

3

Greenhouse Gas Inventory

An emissions inventory that identifies and quantifies a country's primary anthropogenic¹ sources and sinks of greenhouse gases (GHGs) is essential for addressing climate change. *The Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007* (U.S. EPA/OAP 2009) adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic GHGs, 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 GHGs 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 GHG 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 GHGs not controlled by the *Montreal Protocol*, using comparable

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 United Nations Framework Convention on Climate Change, published by the United Nations Environment Programme/World Meteorological Organization Information Unit on Climate Change. See http://unfccc.int/essential_background/convention/background/items/1353.php.



methodologies...³ The United States views the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007* (U.S. EPA/OAP 2009) as an opportunity to fulfill these commitments.

This chapter summarizes the latest information on U.S. anthropogenic GHG emission trends from 1990 through 2007. 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. emissions inventory has begun to incorporate new methodologies and data from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). The structure of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007* (U.S. EPA/OAP 2009) is consistent with the UNFCCC guidelines for inventory reporting (UNFCCC 2003).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 (Box 3-1).

BACKGROUND INFORMATION

Naturally occurring GHGs include water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also GHGs, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons). As stratospheric ozone-depleting substances (ODS), CFCs, HCFCs, and halons are covered 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 GHG emission inventories.⁵ Some other fluorine-containing halogenated substances—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆)—do not deplete stratospheric ozone but are potent GHGs (Box 3-2). These latter substances are addressed by the UNFCCC and accounted for in national GHG 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 GHGs, including

Box 3-1 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 and Uncertainty Management in National Greenhouse Gas Inventories* (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. GHG 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 appear within each source’s description 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 2007) has been recalculated to reflect the change, per *IPCC Good Practice Guidance*. Changes in historical data are generally the result of changes in statistical data supplied by other agencies. References for the data are provided for additional information. More information on the most recent changes is provided in the “Recalculations and Improvements” chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007* (U.S. EPA/OAP 2009), and previous *Inventory* reports can further describe the changes in calculation methods and data since the 2006 *U.S. Climate Action Report*.

tropospheric and stratospheric ozone. These gases include carbon monoxide (CO), oxides of nitrogen (NO_x), and non-methane volatile organic compounds (NMVOCs). Aerosols, which are extremely small particles or liquid droplets, such as those produced by sulfur dioxide (SO₂) or elemental carbon emissions, can also affect the ability of the atmosphere to absorb radiation.

Although the direct GHGs CO₂, CH₄, and N₂O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2005, concentrations of these GHGs have increased globally by 36, 148, and 18 percent, respectively (IPCC 2007).

Beginning in the 1950s, the use of CFCs and other stratospheric ODS increased by nearly 10 percent per year until the mid-1980s, when international concern about stratospheric 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 2007).

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

In 2007, total U.S. GHG emissions were 7,150.1 teragrams of CO₂ equivalents (Tg CO₂ Eq.). Overall, total U.S. emissions rose by 17 percent from 1990 to 2007. Emissions rose from 2006 to 2007, increasing by 1.4 percent (99.0 Tg CO₂ Eq.). The following factors were primary contributors to this increase:

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 on the role of Annex I Parties in preparing national inventories. See http://unfccc.int/essential_background/convention/background/items/1362.php.

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

⁵ Emission estimates of CFCs, HCFCs, halons, and other ODS are included in the annexes of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007* for informational purposes (U.S. EPA/OAP 2009).

Box 3-2 Emissions Reporting Nomenclature

The global warming potential (GWP)-weighted emissions of all direct GHGs throughout this report are presented in terms of equivalent emissions of carbon dioxide (CO₂), using units of teragrams of CO₂ equivalents (Tg CO₂ Eq.). The GWP of a GHG 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). The relationship between gigagrams (Gg) of a gas and Tg CO₂ Eq. can be expressed as follows:

$$\text{Tg CO}_2 \text{ Eq.} = (\text{Gg of gas}) \times (\text{GWP}) \times \left(\frac{\text{Tg}}{1,000 \text{ Gg}} \right)$$

The UNFCCC reporting guidelines for national inventories were updated in 2006 (UNFCCC 2006), but continue to require the use of GWPs from the IPCC Second Assessment Report (SAR) (IPCC 1996). The GWP values used in this report are listed below in Table 3-1, and are explained in more detail in Chapter 1 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007* (U.S. EPA/OAP 2009).

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

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

Gas	GWP	Gas	GWP
CO ₂	1	HFC-227ea	2,900
CH ₄ *	21	HFC-236fa	6,300
N ₂ O	310	HFC-4310mee	1,300
HFC-23	11,700	CF ₄	6,500
HFC-32	650	C ₂ F ₆	9,200
HFC-125	2,800	C ₄ F ₁₀	7,000
HFC-134a	1,300	C ₆ F ₁₄	7,400
HFC-143a	3,800	SF ₆	23,900
HFC-152a	140		

* The methane GWP includes both the direct effects and those indirect effects of the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO₂ is not included.

GWP = global warming potential; CO₂ = carbon dioxide; CH₄ = methane; N₂O = nitrous oxide; HFC = hydrofluorocarbon; CF₄ = tetrafluoromethane; C₂F₆ = hexafluoroethane; C₄F₁₀ = perfluorobutane; C₆F₁₄ = perfluorohexane or tetradecafluorohexane; SF₆ = sulfur hexafluoride.

Source: IPCC 1996.

(1) cooler winter and warmer summer conditions in 2007 than in 2006, which increased the demand for heating fuels and contributed to the increase in the demand for electricity; (2) increased consumption of fossil fuels to generate electricity; and (3) a significant decrease (14.2 percent) in hydropower generation used to meet this demand.

Figures 3-1 through 3-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute change since 1990. Table 3-2 provides a detailed summary of U.S. GHG emissions and sinks for 1990 through 2007.

Figure 3-4 illustrates the relative contribution of the direct GHGs to total U.S. emissions in 2007. The primary GHG emitted by human activities in the United States was CO₂, representing approximately 85.4 percent of total GHG emissions. The largest source of CO₂, and of overall U.S. anthropogenic GHG emissions, was fossil fuel combustion. CH₄ emissions,

which have declined from 1990 levels, resulted primarily from enteric fermentation associated with domestic livestock, decomposition of wastes in landfills, and natural gas systems. Agricultural soil management and mobile source fuel combustion were the major sources of N₂O emissions. The emissions of substitutes for ODS 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 SF₆ emissions, while PFC emissions resulted as a by-product of primary aluminum production and from semiconductor manufacturing.

Overall, from 1990 to 2007, total emissions of CO₂ increased by 1,026.7 Tg CO₂ Eq. (20.2 percent), while CH₄ and N₂O emissions decreased by 31.2 Tg CO₂ Eq. (5.1 percent) and 3.1 Tg CO₂ Eq. (1.0 percent), respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and SF₆ rose by 59.0 Tg CO₂ Eq. (65.2 percent). From 1990 to 2007, HFCs increased by 88.6 Tg CO₂ Eq. (240.0 percent), PFCs decreased by 13.3 Tg CO₂ Eq. (64.0 percent), and SF₆ decreased by 16.3 Tg CO₂ Eq. (49.8 percent). Despite being emitted in smaller quantities relative to the other principal GHGs, emissions of HFCs, PFCs, and SF₆ are significant because many of them have extremely high GWPs. Conversely, U.S. GHG emissions were partly offset by carbon sequestration in forests, trees in urban areas, agricultural soils, and land-filled yard trimmings and food scraps, which, in aggregate, offset 14.9 percent of total emissions in 2007. The following sections describe each gas's contribution to total U.S. GHG emissions in more detail. Further information on source and sink categories, methods used to calculate emissions and fluxes, and trends across the entire time series may be found in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007* (U.S. EPA/OAP 2009).

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 CO₂ 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, global atmospheric concentrations of CO₂ have risen about 36 percent (IPCC 2007), principally due to the combustion of fossil fuels. Within the United States, fuel combustion accounted for 94 percent of CO₂ emissions in 2007. Globally, approximately 29,195 Tg of CO₂ were added to the atmosphere through the combustion of fossil fuels in 2006, of which the United States accounted for about 20 percent.⁶ Changes in land use and forestry practices can also emit CO₂ (e.g., through conversion of forest

⁶ Global CO₂ emissions from fossil fuel combustion were taken from the U.S. Department of Energy, Energy Information Administration *International Energy Annual 2006* (U.S. DOE/EIA 2008b).

Figure 3-1 Growth in U.S. Greenhouse Gas Emissions by Gas: 1990–2007

In 2007, total U.S. greenhouse gas emissions rose to 7,150.1 Tg CO₂ Eq., which was 17 percent above 1990 emissions, and 0.6 percent above 2005 emissions.

