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Emissions of Greenhouse Gases in the United States 2001

Executive Summary

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Energy Information Administration
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Preface

Emissions of Greenhouse Gases in the United States 2001 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 tenth 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/057301.pdf.

The estimates of greenhouse gas emissions contained in this report are based on energy consumption data from the Energy Information Administration's (EIA's) *Annual Energy Review 2001* (*AER2001*). The *AER2001* is the first EIA publication that contains revised electricity and fuel data from 1989 to 2000. As a result, EIA has revised its estimates for the years 1989 through 2000 for energy-related carbon dioxide emissions, total greenhouse gas emissions, sector-specific emissions, and emissions by fuel type. Last year's emissions report was based primarily on EIA's July 2001 *Monthly Energy Review*.

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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 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

[1]See "Units for Measuring Greenhouse Gases" on page 4, 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).
[3]Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996).

Assessment Reports, see the box on page 9. 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 (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, 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.

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	*	*	*	*	*	*	*	*	*	*	*	*

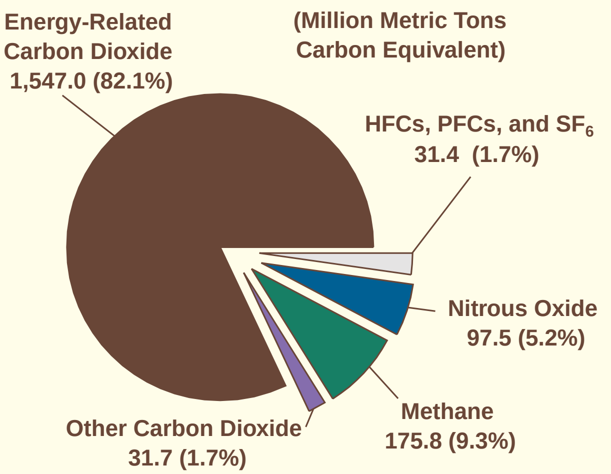
[R]Estimates of energy-related carbon dioxide emissions have been revised as part of an agency-wide adjustment to energy consumption data.
*Less than 0.05 million metric tons of gas.
P = preliminary data.
Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001).
Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057301.pdf.

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**

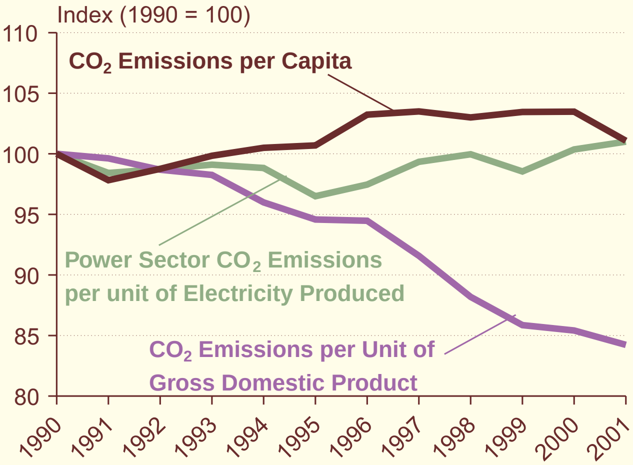
[R]Estimates of energy-related carbon dioxide emissions have been revised as part of an agency-wide adjustment to energy consumption data and sectoral allocations.
P = preliminary data.
Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001).
Sources: **Emissions:** Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057301.pdf. **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.

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



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057301.pdf.

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



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/ 057301.pdf.

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 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

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 is reported in carbon units, defined as the weight of the carbon content of carbon dioxide (i.e., just the "C" in CO_2). Carbon dioxide units at full molecular weight can be converted into carbon units by dividing by 44/12, or 3.6667. This approach has been adopted for two reasons:

- Carbon dioxide is most commonly measured in carbon units in the scientific community. Scientists argue that not all carbon from combustion is, in fact, emitted in the form of carbon dioxide. Because combustion is never perfect, some portion of the emissions consists of carbon monoxide, methane, other volatile organic compounds, and particulates. These other gases (particularly carbon monoxide) eventually decay into carbon dioxide, but it is not strictly accurate to talk about "tons of carbon dioxide" emitted.
- Carbon units are more convenient for comparisons with data on fuel consumption and carbon sequestration. Because most fossil fuels are 75 percent to 90 percent carbon by weight, it is easy and convenient to compare the weight of carbon emissions (in carbon units) with the weight of the fuel burned. Similarly, carbon sequestration in forests and soils is always measured in tons of carbon, and the use of carbon units makes it simple to compare sequestration with emissions.

