3 Greenhouse Gas Inventory

An emissions inventory that identifies and quantifies a country's primary anthropogenic[1] sources and sinks of greenhouse gases is essential for addressing climate change. The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OAP 2006c) adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and (2) a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contributions of different emission sources and greenhouse gases to climate change.

In 1992, the United States signed and ratified the UNFCCC. Parties to the Convention, by ratifying, "shall develop, periodically update, publish and make available … national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the *Montreal Protocol*, using comparable methodologies…."[2] The United States views the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OPA 2006b) as an opportunity to fulfill these commitments.

This chapter summarizes the latest information on U.S. anthropogenic greenhouse gas emission trends from 1990 through 2004. To ensure that the U.S. emissions inventory is comparable to those of other UNFCCC Parties, the estimates presented here were calculated using methodologies consistent with those recommended in the Intergovernmental Panel on Climate Change (IPCC) *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997), the IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000), and the IPCC *Good Practice Guidance for Land Use, Land-Use Change, and Forestry* (IPCC 2003). The structure of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* is consistent with the UNFCCC guidelines for inventory reporting.[3] For most source categories, the IPCC methodologies were expanded, resulting in a more comprehensive and detailed estimate of emissions.

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons). As stratospheric ozone-depleting substances (ODS), CFCs, HCFCs, and halons are covered

[1] The term *anthropogenic*, in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes affected by human activities (IPCC/UNEP/OECD/IEA 1997).

[2] Article 4(1)(a) of the UNFCCC (also identified in Article 12). Subsequent decisions by the Conference of the Parties elaborated the role of Annex I Parties in preparing national inventories. See <http://unfccc.int/essential_background/convention/background/items/1349.php>.

[3] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

under the *Montreal Protocol on Substances That Deplete the Ozone Layer*. The UNFCCC defers to this earlier international treaty. Consequently, Parties to the UNFCCC are not required to include these gases in their national greenhouse gas emission inventories.[4] Some other fluorine-containing halogenated substances—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—do not deplete stratospheric ozone, but are potent greenhouse gases. These latter substances are addressed by the UNFCCC and accounted for in national greenhouse gas emission inventories.

There are also several gases that do not have a direct global warming effect but indirectly affect terrestrial and/or solar radiation absorption by influencing the formation or destruction of greenhouse gases, including tropospheric and stratospheric ozone. These gases include carbon monoxide (CO), oxides of nitrogen (NO_x), and nonmethane volatile organic compounds (NMVOCs). Aerosols, which are extremely small particles or liquid droplets, such as those produced by sulfur dioxide (SO_2) or elemental carbon emissions, can also affect the absorptive characteristics of the atmosphere.

Although the direct greenhouse gases CO_2, CH_4, and N_2O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2004, concentrations of these greenhouse gases have increased globally by 35, 143, and 18 percent, respectively (IPCC 2001; Hofmann 2004).

Beginning in the 1950s, the use of CFCs and other stratospheric ODSs increased by nearly 10 percent per year until the mid-1980s, when international concern about ozone depletion led to the entry into force of the *Montreal Protocol*. Since then, the production of ODSs is being phased out.

Emissions Reporting Nomenclature

The global warming potential (GWP)-weighted emissions of all direct greenhouse gases throughout this chapter are presented in terms of equivalent emissions of carbon dioxide (CO_2), using units of teragrams of CO_2 equivalent (Tg CO_2 Eq.). The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) (2.2 pounds (lb)) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001a). The relationship between gigagrams (Gg) of a gas and Tg CO_2 Eq. can be expressed as follows:

$$\text{Tg } CO_2 \text{ Eq.} = (\text{Gg of gas}) \times (\text{GWP}) \times \left(\frac{\text{Tg}}{1{,}000 \text{ Gg}}\right)$$

The UNFCCC reporting guidelines for national inventories were updated in 2002,[5] but continue to require the use of GWPs from the IPCC Second Assessment Report (IPCC 1996b). The GWP values used in this report are listed below in Table 3-1, and are explained in more detail in Chapter 1 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OAP 2006c).

TABLE 3-1 **Global Warming Potentials (100 Year Time Horizon) Used in This Report**

The concept of a global warming potential (GWP) has been developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. Carbon dioxide was chosen as the reference gas to be consistent with IPCC guidelines.

Gas	GWP
CO_2	1
CH_4*	21
N_2O	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

* The methane GWP includes the direct and indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.
Source: IPCC 1996b.

[4] Emission estimates of CFCs, HCFCs, halons, and other ODS are included in the annexes of the Inventory report for informational purposes.

[5] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

In recent years, use of ODS substitutes, such as HFCs and PFCs, has grown as they begin to be phased in as replacements for CFCs and HCFCs. Accordingly, atmospheric concentrations of these substitutes have been growing (IPCC 2001a).

RECENT TRENDS IN U.S. GREENHOUSE GAS EMISSIONS AND SINKS

In 2004, total U.S. greenhouse gas emissions were 7,074.4 Tg CO_2 Eq. Overall, total U.S. emissions rose by 15.8 percent from 1990 through 2004, while the U.S. gross domestic product increased by 51 percent over the same period (U.S. DOC/BEA 2006a). Emissions rose from 2003 through 2004, increasing by 1.7 percent (115.3 Tg CO_2 Eq.). The following factors were primary contributors to this increase: (1) robust economic growth in 2004, leading to increased demand for electricity and fossil fuels; (2) expanding industrial production in energy-intensive industries, also increasing demand for electricity and fossil fuels; and (3) increased travel, leading to higher rates of consumption of petroleum fuels.

Figures 3-1 through 3-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute change since 1990. Table 3-2 provides a detailed summary of U.S. greenhouse gas emissions and sinks from 1990 through 2004.

Figure 3-4 illustrates the relative contribution of the direct greenhouse gases to total U.S. emissions in 2004. The primary greenhouse gas emitted by human activities in the United States was CO_2, representing approximately 85 percent of total greenhouse gas emissions. The largest source of CO_2, and of overall greenhouse gas emissions, was fossil fuel combustion. CH_4 emissions, which have steadily declined since 1990, resulted primarily from decomposition of wastes in landfills, natural gas systems, and enteric fermentation associated with domestic livestock. Agricultural soil management and mobile source fossil fuel combustion were the major sources of N_2O emissions. The emissions of ODS substitutes and

FIGURE 3-1 Growth in U.S. Greenhouse Gas Emissions by Gas

In 2004, total U.S. greenhouse gas emissions rose to 7,074.4 teragrams of carbon dioxide equivalent (Tg CO_2 Eq.), which was 15.8 percent above 1990 emissions. The U.S. gross domestic product increased by 51 percent over the same period.

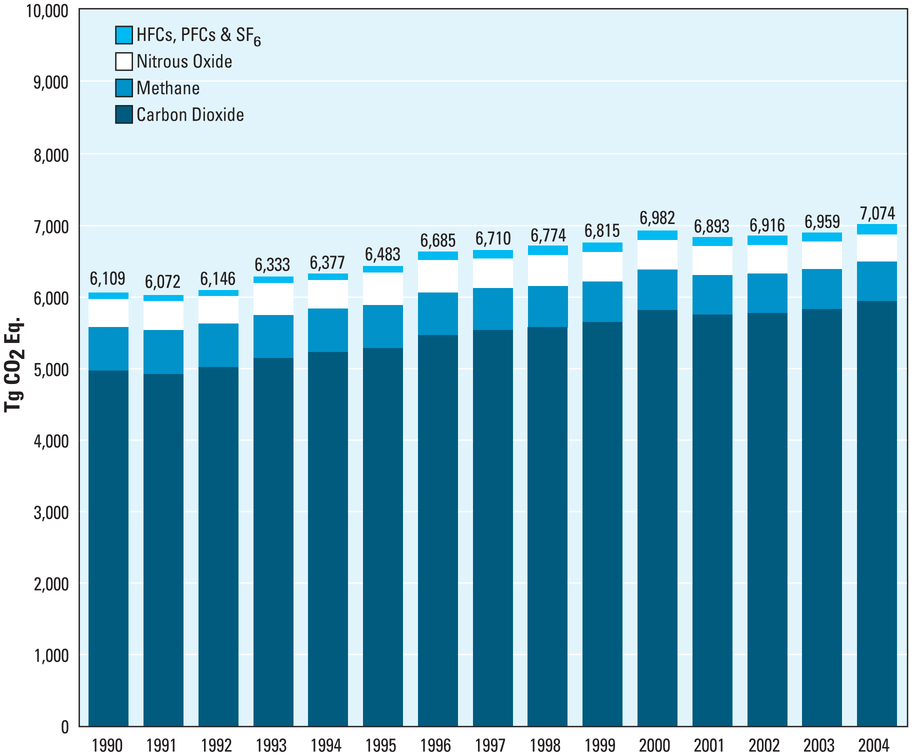


FIGURE 3-2 Annual Percent Change in U.S. Greenhouse Gas Emissions

Between 2003 and 2004, U.S. greenhouse gas emissions rose by 1.7 percent; the average annual rate increase from 1990 through 2004 was also 1.1 percent.

