Executive Summary

Central to any study of climate change is the development of an emissions inventory that identifies and quantifies a country's primary anthropogenic[1] sources and sinks of greenhouse gases. This inventory adheres to both (1) a comprehensive and detailed methodology 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 contribution of different emission sources and greenhouse gases to climate change.

In 1992, the United States signed and ratified the UNFCCC. As stated in Article 2 of the UNFCCC, "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."[2]

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…."[3] The United States views this report 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 *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 this report is consistent with the UNFCCC guidelines for inventory reporting.[4] For most source categories, the Intergovernmental Panel on Climate Change (IPCC) methodologies were expanded, resulting in a more comprehensive and detailed estimate of emissions.

[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 that have been affected by human activities (IPCC/UNEP/OECD/IEA 1997).

[2] Article 2 of the Framework Convention on Climate Change published by the UNEP/WMO Information Unit on Climate Change. See <http://unfccc.int>.

[3] Article 4(1)(a) of the United Nations Framework Convention on Climate Change (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>.

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

Box ES- 1: 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 this 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 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 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.

ES.1. Background Information

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, CFCs, HCFCs, and halons are covered under the *Montreal Protocol on Substances that Deplete the Ozone Layer*. The UNFCCC defers to this earlier international treaty. Consequently, Parties are not required to include these gases in their national greenhouse gas emission inventories.[5] 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 non-CH_4 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 ozone depleting substances (ODS) 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 ODS is being phased out. 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 2001).

Global Warming Potentials

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects occur when the gas itself absorbs radiation. Indirect radiative forcing occurs when chemical transformations of the substance produce other greenhouse gases, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation

[5] Emissions estimates of CFCs, HCFCs, halons and other ozone-depleting substances are included in the annexes of this report for informational purposes.

or albedo).[6] The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas.

The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001). Direct radiative effects occur when the gas itself is a greenhouse gas. The reference gas used is CO_2, and therefore GWP-weighted emissions are measured in teragrams of CO_2 equivalent (Tg CO_2 Eq.).[7] All gases in this Executive Summary are presented in units of Tg CO_2 Eq.

The UNFCCC reporting guidelines for national inventories were updated in 2002,[8] but continue to require the use of GWPs from the IPCC Second Assessment Report (SAR). This requirement ensures that current estimates of aggregate greenhouse gas emissions for 1990 to 2004 are consistent with estimates developed prior to the publication of the IPCC Third Assessment Report (TAR). Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values. All estimates are provided throughout this report in both CO_2 equivalents and unweighted units. A comparison of emission values using the SAR GWPs versus the TAR GWPs can be found in Chapter 1 and, in more detail, in Annex 6.1 of this report. The GWP values used in this report are listed below in Table ES-1.

Global warming potentials are not provided for CO, NO_x, NMVOCs, SO_2, and aerosols because there is no agreed-upon method to estimate the contribution of gases that are short-lived in the atmosphere, spatially variable, or have only indirect effects on radiative forcing (IPCC 1996).

Table ES-1: Global Warming Potentials (100-Year Time Horizon) Used in this Report

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

Source: IPCC (1996)
* The CH_4 GWP includes the direct effects and those 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.

ES.2. 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 have risen by 15.8 percent from 1990 to 2004, while the U.S. gross domestic product has increased by 51 percent over the same period (BEA 2005). Emissions rose from 2003 to 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.

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

Figure ES-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

[6] Albedo is a measure of the Earth's reflectivity, and is defined as the fraction of the total solar radiation incident on a body that is reflected by it.

[7] Carbon comprises 12/44[ths] of carbon dioxide by weight.

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

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 substitutes for ozone depleting substances and 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 to 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 global warming potentials 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

