DOE/EIA-0573(2000/ES)

Emissions of Greenhouse Gases in the United States 2000

Executive Summary

November 2001

Energy Information Administration
Office of Integrated Analysis and Forecasting
U.S. Department of Energy
Washington, DC 20585

This publication is on the WEB at:
www.eia.doe.gov/oiaf/1605/ggrpt/index.html

Preface

Emissions of Greenhouse Gases in the United States 2000 was prepared under the general direction of Scott Sitzer, Acting 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 ninth 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. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrept/057300.pdf.

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Introduction

U.S. Anthropogenic Greenhouse Gas Emissions, 1990-2000

	Carbon Equivalent
Estimated 2000 Emissions (Million Metric Tons)	1,906.3
Change Compared to 1999 (Million Metric Tons)	46.1
Change from 1999 *(Percent)*	*2.5%*
Change Compared to 1990 (Million Metric Tons)	228.4
Change from 1990 *(Percent)*	*13.6%*
Average Annual Increase, 1990-2000 *(Percent)*	*1.3%*

U.S. emissions of greenhouse gases in 2000 totaled 1,906 million metric tons carbon equivalent, 2.5 percent more than in 1999 (1,860 million metric tons carbon equivalent). The increase from 1999 to 2000 is nearly double the 1.3-percent average annual growth rate of total U.S. greenhouse gas emissions from 1990 to 2000 and the 1.3-percent increase from 1998 to 1999. The increase from 1999 to 2000 is attributed to strong growth in carbon dioxide emissions due to a return to more normal weather, decreased hydroelectric power generation that was replaced by fossil-fuel power generation, and strong economic growth (a 4.1-percent increase in gross domestic product).

U.S. greenhouse gas emissions in 2000 were about 14 percent higher than 1990 emissions (1,678 million metric tons carbon equivalent). Since 1990, U.S. emissions have increased slightly faster than the average annual growth in population (1.2 percent) but more slowly than the growth in energy consumption (1.6 percent), electric power generation (2.3 percent), or gross domestic product (3.2 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." This concept, developed by the Intergovernmental Panel on Climate Change (IPCC), provides a comparative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.[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 Assessment Reports, see the box on page 9. Generally, total U.S. carbon-equivalent emissions are 0.6 percent higher when the GWPs from the Third Assessment Report are used.

During 2000, 81.2 percent of total U.S. greenhouse gas emissions consisted of carbon dioxide from the

[1]See "Units for Measuring Greenhouse Gases" on page 3, and Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

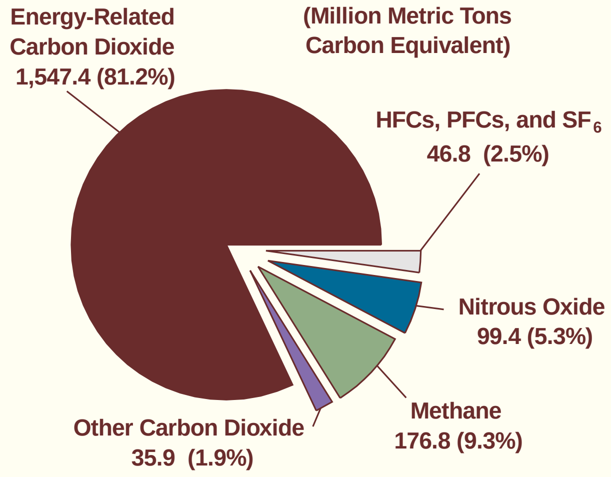
[2]Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

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

combustion of fossil fuels such as coal, petroleum, and natural gas. 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 2000 U.S. greenhouse gas emissions include carbon dioxide from non-combustion sources (1.9 percent of total U.S. greenhouse gas emissions), methane (9.3 percent), nitrous oxide (5.3 percent), and other gases (2.5 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

Figure ES1. U.S. Greenhouse Gas Emissions by Gas, 2000



Source: EIA estimates presented in this report.