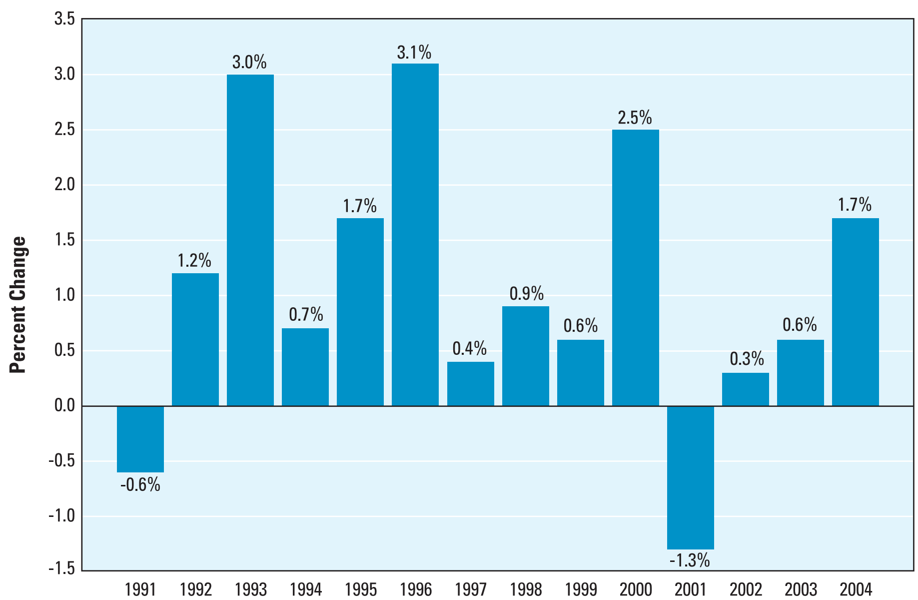


FIGURE 3-3 Cumulative Change in U.S. Greenhouse Gas Emissions Relative to 1990

From 1990 to 2004, total U.S. greenhouse gas emissions rose by 965.4 Tg CO_2 Eq., an increase of 15.8 percent.

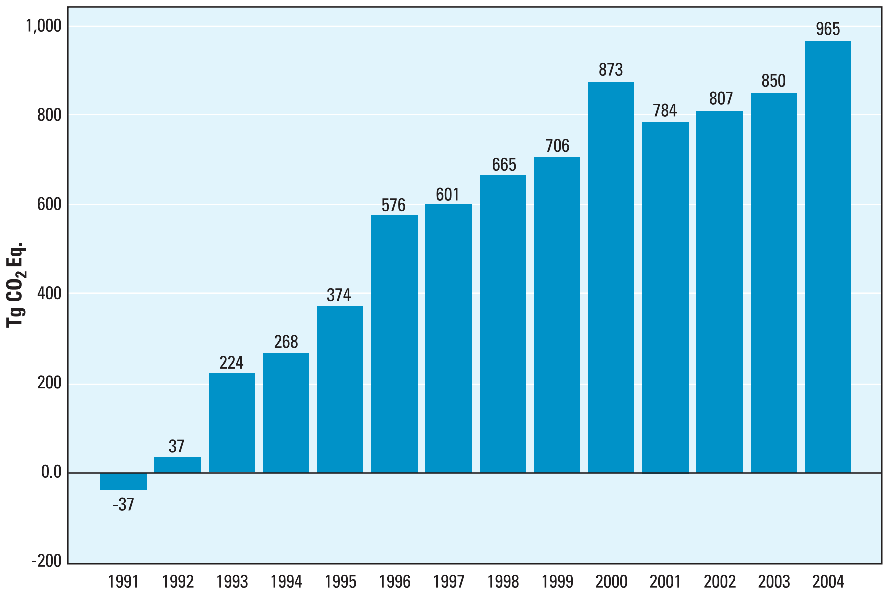
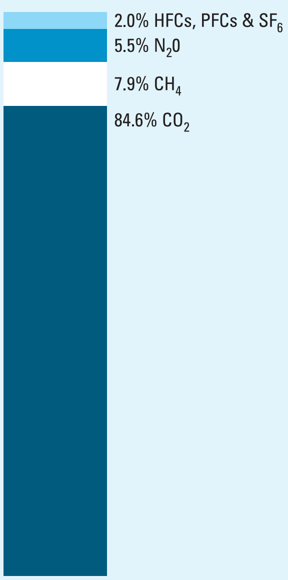


FIGURE 3-4 2004 U.S. Greenhouse Gas Emissions by Gas

The principal greenhouse gas emitted by human activities in 2004 was CO_2, driven primarily by emissions from fossil fuel combustion.



emissions of HFC-23 during the production of HCFC-22 were the primary contributors to aggregate HFC emissions. Electrical transmission and distribution systems accounted for most SF_6 emissions, while PFC emissions resulted from semiconductor manufacturing and as a by-product of primary aluminum production.

Overall, from 1990 through 2004, total emissions of CO_2 increased by 982.7 Tg CO_2 Eq. (20 percent), while CH_4 and N_2O emissions decreased by 61.3 Tg CO_2 Eq. (10 percent) and 8.2 Tg CO_2 Eq. (2 percent), respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 52.2 Tg CO_2 Eq. (58 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF_6 are significant because many of them have extremely high GWPs and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon sequestration in forests, trees in urban areas, agricultural soils, and landfilled yard trimmings and food scraps, which, in aggregate, offset 11 percent of total emissions in 2004. The following sections describe each gas's contribution to total U.S. greenhouse gas emissions in more detail.

Carbon Dioxide Emissions

The global carbon cycle is made up of large carbon flows and reservoirs. Billions of tons of carbon in the form of CO_2 are absorbed by oceans and living biomass (i.e., sinks) and are emitted to the atmosphere annually through natural processes (i.e., sources). When in equilibrium, carbon fluxes among these various reservoirs are roughly balanced. Since the Industrial Revolution (i.e., about 1750), global atmospheric concentrations of CO_2 have risen about 35 percent (IPCC 2001a; Hofmann 2004), principally due to the combustion of fossil fuels. Within the United States, fuel combustion accounted for 94 percent of CO_2 emissions in 2004 (Figure 3-5 and Table 3-3). Globally, approximately 25,575 Tg of CO_2 were added to the atmosphere through the combustion of fossil fuels in 2002, of which the United States accounted for about 23 percent.[6] Changes in land use and forestry practices can also emit CO_2 (e.g., through conversion of forest land to agricultural or urban use) or can act as a sink for CO_2 (e.g., through net additions to forest biomass)

As the largest source of U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 80 percent of GWP-weighted emissions since 1990, growing slowly from 77 percent of total GWP-weighted emissions in 1990 to 80 percent in 2004. Emissions of CO_2 from fossil fuel combustion increased at an average annual rate of 1.3 percent from 1990 through 2004. The fundamental factors influencing this trend include a generally growing domestic economy over the last 14 years, and significant growth in emissions from transportation activities and electricity generation. Between 1990 and 2004, CO_2 emissions from fossil fuel combustion increased from 4,696.6 Tg

[6] Global CO_2 emissions from fossil fuel combustion were taken from Marland et al. 2005 <http://cdiac.esd.ornl.gov/trends/emis/tre_glob.htm>.

TABLE 3-2 **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks** (Tg CO_2 Eq.)

From 1990 through 2004, U.S. greenhouse gas emissions increased by 15.8 percent. Specifically, CO_2 emissions increased by 20 percent; CH_4 and N_2O emissions decreased by 10 and 2 percent, respectively; and HFC, PFC, and SF_6 emissions increased by 58 percent.

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
CO_2	**5,005.3**	**5,620.2**	**5,695.0**	**5,864.5**	**5,795.2**	**5,815.9**	**5,877.7**	**5,988.0**
Fossil Fuel Combustion	4,696.6	5,271.8	5,342.4	5,533.7	5,486.9	5,501.8	5,571.1	5,656.6
Nonenergy Use of Fuels	117.2	152.8	160.6	140.7	131.0	136.5	133.5	153.4
Iron and Steel Production	85.0	67.7	63.8	65.3	57.8	54.6	53.3	51.3
Cement Manufacture	33.3	39.2	40.0	41.2	41.4	42.9	43.1	45.6
Waste Combustion	10.9	17.1	17.6	17.9	18.6	18.9	19.4	19.4
Ammonia Production and Urea Application	19.3	21.9	20.6	19.6	16.7	18.5	15.3	16.9
Lime Manufacture	11.2	13.9	13.5	13.3	12.8	12.3	13.0	13.7
Limestone and Dolomite Use	5.5	7.4	8.1	6.0	5.7	5.9	4.7	6.7
Natural Gas Flaring	5.8	6.6	6.9	5.8	6.1	6.2	6.1	6.0
Aluminum Production	7.0	6.4	6.5	6.2	4.5	4.6	4.6	4.3
Soda Ash Manufacture and Consumption	4.1	4.3	4.2	4.2	4.1	4.1	4.1	4.2
Petrochemical Production	2.2	3.0	3.1	3.0	2.8	2.9	2.8	2.9
Titanium Dioxide Production	1.3	1.8	1.9	1.9	1.9	2.0	2.0	2.3
Phosphoric Acid Production	1.5	1.6	1.5	1.4	1.3	1.3	1.4	1.4
Ferroalloy Production	2.0	2.0	2.0	1.7	1.3	1.2	1.2	1.3
CO_2 Consumption	0.9	0.9	0.8	1.0	0.8	1.0	1.3	1.2
Zinc Production	0.9	1.1	1.1	1.1	1.0	0.9	0.5	0.5
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Consumption	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry[a]	*(910.4)*	*(744.0)*	*(765.7)*	*(759.5)*	*(768.0)*	*(768.6)*	*(774.8)*	*(780.1)*
International Bunker Fuels[b]	*113.5*	*114.6*	*105.2*	*101.4*	*97.8*	*89.5*	*84.1*	*94.5*
Wood Biomass and Ethanol Combustion[b]	*216.7*	*217.2*	*222.3*	*226.8*	*200.5*	*194.4*	*202.1*	*211.2*
CH_4	**618.1**	**579.5**	**569.0**	**566.9**	**560.3**	**559.8**	**564.4**	**556.7**
Landfills	172.3	144.4	141.6	139.0	136.2	139.8	142.4	140.9
Natural Gas Systems	126.7	125.4	121.7	126.7	125.6	125.4	124.7	118.8
Enteric Fermentation	117.9	116.7	116.8	115.6	114.6	114.7	115.1	112.6
Coal Mining	81.9	62.8	58.9	56.3	55.5	52.5	54.8	56.3
Manure Management	31.2	38.8	38.1	38.0	38.9	39.3	39.2	39.4
Wastewater Treatment	24.8	32.6	33.6	34.3	34.7	35.8	36.6	36.9
Petroleum Systems	34.4	29.7	28.5	27.8	27.4	26.8	25.9	25.7
Rice Cultivation	7.1	7.9	8.3	7.5	7.6	6.8	6.9	7.6
Stationary Sources	7.9	6.8	7.0	7.3	6.6	6.2	6.5	6.4
Abandoned Coal Mines	6.0	6.9	6.9	7.2	6.6	6.0	5.8	5.6
Mobile Sources	4.7	3.8	3.6	3.5	3.3	3.2	3.0	2.9
Petrochemical Production	1.2	1.7	1.7	1.7	1.4	1.5	1.5	1.6
Iron and Steel Production	1.3	1.2	1.2	1.2	1.1	1.0	1.0	1.0
Agricultural Residue Burning	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.9
Silicon Carbide Production	+	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*

TABLE 3-2 (Continued) **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks** (Tg CO_2 Eq.)