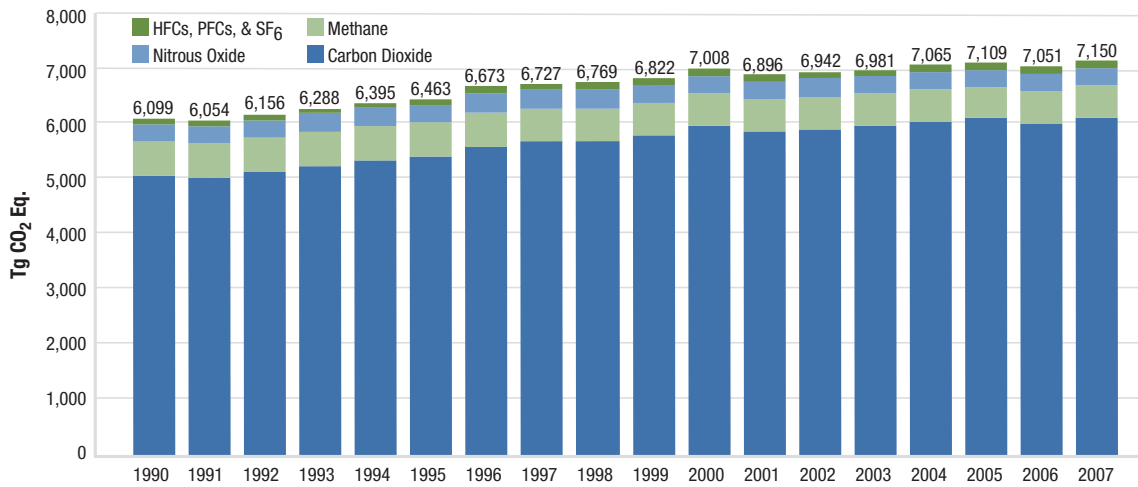


Figure 3-2 Annual Percentage Change in U.S. Greenhouse Gas Emissions: 1990–2007

Between 2005 and 2007, U.S. greenhouse gas emissions rose by 0.6 percent. The average annual rate of increase from 1990 through 2007 was 0.9 percent.

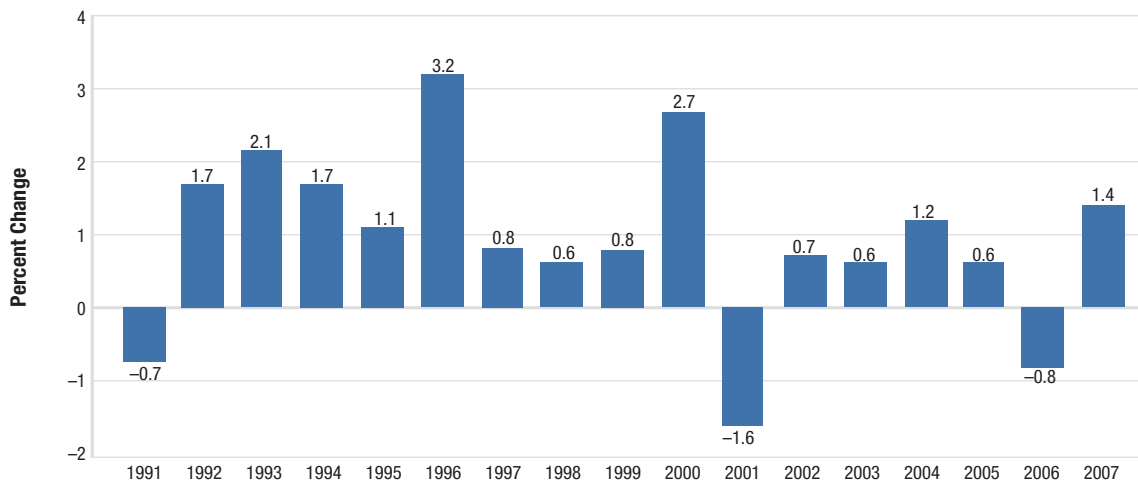


Figure 3-4 2007 U.S. Greenhouse Gas Emissions by Gas (presented on a CO₂ Eq. basis)

In 2007, CO₂ was the principal greenhouse gas emitted by human activities in the United States, driven primarily by emissions from fossil fuel combustion.

Figure 3-3 Cumulative Change in U.S. Greenhouse Gas Emissions: 1990–2007

From 1990 to 2007, total U.S. greenhouse gas emissions rose by 1,051 Tg CO₂ Eq., an increase of 17 percent. More recently, between 2005 and 2007, U.S. greenhouse gas emissions rose by 41 Tg CO₂ Eq., or 0.6 percent.

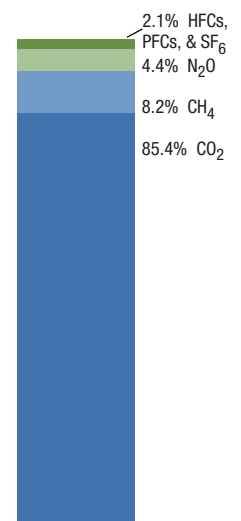
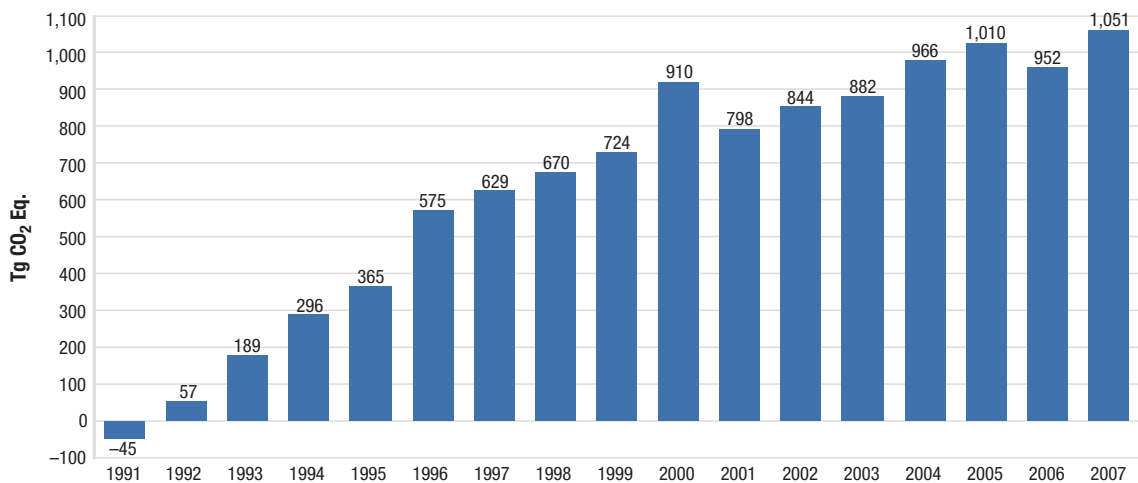


Table 3-2 Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg CO₂ Eq.)

In 2007, total U.S. greenhouse gas emissions were 7,150.1 Tg CO₂ Eq., representing a 17 percent rise since 1990.

Gas/Source	1990	1995	2000	2005	2006	2007
Carbon Dioxide (CO₂)	5,076.7	5,407.9	5,955.2	6,090.8	6,014.9	6,103.4
Fossil Fuel Combustion	4,708.9	5,013.9	5,561.5	5,723.5	5,635.4	5,735.8
Electricity Generation	1,809.7	1,938.9	2,283.2	2,381.0	2,327.3	2,397.2
Transportation	1,484.5	1,598.7	1,800.3	1,881.5	1,880.9	1,887.4
Industrial	834.2	862.6	844.6	828.0	844.5	845.4
Residential	337.7	354.4	370.4	358.0	321.9	340.6
Commercial	214.5	224.4	226.9	221.8	206.0	214.4
U.S. Territories	28.3	35.0	36.2	53.2	54.8	50.8
Non-Energy Use of Fuels	117.0	137.5	144.5	138.1	145.1	133.9
Iron and Steel Production & Metallurgical Coke Production	109.8	103.1	95.1	73.2	76.1	77.4
Cement Production	33.3	36.8	41.2	45.9	46.6	44.5
Natural Gas Systems	33.7	33.8	29.4	29.5	29.5	28.7
Incineration of Waste	10.9	15.7	17.5	19.5	19.8	20.8
Lime Production	11.5	13.3	14.1	14.4	15.1	14.6
Ammonia Production and Urea Consumption	16.8	17.8	16.4	12.8	12.3	13.8
Cropland Remaining Cropland	7.1	7.0	7.5	7.9	7.9	8.0
Limestone and Dolomite Use	5.1	6.7	5.1	6.8	8.0	6.2
Aluminum Production	6.8	5.7	6.1	4.1	3.8	4.3
Soda Ash Production and Consumption	4.1	4.3	4.2	4.2	4.2	4.1
Petrochemical Production	2.2	2.8	3.0	2.8	2.6	2.6
Titanium Dioxide Production	1.2	1.5	1.8	1.8	1.9	1.9
Carbon Dioxide Consumption	1.4	1.4	1.4	1.3	1.7	1.9
Ferroalloy Production	2.2	2.0	1.9	1.4	1.5	1.6
Phosphoric Acid Production	1.5	1.5	1.4	1.4	1.2	1.2
Wetlands Remaining Wetlands	1.0	1.0	1.2	1.1	0.9	1.0
Zinc Production	0.9	1.0	1.1	0.5	0.5	0.5
Petroleum Systems	0.4	0.3	0.3	0.3	0.3	0.3
Lead Production	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
<i>Land Use, Land-Use Change, and Forestry (Sink)^a</i>	<i>(841.4)</i>	<i>(851.0)</i>	<i>(717.5)</i>	<i>(1,122.7)</i>	<i>(1,050.5)</i>	<i>(1,062.6)</i>
<i>Biomass—Wood</i>	<i>215.2</i>	<i>229.1</i>	<i>218.1</i>	<i>208.9</i>	<i>209.9</i>	<i>209.8</i>
<i>International Bunker Fuels^b</i>	<i>114.3</i>	<i>101.6</i>	<i>99.0</i>	<i>111.5</i>	<i>110.5</i>	<i>108.8</i>
<i>Biomass—Ethanol^b</i>	<i>4.2</i>	<i>7.7</i>	<i>9.2</i>	<i>22.6</i>	<i>30.5</i>	<i>38.0</i>
Methane (CH₄)	616.6	615.8	591.1	561.7	582.0	585.3
Enteric Fermentation	133.2	143.6	134.4	136.0	138.2	139.0
Landfills	149.2	144.3	122.3	127.8	130.4	132.9
Natural Gas Systems	129.6	132.6	130.8	106.3	104.8	104.7
Coal Mining	84.1	67.1	60.5	57.1	58.4	57.6
Manure Management	30.4	34.5	37.9	41.8	41.9	44.0
Forest Land Remaining Forest Land	4.6	6.1	20.6	14.2	31.3	29.0
Petroleum Systems	33.9	32.0	30.3	28.3	28.3	28.8
Wastewater Treatment	23.5	24.8	25.2	24.3	24.5	24.4
Stationary Combustion	7.4	7.1	6.6	6.7	6.3	6.6
Rice Cultivation	7.1	7.6	7.5	6.8	5.9	6.2
Abandoned Underground Coal Mines	6.0	8.2	7.4	5.6	5.5	5.7
Mobile Combustion	4.7	4.3	3.4	2.5	2.4	2.3
Composting	0.3	0.7	1.3	1.6	1.6	1.7
Petrochemical Production	0.9	1.1	1.2	1.1	1.0	1.0
Field Burning of Agricultural Residues	0.7	0.7	0.8	0.9	0.8	0.9
Iron and Steel Production & Metallurgical Coke Production	1.0	1.0	0.9	0.7	0.7	0.7
Ferroalloy Production	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+
<i>International Bunker Fuels^b</i>	<i>0.2</i>	<i>0.1</i>	<i>0.1</i>	<i>0.1</i>	<i>0.1</i>	<i>0.1</i>