Figure ES-1

U.S. Greenhouse Gas Emissions by Gas

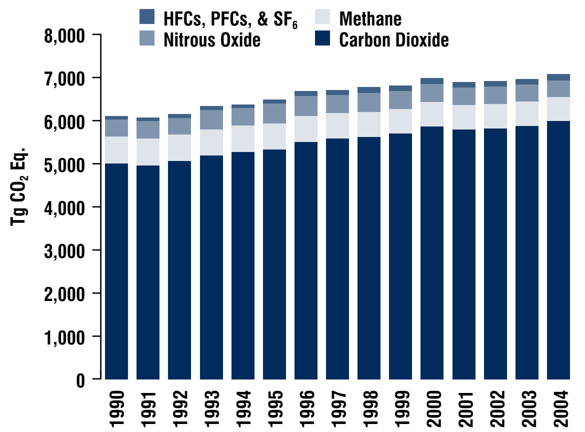


Figure ES-2

Annual Percent Change in U.S. Greenhouse Gas Emissions

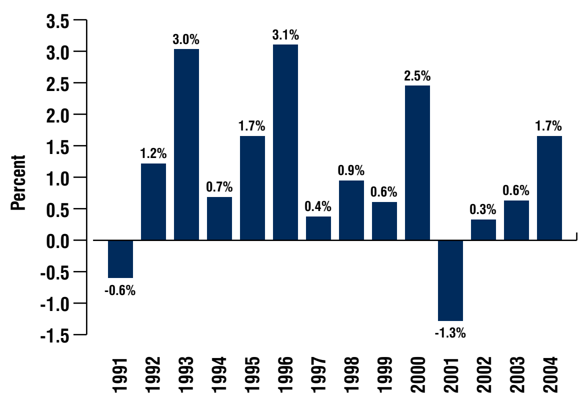


Figure ES-3

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

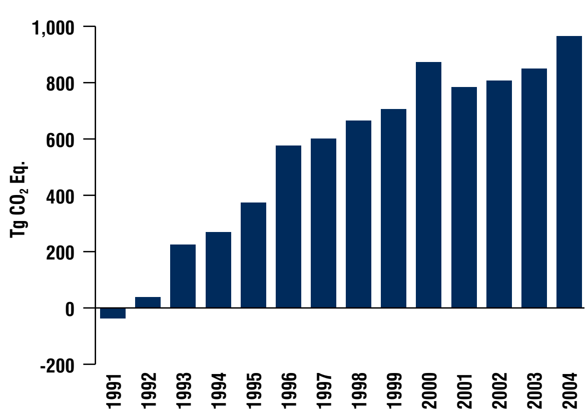


Figure ES-4

2004 Greenhouse Gas Emissions by Gas

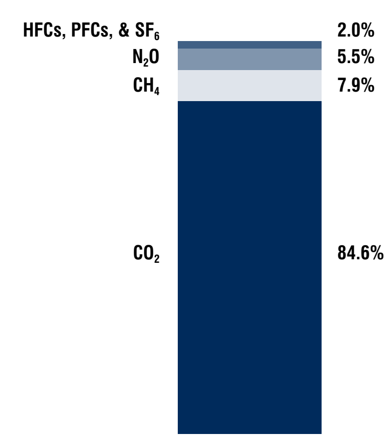


Table ES-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg CO_2 Eq.)

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
Non-Energy 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
Municipal Solid Waste Combustion	10.9	17.1	17.6	17.9	18.6	18.9	19.4	19.4
Ammonia Manufacture 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 Consumption[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 Combustion	7.9	6.8	7.0	7.3	6.6	6.2	6.5	6.4
Abandoned Underground Coal Mines	6.0	6.9	6.9	7.2	6.6	6.0	5.8	5.6
Mobile Combustion	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
Field Burning of Agricultural Residues	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*
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 Combustion	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 Combustion	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
Municipal Solid Waste Combustion	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Field Burning of Agricultural Residues	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 net emissions total.

[b] Emissions from International Bunker Fuels and Wood Biomass and Ethanol Consumption are not included in totals.

Note: Totals may not sum due to independent rounding.

describe each gas's contribution to total U.S. greenhouse gas emissions in more detail.

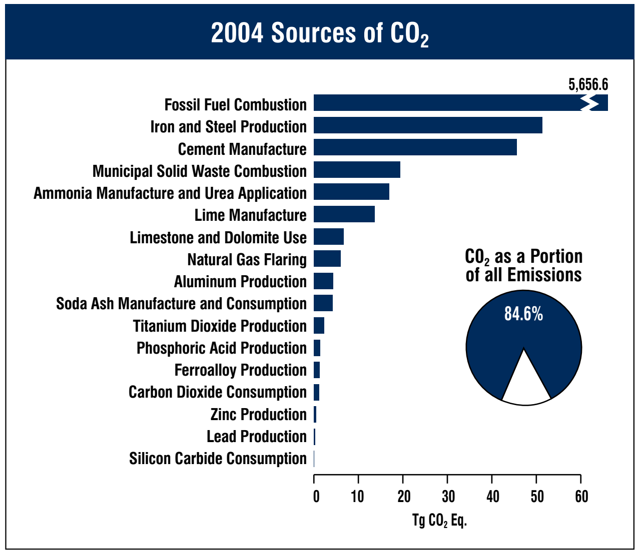
Carbon Dioxide Emissions

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 2001, 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. 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.[9] 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).

U.S. anthropogenic sources of CO_2 are shown in Figure ES-5. 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 to 2004. The fundamental factors influencing this trend include (1) a generally growing domestic economy over the last 14 years, and (2) 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 CO_2 Eq. to 5,656.6 Tg CO_2 Eq.—a 20 percent total increase over the fourteen-year period. Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

From 2003 to 2004, these emissions 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 both the residential and commercial sectors. Moreover, much of the increased electricity demanded was generated by natural gas consumption and nuclear power, rather than 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.

Figure ES-5



The four major end-use sectors contributing to CO_2 emissions from fossil fuel combustion are industrial, transportation, residential, and commercial. Electricity generation also emits CO_2, although these emissions are produced as fossil fuel is consumed to provide electricity to one of the four end-use sectors. For the discussion below, electricity generation emissions have been distributed to each end-use sector on the basis of each sector's share of aggregate electricity consumption. This method of distributing emissions assumes that each end-use sector consumes electricity that is generated from the national average mix of fuels according to their carbon intensity. Emissions from electricity generation are also addressed separately after the end-use sectors have been discussed.

Note that emissions from U.S. territories are calculated separately due to a lack of specific consumption data for the individual end-use sectors.

[9] 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>.

Figure ES-6, Figure ES-7, and Table ES-3 summarize CO_2 emissions from fossil fuel combustion by end-use sector.