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
N_2O	**394.9**	**440.6**	**419.4**	**416.2**	**412.8**	**407.4**	**386.1**	**386.7**
Agricultural Soil Management	266.1	301.1	281.2	278.2	282.9	277.8	259.2	261.5
Mobile Sources	43.5	54.8	54.1	53.1	50.0	47.5	44.8	42.8
Manure Management	16.3	17.4	17.4	17.8	18.1	18.0	17.5	17.7
Nitric Acid Production	17.8	20.9	20.1	19.6	15.9	17.2	16.7	16.6
Human Sewage	12.9	14.9	15.4	15.5	15.6	15.6	15.8	16.0
Stationary Sources	12.3	13.4	13.4	13.9	13.5	13.2	13.6	13.7
Settlements Remaining Settlements	5.6	6.2	6.2	6.0	5.8	6.0	6.2	6.4
Adipic Acid Production	15.2	6.0	5.5	6.0	4.9	5.9	6.2	5.7
N_2O Product Usage	4.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Waste Combustion	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Agricultural Residue Burning	0.4	0.5	0.4	0.5	0.5	0.4	0.4	0.5
Forest Land Remaining Forest Land	0.1	0.4	0.5	0.4	0.4	0.4	0.4	0.4
International Bunker Fuels[b]	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*	*0.9*
HFCs, PFCs, and SF_6	**90.8**	**133.4**	**131.5**	**134.7**	**124.9**	**132.7**	**131.0**	**143.0**
Substitution of Ozone-Depleting Substances	0.4	54.5	62.8	71.2	78.6	86.2	93.5	103.3
HCFC-22 Production	35.0	40.1	30.4	29.8	19.8	19.8	12.3	15.6
Electrical Transmission and Distribution	28.6	16.7	16.1	15.3	15.3	14.5	14.0	13.8
Semiconductor Manufacture	2.9	7.1	7.2	6.3	4.5	4.4	4.3	4.7
Aluminum Production	18.4	9.1	9.0	9.0	4.0	5.3	3.8	2.8
Magnesium Production and Processing	5.4	5.8	6.0	3.2	2.6	2.6	3.0	2.7
Total	**6,109.0**	**6,773.7**	**6,814.9**	**6,982.3**	**6,893.1**	**6,915.8**	**6,959.1**	**7,074.4**
Net Emissions (Sources and Sinks)	**5,198.6**	**6,029.6**	**6,049.2**	**6,222.8**	**6,125.1**	**6,147.2**	**6,184.3**	**6,294.3**

\+ Does not exceed 0.05 Tg CO_2 Eq.

[a] Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.

[b] Emissions from international bunker fuels and from wood biomass and ethanol combustion are not included in the totals.

Note: Totals may not sum due to independent rounding.

CO_2 Eq. to 5,656.6 Tg CO_2 Eq.—a 20 percent total increase over the 14-year period. Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

From 2003 through 2004, emissions from fossil fuel combustion increased by 85.5 Tg CO_2 Eq. (1.5 percent). A number of factors played a major role in the magnitude of this increase. Strong growth in the U.S. economy and industrial production, particularly in energy-intensive industries, caused an increase in the demand for electricity and fossil fuels. Demand for travel was also higher, causing an increase in petroleum consumed for transportation. In contrast, the warmer winter conditions led to decreases in demand for heating fuels in the residential and commercial sectors. Moreover, much of the increased electricity demanded was generated by natural gas consumption and nuclear power, rather than by more carbon-intensive coal, moderating the increase in CO_2 emissions from electricity generation. Use of renewable fuels rose very slightly, due to increases in the use of biofuels. Figures 3-6 and 3-7 summarize CO_2 emissions from fossil fuel combustion by sector and fuel type and by end-use sector.

Other significant CO_2 trends included the following:

- CO_2 emissions from iron and steel production decreased to 51.3 Tg CO_2 Eq. in 2004, and declined by 33.7 Tg CO_2 Eq. (40 percent) from 1990 through 2004, due to reduced domestic production of pig iron, sinter, and coal coke.
- CO_2 emissions from cement production increased to 45.6 Tg CO_2 Eq. in 2004, a 37 percent increase in emissions since 1990. Emissions mirror growth in the construction industry. In contrast to many other manufacturing sectors, demand for domestic cement remains strong, because it is not cost-effective to transport cement far from its point of manufacture.
- CO_2 emissions from waste combustion (19.4 Tg CO_2 Eq. in 2004) increased by

TABLE 3-3 AND FIGURE 3-5 **2004 U.S. Sources of CO_2** (Tg CO_2 Eq.)

In 2004, CO_2 accounted for 84.6 percent of U.S. greenhouse gas emissions. Between 1990 and 2004, CO_2 emissions from fossil fuel combustion increased at an average annual rate of 1.3 percent and grew by 20.4 percent over the 14-year period.

Sources	1990	1998	1999	2000	2001	2002	2003	2004
Fossil Fuel Combustion	4,696.6	5,271.8	5,342.4	5,533.7	5,486.9	5,501.8	5,571.1	5,656.6
Nonenergy Use of Fuels	117.2	152.8	160.6	140.7	131.0	136.5	133.5	153.4
Iron and Steel Production	85.0	67.7	63.8	65.3	57.8	54.6	53.3	51.3
Cement Manufacture	33.3	39.2	40.0	41.2	41.4	42.9	43.1	45.6
Waste Combustion	10.9	17.1	17.6	17.9	18.6	18.9	19.4	19.4
Ammonia Production and Urea Application	19.3	21.9	20.6	19.6	16.7	18.5	15.3	16.9
Lime Manufacture	11.2	13.9	13.5	13.3	12.8	12.3	13.0	13.7
Limestone and Dolomite Use	5.5	7.4	8.1	6.0	5.7	5.9	4.7	6.7
Natural Gas Flaring	5.8	6.6	6.9	5.8	6.1	6.2	6.1	6.0
Aluminum Production	7.0	6.4	6.5	6.2	4.5	4.6	4.6	4.3
Soda Ash Manufacture and Consumption	4.1	4.3	4.2	4.2	4.1	4.1	4.1	4.2
Petrochemical Production	2.2	3.0	3.1	3.0	2.8	2.9	2.8	2.9
Titanium Dioxide Production	1.3	1.8	1.9	1.9	1.9	2.0	2.0	2.3
Phosphoric Acid Production	1.5	1.6	1.5	1.4	1.3	1.3	1.4	1.4
Ferroalloy Production	2.0	2.0	2.0	1.7	1.3	1.2	1.2	1.3
CO_2 Consumption	0.9	0.9	0.8	1.0	0.8	1.0	1.3	1.2
Zinc Production	0.9	1.1	1.1	1.1	1.0	0.9	0.5	0.5
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Consumption	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry[a]	*(910.4)*	*(744.0)*	*(765.7)*	*(759.5)*	*(768.0)*	*(768.6)*	*(774.8)*	*(780.1)*
International Bunker Fuels[b]	*113.5*	*114.6*	*105.2*	*101.4*	*97.8*	*89.5*	*84.1*	*94.5*
Wood Biomass and Ethanol Combustion[b]	*216.7*	*217.2*	*222.3*	*226.8*	*200.5*	*194.4*	*202.1*	*211.2*
Total	**5,005.3**	**5,620.2**	**5,695.0**	**5,864.5**	**5,795.2**	**5,815.9**	**5,877.7**	**5,988.0**

[a] Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in separate net emissions totals.

[b] Emissions from international bunker fuels and from wood biomass and ethanol combustion are not included in the totals.

Note: Totals may not sum due to independent rounding.