Table 3-2 (Continued) **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg CO₂ Eq.)**

Gas/Source	1990	1995	2000	2005	2006	2007
Nitrous Oxide (N₂O)	315.0	334.1	329.2	315.9	312.1	311.9
Agricultural Soil Management	200.3	202.3	204.5	210.6	208.4	207.9
Mobile Combustion	43.7	53.7	52.8	36.7	33.5	30.1
Nitric Acid Production	20.0	22.3	21.9	18.6	18.2	21.7
Manure Management	12.1	12.9	14.0	14.2	14.6	14.7
Stationary Combustion	12.8	13.3	14.5	14.8	14.5	14.7
Adipic Acid Production	15.3	17.3	6.2	5.9	5.9	5.9
Wastewater Treatment	3.7	4.0	4.5	4.8	4.8	4.9
N ₂ O from Product Uses	4.4	4.6	4.9	4.4	4.4	4.4
Forest Land Remaining Forest Land	0.5	0.8	2.4	1.8	3.5	3.3
Composting	0.4	0.8	1.4	1.7	1.8	1.8
Settlements Remaining Settlements	1.0	1.2	1.2	1.5	1.5	1.6
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.5	0.5
Incineration of Waste	0.5	0.5	0.4	0.4	0.4	0.4
Wetlands Remaining Wetlands	+	+	+	+	+	+
<i>International Bunker Fuels^b</i>	<i>1.1</i>	<i>0.9</i>	<i>0.9</i>	<i>1.0</i>	<i>1.0</i>	<i>1.0</i>
Hydrofluorocarbons (HFCs)	36.9	61.8	100.1	116.1	119.1	125.5
Substitution of Ozone-Depleting Substances ^c	0.3	28.5	71.2	100.0	105.0	108.3
HCFC-22 Production	36.4	33.0	28.6	15.8	13.8	17.0
Semiconductor Manufacture	0.2	0.3	0.3	0.2	0.3	0.3
Perfluorocarbons (PFCs)	20.8	15.6	13.5	6.2	6.0	7.5
Aluminum Production	18.5	11.8	8.6	3.0	2.5	3.8
Semiconductor Manufacture	2.2	3.8	4.9	3.2	3.5	3.6
Sulfur Hexafluoride (SF₆)	32.8	28.1	19.2	17.9	17.0	16.5
Electrical Transmission and Distribution	26.8	21.6	15.1	14.0	13.2	12.7
Magnesium Production and Processing	5.4	5.6	3.0	2.9	2.9	3.0
Semiconductor Manufacture	0.5	0.9	1.1	1.0	1.0	0.8
Total	6,098.7	6,463.3	7,008.2	7,108.6	7,051.1	7,150.1
Net Emissions (Sources and Sinks)	5,257.3	5,612.3	6,290.7	5,985.9	6,000.6	6,087.5

Tg CO₂ Eq. = teragrams of carbon dioxide equivalents; HCFC = hydrochlorofluorocarbon.

+ Does not exceed 0.05 Tg CO₂ Eq.

^a Parentheses indicate negative values or sequestration. The net CO₂ flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.

^b Emissions from International Bunker Fuels and Biomass Combustion are not included in the totals.

^c Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding. One teragram equals one million metric tons.

land to agricultural or urban use), or can act as a sink for CO₂ (e.g., through net additions to forest biomass) (Figure 3-5).

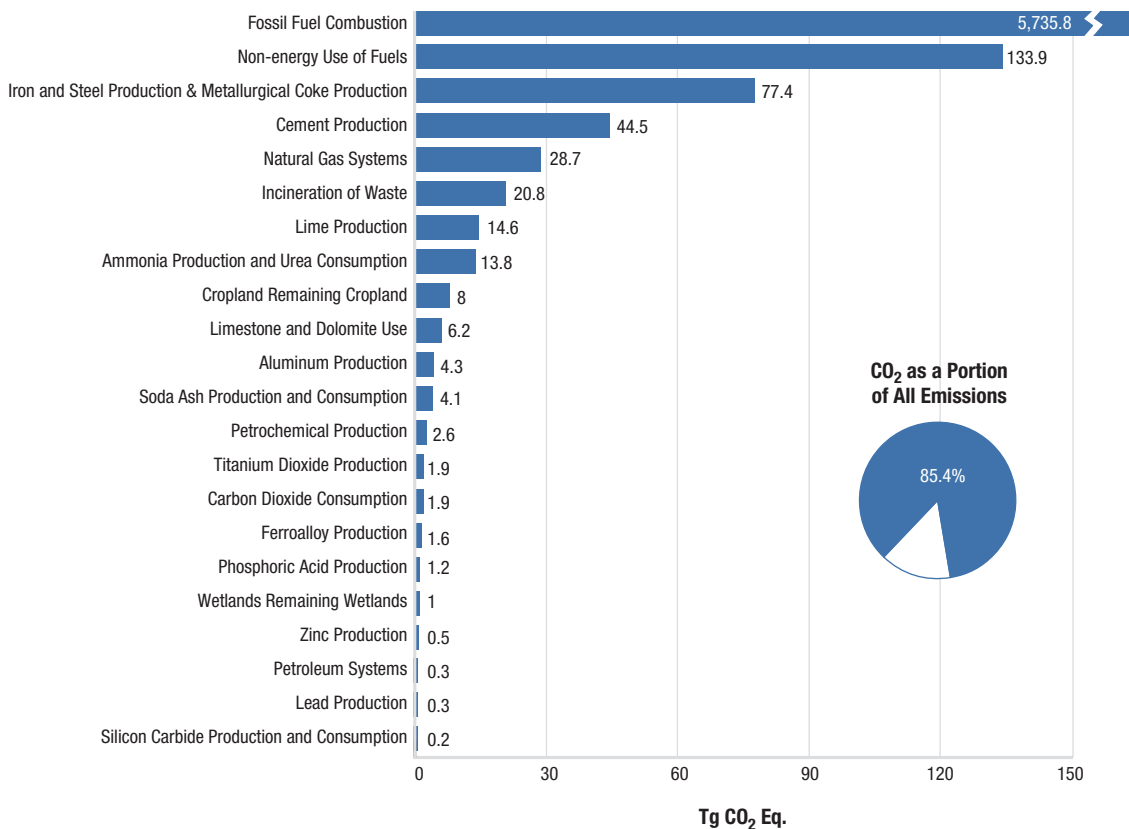
As the largest source of U.S. anthropogenic GHG emissions, CO₂ from fossil fuel combustion has accounted for approximately 79 percent of total GWP-weighted emissions since 1990, growing slowly from 77 percent of total GWP-weighted emissions in 1990 to 80 percent in 2007. Emissions of CO₂ from fossil fuel combustion increased at an average annual rate of 1.3 percent from 1990 to 2007. The fundamental factors influencing this trend include a generally growing domestic economy over the last 17 years, and the subsequent significant overall growth in emissions from electricity generation and transportation activities. Between 1990 and 2007, CO₂ emissions from fossil fuel combustion increased from 4,708.9 Tg CO₂

Eq. to 5,735.8 Tg CO₂ Eq.—a 21.8 percent total increase over the 18-year period. From 2006 to 2007, these emissions increased by 100.4 Tg CO₂ Eq. (1.8 percent).

Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends. Changes in CO₂ 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

Figure 3-5 2007 U.S. Emissions of Carbon Dioxide by Source

In 2007, CO₂ accounted for 85.4 percent of U.S. greenhouse gas emissions, with fossil fuel combustion accounting for 80.2 percent of emissions on a global warming potential (GWP)-weighted basis.



winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than in a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

The five major fuel-consuming sectors contributing to CO₂ emissions from fossil fuel combustion are electricity generation, transportation, industrial, residential, and commercial. CO₂ emissions are produced by the electricity generation sector as it consumes fossil fuel to provide electricity to one of the other four sectors, or “end-use” sectors. In the following discussion, emissions from electricity generation have been distributed to each end-use sector on the basis of each sector’s share of aggregate electricity consumption. The distribution of the electricity-related 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.

Figures 3-6 and 3-7 summarize CO₂ emissions from fossil fuel combustion by sector and fuel type and by end-use sector.

Transportation End-Use Sector

Transportation activities (excluding international bunker fuels) accounted for 33 percent of CO₂ emissions from fossil fuel combustion in 2007.⁷ Virtually all of the energy consumed in this end-use sector came from petroleum products. Nearly 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 CO₂ 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 CO₂ from fossil fuel combustion in 2007. Just over half of these emissions resulted from direct fossil fuel combustion to produce steam and/or heat for industrial processes. The remaining emissions resulted from consuming electricity for motors, electric furnaces, ovens, lighting, and other applications.

⁷ 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 2007.

Residential and Commercial End-Use Sectors

The residential and commercial end-use sectors accounted for 21 and 18 percent, respectively, of CO₂ emissions from fossil fuel combustion in 2007. Both sectors relied heavily on electricity for meeting energy demands, with 72 and 79 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 42 percent of the CO₂ from fossil fuel combustion in 2007.⁸ The type of fuel combusted by electricity generators has a significant effect on their emissions. For example, some electricity is generated with low-CO₂-emitting energy technologies, particularly non-fossil options, such as nuclear, hydroelectric, wind, 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 2007. Consequently, changes in electricity demand have a significant impact on coal consumption and associated CO₂ emissions.

Other significant CO₂ trends included the following:

- CO₂ emissions from non-energy use of fossil fuels increased by 16.9 Tg CO₂ Eq. (14.5 percent) from 1990 through 2007. Emissions from non-energy uses of fossil fuels were 133.9 Tg CO₂ Eq. in 2007,

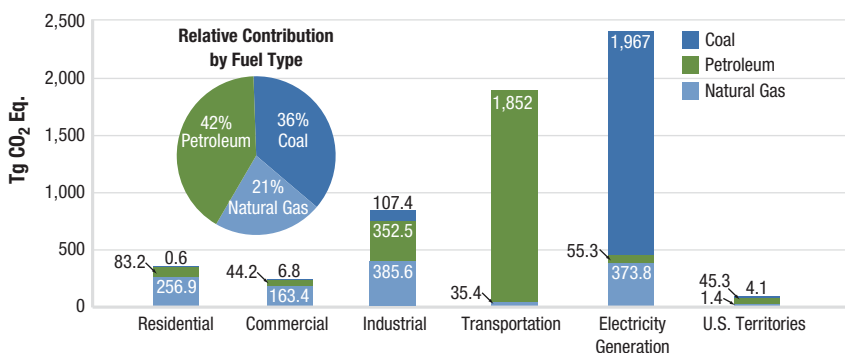
which constituted 2.2 percent of total national CO₂ emissions, approximately the same proportion as in 1990.

- CO₂ emissions from iron and steel production and metallurgical coke production increased slightly from 2006 to 2007 (1.3 Tg CO₂ Eq.), but decreased by 29.5 percent to 77.4 Tg CO₂ Eq. from 1990 through 2007, due to restructuring of the industry, technological improvements, and increased scrap utilization.
- In 2007, CO₂ emissions from cement production decreased slightly by 2.0 Tg CO₂ Eq. (4.4 percent) from 2006 to 2007. This decrease occurred despite the overall increase over the time series. After falling in 1991 by 2 percent from 1990 levels, cement production emissions grew every year through 2006. Overall, from 1990 to 2007, emissions from cement production increased by 34 percent, an increase of 11.2 Tg CO₂ Eq.
- CO₂ emissions from incineration of waste (20.8 Tg CO₂ Eq. in 2007) increased by 9.8 Tg CO₂ Eq. (90 percent) from 1990 through 2007, as the volume of plastics and other fossil carbon-containing materials in the waste stream grew.
- Net CO₂ sequestration from land use, land-use change, and forestry increased by 221.1 Tg CO₂ Eq. (26 percent) from 1990 through 2007. This increase was primarily due to growth in the rate of net carbon accumulation in forest carbon stocks, particularly in above-ground and below-ground tree biomass. Annual carbon accumulation in land-filled yard trimmings and food scraps slowed over this period, while the rate of carbon accumulation in urban trees increased.

⁸ The emissions of CO₂ attributable to electricity generation were allocated to the end-use sectors, as described in the end-use sector discussions.

Figure 3-6 2007 U.S. CO₂ Emissions from Fossil Fuel Combustion by Sector and Fuel Type

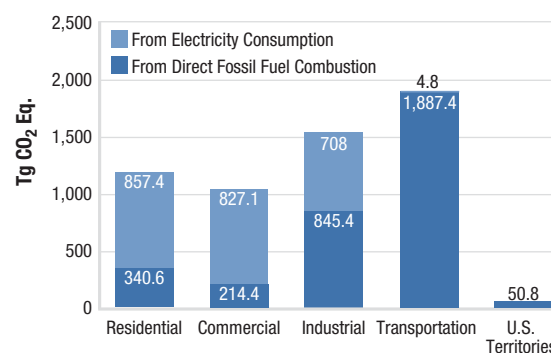
In 2007, U.S. transportation sector emissions were primarily from petroleum consumption, while electricity generation emissions were primarily from coal consumption.



Note: Electricity generation also includes emissions of less than 1 Tg CO₂ Eq. from geothermal-based electricity generation.

Figure 3-7 2007 U.S. End-Use Sector CO₂ Emissions from Fossil Fuel Combustion

In 2007, direct fossil fuel combustion accounted for the vast majority of fossil fuel-related CO₂ emissions from the transportation sector (mostly petroleum combustion). Electricity consumption indirectly accounted for most of the fossil fuel-related CO₂ emissions from the commercial and residential sectors.



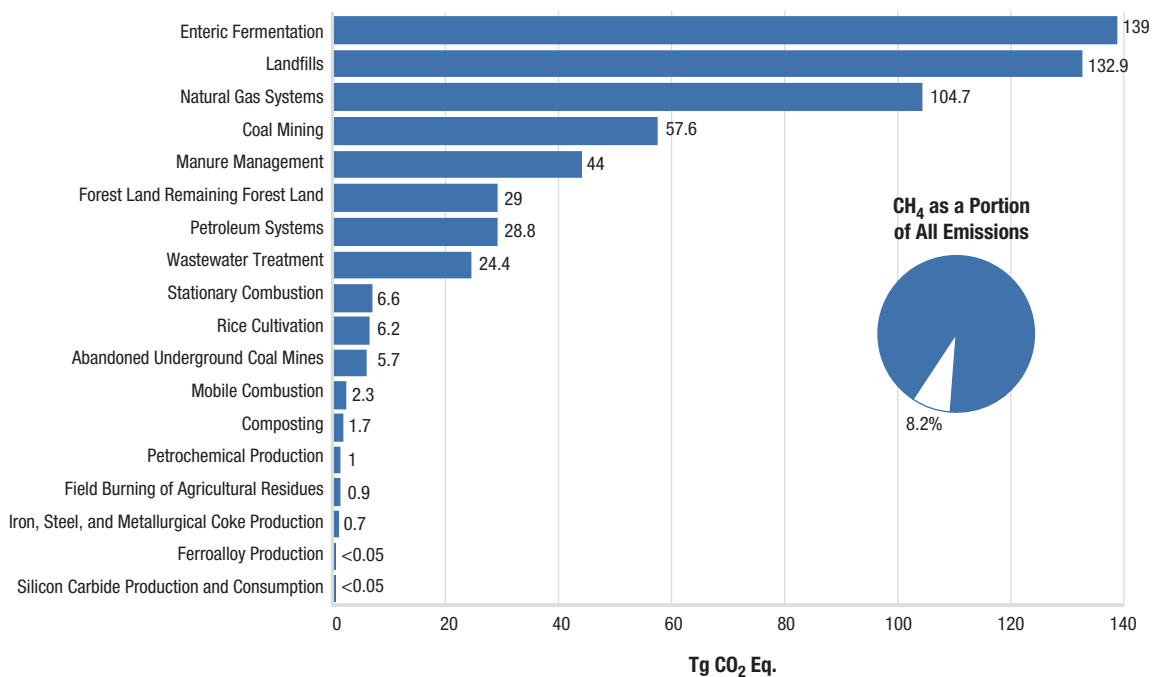
Methane Emissions

According to the IPCC, CH₄ is more than 20 times as effective as CO₂ at trapping heat in the atmosphere. Over the last 250 years, the concentration of CH₄ in the atmosphere increased by 148 percent (IPCC 2007). Anthropogenic sources of CH₄ include landfills, natural gas and petroleum systems, agricultural activities, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (see Figure 3-8). Some significant trends in U.S. emissions of CH₄ include the following:

