2. Trends in Greenhouse Gas Emissions

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

In 2003, total U.S. greenhouse gas emissions were 6,900.2 teragrams of carbon dioxide equivalent (Tg CO_2 Eq.)[1] (13.3 percent above 1990 emissions). Emissions rose slightly from 2002 to 2003, increasing by 0.6 percent (42.2 Tg CO_2 Eq.). The following factors were primary contributors to this increase: 1) moderate economic growth in 2003, leading to increased demand for electricity and fossil fuels, 2) increased natural gas prices, causing some electric power producers to switch to burning coal, and 3) a colder winter, which caused an increase in the use of heating fuels, primarily in the residential sector. (See the following section for an analysis of emission trends by general economic sectors.) Figure 2-1 through Figure 2-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute changes since 1990.

Figure 2-1: U.S. Greenhouse Gas Emissions by Gas

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

As the largest source of U.S. greenhouse gas emissions, carbon dioxide (CO_2) from fossil fuel combustion has accounted for a nearly constant 80 percent of global warming potential (GWP) weighted emissions since 1990. Emissions from this source category grew by 17.8 percent (839.8 Tg CO_2 Eq.) from 1990 to 2003 and were responsible for most of the increase in national emissions during this period. From 2002 to 2003, these emissions increased by 50.2 Tg CO_2 Eq. (0.9 percent), the same rate as the source's average annual growth rate of 1.3 percent from 1990 through 2003. Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

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

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).

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[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.)

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

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	1999 to 2000		2000 to 2001		2001 to 2002		2002 to 2003	
Electricity Generation	Coal	87.6	5%	-62.6	-3%	22.2	1%	36.6	2%
Electricity Generation	Natural Gas	20.8	8%	8.4	3%	16.5	6%	-28.0	-9%
Electricity Generation	Petroleum	-5.6	-6%	9.8	11%	-23.5	-23%	18.9	24%
Transportation[a]	Petroleum	47.0	3%	-16.4	-1%	29.4	2%	16.6	1%
Residential	Natural Gas	13.9	5%	-10.7	-4%	6.2	2%	11.5	4%
Commercial	Natural Gas	7.1	4%	-7.9	-5%	4.2	3%	2.0	1%
Industrial	Coal	1.1	1%	-4.4	-3%	-7.9	-6%	0.8	1%
Industrial	Natural Gas	8.2	2%	-38.5	-8%	9.5	2%	-27.6	-6%
All Sectors[b]	**All Fuels[b]**	**199.2**	**4%**	**-97.1**	**-2%**	**53.5**	**1%**	**50.2**	**1%**

[a] Excludes emissions from International Bunker Fuels.
[b] Includes fuels and sectors not shown in table.

In 1999, the increase in emissions from fossil fuel combustion was driven largely by growth in petroleum consumption for transportation. In addition, residential and commercial heating fuel demand partially recovered as winter temperatures dropped relative to 1998, although temperatures were still warmer than normal.[2] These increases were offset, in part, by a decline in emissions from electric power producers due primarily to: 1) an increase in net generation of electricity by nuclear plants which reduced demand from fossil fuel plants; and 2) moderated summer temperatures compared to the previous year—thereby reducing electricity demand for air conditioning.

Emissions from fuel combustion increased considerably in 2000, due to several factors. The primary reason for the increase was the robust U.S. economy, which produced a high demand for fuels—especially for petroleum in the transportation sector—despite increases in the price of both natural gas and petroleum. Colder winter conditions relative to the previous year triggered a rise in residential and commercial demand for heating. Additionally, electricity generation became more carbon intensive as coal and natural gas consumption offset reduced hydropower output.

In 2001, economic growth in the United States slowed considerably for the second time since 1990, contributing to a decrease in CO_2 emissions from fossil fuel combustion, also for the second time since 1990. A significant reduction in industrial output contributed to weak economic growth, primarily in manufacturing, and led to lower emissions from the industrial sector. Several other factors also played a role in this decrease in emissions. Warmer winter conditions compared to 2000, along with higher natural gas prices, reduced demand for heating fuels. Additionally, nuclear facilities operated at a very high capacity, offsetting electricity produced from fossil fuels. Since there are no greenhouse gas emissions associated with electricity production from nuclear plants, this substitution reduces the overall carbon intensity of electricity generation.

Emissions from fuel combustion resumed a 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 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

[2] Normals are based on data from 1971 through 2000. Source: EIA (2004b)

the residential sector as the use of air-conditioners increased. Partially offsetting this increased consumption of fossil fuels, however, were 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. Use of nuclear and renewable fuels remained relatively stable. Nuclear capacity decreased slightly, and for the first time since 1997. Use of renewable fuels rose slightly due to increases in the use of hydroelectric power and biofuels.

Other significant trends in emissions from additional source categories over the fourteen-year period from 1990 through 2003 included the following:

- Carbon dioxide emissions from waste combustion increased by 7.9 Tg CO_2 Eq. (72 percent), as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.
- Net CO_2 sequestration from land use change and forestry decreased by 214.0 Tg CO_2 Eq. (21 percent), primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks. This decline largely resulted from a decrease in the estimated rate of forest soil sequestration caused by a slowing rate of increase in forest area after 1997.
- Methane (CH_4) emissions from coal mining declined by 28.1 Tg CO_2 Eq. (34 percent) from 1990 to 2003, as a result of the mining of less gassy coal from underground mines and the increased use of methane collected from degasification systems.
- The increase in ODS emissions is offset substantially by decreases in emission of HFCs, PFCs, and SF_6 from other sources. Emissions from aluminum production decreased by 79 percent (14.5 Tg CO_2 Eq.) from 1990 to 2003, due to both industry emission reduction efforts and lower domestic aluminum production. Emissions from the production of HCFC-22 decreased by 65 percent (22.6 Tg CO_2 Eq.) from 1990 to 2003, due to a steady decline in the emission rate of HFC-23 (i.e., the amount of HFC-23 emitted per kilogram of HCFC-22 manufactured) and the use of thermal oxidation at some plants to reduce HFC-23 emissions. Emissions from electric power transmission and distribution systems decreased by 52 percent (15.1 Tg CO_2 Eq.) from 1990 to 2003, primarily because of higher purchase prices for SF_6 and efforts by industry to reduce emissions.

Overall, from 1990 to 2003, total emissions of CO_2 increased by 832.0 Tg CO_2 Eq. (17 percent), while CH_4 and N_2O emissions decreased by 60.4 Tg CO_2 Eq. (10 percent) and 5.2 Tg CO_2 Eq. (just over 1 percent), respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 45.8 Tg CO_2 Eq. (50 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF_6 are significant because many of them have extremely high global warming potentials and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon sequestration in forests, trees in urban areas, agricultural soils, and landfilled yard trimmings, which was estimated to be 12 percent of total emissions in 2003.

[BEGIN BOX]

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 2003; 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 1.0 percent since 1990. This rate is slower than that for total energy or fossil fuel consumption and much slower than that for either electricity consumption or overall gross domestic product. Total U.S. greenhouse gas emissions have also grown more slowly than national population since 1990 (see Figure 2-4). Overall, global atmospheric CO_2 concentrations—a function of many complex anthropogenic and natural processes—are increasing at 0.5 percent per year.

