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Emissions of Greenhouse Gases in the United States 2004

Executive Summary

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Energy Information Administration
Office of Integrated Analysis and Forecasting
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The full report is on the WEB at:
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Preface

Emissions of Greenhouse Gases in the United States 2004, was prepared under the general direction of John Conti, Director of the Office of Integrated Analysis and Forecasting, Energy Information Administration. General questions concerning the content of this report may be directed to the National Energy Information Center at 202/586-8800.

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

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

The first report in this series, *Emissions of Greenhouse Gases 1985-1990*, was published in September 1993. This report—the thirteenth annual report—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.

For this report, data on coal and natural gas consumption and electricity sales and losses by sector were obtained from the Energy Information Administration's (EIA's) September 2005 *Monthly Energy Review*. Additional detailed information on petroleum consumption was obtained from unpublished material in support of EIA's *Annual Energy Review 2004*. Electric power sector emissions were obtained from data underlying EIA's *Electric Power Annual*. In keeping with current international practice, this report presents data on greenhouse gas emissions in million metric tons carbon dioxide equivalent. The data can be converted to carbon equivalent units by multiplying times 12/44.

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U.S. Anthropogenic Emissions of Greenhouse Gases, 1990-2004

	Carbon Dioxide Equivalent
Estimated 2004 Emissions (Million Metric Tons)	7,122.1
Change Compared to 2003 (Million Metric Tons)	138.8
Change from 2003 *(Percent)*	*2.0%*
Change Compared to 1990 (Million Metric Tons)	973.3
Change from 1990 *(Percent)*	*15.8%*
Average Annual Increase, 1990-2004 *(Percent)*	*1.1%*

Overview

U.S. emissions of greenhouse gases in 2004 totaled 7,122.1 million metric tons carbon dioxide equivalent (MMTCO_2e), 2.0 percent more than in 2003 (6,983.2 MMTCO_2e). The 2004 increase in total greenhouse gas emissions is attributable primarily to a 1.7-percent increase in emissions of carbon dioxide, along with increases in emissions of nitrous oxide (5.5 percent) and methane (0.9 percent). Emissions of engineered gases—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—also increased, by 9.6 percent. The U.S. economy grew by 4.2 percent in 2004, the highest rate of growth since 1999. Consequently, U.S. greenhouse gas intensity (greenhouse gas emissions per unit of real economic output) was 2.1 percent lower in 2004 than in 2003. From 1990 to 2004, U.S. greenhouse gas intensity declined by 23 percent, or by an average of 1.9 percent per year (see box on page 4 for details).

U.S. greenhouse gas emissions in 2004 were 16 percent higher than the 1990 emissions level of 6,148.8 MMTCO_2e—an average annual increase of 1.1 percent over the period. Since 1990, U.S. emissions have increased more slowly than the average annual growth in population (1.2 percent), primary energy consumption (1.2 percent), electric power generation (1.9 percent), or gross domestic product (3.0 percent). While the annual growth rate in carbon dioxide emissions since 1990 (1.3 percent) has closely tracked annual growth in population and energy consumption, the average annual rate of growth in total greenhouse gas emissions has been lower (1.1 percent) because of reductions in methane emissions and low growth in nitrous oxide emissions (0.7 percent) since 1990.

Table ES1 shows trends in emissions of the principal greenhouse gases, measured in million metric tons of native gas. In Table ES2, emissions trends are shown in carbon dioxide equivalents, which are derived by multiplying the volumes of native gas by the global warming potential (GWP) of each gas. The GWPs provide a measure of marginal radiative efficiency for each of the native gases. The GWP concept, developed by the Intergovernmental Panel on Climate Change (IPCC), provides a comparative measure of the impacts of added units of different greenhouse gases on global warming relative to the impact of carbon dioxide.[1] This allows for the normalization of different greenhouse gases, which have different warming impacts, into a common unit of

Table ES1. Summary of Estimated U.S. Emissions of Greenhouse Gases, 1990 and 1996-2004
(Million Metric Tons of Gas)

Gas	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Carbon Dioxide	5,002.3	5,499.7	5,563.0	5,598.1	5,677.9	5,845.5	5,785.5	5,808.5	5,871.8	5,973.0
Methane	31.4	29.4	29.4	28.4	27.9	27.8	27.2	27.2	27.6	27.8
Nitrous Oxide	1.1	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.2
HFCs, PFCs, and SF_6	M	M	M	M	M	M	M	M	M	M

M = mixture of gases. These gases cannot be summed in native units. See Table ES2 for estimated totals in carbon dioxide equivalent.
P = preliminary data.
Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).
Sources: EIA estimates presented in *Emissions of Greenhouse Gases in the United States 2004*.

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

measure—carbon dioxide equivalents—which can be aggregated across gases (see box on page 7).

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. Generally, the level of total U.S. carbon dioxide equivalent emissions is 0.7 percent higher when the GWPs from the Third Assessment Report are used; however, the trends in growth of greenhouse gas emissions are similar for both sets of GWP values.

During 2004, 82.4 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.

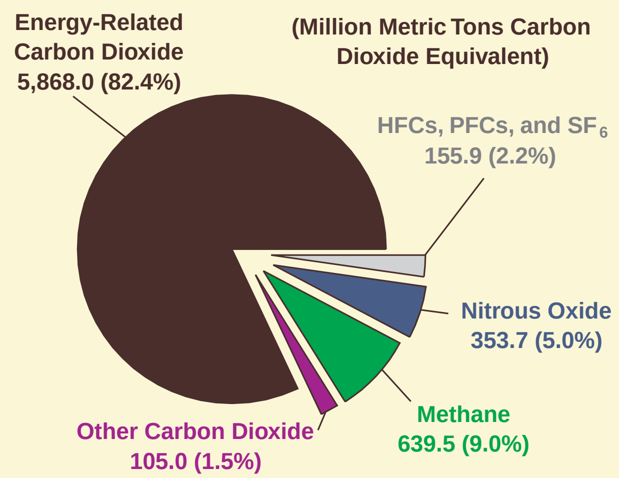
Other 2004 U.S. greenhouse gas emissions (Figure ES1) include carbon dioxide from non-combustion sources (1.5 percent of total U.S. greenhouse gas emissions), methane (9.0 percent), nitrous oxide (5.0 percent), and other gases (2.2 percent). Methane and nitrous oxide emissions are caused by the biological decomposition of various waste streams and fertilizer; fugitive emissions from chemical processes; fossil fuel production, transmission, and combustion; and many smaller sources. The other gases include HFCs, used primarily as refrigerants; PFCs, released as fugitive emissions from aluminum smelting and used in semiconductor manufacture; and SF_6, used as an insulator in utility-scale electrical equipment.

This report, in accordance with 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.

Carbon Dioxide

The preliminary estimate of U.S. carbon dioxide emissions from both energy consumption and industrial processes in 2004 is 5,973.0 million metric tons (MMT), which is 1.7 percent higher than in 2003 (5,871.8 MMT)

Figure ES1. U.S. Greenhouse Gas Emissions by Gas, 2004



Source: Tables ES2 and ES3.

Table ES2. U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990 and 1996-2004
(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Carbon Dioxide	5,002.3	5,499.7	5,563.0	5,598.1	5,677.9	5,845.5	5,785.5	5,808.5	5,871.8	5,973.0
Methane.	721.4	675.8	675.2	654.2	642.2	639.8	625.8	626.2	633.9	639.5
Nitrous Oxide.	337.0	358.0	349.1	348.8	347.1	343.5	338.8	335.1	335.2	353.7
HFCs, PFCs, and SF_6 . .	88.1	114.3	122.0	137.7	137.4	142.1	133.9	143.1	142.4	155.9
Total	**6,148.8**	**6,647.7**	**6,709.3**	**6,738.8**	**6,804.7**	**6,970.8**	**6,884.1**	**6,912.9**	**6,983.2**	**7,122.1**

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 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004).

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.