- Enteric fermentation is the largest anthropogenic source of CH₄ emissions in the United States. In 2007, enteric fermentation CH₄ emissions were 139.0 Tg CO₂ Eq. (approximately 24 percent of total CH₄ emissions), which represents an increase of 5.8 Tg CO₂ Eq., or 4.3 percent, since 1990.
- Landfills are the second-largest anthropogenic source of CH₄ emissions in the United States, accounting for approximately 23 percent of total CH₄ emissions (132.9 Tg CO₂ Eq.) in 2007. From 1990 to 2007, net CH₄ emissions from landfills decreased by 16.3 Tg CO₂ Eq. (11 percent), with small increases occurring in some interim years, including 2007. This downward trend in overall emissions is the result of increases in the amount of landfill gas collected and combusted,⁹ which has more than offset the additional CH₄ emissions resulting from an increase in the amount of municipal solid waste landfilled.
- CH₄ emissions from natural gas systems were 104.7 Tg CO₂ Eq. in 2007. Emissions have declined by 24.9 Tg CO₂ Eq. (19 percent) since 1990, due to improvements in technology and management practices, as well as some replacement of old equipment.
- In 2007, CH₄ emissions from coal mining were 57.6 Tg CO₂ Eq., a 0.8 Tg CO₂ Eq. (1.3 percent) decrease over 2006 emission levels. The overall decline of 26.4 Tg CO₂ Eq. (31 percent) from 1990 results from the mining of less gassy coal from underground mines and the increased use of CH₄ collected from degasification systems.
- CH₄ emissions from manure management increased by 44.7 percent, from 30.4 Tg CO₂ Eq. in 1990 to 44.0 Tg CO₂ Eq. in 2007. The majority of this increase was from swine and dairy cow manure, since the general trend in manure management is increasing use of liquid systems, which tends to produce higher CH₄ emissions. The increase in liquid systems is the combined result of a shift to larger facilities, and to facilities in the U.S. West and Southwest, all of which tend to use liquid systems. Also, new regulations limiting the application of manure nutrients have shifted manure management practices at smaller dairies from daily spread to manure managed and stored on site.

Figure 3-8 2007 U.S. Emissions of Methane by Source

In 2007, methane (CH₄) accounted for 8.2 percent of U.S. greenhouse gas emissions on a GWP-weighted basis. Enteric fermentation was the largest source of U.S. CH₄ emissions (24 percent), followed closely by emissions from landfills (23 percent) and natural gas systems (18 percent).



⁹ The CO₂ produced from combusted CH₄ at landfills is not counted in national inventories, as it is considered part of the natural carbon cycle of decomposition.

Nitrous Oxide Emissions

N₂O 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 N₂O emissions are much lower than CO₂ emissions, N₂O is approximately 300 times more powerful than CO₂ at trapping heat in the atmosphere. Since 1750, the global atmospheric concentration of N₂O has risen by approximately 18 percent (IPCC 2007). The main anthropogenic activities producing N₂O in the United States are agricultural soil management, fuel combustion in motor vehicles, nitric acid production, stationary fuel combustion, manure management, and adipic acid production (see Figure 3-9).

Some significant trends in U.S. emissions of N₂O include the following:

- Agricultural soils produced approximately 67 percent of N₂O emissions in the United States in 2007. Estimated emissions from this source in 2007 were 207.9 Tg CO₂ Eq. Annual N₂O emissions from agricultural soils fluctuated between 1990 and 2007, although overall emissions were 3.8 percent higher in 2007 than in 1990. N₂O emissions from this source have not shown any significant long-term trend, as they are highly sensitive to the amount of nitrogen applied to soils, which has not changed significantly over the time period, and to weather patterns and crop type.
- In 2007, N₂O emissions from mobile combustion were 30.1 Tg CO₂ Eq. (approximately 10 percent of U.S. N₂O emissions). From 1990 to 2007, N₂O emissions from mobile combustion decreased by 31 percent. However, from 1990 to 1998, emissions increased by 26 percent, due to control technologies that reduced NO_x emissions while increasing N₂O emissions. Since 1998, newer control technologies have led to a steady decline in N₂O from this source.
- N₂O emissions from adipic acid production were 5.9 Tg CO₂ Eq. in 2007, and have decreased significantly since 1996 from the widespread installation of pollution control measures. Emissions from adipic acid production have decreased by 61 percent since 1990, and emissions from adipic acid production have fluctuated by less than 1.2 Tg CO₂ Eq. annually since 1998.

HFC, PFC, and SF₆ Emissions

HFCs and PFCs are families of synthetic chemicals that are used as alternatives to the ODS, and along with SF₆, are potent GHGs. SF₆ and PFCs have extremely long atmospheric lifetimes, contributing to their high GWP values and resulting in their essentially irreversible accumulation in the atmosphere once

Figure 3-9 2007 U.S. Emissions of Nitrous Oxide by Source

In 2007, nitrous oxide (N₂O) accounted for 4.4 percent of U.S. greenhouse gas emissions on a GWP-weighted basis. Agricultural soil management was the largest U.S. source of N₂O, producing 67 percent of emissions.

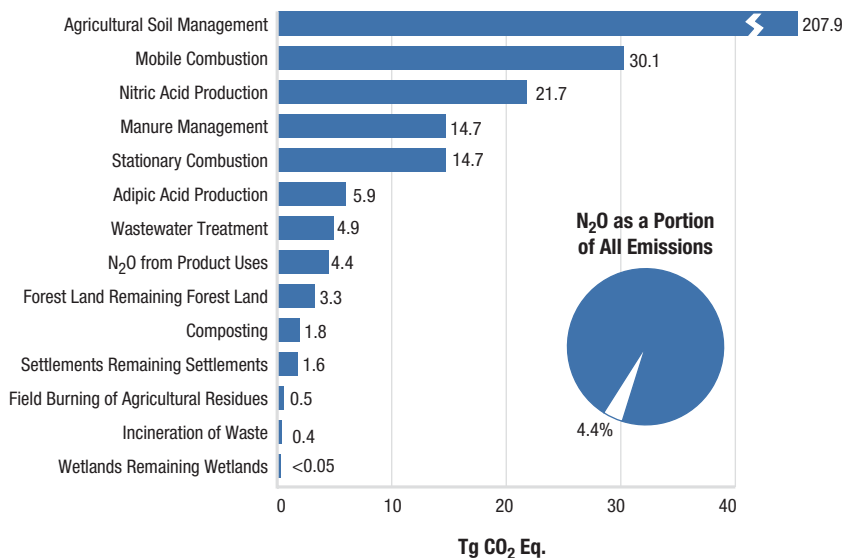
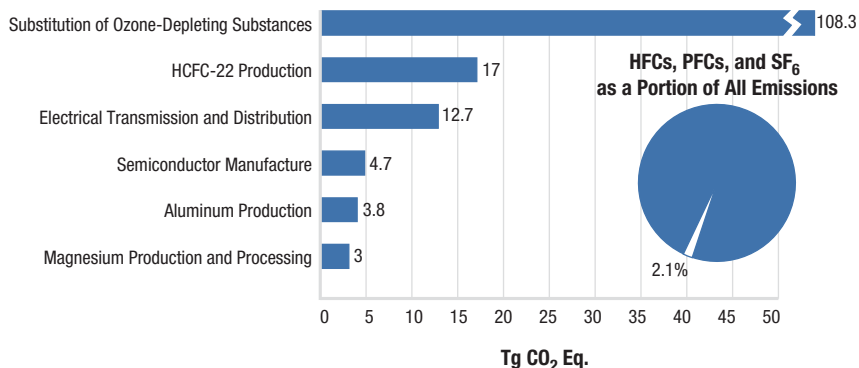


Figure 3-10 2007 U.S. Emissions of HFCs, PFCs, and SF₆ by Source

In 2007, HFCs, PFCs, and SF₆ accounted for 2.1 percent of U.S. greenhouse gas emissions on a GWP-weighted basis. Although the mass of these gases emitted is comparatively small, these emissions have high global warming potentials, and therefore have significant climate impacts.



emitted. SF₆ is the most potent GHG 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 3-10).

Some significant trends in U.S. HFC, PFC, and SF₆ emissions include the following:

- Emissions resulting from the substitution of ODS (e.g., CFCs) have been increasing from small amounts in 1990 to 108.3 Tg CO₂ Eq. in 2007. Emissions from substitutes for ODS are both the largest and the fastest-growing source of HFC, PFC, and SF₆ 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.

- HFC emissions from the production of HCFC-22 decreased by 53 percent (19.4 Tg CO₂ Eq.) from 1990 through 2007, 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.
- SF₆ emissions from electric power transmission and distribution systems decreased by 53 percent (14.1 Tg CO₂ Eq.) from 1990 to 2007, primarily because of higher purchase prices for SF₆ and efforts by industry to reduce emissions.
- PFC emissions from aluminum production decreased by 79 percent (14.7 Tg CO₂ Eq.) from 1990 to 2007, due to both industry emission reduction efforts and lower domestic aluminum production.