Table ES1. Summary of Estimated U.S. Emissions of Greenhouse Gases, 1990-2000
(Million Metric Tons of Gas)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Carbon Dioxide	4,969.4	4,917.7	5,013.0	5,130.4	5,224.4	5,273.5	5,454.8	5,533.0	5,540.0	5,630.7	5,805.5
Methane	31.7	31.9	31.8	31.0	31.0	31.1	29.9	29.6	28.9	28.7	28.2
Nitrous Oxide	1.2	1.2	1.2	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2
HFCs, PFCs, and SF_6 . .	*	*	*	*	*	*	*	*	*	*	*

*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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000).

Source: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrept/057300.pdf.

Table ES2. U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990-2000
(Million Metric Tons Carbon Equivalent)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Carbon Dioxide	1,355	1,341	1,367	1,399	1,425	1,438	1,488	1,509	1,511	1,536	1,583
Methane	199	200	200	194	194	195	188	186	181	180	177
Nitrous Oxide	94	96	98	98	106	101	101	99	99	100	99
HFCs, PFCs, and SF_6 . .	30	28	29	30	32	35	39	42	46	45	47
Total.	**1,678**	**1,665**	**1,694**	**1,722**	**1,757**	**1,770**	**1,815**	**1,836**	**1,836**	**1,860**	**1,906**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000).

Sources: **Emissions:** Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrept/057300.pdf. **Global Warming Potentials:** Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996).

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 page 4 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 4)

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.

The Kyoto Protocol, drafted in December 1997 under the auspices of the United Nations Framework Convention on Climate Change, raised the public profile of climate change issues in the United States in general, and of emissions estimates in particular. 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.

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.

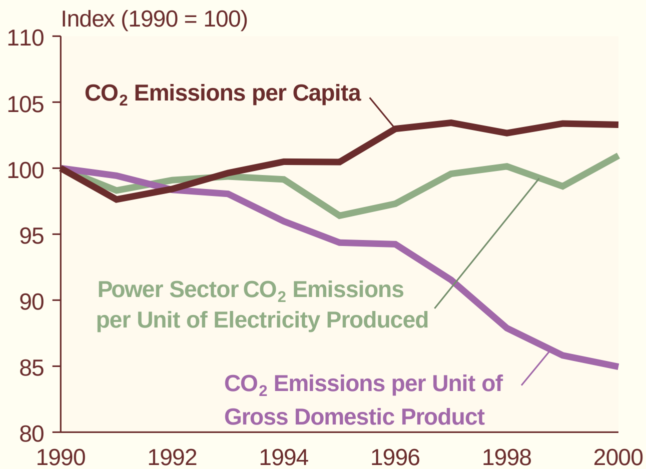
Source: Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 1996), pp. 38 and 388-389.

Carbon Dioxide

The preliminary estimate of U.S. carbon dioxide emissions in 2000 is 1,583 million metric tons carbon equivalent—3.1 percent higher than in 1999 and accounting for 83 percent of total U.S. greenhouse gas emissions. The 3.1-percent growth rate in 2000 is the second highest for the 1990 to 2000 period, with only the 3.4-percent growth rate in 1996 being higher. 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, energy use, and income, as well as the "carbon intensity" of energy use (carbon dioxide emissions per unit of energy consumed).

Figure ES2 illustrates some recent U.S. trends in carbon dioxide emissions and energy consumption. Although annual carbon dioxide emissions per dollar of GDP have fallen by 15 percent since 1990, carbon dioxide emissions per capita have risen by 3 percent. The combination of

Figure ES2. Carbon Dioxide Emissions Intensity of U.S. Gross Domestic Product, Population, and Electricity Production, 1990-2000



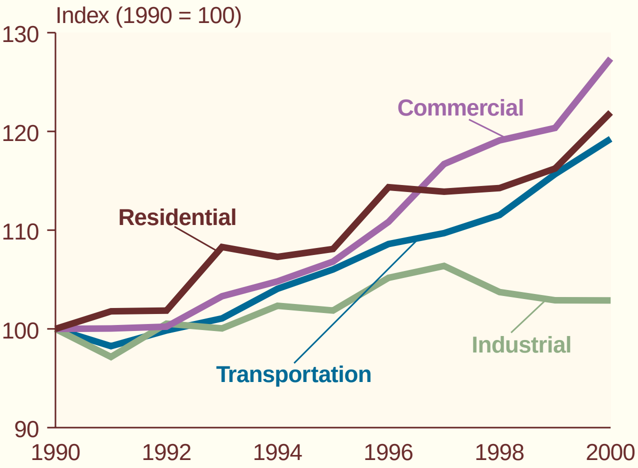
Sources: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrept/ 057300.pdf.

