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Emissions of Greenhouse Gases in the United States 2002

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 2002 was prepared under the general direction of John Conti, Director of the International, Economic and Greenhouse Gas Division, and Mary Hutzler, Director of the Office of Integrated Analysis and Forecasting, Energy Information Administration. General questions concerning the content of the 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 eleventh 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: ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057302.pdf.

Data for this report were obtained from the Energy Information Administration's (EIA's) July 2003 *Monthly Energy Review*. Additional detailed information on petroleum was obtained from unpublished material in support of EIA's *Annual Energy Review 2002*. In keeping with current international practice, this year's 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, 1990-2002

	Carbon Dioxide Equivalent
Estimated 2002 Emissions (Million Metric Tons)	6,862.0
Change Compared to 2001 (Million Metric Tons)	33.2
Change from 2001 *(Percent)*	*0.5%*
Change Compared to 1990 (Million Metric Tons)	706.2
Change from 1990 *(Percent)*	*10.9%*
Average Annual Increase, 1990-2002 *(Percent)*	*0.9%*

U.S. emissions of greenhouse gases in 2002 totaled 6,862.0 million metric tons carbon dioxide equivalent, 0.5 percent more than in 2001 (6,828.9 million metric tons carbon dioxide equivalent). Although emissions of carbon dioxide and emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride grew by 0.8 percent and 6.2 percent, respectively, those increases were moderated by reductions in methane (-2.7 percent) and nitrous oxide (-1.1 percent) emissions, resulting in a relatively low 0.5-percent growth in total greenhouse gas emissions. U.S. greenhouse gas emissions have averaged 0.9-percent annual growth since 1990. Even though the U.S. economy grew by 2.4 percent in 2002 (slightly less than its 2.9-percent growth trend for the 1990-2002 period), growth in total greenhouse gas emissions was restrained somewhat due to a 1.1-percent reduction in output from the energy- and emissions-intensive manufacturing sector. Consequently, U.S. greenhouse gas intensity (greenhouse gas emissions per unit of real economic output) was 2.1 percent lower in 2002 than in 2001. From 1990 to 2002, U.S. greenhouse gas intensity has declined by 21.4 percent, or by an average of 2.0 percent per year.

U.S. greenhouse gas emissions in 2002 were 11.5 percent higher than 1990 emissions (6,155.8 million metric tons carbon dioxide 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 (2.0 percent), or gross domestic product (2.9 percent). While the annual growth rate in carbon dioxide emissions since 1990 (1.2 percent) has closely tracked annual growth in population (1.2 percent) and energy consumption (1.2 percent), the average annual rate of growth in total greenhouse gas emissions has been lower (0.9 percent) because of reductions in methane and nitrous oxide emissions since 1990. Growth rates in electricity generation (2.0 percent) and gross domestic product (2.9 percent), meanwhile, have outstripped the growth in total greenhouse gas emissions because of the increased electrification of energy use and rapid growth in non-greenhouse-gas-intensive segments of the economy.

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]

[1]See "Units for Measuring Greenhouse Gases" on page 4 of this Executive Summary, and Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

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 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. For a discussion of GWPs and a comparison of U.S. carbon dioxide equivalent emissions calculated using the GWPs from the IPCC's Third and Second Assessment Reports see the box on page 6 of this Executive Summary. Generally, total U.S. carbon dioxide equivalent emissions are 0.6 percent higher when the GWPs from the Third Assessment Report are used.

During 2002, 82.8 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 2002 U.S. greenhouse gas emissions include carbon dioxide from non-combustion sources (1.7 percent of total U.S. greenhouse gas emissions), methane (8.9 percent), nitrous oxide (4.9 percent), and other gases (1.8 percent) (Figure ES1). Methane and nitrous oxide

Table ES1. Summary of Estimated U.S. Emissions of Greenhouse Gases, 1990-2002
(Million Metric Tons of Gas)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Carbon Dioxide	5,006.1	4,959.0	5,072.6	5,180.0	5,262.5	5,318.5	5,508.9	5,572.5	5,602.4	5,686.1	5,854.0	5,748.3	5,795.6
Methane	31.3	31.4	31.6	30.6	30.6	30.5	29.4	29.1	28.2	27.8	27.8	27.4	26.6
Nitrous Oxide	1.1	1.1	1.2	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1
HFCs, PFCs, and SF_6	M	M	M	M	M	M	M	M	M	M	M	M	M

M = mixture of gases. 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 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002).
Source: Estimates presented in this report. To download the full report, go to web site ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057302.pdf.