[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).

and accounts for 83.9 percent of total U.S. greenhouse gas emissions (see Table ES3 for a breakdown of U.S. carbon dioxide emissions by source). U.S. carbon dioxide emissions have grown by an average of 1.3 percent annually since 1990. Although short-term changes in carbon dioxide emissions can result from temporary variations in weather, power generation fuel mixes, and the economy, growth in carbon dioxide emissions in the longer term results largely from population- and income-driven increases in energy use, as well as consumer choices of energy-using equipment. The "carbon intensity" of energy use (carbon dioxide emissions per unit of energy consumed) can also influence the trend of growth in energy-related carbon dioxide emissions.

Figure ES2 shows recent trends in some common indexes used to measure the carbon intensity of the U.S. economy. Carbon dioxide emissions per unit of gross domestic product (GDP) have continued to fall relative to 1990; by 2004, this measure was 21 percent lower than in 1990. Carbon dioxide emissions per capita, however, were 1.2 percent above 1990 levels in 2004. Population growth and other factors resulted in increased aggregate carbon dioxide emissions per year from 1990 through 2004 (a total increase of 19 percent). Carbon dioxide emissions per unit of net electricity generation in 2004 were 1.1 percent lower than in 2003.

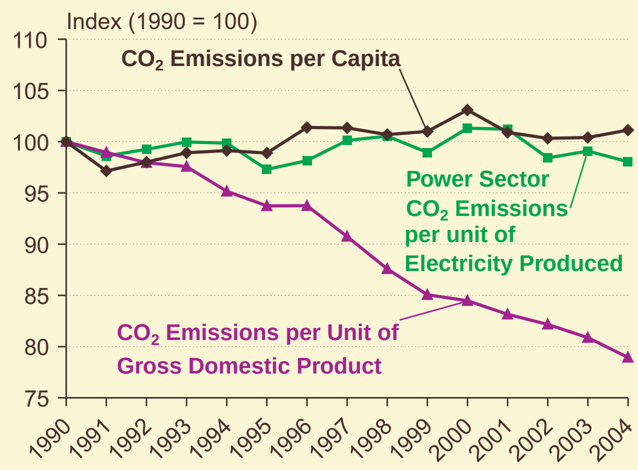
Energy Consumption

The consumption of energy in the form of fossil fuel combustion is the largest single contributor to anthropogenic greenhouse gas emissions in the United States and the world. Of total 2004 U.S. carbon dioxide emissions (adjusting for U.S. Territories and bunker fuels), 98 percent, or 5,868.0 MMT, resulted from the combustion of fossil fuels. This figure represents an increase of 1.7 percent from 2003 levels.

The Energy Information Administration (EIA) divides energy consumption into four general end-use categories: residential, commercial, industrial, and transportation. Emissions from electricity generators, which provide electricity to the end-use sectors, are allocated in proportion to the electricity consumed in, and losses allocated to, each sector. Figure ES3 illustrates trends in carbon dioxide emissions by energy consumption sector. Average annual growth rates in carbon dioxide emissions by sector during the 1990-2004 period were 2.0 percent for the commercial sector, 1.7 percent for the residential sector, 1.5 percent for the transportation sector, and 0.2 percent for the industrial sector.

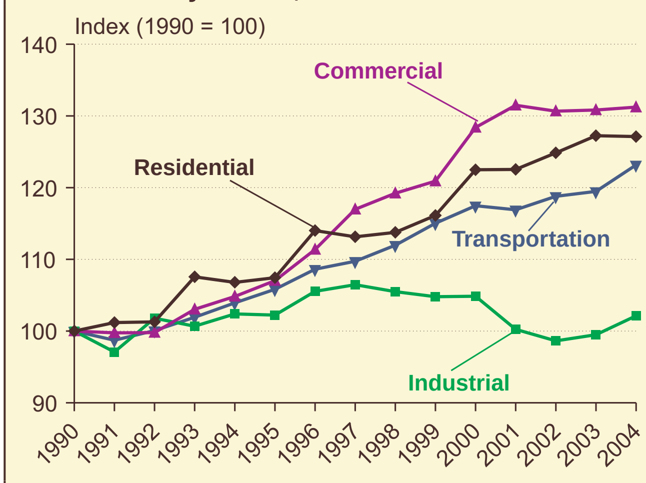
Carbon dioxide emissions from the transportation sector are the largest source of energy-related carbon dioxide emissions. At 1,933.7 MMT, the transportation sector accounted for 33 percent of total U.S. energy-related carbon dioxide emissions in 2004. Transportation sector emissions increased by 3.1 percent in 2004 relative to the 2003 level of 1,875.7 MMT. Almost all (98 percent) of transportation sector carbon dioxide emissions result from the consumption of petroleum products: motor gasoline, 1,162.6 MMT (60 percent of total transportation sector emissions in 2004); middle distillates (diesel fuel), 428.2 MMT (22 percent); jet fuel, 237.4 MMT (12 percent); and residual oil (heavy fuel oil, largely for maritime use), 54.6 MMT (2.8 percent). The growth in transportation-related carbon dioxide emissions in 2004 included

Figure ES2. Carbon Dioxide Emissions Intensity of U.S. Gross Domestic Product, Population, and Electricity Production, 1990-2004



Source: EIA, *Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005).

Figure ES3. U.S. Carbon Dioxide Emissions by Sector, 1990-2004



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

Source: EIA, *Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005).

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

From 2003 to 2004, the greenhouse gas intensity of the U.S. economy fell from 677 to 662 metric tons per million 2000 dollars of GDP (2.1 percent), continuing a trend of decreases in both carbon intensity (see figure at right) and total greenhouse gas intensity. As shown in the table below, declines in carbon intensity by decade have ranged from a low of 3.3 percent in the 1960s to 25.6 percent in the 1980s. From 1990 to 2004, total U.S. greenhouse gas intensity fell by 23.5 percent, at an average rate of 1.9 percent per year.

Historical Growth Rates for U.S. Carbon Intensity

Decade	Overall Change in Intensity (Percent)		Average Annual Change in Intensity (Percent)	
	Carbon Dioxide	Total GHG	Carbon Dioxide	Total GHG
History				
1950-1960	-12.9	—	-1.4	—
1960-1970	-3.3	—	-0.3	—
1970-1980	-17.7	—	-1.9	—
1980-1990	-25.6	—	-2.7	—
1990-2000	-15.3	-17.9	-1.6	-1.9

Source: Energy Information Administration, *Annual Energy Review 2004*, DOE/EIA-0384(2003) (Washington, DC, August 2005), and estimates presented in Appendix B of this report.

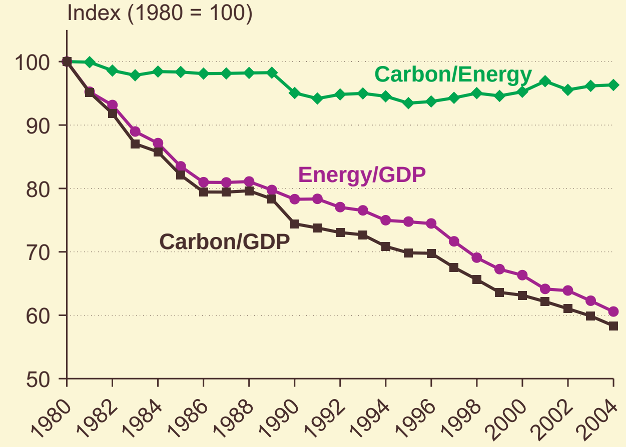
The carbon intensity and greenhouse gas intensity of the U.S. economy move in lockstep, because carbon dioxide emissions make up most of the total for U.S. greenhouse gas emissions. Energy-related carbon dioxide emissions represent approximately 80 percent of total U.S. greenhouse gas emissions. As such, trends in energy-related carbon dioxide emissions have a significant impact on trends in total greenhouse gas emissions. Historical trends in U.S. carbon intensity (energy-related carbon dioxide emissions per unit of economic output) are described below.

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

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

or, algebraically,

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



Source: Estimates presented in Appendix B of *Emissions of Greenhouse Gases in the United States 2004*.

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

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

- Improvements in the energy efficiency of industrial equipment as new materials and methods improved performance in terms of energy inputs versus outputs
- Increased efficiency of transportation equipment as lighter materials and more efficient engines entered the marketplace
- Improvements in commercial and residential lighting, refrigeration, and heating and cooling equipment
- Developments in new electricity generating technologies, such as combined-cycle turbines.

