2. Trends in Greenhouse Gas Emissions

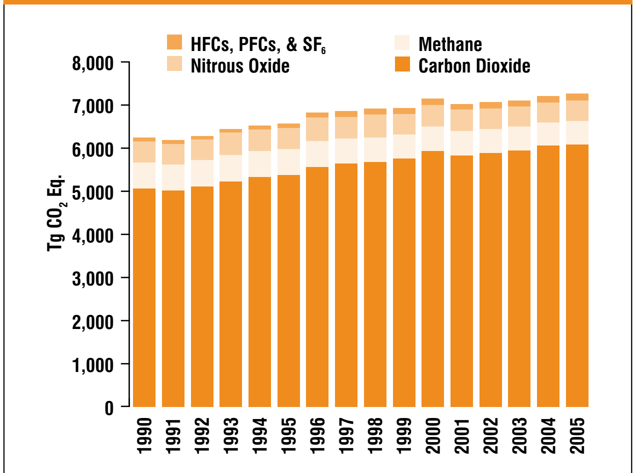
2.1. Recent Trends in U.S. Greenhouse Gas Emissions

In 2005, total U.S. greenhouse gas emissions were 7,260.4 teragrams of carbon dioxide equivalents (Tg CO_2 Eq.).[1] 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. Figure 2-1 through Figure 2-3 illustrate the overall trends in total U.S. emissions by gas,[2] annual changes, and absolute changes since 1990.

As the largest source of U.S. greenhouse gas emissions, carbon dioxide (CO_2) from fossil fuel combustion has accounted for approximately 77 percent of global warming potential (GWP) weighted emissions since 1990, growing slowly from 76 percent of total GWP-weighted emissions in 1990 to 79 percent in 2005. Emissions from this source category grew by 21.7 percent (1,027.1 Tg CO_2 Eq.) from 1990 to 2005 and were responsible for most of the increase in national emissions during this period. From 2004 to 2005, these emissions increased by 0.7 percent (38.2 Tg CO_2 Eq.), slightly less than the source's average annual growth rate of 1.4 percent from 1990 through 2005. Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

Figure 2-1

U.S. Greenhouse Gas Emissions by Gas



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.

[1] Estimates are presented in units of teragrams of carbon dioxide equivalent (Tg CO_2 Eq.), which weight each gas by its global warming potential, or GWP, value. (See section on global warming potentials, Chapter 1.)

[2] See the following section for an analysis of emission trends by general economic sector.

Figure 2-2

Annual Percent Change in U.S. Greenhouse Gas Emissions

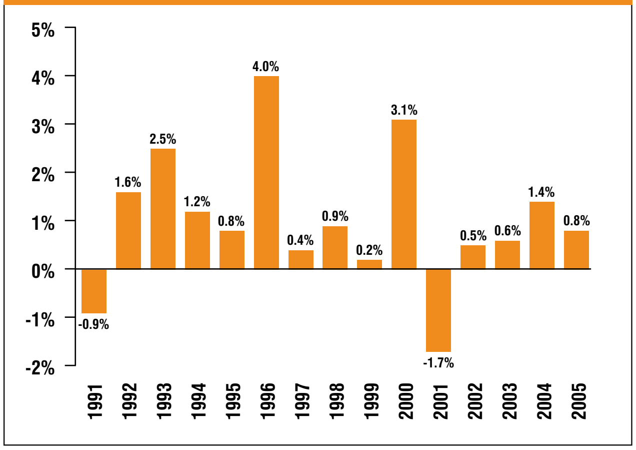
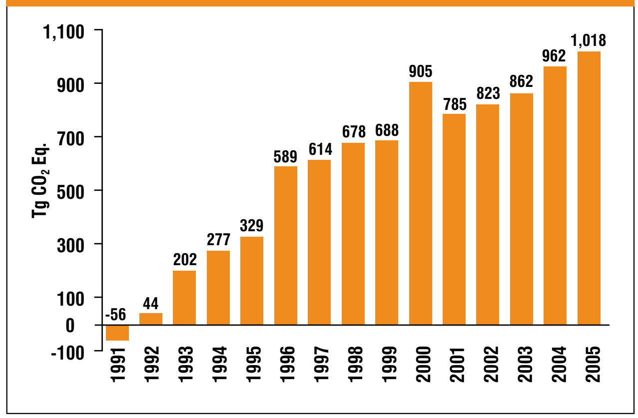


Figure 2-3

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



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 in a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

In the longer-term, energy consumption patterns respond to changes that affect the scale of consumption (e.g., population, number of cars, and size of houses), the efficiency with which energy is used in equipment (e.g., cars, power plants, steel mills, and light bulbs) and consumer behavior (e.g., walking, bicycling, or telecommuting to work instead of driving).

Energy-related CO_2 emissions also depend on the type of fuel or energy consumed and its carbon (C) intensity. Producing a unit of heat or electricity using natural gas instead of coal, for example, can reduce the CO_2 emissions because of the lower C content of natural gas. Table 2-1 shows annual changes in emissions during the last five years for coal, petroleum, and natural gas in selected sectors.

After emissions significantly decreased in 2001 due to the economic slowdown, emissions from fuel combustion resumed modest growth in 2002, slightly less than the average annual growth rate since 1990. There were a number of reasons behind this increase. The U.S. economy experienced moderate growth, recovering from weak economic conditions in 2001. Prices for fuels remained at or below 2001 levels; the cost of natural gas, motor gasoline, and electricity were all lower—triggering an increase in demand for fuel. In addition, the United States experienced one of the hottest summers on record, causing a significant increase in electricity use in the residential sector as the use of air-conditioners increased. Partially offsetting this increased consumption of fossil fuels, however, were

Table 2-1: Annual Change in CO_2 Emissions from Fossil Fuel Combustion for Selected Fuels and Sectors (Tg CO_2 Eq. and Percent)

Sector	Fuel Type	2001 to 2002		2002 to 2003		2003 to 2004		2004 to 2005	
Electricity Generation	Coal	16.0	0.9%	38.0	2.0%	11.4	0.6%	40.8	2.1%
Electricity Generation	Natural Gas	16.1	5.5%	-27.7	-9.0%	18.4	6.6%	22.4	7.5%
Electricity Generation	Petroleum	-22.9	-22.5%	19.0	24.0%	2.0	2.0%	2.2	2.2%
Transportation[a]	Petroleum	51.8	3.0%	2.0	0.1%	55.1	3.1%	28.8	1.6%
Residential	Natural Gas	6.4	2.5%	11.5	4.3%	-12.2	-4.4%	-3.4	-1.3%
Commercial	Natural Gas	6.6	4.0%	2.6	1.5%	-3.1	-1.8%	-4.2	-2.5%
Industrial	Coal	-10.1	-7.6%	0.6	0.5%	2.3	1.8%	-4.0	-3.2%
Industrial	Natural Gas	9.4	2.2%	-14.5	-3.3%	0.6	0.1%	-34.8	-8.2%
All Sectors[b]	**All Fuels[b]**	**45.5**	**0.8%**	**67.3**	**1.2%**	**88.5**	**1.6%**	**38.2**	**0.7%**

[a] Excludes emissions from International Bunker Fuels.
[b] Includes fuels and sectors not shown in table (see Table 3-3 for complete list of fuels by sector).

increases in the use of nuclear and renewable fuels. Nuclear facilities operated at the highest capacity on record in 2002. Furthermore, there was a considerable increase in the use of hydroelectric power in 2002 after a very low output the previous year.

Emissions from fuel combustion continued growing in 2003, at about the average annual growth rate since 1990. A number of factors played a major role in the magnitude of this increase. The U.S. economy experienced moderate growth from 2002, causing an increase in the demand for fuels. The price of natural gas escalated dramatically, causing some electric power producers to switch to coal, which remained at relatively stable prices. Colder winter conditions brought on more demand for heating fuels, primarily in the residential sector. Though a cooler summer partially offset demand for electricity as the use of air-conditioners decreased, electricity consumption continued to increase in 2003. The primary drivers behind this trend were the growing economy and the increase in U.S. housing stock. Nuclear capacity decreased slightly, for the first time since 1997. Use of renewable fuels rose slightly due to increases in the use of hydroelectric power and biofuels.

From 2003 to 2004, these emissions increased at a rate slightly higher than the average growth rate since 1990. A number of factors played a major role in the magnitude of this increase. A primary reason behind this trend was strong growth in the U.S. economy and industrial production, particularly in energy-intensive industries, causing an increase in the demand for electricity and fossil fuels. Demand for travel was also higher, causing an increase in petroleum consumed for transportation. In contrast, the warmer winter conditions led to decreases in demand for heating fuels, principally natural gas, in both the residential and commercial sectors. Moreover, much of the increased electricity demanded was generated by natural gas combustion and nuclear power, which moderated the increase in CO_2 emissions from electricity generation. Use of renewable fuels rose very slightly due to increases in the use of biofuels.

Emissions from fuel combustion increased from 2004 to 2005 at a rate slightly lower than the average annual growth rate since 1990. A number of factors played a role in this slight increase. This small increase is primarily a result of the restraint on fuel consumption, primarily in the transportation sector, caused by rising fuel prices. Although electricity prices increased slightly, there was a significant increase in electricity consumption in the residential and commercial sectors due to warmer summer weather conditions. This led to an increase in emissions in these sectors with the increased use of air-conditioners. As electricity emissions increased among all end-use sectors, the fuels used to generate electricity increased as well. Despite a slight decrease in industrial energy-related emissions, industrial production and manufacturing output actually increased. The price of natural gas escalated dramatically, causing a decrease in consumption of natural gas in the industrial sector. Use of renewable fuels decreased slightly due to decreased use of biofuels and decreased electricity output by hydroelectric power plants.

Other significant trends in emissions from additional source categories over the fifteen-year period from 1990 through 2005 included the following:

- CO_2 emissions from waste combustion increased by 10.0 Tg CO_2 Eq. (91percent), 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 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 period, while the rate of C accumulation in urban trees increased.
- Methane (CH_4) emissions from coal mining declined by 29.5 Tg CO_2 Eq. (36 percent) from 1990 to 2005 as a result of the mining of less gassy coal from underground mines and the increased combustion of CH_4 collected from degasification systems.
- From 1990 to 2005, nitrous oxide (N_2O) emissions from mobile combustion decreased by 13.1 percent. However, from 1990 to 1998 emissions increased by 26 percent, due to control technologies that reduced CH_4 emissions while increasing N_2O emissions. Since 1998, new control technologies have led to a steady decline in N_2O from this source.
- Emissions resulting from the substitution of ozone depleting substances (ODS, e.g., chlorofluorocarbons

Box 2-1: 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 2-2 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. Greenhouse gas emissions in the United States have grown at an average annual rate of 1.1 percent since 1990. This rate is 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 2-4).

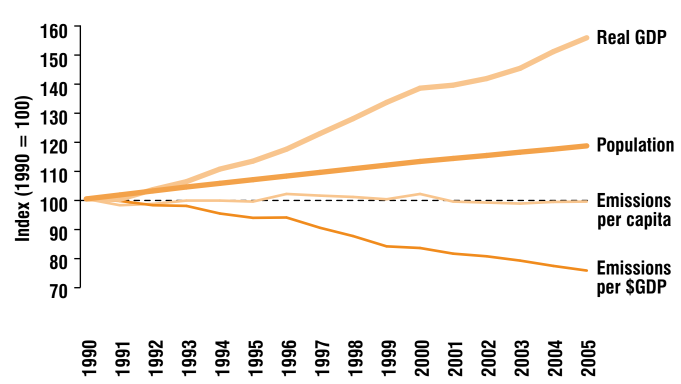
Table 2-2: Recent Trends in Various U.S. Data (Index 1990 = 100)

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 2-4

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



Source: BEA (2006), U.S. Census Bureau (2006), and emission estimates in the this report.

[CFCs]) have increased dramatically, from small amounts in 1990 to 123.3 Tg CO_2 Eq. in 2005. These emissions have been increasing as phase-outs of ODS required under the Montreal Protocol come into effect.

- The increase in ODS substitutes emissions is offset substantially by decreases in emission of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (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 to 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.

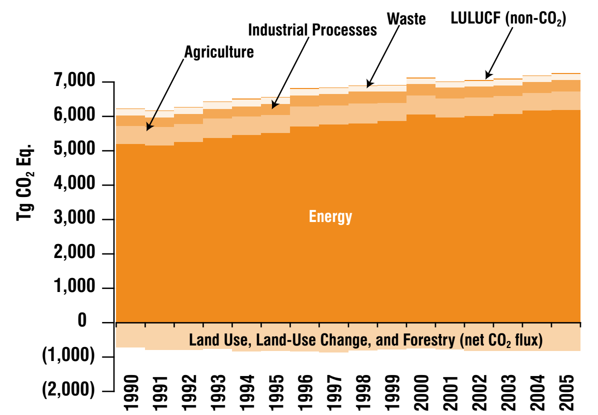
Overall, from 1990 to 2005, total emissions of CO_2 increased by 1,027.9 Tg CO_2 Eq. (20 percent), while CH_4 and N_2O emissions decreased by 69.8 Tg CO_2 Eq. (11 percent) and 13.4 Tg CO_2 Eq. (2.8 percent) respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 73.7 Tg CO_2 Eq. (82.5 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF_6 are significant because many of them have extremely high GWPs and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by C sequestration in managed forests, trees in urban areas, agricultural soils, and landfilled yard trimmings, which was estimated to be 11 percent of total emissions in 2005.