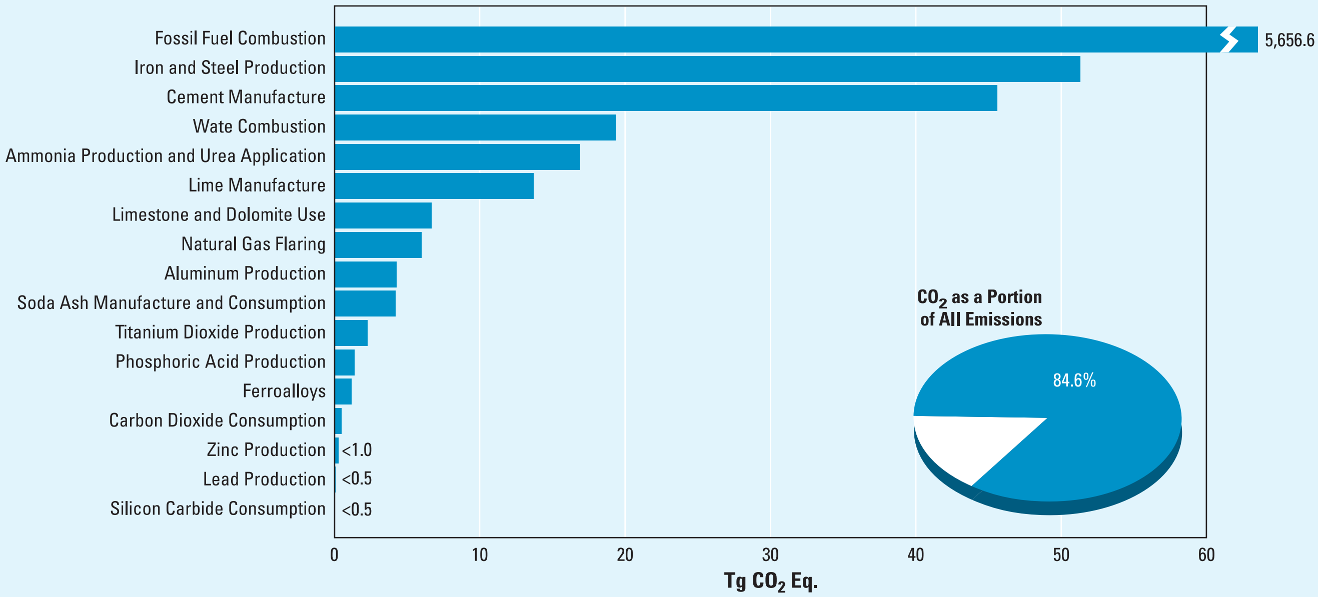
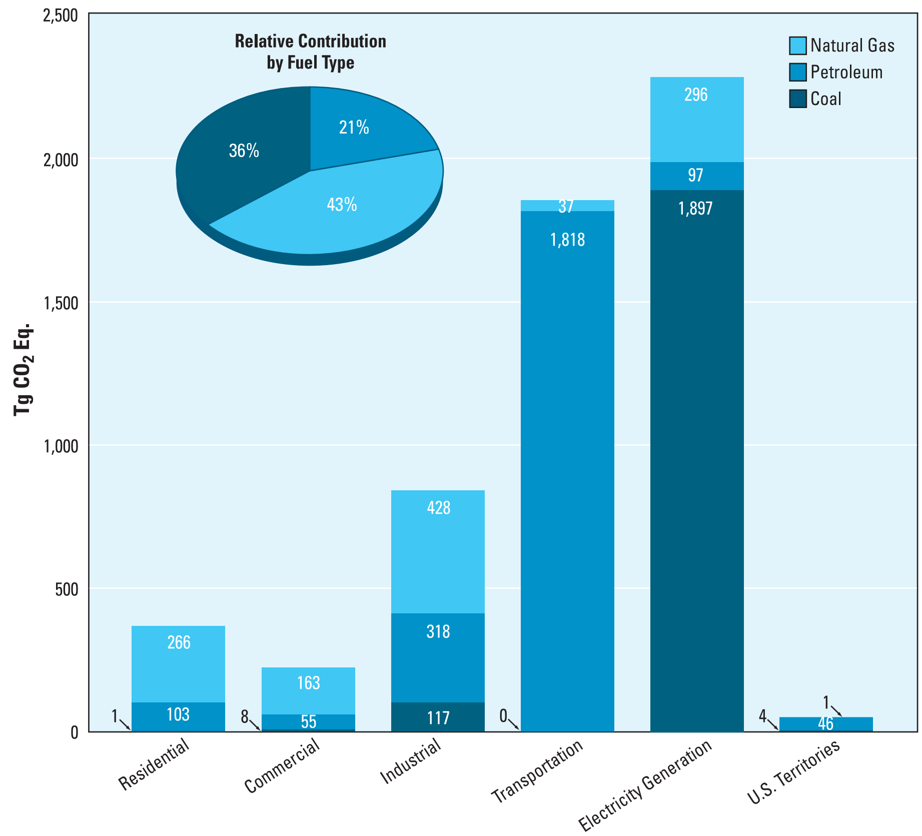


FIGURE 3-6 2004 U.S. CO_2 Emissions From Fossil Fuel Combustion by Sector and Fuel Type

Of the emissions from fossil fuel combustion in 2004, transportation sector emissions were primarily from petroleum consumption, while electricity generation emissions were primarily from coal consumption.



Note: Electricity generation also includes emissions of less than 1 Tg CO_2 Eq. from geothermal-based electricity generation.

8.4 Tg CO_2 Eq. (77 percent) from 1990 through 2004, as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.

- Net CO_2 sequestration from land use, land-use change, and forestry decreased by 130.3 Tg CO_2 Eq. (14 percent) from 1990 through 2004. This decline was primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks. Annual carbon accumulation in landfilled yard trimmings and food scraps also slowed over this period, while the rate of carbon accumulation in agricultural soils and urban trees increased.

Methane Emissions

According to the IPCC, CH_4 is more than 20 times as effective as CO_2 at trapping heat in the atmosphere. Over the last 250 years, the concentration of CH_4 in the atmosphere increased by 143 percent (IPCC 2001a; Hofmann 2004). Anthropogenic emission sources of CH_4 include landfills, natural gas and petroleum systems, agricultural activities, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (Figure 3-8 and Table 3-4).

Some significant trends in U.S. emissions of CH_4 include the following:

- Landfills are the largest anthropogenic source of CH_4 emissions in the United States. In 2004, landfill CH_4 emissions were 140.9 Tg CO_2 Eq. (approximately 25 percent of total CH_4 emissions), which represents a decline of 31.4 Tg CO_2 Eq., or 18 percent, since 1990. Although the amount of solid waste landfilled each year continues to climb, the amount of CH_4 captured and burned at landfills has increased dramatically, countering this trend.
- CH_4 emissions from natural gas systems were 118.8 Tg CO_2 Eq. in 2004; emissions have declined by 7.9 Tg CO_2 Eq. (6 percent) since 1990. This decline has been due to improvements in technology and management practices, as well as some replacement of old equipment.
- Enteric fermentation was also a significant source of CH_4, accounting for 112.6 Tg CO_2 Eq. in 2004. This amount has declined by 5.3 Tg CO_2 Eq. (4 percent) since 1990, and by 10.4 Tg CO_2 Eq. (8 percent) from a high in 1995. Generally, emissions have been decreasing since 1995, mainly due to decreasing populations of both beef and dairy cattle and improved feed quality for feedlot cattle.

Nitrous Oxide Emissions

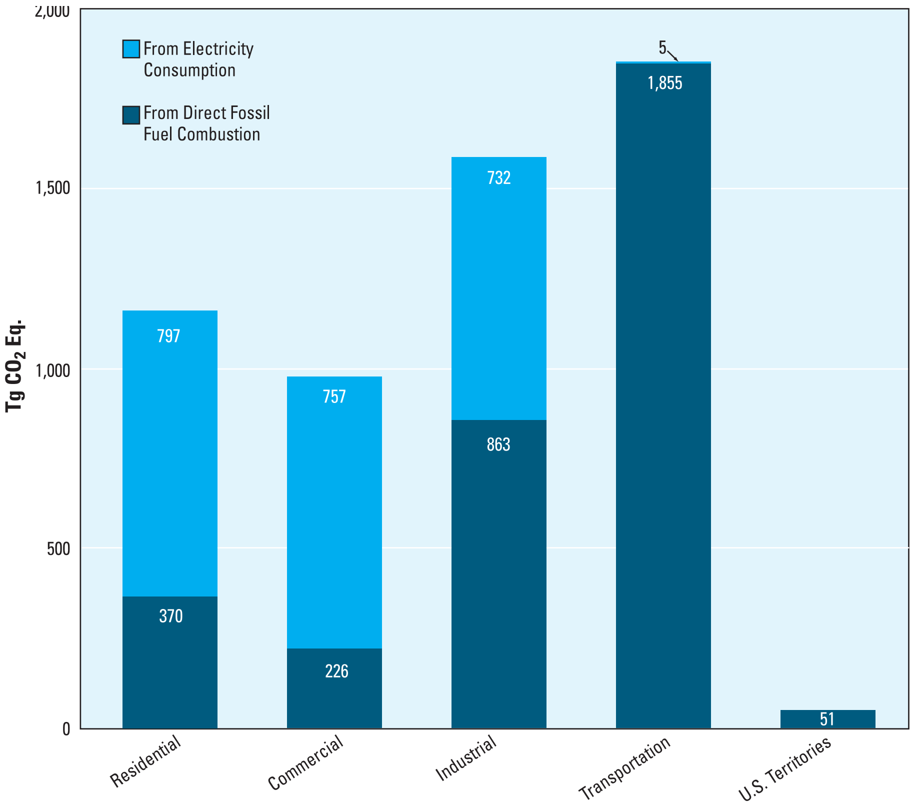
Nitrous oxide is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in the agricultural, energy-related, industrial, and waste management fields. While total N_2O emissions are much lower than CO_2 emissions, N_2O is approximately 300 times more powerful than CO_2 at trapping heat in the atmosphere. Since 1750, the global atmospheric concentration of N_2O has risen by approximately 18 percent (IPCC 2001a; Hofmann 2004). The main anthropogenic activities producing N_2O in the United States are agricultural soil management, fuel combustion in motor vehicles, manure management, nitric acid production, human sewage, and stationary fuel combustion (Figure 3-9 and Table 3-5).

Some significant trends in U.S. emissions of N_2O include the following:

- Agricultural soil management activities, such as fertilizer application and other

FIGURE 3-7 **2004 U.S. End-Use Sector Emissions of CO_2 From Fossil Fuel Combustion**

In 2004, most commercial and residential emissions were from these sectors' use of electricity. The transportation sector has small emissions associated with electricity use.



cropping practices, were the largest source of U.S. N_2O emissions, accounting for 68 percent (261.5 Tg CO_2 Eq.) of 2004 emissions. N_2O emissions from this source have not shown any significant long-term trend, as they are highly sensitive to such factors as temperature and precipitation, which have generally outweighed changes in the amount of nitrogen applied to soils.

- In 2004, N_2O emissions from mobile combustion were 42.8 Tg CO_2 Eq. (approximately 11 percent of U.S. N_2O emissions). From 1990 through 2004, N_2O emissions from mobile combustion decreased by 1 percent. However, from 1990 through 1998, emissions increased by 26 percent, due to control technologies that reduced NO_x emissions while increasing N_2O emissions. Since 1998, newer control technologies have led to a steady decline in N_2O emissions from this source.