Table ES2. U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990-2002
(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Carbon Dioxide	5,006	4,959	5,073	5,180	5,263	5,319	5,509	5,573	5,602	5,686	5,854	5,748	5,796
Methane	719	723	726	703	703	702	676	668	648	640	639	630	613
Nitrous Oxide	334	339	347	348	371	355	352	344	343	347	341	337	333
HFCs, PFCs, and SF_6	97	88	88	94	91	95	113	116	126	122	123	114	121
Total	**6,156**	**6,109**	**6,233**	**6,324**	**6,428**	**6,470**	**6,650**	**6,701**	**6,720**	**6,795**	**6,957**	**6,829**	**6,862**

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 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002).
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. To download the full report, go to web site ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057302.pdf.

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

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

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 (SF_6), used as an insulator in utility-scale electrical equipment.

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.

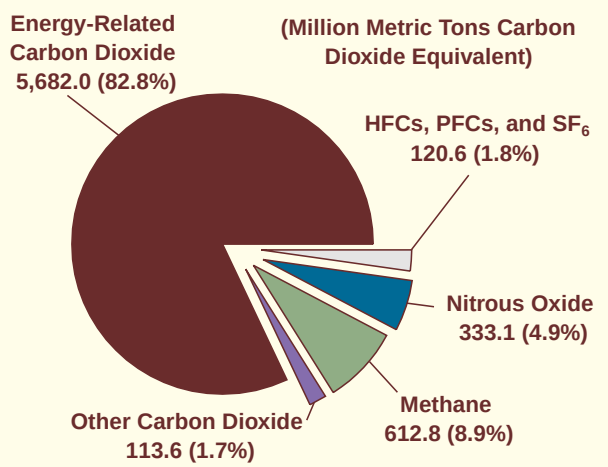
Carbon Dioxide

The preliminary estimate of U.S. carbon dioxide emissions from both energy consumption and industrial processes in 2002 is 5,795.6 million metric tons, which is 0.8 percent higher than in 2001 and accounts for 84.5 percent of total U.S. greenhouse gas emissions. U.S. carbon dioxide emissions have grown by an average of 1.2 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; by 2002, this measure was 17.7 percent lower than in 1990. Carbon dioxide emissions per capita were 0.1 percent above the 1990 level in 2001 and 0.1 percent below the 1990 level in 2002. Population growth and other factors resulted in increased aggregate carbon dioxide emissions per year from 1990 through 2002 (a total increase of 15.8 percent). Carbon dioxide emissions per unit of net electricity generation in 2002 were 1.6 percent lower than in 2001.

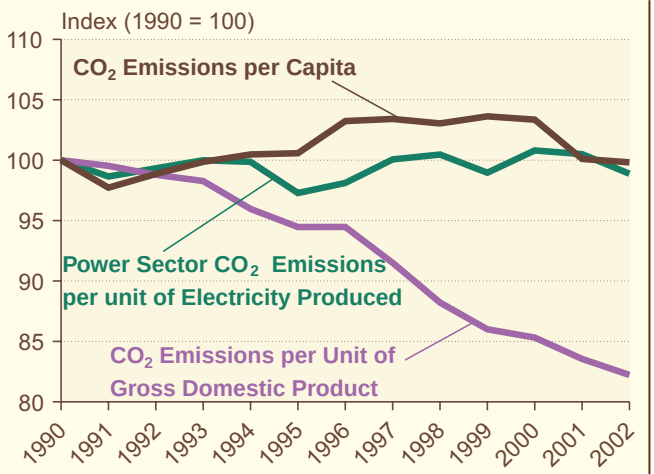
Carbon dioxide emissions from the U.S. electric power sector (which includes utilities, independent power producers, and combined heat and power facilities whose primary business is the production and sale of

Figure ES1. U.S. Greenhouse Gas Emissions by Gas, 2002



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057302.pdf.

Figure ES2. Carbon Dioxide Emissions Intensity of U.S. Gross Domestic Product, Population, and Electricity Production, 1990-2002



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057302.pdf.