Table 2-2: Recent Trends in Various U.S. Data (Index 1990 = 100) and Global Atmospheric CO_2 Concentration

Variable	1991		1997	1998	1999	2000	2001	2002	2003	Growth Rate[f]
Greenhouse Gas Emissions[a]	99		110	110	111	114	112	113	113	**1.0%**
Energy Consumption[b]	100		112	113	114	117	114	116	116	**1.2%**
Fossil Fuel Consumption[b]	99		112	113	114	117	115	116	116	**1.2%**
Electricity Consumption[b]	102		117	121	124	128	125	129	130	**2.1%**
GDP[c]	100		122	127	133	138	139	142	146	**3.0%**
Population[d]	101		109	110	112	113	114	115	116	**1.1%**
Atmospheric CO_2 Concentration[e]	100		103	104	104	104	105	105	106	**0.5%**

[a] GWP weighted values
[b] Energy content weighted values (EIA 2004a)
[c] Gross Domestic Product in chained 2000 dollars (BEA 2004)
[d] (U.S. Census Bureau 2004)
[e] Mauna Loa Observatory, Hawaii (Keeling and Whorf 2004)
[f] Average annual growth rate

Figure 2-4: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product
Source: BEA (2004), U.S. Census Bureau (2004), and emission estimates in this report.

[END BOX]

As an alternative, emissions of all gases can be totaled for each of the IPCC sectors. Over the thirteen year period of 1990 to 2003, total emissions in the Energy, Industrial Processes, Agriculture, and Solvent and Other Product Use sectors climbed by 821.6Tg CO_2 Eq. (16 percent), 8.7 Tg CO_2 Eq. (3 percent), 6.8 Tg CO_2 Eq. (2 percent), and 0.5 Tg CO_2 Eq. (11 percent), respectively, while emissions from the Waste sector decreased 26.3 Tg CO_2 Eq. (13 percent). Over the same period, estimates of net carbon sequestration in the Land-Use Change and Forestry sector declined by 214.8 Tg CO_2 Eq. (21 percent).

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. Alternatively, emissions and sinks are aggregated by chapter in Table 2-5 and Figure 2-5.

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

Gas/Source	1990		1997	1998	1999	2000	2001	2002	2003
CO_2	**5,009.6**		**5,580.0**	**5,607.2**	**5,678.0**	**5,858.2**	**5,744.8**	**5,796.8**	**5,841.5**
Fossil Fuel Combustion	4,711.7		5,263.2	5,278.7	5,345.9	5,545.1	5,448.0	5,501.4	5,551.6
Non-Energy Use of Fuels	108.0		120.3	135.4	141.6	124.7	120.1	118.8	118.0
Iron and Steel Production	85.4		71.9	67.4	64.4	65.7	58.9	55.1	53.8
Cement Manufacture	33.3		38.3	39.2	40.0	41.2	41.4	42.9	43.0

Waste Combustion	10.9		17.8	17.1	17.6	18.0	18.8	18.8	18.8
Ammonia Production and Urea Application	19.3		20.7	21.9	20.6	19.6	16.7	18.6	15.6
Lime Manufacture	11.2		13.7	13.9	13.5	13.3	12.8	12.3	13.0
Natural Gas Flaring	5.8		7.9	6.6	6.9	5.8	6.1	6.2	6.0
Limestone and Dolomite Use	5.5		7.2	7.4	8.1	6.0	5.7	5.9	4.7
Aluminum Production	6.3		5.6	5.8	5.9	5.7	4.1	4.2	4.2
Soda Ash Manufacture and Consumption	4.1		4.4	4.3	4.2	4.2	4.1	4.1	4.1
Petrochemical Production	2.2		2.9	3.0	3.1	3.0	2.8	2.9	2.8
Titanium Dioxide Production	1.3		1.8	1.8	1.9	1.9	1.9	2.0	2.0
Phosphoric Acid Production	1.5		1.5	1.6	1.5	1.4	1.3	1.3	1.4
Ferroalloys	2.0		2.0	2.0	2.0	1.7	1.3	1.2	1.4
Carbon Dioxide Consumption	0.9		0.8	0.9	0.8	1.0	0.8	1.0	1.3
Land-Use Change and Forestry (Sinks)[a]	*(1,042.0)*		*(930.0)*	*(881.0)*	*(826.1)*	*(822.4)*	*(826.9)*	*(826.5)*	*(828.0)*
International Bunker Fuels[b]	*113.5*		*109.9*	*114.6*	*105.3*	*101.4*	*97.9*	*89.5*	*84.2*
Biomass Combustion[b]	*216.7*		*233.2*	*217.2*	*222.3*	*226.8*	*200.5*	*207.2*	*216.8*
CH_4	**605.3**		**579.5**	**569.1**	**557.3**	**554.2**	**546.8**	**542.5**	**545.0**
Landfills	172.2		147.4	138.5	134.0	130.7	126.2	126.8	131.2
Natural Gas Systems	128.3		133.6	131.8	127.4	132.1	131.8	130.6	125.9
Enteric Fermentation	117.9		118.3	116.7	116.8	115.6	114.5	114.6	115.0
Coal Mining	81.9		62.6	62.8	58.9	56.2	55.6	52.4	53.8
Manure Management	31.2		36.4	38.8	38.8	38.1	38.9	39.3	39.1
Wastewater Treatment	24.8		31.7	32.6	33.6	34.3	34.7	35.8	36.8
Petroleum Systems	20.0		18.8	18.5	17.8	17.6	17.4	17.1	17.1
Rice Cultivation	7.1		7.5	7.9	8.3	7.5	7.6	6.8	6.9
Stationary Sources	7.8		7.4	6.9	7.1	7.3	6.7	6.4	6.7
Abandoned Coal Mines	6.1		8.1	7.2	7.3	7.7	6.9	6.4	6.4
Mobile Sources	4.8		4.0	3.9	3.6	3.4	3.1	2.9	2.7
Petrochemical Production	1.2		1.6	1.7	1.7	1.7	1.4	1.5	1.5
Iron and Steel Production	1.3		1.3	1.2	1.2	1.2	1.1	1.0	1.0
Agricultural Residue Burning	0.7		0.8	0.8	0.8	0.8	0.8	0.7	0.8
Silicon Carbide Production	+		+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*		*0.1*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**382.0**		**396.3**	**407.8**	**382.1**	**401.9**	**385.8**	**380.5**	**376.7**
Agricultural Soil Management	253.0		252.0	267.7	243.4	263.9	257.1	252.6	253.5
Mobile Sources	43.7		55.2	55.3	54.6	53.2	49.0	45.6	42.1
Manure Management	16.3		17.3	17.4	17.4	17.8	18.0	17.9	17.5
Human Sewage	13.0		14.7	15.0	15.4	15.6	15.6	15.7	15.9
Nitric Acid	17.8		21.2	20.9	20.1	19.6	15.9	17.2	15.8
Stationary Sources	12.3		13.5	13.4	13.5	14.0	13.5	13.5	13.8
Settlements Remaining Settlements	5.5		6.1	6.1	6.2	6.0	5.8	6.0	6.0
Adipic Acid	15.2		10.3	6.0	5.5	6.0	4.9	5.9	6.0
N_2O Product Usage	4.3		4.8	4.8	4.8	4.8	4.8	4.8	4.8
Waste Combustion	0.4		0.4	0.3	0.3	0.4	0.4	0.5	0.5
Agricultural Residue Burning	0.4		0.4	0.5	0.4	0.5	0.5	0.4	0.4
Forest Land Remaining Forest Land	0.1		0.3	0.4	0.5	0.4	0.4	0.4	0.4
International Bunker Fuels[b]	*1.0*		*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*
HFCs, PFCs, and SF_6	**91.2**		**121.7**	**135.7**	**134.8**	**138.9**	**129.5**	**138.3**	**137.0**
Substitution of Ozone Depleting Substances	0.4		46.5	56.6	65.8	75.0	83.3	91.5	99.5

