Executive Summary

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. This inventory 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 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 2005. 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). Additionally, the U.S. emission inventory has begun to incorporate new methodologies and data from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). 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 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 2004) 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 to the UNFCCC 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

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

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 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 kilogram (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) (IPCC 1996). This requirement ensures that current estimates of aggregate greenhouse gas emissions for 1990 to 2005 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 the 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 2005, total U.S. greenhouse gas emissions were 7,260.4 Tg CO_2 Eq. Overall, total U.S. emissions have risen by 16.3 percent from 1990 to 2005, while the U.S. gross domestic product has increased by 55 percent over the same period (BEA 2006). Emissions rose from 2004 to 2005, increasing by 0.8 percent (56.7 Tg CO_2 Eq.). The following factors were primary contributors to this increase: (1) strong economic growth in 2005, leading to increased demand for electricity and (2) an increase in the demand for electricity due to warmer summer conditions. These factors were moderated by decreasing demand for fuels due to warmer winter conditions and higher fuel prices.

[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 constitutes 12/44ths of carbon dioxide by weight.

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

Figure ES-1

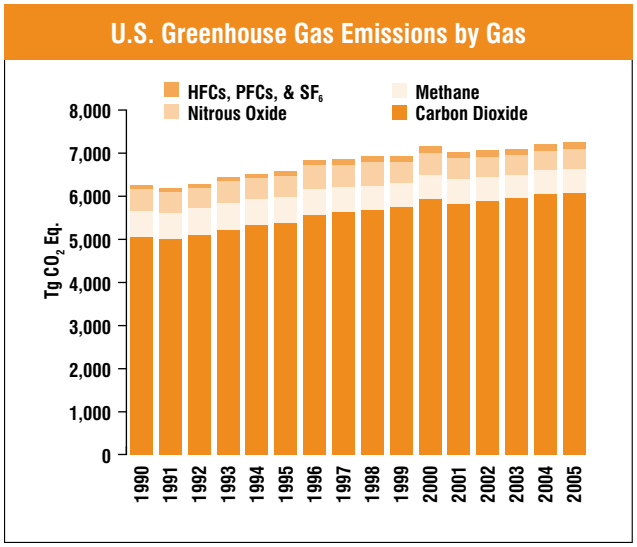
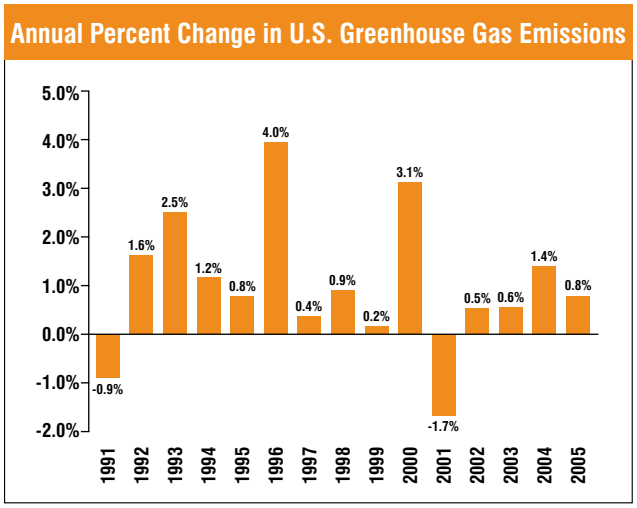


Figure ES-2



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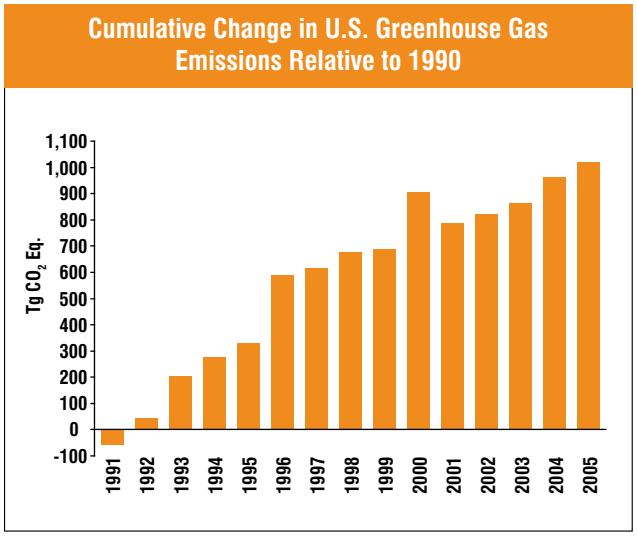


Figure ES-1 through Figure ES-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute change since 1990. Table ES-2 provides a detailed summary of U.S. greenhouse gas emissions and sinks for 1990 through 2005.

Figure ES-4 illustrates the relative contribution of the direct greenhouse gases to total U.S. emissions in 2005. The primary greenhouse gas emitted by human activities in the United States was CO_2, representing approximately 83.9 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 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 2005, total emissions of CO_2 increased by 1,027.9 Tg CO_2 Eq. (20.3 percent), while CH_4 and N_2O emissions decreased by 69.8 Tg CO_2 Eq. (11.5 percent) and 13.4 Tg CO_2 Eq. (2.8 percent), respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 73.7 Tg CO_2 Eq. (82.5