While carbon dioxide emissions can be measured in tons of carbon, emissions of other 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). The table on the following page shows GWPs for various greenhouse gases. For comparability, carbon dioxide equivalent units can be converted to "carbon equivalent" by multiplying by 12/44 (as in Table ES2) to provide a measure of the relative effects of various gases on climate. *(continued on page 5)*

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 and Table ES3 illustrate 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

[4]As described in detail in Chapter 2 of the full report, 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.

Units for Measuring Greenhouse Gases (continued)

Numerical Estimates of Global Warming Potentials Compared With Carbon Dioxide
(Kilogram of Gas per Kilogram of Carbon Dioxide)

Gas	Lifetime (Years)	Direct Effect for Time Horizons of		
		20 Years	100 Years	500 Years
Carbon Dioxide	5 – 200[a]	1	1	1
Methane	12	62	23	7
Nitrous Oxide	114	275	296	156
HFCs, PFCs, and Sulfur Hexafluoride				
HFC-23	260	9,400	12,000	10,000
HFC-125	29	5,900	3,400	1,100
HFC-134a	13.8	3,300	1,300	400
HFC-152a	1.4	410	120	37
HFC-227ea	33	5,600	3,500	1,100
Perfluoromethane (CF_4)	50,000	3,900	5,700	8,900
Perfluoroethane (C_2F_6)	10,000	8,000	11,900	18,000
Sulfur Hexafluoride (SF_6)	3,200	15,100	22,200	32,400

[a]No single lifetime can be defined for carbon dioxide due to different rates of uptake by different removal processes.

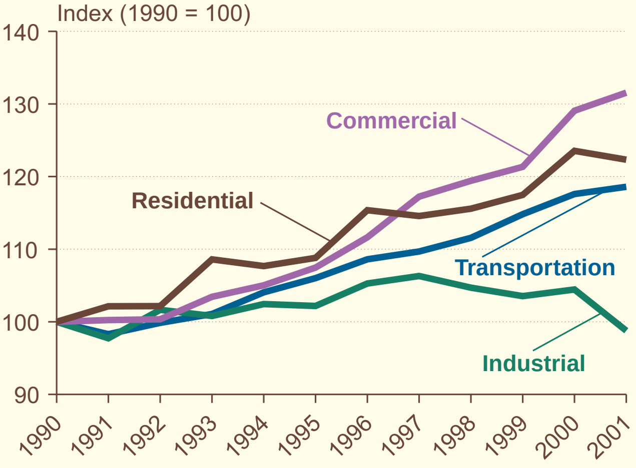
Note: The typical uncertainty for global warming potentials is estimated by the Intergovernmental Panel on Climate Change at ±35 percent.

Source: Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), pp. 38 and 388-389.

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 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

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



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057301.pdf.

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.

Table ES3. U.S. Carbon Dioxide Emissions from Energy Consumption by End-Use Sector, 1990-2001
(Million Metric Tons Carbon Equivalent)

End-Use Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Residential	257.5	263.0	263.0	279.6	277.2	280.1	297.0	295.0	297.6	302.5	318.1	314.9
Commercial	212.6	213.2	213.4	220.0	223.4	228.5	237.4	249.3	253.9	258.0	274.4	279.7
Industrial	458.0	447.6	465.6	461.7	469.2	468.0	482.2	486.9	479.5	474.2	478.4	452.4
Transportation	431.4	424.1	430.8	436.1	448.9	457.4	468.5	473.2	481.3	495.3	507.3	511.6
Total	**1,359.5**	**1,347.8**	**1,372.8**	**1,397.3**	**1,418.7**	**1,434.1**	**1,485.2**	**1,504.3**	**1,512.3**	**1,530.1**	**1,578.3**	**1,558.7**
Electric Power	492.3	492.2	495.7	515.9	522.5	526.8	546.5	564.8	589.2	592.8	621.2	611.7

P = preliminary data.

Notes: 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). Energy-related carbon dioxide emissions have been revised as part of an agency-wide adjustment to energy consumption data and sectoral allocations. Totals may not equal sum of components due to independent rounding. Electric power sector emissions are distributed across the end-use sectors. Emissions allocated to sectors are unadjusted. Adjustments are made to total emissions only.

Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057301.pdf.

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.