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

Components of the Carbon Intensity of Energy Supply. Changes in the carbon intensity of energy supply have been less dramatic than changes in energy

(continued on page 5)

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

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

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

increases in emissions from the use of motor gasoline (21.2 MMT), diesel fuel (17.9 MMT), residual fuel oil (10.0 MMT), and jet fuel (8.2 MMT).

Industrial sector carbon dioxide emissions, at 1,730.2 MMT, accounted for 29 percent of total U.S. energy-related carbon dioxide emissions in 2004. The 2004 emissions level represents a 2.6-percent increase over 2003 emissions of 1,685.6 MMT, the largest since a 3.0-percent increase from 1995 to 1996. The 2004 increase in industrial emissions resulted from strong growth in industrial production, up 4.1 percent from 2003. In terms of fuel shares, electricity consumption was responsible for 38 percent of total industrial sector carbon dioxide emissions (660.9 MMT), natural gas for 26 percent (441.9 MMT), petroleum for 25 percent (440.6 MMT), and coal for 10 percent (181.0 MMT). Carbon dioxide emissions attributable to industrial sector energy consumption, while fluctuating from year to year, have increased by an average of 0.2 percent per year since 1990. As a result, total energy-related industrial emissions in 2004 were 2.2 percent (38.0 MMT) higher than in 1990.

At 1,212.0 MMT, residential carbon dioxide emissions represented 21 percent of U.S. energy-related carbon dioxide emissions in 2004. The 2004 residential emissions were 0.1 percent lower than the 2003 level of 1,213.2 MMT. A warmer winter in 2004, relative to 2003, was a contributor to the 2004 decrease in residential sector emissions. Additionally, while the winter was warmer than 2003, the summer was cooler, leading to a drop of about 4 percent in both heating and cooling degree-days.[4] The residential sector's pro-rated share of electric power sector carbon dioxide emissions, 837.3 MMT, accounted for more than two-thirds of all emissions in the residential sector.[5] Natural gas accounted for 22 percent (265.5 MMT) and petroleum (mainly distillate fuel oil) represented 8.9 percent (108.0 MMT). Since 1990, when residential sector carbon dioxide emission totaled 953.7 MMT, the growth in residential carbon dioxide emissions has averaged 1.7 percent per year.

Commercial sector carbon dioxide emissions accounted for about 17 percent of total energy-related carbon dioxide emissions in 2004, at 1,024.2 MMT, of which 78 percent (795.4 MMT) was the sector's pro-rated share of electricity-related emissions. Natural gas contributed 16 percent (162.7 MMT) and petroleum 5.7 percent (57.9 MMT). Commercial sector carbon dioxide emissions increased by 0.3 percent from the 2003 level of 1,021.1 MMT. Since 1990, carbon dioxide emissions in the commercial sector have increased on average by 2.0 percent per year, the largest growth of any end-use sector. Commercial sector carbon dioxide emissions have risen by 243.4 MMT since 1990, accounting for 27 percent of the total increase in U.S. energy-related carbon dioxide emissions.

Carbon dioxide emissions from the U.S. electric power sector increased by 0.9 percent (19.7 MMT), from 2,278.8 MMT in 2003 to 2,298.6 MMT in 2004. Carbon dioxide emissions from the electric power sector have grown by 27 percent since 1990, while total carbon dioxide emissions from all energy-related sources have grown by 18 percent. Carbon dioxide emissions from the electric power sector represented 39 percent of total U.S. energy-related carbon dioxide emissions in 2004; however, as noted above, in calculating emissions from the end-use sectors EIA distributes electric power sector emissions to the four sectors in proportion to their respective shares of total electricity purchases. Therefore, electric power emissions are already included in the sectoral totals. By fuel, emissions from natural-gas-fired generation increased by 6.6 percent, emissions from coal-fired generation increased by 0.1 percent, and emissions from petroleum-fired generation increased by

[4]Energy Information Administration, *Short-Term Energy Outlook* (Washington, DC, July 2005), Appendix A, Table A2, p. 2, web site www.eia.doe.gov/emeu/steo/pub/pdf/a2tab.pdf.

[5]Sectoral (residential, commercial, and industrial) energy-related carbon dioxide emissions include the share of total electric power sector carbon dioxide emissions that can be attributed to each end-use sector. The share is based on the percentage of total electricity sales purchased by the sector and losses attributed to the sector. (For values used to calculate sectoral shares, see Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035, Tables 2.2, 2.3, 2.4, and 2.5, web site www.eia.doe.gov/emeu/mer/consump.html.) All carbon dioxide emissions associated with industrial or commercial enterprises whose primary business is not the production of electricity are allocated to the sectors in which they occur.

0.3 percent in 2004 from their 2003 levels (see box on page 9 for allocation of all greenhouse gases to EIA's end-use sectors).

Nonfuel Uses of Energy Inputs

Nonfuel uses of fossil fuels, principally petroleum, both emit carbon dioxide and sequester carbon over their life cycles. In 2004, nonfuel uses of fossil fuels resulted in emissions of 114.3 MMT carbon dioxide (Table ES3), an 8.6-percent increase from the 2003 level of 105.2 MMT. Emissions from nonfuel uses of energy fuels are included in the unadjusted energy consumption subtotals in Table ES3.

On the sequestration side of the ledger, nonfuel uses of fossil fuels also resulted in carbon sequestration equal to 316.6 $MMTCO_2e$ in 2004, a 7.7-percent increase from the 2003 level of 294.0 $MMTCO_2e$.[6] The major fossil fuel products that emit and sequester carbon include liquefied petroleum gas (LPG) and feedstocks for plastics and other petrochemicals. Asphalt and road oils are a major source of sequestration, but they do not emit carbon dioxide. It is estimated that, of the amount of carbon sequestered in the form of plastic, about 11.0 $MMTCO_2e$ was emitted as carbon dioxide from the burning of the plastic components of municipal solid waste to produce electricity in 2004. The 2003 estimate of 18.8 $MMTCO_2e$ is used in this report as an estimate for total 2004 emissions of carbon dioxide from the burning of wastes. The U.S. Environmental Protection Agency (EPA) estimates total emissions from waste burning, and its 2004 value was not available at the time this report was published.

Adjustments to Energy Consumption

Total U.S. carbon dioxide emissions and the estimates of energy consumption on which they are based correspond to EIA's coverage of energy consumption, including the 50 States and the District of Columbia. Under the United Nations Framework Convention on Climate Change (UNFCCC), however, the United States is also

Table ES3. U.S. Carbon Dioxide Emissions from Energy and Industry, 1990 and 1996-2004
(Million Metric Tons Carbon Dioxide)