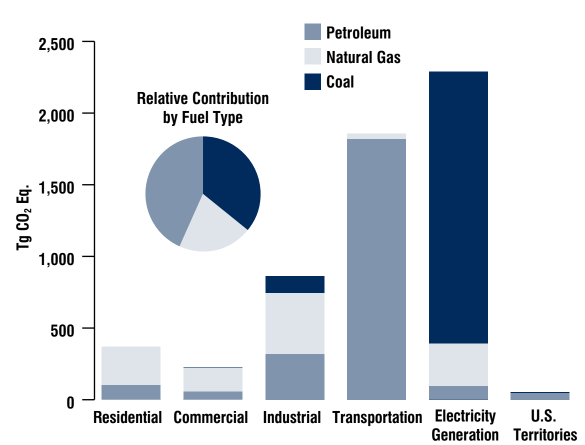
Transportation End-Use Sector. Transportation activities (excluding international bunker fuels) accounted for 33 percent of CO_2 emissions from fossil fuel combustion in 2004.[10] Virtually all of the energy consumed in this end-use sector came from petroleum products. Over 60 percent of the emissions resulted from gasoline consumption for personal vehicle use. The remaining emissions came from other transportation activities, including the combustion of diesel fuel in heavy-duty vehicles and jet fuel in aircraft.

Industrial End-Use Sector. Industrial CO_2 emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity that is consumed by industry, accounted for 28 percent of CO_2 from fossil fuel combustion in 2004. About half of these emissions resulted from direct fossil fuel combustion to produce steam and/or heat for industrial processes. The other half of the emissions resulted from consuming electricity for motors, electric furnaces, ovens, lighting, and other applications.

Residential and Commercial End-Use Sectors. The residential and commercial end-use sectors accounted for 21 and 17 percent, respectively, of CO_2 emissions from fossil fuel combustion in 2004. Both sectors relied heavily on electricity for meeting energy demands, with 68 and 77 percent, respectively, of their emissions attributable to electricity consumption for lighting, heating, cooling, and operating appliances. The remaining emissions were due to the consumption of natural gas and petroleum for heating and cooking.

Figure ES-6

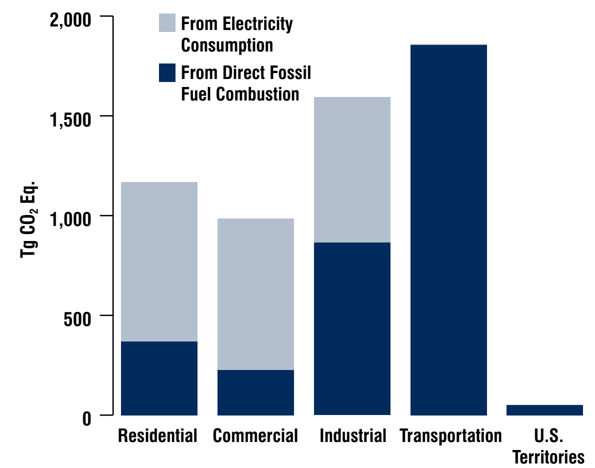
2004 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type



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

Figure ES-7

2004 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion



Electricity Generation. The United States relies on electricity to meet a significant portion of its energy demands, especially for lighting, electric motors, heating, and air conditioning. Electricity generators consumed 34 percent of U.S. energy from fossil fuels and emitted 40 percent of the CO_2 from fossil fuel combustion in 2004. The type of fuel combusted by electricity generators has a significant effect on their emissions. For example, some electricity is generated with low CO_2 emitting energy technologies, particularly non-fossil options such as nuclear, hydroelectric, or geothermal energy. However, electricity generators rely on coal for over half of their total energy requirements and accounted for 94 percent of all coal consumed for energy in the United States in 2004. Consequently, changes in electricity demand have a significant impact on coal consumption and associated CO_2 emissions.

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 have declined by 33.7 Tg CO_2 Eq. (40 percent) from 1990 through 2004, due

[10] If emissions from international bunker fuels are included, the transportation end-use sector accounted for 34 percent of U.S. emissions from fossil fuel combustion in 2004.

Table ES-3: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (Tg CO_2 Eq.)

End-Use Sector	1990	1998	1999	2000	2001	2002	2003	2004
Transportation	**1,464.4**	**1,663.4**	**1,725.6**	**1,770.3**	**1,757.0**	**1,802.2**	**1,805.4**	**1,860.2**
Combustion	1,461.4	1,660.3	1,722.4	1,766.9	1,753.6	1,798.8	1,801.0	1,855.5
Electricity	3.0	3.1	3.2	3.4	3.5	3.4	4.3	4.7
Industrial	**1,528.3**	**1,634.5**	**1,613.5**	**1,642.8**	**1,574.9**	**1,542.8**	**1,572.4**	**1,595.0**
Combustion	851.1	871.9	849.0	862.6	861.2	842.1	844.6	863.5
Electricity	677.2	762.6	764.5	780.3	713.7	700.7	727.7	731.5
Residential	**922.8**	**1,044.5**	**1,064.0**	**1,123.2**	**1,123.2**	**1,139.8**	**1,166.6**	**1,166.8**
Combustion	338.0	333.5	352.3	369.9	361.5	360.0	378.8	369.6
Electricity	584.8	711.0	711.7	753.3	761.7	779.8	787.9	797.2
Commercial	**753.1**	**895.9**	**904.8**	**961.6**	**983.3**	**973.9**	**978.1**	**983.1**
Combustion	222.6	217.7	218.6	229.3	224.9	224.3	235.8	226.0
Electricity	530.5	678.2	686.2	732.4	758.4	749.6	742.2	757.2
U.S. Territories	**28.0**	**33.5**	**34.5**	**35.8**	**48.5**	**43.1**	**48.7**	**51.4**
Total	**4,696.6**	**5,271.8**	**5,342.4**	**5,533.7**	**5,486.9**	**5,501.8**	**5,571.1**	**5,656.6**
Electricity Generation	**1,795.5**	**2,154.9**	**2,165.6**	**2,269.3**	**2,237.3**	**2,233.5**	**2,262.2**	**2,290.6**