HFC, PFC, and SF_6 Emissions

HFCs and PFCs are families of synthetic chemicals that are being used as alternatives to ODSs, which are being phased out under the *Montreal Protocol* and Clean Air Act Amendments of 1990. HFCs and PFCs do not deplete the stratospheric ozone layer, and are therefore acceptable alternatives under the *Montreal Protocol.*

These compounds, however, along with SF_6, are potent greenhouse gases. In addition to having high GWPs, SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted. SF_6 is the most potent greenhouse gas the IPCC has evaluated.

Other emissive sources of these gases include HCFC-22 production, electrical transmission and distribution systems, semiconductor manufacturing, aluminum production, and magnesium production and processing (Figure 3-10 and Table 3-6).

Some significant trends in U.S. HFC, PFC, and SF_6 emissions include the following:

- Emissions resulting from the substitution of ODSs (e.g., CFCs) have been increasing from small amounts in 1990 to 103.3 Tg CO_2 Eq. in 2004. Emissions from ODS substitutes are both the largest and the fastest growing source of HFC, PFC, and SF_6 emissions. These emissions have been increasing as phase-outs required under the *Montreal Protocol* come into effect, especially after 1994, when full market penetration was made for the first generation of new technologies featuring ODS substitutes.
- The increase in ODS substitute emissions is offset substantially by decreases in emissions of HFCs, PFCs, and SF_6 from other sources. Emissions from aluminum production decreased by 85 percent (15.6 Tg CO_2 Eq.) from 1990 through 2004, due to both industry emission reduction efforts and lower domestic aluminum production.
- Emissions from the production of HCFC-22 decreased by 55 percent (19.4 Tg CO_2 Eq.) from 1990 through 2004, due to a steady decline in the emission rate of HFC-23 (i.e., the amount of HFC-23 emitted per kilogram of HCFC-22 manufactured) and the use of thermal oxidation at some plants to reduce HFC-23 emissions.
- Emissions from electric power transmission and distribution systems decreased by 52 percent (14.8 Tg CO_2 Eq.) from 1990 through 2004, primarily because of higher purchase prices for SF_6 and efforts by industry to reduce emissions.

TABLE 3-4 AND FIGURE 3-8 **2004 U.S. Sources of CH_4** ($Tg\ CO_2$ Eq.)

Methane accounted for 7.9 percent of U.S. greenhouse gas emissions in 2004. Landfills were the largest anthropogenic source of CH_4, representing 25 percent of total U.S. CH_4 emissions.

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
Landfills	172.3	144.4	141.6	139.0	136.2	139.8	142.4	140.9
Natural Gas Systems	126.7	125.4	121.7	126.7	125.6	125.4	124.7	118.8
Enteric Fermentation	117.9	116.7	116.8	115.6	114.6	114.7	115.1	112.6
Coal Mining	81.9	62.8	58.9	56.3	55.5	52.5	54.8	56.3
Manure Management	31.2	38.8	38.1	38.0	38.9	39.3	39.2	39.4
Wastewater Treatment	24.8	32.6	33.6	34.3	34.7	35.8	36.6	36.9
Petroleum Systems	34.4	29.7	28.5	27.8	27.4	26.8	25.9	25.7
Rice Cultivation	7.1	7.9	8.3	7.5	7.6	6.8	6.9	7.6
Stationary Sources	7.9	6.8	7.0	7.3	6.6	6.2	6.5	6.4
Abandoned Coal Mines	6.0	6.9	6.9	7.2	6.6	6.0	5.8	5.6
Mobile Sources	4.7	3.8	3.6	3.5	3.3	3.2	3.0	2.9
Petrochemical Production	1.2	1.7	1.7	1.7	1.4	1.5	1.5	1.6
Iron and Steel Production	1.3	1.2	1.2	1.2	1.1	1.0	1.0	1.0
Agricultural Residue Burning	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.9
Silicon Carbide Production	+	+	+	+	+	+	+	+
*International Bunker Fuels**	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
TOTAL	**618.1**	**579.5**	**569.0**	**566.9**	**560.3**	**559.8**	**564.4**	**556.7**

\+ Does not exceed 0.05 $Tg\ CO_2$ Eq.

* Emissions from international bunker fuels are not included in the totals.

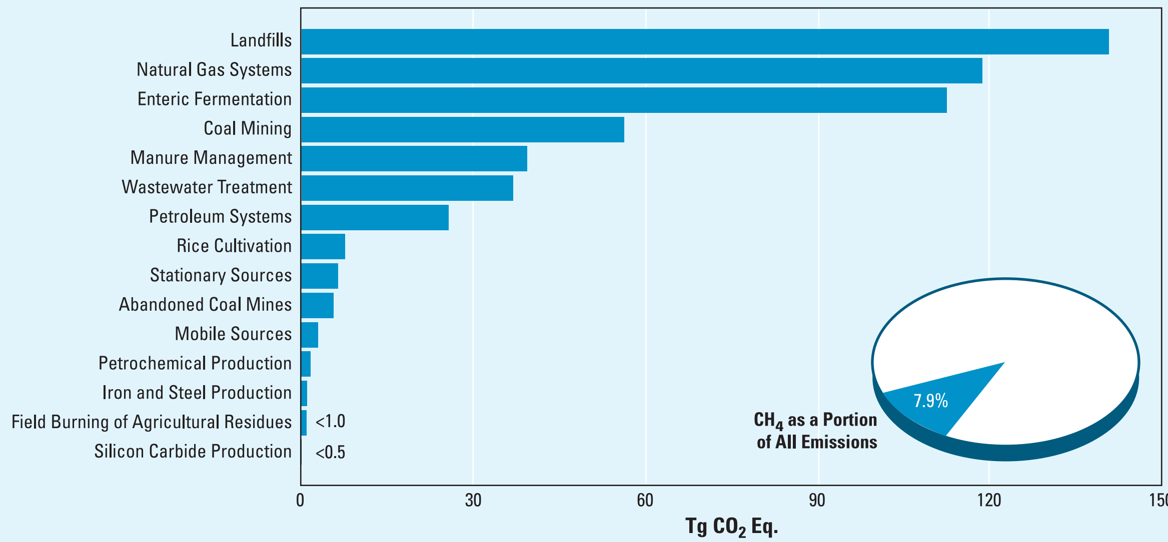
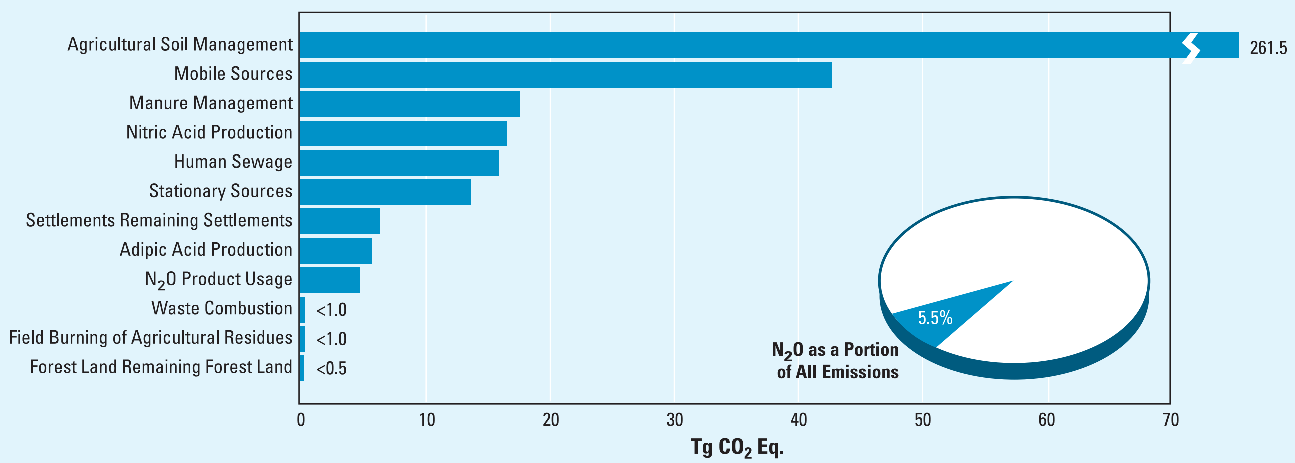


TABLE 3-5 AND FIGURE 3-9 2004 U.S. Sources of N_2O (Tg CO_2 Eq.)

Nitrous oxide accounted for 5.5 percent of U.S. greenhouse gas emissions in 2004. Agricultural soil management was the largest source of N_2O, representing approximately 60 percent of total N_2O emissions in 2004.

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
Agricultural Soil Management	266.1	301.1	281.2	278.2	282.9	277.8	259.2	261.5
Mobile Sources	43.5	54.8	54.1	53.1	50.0	47.5	44.8	42.8
Manure Management	16.3	17.4	17.4	17.8	18.1	18.0	17.5	17.7
Nitric Acid Production	17.8	20.9	20.1	19.6	15.9	17.2	16.7	16.6
Human Sewage	12.9	14.9	15.4	15.5	15.6	15.6	15.8	16.0
Stationary Sources	12.3	13.4	13.4	13.9	13.5	13.2	13.6	13.7
Settlements Remaining Settlements	5.6	6.2	6.2	6.0	5.8	6.0	6.2	6.4
Adipic Acid Production	15.2	6.0	5.5	6.0	4.9	5.9	6.2	5.7
N_2O Product Usage	4.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Waste Combustion	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Agricultural Residue Burning	0.4	0.5	0.4	0.5	0.5	0.4	0.4	0.5
Forest Land Remaining Forest Land	0.1	0.4	0.5	0.4	0.4	0.4	0.4	0.4
International Bunker Fuels[*]	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*	*0.9*
Total	**394.9**	**440.6**	**419.4**	**416.2**	**412.8**	**407.4**	**386.1**	**386.7**

[*] Emissions from international bunker fuels are not included in the totals.
Note: Totals may not sum due to independent rounding.