Figure ES-4

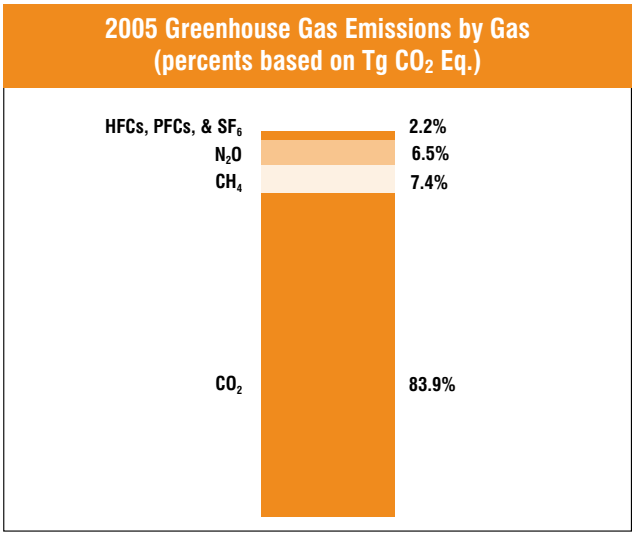


Table ES-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2001	2002	2003	2004	2005
CO_2	**5,061.6**	**5,384.6**	**5,940.0**	**5,843.0**	**5,892.7**	**5,952.5**	**6,064.3**	**6,089.5**
Fossil Fuel Combustion	4,724.1	5,030.0	5,584.9	5,511.7	5,557.2	5,624.5	5,713.0	5,751.2
Non-Energy Use of Fuels	117.3	133.2	141.0	131.4	135.3	131.3	150.2	142.4
Cement Manufacture	33.3	36.8	41.2	41.4	42.9	43.1	45.6	45.9
Iron and Steel Production	84.9	73.3	65.1	57.9	54.6	53.4	51.3	45.2
Natural Gas Systems	33.7	33.8	29.4	28.8	29.6	28.4	28.2	28.2
Municipal Solid Waste Combustion	10.9	15.7	17.9	18.3	18.5	19.5	20.1	20.9
Ammonia Manufacture and Urea Application	19.3	20.5	19.6	16.7	17.8	16.2	16.9	16.3
Lime Manufacture	11.3	12.8	13.3	12.9	12.3	13.0	13.7	13.7
Limestone and Dolomite Use	5.5	7.4	6.0	5.7	5.9	4.7	6.7	7.4
Soda Ash Manufacture and Consumption	4.1	4.3	4.2	4.1	4.1	4.1	4.2	4.2
Aluminum Production	6.8	5.7	6.1	4.4	4.5	4.5	4.2	4.2
Petrochemical Production	2.2	2.8	3.0	2.8	2.9	2.8	2.9	2.9
Titanium Dioxide Production	1.3	1.7	1.9	1.9	2.0	2.0	2.3	1.9
Ferroalloy Production	2.2	2.0	1.9	1.5	1.3	1.3	1.4	1.4
Phosphoric Acid Production	1.5	1.5	1.4	1.3	1.3	1.4	1.4	1.4
Carbon Dioxide Consumption	1.4	1.4	1.4	0.8	1.0	1.3	1.2	1.3
Zinc Production	0.9	1.0	1.1	1.0	0.9	0.5	0.5	0.5
Lead Production	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Production and Consumption	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Land Use, Land-Use Change, and Forestry (Sink)[a]	*(712.8)*	*(828.8)*	*(756.7)*	*(767.5)*	*(811.9)*	*(811.9)*	*(824.8)*	*(828.5)*
International Bunker Fuels[b]	*113.7*	*100.6*	*101.1*	*97.6*	*89.1*	*83.7*	*97.2*	*97.2*
Wood Biomass and Ethanol Consumption[b]	*219.3*	*236.8*	*228.3*	*203.2*	*204.4*	*209.6*	*224.8*	*206.5*
CH_4	**609.1**	**598.7**	**563.7**	**547.7**	**549.7**	**549.2**	**540.3**	**539.3**
Landfills	161.0	157.1	131.9	127.6	130.4	134.9	132.1	132.0
Enteric Fermentation	115.7	120.6	113.5	112.5	112.6	113.0	110.5	112.1
Natural Gas Systems	124.5	128.1	126.6	125.4	125.0	123.7	119.0	111.1
Coal Mining	81.9	66.5	55.9	55.5	52.0	52.1	54.5	52.4
Manure Management	30.9	35.1	38.7	40.1	41.1	40.5	39.7	41.3
Petroleum Systems	34.4	31.1	27.8	27.4	26.8	25.8	25.4	28.5
Wastewater Treatment	24.8	25.1	26.4	25.9	25.8	25.6	25.7	25.4
Forest Land Remaining Forest Land	7.1	4.0	14.0	6.0	10.4	8.1	6.9	11.6
Stationary Combustion	8.0	7.8	7.4	6.8	6.8	7.0	7.1	6.9
Rice Cultivation	7.1	7.6	7.5	7.6	6.8	6.9	7.6	6.9
Abandoned Underground Coal Mines	6.0	8.2	7.3	6.7	6.1	5.9	5.8	5.5
Mobile Combustion	4.7	4.3	3.5	3.2	3.1	2.9	2.8	2.6
Petrochemical Production	0.9	1.1	1.2	1.1	1.1	1.1	1.2	1.1
Iron and Steel Production	1.3	1.3	1.2	1.1	1.0	1.0	1.0	1.0
Field Burning of Agricultural Residues	0.7	0.7	0.8	0.8	0.7	0.8	0.9	0.9
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+	+
Ferroalloy Production	+	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**482.0**	**484.2**	**499.8**	**502.5**	**479.2**	**459.8**	**445.2**	**468.6**
Agricultural Soil Management	366.9	353.4	376.8	389.0	366.1	350.2	338.8	365.1
Mobile Combustion	43.7	53.7	53.2	49.7	47.1	43.8	41.2	38.0
Nitric Acid Production	17.8	19.9	19.6	15.9	17.2	16.7	16.0	15.7
Stationary Combustion	12.3	12.8	14.0	13.5	13.4	13.7	13.9	13.8
Manure Management	8.6	9.0	9.6	9.8	9.7	9.3	9.4	9.5
Wastewater Treatment	6.4	6.9	7.6	7.6	7.7	7.8	7.9	8.0
Adipic Acid Production	15.2	17.2	6.0	4.9	5.9	6.2	5.7	6.0
Settlements Remaining Settlements	5.1	5.5	5.6	5.5	5.6	5.8	6.0	5.8
N_2O Product Usage	4.3	4.5	4.8	4.8	4.3	4.3	4.3	4.3
Forest Land Remaining Forest Land	0.8	0.6	1.7	1.0	1.4	1.2	1.1	1.5
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.4	0.4	0.5	0.5
Municipal Solid Waste Combustion	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
International Bunker Fuels[b]	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*	*0.9*	*0.9*
HFCs, PFCs, and SF_6	**89.3**	**103.5**	**143.8**	**133.8**	**143.0**	**142.7**	**153.9**	**163.0**
Substitution of Ozone Depleting Substances	0.3	32.2	80.9	88.6	96.9	105.5	114.5	123.3
HCFC-22 Production	35.0	27.0	29.8	19.8	19.8	12.3	15.6	16.5
Electrical Transmission and Distribution	27.1	21.8	15.2	15.1	14.3	13.8	13.6	13.2
Semiconductor Manufacture	2.9	5.0	6.3	4.5	4.4	4.3	4.7	4.3
Aluminum Production	18.5	11.8	8.6	3.5	5.2	3.8	2.8	3.0
Magnesium Production and Processing	5.4	5.6	3.0	2.4	2.4	2.9	2.6	2.7
Total	**6,242.0**	**6,571.0**	**7,147.2**	**7,027.0**	**7,064.6**	**7,104.2**	**7,203.7**	**7,260.4**
Net Emissions (Sources and Sinks)	**5,529.2**	**5,742.2**	**6,390.5**	**6,259.5**	**6,252.7**	**6,292.3**	**6,378.9**	**6,431.9**

+ 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 Biomass Combustion are not included in totals.

Note: Totals may not sum due to independent rounding.