OVERVIEW OF SECTOR EMISSIONS AND TRENDS

In accordance with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997), and the 2003 *UNFCCC*

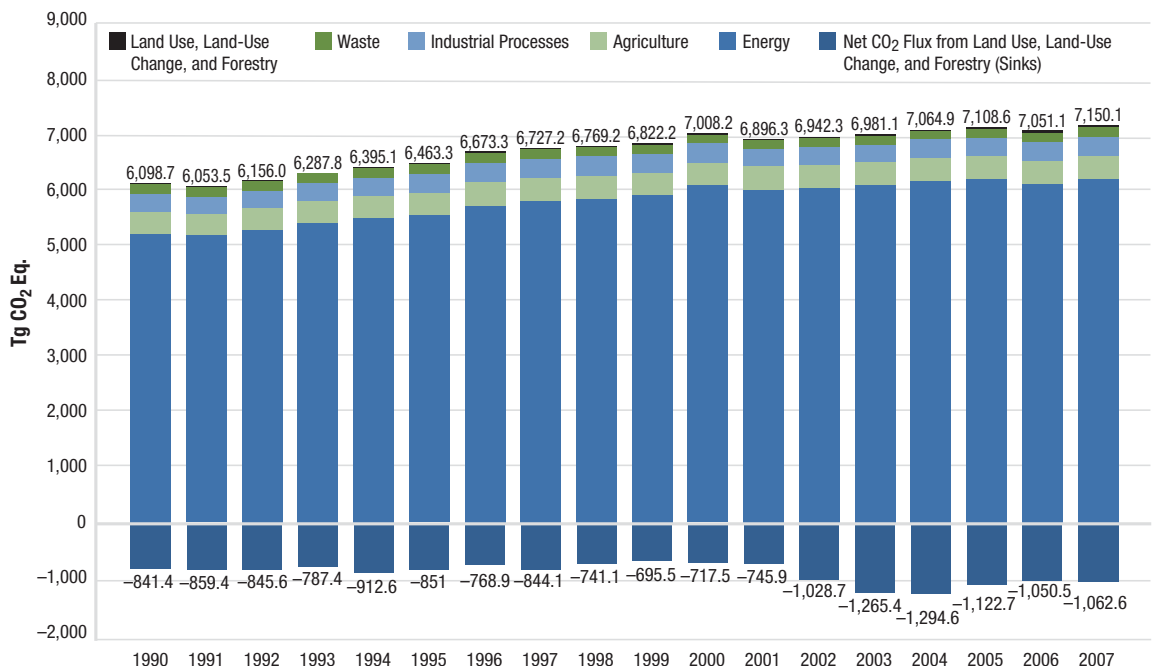
Guidelines on Reporting and Review (UNFCCC 2003), the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007* (U.S. EPA/OAP 2009) is segregated into six sector-specific chapters. Figure 3-11 and Table 3-3 aggregate emissions and sinks by these chapters. Emissions of all gases can be summed from each source category using IPCC guidance. Over the 18-year period from 1990 to 2007, total emissions in the energy, industrial processes, and agriculture sectors climbed by 976.7 Tg CO₂ Eq. (19 percent), 28.5 Tg CO₂ Eq. (9 percent), and 28.9 Tg CO₂ Eq. (8 percent), respectively. Emissions decreased in the waste and the solvent and other product use sectors by 11.5 Tg CO₂ Eq. (6 percent) and less than 0.1 Tg CO₂ Eq. (0.4 percent), respectively. Over the same period, estimates of net carbon sequestration in the land use, land-use change, and forestry sector increased by 192.5 Tg CO₂ Eq. (23 percent).

Energy

The Energy chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* contains emissions of all GHGs 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. CO₂ emissions from 1990 through 2007. In 2007, approximately 85 percent of the energy consumed in the United States (on a British thermal unit basis) was pro-

Figure 3-11 Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

From 1990 to 2007, total emissions in the energy, industrial processes, and agriculture sectors climbed by 19 percent, 9 percent, and 8 percent, respectively. Over the same period, carbon uptake by the land use, land-use change, and forestry sector increased by 23 percent.



Note: Relatively smaller amounts of global warming potential-weighted emissions are also emitted from the Solvent and Other Product Use sectors.

Table 3-3 Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg CO₂ Eq.)

From 1990 to 2007, total emissions in the energy, industrial processes, and agriculture sectors increased, emissions in the waste and the solvent and other product use sectors decreased, and net carbon sequestration in the land use, land-use change, and forestry sector rose by 23 percent.

Chapter/IPCC Sector	1990	1995	2000	2005	2006	2007
Energy	5,193.6	5,520.1	6,059.9	6,169.2	6,084.4	6,170.3
Industrial Processes	325.2	345.8	356.3	337.6	343.9	353.8
Solvent and Other Product Use	4.4	4.6	4.9	4.4	4.4	4.4
Agriculture	384.2	402.0	399.4	410.8	410.3	413.1
Land Use, Land-Use Change, and Forestry (Emissions)	14.2	16.2	33.0	26.4	45.1	42.9
Waste	177.1	174.7	154.6	160.2	163.0	165.6
Total Emissions	6,098.7	6,463.3	7,008.2	7,108.6	7,051.1	7,150.1
Net CO ₂ Flux from Land Use, Land-Use Change, and Forestry (Sinks)*	(841.4)	(851.0)	(717.5)	(1,122.7)	(1,050.5)	(1,062.6)
Net Emissions (Sources and Sinks)	5,257.3	5,612.3	6,290.7	5,985.9	6,000.6	6,087.5

* The net CO₂ flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in the net emissions total.

IPCC = Intergovernmental Panel on Climate Change; Tg CO₂ Eq. = teragrams of carbon dioxide equivalents.

Note: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

duced through the combustion of fossil fuels. The remaining 15 percent came from other energy sources, such as hydropower, biomass, nuclear, wind, and solar energy (see Figure 3-12). Energy-related activities are also responsible for CH₄ and N₂O emissions (35 percent and 14 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy chapter accounted for a combined 86.3 percent of total U.S. GHG emissions in 2007.

Industrial Processes

The Industrial Processes chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* contains by-product or fugitive emissions of GHGs 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 CO₂, CH₄, and N₂O. These processes include iron and steel production and metallurgical coke production, cement production, ammonia production and urea consumption, 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, CO₂ consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production. Additionally, emissions from industrial processes release HFCs, PFCs, and SF₆. Overall, emission sources in the Industrial Process chapter accounted for 4.9 percent of U.S. GHG emissions in 2007.

Solvent and Other Product Use

The Solvent and Other Product Use chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*

contains GHG emissions that are produced as a by-product of various solvent and other product uses. In the United States, emissions from N₂O from product uses—the only source of GHG emissions from this sector—accounted for less than 0.1 percent of total U.S. anthropogenic GHG emissions on a carbon-equivalent basis in 2007.

Agriculture

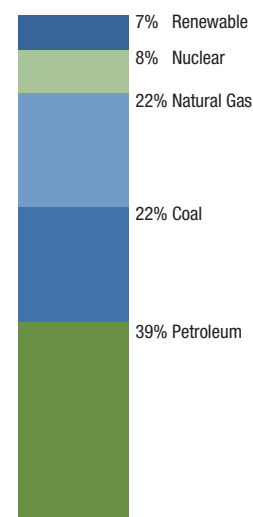
The Agriculture chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy chapter, and agricultural CO₂ fluxes, which are addressed in the Land Use, Land-Use Change, and Forestry chapter). Agricultural activities contribute directly to emissions of GHGs 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. CH₄ and N₂O were the primary GHGs emitted by agricultural activities. In 2007, CH₄ emissions from enteric fermentation and manure management represented about 24 percent and 8 percent of total CH₄ emissions from anthropogenic activities, respectively. Agricultural soil management activities, such as fertilizer application and other cropping practices, were the largest source of U.S. N₂O emissions in 2007, accounting for 67 percent. In 2007, emission sources accounted for in the Agriculture chapter were responsible for 6 percent of total U.S. GHG emissions.

Land Use, Land-Use Change, and Forestry

The Land Use, Land-Use Change, and Forestry chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* contains emissions of CH₄ and N₂O, and emissions and removals of CO₂ from forest manage-

Figure 3-12 2007 U.S. Energy Consumption by Energy Source

In 2007, the combustion of fossil fuels accounted for approximately 85 percent of U.S. energy consumption, with the remaining 15 percent coming from other sources (nuclear, hydropower, wind, etc.).



ment, 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 86 percent of total 2007 net CO₂ flux, urban trees accounted for 9 percent, mineral and organic soil carbon stock changes accounted for 4 percent, and landfilled yard trimmings and food scraps accounted for 1 percent.

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 and organic soils sequester approximately 70 percent more carbon than is emitted through these soils, liming, and urea fertilization, combined. The mineral soil carbon 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 2007 resulted in a net carbon sequestration of 1,062.6 Tg CO₂ Eq. This represents an offset of approximately 17.4 percent of total U.S. CO₂ emissions, or 14.9 percent of total GHG emissions in 2007. Between 1990 and 2007, total land use, land-use change, and forestry net carbon flux resulted in a 26.3 percent increase in CO₂ sequestration, primarily due to an increase in the rate of net carbon accumulation in forest carbon stocks, particularly in above-ground and below-ground tree biomass. Annual carbon accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of annual carbon accumulation increased in urban trees.