Fuel Type or Process	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Energy Use by Sector										
Residential	953.7	1,090.2	1,082.0	1,088.5	1,110.9	1,171.8	1,168.3	1,190.4	1,213.2	1,212.0
Commercial	780.7	872.1	916.1	934.1	947.3	1,005.9	1,026.2	1,019.8	1,021.1	1,024.2
Industrial	1,692.2	1,788.8	1,804.4	1,791.2	1,779.1	1,780.3	1,698.4	1,671.0	1,685.6	1,730.2
Transportation	1,569.9	1,705.3	1,722.7	1,757.9	1,806.0	1,844.2	1,835.5	1,864.9	1,875.7	1,933.7
Energy Subtotal	**4,996.6**	**5,456.5**	**5,525.2**	**5,571.6**	**5,643.2**	**5,802.3**	**5,728.4**	**5,746.0**	**5,795.5**	**5,899.9**
Nonfuel Use Emissions[a]	**98.1**	**105.6**	**110.5**	**118.6**	**124.1**	**110.0**	**104.9**	**107.0**	**105.2**	**114.3**
Nonfuel Use Sequestration	**251.2**	**291.2**	**303.4**	**314.7**	**325.8**	**308.1**	**293.9**	**298.3**	**294.0**	**316.6**
Adjustments to Energy										
U.S. Territories (+)	31.1	37.7	39.0	41.3	40.7	42.2	53.6	52.2	58.4	61.7
Military Bunker Fuels (-)	13.6	8.9	9.6	10.0	9.8	7.8	8.2	8.1	9.2	9.2
International Bunker Fuels (-)	100.1	93.3	100.1	104.9	97.4	93.5	89.6	81.2	75.0	84.4
Bunker Fuels Subtotal (-)	*113.7*	*102.2*	*109.7*	*114.9*	*107.2*	*101.3*	*97.8*	*89.3*	*84.2*	*93.6*
Total Energy Adjustments	**-82.6**	**-64.5**	**-70.7**	**-73.6**	**-66.5**	**-59.1**	**-44.2**	**-37.1**	**-25.9**	**-31.9**
Adjusted Energy Subtotal	**4,914.0**	**5,392.0**	**5,454.6**	**5,498.0**	**5,576.8**	**5,743.1**	**5,684.2**	**5,709.0**	**5,769.6**	**5,868.0**
Other Sources										
Natural Gas Flaring	9.1	16.5	15.5	6.2	6.7	5.5	5.9	6.0	5.9	5.9
Carbon Dioxide in Natural Gas	14.0	17.8	18.0	18.0	17.8	18.2	18.6	17.9	18.0	17.8
Cement Production	33.3	37.2	38.4	39.3	40.1	41.3	41.5	43.0	43.2	44.8
Other Industrial	26.8	29.0	29.2	29.7	29.3	29.4	27.4	26.4	27.6	28.7
Waste Combustion	5.1	7.3	7.3	6.9	7.2	7.9	8.0	6.2	7.5	7.8
Total Other Sources	**88.3**	**107.7**	**108.5**	**100.1**	**101.2**	**102.3**	**101.3**	**99.5**	**102.2**	**105.0**
Total	**5,002.3**	**5,499.7**	**5,563.0**	**5,598.1**	**5,677.9**	**5,845.5**	**5,785.5**	**5,808.5**	**5,871.8**	**5,973.0**

[a]Emissions from nonfuel use are included in the sectoral totals above.
P = preliminary data.
Notes: Data in this table are revised from the data contained in the EIA report, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding. Adjusted energy total includes U.S. Territories.
Sources: EIA estimates presented in *Emissions of Greenhouse Gases in the United States 2004*.

[6]Unlike emissions of carbon that occur in the form of carbon dioxide, carbon is sequestered in combination with other chemicals. Therefore, carbon sequestration is estimated in carbon dioxide equivalent units, rather than simply as carbon dioxide.

responsible for counting emissions emanating from its Territories, and their emissions are added to the U.S. total. Conversely, because the IPCC definition of energy consumption excludes international bunker fuels from the statistics of all countries, emissions from international bunker fuels are subtracted from the U.S. total. Military bunker fuels are also subtracted, because they are also excluded by the IPCC from national emissions totals. On net, these adjustments resulted in the subtraction of 31.9 MMT from total U.S. carbon dioxide emissions related to energy consumption (5,899.9 MMT), resulting in an adjusted total of 5,868.0 MMT for energy-related carbon dioxide emissions in 2004 (Table ES3).

Energy-related carbon dioxide emissions for the U.S. Territories are added as an adjustment, in keeping with IPCC guidelines for national emissions inventories. The Territories included are Puerto Rico, the U.S. Virgin Islands, American Samoa, Guam, the U.S. Pacific Islands, and Wake Island. Most of these emissions are from petroleum products; however, Puerto Rico and the Virgin Islands consume coal in addition to petroleum products. Total energy-related carbon dioxide emissions from the U.S. Territories in 2004 are estimated at 61.7 MMT (Table ES3).

For 2003, the carbon dioxide emissions estimate for military bunker fuels was 9.2 MMT.[7] In 2004, approximately 93.6 MMT carbon dioxide was emitted in total from international bunker fuels, including 84.4 MMT attributed to civilian consumption of bunker fuels. In Table ES3, that amount has been subtracted from the U.S. total. Just over one-half of the carbon dioxide emissions associated with international bunker fuels comes from the combustion of jet fuels; residual and distillate fuels account for the other half, with most of that coming from residual fuel.

Other Carbon Dioxide Emissions

In addition to carbon dioxide emission from fossil fuel combustion and use, a total of 105.0 MMT was emitted from other sources in 2004 (Table ES3). Cement manufacture (44.8 MMT) and industrial sources (28.7 MMT) accounted for nearly three-fourths of the total carbon dioxide emissions from other sources. Energy sector components in the other emissions category included the stripping of carbon dioxide from natural gas (17.8 MMT) and natural gas flaring (5.9 MMT). An additional 7.8 MMT carbon dioxide is estimated to have been released from the burning of wastes other than municipal solid waste in the electric power sector.

Methane

U.S. anthropogenic methane emissions totaled 639.5 $MMTCO_2e$[8] (27.8 million metric tons of methane) in 2004, representing 9.0 percent of total U.S. greenhouse gas emissions. Methane emissions in 2004 were 0.9 percent (5.6 $MMTCO_2e$) higher than the 2003 level of 633.9 $MMTCO_2e$ (Table ES4). The increase is attributable primarily to increases in methane emissions from landfills and, to a lesser extent, emissions associated with animal waste, coal mines, and rice cultivation. Despite the 0.9-percent increase in 2004, methane emissions still were 81.9 $MMTCO_2e$ (11.4 percent) below their 1990 level of 721.4 $MMTCO_2e$.

Units for Measuring Greenhouse Gases

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

Table ES1 shows emissions of greenhouse gases in terms of the full molecular weights of the native gases. In Table ES2, and subsequently throughout this report, emissions of carbon dioxide and other greenhouse gases are given in carbon dioxide equivalents. In the case of carbon dioxide, emissions denominated in the molecular weight of the gas or in carbon dioxide equivalents are the same. Carbon dioxide equivalent data can be converted to carbon equivalents by multiplying by 12/44.

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

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

[7]Data for 2004 military bunker fuels were not available at the time of publication. It should also be noted that only bunker fuels purchased in the United States are subject to adjustment.

[8]Based on an estimated GWP of 23 for methane. For an expanded discussion of global warming potentials, see Chapter 1, page 10.

Methane emissions come from four source categories, 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 40, 29, and 31 percent, respectively, of total 2004 U.S. emissions of methane. Trends in the major sources of anthropogenic methane emissions since 1990 are illustrated in Figure ES4.

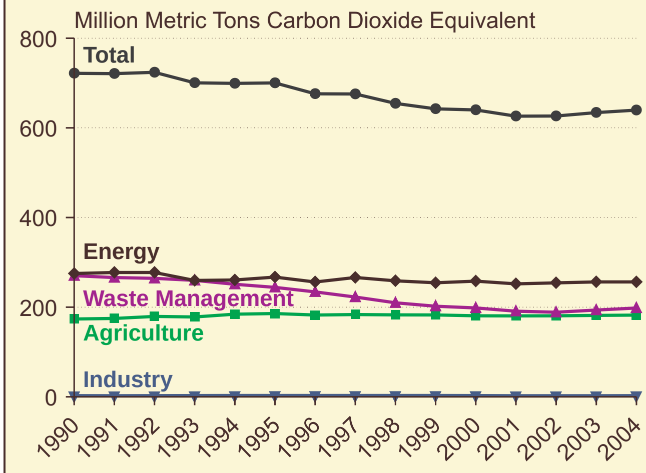
Energy Sources

Methane emissions from energy sources (coal mining, natural gas systems, petroleum systems, stationary combustion, and mobile source combustion) were nearly unchanged at 256.3 MMTCO_2e in 2004 from the 2003 level of 256.4 MMTCO_2e. Methane emissions from energy sources have fallen by 6.8 percent since 1990; however, after bottoming out in 2001, methane emissions from energy sources rose in each of the next 2 years.

Agricultural Sources

Methane emissions from agricultural sources, at 182.3 MMTCO_2e, represented 29 percent of total U.S. anthropogenic methane emissions in 2004. Emissions increased by less than 1 percent (0.9 MMTCO_2e) in 2004 relative to 2003, as a small decrease in emissions from enteric fermentation in domesticated animals was offset by increases in emissions from animal waste management,

Figure ES4. U.S. Emissions of Methane by Source, 1990-2004



Source: EIA, *Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005).