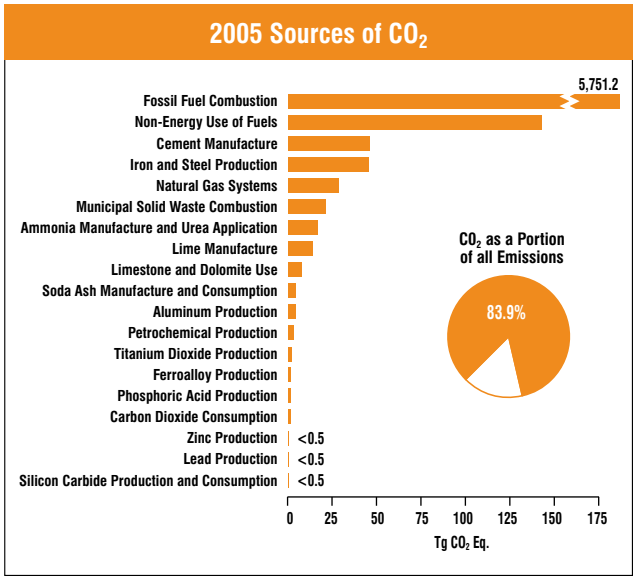
percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF_6 are significant because many of them have extremely high global warming potentials and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. 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 11.4 percent of total emissions in 2005. The following sections describe each gas' 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 2005. Globally, approximately 27,044 Tg of CO_2 were added to the atmosphere through the combustion of fossil fuels in 2004, of which the United States accounted for about 22 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 77 percent of GWP-weighted emissions since 1990, growing slowly from 76 percent of total GWP-weighted emissions in 1990 to 79 percent in 2005. Emissions of CO_2 from fossil fuel combustion increased at an average annual rate of 1.3 percent from 1990 to 2005. The fundamental factors influencing this trend include (1) a generally growing domestic economy over the last 15 years, and (2) significant overall growth in emissions from electricity generation and transportation activities. Between

Figure ES-5



1990 and 2005, CO_2 emissions from fossil fuel combustion increased from 4,724.1 Tg CO_2 Eq. to 5,751.2 Tg CO_2 Eq.—a 21.7 percent total increase over the fifteen-year period. From 2004 to 2005, these emissions increased by 38.2 Tg CO_2 Eq. (0.7 percent).

Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures. On an annual basis, the overall consumption of fossil fuels in the United States generally fluctuates in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

The four major end-use sectors contributing to CO_2 emissions from fossil fuel combustion are industrial, transportation, residential, and commercial. Electricity

[9] Global CO_2 emissions from fossil fuel combustion were taken from Energy Information Administration *International Energy Annual 2004* (EIA 2006a).

generation also emits CO_2, although these emissions are produced as they consume fossil fuel 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.

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 2005.[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.

Figure ES-6

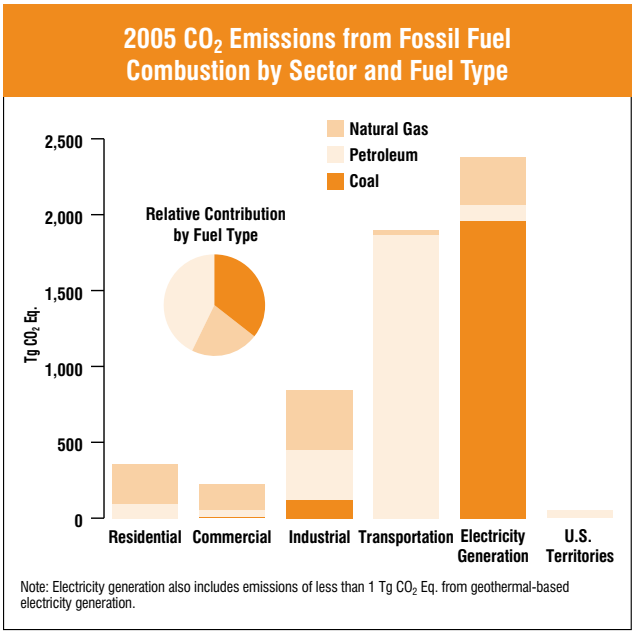
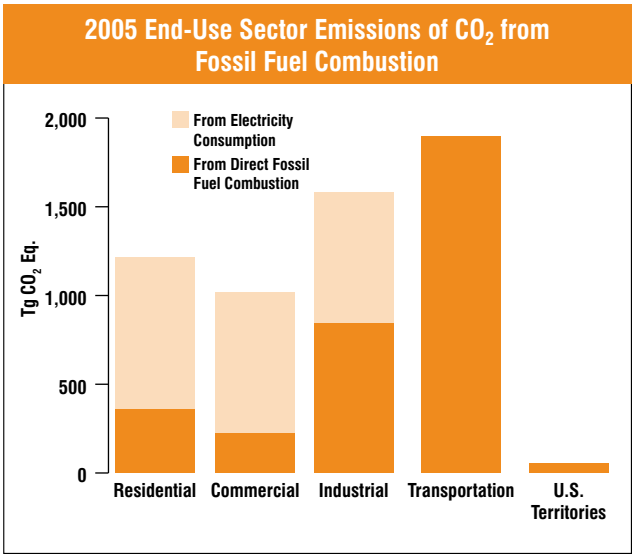


Figure ES-7



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 27 percent of CO_2 from fossil fuel combustion in 2005. 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 18 percent, respectively, of CO_2 emissions from fossil fuel combustion in 2005. Both sectors relied heavily on electricity for meeting energy demands, with 70 and 78 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.

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 36 percent of U.S. energy from fossil fuels and emitted 41 percent of the

[10] If emissions from international bunker fuels are included, the transportation end-use sector accounted for 35 percent of U.S. emissions from fossil fuel combustion in 2005.

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

End-Use Sector	1990	1995	2000	2001	2002	2003	2004	2005
Transportation	**1,467.0**	**1,593.3**	**1,787.8**	**1,761.5**	**1,815.7**	**1,814.8**	**1,868.9**	**1,897.9**
Combustion	1,464.0	1,590.2	1,784.4	1,758.2	1,812.3	1,810.5	1,864.5	1,892.8
Electricity	3.0	3.0	3.4	3.3	3.4	4.3	4.4	5.2
Industrial	**1,539.8**	**1,595.8**	**1,660.1**	**1,596.6**	**1,575.5**	**1,595.1**	**1,615.2**	**1,575.2**
Combustion	857.1	882.7	875.0	869.9	857.7	858.3	875.6	840.1
Electricity	682.7	713.1	785.1	726.7	717.8	736.8	739.6	735.1
Residential	**929.9**	**995.4**	**1,131.5**	**1,124.8**	**1,147.9**	**1,179.1**	**1,175.9**	**1,208.7**
Combustion	340.3	356.4	373.5	363.9	362.4	383.8	369.9	358.7
Electricity	589.6	639.0	758.0	760.9	785.5	795.3	806.0	849.9
Commercial	**759.2**	**810.6**	**969.3**	**979.7**	**973.8**	**984.2**	**999.1**	**1,016.8**
Combustion	224.3	226.4	232.3	225.1	225.7	236.6	233.3	225.8
Electricity	534.9	584.2	736.9	754.6	748.0	747.6	765.8	791.0
U.S. Territories	**28.3**	**35.0**	**36.2**	**49.0**	**44.3**	**51.3**	**54.0**	**52.5**
Total	**4,724.1**	**5,030.0**	**5,584.9**	**5,511.7**	**5,557.2**	**5,624.5**	**5,713.0**	**5,751.2**
Electricity Generation	**1,810.2**	**1,939.3**	**2,283.5**	**2,245.5**	**2,254.7**	**2,284.0**	**2,315.8**	**2,381.2**

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.