Electrical Transmission and Distribution	29.2	21.7	17.1	16.4	15.6	15.4	14.7	14.1
HCFC-22 Production	35.0	30.0	40.1	30.4	29.8	19.8	19.8	12.3
Semiconductor Manufacture	2.9	6.3	7.1	7.2	6.3	4.5	4.4	4.3
Aluminum Production	18.3	11.0	9.1	9.0	9.0	4.0	5.2	3.8
Magnesium Production and Processing	5.4	6.3	5.8	6.0	3.2	2.6	2.6	3.0
Total	**6,088.1**	**6,677.5**	**6,719.7**	**6,752.2**	**6,953.2**	**6,806.9**	**6,858.1**	**6,900.2**
Net Emissions (Sources and Sinks)	**5,046.1**	**5,747.5**	**5,838.8**	**5,926.1**	**6,130.8**	**5,980.1**	**6,031.6**	**6,072.2**

+ Does not exceed 0.05 Tg CO_2 Eq.
[a] Sinks are only included in net emissions total, and are based partially on projected activity data. Parentheses indicate negative values (or sequestration).
[b] Emissions from International Bunker Fuels and Biomass Combustion 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	1997	1998	1999	2000	2001	2002	2003
CO_2	**5,009,552**	**5,579,984**	**5,607,159**	**5,677,970**	**5,858,201**	**5,744,782**	**5,796,757**	**5,841,504**
Fossil Fuel Combustion	4,711,741	5,263,164	5,278,721	5,345,904	5,545,083	5,447,969	5,501,427	5,551,580
Non-Energy Use of Fuels	107,965	120,301	135,352	141,583	124,714	120,104	118,811	118,001
Iron and Steel Production	85,413	71,863	67,428	64,376	65,693	58,887	55,082	53,763
Cement Manufacture	33,278	38,323	39,218	39,991	41,190	41,357	42,898	43,030
Waste Combustion	10,919	17,761	17,094	17,632	17,979	18,781	18,781	18,781
Ammonia Production and Urea Application	19,306	20,650	21,934	20,615	19,616	16,719	18,571	15,560
Lime Manufacture	11,238	13,685	13,914	13,466	13,315	12,823	12,304	12,983
Natural Gas Flaring	5,805	7,874	6,566	6,943	5,769	6,094	6,233	5,970
Limestone and Dolomite Use	5,533	7,242	7,449	8,057	5,959	5,733	5,885	4,720
Aluminum Production	6,315	5,621	5,792	5,895	5,723	4,114	4,220	4,219
Soda Ash Manufacture and Consumption	4,141	4,354	4,325	4,217	4,181	4,147	4,139	4,082
Petrochemical Production	2,221	2,919	3,015	3,054	3,004	2,787	2,857	2,777
Titanium Dioxide Production	1,308	1,836	1,819	1,853	1,918	1,857	1,997	2,013
Phosphoric Acid Production	1,529	1,544	1,593	1,539	1,382	1,264	1,338	1,382
Ferroalloys	1,980	2,038	2,027	1,996	1,719	1,329	1,237	1,374
Carbon Dioxide Consumption	860	808	912	849	957	818	978	1,267
Land-Use Change and Forestry (Sinks)[a]	*(1,042,050)*	*(930,011)*	*(880,995)*	*(826,106)*	*(822,409)*	*(826,879)*	*(826,483)*	*(828,046)*
International Bunker Fuels[b]	*113,503*	*109,858*	*114,557*	*105,294*	*101,404*	*97,865*	*89,489*	*84,193*
Biomass Combustion	*216,702*	*233,243*	*217,201*	*222,340*	*226,765*	*200,477*	*207,249*	*216,813*
CH_4	**28,826**	**27,595**	**27,100**	**26,537**	**26,389**	**26,039**	**25,832**	**25,950**
Landfills	8,202	7,017	6,595	6,382	6,223	6,010	6,039	6,246
Natural Gas Systems	6,112	6,363	6,276	6,066	6,289	6,277	6,221	5,998
Enteric Fermentation	5,612	5,634	5,557	5,561	5,505	5,454	5,458	5,475
Coal Mining	3,900	2,983	2,989	2,805	2,677	2,647	2,497	2,561
Manure Management	1,485	1,733	1,850	1,846	1,813	1,853	1,873	1,864

Wastewater Treatment	1,183	1,509	1,550	1,602	1,635	1,651	1,705	1,751
Petroleum Systems	951	895	879	848	836	831	815	815
Rice Cultivation	339	356	376	395	357	364	325	328
Stationary Sources	373	351	328	338	349	318	305	319
Abandoned Coal Mines	288	385	341	349	369	331	303	306
Mobile Sources	228	193	185	172	161	147	138	128
Petrochemical Production	56	78	80	81	80	68	72	72
Iron and Steel Production	63	60	57	56	57	51	48	49
Field Burning of Agricultural Residues	33	37	38	37	38	37	34	38
Silicon Carbide Production	1	1	1	1	1	+	+	+
International Bunker Fuels[b]	*8*	*7*	*7*	*6*	*6*	*5*	*4*	*4*
N_2O	**1,232**	**1,278**	**1,315**	**1,233**	**1,297**	**1,245**	**1,228**	**1,215**
Agricultural Soil Management	816	813	864	785	851	829	815	818
Mobile Sources	141	178	179	176	171	158	147	136
Manure Management	52	56	56	56	57	58	58	57
Human Sewage	42	47	48	50	50	50	51	51
Nitric Acid	58	68	67	65	63	51	56	51
Stationary Sources	40	44	43	43	45	43	44	45
Settlements Remaining Settlements	18	20	20	20	19	19	19	19
Adipic Acid	49	33	19	18	19	16	19	19
N_2O Product Usage	14	15	15	15	15	15	15	15
Waste Combustion	1	1	1	1	1	1	1	1
Field Burning of Agricultural Residues	1	1	1	1	1	1	1	1
Forest Land Remaining Forest Land	+	1	1	2	1	1	1	1
International Bunker Fuels[b]	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*2*
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
Electrical Transmission and Distribution[d]	1	1	1	1	1	1	1	1
HCFC-22 Production[c]	3	3	3	3	3	2	2	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[d]	+	+	+	+	+	+	+	+
SO_2	**20,936**	**17,091**	**17,189**	**15,917**	**14,829**	**14,452**	**13,928**	**14,463**
NO_x	**22,860**	**22,284**	**21,964**	**20,530**	**20,288**	**19,414**	**18,850**	**18,573**
CO	**130,580**	**101,138**	**98,984**	**94,361**	**92,895**	**89,329**	**87,451**	**85,077**
NMVOCs	**20,937**	**16,994**	**16,403**	**15,869**	**15,228**	**15,048**	**14,222**	**13,939**