Note: Totals may not sum due to independent rounding. Combustion-related emissions from electricity generation are allocated based on aggregate national electricity consumption by each end-use sector.

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 municipal solid waste combustion (19.4 Tg CO_2 Eq. in 2004) increased by 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.

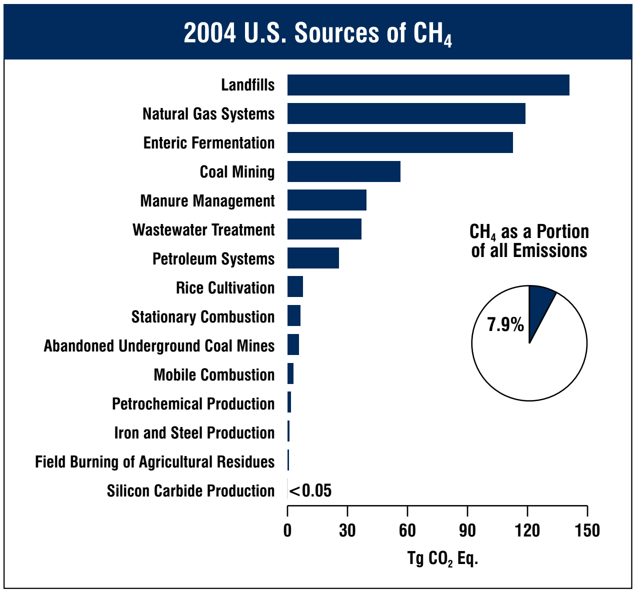
Methane Emissions

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 two hundred and fifty years, the concentration of CH_4 in the atmosphere increased by 143 percent (IPCC 2001, Hofmann 2004). Experts believe that over half of this atmospheric increase was due to emissions from anthropogenic sources, such as landfills, natural gas and petroleum systems, agricultural activities, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (see Figure ES-8).

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

Figure ES-8



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

N_2O 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 2001, 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 (see Figure ES-9).

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

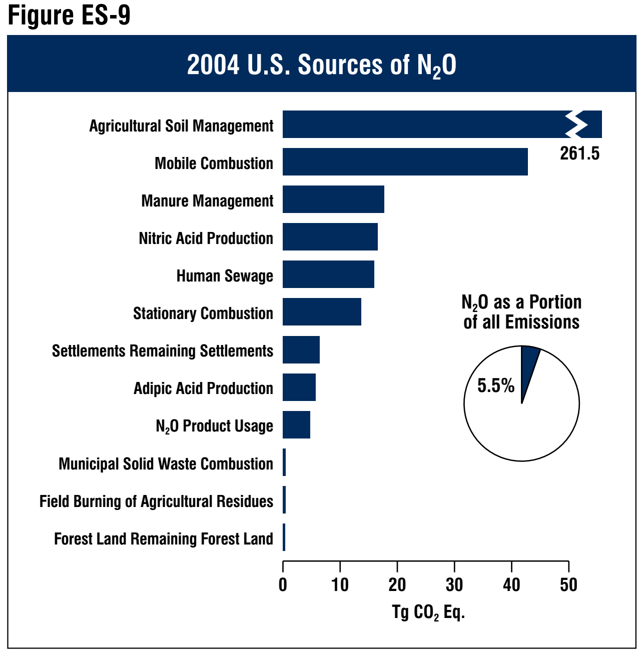
- Agricultural soil management activities such as fertilizer application and other cropping practices were the largest source of U.S. N_2O emissions, accounting for 68 percent (261.5 Tg CO_2 Eq.) of 2004 emissions. N_2O emissions from this source have not shown any significant long-term trend, as they 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 to 2004, N_2O emissions from mobile combustion decreased by 1 percent. However, from 1990 to 1998 emissions increased by 26 percent, due to control technologies that reduced CH_4 emissions while increasing N_2O emissions. Since 1998, new control technologies have led to a steady decline in N_2O from this source.

HFC, PFC, and SF_6 Emissions

HFCs and PFCs are families of synthetic chemicals that are being used as alternatives to the 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 global warming potentials, SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted. Sulfur hexafluoride is the most potent greenhouse gas the IPCC has evaluated.