CO_2 from fossil fuel combustion in 2005. 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 93 percent of all coal consumed for energy in the United States in 2005. 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 non-energy use of fossil fuels have increased 25.1 Tg CO_2 Eq. (21 percent) from 1990 through 2005. Emissions from non-energy uses of fossil fuels were 142.4 Tg CO_2 Eq. in 2005, which constituted 2.5 percent of overall fossil fuel CO_2 emissions and 2.3 percent of total national CO_2 emissions, approximately the same proportion as in 1990.
- CO_2 emissions from cement production increased to 45.9 Tg CO_2 Eq. in 2005, a 38 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 iron and steel production decreased to 45.2 Tg CO_2 Eq. in 2005, and have declined by 39.6 Tg CO_2 Eq. (47 percent) from 1990 through 2005, due to restructuring of the industry, technological improvements, and increased scrap utilization.
- CO_2 emissions from municipal solid waste combustion (20.9 Tg CO_2 Eq. in 2005) increased by 10.0 Tg CO_2 Eq. (91 percent) from 1990 through 2005, 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 increased by 115.7 Tg CO_2 Eq. (16 percent) from 1990 through 2005. This increase was primarily due to an increase in the rate of net carbon accumulation in forest carbon stocks, particularly in aboveground and belowground tree biomass. Annual carbon accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of carbon accumulation in urban trees increased.

Methane Emissions

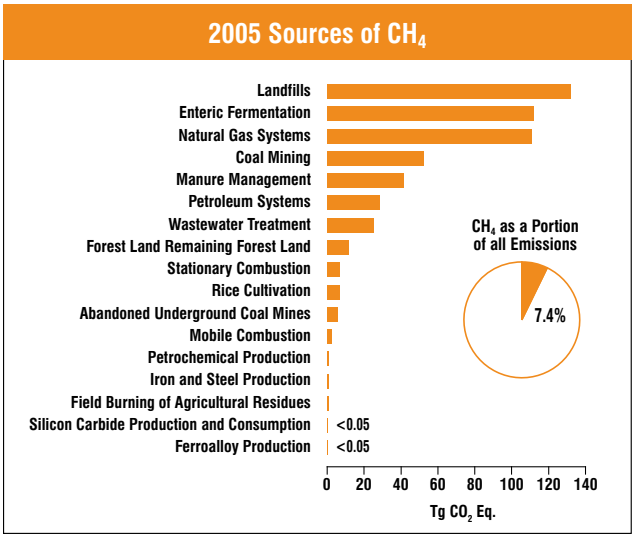
According to the IPCC, CH_4 is more than 20 times as effective as CO_2 at trapping heat in the atmosphere. Over the last two hundred and fifty years, the concentration of CH_4 in the atmosphere increased by 143 percent (IPCC 2001, Hofmann 2004). Anthropogenic sources of CH_4 include landfills, natural gas and petroleum systems, agricultural

activities, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (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 2005, landfill CH_4 emissions were 132.0 Tg CO_2 Eq. (approximately 24 percent of total CH_4 emissions), which represents a decline of 29.0 Tg CO_2 Eq., or 18 percent, since 1990. Although the amount of solid waste landfilled each year continues to grow, the amount of CH_4 captured and burned at landfills has increased dramatically, countering this trend.[11]
- In 2005, CH_4 emissions from coal mining were 52.4 Tg CO_2 Eq. This decline of 29.5 Tg CO_2 Eq. (36 percent) from 1990 results from the mining of less gassy coal from underground mines and the increased use of CH_4 collected from degasification systems.
- CH_4 emissions from natural gas systems were 111.1 Tg CO_2 Eq. in 2005; emissions have declined by 13.3 Tg CO_2 Eq. (11 percent) since 1990. This decline has been due to improvements in technology and management practices, as well as some replacement of old equipment.

Figure ES-8



- CH_4 emissions from manure management were 41.3 Tg CO_2 Eq. in 2005. From 1990 to 2005, emissions from this source increased by 10.4 Tg CO_2 Eq. (34 percent). The bulk of this increase was from swine and dairy cow manure, and is attributed to the shift in the composition of the swine and dairy industries toward larger facilities. Larger swine and dairy farms tend to use liquid management systems, where the decomposition of materials in the manure tends to produce CH_4.

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, wastewater treatment, 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 78 percent (365.1 Tg CO_2 Eq.) of 2005 emissions. N_2O emissions from this source have not shown any significant long-term trend, as they are highly sensitive to the amount of N applied to soils, which has not changed significantly over the time-period.
- In 2005, N_2O emissions from mobile combustion were 38.0 Tg CO_2 Eq. (approximately 8 percent of U.S. N_2O emissions). From 1990 to 2005, N_2O emissions from mobile combustion decreased by 13 percent. However, from 1990 to 1998 emissions increased by 10 percent, due to control technologies that reduced NO_x emissions while increasing N_2O emissions. Since 1998, newer

[11] The CO_2 produced from combusted landfill CH_4 is not counted in national inventories as it is considered part of the natural C cycle of decomposition.

Figure ES-9

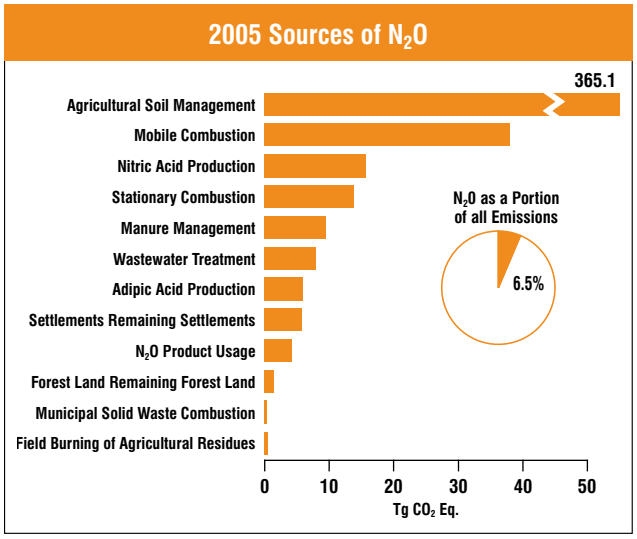
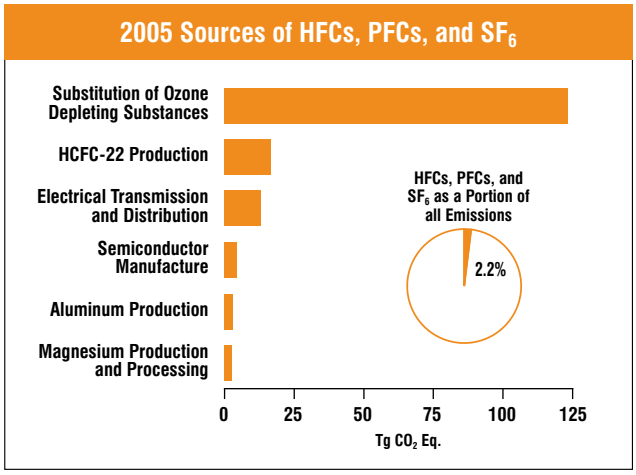


Figure ES-10



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 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.