Units for Measuring Greenhouse Gases

In this publication, EIA reports information in forms that are most likely to be familiar to users of the document. Therefore, energy and industrial data are reported in their native units. For example, oil production is reported in thousand barrels per day, and energy production and sales are reported in British thermal units (Btu). For readers familiar with metric units, Btu can be a relatively intuitive unit because an exajoule is only 5 to 6 percent larger in energy content than a quadrillion Btu.

Emissions data are reported in metric units. This report uses the familiar "million metric tons" common in European industry instead of "gigagram," which is equal to 1,000 metric tons and is the term favored by the scientific community. Metric tons are also relatively intuitive for users of English units, because a metric ton is only about 10 percent heavier than an English short ton.

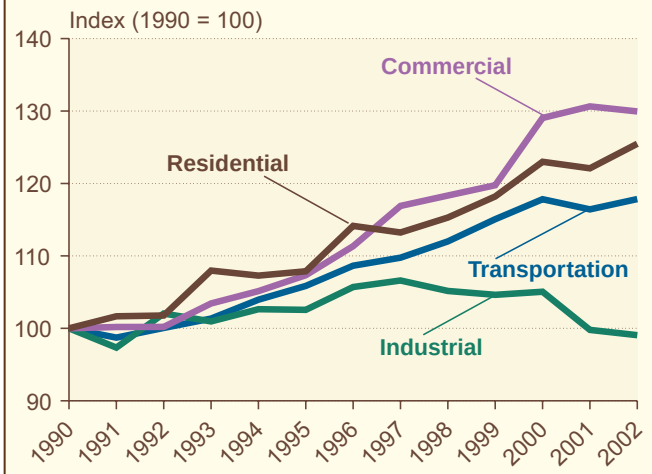
Emissions of most greenhouse gases are reported here in terms of the full molecular weight of the gas (as in Table ES1). In Table ES2, however, and subsequently throughout the report, carbon dioxide and other greenhouse gases are reported in carbon dioxide equivalents. In the case of carbon dioxide, emissions denominated in the molecular weight of the gas or in carbon dioxide equivalents are the same. It is important to note that, in previous issues of this report, greenhouse gas emissions were reported in carbon equivalents. This change is being made to be consistent with the current trend, both domestically and internationally, to report greenhouse gas emissions in carbon dioxide equivalents.

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). GWPs are discussed in the text box on page 6 of this Executive Summary.

electricity) in 2002 are estimated at 2,249.0 million metric tons, 1.0 percent higher than the 2001 level of 2,226.6 million metric tons. The 1-percent increase is less than the 2.7-percent increase in electricity generation during 2002 because of an increase in the average efficiency of natural-gas-fired power plants. Although total electricity generation from natural gas increased by 8.2 percent from 2001 to 2002, emissions from natural-gas-fired generators increased by only 3.4 percent, due to the improved efficiency of new natural-gas-fired combined-cycle generating units.

Figure ES3 illustrates trends in carbon dioxide emissions by energy consumption sector. In general, emissions have increased steadily at the sectoral level since 1990. Average annual growth rates in carbon dioxide emissions by sector during the 1990-2002 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

Figure ES3. U.S. Carbon Dioxide Emissions by Sector, 1990-2002



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057302.pdf.

peaking in 1997, have continued to fall and are now below 1990 levels.

In the residential sector, total carbon dioxide emissions were up by 2.8 percent, from 1,160.8 million metric tons in 2001 to 1,193.0 million metric tons in 2002. The increase is attributed mainly to a 1.2-percent rise in natural gas use due to colder winter weather that increased heating degree-days by 1.4 percent. Emissions attributable to purchased electricity also rose by 3.3 percent, which also contributed to the overall increase in residential carbon dioxide emissions. Since 1990, residential carbon dioxide emissions have grown by an average of 1.9 percent annually.

Carbon dioxide emissions in the commercial sector fell by 0.5 percent, from 1,018.3 million metric tons in 2001 to 1,012.9 million metric tons in 2002. Emissions attributable to purchased electricity decreased by 1.2 percent, from 791.1 million metric tons in 2001 to 781.8 million metric tons in 2002. Carbon dioxide emissions from the direct combustion of fossil fuels in the commercial sector, primarily natural gas, rose from 227.1 million metric tons in 2001 to 231.1 million metric tons in 2002, a 1.7-percent increase. Despite the slight decrease in 2002, commercial sector emissions of carbon dioxide have increased at an average annual rate of 2.2 percent since 1990.