The application of crushed limestone and dolomite to managed land (i.e., soil liming) and urea fertilization resulted in CO₂ emissions of 8.0 Tg CO₂ Eq. in 2007, an increase of 13 percent relative to 1990. The application of synthetic fertilizers to forest and settlement soils in 2007 resulted in direct N₂O emissions of 1.6 Tg CO₂ Eq. Direct N₂O emissions from fertilizer application increased by approximately 61 percent between 1990 and 2007. Non-CO₂ emissions from forest fires in 2007 resulted in CH₄ emissions of 29.0 Tg CO₂ Eq., and in N₂O emissions of 2.9 Tg CO₂ Eq. CO₂ and N₂O emissions from peatlands in 2007

totaled 1.0 Tg CO₂ Eq. and less than 0.01 Tg CO₂ Eq., respectively.

Waste

The Waste chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* contains emissions from waste management activities (except incineration of waste, which is addressed in the Energy chapter). Landfills were the largest source of anthropogenic CH₄ emissions in the Waste chapter, accounting for 23 percent of total U.S. CH₄ emissions.¹⁰ Additionally, wastewater treatment accounted for 4 percent of U.S. CH₄ emissions. N₂O emissions from the discharge of wastewater treatment effluents into aquatic environments were estimated, as were N₂O emissions from the treatment process itself. Emissions of CH₄ and N₂O from composting grew from 1990 to 2007, and resulted in emissions of 1.7 Tg CO₂ Eq. and 1.8 Tg CO₂ Eq., respectively. Overall, in 2007, emission sources accounted for in the Waste chapter generated 2.3 percent of total U.S. GHG emissions.

EMISSIONS BY ECONOMIC SECTOR

Throughout the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* 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 (U.S. EPA/OAP 2009). 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, agriculture, and U.S. territories. Table 3-4 summarizes emissions from each of these sectors, and Figure 3-13 shows the trend in emissions by sector from 1990 to 2007.

Using this categorization, emissions from electricity generation accounted for the largest portion (34 percent) of U.S. GHG emissions in 2007, while transportation activities, in aggregate, accounted for 28 percent, and emissions from industry accounted for 20 percent. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade, 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 18 percent of U.S. GHG emissions were from the residential, agriculture, and commercial sectors, plus emissions from U.S. territories. The residential sector accounted for about 5 percent, and primarily consisted of CO₂ emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 7 percent of U.S. emissions; unlike

¹⁰ 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 the *Inventory* report.

Table 3-4 U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO₂ Eq.)

In 2007, electricity generation accounted for 34 percent of total U.S. greenhouse gas emissions, transportation accounted for 28 percent, and industry accounted for 30 percent.

Economic Sectors	1990	1995	2000	2005	2006	2007
Electric Power Industry	1,859.1	1,989.0	2,329.3	2,429.4	2,375.5	2,445.1
Transportation	1,543.6	1,685.2	1,919.7	1,998.9	1,994.4	1,995.2
Industry	1,496.0	1,524.5	1,467.5	1,364.9	1,388.4	1,386.3
Agriculture	428.5	453.7	470.2	482.6	502.9	502.8
Commercial	392.9	401.0	388.2	401.8	392.6	407.6
Residential	344.5	368.8	386.0	370.5	334.9	355.3
U.S. Territories	34.1	41.1	47.3	60.5	62.3	57.7
Total Emissions	6,098.7	6,463.3	7,008.2	7,108.6	7,051.1	7,150.1
Land Use, Land-Use Change, and Forestry (Sinks)	(841.4)	(851.0)	(717.5)	(1,122.7)	(1,050.5)	(1,062.6)
Net Emissions (Sources and Sinks)	5,257.3	5,612.3	6,290.7	5,985.9	6,000.6	6,087.5

Tg CO₂ Eq. = teragrams of carbon dioxide equivalents.

Note: Totals may not sum due to independent rounding. Emissions include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

Figure 3-13 U.S. Greenhouse Gas Emissions Allocated to Economic Sectors: 1990–2007

In 2007, electricity generation accounted for 34 percent of total U.S. greenhouse gas emissions, transportation accounted for 28 percent, and industry accounted for 20 percent.

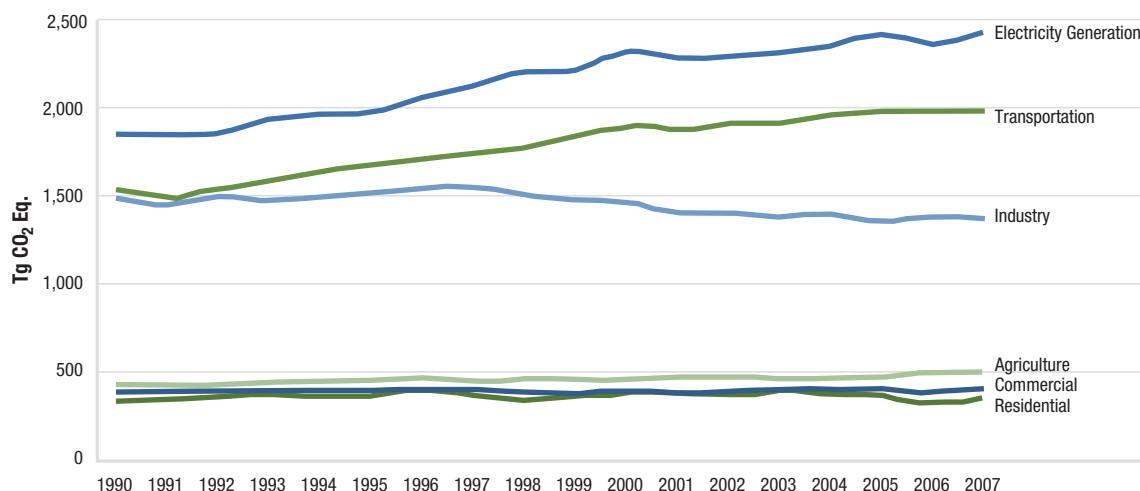


Table 3-5 U.S. Greenhouse Gas Emissions by Economic Sector, with Electricity-Related Emissions Distributed Among Sectors (Tg CO₂ Eq.)

In 2007, after distributing emissions from electricity generation to end-use sectors, industry accounted for 30 percent of total U.S. greenhouse gas emissions, and the transportation sector accounted for 28 percent.

Implied Sectors	1990	1995	2000	2005	2006	2007
Industry	2,166.5	2,219.8	2,235.5	2,081.2	2,082.3	2,081.2
Transportation	1,546.7	1,688.3	1,923.2	2,003.6	1,999.0	2,000.1
Commercial	942.2	1,000.2	1,140.0	1,214.6	1,201.5	1,251.2
Residential	950.0	1,024.2	1,159.2	1,237.0	1,176.1	1,229.8
Agriculture	459.2	489.7	503.2	511.7	530.0	530.1
U.S. Territories	34.1	41.1	47.3	60.5	62.3	57.7
Total Emissions	6,098.7	6,463.3	7,008.2	7,108.6	7,051.1	7,150.1
Land Use, Land-Use Change, and Forestry (Sinks)	(841.4)	(851.0)	(717.5)	(1,122.7)	(1,050.5)	(1,062.6)
Net Emissions (Sources and Sinks)	5,257.3	5,612.3	6,290.7	5,985.9	6,000.6	6,087.5

Tg CO₂ Eq. = teragrams of carbon dioxide equivalents.

other economic sectors, agricultural sector emissions were dominated by N₂O emissions from agricultural soil management and CH₄ emissions from enteric fermentation, rather than CO₂ from fossil fuel combustion. The commercial sector accounted for about 6 percent of emissions, while U.S. territories accounted for approximately 1 percent.

CO₂ was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Electricity is ultimately consumed in the economic sectors described above. Table 3-5 presents GHG 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.¹¹ These source categories include CO₂ from fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO₂ and N₂O from incineration of waste, CH₄ and N₂O from stationary sources, and SF₆ from electrical transmission and distribution systems.

When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S. GHG emissions (30 percent) in 2007. Emissions from the residential and commercial sectors also increase substantially when emissions from elec-

tricity are included, due to their relatively large share of electricity consumption (lighting, appliances, etc.). Transportation activities remain the second-largest contributor to total U.S. emissions (28 percent). In all sectors except agriculture, CO₂ accounts for more than 80 percent of GHG emissions, primarily from the combustion of fossil fuels. Figure 3-14 shows the trend in these emissions by sector from 1990 to 2007, while Box 3-3 shows recent trends in various U.S. GHG emissions-related data.