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 123.3 Tg CO_2 Eq. in 2005. 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 substitute emissions is offset substantially by decreases in emission of HFCs, PFCs, and SF_6 from other sources. Emissions from aluminum production decreased by 84 percent (15.6 Tg CO_2 Eq.) from 1990 to 2005, due to both industry emission reduction efforts and lower domestic aluminum production.
- Emissions from the production of HCFC-22 decreased by 53 percent (18.4 Tg CO_2 Eq.) from 1990 through 2005, 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 51 percent (13.9 Tg CO_2 Eq.) from 1990 to 2005, 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*

Figure ES-11

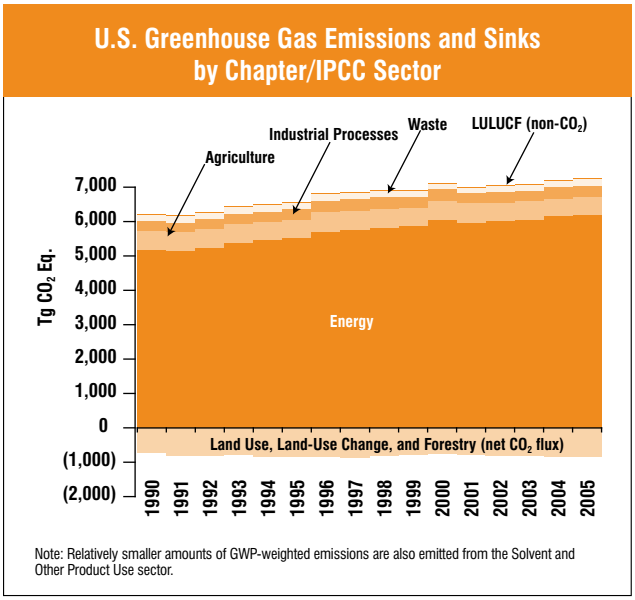
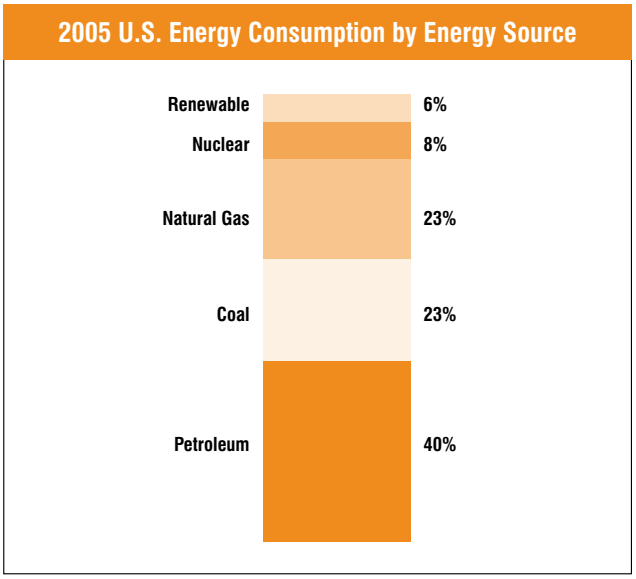


Figure ES-12



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 2005. In 2005, approximately 86 percent of the energy consumed in the United States (on a Btu basis) 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 (see Figure ES-12). Energy related activities are also responsible for CH_4 and N_2O emissions (38 percent and 11 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy chapter account for a combined 85 percent of total U.S. greenhouse gas emissions in 2005.

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

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	1995	2000	2001	2002	2003	2004	2005
Energy	5,202.2	5,525.8	6,069.2	5,978.9	6,021.4	6,079.1	6,181.7	6,201.9
Industrial Processes	300.1	314.8	338.7	309.6	320.2	316.4	330.6	333.6
Solvent and Other Product Use	4.3	4.5	4.8	4.8	4.3	4.3	4.3	4.3
Agriculture	530.3	526.8	547.4	560.3	537.4	521.1	507.4	536.3
Land Use, Land-Use Change, and Forestry (Non-CO_2 Emissions)	13.0	10.1	21.3	12.4	17.4	15.0	13.9	18.9
Waste	192.2	189.1	165.9	161.1	163.9	168.4	165.7	165.4
Total	**6,242.0**	**6,571.0**	**7,147.2**	**7,027.0**	**7,064.6**	**7,104.2**	**7,203.7**	**7,260.4**
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry*	(712.8)	(828.8)	(756.7)	(767.5)	(811.9)	(811.9)	(824.8)	(828.5)
Net Emissions (Sources and Sinks)	**5,529.2**	**5,742.2**	**6,390.5**	**6,259.5**	**6,252.7**	**6,292.3**	**6,378.9**	**6,431.9**

* 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. Parentheses indicate negative values or sequestration.

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 accounted for 4.6 percent of U.S. greenhouse gas emissions in 2005.

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 2005.

Agriculture

The Agriculture chapter contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy chapter, and agricultural CO_2 fluxes, which are addressed in the Land Use, Land-Use Change, and Forestry 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 21 percent and 8 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2005. Agricultural soil management activities such as fertilizer application and other cropping practices were the largest source of U.S. N_2O emissions in 2005, accounting for 78 percent. In 2005, emission sources accounted for in the Agriculture chapter were responsible for 7.4 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 of CH_4 and N_2O, and 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 C in the United States. Forests (including vegetation, soils, and harvested wood) accounted for approximately 84 percent of total 2005 sequestration, urban trees accounted for 11 percent, agricultural soils (including mineral and organic soils and the application of lime) accounted for 2 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total sequestration in 2005. 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 C sink that is almost two times larger than the sum of emissions from organic soils and liming. The mineral soil C sequestration is largely due to the 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 2005 resulted in a net C sequestration of 828.5 Tg CO_2 Eq. (Table ES-5). This represents an offset of approximately 13.6 percent of total U.S. CO_2 emissions, or 11.4 percent of total greenhouse gas emissions in 2005. Total land use, land-use change, and forestry net C sequestration increased by approximately 16 percent between 1990 and 2005, primarily due to an increase in the rate of net C accumulation in forest C stocks, particularly in aboveground and belowground tree biomass. Annual C accumulation in landfilled yard trimmings and food scraps slowed over this