Figure ES-9



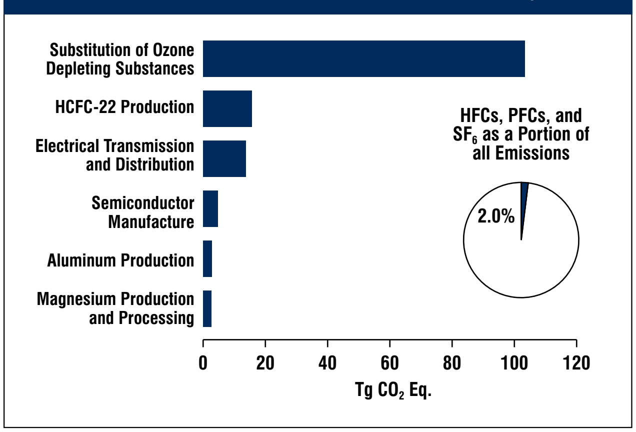
Other emissive sources of these gases include HCFC-22 production, electrical transmission and distribution systems, semiconductor manufacturing, aluminum production, and magnesium production and processing (see Figure ES-10).

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

- Emissions resulting from the substitution of ozone depleting substances (e.g., CFCs) have been increasing from small amounts in 1990 to 103.3 Tg CO_2 Eq. in 2004. Emissions from substitutes for ozone depleting substances 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 emissions is offset substantially by decreases in emission 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 to 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.), 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.

Figure ES-10

2004 U.S. Sources of HFCs, PFCs, and SF_6



- Emissions from electric power transmission and distribution systems decreased by 52 percent (14.8 Tg CO_2 Eq.) from 1990 to 2004, primarily because of higher purchase prices for SF_6 and efforts by industry to reduce emissions.

ES.3. Overview of Sector Emissions and Trends

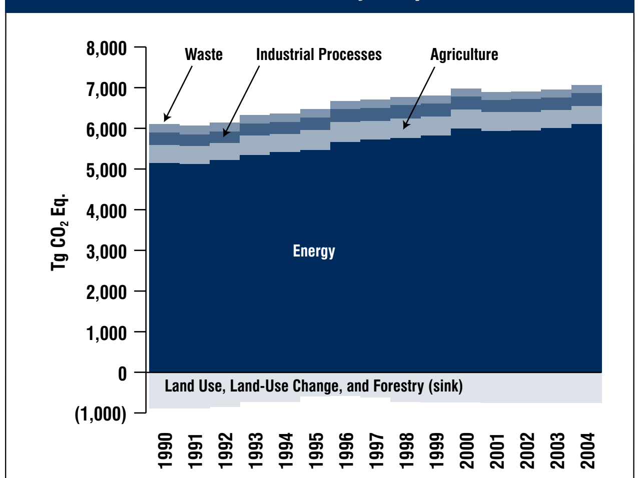
In accordance with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997), and the 2003 *UNFCCC Guidelines on Reporting and Review* (UNFCCC 2003), the Inventory of U.S. Greenhouse Gas Emissions and Sinks report is segregated into six sector-specific chapters. Figure ES-11 and Table ES-4 aggregate emissions and sinks by these chapters.

Energy

The Energy chapter 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 for the period of 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,

Figure ES-11

U.S. Greenhouse Emissions by Chapter/IPCC Sector



Note: Relatively smaller amounts of GWP-weighted emissions are also emitted from the Land-Use Change and Forestry sector and the Solvent and Other Product Use sector.

Table ES-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg CO_2 Eq.)

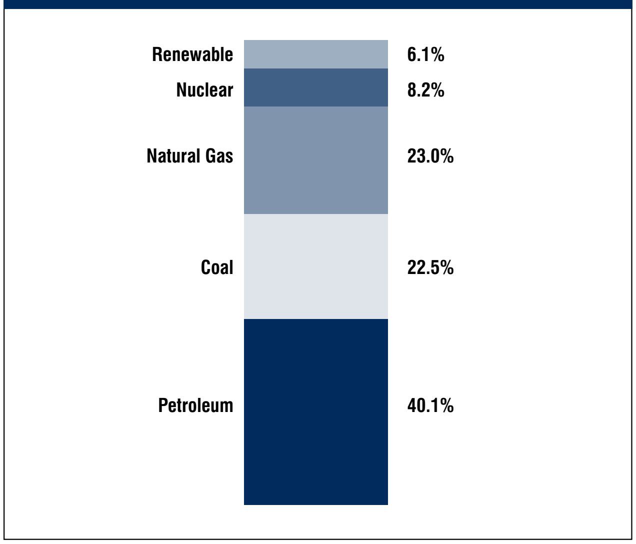
Chapter/IPCC Sector	1990		1998	1999	2000	2001	2002	2003	2004
Energy	5,148.3		5,752.3	5,822.3	5,994.3	5,931.6	5,944.6	6,009.8	6,108.2
Industrial Processes	301.1		335.1	327.5	329.6	300.7	310.9	304.1	320.7
Solvent and Other Product Use	4.3		4.8	4.8	4.8	4.8	4.8	4.8	4.8
Agriculture	439.6		483.2	463.1	458.4	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**

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

Note: Totals may not sum due to independent rounding.

Figure ES-12

2004 U.S. Energy Consumption by Energy Source



biomass, nuclear, wind, and solar energy (see Figure ES-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 chapter account for a combined 86 percent of total U.S. greenhouse gas emissions in 2004.

Industrial Processes

The Industrial Processes chapter 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 chapter account for 4.5 percent of U.S. greenhouse gas emissions in 2004.