+ Does not exceed 0.5 Gg.
M Mixture of multiple gases
[a] Sinks are not included in CO_2 emissions total, and are based partially on projected activity data.
[b] Emissions from International Bunker Fuels and Biomass Combustion are not included in totals.
[c] HFC-23 emitted

[d] SF_6 emitted
Note: Totals may not sum due to independent rounding.
Note: Parentheses indicate negative values (or sequestration).

Figure 2-5: U.S. Greenhouse Gas Emissions by Chapter/IPCC Sector

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		1997	1998	1999	2000	2001	2002	2003
Energy	5,141.7		5,712.8	5,737.7	5,802.6	5,985.3	5,877.3	5,920.7	5,963.4
Industrial Processes	299.9		327.1	334.9	329.2	332.1	304.7	315.4	308.6
Solvent and Other Product Use	4.3		4.8	4.8	4.8	4.8	4.8	4.8	4.8
Agriculture	426.5		432.8	449.8	425.9	444.1	437.5	432.4	433.3
Land-Use Change and Forestry (Emissions)	5.6		6.4	6.5	6.6	6.3	6.2	6.4	6.4
Waste	210.1		193.7	186.0	183.1	180.6	176.5	178.3	183.8
Total	**6,088.1**		**6,677.5**	**6,719.7**	**6,752.2**	**6,953.2**	**6,806.9**	**6,858.1**	**6,900.2**
Land-Use Change and Forestry (Sinks)	(1042.0)		(930.0)	(881.0)	(826.1)	(822.4)	(826.9)	(826.5)	(828.0)
Net Emissions (Sources and Sinks)	**5,046.1**		**5,747.5**	**5,838.8**	**5,926.1**	**6,130.8**	**5,980.1**	**6,031.6**	**6,072.2**

* Sinks are only included in net emissions total, and are based partially on projected activity data.
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 2003. In 2003, approximately 86 percent of the energy consumed in the United States was produced through the combustion of fossil fuels. The remaining 14 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (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 (39 percent and 15 percent of total U.S. emissions, respectively). Table 2-6 presents greenhouse gas emissions from the Energy sector, by source and gas.

Figure 2-6: 2003 Energy Sector Greenhouse Gas Sources

Figure 2-7: 2003 U.S. Fossil Carbon Flows (Tg CO_2 Eq.)

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

Gas/Source	1990		1997	1998	1999	2000	2001	2002	2003
CO_2	**4,836.4**		**5,409.1**	**5,437.7**	**5,512.1**	**5,693.5**	**5,592.9**	**5,645.3**	**5,694.3**
Fossil Fuel Combustion	4,711.7		5,263.2	5,278.7	5,345.9	5,545.1	5,448.0	5,501.4	5,551.6
Non-Energy Use of Fuels	108.0		120.3	135.4	141.6	124.7	120.1	118.8	118.0
Waste Combustion	10.9		17.8	17.1	17.6	18.0	18.8	18.8	18.8
Natural Gas Flaring	5.8		7.9	6.6	6.9	5.8	6.1	6.2	6.0
*Biomass-Wood**	*212.5*		*226.3*	*209.5*	*214.3*	*217.6*	*190.8*	*195.8*	*201.0*
*International Bunker Fuels**	*113.5*		*109.9*	*114.6*	*105.3*	*101.4*	*97.9*	*89.5*	*84.2*
*Biomass-Ethanol**	*4.2*		*7.0*	*7.7*	*8.0*	*9.2*	*9.7*	*11.5*	*15.8*
CH_4	**248.9**		**234.6**	**230.9**	**222.1**	**224.3**	**221.6**	**215.8**	**212.7**
Natural Gas Systems	128.3		133.6	131.8	127.4	132.1	131.8	130.6	125.9
Coal Mining	81.9		62.6	62.8	58.9	56.2	55.6	52.4	53.8
Petroleum Systems	20.0		18.8	18.5	17.8	17.6	17.4	17.1	17.1

	1990		1997	1998	1999	2000	2001	2002	2003
Stationary Sources	7.8		7.4	6.9	7.1	7.3	6.7	6.4	6.7
Abandoned Coal Mines	6.1		8.1	7.2	7.3	7.7	6.9	6.4	6.4
Mobile Sources	4.8		4.0	3.9	3.6	3.4	3.1	2.9	2.7
*International Bunker Fuels**	*0.2*		*0.1*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**56.4**		**69.1**	**69.1**	**68.4**	**67.5**	**62.8**	**59.6**	**56.4**
Mobile Sources	43.7		55.2	55.3	54.6	53.2	49.0	45.6	42.1
Stationary Sources	12.3		13.5	13.4	13.5	14.0	13.5	13.5	13.8
Waste Combustion	0.4		0.4	0.3	0.3	0.4	0.4	0.5	0.5
*International Bunker Fuels**	*1.0*		*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*
Total	**5,141.7**		**5,712.8**	**5,737.7**	**5,802.6**	**5,985.3**	**5,877.3**	**5,920.7**	**5,963.4**

* 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.

Fossil Fuel Combustion (5,551.6 Tg CO_2 Eq.)

As fossil fuels are combusted, the carbon stored in them is emitted almost entirely as CO_2. The amount of carbon in fuels per unit of energy content varies significantly by fuel type. For example, coal contains the highest amount of carbon per unit of energy, while petroleum and natural gas have about 25 percent and 45 percent less carbon than coal, respectively. From 1990 through 2003, petroleum supplied the largest share of U.S. energy demands, accounting for an average of 39 percent of total energy consumption with natural gas and coal accounting for 24 and 23 percent of total energy consumption, respectively. 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 1.3 percent from 1990 to 2003. The fundamental factors influencing this trend include (1) a generally growing domestic economy over the last 13 years, and (2) significant growth in emissions from transportation activities and electricity generation. Between 1990 and 2003, CO_2 emissions from fossil fuel combustion increased from 4,711.7 Tg CO_2 Eq. to 5,551.6 Tg CO_2 Eq.—an 18 percent total increase over the thirteen-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 each end-use sector on the basis of each sector's share of aggregate electricity consumption. This method of distributing emissions assumes that each end-use sector consumes electricity that is generated from the national average mix of fuels according to their carbon intensity. In reality, sources of electricity vary widely in carbon intensity. By assuming the same carbon intensity for each end-use sector's electricity consumption, for example, emissions attributed to the residential end-use sector may be underestimated, while emissions attributed to the industrial end-use sector may be overestimated. 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.