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

Category	1990	1995	2000	2001	2002	2003	2004	2005
Forest Land Remaining Forest Land	**(598.5)**	**(717.5)**	**(638.7)**	**(645.7)**	**(688.1)**	**(687.0)**	**(697.3)**	**(698.7)**
Changes in Forest Carbon Stocks	(598.5)	(717.5)	(638.7)	(645.7)	(688.1)	(687.0)	(697.3)	(698.7)
Cropland Remaining Cropland	**(28.1)**	**(37.4)**	**(36.5)**	**(38.0)**	**(37.8)**	**(38.3)**	**(39.4)**	**(39.4)**
Changes in Agricultural Soil Carbon Stocks and Liming Emissions	(28.1)	(37.4)	(36.5)	(38.0)	(37.8)	(38.3)	(39.4)	(39.4)
Land Converted to Cropland	**8.7**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**
Changes in Agricultural Soil Carbon Stocks	8.7	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Grassland Remaining Grassland	**0.1**	**16.4**	**16.3**	**16.2**	**16.2**	**16.2**	**16.1**	**16.1**
Changes in Agricultural Soil Carbon Stocks	0.1	16.4	16.3	16.2	16.2	16.2	16.1	16.1
Land Converted to Grassland	**(14.6)**	**(16.3)**	**(16.3)**	**(16.3)**	**(16.3)**	**(16.3)**	**(16.3)**	**(16.3)**
Changes in Agricultural Soil Carbon Stocks	(14.6)	(16.3)	(16.3)	(16.3)	(16.3)	(16.3)	(16.3)	(16.3)
Settlements Remaining Settlements	**(57.5)**	**(67.8)**	**(78.2)**	**(80.2)**	**(82.3)**	**(84.4)**	**(86.4)**	**(88.5)**
Urban Trees	(57.5)	(67.8)	(78.2)	(80.2)	(82.3)	(84.4)	(86.4)	(88.5)
Other	**(22.8)**	**(13.3)**	**(10.5)**	**(10.6)**	**(10.8)**	**(9.3)**	**(8.7)**	**(8.8)**
Landfilled Yard Trimmings and Food Scraps	(22.8)	(13.3)	(10.5)	(10.6)	(10.8)	(9.3)	(8.7)	(8.8)
Total	**(712.8)**	**(828.8)**	**(756.7)**	**(767.5)**	**(811.9)**	**(811.9)**	**(824.8)**	**(828.5)**

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

Table ES-6: Non-CO_2 Emissions from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Category	1990	1995	2000	2001	2002	2003	2004	2005
Forest Land Remaining Forest Land	**7.8**	**4.5**	**15.7**	**6.9**	**11.8**	**9.2**	**8.0**	**13.1**
CH_4 Emissions from Forest Fires	7.1	4.0	14.0	6.0	10.4	8.1	6.9	11.6
N_2O Emissions from Forest Fires	0.7	0.4	1.4	0.6	1.1	0.8	0.7	1.2
N_2O Emissions from Soils	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Settlements Remaining Settlements	**5.1**	**5.5**	**5.6**	**5.5**	**5.6**	**5.8**	**6.0**	**5.8**
N_2O Emissions from Soils	5.1	5.5	5.6	5.5	5.6	5.8	6.0	5.8
Total	**13.0**	**10.1**	**21.3**	**12.4**	**17.4**	**15.0**	**13.9**	**18.9**

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

period, while the rate of annual C accumulation increased in urban trees. Net U.S. emissions (all sources and sinks) increased by 16.4 percent from 1990 to 2005.

Non-CO_2 emissions from Land Use, Land-Use Change, and Forestry are shown in Table ES-6. The application of synthetic fertilizers to forest and settlement soils in 2005 resulted in direct N_2O emissions of 6.2 Tg CO_2 Eq. Direct N_2O emissions from fertilizer application increased by approximately 19 percent between 1990 and 2005. Non-CO_2 emissions from forest fires in 2005 resulted in CH_4 emissions of 11.6 Tg CO_2 Eq., and in N_2O emissions of 1.2 Tg CO_2 Eq.

Waste

The Waste chapter contains emissions from waste management activities (except waste incineration, which is addressed in the Energy chapter). Landfills were the largest source of anthropogenic CH_4 emissions, accounting for 24 percent of total U.S. CH_4 emissions.[12] Additionally, wastewater treatment accounts for just under 5 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. Overall, in 2005, emission sources accounted for in the Waste chapter generated 2.3 percent of total U.S. greenhouse gas emissions.

[12] 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.

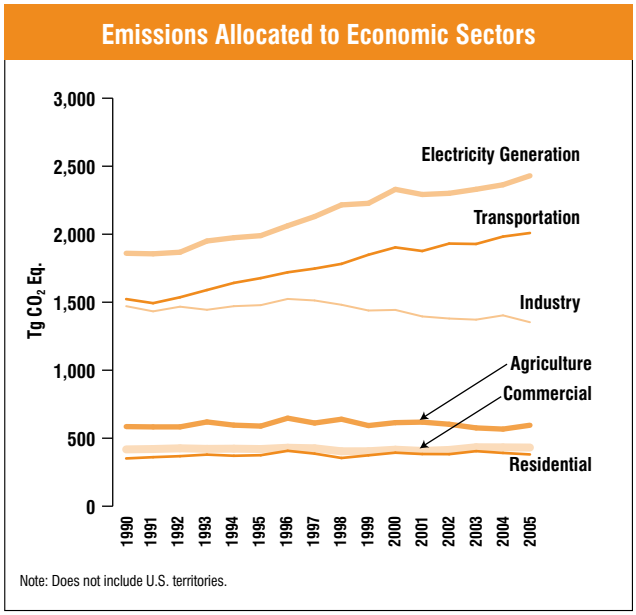
ES.4. Other Information

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, Industry, Transportation, Electricity Generation, and Agriculture, and U.S. Territories.

Table ES-7 summarizes emissions from each of these sectors, and Figure ES-13 shows the trend in emissions by sector from 1990 to 2005.

Figure ES-13



Using this categorization, emissions from electricity generation accounted for the largest portion (33 percent) of U.S. greenhouse gas emissions in 2005. 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 2005. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade. 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 energy 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 5 percent, and primarily consisted of CO_2 emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 8 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 6 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

Table ES-7: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq.)