increasing population growth and rising carbon dioxide emissions per capita results in increased aggregate carbon dioxide emissions per year during the 1990 to 2000 time frame. Carbon dioxide emissions per unit of net electricity generation, after initially falling during the early to mid-1990s, have increased to above the 1990 level. The upturn in this measure from 1999 to 2000 helps explain the high 2000 growth rate in carbon dioxide emissions.

Figure ES3 and Table ES3 illustrate trends in carbon dioxide emissions by energy consumption sector. In general, emissions have increased in each of the four sectors since 1990. An exception to the general upward trend was 1990-1991, when economic recession and higher oil prices following the Iraqi invasion of Kuwait led to a 1.0-percent decrease in national carbon dioxide emissions in 1991. Average annual growth rates in carbon dioxide emissions by sector during the 1990-2000 period were 2.4 percent for the commercial sector, 2.0 percent for the residential sector and 1.8 percent for the transportation sector, all higher than the 1.6-percent average for total U.S. carbon dioxide emissions during the 1990-2000 period. For the industrial sector, however, annual growth in carbon dioxide emissions has averaged only 0.3 percent. Industrial sector carbon dioxide emissions, which are relatively sensitive to economic fluctuations, declined by 2.5 percent in 1991 during the economic recession and dipped again in 1998 in the wake of the Asian economic slowdown.

Carbon dioxide emissions from the U.S. electric power sector (which includes cogeneration) in 2000 are estimated at 642 million metric tons carbon equivalent, 4.7 percent higher than the 1999 level. The 2000 increase is almost double the 1990-2000 average increase of 2.4 percent per year. Contributing to the relatively large increase in 2000 was a 4.2-percent increase in fossil fuel use for electricity generation, including a 4.3-percent

Figure ES3. U.S. Carbon Dioxide Emissions by Sector, 1990-2000



Sources: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrept/ 057300.pdf.

Table ES3. U.S. Carbon Dioxide Emissions from Energy Consumption by End-Use Sector, 1990-2000
(Million Metric Tons Carbon Equivalent)

End-Use Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Residential	257.0	261.6	261.8	278.4	275.8	277.9	293.9	292.8	293.7	298.8	313.4
Commercial	210.3	210.4	210.8	217.2	220.4	224.6	233.1	245.4	250.4	253.1	267.8
Industrial	452.7	439.8	455.1	452.9	463.3	461.1	476.1	481.5	469.5	465.8	465.7
Transportation	431.8	424.2	431.1	436.4	449.3	457.8	468.9	473.6	481.5	499.4	514.8
Total	**1,351.7**	**1,336.0**	**1,358.7**	**1,384.8**	**1,408.8**	**1,421.3**	**1,471.9**	**1,493.3**	**1,495.2**	**1,517.1**	**1,561.7**
Electric Power	507.0	506.0	512.0	532.4	540.7	542.5	562.1	583.1	607.2	612.6	641.6

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). 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 (Table 4).

Sources: EIA estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrept/057300.pdf.

increase in coal-fired generation and a 7.1-percent increase in natural-gas-fired generation. Electricity generation from renewable fuels was down by 11 percent, including a 14-percent drop in hydroelectric generation. On the demand side, electricity-related emissions in the residential sector were 5.6 percent higher in 2000 than in 1999, and in the commercial sector they were 4.9 percent higher.[4] Although summer cooling degree-days were 4.4 percent above normal in 2000, air conditioning usage was lower than in 1999, when cooling degree-days were 7.3 percent above normal.