Table 2-7: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (Tg CO_2 Eq.)

End-Use Sector	**1990**		**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Transportation	**1,449.8**		**1,606.4**	**1,636.5**	**1,693.9**	**1,741.0**	**1,723.1**	**1,755.4**	**1,770.4**
Combustion	1,446.8		1,603.3	1,633.4	1,690.8	1,737.7	1,719.7	1,752.3	1,767.2
Electricity	3.0		3.1	3.1	3.2	3.4	3.4	3.2	3.2
Industrial	**1,553.9**		**1,703.0**	**1,668.5**	**1,651.2**	**1,684.4**	**1,587.4**	**1,579.0**	**1,572.9**
Combustion	882.8		963.8	911.6	888.1	905.0	878.2	876.6	858.6
Electricity	671.1		739.2	757.0	763.1	779.4	709.3	702.4	714.3
Residential	**924.8**		**1,040.7**	**1,044.4**	**1,063.5**	**1,124.2**	**1,116.2**	**1,145.0**	**1,168.9**

Combustion	339.6	370.6	338.6	359.3	379.1	367.0	371.4	385.1
Electricity	585.3	670.2	705.8	704.2	745.0	749.2	773.6	783.8
Commercial	**755.1**	**876.7**	**892.9**	**901.2**	**959.5**	**972.7**	**973.9**	**983.1**
Combustion	224.2	237.2	219.7	222.3	235.2	226.7	230.0	234.0
Electricity	530.9	639.5	673.2	678.9	724.3	745.9	743.9	749.2
U.S. Territories	**28.0**	**36.4**	**36.3**	**36.2**	**35.9**	**48.6**	**48.1**	**56.2**
Total	**4,711.7**	**5,263.2**	**5,278.7**	**5,345.9**	**5,545.1**	**5,448.0**	**5,501.4**	**5,551.6**
Electricity Generation	**1,790.3**	**2,051.9**	**2,139.0**	**2,149.3**	**2,252.1**	**2,207.8**	**2,223.0**	**2,250.5**

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: 2003 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Figure 2-9: 2003 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion

Transportation End-Use Sector. Transportation activities (excluding international bunker fuels) accounted for 32 percent of CO_2 emissions from fossil fuel combustion in 2003.[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 transportation activities, including the combustion of diesel fuel in heavy-duty vehicles and jet fuel in aircraft.

Industrial End-Use Sector. Industrial CO_2 emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity that is consumed by industry, accounted for 28 percent of CO_2 from fossil fuel combustion in 2003. 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 2003. Both sectors relied heavily on electricity for meeting energy demands, with 67 and 76 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 35 percent of U.S. energy from fossil fuels and emitted 41 percent of the CO_2 from fossil fuel combustion in 2003. 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 2003. Consequently, changes in electricity demand have a significant impact on coal consumption and associated CO_2 emissions.

[3] If emissions from international bunker fuels are included, the transportation end-use sector accounted for 33 percent of U.S. emissions from fossil fuel combustion in 2003.

Non-Energy Use of Fossil Fuels (118.0 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. Carbon dioxide 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 sector. Emissions in 2003 for non-energy uses of fossil fuels were 118.0 Tg CO_2 Eq., which constituted 2 percent of overall fossil fuel CO_2 emissions and 2 percent of total national CO_2 emissions, approximately the same proportion as in 1990.

Waste Combustion (19.2 Tg CO_2 Eq.)

Combustion is used to manage about 7 to 17 percent of the municipal solid wastes 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. Carbon dioxide and N_2O emissions arise from the organic materials found in these wastes. Within municipal solid waste, many products contain carbon of biogenic origin (e.g., paper, yard trimmings), and the CO_2 emissions from their combustion are accounted for under the 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 2003, CO_2 emissions from waste combustion amounted to 18.8 Tg CO_2 Eq., while N_2O emissions amounted to 0.5 Tg CO_2 Eq.

Natural Gas Flaring (6.0 Tg CO_2 Eq.)

The flaring of natural gas from oil wells results in the release of CO_2 emissions. Natural gas is flared from both on-shore and off-shore oil wells to relieve rising pressure or to dispose of small quantities of gas that are not commercially marketable. In 2003, flaring accounted for approximately 0.1 percent of U.S. CO_2 emissions.

Natural Gas Systems (125.9 Tg CO_2 Eq.)

Methane is the major component of natural gas. Fugitive emissions of CH_4 occur throughout the production, processing, transmission, and distribution of natural gas. Because natural gas is often found in conjunction with petroleum deposits, leakage from petroleum systems is also a source of emissions. Emissions vary greatly from facility to facility and are largely a function of operation and maintenance procedures and equipment conditions. In 2003, CH_4 emissions from U.S. natural gas systems accounted for approximately 23 percent of U.S. CH_4 emissions.

Coal Mining (53.8 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.

Methane 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 methane, typically to the atmosphere. At some mines, CH_4-recovery systems may supplement these ventilation systems. Recovery of CH_4 in the United States has increased in recent years. During 2003, coal mining activities emitted 10 percent of U.S. CH_4 emissions. From 1990 to 2003, emissions from this source decreased by 34 percent due to increased use of the CH_4 collected by mine degasification systems and a general shift toward surface mining.

Petroleum Systems (17.1 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 methane. 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. Methane emissions from the components of petroleum systems generally occur as a result of system leaks, disruptions, and routine maintenance. In 2003, emissions from petroleum systems were just over 3 percent of U.S. CH_4 emissions.

Mobile Combustion (44.8 Tg CO_2 Eq.)

Mobile combustion results in N_2O and CH_4 emissions. Nitrous oxide 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 2003, N_2O emissions from mobile combustion were 42.1 Tg CO_2 Eq. (11 percent of U.S. N_2O emissions). From 1990 to 2003, N_2O emissions from mobile combustion decreased by about 4 percent.

In 2003, CH_4 emissions were estimated to be 2.7 Tg CO_2 Eq. The combustion of gasoline in highway vehicles was responsible for the majority of the CH_4 emitted from mobile combustion.

Stationary Combustion (20.5 Tg CO_2 Eq.)

Stationary combustion results in N_2O and CH_4 emissions. In 2003, N_2O emissions from stationary combustion accounted for 13.8 Tg CO_2 Eq. (4 percent of U.S. N_2O emissions). From 1990 to 2003, N_2O emissions from stationary combustion increased by 13 percent, due to increased fuel consumption. In 2003, CH_4 emissions were 6.7 Tg CO_2 Eq. (1 percent of U.S. CH_4 emissions). The majority of CH_4 emissions from stationary combustion resulted from the burning of wood in the residential end-use sector.

Abandoned Coal Mines (6.4 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 2003, the emissions from abandoned coal mines constituted 1 percent of U.S. CH_4 emissions.

CO_2 from Biomass Combustion (216.8 Tg CO_2 Eq.)