Implied Sectors	1990	1995	2000	2001	2002	2003	2004	2005
Electric Power Industry	1,859.7	1,989.5	2,329.9	2,292.0	2,300.7	2,330.2	2,363.4	2,429.8
Transportation	1,523.0	1,677.2	1,903.2	1,876.4	1,931.2	1,928.2	1,982.6	2,008.9
Industry	1,470.9	1,478.4	1,443.3	1,395.4	1,380.0	1,371.8	1,403.3	1,352.8
Agriculture	585.3	589.2	614.4	618.4	602.6	575.7	567.0	595.4
Commercial	417.8	420.5	415.5	406.6	413.7	433.5	432.6	431.4
Residential	351.3	375.1	393.6	383.6	382.7	404.8	391.6	380.7
U.S. Territories	34.1	41.1	47.3	54.5	53.6	60.0	63.2	61.5
Total Emissions	**6,242.0**	**6,571.0**	**7,147.2**	**7,027.0**	**7,064.6**	**7,104.2**	**7,203.7**	**7,260.4**
Land Use, Land-Use Change, and Forestry (Sinks)	(712.8)	(828.8)	(756.7)	(767.5)	(811.9)	(811.9)	(824.8)	(828.5)
Net Emissions (Sources and Sinks)	**5,529.2**	**5,742.2**	**6,390.5**	**6,259.5**	**6,252.7**	**6,292.3**	**6,378.9**	**6,431.9**

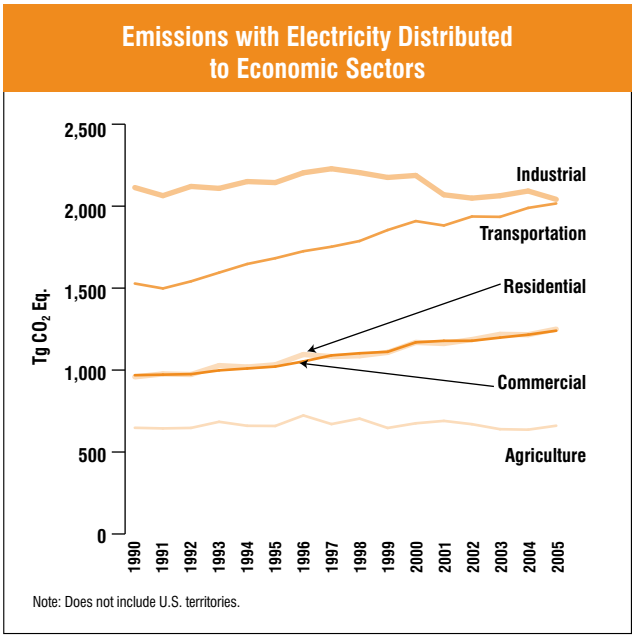
Note: Totals may not sum due to independent rounding. Emissions include CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6.
See Table 2-14 for more detailed data.

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-8 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.[13] 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 (28 percent) in 2005. 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 2005.

Figure ES-14



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

The reporting requirements of the UNFCCC[14] 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

Table ES-8: U.S Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed (Tg CO_2 Eq.)

Implied Sectors	1990	1995	2000	2001	2002	2003	2004	2005
Industry	2,111.1	2,141.5	2,185.0	2,067.1	2,046.6	2,061.4	2,090.1	2,039.3
Transportation	1,526.1	1,680.3	1,906.7	1,879.8	1,934.7	1,932.5	1,987.1	2,014.2
Commercial	967.2	1,019.8	1,167.4	1,176.8	1,177.0	1,196.2	1,214.1	1,238.5
Residential	956.9	1,030.6	1,167.0	1,160.3	1,184.3	1,216.2	1,214.2	1,248.0
Agriculture	646.5	657.6	673.9	688.5	668.4	637.9	635.0	659.1
U.S. Territories	34.1	41.1	47.3	54.5	53.6	60.0	63.2	61.5
Total Emissions	**6,242.0**	**6,571.0**	**7,147.2**	**7,027.0**	**7,064.6**	**7,104.2**	**7,203.7**	**7,260.4**
Land Use, Land-Use Change, and Forestry (Sinks)	(712.8)	(828.8)	(756.7)	(767.5)	(811.9)	(811.9)	(824.8)	(828.5)
Net Emissions (Sources and Sinks)	**5,529.2**	**5,742.2**	**6,390.5**	**6,259.5**	**6,252.7**	**6,292.3**	**6,378.9**	**6,431.9**

See Table 2-16 of this report for more detailed data.

[13] 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.

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

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 2005; (4) emissions per unit of total gross domestic product as a measure of national economic activity; or (5) emissions per capita.

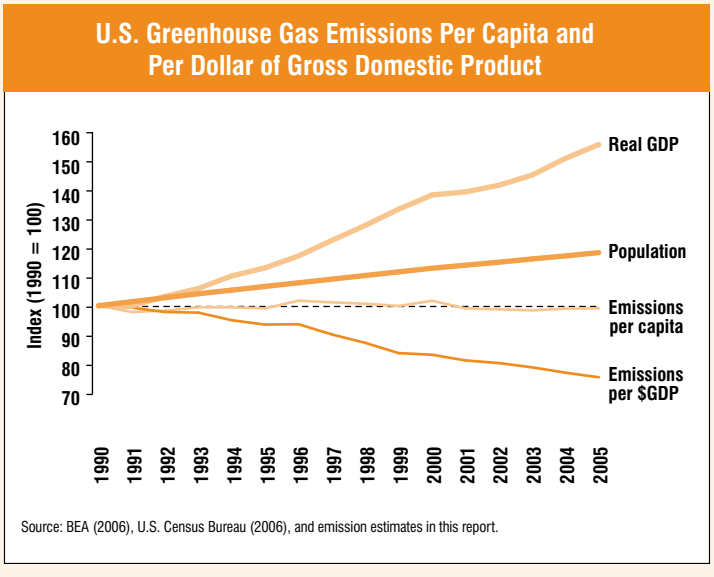
Table ES-9 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. Greenhouse gas emissions in the United States have grown at an average annual rate of 1.0 percent since 1990. This rate is slightly slower than that for total energy or fossil 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 slightly slower than national population since 1990 (see Figure ES-15).

Table ES-9: Recent Trends in Various U.S. Data (Index 1990 = 100)

Variable	1990	1995	2000	2001	2002	2003	2004	2005	Growth Rate[a]
GDP[b]	100	113	138	139	141	145	150	155	3.0%
Electricity Consumption[c]	100	112	127	125	128	129	131	134	2.0%
Fossil Fuel Consumption[c]	100	107	117	115	116	118	119	119	1.2%
Energy Consumption[c]	100	108	117	114	116	117	119	118	1.1%
Population[d]	100	107	113	114	115	116	117	118	1.1%
Greenhouse Gas Emissions[e]	100	105	115	113	113	114	115	116	1.0%

[a] Average annual growth rate
[b] Gross Domestic Product in chained 2000 dollars (BEA 2006)
[c] Energy-content-weighted values (EIA 2006b)
[d] U.S. Census Bureau (2006)
[e] GWP-weighted values

Figure ES-15



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 (EPA 2006),[15] which are regulated under the Clean Air Act. Table ES-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.