Table ES4. U.S. Methane Emissions from Anthropogenic Sources, 1990 and 1996-2004
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Energy Sources										
Coal Mining	97.7	73.4	80.4	75.6	71.7	68.5	68.0	64.7	67.2	68.2
Natural Gas Systems	128.9	138.1	144.3	143.9	144.2	151.0	147.0	154.0	153.1	152.6
Petroleum Systems	29.9	26.4	26.3	25.5	24.0	23.8	23.7	23.5	23.3	23.2
Stationary Combustion	13.0	13.3	10.1	9.1	9.6	10.1	8.7	7.6	8.5	8.0
Mobile Sources	5.6	5.1	5.1	4.8	4.8	4.7	4.6	4.6	4.3	4.4
Total Energy Sources	**275.0**	**256.3**	**266.2**	**258.9**	**254.4**	**258.1**	**252.0**	**254.3**	**256.4**	**256.3**
Waste Management										
Landfills	257.0	219.8	208.1	195.0	187.4	183.3	175.8	173.4	178.1	182.6
Wastewater Treatment	13.2	14.3	14.5	14.7	14.8	15.0	15.2	15.3	15.5	15.6
Total Waste Management	**270.2**	**234.2**	**222.6**	**209.7**	**202.2**	**198.3**	**191.0**	**188.7**	**193.6**	**198.2**
Agricultural Sources										
Enteric Fermentation	119.6	122.0	119.1	117.2	117.3	116.3	115.1	115.7	116.2	115.2
Animal Waste	43.5	49.7	52.7	53.6	52.7	52.8	53.3	53.7	54.2	54.7
Rice Cultivation	9.3	9.4	10.3	10.7	11.5	10.2	10.7	10.2	9.8	11.0
Crop Residue Burning	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.2	1.3
Total Agricultural Sources	**173.4**	**182.2**	**183.3**	**182.6**	**182.5**	**180.5**	**180.3**	**180.6**	**181.3**	**182.3**
Industrial Processes	**2.7**	**3.1**	**3.1**	**3.1**	**3.1**	**2.9**	**2.5**	**2.6**	**2.6**	**2.7**
Total	**721.4**	**675.8**	**675.2**	**654.2**	**642.2**	**639.8**	**625.8**	**626.2**	**633.9**	**639.5**

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 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: EIA estimates presented in this report. Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.83-4.84, web site www.ipcc.ch/pub/guide.htm; and U.S. U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2003*, EPA-430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html.

Greenhouse Gas Emissions in the U.S. Economy

The diagram on page 10 illustrates the flow of U.S. greenhouse gas emissions in 2004, from their sources to their distribution across the U.S. end-use sectors. The left side shows gases and quantities; the right side shows their distribution by sector. The center of the diagram indicates the split between emissions from direct fuel combustion and electricity conversion. Adjustments indicated at the top of the diagram for U.S. territories and international bunker fuels correspond to greenhouse gas reporting requirements developed by the UNFCCC.

CO_2. CO_2 emission sources include energy-related emissions (primarily from fossil fuel combustion) and emissions from industrial processes. The energy subtotal (5,900 $MMTCO_2e$) includes petroleum, coal, and natural gas consumption and smaller amounts from renewable sources, including municipal solid waste and geothermal power generation. The energy subtotal also includes emissions from nonfuel uses of fossil fuels, mainly as inputs to other products. Industrial process emissions (105 $MMTCO_2e$) include cement manufacture, limestone and dolomite calcination, soda ash manufacture and consumption, carbon dioxide manufacture, and aluminum production. The sum of the energy subtotal and industrial processes equals unadjusted CO_2 emissions (6,005 $MMTCO_2e$). The energy component of unadjusted emissions can be divided into direct fuel use (3,601 $MMTCO_2e$) and fuel converted to electricity (2,299 $MMTCO_2e$).

Non-CO_2 Gases. Methane (639 $MMTCO_2e$) and nitrous oxide (354 $MMTCO_2e$) sources include emissions related to energy, agriculture, waste management, and industrial processes. Other gases (156 $MMTCO_2e$) include HFCs, PFCs, and SF_6. These gases have a variety of uses in the U.S. economy, including refrigerants, insulators, solvents, and aerosols; as etching, cleaning, and firefighting agents; and as cover gases in various manufacturing processes.

Adjustments. In keeping with the UNFCCC, CO_2 emissions from U.S. Territories (62 $MMTCO_2e$) are added to the U.S. total, and CO_2 emissions from fuels used for international transport (both oceangoing vessels and airplanes) (94 $MMTCO_2e$) are subtracted to derive total U.S. greenhouse gas emissions (7,122 $MMTCO_2e$).

Emissions by End-Use Sector. CO_2 emissions by end-use sectors are based on EIA's estimates of energy consumption (direct fuel use and purchased electricity) by sector and on the attribution of industrial process emissions by sector. CO_2 emissions from purchased electricity are allocated to the end-use sectors based on their shares of total electricity sales. Non-CO_2 gases are allocated by direct emissions in those sectors plus emissions in the electric power sector that can be attributed to the end-use sectors based on electricity sales.

Residential emissions (1,241 $MMTCO_2e$) include energy-related CO_2 emissions (1,225 $MMTCO_2e$); and non-CO_2 emissions (16 $MMTCO_2e$). The non-CO_2 sources include direct methane and nitrous oxide emissions from direct fuel use. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Commercial sector emissions (1,298 $MMTCO_2e$) include energy-related CO_2 emissions (1,035 $MMTCO_2e$); and non-CO_2 emissions (263 $MMTCO_2e$). The non-CO_2 emissions include direct emissions from landfills, wastewater treatment plants, commercial refrigerants, and stationary combustion emissions of methane and nitrous oxide. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Industrial emissions (2,599 $MMTCO_2e$) include CO_2 emissions (1,853 $MMTCO_2e$), which can be broken down between stationary source combustion (1,748 $MMTCO_2e$) and industrial emissions (105 $MMTCO_2e$); and non-CO_2 emissions (746 $MMTCO_2e$). The non-CO_2 direct emissions include emissions from agriculture (methane and nitrous oxide), coal mines (methane), petroleum and natural gas pipelines (methane), industrial process emissions (methane, nitrous oxide, HFCs, PFCs and SF_6), and direct stationary combustion emissions of methane and nitrous oxide. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Transportation emissions (1,984 $MMTCO_2e$) include energy-related CO_2 emissions from mobile source combustion (1,869 $MMTCO_2e$); and non-CO_2 emissions (124 $MMTCO_2e$). The non-CO_2 emissions include methane and nitrous oxide emissions from mobile source combustion and HFC emissions from the use of refrigerants for mobile source air-conditioning units.

(continued on page 10)

Greenhouse Gas Emissions in the U.S. Economy (Continued)