Table 2-3 summarizes emissions and sinks from all U.S. anthropogenic sources in weighted units of Tg CO_2 Eq., while unweighted gas emissions and sinks in gigagrams (Gg) are provided in Table 2-4. Figure 2-5 and Table 2-5 show emissions and sinks aggregated by sector/chapter.

Emissions of all gases can be summed from each source category from Intergovernmental Panel on Climate Change (IPCC) guidance. Over the fifteen-year period of 1990 to 2005, total emissions in the Energy, Industrial Processes, and Agriculture sectors climbed by 1,001.5 Tg CO_2 Eq. (19 percent), 33.6 Tg CO_2 Eq. (11 percent), and 6.0 Tg CO_2 Eq. (1.1 percent), respectively. Emissions decreased from the Solvent and Other Product Use and Waste sectors by 0.02 Tg CO_2 Eq. (less than 1 percent) and 26.7 Tg CO_2 Eq. (14 percent), respectively. Over the same period, estimates of net C sequestration in the Land Use, Land-Use Change, and Forestry sector increased by 109.5 Tg CO_2 Eq. (16 percent).

Figure 2-5

U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector



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

Table 2-3: 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
CO_2 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
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry[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
Ferroalloy Production	+	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+	+
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
Municipal Solid Waste Combustion	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.4	0.4	0.5	0.5
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] 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. Parentheses indicate negative values or sequestration.

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

Note: Totals may not sum due to independent rounding.

Table 2-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Gg)

Gas/Source	1990	1995	2000	2001	2002	2003	2004	2005
CO_2	**5,061,634**	**5,384,615**	**5,939,968**	**5,843,025**	**5,892,744**	**5,952,538**	**6,064,329**	**6,089,490**
Fossil Fuel Combustion	4,724,149	5,030,036	5,584,880	5,511,719	5,557,242	5,624,500	5,713,018	5,751,200
Non-Energy Use of Fuels	117,307	133,228	141,005	131,375	135,327	131,334	150,208	142,368
Cement Manufacture	33,278	36,847	41,190	41,357	42,898	43,082	45,603	45,910
Iron and Steel Production	84,904	73,333	65,115	57,927	54,595	53,370	51,309	45,235
Natural Gas Systems	33,729	33,807	29,390	28,793	29,630	28,445	28,190	28,185
Municipal Solid Waste Combustion	10,950	15,712	17,889	18,344	18,513	19,490	20,115	20,912
Ammonia Manufacture and Urea Application	19,306	20,453	19,616	16,719	17,766	16,173	16,894	16,321
Lime Manufacture	11,273	12,844	13,344	12,861	12,330	13,022	13,728	13,660
Limestone and Dolomite Use	5,533	7,359	5,960	5,733	5,885	4,720	6,702	7,397
Soda Ash Manufacture and Consumption	4,141	4,304	4,181	4,147	4,139	4,111	4,205	4,228
Aluminum Production	6,831	5,659	6,086	4,381	4,490	4,503	4,231	4,208
Petrochemical Production	2,221	2,750	3,004	2,787	2,857	2,777	2,895	2,897
Titanium Dioxide Production	1,308	1,670	1,918	1,857	1,997	2,013	2,259	1,921
Ferroalloy Production	2,152	2,036	1,893	1,459	1,349	1,305	1,419	1,392
Phosphoric Acid Production	1,529	1,513	1,382	1,264	1,338	1,382	1,395	1,383
CO_2 Consumption	1,415	1,423	1,416	825	978	1,310	1,199	1,324
Zinc Production	949	1,013	1,140	986	937	507	477	465
Lead Production	285	298	311	293	290	289	259	265
Silicon Carbide Production and Consumption	375	329	248	199	183	202	224	219
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry[a]	*(712,778)*	*(828,798)*	*(756,705)*	*(767,472)*	*(811,892)*	*(811,945)*	*(824,785)*	*(828,453)*
International Bunker Fuels[b]	*113,683*	*100,627*	*101,125*	*97,563*	*89,101*	*83,690*	*97,177*	*97,191*
Wood Biomass and Ethanol Consumption[b]	*219,341*	*236,775*	*228,308*	*203,163*	*204,351*	*209,603*	*224,825*	*206,475*
CH_4	**29,003**	**28,509**	**26,842**	**26,080**	**26,176**	**26,154**	**25,727**	**25,681**
Landfills	7,668	7,479	6,280	6,078	6,210	6,425	6,292	6,286
Enteric Fermentation	5,510	5,744	5,404	5,356	5,361	5,379	5,262	5,340
Natural Gas Systems	5,927	6,101	6,027	5,971	5,951	5,891	5,669	5,292
Coal Mining	3,899	3,165	2,662	2,644	2,476	2,480	2,597	2,494
Manure Management	1,471	1,673	1,844	1,911	1,959	1,928	1,892	1,966
Petroleum Systems	1,640	1,482	1,325	1,303	1,275	1,229	1,209	1,357
Wastewater Treatment	1,180	1,195	1,257	1,232	1,229	1,220	1,222	1,210
Forest Land Remaining Forest Land	337	189	667	285	494	384	330	551
Stationary Combustion	382	373	351	324	324	334	340	330
Rice Cultivation	339	363	357	364	325	328	360	328
Abandoned Underground Coal Mines	286	391	349	318	292	282	275	263
Mobile Combustion	226	207	165	154	146	136	131	125
Petrochemical Production	41	52	58	51	52	51	55	51
Iron and Steel Production	63	62	57	51	48	49	50	45
Field Burning of Agricultural Residues	33	32	38	37	34	38	42	41
Ferroalloy Production	1	1	1	+	+	+	+	+
Silicon Carbide Production and Consumption	1	1	1	+	+	+	+	+
International Bunker Fuels[b]	*8*	*6*	*6*	*5*	*4*	*4*	*5*	*5*
N_2O	**1,555**	**1,562**	**1,612**	**1,621**	**1,546**	**1,483**	**1,436**	**1,512**
Agricultural Soil Management	1,184	1,140	1,215	1,255	1,181	1,130	1,093	1,178
Mobile Combustion	141	173	172	160	152	141	133	123
Nitric Acid Production	58	64	63	51	56	54	52	51
Stationary Combustion	40	41	45	44	43	44	45	45
Manure Management	28	29	31	32	31	30	30	31
Wastewater Treatment	21	22	24	25	25	25	26	26
Adipic Acid Production	49	56	19	16	19	20	19	19
Settlements Remaining Settlements	17	18	18	18	18	19	19	19
N_2O Product Usage	14	14	15	15	14	14	14	14
Forest Land Remaining Forest Land	2	2	6	3	5	4	3	5
Municipal Solid Waste Combustion	2	1	1	1	1	1	1	1
Field Burning of Agricultural Residues	1	1	1	1	1	1	2	2
International Bunker Fuels[b]	*3*	*3*	*3*	*3*	*3*	*2*	*3*	*3*
HFCs, PFCs, and SF_6	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Substitution of Ozone Depleting Substances	M	M	M	M	M	M	M	M
HCFC-22 Production	3	2	3	2	2	1	1	1
Electrical Transmission and Distribution	1	1	1	1	1	1	1	1
Semiconductor Manufacture	M	M	M	M	M	M	M	M
Aluminum Production	M	M	M	M	M	M	M	M
Magnesium Production and Processing	+	+	+	+	+	+	+	+

+ Does not exceed 0.5 Gg.

M Mixture of multiple gases.

[a] 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. Parentheses indicate negative values or sequestration.

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

Note: Totals may not sum due to independent rounding.

Table 2-5: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg CO_2 Eq.)

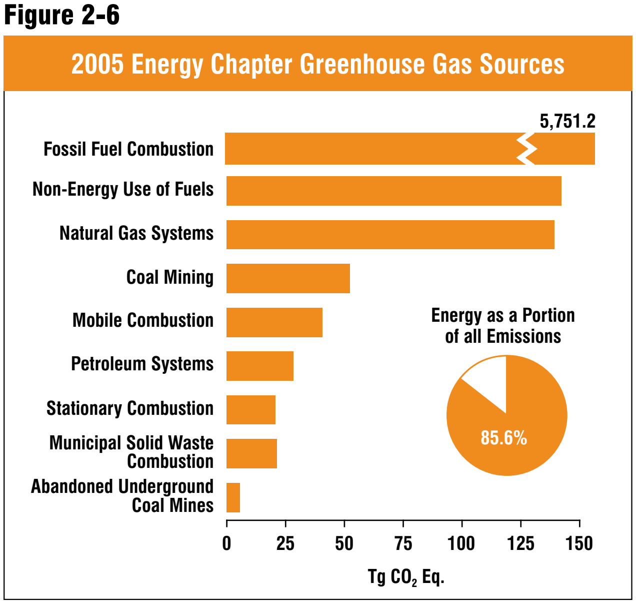
Chapter/IPCC Sector	1990	1995	2000	2001	2002	2003	2004	2005
Energy	5,202.2	5,525.8	6,069.2	5,978.9	6,021.4	6,079.1	6,181.7	6,201.9
Industrial Processes	300.1	314.8	338.7	309.6	320.2	316.4	330.6	333.6
Solvent and Other Product Use	4.3	4.5	4.8	4.8	4.3	4.3	4.3	4.3
Agriculture	530.3	526.8	547.4	560.3	537.4	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.
Note: Parentheses indicate negative values or sequestration.

Energy

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 2-6 and Figure 2-7). A discussion of specific trends related to CO_2 as well as other greenhouse gas emissions from energy consumption is presented below. 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). Table 2-6 presents greenhouse gas emissions from the Energy chapter, by source and gas.

Figure 2-6



Fossil Fuel Combustion (5,751.2 Tg CO_2 Eq.)

As fossil fuels are combusted, the C stored in them is emitted almost entirely as CO_2. The amount of C in fuels per unit of energy content varies significantly by fuel type. For example, coal contains the highest amount of C per unit of energy, while petroleum and natural gas have about 25 percent and 45 percent less C than coal, respectively. From 1990 through 2005, petroleum supplied the largest share of U.S. energy demands, accounting for an average of 44 percent of total energy consumption, with natural gas and coal each accounting for 28 percent of total energy consumption. Petroleum was consumed primarily in the transportation end-use sector, the vast majority of coal was used by electric power generators, and natural gas was consumed largely in the industrial and residential end-use sectors.

Emissions of CO_2 from fossil fuel combustion increased at an average annual rate of 1.4 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 growth in emissions from electricity generation and transportation activities. Between 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.

The four major end-use sectors contributing to CO_2 emissions from fossil fuel combustion are industrial, transportation, residential, and commercial. Electricity generation also emits CO_2, although these emissions are produced as 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