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."[16] By

Table ES-10: Emissions of NO_x, CO, NMVOCs, and SO_2 (Gg)

Gas/Activity	1990	1995	2000	2001	2002	2003	2004	2005
NO_x	**21,645**	**21,272**	**19,203**	**18,410**	**18,141**	**17,327**	**16,466**	**15,965**
Mobile Fossil Fuel Combustion	10,920	10,622	10,310	9,819	10,319	9,911	9,520	9,145
Stationary Fossil Fuel Combustion	9,883	9,821	8,002	7,667	6,837	6,428	5,952	5,824
Industrial Processes	591	607	626	656	532	533	534	535
Oil and Gas Activities	139	100	111	113	316	317	317	318
Municipal Solid Waste Combustion	82	88	114	114	97	98	98	98
Agricultural Burning	28	29	35	35	33	34	39	39
Solvent Use	1	3	3	3	5	5	5	5
Waste	0	1	2	2	2	2	2	2
CO	**130,581**	**109,157**	**92,897**	**89,333**	**86,796**	**84,370**	**82,073**	**79,811**
Mobile Fossil Fuel Combustion	119,480	97,755	83,680	79,972	77,382	74,756	72,269	69,915
Stationary Fossil Fuel Combustion	5,000	5,383	4,340	4,377	5,224	5,292	5,361	5,431
Municipal Solid Waste Combustion	978	1,073	1,670	1,672	1,440	1,457	1,475	1,493
Industrial Processes	4,125	3,959	2,217	2,339	1,710	1,730	1,751	1,772
Agricultural Burning	691	663	792	774	709	800	879	858
Oil and Gas Activities	302	316	146	147	323	327	331	335
Waste	1	2	8	8	7	7	7	7
Solvent Use	5	5	46	45	1	1	1	1
NMVOCs	**20,930**	**19,520**	**15,228**	**15,048**	**14,968**	**14,672**	**14,391**	**14,123**
Mobile Fossil Fuel Combustion	10,932	8,745	7,230	6,872	6,608	6,302	6,011	5,734
Solvent Use	5,216	5,609	4,384	4,547	3,911	3,916	3,921	3,926
Industrial Processes	2,422	2,642	1,773	1,769	1,811	1,813	1,815	1,818
Stationary Fossil Fuel Combustion	912	973	1,077	1,080	1,733	1,734	1,735	1,736
Oil and Gas Activities	554	582	389	400	546	547	547	548
Municipal Solid Waste Combustion	222	237	257	258	244	244	244	245
Waste	673	731	119	122	116	116	116	116
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA	NA
SO_2	**20,935**	**16,891**	**14,829**	**14,452**	**13,541**	**13,648**	**13,328**	**13,271**
Stationary Fossil Fuel Combustion	18,407	14,724	12,848	12,461	11,852	12,002	11,721	11,698
Industrial Processes	1,307	1,117	1,031	1,047	752	759	766	774
Mobile Fossil Fuel Combustion	793	672	632	624	681	628	579	535
Oil and Gas Activities	390	335	286	289	233	235	238	240
Municipal Solid Waste Combustion	38	42	29	30	23	23	23	23
Waste	0	1	1	1	1	1	1	1
Solvent Use	0	1	1	1	0	0	0	0
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA	NA

Source: (EPA 2006, disaggregated based on EPA 2003) except for estimates from field burning of agricultural residues.
NA (Not Available)
Note: Totals may not sum due to independent rounding.

[15] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2006).

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

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 2005 emission estimates for the 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 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.

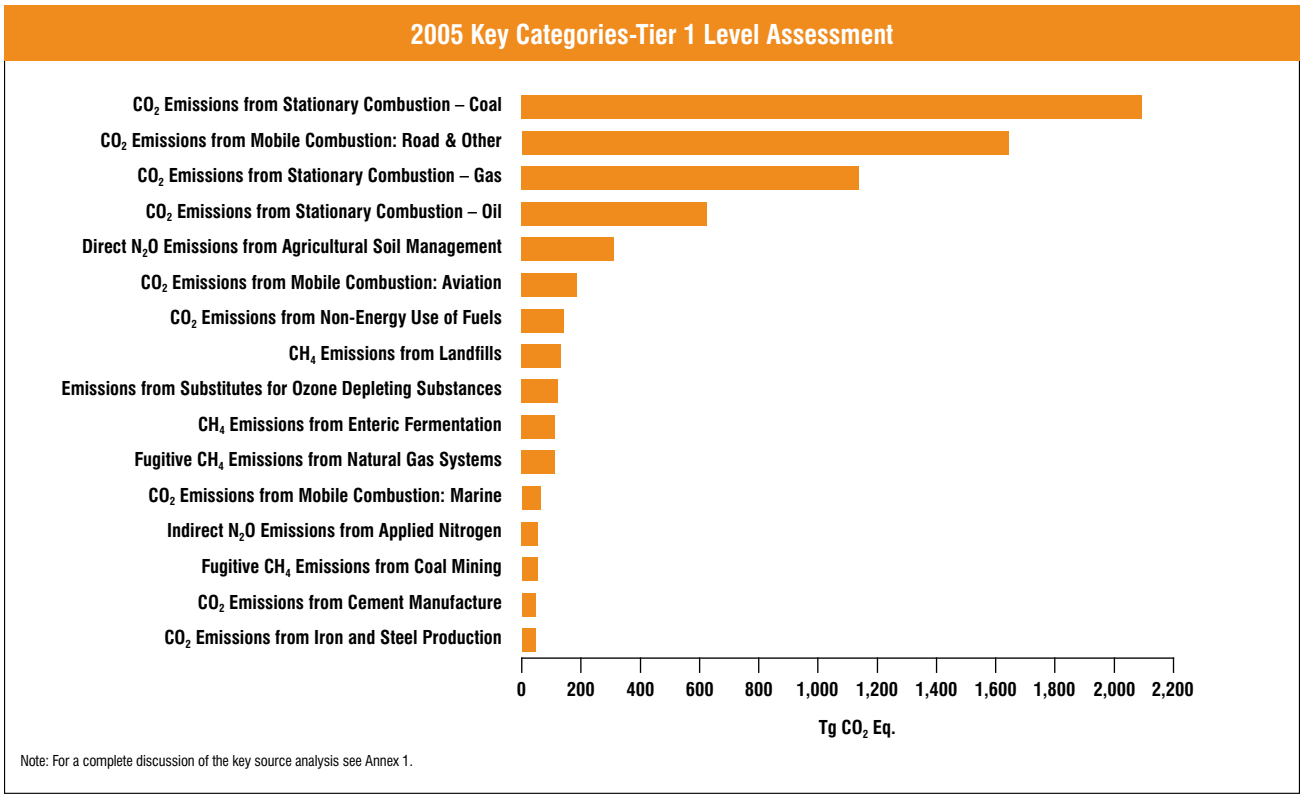
Quality Assurance and Quality Control (QA/QC)

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 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 associated with the emission estimates. Some of the current estimates, such as those for CO_2 emissions from energy-

Figure ES-16



Note: For a complete discussion of the key source analysis see Annex 1.

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. 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.