Biomass refers to organically-based carbon 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 carbon emitted is offset by the growth of new biomass. For example, fuel wood burned one year but re-grown the next only recycles carbon, rather than creating a net increase in total atmospheric carbon. Net carbon fluxes from changes in biogenic carbon reservoirs in wooded or croplands are accounted for in the estimates for the 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.

The consumption of wood biomass in the industrial, residential, electric power, and commercial end-use sectors accounted for 66, 17, 8, and 2 percent of gross CO_2 emissions from biomass combustion, respectively. Ethanol consumption in the transportation end-use sector accounted for the remaining 7 percent.

International Bunker Fuels (85.1 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 84.2, 0.1, and 0.8 Tg CO_2 Eq. in 2003, 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. The 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 consumption, aluminum production, petrochemical production, silicon carbide production, nitric acid production, and adipic acid 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.

Figure 2-10: 2003 Industrial Processes Chapter Greenhouse Gas Sources

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

Gas/Source	1990	1997	1998	1999	2000	2001	2002	2003
CO_2	**173.1**	**170.9**	**169.4**	**165.9**	**164.7**	**151.8**	**151.5**	**147.2**
Iron and Steel Production	85.4	71.9	67.4	64.4	65.7	58.9	55.1	53.8
Cement Manufacture	33.3	38.3	39.2	40.0	41.2	41.4	42.9	43.0
Ammonia Manufacture & Urea Application	19.3	20.7	21.9	20.6	19.6	16.7	18.6	15.6
Lime Manufacture	11.2	13.7	13.9	13.5	13.3	12.8	12.3	13.0
Limestone and Dolomite Use	5.5	7.2	7.4	8.1	6.0	5.7	5.9	4.7
Aluminum Production	6.3	5.6	5.8	5.9	5.7	4.1	4.2	4.2
Soda Ash Manufacture and Consumption	4.1	4.4	4.3	4.2	4.2	4.1	4.1	4.1
Petrochemical Production	2.2	2.9	3.0	3.1	3.0	2.8	2.9	2.8
Titanium Dioxide Production	1.3	1.8	1.8	1.9	1.9	1.9	2.0	2.0
Phosphoric Acid Production	1.5	1.5	1.6	1.5	1.4	1.3	1.3	1.4
Ferroalloy Production	2.0	2.0	2.0	2.0	1.7	1.3	1.2	1.4
Carbon Dioxide Consumption	0.9	0.8	0.9	0.8	1.0	0.8	1.0	1.3
CH_4	**2.5**	**2.9**	**2.9**	**2.9**	**2.9**	**2.5**	**2.5**	**2.5**
Petrochemical Production	1.2	1.6	1.7	1.7	1.7	1.4	1.5	1.5
Iron and Steel Production	1.3	1.3	1.2	1.2	1.2	1.1	1.0	1.0
Silicon Carbide Production	+	+	+	+	+	+	+	+
N_2O	**33.0**	**31.5**	**26.9**	**25.6**	**25.6**	**20.8**	**23.1**	**21.8**
Nitric Acid Production	17.8	21.2	20.9	20.1	19.6	15.9	17.2	15.8

Adipic Acid Production	15.2		10.3	6.0	5.5	6.0	4.9	5.9	6.0
HFCs, PFCs, and SF_6	**91.2**		**121.7**	**135.7**	**134.8**	**138.9**	**129.5**	**138.3**	**137.0**
Substitution of Ozone Depleting Substances	0.4		46.5	56.6	65.8	75.0	83.3	91.5	99.5
Electrical Transmission and Distribution	29.2		21.7	17.1	16.4	15.6	15.4	14.7	14.1
HCFC-22 Production	35.0		30.0	40.1	30.4	29.8	19.8	19.8	12.3
Aluminum Production	18.3		11.0	9.1	9.0	9.0	4.0	5.2	3.8
Semiconductor Manufacture	2.9		6.3	7.1	7.2	6.3	4.5	4.4	4.3
Magnesium Production and Processing	5.4		6.3	5.8	6.0	3.2	2.6	2.6	3.0
Total	**299.9**		**327.1**	**334.9**	**329.2**	**332.1**	**304.7**	**315.4**	**308.6**

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

Iron and Steel Production (54.8 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, resulted in emissions of CO_2 and CH_4. In 2003, 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 53.8 Tg CO_2 Eq. in 2003. From 1990 to 2003, emissions from this source decreased by 37 percent.

Cement Manufacture (43.0 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 2003, emissions from this source increased by 29 percent.

Ammonia Manufacture and Urea Application (15.6 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.

Lime Manufacture (13.0 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 calcium carbonate, $CaCO_3$) in a kiln, creating quicklime (calcium oxide, CaO) and CO_2, which is normally emitted to the atmosphere.

Limestone and Dolomite Use (4.7 Tg CO_2 Eq.)

Limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)$) 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.

Aluminum Production (8.0 Tg CO_2 Eq.)

Aluminum production results in emissions of CO_2, CF_4 and C_2F_6. Carbon dioxide 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 2003, CO_2 emissions from aluminum production amounted to 4.2 Tg CO_2 Eq.

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 79 percent between 1990 and 2003 due to emission reduction efforts by the industry and falling domestic aluminum production. In 2003, CF_4 and C_2F_6 emissions from aluminum production amounted to 3.8 Tg CO_2 Eq.

Soda Ash Manufacture and Consumption (4.1 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.

Petrochemical Production (4.3 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 2.8 Tg CO_2 Eq. of CO_2 and 1.5 Tg CO_2 Eq. of CH_4 in 2003.

Titanium Dioxide Production (2.0 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. Carbon dioxide is emitted from the chloride process, which uses petroleum coke and chlorine as raw materials.

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.

Ferroalloy Production (1.4 Tg CO_2 Eq.)

Carbon dioxide 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.

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. Carbon dioxide 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.

Silicon Carbide Production (0.01 Tg CO_2 Eq.)

Small amounts of CH_4 are released during the production of silicon carbide, a material used as an industrial abrasive. Silicon carbide (SiC) is made through a reaction of quartz (SiO_2) and carbon (in the form of petroleum coke). Methane is produced during this reaction from volatile compounds in the petroleum coke. Methane emissions from silicon carbide production have declined significantly due a 67 percent decrease in silicon carbide production since 1990. In 2003, only two companies produced silicon carbide in the United States (one company produced abrasive-grade silicon carbide and the other produced a small quantity for heat-resistant products).

Nitric Acid Production (15.8 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 2003, N_2O emissions from nitric acid production accounted for 4 percent of U.S. N_2O emissions. From 1990 to 2003, emissions from this source category decreased by11 percent with the trend in the time series closely tracking the changes in production.

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. Nitrous oxide is emitted as a by-product of the chemical synthesis of adipic acid.

In 2003, U.S. adipic acid plants emitted 2 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 60 percent since 1990.

Substitution of Ozone Depleting Substances (99.5 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 account for 73 percent of aggregate HFC, PFC, and SF_6 emissions. 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 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.

HCFC-22 Production (12.3 Tg CO_2 Eq.)