Figure 2-7

2005 U.S. Fossil Carbon Flows (Tg CO_2 Eq.)

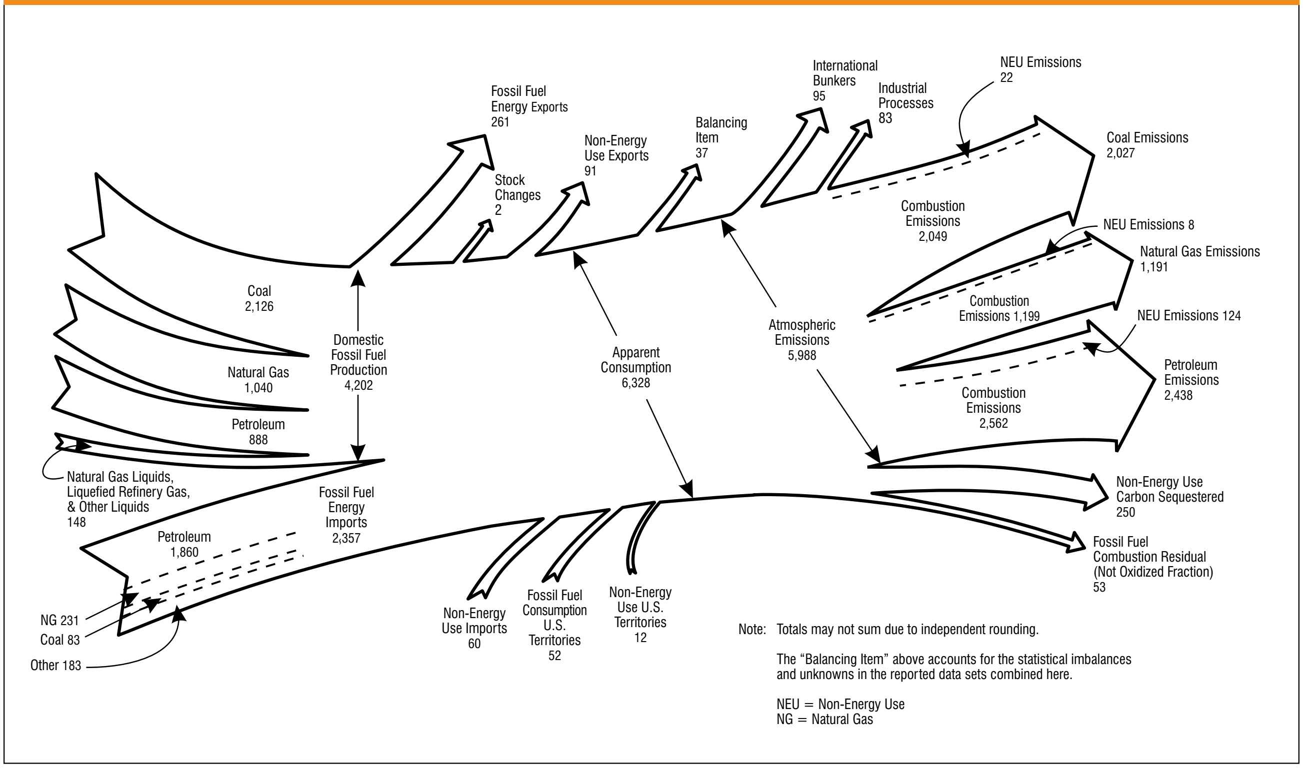


Table 2-6: Emissions from Energy (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2001	2002	2003	2004	2005
CO_2	**4,886.1**	**5,212.8**	**5,773.2**	**5,690.2**	**5,740.7**	**5,803.8**	**5,911.5**	**5,942.7**
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
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
*International Bunker Fuels**	*113.7*	*100.6*	*101.1*	*97.6*	*89.1*	*83.7*	*97.2*	*97.2*
*Wood Biomass and Ethanol Consumption**	*219.3*	*236.8*	*228.3*	*203.2*	*204.4*	*209.6*	*224.8*	*206.5*
CH_4	**259.6**	**246.1**	**228.5**	**225.0**	**219.7**	**217.4**	**214.6**	**207.1**
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
Petroleum Systems	34.4	31.1	27.8	27.4	26.8	25.8	25.4	28.5
Stationary Combustion	8.0	7.8	7.4	6.8	6.8	7.0	7.1	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
*International Bunker Fuels**	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**56.5**	**66.9**	**67.6**	**63.6**	**60.9**	**57.9**	**55.5**	**52.2**
Mobile Combustion	43.7	53.7	53.2	49.7	47.1	43.8	41.2	38.0
Stationary Combustion	12.3	12.8	14.0	13.5	13.4	13.7	13.9	13.8
Municipal Solid Waste Combustion	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
*International Bunker Fuels**	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*	*0.9*	*0.9*
Total	**5,202.2**	**5,525.8**	**6,069.2**	**5,978.9**	**6,021.4**	**6,079.1**	**6,181.7**	**6,201.9**

* These values are presented for informational purposes only and are not included in totals or are already accounted for in other source categories.
Note: Totals may not sum due to independent rounding.

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 C 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.

Table 2-7, Figure 2-8, and Figure 2-9 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.[3] 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

Table 2-7: 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.

Figure 2-8

2005 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

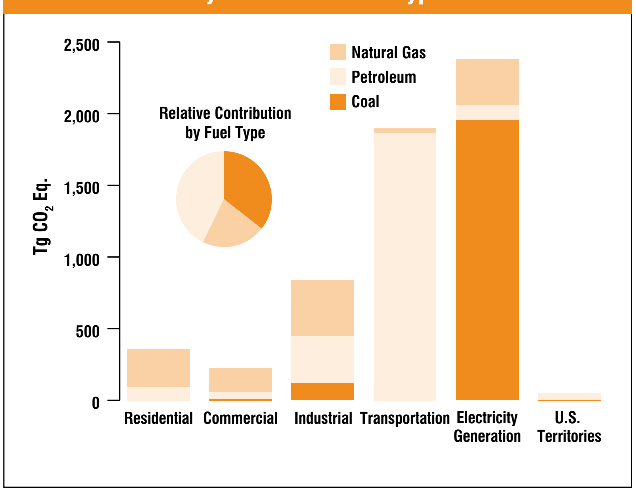
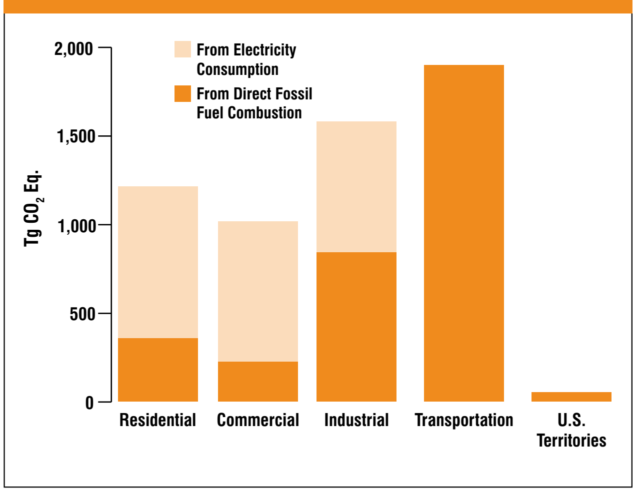


Figure 2-9

2005 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion



[3] 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.

transportation activities, including the combustion of diesel fuel in heavy-duty vehicles and jet fuel in aircraft.

Industrial End-Use Sector. Industrial CO_2 emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity that is consumed by industry, accounted for 27 percent of CO_2 emissions 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 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.

Non-Energy Use of Fossil Fuels (142.4 Tg CO_2 Eq.)

In addition to being combusted for energy, fossil fuels are also consumed for non-energy uses (NEUs). Fuels are used in the industrial and transportation end-use sectors for a variety of NEUs, including application as solvents, lubricants, and waxes, or as raw materials in the manufacture of plastics, rubber, and synthetic fibers. CO_2 emissions arise from non-energy uses via several pathways. Emissions may occur during the manufacture of a product, as is the case in producing plastics or rubber from fuel-derived feedstocks. Additionally, emissions may occur during the product's lifetime, such as during solvent use. Where appropriate data and methodologies are available, NEUs of fossil fuels used for industrial processes are reported in the Industrial Processes chapter. Emissions in 2005 for non-energy uses of fossil fuels were 142.4 Tg CO_2 Eq., which constituted 2.5 percent of overall fossil fuel CO_2 emissions and 2 percent of total national CO_2 emissions, approximately the same proportion as in 1990. CO_2 emissions from non-energy use of fossil fuels increased by 25.1 Tg CO_2 Eq. (21 percent) from 1990 through 2005.

Natural Gas Systems (139.3 Tg CO_2 Eq.)

CH_4 and non-energy CO_2 emissions from natural gas systems are generally process-related, with normal operations, routine maintenance, and system upsets being the primary contributors. Emissions from normal operations include: natural gas engines and turbine uncombusted exhaust, bleed and discharge emissions from pneumatic devices, and fugitive emissions from system components. Routine maintenance emissions originate from pipelines, equipment, and wells during repair and maintenance activities. Pressure surge relief systems and accidents can lead to system upset emissions. In 2005, CH_4 emissions from U.S. natural gas systems accounted for approximately 21 percent of U.S. CH_4 emissions. Also in 2005, natural gas systems accounted for approximately 0.5 percent of U.S. CO_2 emissions (28.2 Tg CO_2 Eq.). From 1990 through 2005, CH_4 and CO_2 emissions from natural gas systems decreased by 13.3 Tg CO_2 Eq. (11 percent), and 5.5 Tg CO_2 Eq. (16 percent) respectively.

Coal Mining (52.4 Tg CO_2 Eq.)

Produced millions of years ago during the formation of coal, CH_4 trapped within coal seams and surrounding rock strata is released when the coal is mined. The quantity of CH_4 released to the atmosphere during coal mining operations depends primarily upon the type of coal and the method and rate of mining.

CH_4 from surface mines is emitted directly to the atmosphere as the rock strata overlying the coal seam are removed. Because CH_4 in underground mines is explosive at concentrations of 5 to 15 percent in air, most active underground mines are required to vent this CH_4, typically to the atmosphere. At some mines, CH_4-recovery systems may supplement these ventilation systems. During 2005, coal mining activities emitted 10 percent of U.S. CH_4 emissions. From 1990 to 2005, emissions from this source decreased by 29.5 Tg CO_2 Eq. (36 percent) due to increased use of the CH_4 collected by mine degasification systems and a general shift toward surface mining.

Mobile Combustion (40.6 Tg CO_2 Eq.)

In addition to CO_2, mobile combustion results in N_2O and CH_4 emissions. N_2O is a product of the reaction that occurs between nitrogen and oxygen during fuel combustion. The quantity emitted varies according to the type of fuel, technology, and pollution control device used, as well as maintenance and operating practices. For example, some types of catalytic converters installed to reduce motor vehicle pollution can promote the formation of N_2O. In 2005, N_2O emissions from mobile combustion were 38.0 Tg CO_2 Eq. (8 percent of U.S. N_2O emissions). From 1990 to 2005, N_2O emissions from mobile combustion decreased by 5.7 Tg CO_2 Eq. (13 percent). In 2005, CH_4 emissions were estimated to be 2.6 Tg CO_2 Eq. The combustion of gasoline in highway vehicles was responsible for the majority of the CH_4 emitted from mobile combustion. From 1990 to 2005, CH_4 emissions from mobile combustion decreased by 2.1 Tg CO_2 Eq. (45 percent).

Petroleum Systems (28.5 Tg CO_2 Eq.)

Petroleum is often found in the same geological structures as natural gas, and the two are often retrieved together. Crude oil is saturated with many lighter hydrocarbons, including CH_4. When the oil is brought to the surface and processed, many of the dissolved lighter hydrocarbons (as well as water) are removed through a series of high-pressure and low-pressure separators. The remaining hydrocarbons in the oil are emitted at various points along the system. CH_4 emissions from the components of petroleum systems generally occur as a result of system leaks, disruptions, and routine maintenance. In 2005, emissions from petroleum systems were about 5 percent of U.S. CH_4 emissions. From 1990 to 2005, CH_4 emissions from petroleum systems decreased by 6 Tg CO_2 Eq. (17 percent).

Municipal Solid Waste Combustion (21.3 Tg CO_2 Eq.)

Combustion is used to manage about 14 percent of the municipal solid waste generated in the United States. The burning of garbage and non-hazardous solids, referred to as municipal solid waste, as well as the burning of hazardous waste, is usually performed to recover energy from the waste materials. CO_2 and N_2O emissions arise from the organic materials found in these wastes. The CO_2 emissions from municipal solid waste containing C of biogenic origin (e.g., paper, yard trimmings) are not accounted for in this Inventory, since they are presumed to be offset by regrowth of the original living source, and are ultimately accounted for in the Land Use, Land-Use Change, and Forestry chapter. Several components of municipal solid waste, such as plastics, synthetic rubber, synthetic fibers, and carbon black, are of fossil-fuel origin, and are included as sources of CO_2 and N_2O emissions. In 2005, CO_2 emissions from waste combustion amounted to 20.9 Tg CO_2 Eq., while N_2O emissions amounted to 0.4 Tg CO_2 Eq. From 1990 through 2005, CO_2 emissions from waste combustion increased by 10 Tg CO_2 Eq. (91 percent), while N_2O emissions decreased by 0.1 Tg CO_2 Eq. (15 percent).

Stationary Combustion (20.7 Tg CO_2 Eq.)

In addition to CO_2, stationary combustion results in N_2O and CH_4 emissions. In 2005, N_2O emissions from stationary combustion accounted for 13.8 Tg CO_2 Eq. (3 percent of U.S. N_2O emissions). From 1990 to 2005, N_2O emissions from stationary combustion increased by 1.5 Tg CO_2 Eq. (12 percent), due to increased fuel consumption. In 2005, CH_4 emissions were 6.9 Tg CO_2 Eq. (1 percent of U.S. CH_4 emissions). From 1990 to 2005, CH_4 emissions from stationary combustion decreased by 1.1 Tg CO_2 Eq. (13.5 percent). The majority of CH_4 emissions from stationary combustion resulted from the burning of wood in the residential end-use sector.

Abandoned Underground Coal Mines (5.5 Tg CO_2 Eq.)

Coal mining activities result in the emission of CH_4 into the atmosphere. However, the closure of a coal mine does not correspond with an immediate cessation in the release of emissions. Following an initial decline, abandoned mines can liberate CH_4 at a near-steady rate over an extended period of time, or, if flooded, produce gas for only a few years. In 2005, the emissions from abandoned underground coal mines constituted 1 percent of U.S. CH_4 emissions. Between 1990 and 2005, emissions from this source decreased by 0.5 Tg CO_2 Eq. (8 percent).

Wood Biomass and Ethanol Consumption (206.5 Tg CO_2 Eq.)

Biomass refers to organically-based C fuels (as opposed to fossil-based). Biomass in the form of fuel wood and wood waste was used primarily in the industrial sector, while the transportation sector was the predominant user of biomass-based fuels, such as ethanol from corn and woody crops.

Although these fuels do emit CO_2, in the long run the CO_2 emitted from biomass consumption does not increase atmospheric CO_2 concentrations if the biogenic C emitted is offset by the growth of new biomass. For example, fuel wood burned one year but re-grown the next only recycles C, rather than creating a net increase in total atmospheric C. Net C fluxes from changes in biogenic C reservoirs in forest lands or croplands are accounted for in the estimates for the Land Use, Land-Use Change, and Forestry sector. As a result, CO_2 emissions from biomass combustion have been estimated separately from fossil-fuel-based emissions and are not included in the U.S. totals. CH_4 emissions from biomass combustion are included in the Stationary Combustion source.