Energy-related carbon dioxide emissions in the industrial sector in 2002 are estimated at 1,673.7 million metric tons, which is approximately equal to the level of emissions in 1990. 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 2002, is a case in point: industrial emissions fell by 0.7 percent in 2002, coinciding with a 1.1-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. 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 2002 (see the text box in the full report, Chapter 2, page 20). Declines in output relative to 2001 were seen in 2002 for the primary metals and pulp and paper industries (-3.0 percent and -2.3 percent, respectively), while increases in output were seen for the chemicals industry (3.9 percent) and stone, clay and glass products (1.0 percent). Smaller increases in output were seen for the other energy-intensive industries: food (0.5 percent) and petroleum refining (0.5 percent). By fuel type, industrial sector carbon dioxide emissions from purchased electricity rose by 0.9 percent, while emissions from natural gas and coal fell by 2.0 percent and 6.9 percent, respectively. Carbon dioxide emissions from petroleum use in the industrial sector increased by 0.7 percent in 2002.

Carbon dioxide emissions in the transportation sector, at 1,849.7 million metric tons, were 1.2 percent higher in 2002 than in 2001. Emissions of carbon dioxide from gasoline consumption (61.6 percent of transportation sector emissions) grew by 2.5 percent, while emissions from jet fuel use for air travel fell by 2.5 percent. Transportation sector carbon dioxide emissions have grown by an average of 1.4 percent annually since 1990.

Methane

U.S. emissions of methane in 2002 were 2.7 percent lower than in 2001, at 26.6 million metric tons of methane or 612.8 million metric tons carbon dioxide equivalent (8.9 percent of total U.S. greenhouse gas emissions). Total U.S. methane emissions in 2001 were 27.4 million metric tons of methane or 630.2 million metric tons carbon dioxide equivalent (9.2 percent of total U.S. greenhouse gas emissions). The 2002 decline resulted primarily from decreases in methane emissions from landfills and, to a smaller extent, from reductions in methane emissions from coal mining.

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 41.1, 29.9, and 28.6 percent, respectively, of total 2002 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) declined from 11.0 million metric tons of methane in 2001 to 10.9 million metric tons of methane in 2002, representing a 0.7-percent reduction in emissions from energy sources. Methane emissions from energy sources have fallen by 8.5 percent since 1990. The drop in 2002 was the result of

Comparison of Global Warming Potentials from the IPCC's Second and Third Assessment Reports

Global warming potentials (GWPs) are used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. GWPs are based on the radiative efficiency (heat-absorbing ability) of each gas relative to that of carbon dioxide (CO_2), as well as the decay rate of each gas (the amount removed from the atmosphere over a given number of years) relative to that of CO_2. The GWP provides a construct for converting emissions of various gases into a common measure, which allows climate analysts to aggregate the radiative impacts of various greenhouse gases into a uniform measure denominated in carbon or carbon dioxide equivalents. The table at the right compares the GWPs published in the Second and Third Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC).

In compiling its greenhouse gas emission estimates, EIA attempts to employ the most current data sources. For that reason, and because the IPCC is generally considered the authoritative source for GWPs, the GWP values from the IPCC's Third Assessment Report are used in this report. It is important to point out, however, that countries reporting to the United Nations Framework Convention on Climate Change (UNFCCC), including the United States, have been compiling estimates based on the GWPs from the IPCC's Second Assessment Report. The UNFCCC Guidelines on Reporting and Review, adopted before the publication of the Third Assessment Report, require emission estimates to be based on the GWPs in the IPCC Second Assessment Report. This will probably continue in the short term, until the UNFCCC reporting rules are changed. Following the current rules, the U.S. Environmental Protection Agency (EPA), which compiles the official U.S. emissions inventory for submission to the UNFCCC, intends to present estimates based on the GWPs published in the Second Assessment Report in its report, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002*, scheduled for release in April 2004.

Comparison of 100-Year GWP Estimates from the IPCC's Second (1996) and Third (2001) Assessment Reports

Gas	1996 IPCC GWP	2001 IPCC GWP
Methane	21	23
Nitrous Oxide	310	296
HFC-23	11,700	12,000
HFC-125	2,800	3,400
HFC-134a	1,300	1,300
HFC-143a	3,800	4,300
HFC-152a	140	120
HFC-227ea	2,900	3,500
HFC-236fa	6,300	9,400
Perfluoromethane (CF_4)	6,500	5,700
Perfluoroethane (C_2F_6)	9,200	11,900
Sulfur Hexafluoride (SF_6)	23,900	22,200

Sources: UNFCCC, Second Assessment Report (1996) and Third Assessment Report (2001).