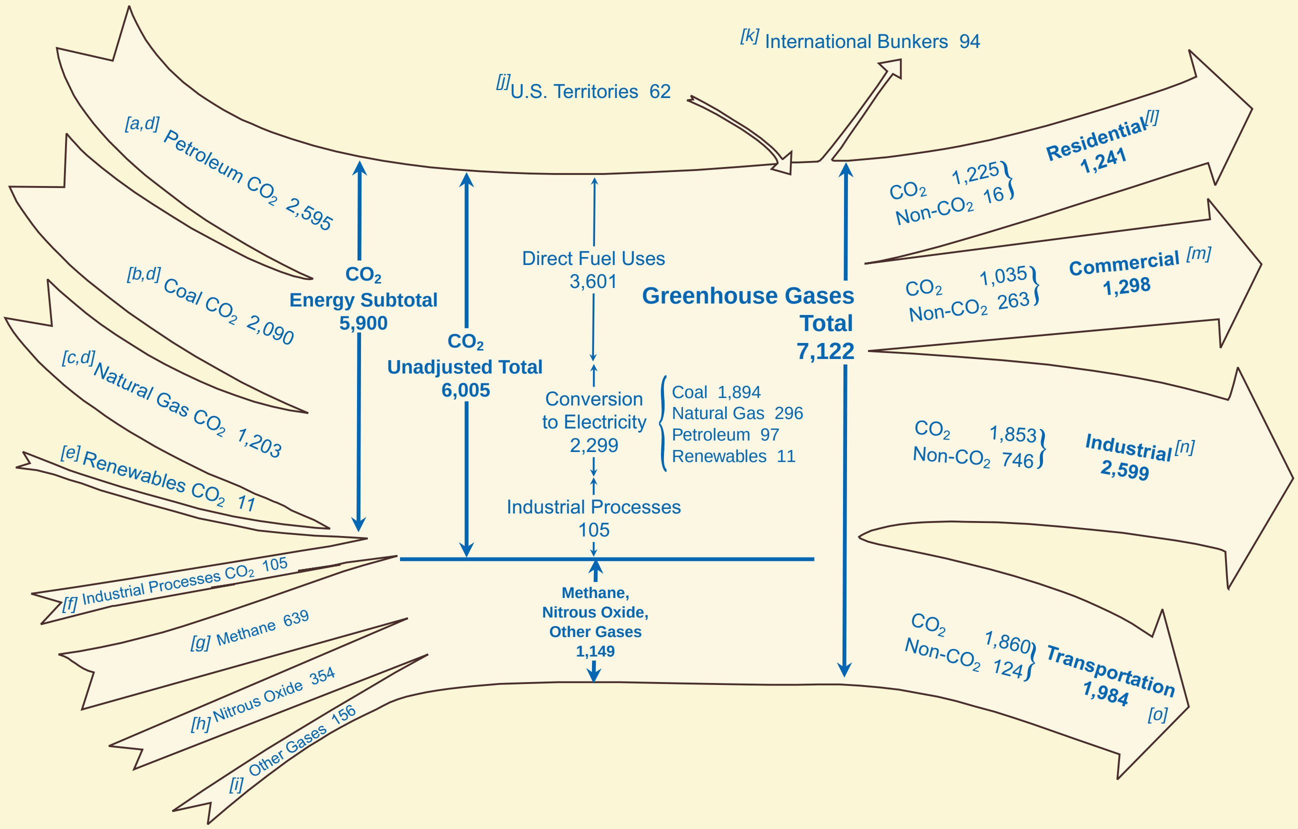


Diagram Notes

[*a*] CO_2 emissions related to petroleum consumption (includes 89.0 $MMTCO_2$ of non-fuel-related emissions).

[*b*] CO_2 emissions related to coal consumption (includes 0.5 $MMTCO_2$ of non-fuel-related emissions).

[*c*] CO_2 emissions related to natural gas consumption (includes 19.2 $MMTCO_2$ of non-fuel-related emissions).

[*d*] Excludes carbon sequestered in nonfuel fossil products.

[*e*] CO_2 emissions from the plastics portion of municipal solid waste (11 $MMTCO_2$) combusted for electricity generation and very small amounts (<0.5 $MMTCO_2$) of geothermal-related emissions.

[*f*] Includes mainly direct process emissions. Some combustion emissions are included from waste combustion outside the electric power sector and flaring of non-marketed natural gas.

[*g*] Includes methane emissions related to energy, agriculture, waste management, and industrial processes.

[*h*] Includes nitrous oxide emissions related to agriculture, energy, industrial processes, and waste management.

[*i*] Includes hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

[*j*] Includes only energy-related CO_2 emissions from fossil fuels.

[*k*] Includes vessel bunkers and jet fuel consumed for international travel. Under the UNFCCC, these emissions are not included in country emission inventories.

[*l*] Direct stationary combustion emissions of methane and nitrous oxide plus indirect power sector emissions of methane, nitrous oxide, and other greenhouse gases.

[*m*] Direct stationary combustion emissions of methane and nitrous oxide plus indirect power sector emissions of methane, nitrous oxide, and other greenhouse gases. Additional direct emissions include emissions from landfills, wastewater treatment, and commercial refrigerants.

[*n*] Direct stationary combustion emissions of methane and nitrous oxide plus indirect power sector emissions of methane, nitrous oxide, and other greenhouse gases. In addition, all agricultural emissions are included in the industrial sector as well as direct process emissions of methane, nitrous oxide, and the other gases.

[*o*] Direct mobile combustion emissions of methane and nitrous oxide. Also, emissions related to transportation refrigerants are included.

Source: Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0573(2004) (Washington, DC, December, 2005). CO_2 emissions by end-use sector are based on EIA's estimates of energy consumption by sector and on industrial process emissions. CO_2 emissions from the electric power sector are allocated to the end-use sectors based on electricity sales to the sector. Non-CO_2 emissions by end-use sector are allocated by direct emissions in those sectors plus indirect emissions from the electric power sector allocated by electricity sales. Data are preliminary. Totals may not equal sum of components due to independent rounding.

(continued on page 11)

rice cultivation, and burning of crop residues. Of the total 2004 methane emissions from agricultural sources, 93 percent (170.0 $MMTCO_2e$) resulted from livestock management, of which 68 percent (115.2 $MMTCO_2e$) was from enteric fermentation and the remainder (54.7 $MMTCO_2e$) was from anaerobic decomposition of livestock wastes. Methane emissions from rice cultivation (11 $MMTCO_2e$) and crop residue burning (1.3 $MMTCO_2e$) together represented about 6.7 percent of total methane emissions from agricultural sources in 2004, which have increased by 5.1 percent since 1990.

Greenhouse Gas Emissions in the U.S. Economy (Continued)

Distribution of Total U.S. Greenhouse Gas Emissions by End-Use Sector

Greenhouse Gas and Source	Sector				
	Residential	Commercial	Industrial	Transportation	Total
Carbon Dioxide					
Energy-Related	1,224.7	1,034.9	1,748.3	1,860.3	**5,868.2**
Industrial Processes	—	—	105.0	—	**105.0**
Total CO_2	**1,224.7**	**1,034.9**	**1,853.3**	**1,860.3**	**5,973.2**
Methane					
Energy					
Coal Mining	—	—	68.2	—	**68.2**
Natural Gas Systems	—	—	152.6	—	**152.6**
Petroleum Systems	—	—	23.2	—	**23.2**
Stationary Combustion	7.0	0.1	0.6	—	**7.7**
Stationary Combustion: Electricity	0.1	0.1	0.1	—	**0.3**
Mobile Sources	—	—	—	4.4	**4.4**
Waste Management					
Landfills	—	182.6	—	—	**182.6**
Wastewater Treatment	—	15.6	—	—	**15.6**
Industrial Processes	—	—	2.7	—	**2.7**
Agricultural Sources					
Enteric Fermentation	—	—	115.2	—	**115.2**
Animal Waste	—	—	54.7	—	**54.7**
Rice Cultivation	—	—	11.0	—	**11.0**
Crop Residue Burning	—	—	1.3	—	**1.3**
Total Methane	**7.1**	**198.4**	**429.6**	**4.4**	**639.4**
Nitrous Oxide					
Agriculture					
Nitrogen Fertilization of Soils	—	—	204.3	—	**204.3**
Solid Waste of Animals	—	—	60.3	—	**60.3**
Crop Residue Burning	—	—	0.6	—	**0.6**
Energy Use					
Mobile Combustion	—	—	—	53.8	**53.8**
Stationary Combustion	0.8	0.3	4.5	—	**5.6**
Stationary Combustion: Electricity	3.3	3.1	2.6	—	**9.0**
Industrial Sources	—	—	14.0	—	**14.0**
Waste Management					
Human Sewage in Wastewater	—	5.8	—	—	**5.8**
Waste Combustion	—	—	—	—	**0.0**
Waste Combustion: Electricity	0.1	0.1	0.1	—	**0.2**
Total Nitrous Oxide	**4.2**	**9.3**	**286.4**	**53.8**	**353.6**
Hydrofluorocarbons					
HFC-23	—	—	16.3	—	**16.3**
HFC-125	—	19.7	—	—	**19.7**
HFC-134a	—	—	—	65.8	**65.8**
HFC-143a	—	19.5	—	—	**19.5**
HFC-236fa	—	3.5	—	—	**3.5**
Total HFCs	**0.0**	**42.7**	**16.3**	**65.8**	**124.8**
Perfluorocarbons					
CF_4	—	—	3.2	—	**3.2**
C_2F_6	—	—	3.5	—	**3.5**
Total PFCs	**0.0**	**0.0**	**6.7**	**0.0**	**6.7**
Other HFCs, PFCs/PFPEs	**—**	**8.6**	**—**	**—**	**8.6**
Sulfur Hexafluoride					
SF_6: Utility	4.6	4.4	3.6	—	**12.6**
SF_6: Other	—	—	3.3	—	**3.3**
Total SF_6	**4.6**	**4.4**	**6.9**	**0.0**	**15.9**
Total Non-CO_2	**15.8**	**263.3**	**745.8**	**123.9**	**1,148.9**
Total Emissions	**1,240.5**	**1,298.2**	**2,599.1**	**1,984.2**	**7,122.1**