Solvent and Other Product Use

The Solvent and Other Product Use chapter contains greenhouse gas emissions that are produced as a by-product of various solvent and other product uses. In the United States, 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 in 2004.

Agriculture

The Agriculture chapter contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy chapter). 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. 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, in 2004. 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 chapter were responsible for 6.2 percent of total U.S. greenhouse gas emissions.

Land Use, Land-Use Change, and Forestry

The Land Use, Land-Use Change, and Forestry chapter 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 conversion of cropland to permanent 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 ES-5). 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 between 1990 and 2004, which contributed to an increase in net U.S. emissions (all sources and sinks) of 21 percent from 1990 to 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 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 between 1990 and 2004.

Waste

The Waste chapter contains emissions from waste management activities (except municipal solid waste incineration, which is addressed in the Energy chapter). Landfills were the largest source of anthropogenic CH_4 emissions, accounting for 25 percent of total U.S. CH_4 emissions.[11] 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

[11] Landfills also store carbon, due to 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 this report.

Table ES-5: Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Sink Category	1990	1998	1999	2000	2001	2002	2003	2004
Forest Land Remaining Forest Land	**(773.4)**	**(618.8)**	**(637.9)**	**(631.0)**	**(634.0)**	**(634.6)**	**(635.8)**	**(637.2)**
Changes in Forest Carbon Stocks	(773.4)	(618.8)	(637.9)	(631.0)	(634.0)	(634.6)	(635.8)	(637.2)
Cropland Remaining Cropland	**(33.1)**	**(24.6)**	**(24.6)**	**(26.1)**	**(27.8)**	**(27.5)**	**(28.7)**	**(28.9)**
Changes in Agricultural Soil Carbon Stocks and Liming Emissions	(33.1)	(24.6)	(24.6)	(26.1)	(27.8)	(27.5)	(28.7)	(28.9)
Land Converted to Cropland	**1.5**	**(2.8)**	**(2.8)**	**(2.8)**	**(2.8)**	**(2.8)**	**(2.8)**	**(2.8)**
Changes in Agricultural Soil Carbon Stocks	1.5	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)
Grassland Remaining Grassland	**(4.5)**	**7.5**	**7.5**	**7.4**	**7.4**	**7.4**	**7.3**	**7.3**
Changes in Agricultural Soil Carbon Stocks	(4.5)	7.5	7.5	7.4	7.4	7.4	7.3	7.3
Land Converted to Grassland	**(17.6)**	**(21.1)**	**(21.1)**	**(21.1)**	**(21.1)**	**(21.1)**	**(21.1)**	**(21.1)**
Changes in Agricultural Soil Carbon Stocks	(17.6)	(21.1)	(21.1)	(21.1)	(21.1)	(21.1)	(21.1)	(21.1)
Settlements Remaining Settlements	**(83.2)**	**(84.2)**	**(86.8)**	**(85.9)**	**(89.7)**	**(89.9)**	**(93.8)**	**(97.3)**
Urban Trees	(58.7)	(73.3)	(77.0)	(77.0)	(80.7)	(80.7)	(84.3)	(88.0)
Landfilled Yard Trimmings and Food Scraps	(24.5)	(10.9)	(9.8)	(8.9)	(9.0)	(9.3)	(9.4)	(9.3)
Total	**(910.4)**	**(744.0)**	**(765.7)**	**(759.5)**	**(768.0)**	**(768.6)**	**(774.8)**	**(780.1)**

Note: Totals may not sum due to independent rounding. Parentheses indicate net sequestration.

component of wastewater were estimated, however, using a simplified methodology. Overall, in 2004, emission sources accounted for in the Waste chapter generated 2.7 percent of total U.S. greenhouse gas emissions.

ES.4. Other Information

Emissions by Economic Sector

Throughout this report, emission estimates are grouped into six sectors (i.e., chapters) defined by the IPCC: Energy; Industrial Processes; Solvent Use; Agriculture; Land Use, 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, industrial, industry, transportation, electricity generation, agriculture, and U.S. territories.

Table ES-6 summarizes emissions from each of these sectors, and Figure ES-13 shows the trend in emissions by sector from 1990 to 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, agricultural 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.

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 ES-7 presents greenhouse gas emissions from economic sectors with emissions related

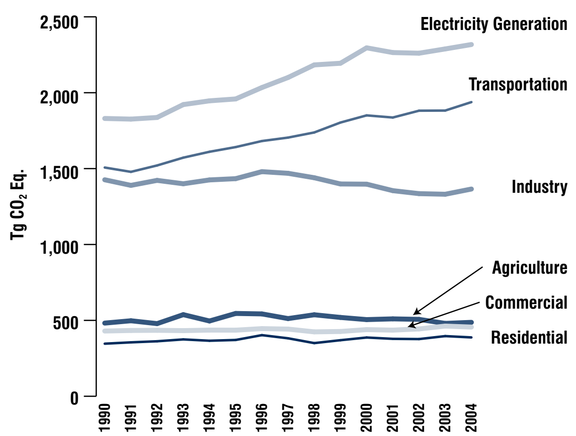
Table ES-6: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq.)

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**
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**

* The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total.
Note: Totals may not sum due to independent rounding. Emissions include CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6.
See Table 2-14 for more detailed data.