The table on page 7 shows U.S. carbon dioxide equivalent greenhouse gas emissions calculated using the IPCC's 1996 (Second Assessment Report) and 2001 (Third Assessment Report) GWPs. The estimate for total U.S. emissions in 2002 is 0.6 percent higher when the revised GWPs are used. The estimates for earlier years generally follow the same pattern. Using the 2001 GWPs, estimates of carbon dioxide equivalent methane emissions are 9.5 percent higher, and carbon-equivalent nitrous oxide emissions are 4.5 percent lower. Carbon dioxide equivalent emissions of HFCs, PFCs, and SF_6 are lower for some years and higher for others, depending on the relative shares of the three gases.

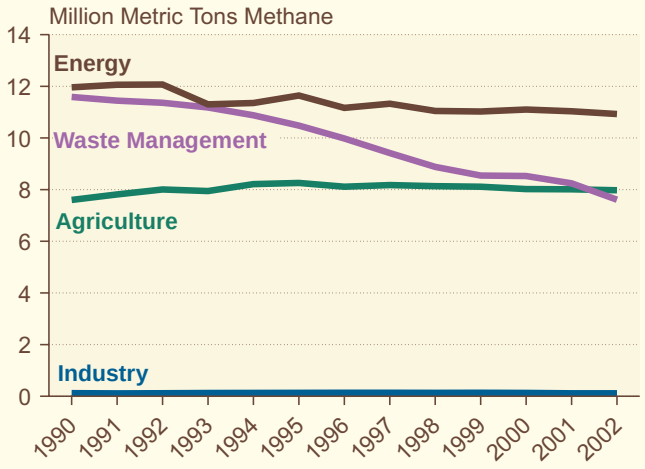
reductions in emissions associated with natural gas production, lower emissions from underground coal mines, a drop in residential wood combustion, and lower emissions from petroleum systems and the transportation sector.

Methane emissions from agricultural sources (8.0 million metric tons) decreased by 0.5 percent in 2002. 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 2002 were slightly (0.03 percent) lower than in 2001, and methane emissions from animal waste were 0.9 percent lower. Agricultural emissions have increased by 5.0 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 decreased by 7.7 percent, from 8.2 million metric tons in 2001 to 7.6 million metric tons in 2002. Contributing to the decrease was an 8.5-percent decrease in emissions from landfills that resulted from a 0.6 million metric ton increase in methane recovery for energy use. Emissions of methane from waste management have declined by 34.3 percent since 1990 as a result of an increase in the amount of methane recovered from landfills (4.7 million metric tons more in 2002 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

Figure ES4. U.S. Emissions of Methane by Source, 1990-2002



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057302.pdf.

Comparison of Global Warming Potentials from the IPCC's Second and Third Assessment Reports (Continued)

Gas	IPCC GWP		Annual GWP-Weighted Emissions (Million Metric Tons Carbon Dioxide Equivalent)								
			1990			2001			2002		
	1996	2001	1996 GWP	2001 GWP	Percent Change	1996 GWP	2001 GWP	Percent Change	1996 GWP	2001 GWP	Percent Change
Carbon Dioxide	1	1	5,006	5,006	0.0	5,748	5,748	0.0	5,796	5,796	0.0
Methane	21	23	657	719	9.5	575	630	10.0	560	613	9.5
Nitrous Oxide	310	296	350	334	-4.5	353	337	-5.0	349	333	-4.5
HFCs, PFCs, and SF_6	M	M	101	97	-4.1	110	114	3.1	117	121	3.4
Total	—	—	**6,113**	**6,156**	**0.7**	**6,787**	**6,829**	**0.6**	**6,820**	**6,862**	**0.6**

M = mixture of gases.

Sources: UNFCCC, Second Assessment Report (1996) and Third Assessment Report (2001), and estimates provided in this report. To download the full report, go to web site ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057302.pdf.

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 volume of municipal waste generated and recycled, as well as the amount of methane recaptured at landfills.