The consumption of wood biomass in the industrial, residential, electric power, and commercial end-use sectors accounted for 56, 21, 8, and 4 percent of gross CO_2 emissions from wood biomass and ethanol consumption, respectively. Ethanol consumption in the transportation end-use sector accounted for the remaining 11 percent.

CO_2 emissions from wood biomass and ethanol consumption decreased by 12.9 Tg CO_2 Eq. (approximately 6 percent) from 1990 through 2005.

International Bunker Fuels (98.2 Tg CO_2 Eq.)

Greenhouse gases emitted from the combustion of fuels used for international transport activities, termed international bunker fuels under the UNFCCC, include CO_2, CH_4, and N_2O. Emissions from these activities are currently not included in national emission totals, but are reported separately based upon location of fuel sales. The decision to report emissions from international bunker fuels separately, instead of allocating them to a particular country, was made by the Intergovernmental Negotiating Committee in establishing the Framework Convention on Climate Change. These decisions are reflected in the *Revised 1996 IPCC Guidelines*, in which countries are requested to report emissions from ships or aircraft that depart from their ports with fuel purchased within national boundaries and are engaged in international transport separately from national totals (IPCC/UNEP/OECD/IEA 1997).

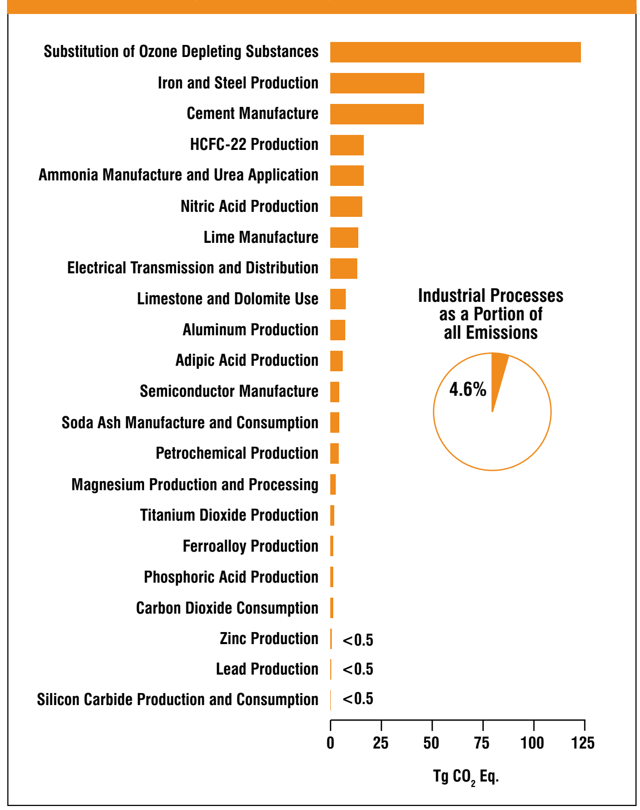
Two transport modes are addressed under the IPCC definition of international bunker fuels: aviation and marine. Emissions from ground transport activities—by road vehicles and trains, even when crossing international borders—are allocated to the country where the fuel was loaded into the vehicle and, therefore, are not counted as bunker fuel emissions. Emissions of CO_2, CH_4, and N_2O from international bunker fuel combustion were 97.2, 0.1, and 0.9 Tg CO_2 Eq. in 2005, respectively. From 1990 through 2005, CO_2, CH_4, and N_2O emissions from international bunker fuels decreased by 16.5 Tg CO_2 Eq. (15 percent), 0.1 Tg CO_2 Eq. (35 percent), and 0.1 Tg CO_2 Eq. (9 percent), respectively.

Industrial Processes

Emissions are produced as a by-product of many non-energy-related industrial process activities. For example, industrial processes can chemically transform raw materials, which often release waste gases such as CO_2, CH_4, and N_2O. These processes include iron and steel 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

Figure 2-10

2005 Industrial Processes Chapter Greenhouse Gas Sources



consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production (see Figure 2-10). Additionally, emissions from industrial processes release HFCs, PFCs and SF_6. Table 2-8 presents greenhouse gas emissions from industrial processes by source category.

Substitution of Ozone Depleting Substances (123.3 Tg CO_2 Eq.)

The use and subsequent emissions of HFCs and PFCs as substitutes for ODSs have increased from small amounts in 1990 to 123 Tg CO_2 Eq. in 2005, accounting for 76 percent of aggregate HFC, PFC, and SF_6 emissions, an increase of 36,899 percent over this time period. This increase was in large part the result of efforts to phase-out CFCs and other ODSs in the United States, especially the introduction of HFC-134a as a CFC substitute in refrigeration and air-conditioning applications. In the short term, this trend is expected to continue, and will likely accelerate over the coming decade as HCFCs, which are interim substitutes in many applications, are themselves phased-out under the provisions of the Copenhagen Amendments to the Montreal

Table 2-8: Emissions from Industrial Processes (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2001	2002	2003	2004	2005
CO_2	**175.5**	**171.8**	**166.8**	**152.8**	**152.0**	**148.8**	**152.8**	**146.8**
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
Ammonia Manufacture & 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
Aluminum Production	4.1	4.3	4.2	4.1	4.1	4.1	4.2	4.2
Soda Ash Manufacture and Consumption	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
Phosphoric Acid Production	2.2	2.0	1.9	1.5	1.3	1.3	1.4	1.4
Ferroalloy Production	1.5	1.5	1.4	1.3	1.3	1.4	1.4	1.4
CO_2 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
CH_4	**2.2**	**2.4**	**2.5**	**2.2**	**2.1**	**2.1**	**2.2**	**2.0**
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
Ferroalloy Production	+	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+	+
N_2O	**33.0**	**37.1**	**25.6**	**20.8**	**23.1**	**22.9**	**21.8**	**21.7**
Nitric Acid Production	17.8	19.9	19.6	15.9	17.2	16.7	16.0	15.7
Adipic Acid Production	15.2	17.2	6.0	4.9	5.9	6.2	5.7	6.0
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	**300.1**	**314.8**	**338.7**	**309.6**	**320.2**	**316.4**	**330.6**	**333.6**

+ Does not exceed 0.05 Tg CO_2 Eq.
Note: Totals may not sum due to independent rounding.

Protocol. Improvements in the technologies associated with the use of these gases and the introduction of alternative gases and technologies, however, may help to offset this anticipated increase in emissions.

Iron and Steel Production (46.2 Tg CO_2 Eq.)

Pig iron is the product of combining iron oxide (i.e., iron ore) and sinter with metallurgical coke in a blast furnace. The pig iron production process, as well as the thermal processes used to create sinter and metallurgical coke, results in emissions of CO_2 and CH_4. In 2005, iron and steel production resulted in 1.0 Tg CO_2 Eq. of CH_4 emissions, with the majority of the emissions coming from the pig iron production process. The majority of CO_2 emissions from iron and steel processes come from the production of coke for use in pig iron creation, with smaller amounts evolving from the removal of carbon from pig iron used to produce steel. CO_2 emissions from iron and steel amounted to 45.2 Tg CO_2 Eq. in 2005. From 1990 to 2005, CO_2 and CH_4 emissions from this source decreased by 39.7 Tg CO_2 Eq. (47 percent), and 0.4 Tg CO_2 Eq. (28 percent) respectively.

Cement Manufacture (45.9 Tg CO_2 Eq.)

Clinker is an intermediate product in the formation of finished portland and masonry cement. Heating calcium carbonate ($CaCO_3$) in a cement kiln forms lime and CO_2. The lime combines with other materials to produce clinker, and the CO_2 is released into the atmosphere. From 1990 to 2005, emissions from this source increased by 12.6 Tg CO_2 Eq. (38 percent).

HCFC-22 Production (16.5 Tg CO_2 Eq.)

HFC-23 is a by-product of the production of HCFC-22. Emissions from this source have decreased by 18.4 Tg CO_2 Eq. (53 percent) since 1990. The HFC-23 emission rate (i.e., the amount of HFC-23 emitted per kilogram of HCFC-22 manufactured) has declined significantly since 1990, although production has been increasing.

Ammonia Manufacture and Urea Application (16.3 Tg CO_2 Eq.)

In the United States, roughly 98 percent of synthetic ammonia is produced by catalytic steam reforming of natural gas, and the remainder is produced using naphtha (i.e., a petroleum fraction) or the electrolysis of brine at chlorine plants (EPA 1997). The two fossil fuel-based reactions produce carbon monoxide and hydrogen gas. This carbon monoxide is transformed into CO_2 in the presence of a catalyst. The CO_2 is generally released into the atmosphere, but some of the CO_2, together with ammonia, is used as a raw material in the production of urea [$CO(NH_2)_2$], which is a type of nitrogenous fertilizer. The carbon in the urea that is produced and assumed to be subsequently applied to agricultural land as a nitrogenous fertilizer is ultimately released into the environment as CO_2. Since 1990, CO_2 emissions from ammonia manufacture and urea application have decreased by 3.0 Tg CO_2 Eq. (15.5 percent).

Nitric Acid Production (15.7 Tg CO_2 Eq.)

Nitric acid production is an industrial source of N_2O emissions. Used primarily to make synthetic commercial fertilizer, this raw material is also a major component in the production of adipic acid and explosives. Virtually all of the nitric acid manufactured in the United States is produced by the oxidation of ammonia, during which N_2O is formed and emitted to the atmosphere. In 2005, N_2O emissions from nitric acid production accounted for 3 percent of U.S. N_2O emissions. From 1990 to 2005, emissions from this source category decreased by 2.2 Tg CO_2 Eq. (12 percent) with the trend in the time series closely tracking the changes in production.

Lime Manufacture (13.7 Tg CO_2 Eq.)

Lime is used in steel making, construction, flue gas desulfurization, and water and sewage treatment. It is manufactured by heating limestone (mostly $CaCO_3$) in a kiln, creating quicklime (calcium oxide, CaO) and CO_2, which is normally emitted to the atmosphere. From 1990 to 2005, CO_2 emissions from lime manufacture increased by 2.4 Tg CO_2 Eq. (21 percent).

Electrical Transmission and Distribution Systems (13.2 Tg CO_2 Eq.)

The primary use of SF_6 is as a dielectric in electrical transmission and distribution systems. Fugitive emissions of SF_6 occur from leaks in and servicing of substations and circuit breakers, especially from older equipment. The gas can also be released during equipment manufacturing, installation, servicing, and disposal. Estimated emissions from this source decreased by 13.9 Tg CO_2 Eq. (51 percent) since 1990, primarily due to higher SF_6 prices and industrial efforts to reduce emissions.

Limestone and Dolomite Use (7.4 Tg CO_2 Eq.)

Limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) are basic raw materials used in a wide variety of industries, including construction, agriculture, chemical, and metallurgy. For example, limestone can be used as a purifier in refining metals. In the case of iron ore, limestone heated in a blast furnace reacts with impurities in the iron ore and fuels, generating CO_2 as a by-product. Limestone is also used in flue gas desulfurization systems to remove sulfur dioxide from the exhaust gases. From 1990 to 2005, emissions from this source increased by 1.9 Tg CO_2 Eq. (34 percent).

Aluminum Production (7.2 Tg CO_2 Eq.)

Aluminum production results in emissions of CO_2, CF_4 and C_2F_6. CO_2 is emitted when alumina (aluminum oxide, Al_2O_3) is reduced to aluminum. The reduction of the alumina occurs through electrolysis in a molten bath of natural or synthetic cryolite. The reduction cells contain a carbon lining that serves as the cathode. Carbon is also contained in the anode, which can be a carbon mass of paste, coke briquettes, or prebaked carbon blocks from petroleum coke. During reduction, some of this carbon is oxidized and released to the atmosphere as CO_2. In 2005, CO_2 emissions from aluminum production amounted to 4.2 Tg CO_2 Eq. Since 1990, CO_2 emissions from this source have decreased by 2.6 Tg CO_2 Eq. (38 percent).

During the production of primary aluminum, CF_4 and C_2F_6 are emitted as intermittent by-products of the smelting process. These PFCs are formed when fluorine from the cryolite bath combines with carbon from the electrolyte anode. PFC emissions from aluminum production have decreased by 15.6 Tg CO_2 Eq. (84 percent) between 1990 and 2005 due to emission reduction efforts by the industry and falling domestic aluminum production, although there was a slight increase in emissions between 2004 and 2005, due to slightly higher production. In 2005, CF_4 and C_2F_6 emissions from aluminum production amounted to 3.0 Tg CO_2 Eq.

Adipic Acid Production (6.0 Tg CO_2 Eq.)

Most adipic acid produced in the United States is used to manufacture nylon 6,6. Adipic acid is also used to produce some low-temperature lubricants and to add a "tangy" flavor to foods. N_2O is emitted as a by-product of the chemical synthesis of adipic acid. In 2005, U.S. adipic acid plants emitted 1.3 percent of U.S. N_2O emissions. Even though adipic acid production has increased in recent years, by 1998 all three major adipic acid plants in the United States had voluntarily implemented N_2O abatement technology. As a result, emissions have decreased by 9.2 Tg CO_2 Eq. (61 percent) between 1990 and 2005.