In addition to electricity-related emissions, direct use of energy fuels in the residential, commercial, industrial, and transportation sectors produces carbon dioxide emissions. In the residential and commercial sectors, consumption of winter heating fuels, particularly natural gas, was higher in 2000 than in 1999 as a result of winter weather that was 7.0 percent colder than in 1999.[5] Carbon dioxide emissions from the direct combustion of fuels (primarily natural gas) increased by 3.5 percent in the residential sector and by 8.8 percent in the commercial sector. Overall, carbon dioxide emissions in the residential and commercial sectors, at a combined 581 million metric tons carbon equivalent and 37.2 percent of total carbon dioxide emissions, grew by 5.3 percent in 2000.

Energy-related carbon dioxide emissions in the industrial sector in 2000 are estimated at 466 million metric tons carbon equivalent—which is equal to the level of emissions in 1999. The lack of growth in industrial emissions is noteworthy because, historically, industrial energy consumption and carbon dioxide emissions have been more sensitive to economic growth than to the weather, and 2000 was a year of solid economic growth (4.1 percent). Industrial energy consumption and emissions are concentrated in a few industries, however, and their performance may have more influence on emissions than does the performance of the industrial sector as a whole. Six industry groups—petroleum refining, chemicals and related products, primary metals, paper, food, and stone, clay and glass—collectively account for 79.6 percent of carbon dioxide emissions from manufacturing and 68.2 percent of carbon dioxide emissions from the industrial sector.

In 2000 the six energy-intensive industry groups appeared to be still recovering from downturns from their 1997 growth rates. Their 2000 annual growth rates were lower than those for the overall economy (4.1 percent), the industrial sector (5.6 percent), and the manufacturing component of industrial production (6.1 percent). For the six energy-intensive industries, 2000 growth rates were 2.5 percent (primary metals), 1.8 percent (chemicals), -0.9 percent (paper), 2.3 percent (stone, clay and glass), 1.6 percent (petroleum products), and 1.9 percent (food). The industries that grew rapidly in 2000 were primarily those with lower energy intensities, including computer equipment, which grew by 43 percent, and semiconductors and related components, which grew by 76 percent.[6]

Carbon dioxide emissions in the transportation sector, at 515 million metric tons carbon equivalent, were 3.1 percent higher in 2000 than in 1999. Gasoline consumption, which accounted for 59 percent of transportation sector emissions, grew by 0.6 percent. Emissions from jet fuel use grew by 3.4 percent, and emissions from residual fuel (used mostly by oceangoing ships) grew by 35.9 percent. Emissions from distillate use increased by 4.6 percent, as a healthy U.S. economy led to greater consumption of diesel fuel by freight trucks.

[4]The sectoral shares of electricity-related carbon dioxide emissions are based on the shares of total electric utility power sales purchased in each sector.

[5]Population-weighted heating degree-days in 2000 were 7.0 percent higher than in 1999. See Energy Information Administration, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, DC, August 2000), Table 1.7.

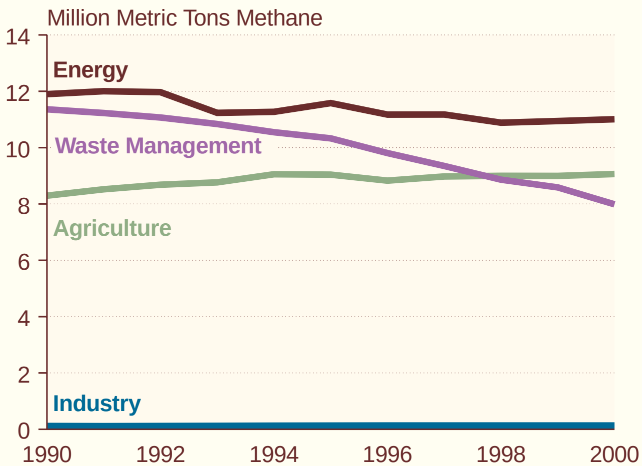
[6]All industrial and manufacturing growth rates are taken from U.S. Federal Reserve Board, "G17 Historical Data: Industrial Production and Capacity Utilization." Although the Federal Reserve Board, in calculating indexes, bases its estimates on two main types of source data, output measured in physical units and data on inputs to the production process, it also adjusts its indexes on the basis of technological improvements in factor productivity and outputs. This could be particularly important for indexes related to computers and semiconductors, for which productivity and quality of outputs have improved dramatically over time.