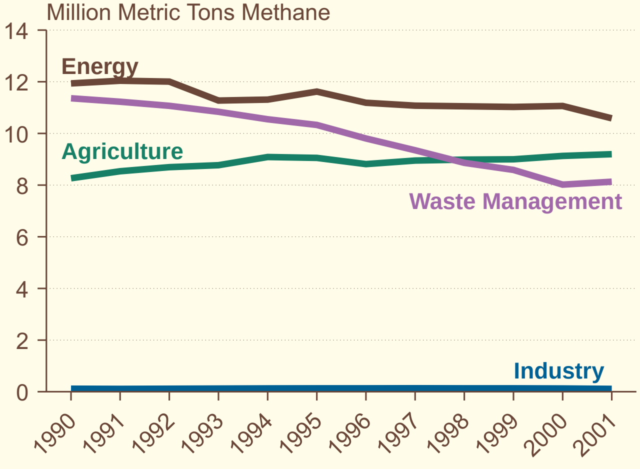
Methane emissions come from four categories of sources, three major and one minor. The major sources are energy, agriculture, and waste management, and the minor source is industrial processes. The three major sources accounted for 37.8, 32.8, and 29.0 percent, respectively, of total 2001 U.S. emissions 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

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



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057301.pdf.

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

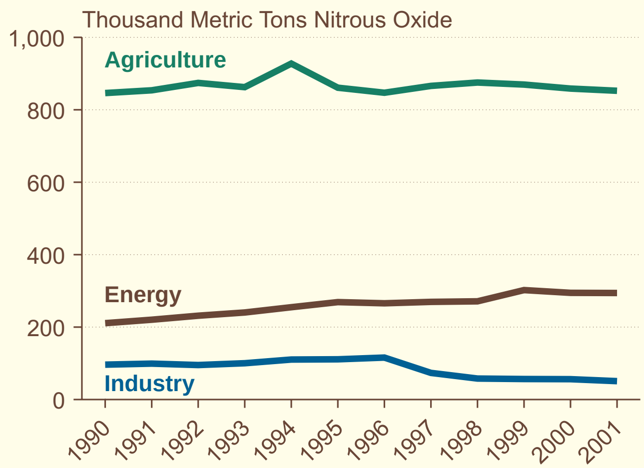
The estimates for methane emissions are more uncertain than those for carbon dioxide. U.S. methane emissions do not necessarily increase with growth in energy consumption or the economy. Energy-related methane emissions are strongly influenced by coal production from a relatively restricted number of 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 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.

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



Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057301.pdf.

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 SF_6 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 SF_6 (6.7 percent). At 21.0 million metric tons carbon equivalent, emissions of HFCs make up the majority of this category, followed by SF_6 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 SF_6 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 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, 4310, 227ea), which are used as replacements for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), have shorter atmospheric lifetimes, ranging from 1 to 33 years.

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

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

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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.

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

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 continue until the UNFCCC reporting rules are changed. Therefore, the U.S. Environmental Protection Agency (EPA), in its *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000* (April 2002), compiled the official U.S. emissions inventory for submission to the UNFCCC based on the GWPs published in the Second Assessment Report. In its next inventory report, the EPA will present aggregate emissions calculated with GWPs from the Third Assessment Report for informational purposes.

The table below shows 2001 U.S. carbon-equivalent greenhouse gas emissions calculated using the IPCC's 1996 and 2001 GWPs. The estimate for total U.S. emissions in 2001 is 0.8 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-equivalent methane emissions are 10 percent higher, and carbon-equivalent nitrous oxide emissions are 4 percent lower. Carbon-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.

Gas	IPCC GWP		Annual GWP-Weighted Emissions (Million Metric Tons Carbon Equivalent)								
			1990			2000			2001		
	1996	2001	1996 GWP	2001 GWP	Percent Change	1996 GWP	2001 GWP	Percent Change	1996 GWP	2001 GWP	Percent Change
Carbon Dioxide	1	1	1,364	1,364	0.0	1,597	1,597	0.0	1,579	1,579	0.0
Methane	21	23	181	199	9.5	162	178	9.5	160	176	10.0
Nitrous Oxide	310	296	99	94	-4.5	103	98	-4.5	102	97	-4.0
HFCs, PFCs, and SF_6	—	—	26	25	-3.8	31	34	9.7	28	31	10.7
Total	—	—	**1,670**	**1,683**	**0.7**	**1,891**	**1,907**	**0.8**	**1,868**	**1,883**	**0.8**

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