Semiconductor Manufacture (4.3 Tg CO_2 Eq.)

The semiconductor industry uses combinations of HFCs, PFCs, SF_6, and other gases for plasma etching and to clean chemical vapor deposition tools. Emissions from this source category have increased 1.4 Tg CO_2 Eq. (48 percent) since 1990 with the growth in the semiconductor industry and the rising intricacy of chip designs. However, the growth rate in emissions has slowed since 1997, and emissions actually declined between 1999 and 2005. This later reduction is due to the implementation of PFC emission reduction methods, such as process optimization.

Soda Ash Manufacture and Consumption (4.2 Tg CO_2 Eq.)

Commercial soda ash (sodium carbonate, Na_2CO_3) is used in many consumer products, such as glass, soap and detergents, paper, textiles, and food. During the manufacturing of soda ash, some natural sources of sodium carbonate are heated and transformed into a crude soda ash, in which CO_2 is generated as a by-product. In addition, CO_2 is often released when the soda ash is consumed. From 1990 to 2005, emissions from this source increased by 0.1 Tg CO_2 Eq. (2 percent).

Petrochemical Production (4.0 Tg CO_2 Eq.)

The production process for carbon black results in the release CO_2 emissions to the atmosphere. Carbon black is a black powder generated by the incomplete combustion of an aromatic petroleum or coal-based feedstock production. The majority of carbon black produced in the United States is consumed by the tire industry, which adds it to rubber to increase strength and abrasion resistance. Small amounts of CH_4 are also released during the production of five petrochemicals: carbon black, ethylene, ethylene dichloride, styrene, and methanol. These production processes resulted in emissions of 2.9 Tg CO_2 Eq. of CO_2 and 1.1 Tg CO_2 Eq. of CH_4 in 2005. Emissions from this source increased by 0.9 Tg CO_2 Eq. (29 percent) between 1990 and 2005.

Magnesium Production and Processing (2.7 Tg CO_2 Eq.)

Sulfur hexafluoride is also used as a protective cover gas for the casting of molten magnesium. Emissions from primary magnesium production and magnesium casting have decreased by 2.8 Tg CO_2 Eq. (51 percent) since 1990. This decrease has primarily taken place since 1999, due to a decline in the quantity of magnesium die cast and the closure of a U.S. primary magnesium production facility.

Titanium Dioxide Production (1.9 Tg CO_2 Eq.)

Titanium dioxide (TiO_2) is a metal oxide manufactured from titanium ore, and is principally used as a pigment. It is used in white paint and as a pigment in the manufacture of white paper, foods, and other products. Two processes, the chloride process and the sulfate process, are used for making TiO_2. CO_2 is emitted from the chloride process, which uses petroleum coke and chlorine as raw materials. Since 1990, emissions from this source increased by 0.6 Tg CO_2 Eq. (47 percent).

Phosphoric Acid Production (1.4 Tg CO_2 Eq.)

Phosphoric acid is a basic raw material in the production of phosphate-based fertilizers. The phosphate rock consumed in the United States originates from both domestic mines, located primarily in Florida, North Carolina, Idaho, and Utah, and foreign mining operations in Morocco. The primary use of this material is as a basic component of a series of chemical reactions that lead to the production of phosphoric acid, as well as the by-products CO_2 and phosphogypsum. From 1990 to 2005, CO_2 emissions from phosphoric acid production decreased by 0.1 Tg CO_2 Eq. (9.5 percent).

Ferroalloy Production (1.4 Tg CO_2 Eq.)

CO_2 is emitted from the production of several ferroalloys. Ferroalloys are composites of iron and other elements such as silicon, manganese, and chromium. When incorporated in alloy steels, ferroalloys are used to alter the material properties of the steel. From 1990 to 2005, emissions from this source decreased by 0.8 Tg CO_2 Eq. (35 percent).

Carbon Dioxide Consumption (1.3 Tg CO_2 Eq.)

Many segments of the economy consume CO_2, including food processing, beverage manufacturing, chemical processing, and a host of industrial and other miscellaneous applications. CO_2 may be produced as a by-product from the production of certain chemicals (e.g., ammonia), from select natural gas wells, or by separating it from crude oil and natural gas. The majority of the CO_2 used in these applications is eventually released to the atmosphere. Since 1990, emissions from CO_2 consumption have decreased by 0.1 Tg CO_2 Eq. (6.5 percent).

Zinc Production (0.5 Tg CO_2 Eq.)

CO_2 emissions from the production of zinc in the United States occur through the primary production of zinc in the electro-thermic production process, or through the secondary production of zinc using a Waelz Kiln furnace or the electro-thermic production process. Both the electro-thermic and Waelz Kiln processes are emissive due to the use of a carbon-based material (often metallurgical coke); however, zinc is also produced in the United States using non-emissive processes. Due to the closure of an electro-thermic plant in 2003, the only emissive zinc production process remaining occurs through the recycling of electric-arc-furnace (EAF) dust in a Waelz Kiln furnace (secondary production) at a plant in Palmerton, Pennsylvania. From 1990 to 2005, CO_2 emissions from zinc production decreased by 0.5 Tg CO_2 Eq. (51 percent).

Lead Production (0.3 Tg CO_2 Eq.)

Primary and secondary production of lead in the United States results in CO_2 emissions when carbon-based materials (often metallurgical coke) are used as a reducing agent. Primary production involves the direct smelting of lead concentrates while secondary production largely occurs through the recycling of lead-acid batteries. In 2005, emissions from primary lead production decreased by 40 percent due to the closure of one of two primary lead production plants located in Missouri. Secondary lead production accounted for 86 percent of total lead production emissions in 2005. Since 1990, emissions from this source have decreased by 7.2 percent.

Silicon Carbide Production and Consumption (0.2 Tg CO_2 Eq.)

Small amounts of CH_4 are released during the production of silicon carbide (SiC), a material used as an industrial abrasive. Additionally, small amounts of CO_2 are released when SiC is consumed for metallurgical and other non-abrasive purposes (e.g., iron and steel production). Silicon carbide is made through a reaction of quartz (SiO_2) and carbon (in the form of petroleum coke). CH_4 is produced during this reaction from volatile compounds in the petroleum coke. CH_4 emissions from silicon carbide production have declined significantly due to a 67 percent decrease in silicon carbide production since 1990. CO_2 emissions from SiC

Table 2-9: N_2O Emissions from Solvent and Other Product Use (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2001	2002	2003	2004	2005
N_2O	**4.3**	**4.5**	**4.8**	**4.8**	**4.3**	**4.3**	**4.3**	**4.3**
N_2O Product Usage	4.3	4.5	4.8	4.8	4.3	4.3	4.3	4.3
Total	**4.3**	**4.5**	**4.8**	**4.8**	**4.3**	**4.3**	**4.3**	**4.3**

consumption have fluctuated significantly between years dependent on consumption, but overall have decreased by 42 percent since 1990.

Solvent and Other Product Use

Greenhouse gas emissions 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 chapter, accounted for 4.3 Tg CO_2 Eq. of N_2O, or less than 0.1 percent of total U.S. emissions in 2005 (see Table 2-9).

N_2O Product Usage (4.3 Tg CO_2 Eq.)

N_2O is used in carrier gases with oxygen to administer more potent inhalation anesthetics for general anesthesia and as an anesthetic in various dental and veterinary applications. As such, it is used to treat short-term pain, for sedation in minor elective surgeries, and as an induction anesthetic. The second main use of N_2O is as a propellant in pressure and aerosol products, the largest application being pressure-packaged whipped cream. In 2005, N_2O emissions from product usage constituted approximately 1 percent of U.S. N_2O emissions. From 1990 to 2005, emissions from this source category decreased by less than 1 percent.

Agriculture

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.

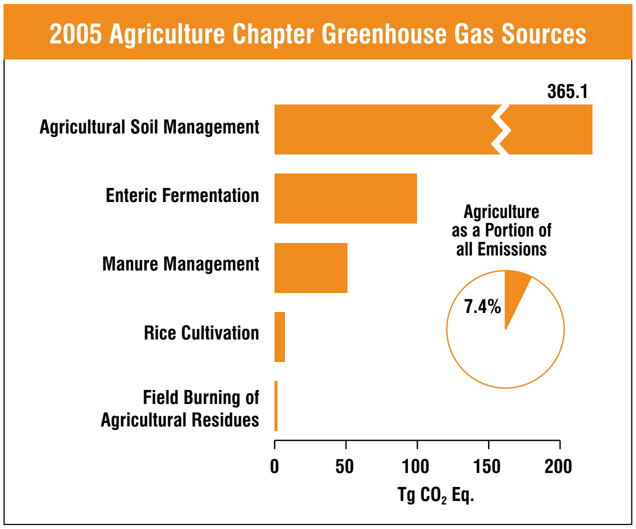
In 2005, agricultural activities were responsible for emissions of 536.3 Tg CO_2 Eq., or 7.4 percent of total U.S. greenhouse gas emissions. CH_4 and N_2O were the primary greenhouse gases emitted by agricultural activities. CH_4 emissions from enteric fermentation and manure management represented about 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. Table 2-10 and Figure 2-11 present emission estimates for the Agriculture chapter.

Table 2-10: Emissions from Agriculture (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2001	2002	2003	2004	2005
CH_4	**154.4**	**164.0**	**160.5**	**161.0**	**161.2**	**161.1**	**158.7**	**161.2**
Enteric Fermentation	115.7	120.6	113.5	112.5	112.6	113.0	110.5	112.1
Manure Management	30.9	35.1	38.7	40.1	41.1	40.5	39.7	41.3
Rice Cultivation	7.1	7.6	7.5	7.6	6.8	6.9	7.6	6.9
Field Burning of Agricultural Residues	0.7	0.7	0.8	0.8	0.7	0.8	0.9	0.9
N_2O	**375.9**	**362.7**	**386.9**	**399.2**	**376.3**	**359.9**	**348.7**	**375.1**
Agricultural Soil Management	366.9	353.4	376.8	389.0	366.1	350.2	338.8	365.1
Manure Management	8.6	9.0	9.6	9.8	9.7	9.3	9.4	9.5
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.4	0.4	0.5	0.5
Total	**530.3**	**526.8**	**547.4**	**560.3**	**537.4**	**521.1**	**507.4**	**536.3**

Note: Totals may not sum due to independent rounding.

Figure 2-11



Agricultural Soil Management (365.1 Tg CO_2 Eq.)

N_2O is produced naturally in soils through microbial nitrification and denitrification processes. A number of anthropogenic activities add to the amount of nitrogen available to be emitted as N_2O by microbial processes. These activities may add nitrogen to soils either directly or indirectly. Direct additions occur through the application of synthetic and organic fertilizers; production of nitrogen-fixing crops and forages; the application of livestock manure, crop residues, and sewage sludge; cultivation of high-organic-content soils; and direct excretion by animals onto soil. Indirect additions result from volatilization and subsequent atmospheric deposition, and from leaching and surface run-off of some of the nitrogen applied to or deposited on soils as fertilizer, livestock manure, and sewage sludge. In 2005, agricultural soil management accounted for 78 percent of U.S. N_2O emissions. From 1990 to 2005, emissions from this source decreased by 1.8 Tg CO_2 Eq. (0.5 percent); year-to-year fluctuations are largely a reflection of annual variations in weather, synthetic fertilizer consumption, and crop production.

Enteric Fermentation (112.1 Tg CO_2 Eq.)

During animal digestion, CH_4 is produced through the process of enteric fermentation, in which microbes residing in animal digestive systems break down food. Ruminants, which include cattle, buffalo, sheep, and goats, have the highest CH_4 emissions among all animal types because they have a rumen, or large fore-stomach, in which CH_4-producing fermentation occurs. Non-ruminant domestic animals, such as pigs and horses, have much lower CH_4 emissions. In 2005, enteric fermentation was the source of about 21 percent of U.S. CH_4 emissions, and about 70 percent of the CH_4 emissions from agriculture. From 1990 to 2005, emissions from this source decreased by 3.6 Tg CO_2 Eq. (3 percent). Generally, emissions have been decreasing since 1995, mainly due to decreasing populations of both beef and dairy cattle and improved feed quality for feedlot cattle.

Manure Management (50.8 Tg CO_2 Eq.)

Both CH_4 and N_2O result from manure management. The decomposition of organic animal waste in an anaerobic environment produces CH_4. The most important factor affecting the amount of CH_4 produced is how the manure is managed, because certain types of storage and treatment systems promote an oxygen-free environment. In particular, liquid systems tend to encourage anaerobic conditions and produce significant quantities of CH_4, whereas solid waste management approaches produce little or no CH_4. Higher temperatures and moist climatic conditions also promote CH_4 production.

CH_4 emissions from manure management were 41.3 Tg CO_2 Eq., or about 8 percent of U.S. CH_4 emissions in 2005 and 26 percent of the CH_4 emissions from agriculture. 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 of the swine and dairy industries towards larger facilities. Larger swine and dairy farms tend to use liquid management systems.