Methane

U.S. emissions of methane in 2000 were 1.6 percent lower than in 1999, at 28.2 million metric tons of methane or 177 million metric tons carbon equivalent. The decline resulted primarily from an increase in methane recovery for energy use at landfills and, to a lesser extent, from reductions in emissions from coal mining and petroleum systems.

Methane emissions come from four categories of sources, three major and one minor. The major sources are energy, waste management, and agriculture, and the minor source is industrial processes. The three major sources accounted for 39, 28, and 32 percent, respectively, of total 2000 U.S. emissions of methane, or approximately 9 percent of the Nation's total carbon-equivalent greenhouse gas emissions. The major sources of anthropogenic methane emissions are illustrated in Figure ES4. Methane emissions from the anaerobic decomposition of municipal solid waste in landfills, part of the waste management source category, had been declining slowly before 2000 as a consequence of a reduction in the volume of waste landfilled and a gradual increase in the volumes of landfill gas captured. Emissions of methane resulting from waste management decreased by 7.0 percent in 2000.

Figure ES4. U.S. Methane Emissions by Source, 1990-2000



Sources: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrept/057300.pdf.

Methane recovery for energy at U.S. landfills rose from 2.2 million metric tons in 1999 to 2.5 million metric tons in 2000 due to the lingering effects of Section 29 of the Windfall Profits Tax Act of 1980. To be eligible for the tax credit, methane recovery systems at landfills must have been operational by June 30, 1998. The last recovery projects installed by the tax credit deadline continued to ramp up in 2000. Additionally, for the first time in 40 years, U.S. coal production fell for a second consecutive year as coal imports increased by 37 percent and electric utilities drew down stocks to meet increasing demand,[7] lowering methane emissions from coal mining and post-mining activities by about 0.1 million metric tons. Domestic oil production also declined in 2000, and methane emissions from petroleum systems decreased accordingly.

Methane is also emitted as a byproduct of fossil energy production and transport. Methane can leak from natural gas production and distribution systems and is also emitted during coal production. Energy-related methane emissions were essentially unchanged in 2000 at 11.0 million metric tons. Agricultural emissions have several sources but are dominated by emissions from domestic livestock, including the animals themselves and the anaerobic decomposition of their waste. Agricultural emissions increased by about 0.8 percent in 2000.

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 livestock and municipal waste emissions are influenced by husbandry and waste management practices.

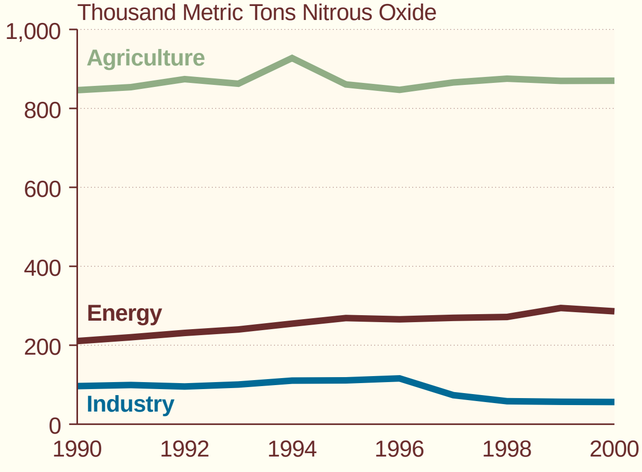
[7]Energy Information Administration, *U.S. Coal Supply and Demand: 2000 Review*, web site http://www.eia.doe.gov/cneaf/coal/page/special/feature.html.

Nitrous Oxide

U.S. nitrous oxide emissions decreased by 0.6 percent from 1999 to 2000, to 99 million metric tons carbon equivalent. Nitrous oxide accounts for 5 percent of U.S. GWP-weighted greenhouse gas emissions. Emissions estimates for nitrous oxide are more uncertain than those for either carbon dioxide or methane, because nitrous oxide is not systematically measured and many sources of nitrous oxide emissions, including nitrogen fertilization of soils and motor vehicles, require a significant number of assumptions to arrive at estimated emissions.