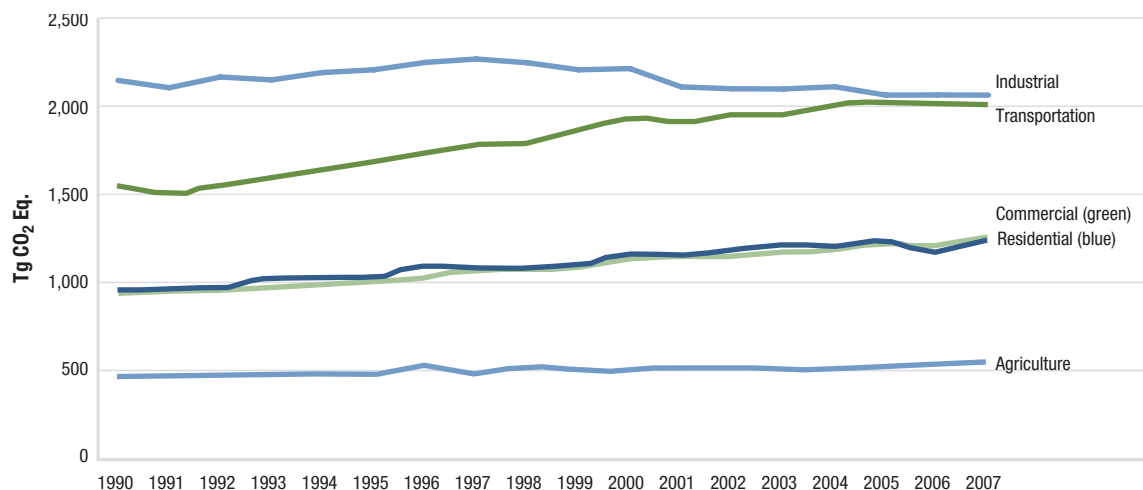
INDIRECT GREENHOUSE GASES

The reporting requirements of the UNFCCC request that information be provided on indirect GHGs, which include CO, NO_x, NMVOCs, and SO₂ (UNFCCC 2003). 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 and methane, or, in the case of SO₂, 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 GHGs.

Since 1970, the United States has published estimates of annual emissions of CO, NO_x, NMVOCs, and SO₂ (U.S. EPA/OAQPS 2008), which are regulated under the Clean Air Act.¹² Table 3-7 shows that fuel combustion accounts for the majority of emissions of these indirect GHGs. 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 3-14 U.S. Electricity-Related Greenhouse Gas Emissions Distributed to Economic Sectors: 1990–2007

In 2007, when electricity generation-related emissions are distributed to economic sectors, the transportation sector accounted for 28 percent of total U.S. greenhouse gas emissions, and the industrial sector accounted for 30 percent (emissions from industrial processes and from electricity use at industrial facilities).



¹¹ 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.

¹² NO_x and CO emissions from field burning of agricultural residues were estimated separately, and therefore not taken from U.S. EPA/OAQPS 2008.

Box 3-3 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 non-utilities combined—was the largest source of U.S. GHG emissions in 2007; (4) emissions per unit of total gross domestic product as a measure of national economic activity; or (5) emissions per capita.

Table 3-6 provides data on various statistics related to U.S. GHG emissions normalized to 1990 as a baseline year. U.S. GHG emissions have grown at an average annual rate of 0.9 percent since 1990. This rate of growth is slightly slower than that for total energy consumption or fossil fuel consumption and much slower than that for either electricity consumption or overall gross domestic product. Total U.S. GHG emissions have also grown slightly slower than the U.S. population since 1990 (see Figure 3-15).

Table 3-6 Recent Trends in Various U.S. Data (Index 1990 = 100) (Tg CO₂ Eq.)

U.S. GHG emissions have grown at an average annual rate of 0.9 percent since 1990. This rate of growth is slightly slower than that for total energy consumption or fossil fuel consumption and much slower than that for either electricity consumption or overall gross domestic product.

Variable	1990	1995	2000	2005	2006	2007	Growth Rate ^a
Gross Domestic Product ^b	100	113	138	155	159	162	2.9%
Electricity Consumption ^c	100	112	127	134	135	137	1.9%
Fossil Fuel Consumption ^c	100	107	117	119	117	119	1.1%
Energy Consumption ^c	100	108	117	119	118	120	1.1%
Population ^d	100	107	113	118	119	120	1.1%
Greenhouse Gas Emissions ^e	100	106	115	117	115	117	0.9%

^a Average annual growth rate.

^b Gross domestic product in chained 2000 dollars (U.S. DOC/BEA 2008).

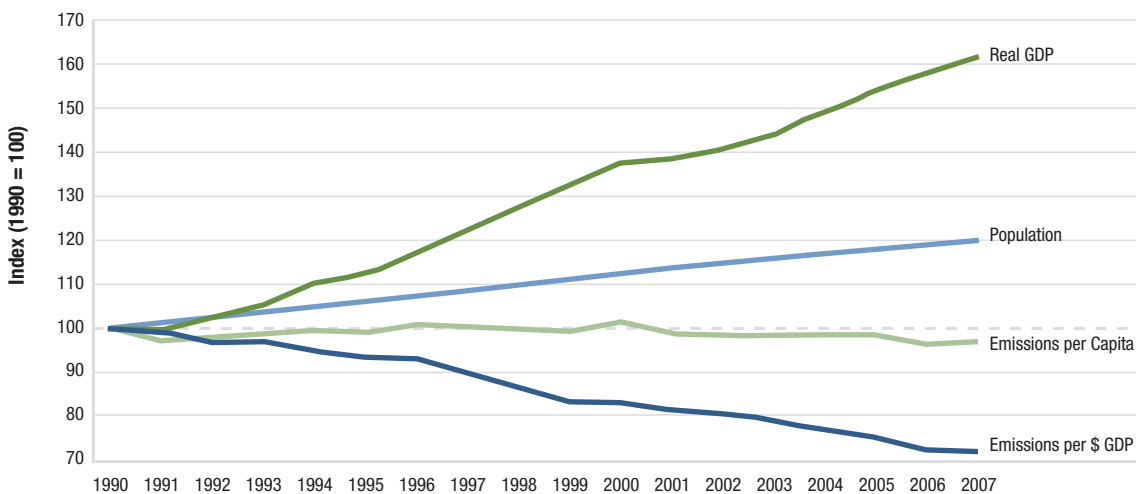
^c Energy content-weighted values (U.S. DOE/EIA 2008a).

^d U.S. DOC/Census 2008a.

^e Global warming potential-weighted values.

Figure 3-15 Recent Trends in U.S. Greenhouse Gas Emissions per Capita and per Dollar of Gross Domestic Product: 1990–2007

Since 1990, U.S. greenhouse gas emissions have grown at an average annual rate of 0.9 percent. This is significantly slower than the average annual 2.9 percent growth rate in the U.S. gross domestic product (GDP).



Sources: U.S. DOC/BEA 2008, U.S. DOC/Census 2008a, and emission estimates in this report.

Table 3-7 Emissions of NO_x, CO, NMVOCs, and SO₂ (Gg)

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

Gas/Activity	1990	1995	2000	2005	2006	2007
Nitrogen Oxides (NO_x)	21,450	21,070	19,004	15,612	14,701	14,250
Mobile Fossil Fuel Combustion	10,920	10,622	10,310	8,757	8,271	7,831
Stationary Fossil Fuel Combustion	9,689	9,619	7,802	5,857	5,445	5,445
Industrial Processes	591	607	626	534	527	520
Oil and Gas Activities	139	100	111	321	316	314
Incineration of Waste	82	88	114	98	98	97
Agricultural Burning	28	29	35	39	38	37
Solvent Use	1	3	3	5	5	5
Waste	0	1	2	2	2	2
Carbon Monoxide (CO)	130,461	109,032	92,776	71,672	67,453	63,875
Mobile Fossil Fuel Combustion	119,360	97,630	83,559	62,519	58,322	54,678
Stationary Fossil Fuel Combustion	5,000	5,383	4,340	4,778	4,792	4,792
Industrial Processes	4,125	3,959	2,216	1,744	1,743	1,743
Incineration of Waste	978	1,073	1,670	1,439	1,438	1,438
Agricultural Burning	691	663	792	860	825	892
Oil and Gas Activities	302	316	146	324	323	323
Waste	1	2	8	7	7	7
Solvent Use	5	5	45	2	2	2
Non-Methane Volatile Organic Compounds (NMVOCs)	20,930	19,520	15,227	14,562	14,129	13,747
Mobile Fossil Fuel Combustion	10,932	8,745	7,229	6,292	5,954	5,672
Solvent Use	5,216	5,609	4,384	3,881	3,867	3,855
Industrial Processes	2,422	2,642	1,773	2,035	1,950	1,878
Stationary Fossil Fuel Combustion	912	973	1,077	1,450	1,470	1,470
Oil and Gas Activities	554	582	388	545	535	526
Incineration of Waste	222	237	257	243	239	234
Waste	673	731	119	115	113	111
Agricultural Burning	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur Dioxide (SO₂)	20,935	16,891	14,830	13,348	12,259	11,725
Stationary Fossil Fuel Combustion	18,407	14,724	12,849	11,641	10,650	10,211
Industrial Processes	1,307	1,117	1,031	852	845	839
Mobile Fossil Fuel Combustion	793	672	632	600	520	442
Oil and Gas Activities	390	335	287	233	221	210
Incineration of Waste	38	42	29	22	22	22
Waste	0	1	1	1	1	1
Solvent Use	0	1	1	0	0	0
Agricultural Burning	N/A	N/A	N/A	N/A	N/A	N/A

Gg = gigagrams; N/A = not available.

Note: Totals may not sum due to independent rounding.

Source: U.S. EPA 2008, disaggregated based on U.S. EPA 2003, except for estimates from field burning of agricultural residues.