N_2O is also produced as part of microbial nitrification and denitrification processes in managed and unmanaged manure. Emissions from unmanaged manure are accounted for within the agricultural soil management source category. Total N_2O emissions from managed manure systems in 2005 accounted for 9.5 Tg CO_2 Eq., or 2 percent of U.S. N_2O emissions. From 1990 to 2005, emissions from this source category increased by 0.9 Tg CO_2 Eq. (10 percent), primarily due to increases in swine and poultry populations over the same period.

Rice Cultivation (6.9 Tg CO_2 Eq.)

Most of the world's rice, and all of the rice in the United States, is grown on flooded fields. When fields are flooded, anaerobic conditions develop and the organic matter in the soil decomposes, releasing CH_4 to the atmosphere, primarily through the rice plants. In 2005, rice cultivation was the source of 1 percent of U.S. CH_4 emissions, and about 4 percent of U.S. CH_4 emissions from agriculture. Emission estimates from this source have decreased about 3 percent since 1990.

Field Burning of Agricultural Residues (1.4 Tg CO_2 Eq.)

Burning crop residues releases N_2O and CH_4. Because field burning is not a common debris clearing method in the United States, it was responsible for only 0.2 percent of U.S. CH_4 (0.9 Tg CO_2 Eq.) and 0.1 percent of U.S. N_2O (0.5 Tg CO_2 Eq.) emissions in 2005. Since 1990, emissions from this source have increased by approximately 28 percent.

Land Use, Land-Use Change, and Forestry

When humans alter the terrestrial biosphere through land use, changes in land use, and land management practices, they also alter the background carbon fluxes between biomass, soils, and the atmosphere. 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, which offset about 11 percent of total U.S. greenhouse gas emissions in 2005. Forests (including vegetation, soils, and harvested wood) accounted for approximately 85 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 3 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 carbon 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 828.4 Tg CO_2 Eq. (Table 2-11). 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 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.

Table 2-11: Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Sink 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 2-12: Non-CO_2 Emissions from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Land-Use 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.

Land use, land-use change, and forestry activities in 2005 also resulted in emissions of N_2O (7.3 Tg CO_2 Eq.) from application of fertilizers to forests and settlements and from forest fires, and of CH_4 (11.6 Tg CO_2 Eq.) from forest fires, as shown in Table 2-12. Total N_2O emissions from the application of fertilizers to forests and settlements increased by approximately 19 percent between 1990 and 2005. Emissions of CH_4 and N_2O from forest fires fluctuate widely from year to year, but overall increased by 64 percent between 1990 and 2005.

Forest Land Remaining Forest Land (13.1 Tg CO_2 Eq.)

As with other agricultural applications, forests may be fertilized to stimulate growth rates. The relative magnitude of the impact of this practice is limited, however, because forests are generally only fertilized twice during their life cycles, and applications account for no more than one percent of total U.S. fertilizer applications annually. In terms of trends, however, N_2O emissions from forest soils for 2005 were more than 5 times higher than in 1990, primarily the result of an increase in the fertilized area of pine plantations in the southeastern United States. This source accounts for approximately 0.1 percent of total U.S. N_2O emissions. Non-CO_2 emissions from forest fires are directly related to the area of forest burned, which varies greatly from year to year. CH_4 from this source (11.6 Tg CO_2 Eq.) accounts for approximately 2 percent of total U.S. CH_4 emissions, while N_2O from forest fires (1.2 Tg CO_2 Eq.) accounts for about 0.3 percent of U.S. N_2O emissions. From 1990 to 2005, CH_4 and N_2O emissions from *Forest Land Remaining Forest Land* increased by 4.5 Tg CO_2 Eq. (64 percent) and 0.8 Tg CO_2 Eq. (98 percent), respectively.

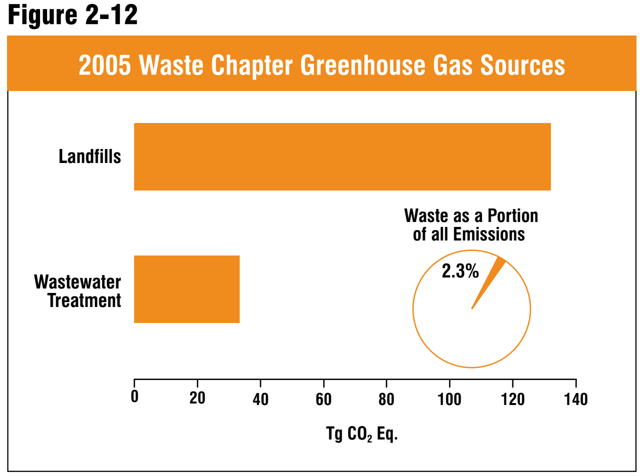
Settlements Remaining Settlements (5.8 Tg CO_2 Eq.)

Of the fertilizers applied to soils in the United States, approximately 10 percent are applied to lawns, golf courses, and other landscaping within settled areas. In 2005, N_2O emissions from settlement soils constituted approximately 1 percent of total U.S. N_2O emissions. There has been an overall increase in emissions of 13 percent since 1990, a result of a general increase in the applications of synthetic fertilizers.

Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-12). Landfills were the largest source of anthropogenic CH_4 emissions, accounting for 24 percent of total U.S. CH_4 emissions.[4] Additionally, wastewater treatment accounts for 5 percent of U.S. CH_4 emissions, and 2 percent of N_2O emissions. Nitrogen oxides (NO_x), carbon monoxide (CO), and non-CH_4 volatile organic compounds (NMVOCs) are also emitted by

Figure 2-12



[4] 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.

Table 2-13: Emissions from Waste (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2001	2002	2003	2004	2005
CH_4	**185.8**	**182.2**	**158.3**	**153.5**	**156.2**	**160.5**	**157.8**	**157.4**
Landfills	161.0	157.1	131.9	127.6	130.4	134.9	132.1	132.0
Wastewater Treatment	24.8	25.1	26.4	25.9	25.8	25.6	25.7	25.4
N_2O	**6.4**	**6.9**	**7.6**	**7.6**	**7.7**	**7.8**	**7.9**	**8.0**
Wastewater Treatment	6.4	6.9	7.6	7.6	7.7	7.8	7.9	8.0
Total	**192.2**	**189.1**	**165.9**	**161.1**	**163.9**	**168.4**	**165.7**	**165.4**

Note: Totals may not sum due to independent rounding.

waste activities. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 2-13.

Overall, in 2005, waste activities generated emissions of 165.4 Tg CO_2 Eq., or 2.3 percent of total U.S. greenhouse gas emissions.

Landfills (132.0 Tg CO_2 Eq.)

Landfills are the largest anthropogenic source of CH_4 emissions in the United States, accounting for approximately 24 percent of total CH_4 emissions in 2005. In an environment where the oxygen content is low or zero, anaerobic bacteria decompose organic materials, such as yard waste, household waste, food waste, and paper, resulting in the generation of CH_4 and biogenic CO_2. Factors such as waste composition and moisture influence the level of CH_4 generation. From 1990 to 2005, net CH_4 emissions from landfills decreased by 29 Tg CO_2 Eq. (18 percent), with small increases occurring in some interim years. This downward trend in overall emissions is the result of increases in the amount of landfill gas collected and combusted,[5] which has more than offset the additional CH_4 emissions resulting from an increase in the amount of municipal solid waste landfilled.

Wastewater Treatment (33.4 Tg CO_2 Eq.)

Wastewater from domestic sources (i.e., municipal sewage) and industrial sources is treated to remove soluble organic matter, suspended solids, pathogenic organisms and chemical contaminants. Soluble organic matter is generally removed using biological processes in which microorganisms consume the organic matter for maintenance and growth. Microorganisms can biodegrade soluble organic material in wastewater under aerobic or anaerobic conditions, with the latter condition producing CH_4. During collection and treatment, wastewater may be accidentally or deliberately managed under anaerobic conditions. In addition, the sludge may be further biodegraded under aerobic or anaerobic conditions. Untreated wastewater may also produce CH_4 if contained under anaerobic conditions. N_2O may be generated during both nitrification and denitrification of the nitrogen present, usually in the form of urea, ammonia, and proteins. In 2005, wastewater treatment was the source of approximately 5 percent of U.S. CH_4 emissions, and 2 percent of N_2O emissions. From 1990 to 2005, CH_4 and N_2O emissions from wastewater treatment increased by 0.6 Tg CO_2 Eq. (2.5 percent) and 1.6 Tg CO_2 Eq. (26 percent), respectively.

2.2. 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 and Other Product 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, as well as U.S. territories.

Using this categorization, emissions from electricity generation accounted for the largest portion (34 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

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

has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. The remaining 20 percent of U.S. greenhouse gas emissions were contributed by the residential, agriculture, and commercial sectors, plus emissions from U.S. territories. The residential sector accounted for about 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 planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Table 2-14 presents a detailed breakdown of emissions from each of these economic sectors by source category, as they are defined in this report. Figure 2-13 shows the trend in emissions by sector from 1990 to 2005.

Table 2-14: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq. and Percent of Total in 2005)

Sector/Source	1990	1995	2000	2001	2002	2003	2004	2005	Percent[a]
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**	**33.5%**
CO_2 from Fossil Fuel Combustion	1,810.2	1,939.3	2,283.5	2,245.5	2,254.7	2,284.0	2,315.8	2,381.2	32.8%
Municipal Solid Waste Combustion	11.4	16.2	18.3	18.7	18.9	19.9	20.5	21.3	0.3%
Electrical Transmission and Distribution	27.1	21.8	15.2	15.1	14.3	13.8	13.6	13.2	0.2%
Stationary Combustion	8.1	8.6	10.0	9.8	9.8	10.1	10.1	10.4	0.1%
Limestone and Dolomite Use	2.8	3.7	3.0	2.9	2.9	2.4	3.4	3.7	0.1%
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**	**27.7%**
CO_2 from Fossil Fuel 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	26.1%
Substitution of Ozone Depleting Substances	+	19.2	51.6	55.8	59.4	62.5	65.6	67.1	0.9%
Mobile Combustion	47.2	56.5	55.2	51.3	48.5	45.0	42.2	38.9	0.5%
Non-Energy Use of Fuels	11.9	11.3	12.1	11.1	10.9	10.1	10.2	10.2	0.1%
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**	**18.6%**
CO_2 from Fossil Fuel Combustion	810.3	825.4	824.1	819.3	804.8	813.3	824.5	794.6	10.9%
Natural Gas Systems	158.2	161.9	156.0	154.2	154.6	152.1	147.2	139.3	1.9%
Non-Energy Use of Fuels	99.7	115.9	118.0	115.0	115.2	112.8	130.9	123.4	1.7%
Coal Mining	81.9	66.5	55.9	55.5	52.0	52.1	54.5	52.4	0.7%
Iron and Steel Production	86.2	74.6	66.3	59.0	55.6	54.4	52.4	46.2	0.6%
Cement Manufacture	33.3	36.8	41.2	41.4	42.9	43.1	45.6	45.9	0.6%
Petroleum Systems	34.4	31.1	27.8	27.4	26.8	25.8	25.4	28.5	0.4%
HCFC-22 Production	35.0	27.0	29.8	19.8	19.8	12.3	15.6	16.5	0.2%
Ammonia Manufacture and Urea Application	19.3	20.5	19.6	16.7	17.8	16.2	16.9	16.3	0.2%
Nitric Acid Production	17.8	19.9	19.6	15.9	17.2	16.7	16.0	15.7	0.2%
Lime Manufacture	11.3	12.8	13.3	12.9	12.3	13.0	13.7	13.7	0.2%
Aluminum Production	25.4	17.5	14.7	7.8	9.7	8.3	7.1	7.2	0.1%
Adipic Acid Production	15.2	17.2	6.0	4.9	5.9	6.2	5.7	6.0	0.1%
Substitution of Ozone Depleting Substances	+	1.2	3.3	3.2	3.9	4.6	5.1	5.5	0.1%
Abandoned Underground Coal Mines	6.0	8.2	7.3	6.7	6.1	5.9	5.8	5.5	0.1%
Stationary Combustion	5.3	5.6	5.5	5.1	5.0	4.9	5.2	4.6	0.1%
Semiconductor Manufacture	2.9	5.0	6.3	4.5	4.4	4.3	4.7	4.3	0.1%
N_2O Product Usage	4.3	4.5	4.8	4.8	4.3	4.3	4.3	4.3	0.1%
Soda Ash Manufacture and Consumption	4.1	4.3	4.2	4.1	4.1	4.1	4.2	4.2	0.1%
Petrochemical Production	3.1	3.8	4.2	3.9	4.0	3.9	4.1	4.0	0.1%
Limestone and Dolomite Use	2.8	3.7	3.0	2.9	2.9	2.4	3.4	3.7	0.1%
Magnesium Production and Processing	5.4	5.6	3.0	2.4	2.4	2.9	2.6	2.7	+
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	1.4	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	+
Mobile Combustion	0.9	1.0	1.1	1.2	1.2	1.3	1.3	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	+