U.S. nitrous oxide emissions include one large class of sources and two small classes (Figure ES5). Agricultural sources account for about 70 percent of nitrous oxide emissions, and emissions associated with nitrogen fertilization of soils account for 73 percent of agricultural emissions. In 2000, estimated nitrous oxide emissions from nitrogen fertilization of soils increased by 0.2 percent from 1999. Emissions associated with fossil fuel use account for another 23 percent of nitrous oxide emissions, of which about 83 percent comes from mobile sources, principally motor vehicles equipped with catalytic converters. The balance of nitrous oxide emissions are caused by certain chemical manufacturing and wastewater treatment processes. The most striking trend in U.S. nitrous oxide emissions has been a 52-percent decline from 1996 levels of industrial emissions of nitrous oxide after the implementation of emissions controls at an adipic acid plant operated by the DuPont Corporation.

Figure ES5. U.S. Nitrous Oxide Emissions by Source, 1990-2000



Sources: Estimates presented in this report. To download the full report, go to ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrept/057300.pdf.

Other Gases: Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride

HFCs, PFCs, and SF_6 are three classes of engineered gases that account for 2.5 percent of U.S. GWP-weighted emissions of greenhouse gases. At 46.8 million metric tons carbon equivalent in 2000, their emissions were 4.5 percent higher than in 1999. The 2000 increase in emissions of the engineered gases was caused almost entirely by an increase in emissions of HFCs (8.3 percent) as emissions of PFCs and SF_6 fell by 3.7 percent and 4.3 percent, respectively. The increase in HFC emissions in 2000 may be attributable in part to maturing markets for chlorofluorocarbon substitutes and increasing awareness of the potential for recycling these gases.

At 28.1 million metric tons carbon equivalent, emissions of HFCs make up the majority of this category, followed by PFCs at 8.7 million metric tons carbon equivalent and SF_6 at 5.5 million metric tons carbon 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 2000, their combined emissions totaled 4.4 million metric tons carbon equivalent. Emissions in this “other” group in 2000 were 10.5 percent higher than in 1999. Since 1990, HFC emissions from U.S. sources have increased by 181.4 percent, PFC emissions have decreased by 14.4 percent, and SF_6 emissions have decreased by 41.4 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 hundreds or thousands of years, and consequently they are potent greenhouse gases with GWPs hundreds or 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 chlorofluorocarbon replacements, have shorter atmospheric lifetimes, ranging from 1 to 36 years.

Land Use and Forestry

Forest lands in the United States are net absorbers of carbon dioxide from the atmosphere. According to U.S. Forest Service researchers, U.S. forest land absorbs about 270 million metric tons of carbon annually, equivalent to 17.1 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. At present, the Energy Information Administration does not have sufficient information to permit reliable estimation of national-level emissions or sequestration from this source. As more reliable information becomes available, estimates will be included in future reports.

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

(continued on page 10)

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 probably continue in the short term, until the UNFCCC reporting rules are changed. 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 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000* for release in April 2002.

The table below shows 2000 U.S. carbon-equivalent greenhouse gas emissions calculated using the IPCC's 1996 and 2001 GWPs. The estimate for total U.S. emissions in 2000 is 0.7 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 9.5 percent higher, and carbon-equivalent nitrous oxide emissions are 4.5 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								
			1990			1999			2000		
	1996	2001	1996 GWP	2001 GWP	Percent Change	1996 GWP	2001 GWP	Percent Change	1996 GWP	2001 GWP	Percent Change
Carbon Dioxide	1	1	1,355	1,355	0.0	1,536	1,536	0.0	1,583	1,583	0.0
Methane	23	21	181	199	9.5	164	180	9.5	161	177	9.5
Nitrous Oxide	296	310	99	94	-4.5	105	100	-4.5	104	99	-4.5
HFCs, PFCs, and SF_6	—	—	31	30	-2.4	44	45	2.9	45	47	3.5
Total	—	—	**1,666**	**1,678**	**0.6**	**1,848**	**1,860**	**0.6**	**1,894**	**1,906**	**0.7**