Figure ES-13

Emissions Allocated to Economic Sectors



Note: Does not include U.S. territories.

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.[12] 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 (e.g., 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 ES-14 shows the trend in these emissions by sector from 1990 to 2004.

Indirect Greenhouse Gases (CO, NO_x, NMVOCs, and SO_2)

The reporting requirements of the UNFCCC[13] 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

[12] 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.

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

Table ES-7: U.S Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed (Tg CO_2 Eq.)

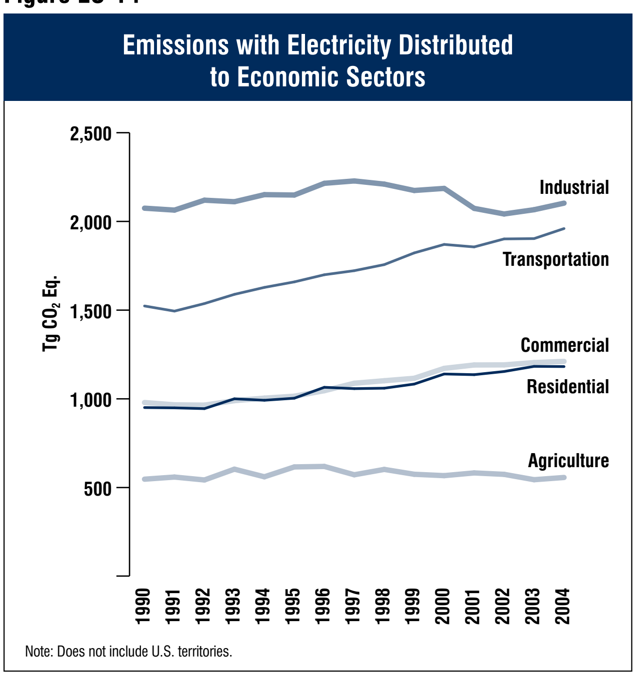
Economic Sector	1990		1998	1999	2000	2001	2002	2003	2004
Industry	2,074.6		2,210.3	2,174.4	2,186.1	2,073.6	2,042.0	2,066.0	2,103.0
Transportation	1,523.4		1,756.5	1,822.5	1,870.3	1,856.2	1,901.4	1,903.2	1,959.8
Commercial	979.2		1,102.0	1,115.8	1,171.8	1,190.8	1,191.4	1,204.3	1,211.0
Residential	950.8		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**
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**

* The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total.
See Table 2-16 of this report for more detailed data.

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 (EPA 2005),[14] which are regulated under the Clean Air Act. Table ES-9 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.

Figure ES-14



Key Categories

The IPCC's *Good Practice Guidance* (IPCC 2000) defines a key category as a "[source or sink category] that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both."[15] By definition, key categories are sources or sinks that have the greatest contribution to the absolute overall level of national emissions in any of the years covered by the time series. In addition, when an entire time series of emission estimates is prepared, a thorough investigation of key categories must also account for the influence of trends of individual source and sink categories. Finally, a qualitative evaluation of key categories should be performed, in order to capture any key categories that were not identified in either of the quantitative analyses.

Figure ES-16 presents 2004 emission estimates for the 2004 key categories as defined by a level analysis (i.e., the contribution of each source or sink category to the total inventory level). The UNFCCC reporting guidelines request that key category analyses be reported at an appropriate level of disaggregation, which may lead to source and sink

[14] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2005).

[15] See Chapter 7 "Methodological Choice and Recalculation" in IPCC (2000). <http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm>

Box ES-2: 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; or (5) emissions per capita.

Table ES-8 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. Greenhouse gas emissions in the United States 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 (see Figure ES-15). Overall, global atmospheric CO_2 concentrations—a function of many complex anthropogenic and natural processes—are increasing at 0.4 percent per year.

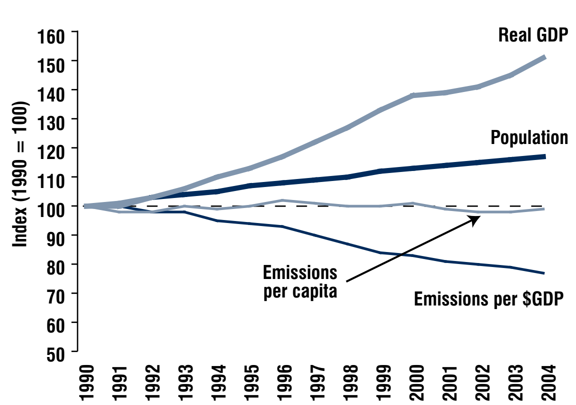
Table ES-8: Recent Trends in Various U.S. Data (Index 1990 = 100) and Global Atmospheric CO_2 Concentration

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

[a] GWP weighted values
[b] Energy content weighted values (EIA 2004)
[c] Gross Domestic Product in chained 2000 dollars (BEA 2005)
[d] U.S. Census Bureau (2005)
[e] Hofmann (2004)
[f] Average annual growth rate

Figure ES-15

U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product



Source: BEA (2005), U.S. Census Bureau (2005), and emission estimates in this report.