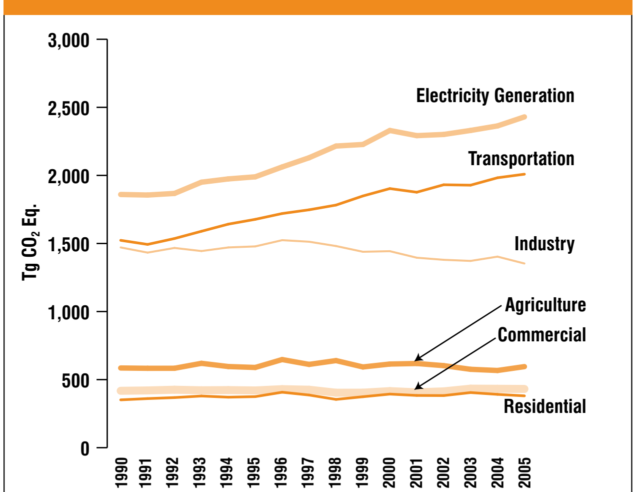
Table 2-14: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq. and Percent of Total in 2005) (continued)

Sector/Source	1990	1995	2000	2001	2002	2003	2004	2005	Percent[a]
Silicon Carbide Production and Consumption	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	+
Agriculture	**585.3**	**589.2**	**614.4**	**618.4**	**602.6**	**575.7**	**567.0**	**595.4**	**8.2%**
Agricultural Soil Management	366.9	353.4	376.8	389.0	366.1	350.2	338.8	365.1	5.0%
Enteric Fermentation	115.7	120.6	113.5	112.5	112.6	113.0	110.5	112.1	1.5%
Manure Management	39.5	44.1	48.3	50.0	50.8	49.8	49.2	50.8	0.7%
CO_2 from Fossil Fuel Combustion	46.8	57.3	50.9	50.7	52.9	45.0	51.1	45.5	0.6%
Forest Land Remaining Forest Land	7.9	4.5	15.7	6.9	11.8	9.2	8.0	13.1	0.2%
Rice Cultivation	7.1	7.6	7.5	7.6	6.8	6.9	7.6	6.9	0.1%
Field Burning of Agricultural Residues	1.1	1.0	1.3	1.2	1.1	1.2	1.4	1.4	+
Mobile Combustion	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.4	+
Stationary Combustion	+	+	+	+	+	+	+	+	+
Commercial	**417.8**	**420.5**	**415.5**	**406.6**	**413.7**	**433.5**	**432.6**	**431.4**	**5.9%**
CO_2 from Fossil Fuel Combustion	224.3	226.4	232.3	225.1	225.7	236.6	233.3	225.8	3.1%
Landfills	161.0	157.1	131.9	127.6	130.4	134.9	132.1	132.0	1.8%
Substitution of Ozone Depleting Substances	+	3.8	16.0	19.1	22.9	27.3	32.3	38.9	0.5%
Wastewater Treatment	31.2	32.0	34.0	33.5	33.5	33.4	33.6	33.4	0.5%
Stationary Combustion	1.3	1.3	1.3	1.2	1.2	1.3	1.3	1.2	+
Residential	**351.3**	**375.1**	**393.6**	**383.6**	**382.7**	**404.8**	**391.6**	**380.7**	**5.2%**
CO_2 from Fossil Fuel Combustion	340.3	356.4	373.5	363.9	362.4	383.8	369.9	358.7	4.9%
Substitution of Ozone Depleting Substances	0.3	8.1	10.1	10.4	10.7	11.0	11.5	11.9	0.2%
Settlement Soil Fertilization	5.1	5.5	5.6	5.5	5.6	5.8	6.0	5.8	0.1%
Stationary Combustion	5.5	5.0	4.4	3.9	4.0	4.2	4.3	4.3	0.1%
U.S. Territories	**34.1**	**41.1**	**47.3**	**54.5**	**53.6**	**60.0**	**63.2**	**61.5**	**0.8%**
CO_2 from Fossil Fuel Combustion	34.1	41.1	47.3	54.5	53.6	60.0	63.2	61.5	0.8%
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**	**100.0%**
Sinks	**(712.8)**	**(828.8)**	**(756.7)**	**(767.5)**	**(811.9)**	**(811.9)**	**(824.8)**	**(828.5)**	**-11.4%**
Forests	(598.5)	(717.5)	(638.7)	(645.7)	(688.1)	(687.0)	(697.3)	(698.7)	-9.6%
Urban Trees	(57.5)	(67.8)	(78.2)	(80.2)	(82.3)	(84.4)	(86.4)	(88.5)	-1.2%
CO_2 Flux from Agricultural Soils	(33.9)	(30.1)	(29.4)	(30.9)	(30.7)	(31.2)	(32.4)	(32.4)	-0.4%
Landfilled Yard Trimmings and Food Scraps	(22.8)	(13.3)	(10.5)	(10.6)	(10.8)	(9.3)	(8.7)	(8.8)	-0.1%
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**	**88.6%**

Note: Includes all emissions of CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. Parentheses indicate negative values or sequestration.
Totals may not sum due to independent rounding.
+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05%.
[a] Percent of total emissions for year 2005.

Figure 2-13

Emissions Allocated to Economic Sectors



Emissions with Electricity Distributed to Economic Sectors

It can also be useful to view 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). The generation, transmission, and distribution of electricity, which is the largest economic sector in the United States, accounted for 34 percent of total U.S. greenhouse gas emissions in 2005. Emissions increased by 31 percent since 1990, as electricity demand grew and fossil fuels remained the dominant energy source for generation. The electricity generation sector in the United States is composed of traditional electric utilities as well as other entities, such as power marketers and nonutility power producers. The majority of electricity generated by these entities was through the combustion of coal in boilers to produce high-pressure steam that is passed through a turbine. Table 2-15 provides a detailed summary of emissions from electricity generation-related activities.

To distribute electricity emissions among economic end-use sectors, emissions from the source categories assigned to the electricity generation sector were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity (EIA 2006c and Duffield 2006). These three source categories include CO_2 from Fossil Fuel Combustion, CH_4 and N_2O from Stationary Combustion, and SF_6 from Electrical Transmission and Distribution Systems.[6]

When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S. greenhouse gas emissions (28 percent), followed closely by emissions from transportation activities, which also account for 28 percent of total emissions. 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.

In all sectors except agriculture, CO_2 accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

Table 2-16 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electricity generation distributed to them. Figure 2-14 shows the trend in these emissions by sector from 1990 to 2005.

Figure 2-14

Emissions with Electricity Distributed to Economic Sectors

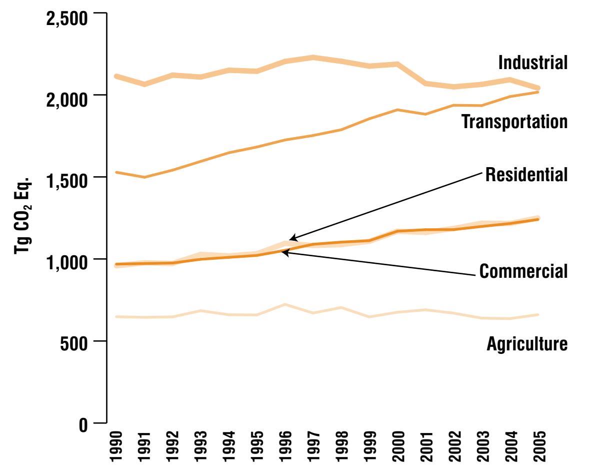


Table 2-15: Electricity Generation-Related Greenhouse Gas Emissions (Tg CO_2 Eq.)

Gas/Fuel Type or Source	1990	1995	2000	2001	2002	2003	2004	2005
CO_2	**1,823.9**	**1,958.7**	**2,304.3**	**2,266.7**	**2,276.2**	**2,305.8**	**2,339.2**	**2,405.8**
CO_2 from Fossil Fuel Combustion	1,810.2	1,939.3	2,283.5	2,245.5	2,254.7	2,284.0	2,315.8	2,381.2
Coal	*1,531.3*	*1,648.7*	*1,909.6*	*1,852.3*	*1,868.3*	*1,906.2*	*1,917.6*	*1,958.4*
Natural Gas	*176.8*	*229.5*	*282.0*	*290.8*	*307.0*	*279.3*	*297.7*	*320.1*
Petroleum	*101.8*	*60.7*	*91.5*	*102.0*	*79.1*	*98.1*	*100.1*	*102.3*
Geothermal	*0.4*	*0.3*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Municipal Solid Waste Combustion	10.9	15.7	17.9	18.3	18.5	19.5	20.1	20.9
Limestone and Dolomite Use	2.8	3.7	3.0	2.9	2.9	2.4	3.4	3.7
CH_4	**0.6**	**0.6**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
Stationary Combustion*	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7
N_2O	**8.0**	**8.5**	**9.7**	**9.5**	**9.5**	**9.8**	**9.8**	**10.0**
Stationary Combustion*	7.6	8.0	9.3	9.1	9.1	9.4	9.4	9.6
Municipal Solid Waste Combustion	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
SF_6	**27.1**	**21.8**	**15.2**	**15.1**	**14.3**	**13.8**	**13.6**	**13.2**
Electrical Transmission and Distribution	27.1	21.8	15.2	15.1	14.3	13.8	13.6	13.2
Total	**1,859.7**	**1,989.5**	**2,329.9**	**2,292.0**	**2,300.7**	**2,330.2**	**2,363.4**	**2,429.8**

Note: Totals may not sum due to independent rounding.
* Includes only stationary combustion emissions related to the generation of electricity.

[6] 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.

Table 2-16: U.S Greenhouse Gas Emissions by Economic Sector and Gas with Electricity-Related Emissions Distributed (Tg CO_2 Eq. and Percent of Total in 2005)

Sector/Gas	1990	1995	2000	2001	2002	2003	2004	2005	Percent[a]
Industry	**2,111.1**	**2,141.5**	**2,185.0**	**2,067.1**	**2,046.6**	**2,061.4**	**2,090.1**	**2,039.2**	**28.1%**
Direct Emissions	1,470.9	1,478.4	1,443.3	1,395.4	1,380.0	1,371.8	1,403.3	1,352.8	18.6%
CO_2	1,082.8	1,109.5	1,105.9	1,084.2	1,069.2	1,072.5	1,104.9	1,061.2	14.6%
CH_4	284.9	272.5	251.8	248.1	243.8	240.2	237.4	229.8	3.2%
N_2O	41.3	45.8	34.6	29.7	31.4	31.2	30.3	29.9	0.4%
HFCs, PFCs, and SF_6	61.9	50.6	50.9	33.4	35.6	27.9	30.8	32.0	0.4%
Electricity-Related	640.2	663.1	741.7	671.6	666.6	689.6	686.7	686.5	9.5%
CO_2	627.9	652.8	733.6	664.2	659.5	682.4	679.7	679.7	9.4%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.8	2.8	3.1	2.8	2.8	2.9	2.9	2.8	+
SF_6	9.3	7.3	4.8	4.4	4.2	4.1	4.0	3.7	0.1%
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**	**27.7%**
Direct Emissions	1,523.0	1,677.2	1,903.2	1,876.4	1,931.2	1,928.2	1,982.6	2,008.9	27.7%
CO_2	1,475.8	1,601.5	1,796.5	1,769.3	1,823.3	1,820.6	1,874.7	1,903.0	26.2%
CH_4	4.5	4.1	3.2	2.9	2.8	2.6	2.5	2.3	+
N_2O	42.7	52.5	52.0	48.4	45.8	42.4	39.8	36.5	0.5%
HFCs[b]	+	19.2	51.6	55.8	59.4	62.5	65.7	67.1	0.9%
Electricity-Related	3.1	3.1	3.5	3.4	3.5	4.3	4.5	5.3	0.1%
CO_2	3.1	3.1	3.5	3.3	3.4	4.3	4.4	5.2	0.1%
CH_4	+	+	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+	+	+
SF_6	+	+	+	+	+	+	+	+	+
Commercial	**967.2**	**1,019.8**	**1,167.4**	**1,176.8**	**1,177.0**	**1,196.2**	**1,214.1**	**1,238.5**	**17.1%**
Direct Emissions	417.8	420.5	415.5	406.6	413.7	433.5	432.6	431.4	5.9%
CO_2	224.3	226.4	232.3	225.1	225.7	236.6	233.3	225.8	3.1%
CH_4	186.7	183.1	159.2	154.4	157.1	161.5	158.7	158.3	2.2%
N_2O	6.8	7.2	7.9	7.9	8.0	8.2	8.3	8.4	0.1%
HFCs	+	3.8	16.0	19.1	22.9	27.3	32.3	38.9	0.5%
Electricity-Related	549.5	599.3	751.9	770.2	763.3	762.7	781.5	807.1	11.1%
CO_2	538.9	590.0	743.7	761.7	755.2	754.8	773.5	799.2	11.0%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.4	2.6	3.1	3.2	3.2	3.2	3.2	3.3	+
SF_6	8.0	6.6	4.9	5.1	4.8	4.5	4.5	4.4	0.1%
Residential	**956.9**	**1,030.6**	**1,167.0**	**1,160.3**	**1,184.3**	**1,216.2**	**1,214.2**	**1,248.0**	**17.2%**
Direct Emissions	351.3	375.1	393.6	383.6	382.7	404.8	391.6	380.7	5.2%
CO_2	340.3	356.4	373.5	363.9	362.4	383.8	369.9	358.7	4.9%
CH_4	4.4	4.0	3.5	3.1	3.1	3.3	3.3	3.4	+
N_2O	6.2	6.5	6.5	6.3	6.5	6.7	6.9	6.7	0.1%
HFCs	0.3	8.1	10.1	10.4	10.7	11.0	11.5	11.9	0.2%
Electricity-Related	605.7	655.5	773.4	776.6	801.5	811.4	822.6	867.3	11.9%
CO_2	594.0	645.4	764.9	768.1	793.0	802.9	814.2	858.7	11.8%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	+
N_2O	2.6	2.8	3.2	3.2	3.3	3.4	3.4	3.6	+
SF_6	8.8	7.2	5.0	5.1	5.0	4.8	4.7	4.7	0.1%
Agriculture	**646.5**	**657.6**	**673.9**	**688.5**	**668.4**	**637.9**	**635.0**	**659.1**	**9.1%**
Direct Emissions	585.3	589.2	614.4	618.4	602.6	575.7	567.0	595.4	8.2%
CO_2	46.8	57.3	50.9	50.7	52.9	45.0	51.1	45.5	0.6%
CH_4	161.6	168.2	174.6	167.2	171.8	169.3	165.8	172.9	2.4%
N_2O	377.0	363.7	388.9	400.5	377.9	361.4	350.1	377.0	5.2%
Electricity-Related	61.2	68.5	59.4	70.1	65.8	62.1	68.0	63.7	0.9%
CO_2	60.0	67.4	58.8	69.3	65.1	61.5	67.4	63.0	0.9%
CH_4	+	+	+	+	+	+	+	+	+
N_2O	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	+
SF_6	0.9	0.8	0.4	0.5	0.4	0.4	0.4	0.3	+
U.S. Territories	**34.1**	**41.1**	**47.3**	**54.5**	**53.6**	**60.0**	**63.2**	**61.5**	**0.8%**
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**	**100.0%**

Note: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector.
Totals may not sum due to independent rounding.
+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05 percent.
[a] Percent of total emissions for year 2005.
[b] Includes primarily HFC-134a.