Waste Management

Methane emissions from waste management, which at 198.2 MMTCO_2e accounted for 31 percent of U.S. anthropogenic methane emissions in 2004, were 2.4 percent above the 2003 level of 193.6 MMTCO_2e. Landfills—the largest single source of U.S. anthropogenic methane emissions—represented 92 percent (182.6 MMTCO_2e) of total U.S. methane emissions from waste management in 2004. The remainder (15.6 MMTCO_2e) of 2004 methane emissions from waste management was associated with domestic wastewater treatment. Methane emissions from waste management have fallen by 27 percent (72.0 MMTCO_2e) from their 1990 level of 270.2 MMTCO_2e, due largely to increased methane recovery at landfills, which increased to 122.1 MMTCO_2e in 2004 from 21.7 MMTCO_2e in 1990. Even at these higher methane recovery levels, however, waste management emissions, after bottoming out in 2002, increased in both 2003 and 2004.

Industrial Processes

Methane emissions from industrial processes totaled 2.7 MMTCO_2e in 2004, including 1.6 MMTCO_2e from chemical manufacturing and 1.1 MMTCO_2e from iron and steel production. Since 1990, growth in methane emissions from chemical production has been balanced by reductions in emissions from iron and steel production, leaving the 2004 total for industrial processes approximately equal to their 1990 level.

Nitrous Oxide

Estimated U.S. anthropogenic emissions of nitrous oxide in 2004 totaled 353.7 MMTCO_2e, or 1.2 MMT nitrous oxide. Nitrous oxide emissions represented 5.0 percent of total U.S. greenhouse gas emissions in 2004 and were 5.5 percent above the 2003 level of 335.2 MMTCO_2e. Most of the increase from 2003 can be attributed to increased emissions from agricultural sources, which rose by 17.4 MMTCO_2e in 2004 and represented 94 percent of the overall increase in nitrous oxide emissions (18.5 MMTCO_2e) from 2003. The 2004 level marks the first year since 2000 in which U.S. emissions of nitrous oxide have been higher than the 1990 level of 337.0 MMTCO_2e (Table ES5 and Figure ES5).

Agriculture

Agricultural sources, at 265.2 MMTCO_2e, accounted for 75 percent of total U.S. nitrous oxide emissions in 2004. Agricultural emissions in 2004 were 7.0 percent above the 2003 total of 247.8 MMTCO_2e, primarily as the result of an increase of 9.5 percent (17.7 MMTCO_2e) in emissions from the nitrogen fertilization of agricultural soils. Emissions from nitrogen fertilization, at 204.3 MMTCO_2e, accounted for 77 percent of nitrous oxide emissions from agriculture in 2004. Emissions from the solid waste of domesticated animals, at 60.3 MMTCO_2e, made up 23 percent of agricultural nitrous oxide emissions in 2004, and burning of crop residues produced

Table ES5. Estimated U.S. Emissions of Nitrous Oxide, 1990 and 1996-2004
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Agriculture										
Nitrogen Fertilization of Soils	186.9	184.2	190.5	194.0	192.7	189.4	189.1	185.1	186.6	204.3
Solid Waste of Domesticated Animals	61.9	65.1	63.8	62.9	62.4	61.8	61.4	61.2	60.7	60.3
Crop Residue Burning	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.5	0.5	0.6
Subtotal	**249.3**	**249.8**	**254.8**	**257.4**	**255.6**	**251.8**	**251.1**	**246.8**	**247.8**	**265.2**
Energy Use										
Mobile Combustion	41.1	53.9	52.4	54.2	54.3	54.3	53.3	53.0	53.0	53.8
Stationary Combustion	13.3	14.5	14.6	14.5	14.7	15.1	14.5	14.2	14.5	14.7
Subtotal	**54.4**	**68.5**	**67.0**	**68.7**	**68.9**	**69.4**	**67.9**	**67.2**	**67.5**	**68.4**
Industrial Sources	**28.6**	**34.3**	**21.8**	**17.2**	**16.8**	**16.6**	**14.0**	**15.2**	**14.0**	**14.0**
Waste Management										
Human Sewage in Wastewater	4.6	5.2	5.2	5.3	5.5	5.6	5.6	5.7	5.7	5.8
Waste Combustion	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Subtotal	**4.8**	**5.4**	**5.4**	**5.5**	**5.7**	**5.8**	**5.9**	**5.9**	**6.0**	**6.0**
Total	**337.0**	**358.0**	**349.1**	**348.8**	**347.1**	**343.5**	**338.8**	**335.1**	**335.2**	**353.7**

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 2003*, DOE/EIA-0573(2003) (Washington, DC, December 2004). Totals may not equal sum of components due to independent rounding.

Sources: Estimates presented in this report. Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.81-4.94, web site www.ipcc.ch/pub/guide.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*, EPA 430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenter PublicationsGHGEmissionsUSEmissionsInventory2005.html.

another 0.6 $MMTCO_2e$. Total U.S. emissions of nitrous oxide from agriculture sources have increased by 6.4 percent since 1990.

Energy Use

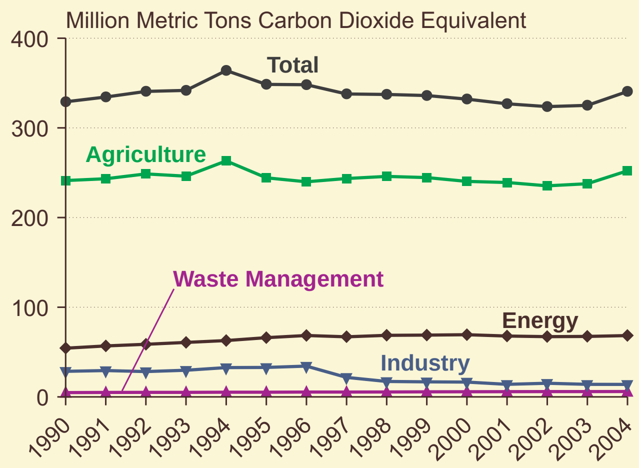
U.S. nitrous oxide emissions associated with fossil fuel combustion in 2004 were 68.4 $MMTCO_2e$, or 19 percent of total nitrous oxide emissions. Most of the energy-related emissions of nitrous oxide in 2004 (79 percent or 53.8 $MMTCO_2e$) were from mobile sources, principally, motor vehicles equipped with catalytic converters. The remainder (21 percent or 14.7 $MMTCO_2e$) was from stationary source combustion of fossil fuels. Nitrous oxide emissions from energy sources have increased by 26 percent since 1990.

Industrial Processes and Waste Management

Industrial processes and waste management facilities were responsible for 3.9 percent and 1.6 percent, respectively, of total U.S. nitrous oxide emissions in 2004. Industrial process emissions in 2004 remained unchanged from 2003 at 14.0 $MMTCO_2e$. Industrial process emissions have fallen by 51 percent since 1990 due to decreases in nitrous oxide emissions from the manufacture of adipic acid.

Nitrous oxide emissions from waste management facilities in 2004 also were unchanged from their 2003 level, at 6.0 $MMTCO_2e$, including 5.8 $MMTCO_2e$ from human sewage in wastewater and 0.2 $MMTCO_2e$ from waste combustion. Nitrous oxide emissions from waste management facilities have increased by 25 percent since 1990.

Figure ES5. U.S. Emissions of Nitrous Oxide by Source, 1990-2004



Source: EIA, *Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005).

Other Gases: Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride

HFCs, PFCs, and SF_6 are three classes of engineered gases that accounted for 2.2 percent of total U.S. greenhouse gas emissions in 2004. At 155.9 $MMTCO_2e$, their emissions were 9.6 percent higher than in 2003 (142.4 $MMTCO_2e$). The increase in emissions of the engineered gases from 2003 to 2004 resulted largely from a 12-percent increase in HFC emissions, which more than offset decreases in emissions of PFCs (7.5 percent lower than in 2003) and SF_6 (2.2 percent lower) (Table ES6).