Table ES-9: Emissions of NO_x, CO, NMVOCs, and SO_2 (Gg)

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

Source: (EPA 2005) except for estimates from field burning of agricultural residues.
\+ Does not exceed 0.5 Gg
NA (Not Available)
Note: Totals may not sum due to independent rounding.

category names which differ from those used elsewhere in this report. For more information regarding key categories, see section 1.5 and Annex 1 of this report.

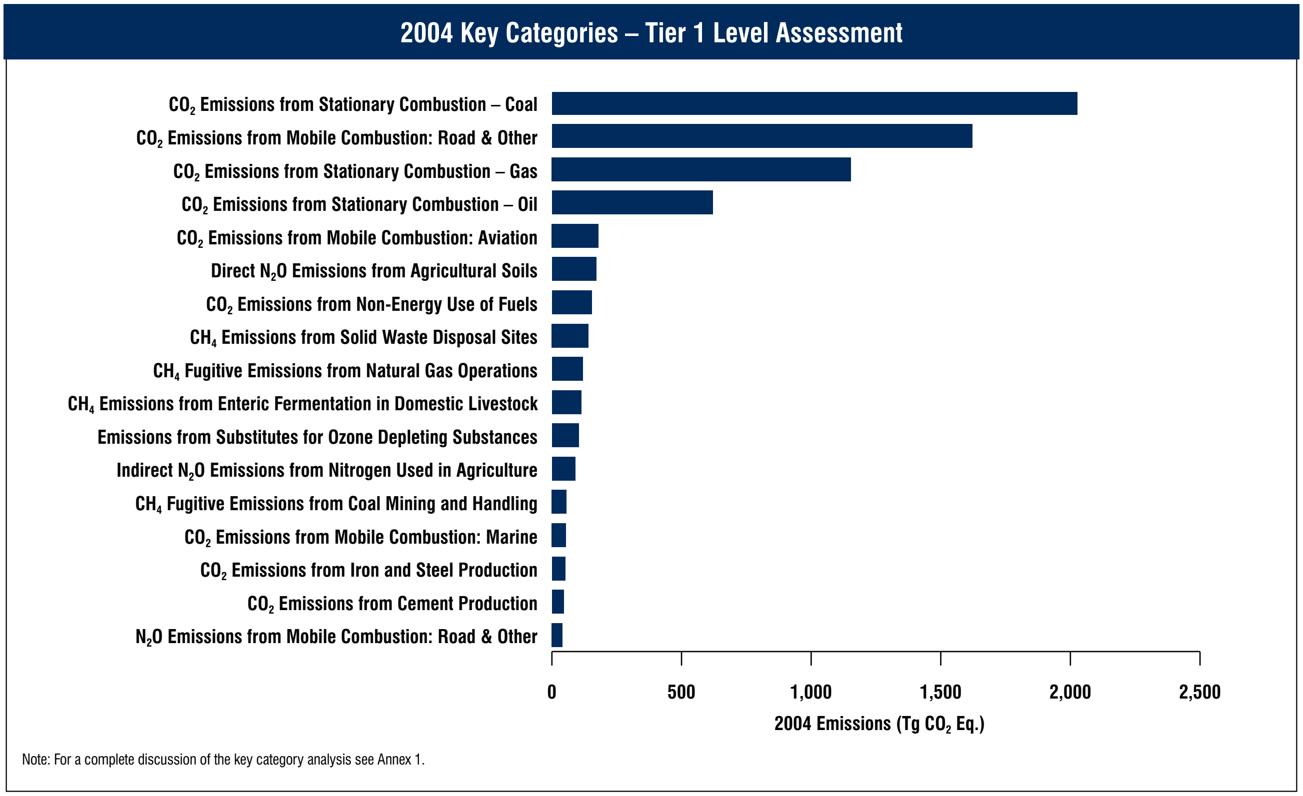
Quality Assurance and Quality Control (QA/QC)

The United States seeks to continually improve the quality, transparency, and credibility of the Inventory of U.S. Greenhouse Gas Emissions and Sinks. To assist in these efforts, the United States implemented a systematic approach to QA/QC. While QA/QC has always been an integral part of the U.S. national system for inventory development, the procedures followed for the current inventory, as described in the Introduction chapter of this report, have been formalized in accordance with the QA/QC plan and the UNFCCC reporting guidelines.

Uncertainty Analysis of Emission Estimates

While the current U.S. emissions inventory provides a solid foundation for the development of a more detailed and comprehensive national inventory, there are uncertainties

Figure ES-16



associated with the emission estimates. Some of the current estimates, such as those for CO_2 emissions from energy-related activities and cement processing, are considered to have low uncertainties. For some other categories of emissions, however, a lack of data or an incomplete understanding of how emissions are generated increases the uncertainty associated with the estimates presented. Acquiring a better understanding of the uncertainty associated with inventory estimates is an important step in helping to prioritize future work and improve the overall quality of the inventory. Recognizing the benefit of conducting an uncertainty analysis, the UNFCCC reporting guidelines follow the recommendations of the IPCC *Good Practice Guidance* (IPCC 2000) and require that countries provide single estimates of uncertainty for source and sink categories.

Currently, a qualitative discussion of uncertainty is presented for all source and sink categories in Annex 7 of this report. Within the discussion of each emission source, specific factors affecting the uncertainty surrounding the estimates are discussed. Most sources also contain a quantitative uncertainty assessment, in accordance with UNFCCC reporting guidelines.