Transportation

Transportation activities accounted for 28 percent of U.S. greenhouse gas emissions in 2005. Table 2-17 provides a detailed summary of greenhouse gas emissions from transportation-related activities. Total emissions in Table 2-17 differ slightly from those shown in Table 2-16 primarily because the table below excludes a few minor non-transportation mobile sources, such as construction and industrial equipment.

From 1990 to 2005, transportation emissions rose by 32 percent due, in part, to increased demand for travel and the stagnation of fuel efficiency across the U.S. vehicle fleet. Since the 1970s, the number of highway vehicles registered in the United States has increased faster than the overall population, according to the Federal Highway Administration (FHWA). Likewise, the number of miles driven (up 21 percent from 1990 to 2005) and the gallons of gasoline consumed each year in the United States have increased steadily since the 1980s, according to the FHWA and Energy Information Administration, respectively. These increases in motor vehicle usage are the result of a confluence of factors including population growth, economic growth, urban sprawl, low fuel prices, and increasing popularity of sport utility vehicles and other light-duty trucks that tend to have lower fuel efficiency. A similar set of social and economic trends has led to a significant increase in air travel

Table 2-17: Transportation-Related Greenhouse Gas Emissions (Tg CO_2 Eq.)

Gas/Vehicle Type	1990	1995	2000	2001	2002	2003	2004	2005
CO_2	**1,478.8**	**1,604.6**	**1,799.9**	**1,772.6**	**1,826.7**	**1,824.9**	**1,879.1**	**1,908.1**
Passenger Cars	615.1	599.6	632.0	634.7	649.6	629.1	628.7	614.9
Light-Duty Trucks	314.0	401.6	459.2	462.7	476.6	510.7	533.6	550.3
Other Trucks	227.0	270.9	343.2	343.3	358.1	355.4	368.5	384.6
Buses	8.3	9.0	11.0	10.1	9.7	10.6	14.9	15.1
Aircraft[a]	180.0	174.6	196.4	186.6	178.0	174.7	179.7	186.1
Ships and Boats	46.8	55.4	63.8	43.0	60.6	53.3	61.1	63.7
Locomotives	38.1	42.2	45.1	45.1	44.9	46.6	49.2	50.3
Other[b]	49.6	51.3	49.1	47.2	49.2	44.4	43.5	43.1
International Bunker Fuels[c]	*113.7*	*100.6*	*101.1*	*97.6*	*89.1*	*83.7*	*97.2*	*97.2*
CH_4	**4.5**	**4.1**	**3.2**	**2.9**	**2.8**	**2.6**	**2.5**	**2.3**
Passenger Cars	2.6	2.1	1.6	1.5	1.4	1.3	1.2	1.1
Light-Duty Trucks	1.4	1.4	1.1	1.0	1.0	0.9	0.8	0.8
Other Trucks and Buses	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Aircraft	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Ships and Boats	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Locomotives	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Motorcycles	+	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**42.7**	**52.5**	**52.0**	**48.4**	**45.8**	**42.4**	**39.7**	**36.5**
Passenger Cars	25.4	26.9	24.7	23.2	21.9	20.3	18.8	17.0
Light-Duty Trucks	14.1	22.1	23.3	21.4	20.1	18.3	17.0	15.6
Other Trucks and Buses	0.8	1.0	1.2	1.3	1.3	1.3	1.3	1.2
Aircraft	1.7	1.7	1.9	1.8	1.7	1.7	1.7	1.8
Ships and Boats	0.4	0.4	0.5	0.3	0.5	0.4	0.5	0.5
Locomotives	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Motorcycles	+	+	+	+	+	+	+	+
International Bunker Fuels[c]	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*	*0.9*	*0.9*
HFCs	**+**	**19.2**	**51.6**	**55.8**	**59.4**	**62.5**	**65.6**	**67.1**
Mobile Air Conditioners[d]	+	16.8	41.6	44.9	47.7	50.0	52.2	53.1
Comfort Cooling in Buses and Trains	+	+	0.2	0.2	0.2	0.2	0.3	0.3
Refrigerated Transport	+	2.3	9.8	10.8	11.5	12.3	13.1	13.6
Total	**1,526.1**	**1,680.4**	**1,906.7**	**1,879.7**	**1,934.6**	**1,932.4**	**1,986.9**	**2,014.0**

+ Does not exceed 0.05 Tg CO_2 Eq.
Note: Totals may not sum due to independent rounding.
[a] Aircraft emissions consist of emissions from all jet fuel (less bunker fuels) and aviation gas consumption.
[b] "Other" CO_2 emissions include motorcycles, pipelines, and lubricants.
[c] Emissions from International Bunker Fuels include emissions from both civilian and military activities, but are not included in totals.
[d] Includes primarily HFC-134a.

and freight transportation by both air and road modes during the time series.

Almost all of the energy consumed for transportation was supplied by petroleum-based products, with nearly two-thirds being related to gasoline consumption in automobiles and other highway vehicles. Other fuel uses, especially diesel fuel for freight trucks and jet fuel for aircraft, accounted for the remainder. The primary driver of transportation-related emissions was CO_2 from fossil fuel combustion, which increased by 29 percent from 1990 to 2005. This rise in CO_2 emissions, combined with an increase of 67.1 Tg CO_2 Eq. in HFC emissions over the same period, led to an increase in overall emissions from transportation activities of 32 percent.

2.3. Indirect Greenhouse Gas Emissions (CO, NO_x, NMVOCs, and SO_2)

The reporting requirements of the UNFCCC[7] request that information be provided on indirect greenhouse gases, which include CO, NO_x, NMVOCs, and SO_2. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the

Box 2-2: Methodology for Aggregating Emissions by Economic Sector

In order to aggregate emissions by economic sector, source category emission estimates were generated according to the methodologies outlined in the appropriate sections of this report. Those emissions were then simply reallocated into economic sectors. In most cases, the IPCC subcategories distinctly fit into an apparent economic sector category. Several exceptions exist, and the methodologies used to disaggregate these subcategories are described below:

- *Agricultural CO_2 Emissions from Fossil Fuel Combustion, and Non-CO_2 Emissions from Stationary and Mobile Combustion.* Emissions from on-farm energy use were accounted for in the Energy chapter as part of the industrial and transportation end-use sectors. To calculate agricultural emissions related to fossil fuel combustion, energy consumption estimates were obtained from economic survey data from the U.S. Department of Agriculture (Duffield 2006) and fuel sales data (EIA 1991 through 2005). To avoid double-counting, emission estimates of CO_2 from fossil fuel combustion and non-CO_2 from stationary and mobile combustion were subtracted from the industrial economic sector, although some of these fuels may have been originally accounted for under the transportation end-use sector.
- *Landfills and Wastewater Treatment.* CH_4 emissions from landfills and CH_4 and N_2O emissions from wastewater treatment were allocated to the commercial sector.
- *Municipal Solid Waste Combustion.* CO_2 and N_2O emissions from waste combustion were allocated completely to the electricity generation sector since nearly all waste combustion occurs in waste-to-energy facilities.
- *Limestone and Dolomite Use.* CO_2 emissions from limestone and dolomite use are allocated to the electricity generation (50 percent) and industrial (50 percent) sectors, because 50 percent of the total emissions for this source are due to flue gas desulfurization.
- *Substitution of Ozone Depleting Substances.* All greenhouse gas emissions resulting from the substitution of ozone depleting substances were placed in the industrial economic sector, with the exception of emissions from domestic, commercial, and mobile and transport refrigeration/air-conditioning systems, which were placed in the residential, commercial, and transportation sectors, respectively. Emissions from non-MDI aerosols were attributed to the residential economic sector.
- *Settlement Soil Fertilization, Forest Soil Fertilization.* Emissions from settlement soil fertilization were allocated to the residential economic sector; forest soil fertilization was allocated to the agriculture economic sector.
- *Forest Fires.* N_2O and CH_4 emissions from forest fires were allocated to the agriculture economic sector.

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

atmosphere to form compounds that are greenhouse gases. Carbon monoxide is produced when carbon-containing fuels are combusted incompletely. Nitrogen oxides (i.e., NO and NO_2) are created by lightning, fires, fossil fuel combustion, and in the stratosphere from N_2O. Non-CH_4 volatile organic compounds—(which include hundreds of organic compounds that participate in atmospheric chemical reactions (i.e., propane, butane, xylene, toluene, ethane, and many others)—are emitted primarily from transportation, industrial processes, and non-industrial consumption of organic solvents. In the United States, SO_2 is primarily emitted from coal combustion for electric power generation and the metals industry. Sulfur-containing compounds emitted into the atmosphere tend to exert a negative radiative forcing (i.e., cooling) and therefore are discussed separately.

One important indirect climate change effect of NMVOCs and NO_x is their role as precursors for tropospheric ozone formation. They can also alter the atmospheric lifetimes of other greenhouse gases. Another example of indirect greenhouse gas formation into greenhouse gases is CO's interaction with the hydroxyl radical—the major atmospheric sink for CH_4 emissions—to form CO_2. Therefore, increased atmospheric concentrations of CO limit the number of hydroxyl molecules (OH) available to destroy CH_4.

Since 1970, the United States has published estimates of annual emissions of CO, NO_x, NMVOCs, and SO_2 (EPA 2005),[8] which are regulated under the Clean Air Act. Table 2-18 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.

Box 2-3: Sources and Effects of Sulfur Dioxide

Sulfur dioxide (SO_2) emitted into the atmosphere through natural and anthropogenic processes affects the earth's radiative budget through its photochemical transformation into sulfate aerosols that can (1) scatter radiation from the sun back to space, thereby reducing the radiation reaching the earth's surface; (2) affect cloud formation; and (3) affect atmospheric chemical composition (e.g., by providing surfaces for heterogeneous chemical reactions). The indirect effect of sulfur-derived aerosols on radiative forcing can be considered in two parts. The first indirect effect is the aerosols' tendency to decrease water droplet size and increase water droplet concentration in the atmosphere. The second indirect effect is the tendency of the reduction in cloud droplet size to affect precipitation by increasing cloud lifetime and thickness. Although still highly uncertain, the radiative forcing estimates from both the first and the second indirect effect are believed to be negative, as is the combined radiative forcing of the two (IPCC 2001). However, because SO_2 is short-lived and unevenly distributed in the atmosphere, its radiative forcing impacts are highly uncertain.

Sulfur dioxide is also a major contributor to the formation of regional haze, which can cause significant increases in acute and chronic respiratory diseases. Once SO_2 is emitted, it is chemically transformed in the atmosphere and returns to the earth as the primary source of acid rain. Because of these harmful effects, the United States has regulated SO_2 emissions in the Clean Air Act.

Electricity generation is the largest anthropogenic source of SO_2 emissions in the United States, accounting for 88 percent in 2005. Coal combustion contributes nearly all of those emissions (approximately 92 percent). Sulfur dioxide emissions have decreased in recent years, primarily as a result of electric power generators switching from high-sulfur to low-sulfur coal and installing flue gas desulfurization equipment.

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

Table 2-18: 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
Industrial Processes	4,125	3,959	2,217	2,339	1,710	1,730	1,751	1,772
Municipal Solid Waste Combustion	978	1,073	1,670	1,672	1,440	1,457	1,475	1,493
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 2005) except for estimates from field burning of agricultural residues.
NA (Not Available)
Note: Totals may not sum due to independent rounding.