 1.2 percent, from 158.5 million metric tons carbon dioxide equivalent in 2002 to 160.4 million metric tons carbon dioxide equivalent in 2003. Contributing to the increase was a 1.3-percent increase in emissions from landfills, which would have been larger but for a 0.3 million metric ton increase in methane recovery for energy use. Methane emissions from wastewater increased by 0.8 percent to 15.5 million metric tons carbon dioxide equivalent. Emissions of methane from waste

Figure ES4. U.S. Emissions of Methane by Source, 1990-2003



Source: EIA, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

management have declined by 37.2 percent since 1990 as a result of an increase in the amount of methane recovered from landfills (5.0 million metric tons more in 2003 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 small 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 volumes of municipal waste generated and recycled, as well as the amount of methane recaptured at landfills (see text box below).

Nitrous Oxide

U.S. nitrous oxide emissions decreased by 0.9 percent from 2002 to 2003, to 1.1 million metric tons of nitrous oxide or 320.2 million metric tons carbon dioxide equivalent (4.6 percent of total U.S. greenhouse gas emissions). The 2003 decline in nitrous oxide emissions resulted mainly from decreases in emissions from agriculture (1.9 million metric tons carbon dioxide equivalent) and industrial processes (1.8 million metric tons carbon dioxide equivalent). Since 1990, U.S. nitrous oxide emissions have fallen by 2.6 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 233.3 million metric tons carbon dioxide equivalent, accounted for 72.9 percent of total U.S. nitrous oxide emissions in 2003. Emissions associated with nitrogen fertilization of soils, at 172.1 million metric tons carbon dioxide equivalent, accounted for 73.8 percent of nitrous oxide emissions from agriculture. Emissions from the solid waste of animals, at 60.7 million metric tons carbon dioxide equivalent, made up 26.0 percent of agricultural nitrous oxide emissions. Nitrous oxide emissions from agriculture have decreased by 3.2 percent since 1990.

U.S. nitrous oxide emissions associated with fossil fuel combustion in 2003 were 67.5 million metric tons carbon dioxide equivalent, or 21.1 percent of total nitrous oxide emissions. Of these energy-related emissions,

The Methane to Markets Partnership

On July 28, 2004, President Bush announced the Methane to Markets Partnership. Under this program, developed countries, developing countries, and countries with economies in transition will collaborate to recover and cost-effectively use methane from landfills, coal mines, and the natural gas and petroleum systems that otherwise would have been emitted to the atmosphere. On November 16, 2004, representatives from Argentina, Australia, Brazil, China, Colombia, India, Italy, Japan, Mexico, Nigeria, Russia, Ukraine, and the United Kingdom, joined the United States in signing Terms of Reference that formally created the Partnership.

The United States intends to commit up to $53 million over the next 5 years to facilitate the development and implementation of methane projects in developing countries and countries with economies in transition. The EPA will have the lead U.S. role in the Partnership, coordinating efforts with the Department of State, DOE, the U.S. Agency for International Development and the U.S. Trade and Development Agency. According to the EPA, the Partnership has the potential to generate reductions of as much as 50 million metric tons of carbon equivalent annually through 2015, the equivalent of removing 33 million cars from the road for one year, or planting 55 million acres of trees. The energy embodied in the methane recovered, equal to about 500 billion cubic feet of natural gas, could heat approximately 7.2 million households for one year.

78.1 percent were from mobile sources, principally motor vehicles equipped with catalytic converters. The remainder were from stationary source combustion of fossil fuels. Nitrous oxide emissions from energy sources have increased by 24.4 percent since 1990.

Industrial processes and wastewater treatment facilities were responsible for 4.2 and 1.8 percent, respectively, of total nitrous oxide emissions in 2003. Industrial process emissions decreased by 11.8 percent, from 15.2 million metric tons carbon dioxide equivalent in 2002 to 13.4 million metric tons carbon dioxide equivalent in 2003. The decrease can be attributed to a 7.9-percent drop in U.S. nitric acid production. Emissions of nitrous oxide from adipic acid production in 2003 were 22.9 percent lower than in 2002, due in large part to a decrease in adipic acid production from uncontrolled sources. Emissions from wastewater treatment facilities in 2003 were 6.0 million metric tons carbon dioxide equivalent, an increase of 0.1 million metric tons carbon dioxide equivalent or 0.9 percent from 2002 levels.

Other Gases: Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride

HFCs, PFCs, and SF_6 are three classes of engineered gases that accounted for 2.1 percent of total U.S. greenhouse gas emissions in 2003. At 143.4 million metric tons carbon dioxide equivalent, their emissions were 0.3 percent lower than in 2002 (143.7 million metric tons). The decrease in emissions of the engineered gases from 2002 to 2003 resulted largely from an 18-percent reduction in PFC emissions that counteracted increases in emissions of HFCs (0.5 percent) and SF_6 (1.6 percent).

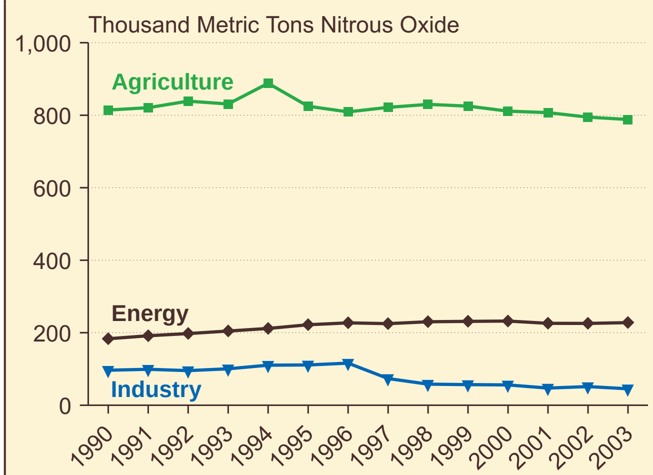
At 111.3 million metric tons carbon dioxide equivalent, emissions of HFCs made up the majority of this category, followed by SF_6 at 17.3 million metric tons carbon dioxide equivalent and PFCs at 7.3 million metric tons carbon dioxide equivalent. Another group of engineered gases, consisting of other 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 2003, their combined emissions totaled 7.1 million metric tons carbon dioxide equivalent. Emissions in this "other" group in 2003 were 5.9 percent higher than in 2002 and orders of magnitude higher than in 1990, when emissions were less than 0.3 million metric tons carbon dioxide equivalent. Since 1990, HFC emissions from U.S. sources have increased by 208.6 percent, PFC emissions have decreased by 62.9 percent, and SF_6 emissions have decreased by 47.1 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 SF_6) 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, 4310mee, 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. Absorption is enabled

Figure ES5. U.S. Emissions of Nitrous Oxide by Source, 1990-2003



Source: EIA, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

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. The U.S. Environmental Protection Agency (EPA) estimates annual U.S. carbon sequestration for the year 2002 at 690.7 million metric tons carbon dioxide, representing an offset of 11.9 percent of total 2002 U.S. anthropogenic carbon dioxide emissions (5,824.8 million metric tons carbon dioxide). In 1990, land use and forestry carbon sequestration was equivalent to 957.9 million metric tons carbon dioxide, or 19.2 percent of total 1990 U.S. anthropogenic carbon dioxide emissions (4,990.1 million metric tons).[4]

[4]Note that EIA does not include sequestration from land-use change and forestry as part of its annual emissions inventory.