Nitrous Oxide

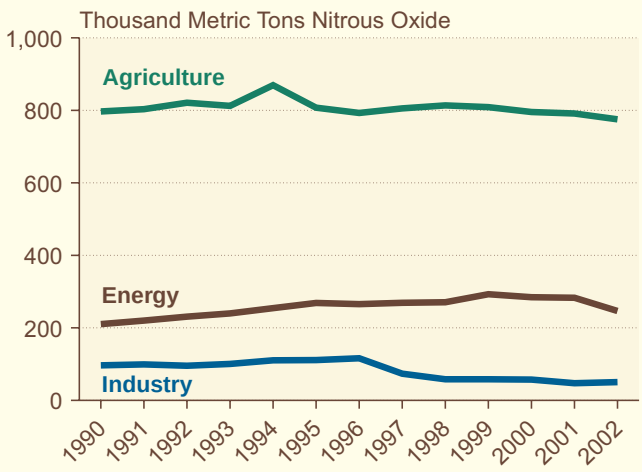
U.S. nitrous oxide emissions decreased by 1.1 percent from 2001 to 2002, to 1.1 million metric tons of nitrous oxide or 333.1 million metric tons carbon dioxide equivalent (4.9 percent of total U.S. greenhouse gas emissions). The 2002 decline in nitrous oxide emissions resulted from decreases in emissions from agricultural sources. Since 1990, U.S. nitrous oxide emissions have fallen by 0.2 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 791 thousand metric tons of nitrous oxide or 234.2 million metric tons carbon dioxide equivalent, account for 70.3 percent of total U.S. nitrous oxide emissions. Emissions associated with nitrogen fertilization of soils, at 583 thousand metric tons or 172.5 million metric tons carbon dioxide equivalent, account for 73.7 percent of nitrous oxide emissions from agriculture. Emissions from the solid waste of animals, at 207 thousand metric tons or 61.2 million metric tons carbon dioxide equivalent, make up 26.1 percent of agricultural nitrous oxide emissions. Nitrous oxide emissions from agriculture have decreased by 2.8 percent since 1990.

U.S. nitrous oxide emissions associated with fossil fuel combustion in 2002 were 0.3 million metric tons of nitrous oxide, or 23.4 percent of total nitrous oxide emissions. Of these energy-related emissions, 81.4 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 31.5 percent since 1990.

Industrial processes and wastewater treatment facilities are responsible for 6.2 percent of total nitrous oxide emissions. Industrial process emissions increased from 47 thousand metric tons (14.0 million metric tons carbon dioxide equivalent) in 2001 to 50 thousand metric tons (14.9 million metric tons carbon dioxide equivalent) in 2002. This represents the first increase in industrial nitrous oxide emissions since 1996. The increase can be attributed to the leveling off of emissions reductions from adipic acid production, as well as a slight increase in emissions from nitric acid production. Emissions from wastewater treatment facilities were 20 thousand metric tons of nitrous oxide (6.0 million metric tons carbon dioxide equivalent), an increase of 0.3 thousand metric tons (0.1 million metric tons carbon dioxide equivalent) or 1.4 percent from 2001.

Figure ES5. U.S. Emissions of Nitrous Oxide by Source, 1990-2002



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057302.pdf.

Other Gases: Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride

HFCs, PFCs, and SF_6 are three classes of engineered gases that account for 1.8 percent of U.S. GWP-weighted emissions of greenhouse gases. At 120.6 million metric tons carbon dioxide equivalent in 2002, their emissions were 6.2 percent higher than in 2001. The increase in emissions of the engineered gases from 2001 to 2002 resulted largely from increases in HFC emissions (8.4 percent) that counteracted decreases in emissions of PFCs (-2.2 percent) and SF_6 (-4.7 percent).

At 83.1 million metric tons carbon dioxide equivalent, emissions of HFCs make up the majority of this category, followed by SF_6 at 16.7 million metric tons and PFCs at 7.6 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 2002, their combined emissions totaled 13.2 million metric tons carbon dioxide equivalent. Emissions in this "other" group in 2002 were 13.5 percent higher than in 2001 and orders of magnitude higher than in 1990, when emissions were less than 180,000 metric tons carbon dioxide equivalent. Since 1990, HFC emissions from U.S. sources have increased by 126.0 percent, PFC emissions have decreased by 60.8 percent, and SF_6 emissions have decreased by 58.7 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 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 2001 at 838.1 million metric tons carbon dioxide equivalent. In 1990, land use change and forestry practices represented an offset of more than 17 percent of total U.S. anthropogenic carbon dioxide emissions. By 2001, the offset had declined to 12 percent.