HFC-23 is a by-product of the production of HCFC-22. Emissions from this source have decreased by 65 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.

Electrical Transmission and Distribution Systems (14.1 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 52 percent since 1990, primarily due to higher SF_6 prices and industrial efforts to reduce emissions.

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 49 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 2003. This later reduction is due to the implementation of PFC emission reduction methods, such as process optimization.

Magnesium Production (3.0 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 45 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.

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 sector, accounted for 4.8 Tg CO_2 Eq. of N_2O, or less than 0.1 percent of total U.S. anthropogenic greenhouse gas emissions on a carbon equivalent basis in 2003 (see Table 2-9).

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

Gas/Source	1990		1997	1998	1999	2000	2001	2002	2003
N_2O	**4.3**		**4.8**	**4.8**	**4.8**	**4.8**	**4.8**	**4.8**	**4.8**
Nitrous Oxide Product Usage	4.3		4.8	4.8	4.8	4.8	4.8	4.8	4.8
Total	**4.3**		**4.8**	**4.8**	**4.8**	**4.8**	**4.8**	**4.8**	**4.8**

N_2O Product Usage (4.8 Tg CO_2 Eq.)

Nitrous oxide 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 2003, N_2O emissions from product usage constituted approximately 1 percent of U.S. N_2O emissions. From 1990 to 2003, emissions from this source category increased by 11 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 2003, agricultural activities were responsible for emissions of 433.3 Tg CO_2 Eq., or 6 percent of total U.S. greenhouse gas emissions. Methane and N_2O were the primary greenhouse gases emitted by agricultural activities. Methane emissions from enteric fermentation and manure management represented about 21 percent and 7 percent of total CH_4 emissions from anthropogenic activities, respectively in 2003. Agricultural soil management activities such as fertilizer application and other cropping practices were the largest source of U.S. N_2O emissions in 2003, accounting for 67 percent. Table 2-10 presents emission estimates for the Agriculture sector.

Figure 2-11: 2003 Agriculture Chapter Greenhouse Gas Sources

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

Gas/Source	1990		1997	1998	1999	2000	2001	2002	2003
CH_4	**156.9**		**163.0**	**164.2**	**164.6**	**162.0**	**161.9**	**161.5**	**161.8**
Enteric Fermentation	117.9		118.3	116.7	116.8	115.6	114.5	114.6	115.0
Manure Management	31.2		36.4	38.8	38.8	38.1	38.9	39.3	39.1
Rice Cultivation	7.1		7.5	7.9	8.3	7.5	7.6	6.8	6.9
Field Burning of Agricultural Residues	0.7		0.8	0.8	0.8	0.8	0.8	0.7	0.8
N_2O	**269.6**		**269.8**	**285.6**	**261.3**	**282.1**	**275.6**	**270.9**	**271.5**
Agricultural Soil Management	253.0		252.0	267.7	243.4	263.9	257.1	252.6	253.5
Manure Management	16.3		17.3	17.4	17.4	17.8	18.0	17.9	17.5
Field Burning of Agricultural Residues	0.4		0.4	0.5	0.4	0.5	0.5	0.4	0.4
Total	**426.5**		**432.8**	**449.8**	**425.9**	**444.1**	**437.5**	**432.4**	**433.3**

Note: Totals may not sum due to independent rounding.

Enteric Fermentation (115.0 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 2003, enteric fermentation was the source of about 21 percent of U.S. CH_4 emissions, and more than 71 percent of the CH_4 emissions from agriculture. From 1990 to 2003, emissions from this source decreased by 2 percent. Emissions from enteric fermentation have decreasing significantly since 1995, primarily due to declining dairy cow and beef cattle populations as a result of improved efficiency in milk and beef production.

Manure Management (56.7 Tg CO_2 Eq.)

Both CH_4 and N_2O resulted 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.

Emissions from manure management were 39.1 Tg CO_2 Eq., or about 7 percent of U.S. CH_4 emissions in 2003 and 24 percent of the CH_4 emissions from the agriculture sector. From 1990 to 2003, emissions from this source increased by 26 percent. The bulk of this increase was from swine and dairy cow manure, and is attributed to the shift in the composition of the swine and dairy industries towards larger facilities. Larger swine and dairy farms tend to use liquid management systems.

Nitrous oxide 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 2003 accounted for 17.5 Tg CO_2 Eq., or 5 percent of U.S. N_2O emissions. From 1990 to 2003, emissions from this source category increased by 8 percent, primarily due to increases in swine and poultry populations over the same time 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 2003, 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 (1.2 Tg CO_2 Eq.)

Burning crop residue releases N_2O and CH_4. Because field burning is not a common debris clearing method used in the United States, it was responsible for only 0.1 percent of U.S. CH_4 (0.8 Tg CO_2 Eq.) and N_2O (0.4 Tg CO_2 Eq.) emissions in 2003.

Agricultural Soil Management (253.5 Tg CO_2 Eq.)

Nitrous oxide is produced naturally in soils through microbial processes of nitrification and denitrification. 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 2003, agricultural soil management accounted for 67 percent of U.S. N_2O emissions. From 1990 to 2003, emissions from this source increased slightly as fertilizer consumption, manure production, and production of nitrogen-fixing and other crops rose. Year-to-year fluctuations are largely a reflection of annual variations in climate, synthetic fertilizer consumption, and crop production.

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 12 percent of total U.S. gross CO_2 emissions in 2003. Forests (including vegetation, soils, and harvested wood) accounted for approximately 91 percent of total 2003 sequestration, urban trees accounted for 7 percent, agricultural soils (including mineral and organic soils and the application of lime) accounted for 1 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total sequestration in 2003. 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 approximately one and a third times larger than the sum of emissions from organic soils and liming. The mineral soil carbon sequestration is largely due to conversion of cropland to permanent pastures and hay production, a reduction in summer fallow areas in semi-arid areas, an increase in the adoption of conservation tillage practices, and an increase in the amounts of organic fertilizers (i.e., manure and sewage sludge) applied to agriculture lands. The landfilled yard trimmings and food scraps net sequestration is due to the long-term accumulation of yard trimming carbon and food scraps in landfills.

Land use, land-use change, and forestry activities in 2003 resulted in a net carbon sequestration of 828.0 Tg CO_2 Eq. (Table ES-5). This represents an offset of approximately 14 percent of total U.S. CO_2 emissions. Total land use, land-use change, and forestry net carbon sequestration declined by approximately 21 percent between 1990 and 2003. This decline was primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks. Annual carbon accumulation in landfilled yard trimmings and food scraps also slowed over this period, as did annual carbon accumulation in agricultural soils. As described above, the constant rate of carbon accumulation in urban trees is a reflection of limited underlying data (i.e., this rate represents an average for 1990 through 1999).