OVERVIEW OF SECTOR EMISSIONS AND TRENDS

In accordance with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997) and the *2003 UNFCCC Guidelines on Reporting and Review* (UNFCCC 2003), the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OAP 2006a) is segregated into six sector-specific chapters. Figure 3-11 and Table 3-7 aggregate emissions and sinks by these chapters.

Energy

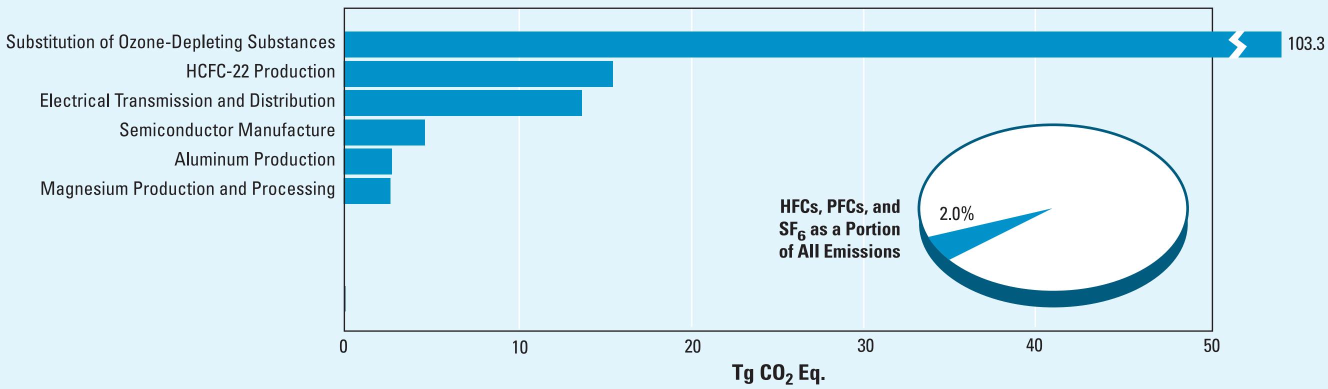
The Energy sector contains emissions of all greenhouse gases resulting from stationary and mobile energy activities, including fuel combustion and fugitive fuel emissions. Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions from 1990 through 2004. In 2004, approximately 86 percent of the energy consumed in the United States was produced through the combustion of fossil fuels. The remaining 14 percent came from other energy sources, such as hydropower, biomass, nuclear, wind, and solar energy (Figure 3-12). Energy-related activities are also responsible for CH_4 and N_2O emissions (39 percent and 15 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy sector accounted for a combined 86 percent of total U.S. greenhouse gas emissions in 2004.

TABLE 3-6 AND FIGURE 3-10 **2004 U.S. Sources of HFCs, PFCs, SF_6** (Tg CO_2 Eq.)

Because HFCs and PFCs do not deplete the stratospheric ozone layer, they are acceptable alternatives under the *Montreal Protocol*. However, these compounds, along with SF_6, have high global warming potentials, and SF_6 and PFCs have extremely long atmospheric lifetimes.

Gas/Source	1990	1998	1999	2000	2001	2002	2003	2004
Substitution of Ozone-Depleting Substances	0.4	54.5	62.8	71.2	78.6	86.2	93.5	103.3
HCFC-22 Production	35.0	40.1	30.4	29.8	19.8	19.8	12.3	15.6
Electrical Transmission and Distribution	28.6	16.7	16.1	15.3	15.3	14.5	14.0	13.8
Semiconductor Manufacture	2.9	7.1	7.2	6.3	4.5	4.4	4.3	4.7
Aluminum Production	18.4	9.1	9.0	9.0	4.0	5.3	3.8	2.8
Magnesium Production and Processing	5.4	5.8	6.0	3.2	2.6	2.6	3.0	2.7
Net Emissions (Sources and Sinks)	**90.8**	**133.4**	**131.5**	**134.7**	**124.9**	**132.7**	**131.0**	**143.0**

Note: Totals may not sum due to independent rounding.



Industrial Processes

The Industrial Processes sector contains by-product or fugitive emissions of greenhouse gases from industrial processes not directly related to energy activities, such as fossil fuel combustion. For example, industrial processes can chemically transform raw materials, which often release waste gases, such as CO_2, CH_4, and N_2O. The processes include iron and steel production, lead and zinc production, cement manufacture, ammonia manufacture and urea application, lime manufacture, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash manufacture and use, titanium dioxide production, phosphoric acid production, ferroalloy production, CO_2 consumption, aluminum production, petrochemical production, silicon carbide production, nitric acid production, and adipic acid production. Additionally, emissions from industrial processes release HFCs, PFCs, and SF_6. Overall, emission sources in the Industrial Process sector accounted for 4.5 percent of U.S. greenhouse gas emissions in 2004.

Solvent and Other Product Use

The Solvent and Other Product Use sector contains greenhouse gas emissions that are produced as a by-product of various solvent and other product uses. In 2004, U.S. emissions from N_2O Product Usage, the only source of greenhouse gas emissions from this sector, accounted for less than 0.1 percent of total U.S. anthropogenic greenhouse gas emissions on a carbon equivalent basis.

Agriculture

The Agriculture sector contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy sector). Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including the following source categories: enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, and field burning of agricultural residues. CH_4 and N_2O were the primary greenhouse gases emitted by agricultural activities. In 2004, CH_4 emissions from enteric fermentation and manure management represented about 20 percent and 7 percent of total CH_4 emissions from anthropogenic activities, respectively. Agricultural soil management activities, such as fertilizer application and other cropping practices, were the largest source of U.S. N_2O emissions in 2004, accounting for 68 percent. In 2004, emission sources accounted for in the Agriculture sector were responsible for 6.2 percent of total U.S. greenhouse gas emissions.

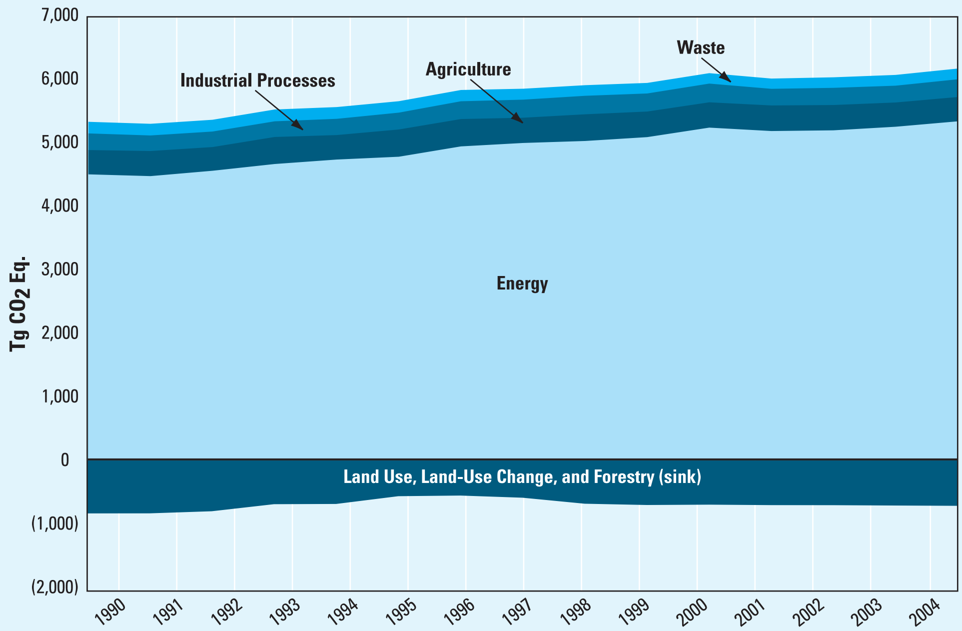
TABLE 3-7 AND FIGURE 3-11 **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by IPCC Sector** (Tg CO_2 Eq.)

In accordance with the IPCC Guidelines, the U.S. greenhouse gas inventory is segregated into six sector-specific chapters.

IPCC Sector	1990	1998	1999	2000	2001	2002	2003	2004
Energy	5,148.3	5,752.3	5,822.3	5,994.3	5,931.6	5,944.6	6,009.8	6,108.2
Industrial Processes	301.1	335.1	327.5	329.6	300.7	310.9	304.1	320.7
Solvent and Other Product Use	4.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Agriculture	439.6	483.2	463.1	458.4	463.4	457.8	439.1	440.1
Land Use, Land-Use Change, and Forestry (Emissions)	5.7	6.5	6.7	6.4	6.2	6.4	6.6	6.8
Waste	210.0	191.8	190.7	188.8	186.4	191.3	194.8	193.8
Total	**6,109.0**	**6,773.7**	**6,814.9**	**6,982.3**	**6,893.1**	**6,915.8**	**6,959.1**	**7,074.4**
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry*	(910.4)	(744.0)	(765.7)	(759.5)	(768.0)	(768.6)	(774.8)	(780.1)
Net Emissions (Sources and Sinks)	**5,198.6**	**6,029.6**	**6,049.2**	**6,222.8**	**6,125.1**	**6,147.2**	**6,184.3**	**6,294.3**

* Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.

Note: Totals may not sum due to independent rounding.