At 124.8 $MMTCO_2e$, emissions of HFCs made up the majority of U.S. emissions of engineered greenhouse gases, followed by SF_6 at 16.0 $MMTCO_2e$ and PFCs at 6.7 $MMTCO_2e$. Another group of engineered gases, consisting of other HFCs, other PFCs, and perfluoropolyethers (PFPEs), includes HFC-152a, HFC-227ea, HFC-245fa, HFC-4310mee, and a variety of PFCs and PFPEs. They are grouped together in this report to protect confidential data. In 2004, their combined emissions totaled 8.6 $MMTCO_2e$. Emissions of the engineered gases in this group in 2004 were 13 percent higher than in 2003 and an order of magnitude higher than in 1990, when they totaled less than 0.3 $MMTCO_2e$. Since 1990, HFC emissions from U.S. sources have increased by 246 percent, PFC emissions have fallen by 66 percent, and SF_6 emissions have fallen by 50 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, and 227ea), which are used as replacements for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), have shorter atmospheric lifetimes, ranging from 1 to 33 years.

Land-Use Change and Forestry

Forest lands in the United States are net absorbers of carbon dioxide from the atmosphere, primarily as a result of the reversal of the extensive deforestation that occurred in the United States during 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 from land-use change and forestry in 2003 at 828.0 $MMTCO_2e$,[9] representing an offset of 11.9 percent of total 2003 U.S. greenhouse gas emissions (6,983.2 $MMTCO_2e$). In 1990, carbon sequestration attributable to land use and forestry was 1,042.1 $MMTCO_2e$, or 16.9 percent of total 1990 U.S. greenhouse gas emissions (6,148.8 $MMTCO_2e$).[10] The EPA's 2003 estimates for carbon sequestration from land-use change and forestry include 752.7 $MMTCO_2e$ from forested land, 58.7 $MMTCO_2e$ from urban trees, 10.1 $MMTCO_2e$ from landfilled yard trimmings and food scraps, and 6.6 $MMTCO_2e$ from agricultural soils (Table ES7).

Table ES6. U.S. Emissions of Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride, 1990 and 1996-2004
(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1996	1997	1998	1999	2000	2001	2002	2003	P2004
Hydrofluorocarbons										
HFC-23	36.1	32.3	31.2	41.7	31.7	30.9	20.6	20.6	13.0	16.3
HFC-125	0.0	6.3	8.6	10.7	12.1	13.6	14.9	16.2	17.8	19.7
HFC-134a	0.0	24.5	31.4	36.7	42.2	48.0	52.7	56.9	60.5	65.8
HFC-143a	0.0	2.3	4.0	5.9	7.5	9.3	11.4	13.8	16.5	19.5
HFC-236fa	0.0	0.0	0.1	0.6	1.3	2.0	2.6	3.2	3.5	3.5
Total HFCs	**36.1**	**65.5**	**75.1**	**95.5**	**94.9**	**103.8**	**102.2**	**110.7**	**111.3**	**124.8**
Perfluorocarbons										
CF_4	14.8	11.0	10.1	8.7	8.6	8.7	4.2	5.0	3.8	3.2
C_2F_6	4.8	5.4	5.6	5.9	6.0	5.0	3.4	3.8	3.4	3.5
Total PFCs	**19.6**	**16.4**	**15.7**	**14.6**	**14.6**	**13.7**	**7.6**	**8.8**	**7.2**	**6.7**
Other HFCs, PFCs/PFPEs	**0.3**	**3.4**	**4.5**	**5.5**	**6.2**	**6.5**	**6.7**	**7.1**	**7.6**	**8.6**
Sulfur Hexafluoride	**32.1**	**29.1**	**26.7**	**22.1**	**21.7**	**18.1**	**17.4**	**16.4**	**16.3**	**16.0**
Total Emissions	**88.1**	**114.3**	**122.0**	**137.7**	**137.4**	**142.1**	**133.9**	**143.1**	**142.4**	**155.9**

P = preliminary data.
Notes: Other HFCs, PFCs/PFPEs include HFC-152a, HFC-227ea, HFC-245fa, HFC-4310mee, and a variety of PFCs and perfluoropolyethers (PFPEs). They are grouped together to protect confidential data. Totals may not equal sum of components due to independent rounding.
Source: U.S. Environmental Protection Agency, Office of Air and Radiation, web site www.epa.gov/globalwarming/ (preliminary estimates, September 2005).

Table ES7. Net Carbon Dioxide Sequestration from U.S. Land-Use Change and Forestry, 1990 and 1997-2003
(Million Metric Tons Carbon Dioxide Equivalent)

Component	1990	1997	1998	1999	2000	2001	2002	2003
Forest Land Remaining Forest Land: Changes in Forest Carbon Stocks	949.3	851.0	805.5	751.7	747.9	750.9	751.5	752.7
Cropland Remaining Cropland: Changes in Agricultural Soil Carbon Stocks	8.1	7.4	4.3	4.3	5.7	7.1	6.2	6.6
Settlements Remaining Settlements	84.7	71.6	71.2	70.0	68.9	68.9	68.8	68.7
Urban Trees	*58.7*	*58.7*	*58.7*	*58.7*	*58.7*	*58.7*	*58.7*	*58.7*
Landfilled Yard Trimmings and Food Scraps	*26.0*	*12.9*	*12.5*	*11.4*	*10.2*	*10.3*	*10.2*	*10.1*
Total Net Flux	**1,042.1**	**930.0**	**881.0**	**826.0**	**822.5**	**826.9**	**826.5**	**828.0**

Note: Totals may not equal sum of components due to independent rounding.
Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*, EPA 430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenter PublicationsGHGEmissionsUSEmissionsInventory2005.html.

[9]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*, EPA 430-R-05-003 (Washington, DC, April 2005), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUS EmissionsInventory2005.html. Estimates for carbon sequestration in 2004 are not yet available.

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

Uncertainty in Emissions Estimates

The emissions numbers presented in this report are estimates based on estimated activity data and estimated emission factors. As such, they have an element of uncertainty, given that the activity data and emission factors on which the emission estimates are based also have a range of possible values. The activity data and emission factors can themselves be characterized by systematic biases and/or random errors. In 2000, EIA employed a Monte Carlo analysis to estimate the range of uncertainty, at a 95-percent confidence level, around estimated emissions of carbon dioxide, methane, and nitrous oxide (HFCs, PFCs, and SF_6 were not part of the analysis).[11]

The Monte Carlo simulations revealed that uncertainty varies by type of gas. There is less uncertainty around the simulated mean for carbon dioxide (-1.4 percent to +1.3 percent) than for methane (-15.6 percent to 16.0 percent) or nitrous oxide (-53.5 percent to +54.2 percent). The simulations also showed that the uncertainty around the simulated mean of total greenhouse gas emissions (excluding HFCs, PFCs, and SF_6) is -4.4 percent to +4.6 percent.

The reliability of emissions data varies by category and by source. In general, the estimates for carbon dioxide emissions are more reliable than the estimates for other gases. It is likely that the estimate of carbon dioxide emissions is accurate to within 5 percent. Estimates of methane emissions are much more uncertain, with a level of uncertainty that may exceed 30 percent. Estimates of methane emissions are also likely to understate actual emissions as a result of the exclusion of sources that are unknown or difficult to quantify, such as abandoned coal mines and industrial wastewater. Nitrous oxide emissions estimates are much less reliable than those for carbon dioxide or methane emissions, in part because nitrous oxide emissions have been studied far less than emissions of the other greenhouse gases and in part because the largest apparent sources of nitrous oxide emissions are area sources that result from biological activity, which makes for emissions that are highly variable and hard to measure or characterize. The uncertainty for nitrous oxide emissions may exceed 100 percent.

[11]Energy Information Administration, *Documentation for Estimation of Greenhouse Gases in the United States 2003*, DOE/EIA-0638(2003) (Washington, DC, May 2005), Chapter 8, web site http://www.eia.doe.gov/oiaf/1605/ggrpt/documentation/pdf/0638(2003).pdf.