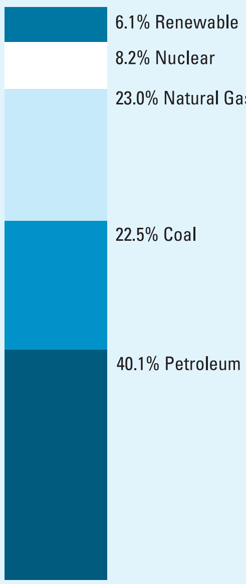


Land Use, Land-Use Change, and Forestry

The Land Use, Land-Use Change, and Forestry sector contains emissions and removals of CO_2 from forest management, other land-use activities, and land-use change. Forest management practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings and food scraps have resulted in a net uptake (sequestration) of carbon in the United States. Forests (including vegetation, soils, and harvested wood) accounted for approximately 82 percent of total 2004 sequestration; urban trees accounted for 11 percent; agricultural soils (including mineral and organic soils and the application of lime) accounted for 6 percent; and landfilled yard trimmings and food scraps accounted for 1 percent of the total sequestration in 2004. The net forest sequestration is a result of net forest growth and increasing forest area, as well as a net accumulation of carbon stocks in harvested wood pools. The net sequestration in urban forests is a result of net tree growth in these areas. In agricultural soils, mineral soils account for a net carbon sink that is almost two times larger than the sum of emissions from organic soils and liming. The mineral soil carbon sequestration is largely due to the conversion of cropland to permanent

FIGURE 3-12 **U.S. Energy Consumption by Energy Source**

In 2004, the combustion of fossil fuels accounted for approximately 86 percent of U.S. energy consumption. Hydropower, biomass, nuclear, wind, and solar energy made up the remaining 14 percent.



pastures and hay production, a reduction in summer fallow areas in semi-arid areas, an increase in the adoption of conservation tillage practices, and an increase in the amounts of organic fertilizers (i.e., manure and sewage sludge) applied to agriculture lands. The landfilled yard trimmings and food scraps net sequestration is due to the long-term accumulation of yard-trimming carbon and food scraps in landfills.

Land use, land-use change, and forestry activities in 2004 resulted in a net carbon sequestration of 780.1 Tg CO_2 Eq. (Table 3-7). This represents an offset of approximately 13 percent of total U.S. CO_2 emissions, or 11 percent of total greenhouse gas emissions in 2004. Total land use, land-use change, and forestry net carbon sequestration declined by approximately 14 percent from 1990 through 2004, which contributed to an increase in net U.S. emissions (all sources and sinks) of 21 percent from 1990 through 2004. This decline was primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks, as forests mature. Annual carbon accumulation in landfilled yard trimmings and food scraps and agricultural soils also slowed over this period. However, the rate of annual carbon accumulation increased in both agricultural soils and urban trees.

Land use, land-use change, and forestry activities in 2004 also resulted in emissions of N_2O (6.8 Tg CO_2 Eq.). Total N_2O emissions from the application of fertilizers to forests and settlements increased by approximately 20 percent from 1990 through 2004.

Waste

The Waste sector contains emissions from waste management activities (except waste incineration, which is addressed in the Energy sector). Landfills were the largest source of anthropogenic CH_4 emissions, accounting for 25 percent of total U.S. CH_4 emissions.[7] Additionally, wastewater treatment accounts for 7 percent of U.S. CH_4 emissions. N_2O emissions from the discharge of wastewater treatment effluents into aquatic environments were estimated, as were N_2O emissions from the treatment process itself, using a simplified methodology. Wastewater treatment systems are a potentially significant source of N_2O emissions; however, methodologies are not currently available to develop a complete estimate. N_2O emissions from the treatment of the human sewage component of wastewater were estimated, however, using a simplified methodology. Overall, in 2004, emission sources accounted for in the Waste sector generated 2.7 percent of total U.S. greenhouse gas emissions.

EMISSIONS BY ECONOMIC SECTOR

Emission estimates, for the purposes of inventory reports, are grouped into six sectors defined by the IPCC: Energy, Industrial Processes, Solvent Use, Agriculture, Land-Use Change and Forestry, and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories. This section reports emissions by the following economic sectors: Residential, Commercial, Industry, Transportation, Electricity Generation, and Agriculture, and U.S. Territories. Table 3-8 summarizes emissions from each of these sectors, and Figure 3-13 shows emission trends by sector from 1990 through 2004.

Using this categorization, emissions from electricity generation accounted for the largest portion (33 percent) of U.S. greenhouse gas emissions in 2004; transportation activities, in aggregate, accounted for the second largest portion (28 percent). Emissions from industry accounted for 19 percent of U.S. greenhouse gas emissions in 2004. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade, although there was an increase in industrial emissions in 2004 (up 3 percent from 2003 levels). The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. The remaining 20 percent of U.S. greenhouse gas emissions were contributed by the residential, agriculture, and commercial sectors, plus emissions from U.S. territories. The residential sector accounted for about 6 percent, and primarily consisted of CO_2 emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 7 percent of U.S. emissions; unlike other economic sectors, agriculture sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation, rather than CO_2 from fossil fuel combustion. The commercial sector accounted for about 7 percent of emissions, while U.S. territories accounted for 1 percent.

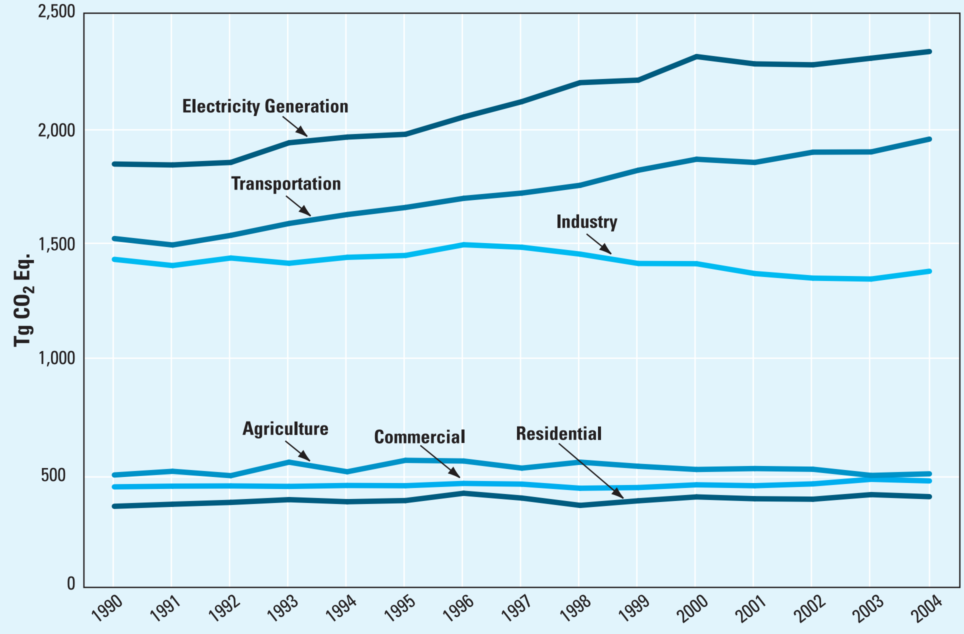
[7] Landfills also store carbon, resulting from incomplete degradation of organic materials, such as wood products and yard trimmings, as described in the Land Use, Land-Use Change, and Forestry chapter of the national *Inventory* report.

TABLE 3-8 AND FIGURE 3-13 **U.S. Greenhouse Gas Emissions Allocated to Economic Sectors** (Tg CO_2 Eq.)

In 2004, U.S. greenhouse gas emissions from electricity generation accounted for one-third of total greenhouse gas emissions, and the transportation sector accounted for almost 28 percent.

Economic Sector	1990	1998	1999	2000	2001	2002	2003	2004
Electricity Generation	1,846.4	2,202.4	2,213.3	2,315.9	2,284.4	2,280.1	2,308.5	2,337.8
Transportation	1,520.3	1,753.4	1,819.3	1,866.9	1,852.7	1,898.0	1,898.9	1,955.1
Industry	1,438.9	1,452.4	1,411.0	1,409.7	1,366.6	1,346.7	1,342.7	1,377.3
Agriculture	486.3	541.6	523.9	509.5	514.4	511.0	484.2	491.3
Commercial	433.6	428.0	430.6	443.0	439.5	447.5	466.5	459.9
Residential	349.4	353.3	372.6	390.4	381.6	380.1	399.8	391.1
U.S. Territories	33.8	42.7	44.2	46.9	54.0	52.4	58.6	61.9
Total	**6,109.0**	**6,773.7**	**6,814.9**	**6,982.3**	**6,893.1**	**6,915.8**	**6,959.1**	**7,074.4**
Land Use, Land-Use Change, and Forestry	(910.4)	(744.0)	(765.7)	(759.5)	(768.0)	(768.6)	(774.8)	(780.1)
Net Emissions (Sources and Sinks)	**5,198.6**	**6,029.6**	**6,049.2**	**6,222.8**	**6,125.1**	**6,147.2**	**6,184.3**	**6,294.3**

Notes:
Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.
Totals may not sum due to independent rounding. Emissions include CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6.



Note: Does not include U.S. territories.

CO_2 was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Electricity is ultimately consumed in the economic sectors described above. Table 3-9 presents greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). To distribute electricity emissions among end-use sectors, emissions from the source categories assigned to electricity generation were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity.[8] These source categories include CO_2 from fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO_2 and N_2O from waste combustion, CH_4 and N_2O from stationary sources, and SF_6 from electrical transmission and distribution systems.

When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S. greenhouse gas emissions (30 percent) in 2004. Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption (lighting, appliances, etc.). Transportation activities remain the second largest contributor to total U.S. emissions (28 percent). In all sectors except agriculture, CO_2 accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels. Figure 3-14 shows the trend in these emissions by sector from 1990 through 2004.

INDIRECT GREENHOUSE GASES

The reporting requirements of the UNFCCC[9] request that information be provided on indirect greenhouse gases, which include CO, NO_x, NMVOCs, and SO_2. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the atmosphere to form compounds that are greenhouse gases.

Since 1970, the United States has published estimates of annual emissions of CO, NO_x, NMVOCs, and SO_2 (U.S. EPA 2005),[10] which are regulated under the Clean Air Act. Table 3-10 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Recalculations of Inventory Estimates

Each year, emission and sink estimates are recalculated and revised for all years in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, as attempts are made to improve both the analyses themselves, through the use of better methods or data, and the overall usefulness of the report. In this effort, the United States follows the IPCC *Good Practice Guidance* (IPCC 2000), which states, regarding recalculations of the time series, "It is good practice to recalculate historic emissions when methods are changed or refined, when new source categories are included in the national inventory, or when errors in the estimates are identified and corrected." In general, recalculations are made to the U.S. greenhouse gas emission estimates either to incorporate new methodologies or, most commonly, to update recent historical data.

In each *Inventory* report, the results of all methodology changes and historical data updates are presented in the "Recalculations and Improvements" chapter; detailed descriptions of each recalculation are contained within each source's description contained in the report, if applicable. In general, when methodological changes have been implemented, the entire time series (in the case of the most recent *Inventory* report, 1990 through 2003) has been recalculated to reflect the change, per IPCC *Good Practice Guidance*. Changes in historical data are generally the result of changes in statistical data supplied by other agencies. References for the data are provided for additional information. More information on the most recent changes is provided in the "Recalculations and Improvements" chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004* (U.S. EPA/OAP 2006c), and previous *Inventory* reports can further describe the changes in calculation methods and data since the previous *Climate Action Report*.

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[8] Emissions were not distributed to U.S. territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

[9] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

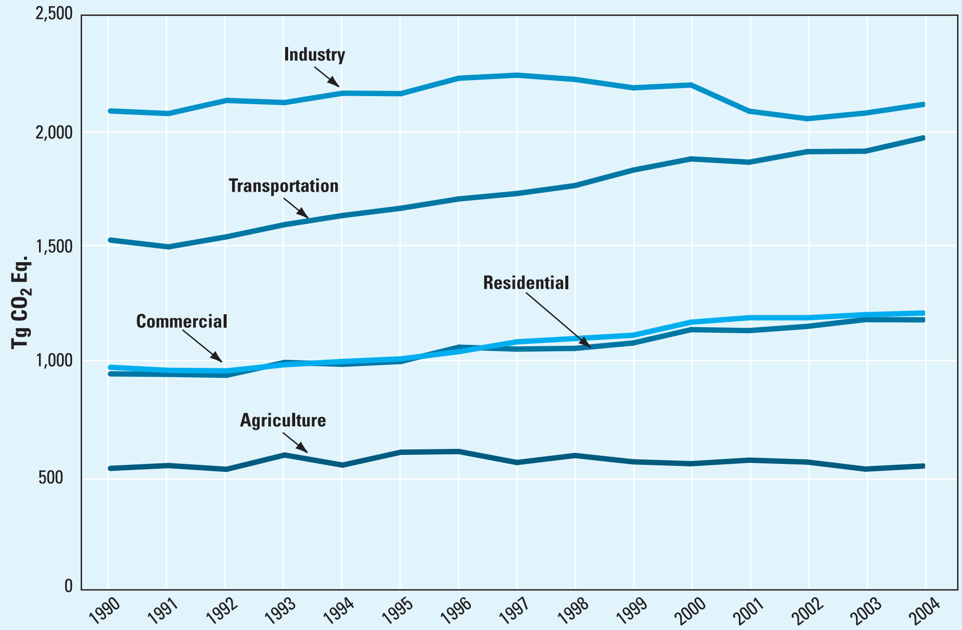
[10] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore were not taken from U.S. EPA 2005.

TABLE 3-9 AND FIGURE 3-14 U.S Electricity-Related Greenhouse Gas Emissions Distributed Among Economic Sectors (Tg CO_2 Eq.)

When 2004 U.S. greenhouse gas emissions from electricity generation were distributed among the economic sectors, industry accounted for the largest share (30 percent) and transportation, the second largest (28 percent).

Economic Sector	1990	1998	1999	2000	2001	2002	2003	2004
Industry	2,074.6	2,210.3	2,174.4	2,186.1	2,073.6	2,042.0	2,066.0	2,103.0
Transportation	1,523.4	1,756.5	1,822.5	1,870.3	1,856.2	1,901.4	1,903.2	1,959.8
Commercial	979.2	1,102.0	1,115.8	1,171.8	1,190.8	1,191.4	1,204.3	1,211.0
Residential	950.8	1,060.0	1,083.2	1,140.0	1,136.2	1,154.1	1,182.9	1,181.9
Agriculture	547.2	602.4	575.0	567.2	582.6	574.5	544.3	556.9
U.S. Territories	33.8	42.7	44.2	46.9	54.0	52.4	58.6	61.9
Total	**6,109.0**	**6,773.7**	**6,814.9**	**6,982.3**	**6,893.1**	**6,915.8**	**6,959.1**	**7,074.4**
Land Use, Land-Use Change, and Forestry	(910.4)	(744.0)	(765.7)	(759.5)	(768.0)	(768.6)	(774.8)	(780.1)
Net Emissions (Sources and Sinks)	**5,198.6**	**6,029.6**	**6,049.2**	**6,222.8**	**6,125.1**	**6,147.2**	**6,184.3**	**6,294.3**

Note: Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.



Note: Does not include U.S. territories.

TABLE 3-10 **Emissions of Indirect Greenhouse Gases** (Gg)

Fuel combustion accounts for the majority of emissions of indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Gas/Activity	1990	1998	1999	2000	2001	2002	2003	2004
NO_x	**22,860**	**21,964**	**20,530**	**20,288**	**19,414**	**18,850**	**17,995**	**17,076**
Stationary Fossil Fuel Combustion	9,884	9,419	8,344	8,002	7,667	7,522	7,138	6,662
Mobile Fossil Fuel Combustion	12,134	11,592	11,300	11,395	10,823	10,389	9,916	9,465
Oil and Gas Activities	139	130	109	111	113	135	135	135
Waste Combustion	82	145	143	114	114	134	134	134
Industrial Processes	591	637	595	626	656	630	631	632
Solvent Use	1	3	3	3	3	6	6	6
Agricultural Burning	28	35	34	35	35	33	34	39
Waste	0	3	3	2	2	2	2	2
CO	**130,580**	**98,984**	**94,361**	**92,895**	**89,329**	**87,428**	**87,518**	**87,599**
Stationary Fossil Fuel Combustion	4,999	3,927	5,024	4,340	4,377	4,020	4,020	4,020
Mobile Fossil Fuel Combustion	119,482	87,940	83,484	83,680	79,972	78,574	78,574	78,574
Oil and Gas Activities	302	332	145	146	147	116	116	116
Waste Combustion	978	2,826	2,725	1,670	1,672	1,672	1,672	1,672
Industrial Processes	4,124	3,163	2,156	2,217	2,339	2,286	2,286	2,286
Solvent Use	4	1	46	46	45	46	46	46
Agricultural Burning	689	789	767	790	770	706	796	877
Waste	1	5	13	8	8	8	8	8
NMVOCs	**20,937**	**16,403**	**15,869**	**15,228**	**15,048**	**14,217**	**13,877**	**13,556**
Stationary Fossil Fuel Combustion	912	1,016	1,045	1,077	1,080	923	922	922
Mobile Fossil Fuel Combustion	10,933	7,742	7,586	7,230	6,872	6,560	6,212	5,882
Oil and Gas Activities	555	440	414	389	400	340	341	341
Waste Combustion	222	326	302	257	258	281	282	282
Industrial Processes	2,426	2,047	1,813	1,773	1,769	1,723	1,725	1,727
Solvent Use	5,217	4,671	4,569	4,384	4,547	4,256	4,262	4,267
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA	NA
Waste	673	161	140	119	122	133	134	134
SO_2	**20,936**	**17,189**	**15,917**	**14,829**	**14,452**	**13,928**	**14,208**	**13,910**
Stationary Fossil Fuel Combustion	18,407	15,191	13,915	12,848	12,461	11,946	12,220	11,916
Mobile Fossil Fuel Combustion	793	665	704	632	624	631	637	644
Oil and Gas Activities	390	310	283	286	289	315	315	315
Waste Combustion	39	30	30	29	30	24	24	24
Industrial Processes	1,306	991	984	1,031	1,047	1,009	1,009	1,009
Solvent Use	0	1	1	1	1	1	1	1
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA	NA
Waste	0	1	1	1	1	1	1	1

NA = Not Available.
Note: Totals may not sum due to independent rounding.
Source: U.S. EPA 2005, except for estimates from field burning of agricultural residues.

Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and nonutilities combined—was the largest source of U.S. greenhouse gas emissions in 2004; (4) emissions per unit of total gross domestic product as a measure of national economic activity; and (5) emissions per capita.

Table 3-11 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. U.S. greenhouse gas emissions have grown at an average annual rate of 1.1 percent since 1990. This rate is slower than that for total energy or fossil fuel consumption and much slower than that for either electricity consumption or overall gross domestic product. Total U.S. greenhouse gas emissions have also grown more slowly than national population since 1990 (Figure 3-15). Overall, global atmospheric CO2 concentrations a function of many complex anthropogenic and natural processes worldwide are increasing at 0.4 percent per year.

TABLE 3-11 AND FIGURE 3-15 **Recent Trends in Various U.S. Data** (Index 1990 = 100) **and Global Atmospheric CO_2 Concentrations**

Since 1990, U.S. greenhouse gas emissions have grown at an average annual rate of 1.1 percent—a rate slower than the growth in energy consumption or overall gross domestic product.

Variable	1991	1998	1999	2000	2001	2002	2003	2004	Growth Rate[f]
GDP Growth[a]	100	127	133	138	139	141	145	151	3.0%
Electricity Consumption[b]	102	121	123	127	125	128	129	131	2.0%
Energy Consumption[b]	100	112	114	117	114	116	116	118	1.2%
Fossil Fuel Consumption[b]	99	113	114	117	115	116	117	118	1.2%
Greenhouse Gas Emissions[c]	99	111	112	114	113	113	114	116	1.1%
Population Growth[d]	101	110	112	113	114	115	116	117	1.1%
Atmospheric CO_2 Concentrations[e]	100	103	104	104	105	105	106	106	0.4%

[a] Gross domestic product in chained 2000 dollars (U.S. DOC/BEA 2006a).
[b] Energy content weighted values (U.S. DOE/EIA 2004a).
[c] GWP weighted values.
[d] U.S. DOC/Census 2005.
[e] Hofmann 2004.
[f] Average annual growth rate.