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

Sink Category	1990		1997	1998	1999	2000	2001	2002	2003
Forest Land Remaining Forest Land	**(949.3)**		**(851.0)**	**(805.5)**	**(751.7)**	**(747.9)**	**(750.9)**	**(751.5)**	**(752.7)**
Changes in Forest Carbon Stocks	(949.3)		(851.0)	(805.5)	(751.7)	(747.9)	(750.9)	(751.5)	(752.7)
Cropland Remaining Cropland	**(8.1)**		**(7.4)**	**(4.3)**	**(4.3)**	**(5.7)**	**(7.1)**	**(6.2)**	**(6.6)**
Changes in Agricultural Soil Carbon	(8.1)		(7.4)	(4.3)	(4.3)	(5.7)	(7.1)	(6.2)	(6.6)

Stocks									
Settlements Remaining Settlements	**(84.7)**		**(71.6)**	**(71.2)**	**(70.0)**	**(68.9)**	**(68.9)**	**(68.8)**	**(68.7)**
Urban Trees	(58.7)		(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)
Landfilled Yard Trimmings and Food Scraps	(26.0)		(12.9)	(12.5)	(11.4)	(10.2)	(10.3)	(10.2)	(10.1)
Total	**(1,042.0)**		**(930.0)**	**(881.0)**	**(826.1)**	**(822.4)**	**(826.9)**	**(826.5)**	**(828.0)**

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

Land use, land-use change, and forestry activities in 2003 also resulted in emissions of N_2O (6.4 Tg CO_2 Eq., Table 2-12). Total N_2O emissions from the application of fertilizers to forests and settlements increased by approximately 14 percent between 1990 and 2003.

Table 2-12: N_2O Emissions from Land-Use Change and Forestry (Tg CO_2 Eq.)

Sink Category	1990		1997	1998	1999	2000	2001	2002	2003
Forest Land Remaining Forest Land	**0.1**		**0.3**	**0.4**	**0.5**	**0.4**	**0.4**	**0.4**	**0.4**
N_2O Fluxes from Soils	0.1		0.3	0.4	0.5	0.4	0.4	0.4	0.4
Settlements Remaining Settlements	**5.5**		**6.1**	**6.1**	**6.2**	**6.0**	**5.8**	**6.0**	**6.0**
N_2O Fluxes from Soils	5.5		6.1	6.1	6.2	6.0	5.8	6.0	6.0
Total	**5.6**		**6.4**	**6.5**	**6.6**	**6.3**	**6.2**	**6.4**	**6.4**

Note: Totals may not sum due to independent rounding.

Forest Land Remaining Forest Land (0.4 Tg CO_2 Eq.)

As with other agricultural applications, forests may be fertilized to stimulate growth rates. This 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 2003 were almost 7 times higher than in 1990, primarily the result of an increase in fertilized area of pine plantations in the southeastern U.S. This source accounts for approximately 0.1 percent of total U.S. N_2O emissions.

Settlements Remaining Settlements (6.0 Tg CO_2 Eq.)

Of the fertilizers applied to soils in the U.S., approximately 10 percent are applied to lawns, golf courses, and other landscaping within settled areas. In 2003, N_2O emissions from settlement soils constituted approximately 1.6 percent of total U.S N_2O emissions. There has been an overall increase in emissions of 9 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 methane (CH_4) emissions, accounting for 24 percent of total U.S. CH_4 emissions.[4] Wastewater treatment systems are a potentially significant source of nitrous oxide (N_2O) emissions; however, methodologies are not currently available to develop a complete estimate. Nitrous oxide emissions from the treatment of the human sewage component of wastewater were estimated, however, using a simplified methodology. Nitrogen oxide (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOCs) are also emitted by waste activities. A summary of greenhouse gas and ambient air pollutant emissions from the Waste sector is presented in Table 2-13.

Figure 2-12: 2003 Waste Sector Greenhouse Gas Sources

[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 Change and Forestry chapter.

Overall, in 2003, waste activities generated emissions of 183.8 Tg CO_2 Eq., or 3 percent of total U.S. greenhouse gas emissions.

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

Gas/Source	1990		1997	1998	1999	2000	2001	2002	2003
CH_4	**197.1**		**179.0**	**171.0**	**167.7**	**165.0**	**160.9**	**162.6**	**167.9**
Landfills	172.2		147.4	138.5	134.0	130.7	126.2	126.8	131.2
Wastewater Treatment	24.8		31.7	32.6	33.6	34.3	34.7	35.8	36.8
N_2O	**13.0**		**14.7**	**15.0**	**15.4**	**15.6**	**15.6**	**15.7**	**15.9**
Human Sewage	13.0		14.7	15.0	15.4	15.6	15.6	15.7	15.9
Total	**210.1**		**193.7**	**186.0**	**183.1**	**180.6**	**176.5**	**178.3**	**183.8**

Note: Totals may not sum due to independent rounding.

Landfills (131.2 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 2003. In an environment where the oxygen content is low or zero, anaerobic bacteria can decompose organic materials, such as yard waste, household waste, food waste, and paper, resulting in the generation of CH_4 and biogenic CO_2. Site-specific factors, such as waste composition, moisture, and landfill size, influence the level of methane generation.

From 1990 to 2003, net CH_4 emissions from landfills decreased by approximately 24 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 by landfill operators, which has more than offset the additional CH_4 emissions resulting from an increase in the amount of municipal solid waste landfilled.

Wastewater Treatment (36.8 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. In 2003, wastewater treatment was the source of approximately 7 percent of U.S. CH_4 emissions.

Human Sewage (Domestic Wastewater) (15.9 Tg CO_2 Eq.)

Domestic human sewage is usually mixed with other household wastewater, which includes shower drains, sink drains, washing machine effluent, etc., and transported by a collection system to either a direct discharge, an on-site or decentralized or centralized wastewater treatment system. After processing, treated effluent may be discharged to a receiving water environment (e.g., river, lake, estuary, etc.), applied to soils, or disposed of below the surface. Nitrous oxide may be generated during both nitrification and denitrification of the nitrogen present, usually in the form of urea, ammonia, and proteins. Emissions of N_2O from treated human sewage discharged into aquatic environments accounted for 4 percent of U.S. N_2O emissions in 2003. From 1990 to 2003, emissions from this source category increased by 22 percent.

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 Use, Agriculture, Land-Use Change and Forestry, and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories. This section reports emissions by the following "economic sectors": Residential, Commercial, Industry, Transportation, Electricity Generation, and Agriculture, as well as U.S. Territories. Using this categorization, emissions from electricity generation accounted for the largest portion (33 percent) of U.S. greenhouse gas emissions in 2003. Transportation activities, in aggregate, accounted for the second largest portion (27 percent). Additional discussion and data on these two economic sectors is provided below.

Emissions from industry accounted for 19 percent of U.S. greenhouse gas emissions in 2003. In contrast to electricity generation and transportation, emissions from industry have declined over the past decade, as structural changes have occurred in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching has occurred, and efficiency improvements have been made. The residential, agriculture, commercial economic sectors, and U.S. territories, contributed the remaining 20 percent of emissions. The residential economic sector accounted for approximately 6 percent, and primarily consisted of CO_2 emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 7 percent of U.S. emissions, but unlike all other economic sectors these emissions were dominated by non-CO_2 emissions. The commercial sector accounted for about 7 percent of emissions, while U.S. territories accounted for 1 percent of total emissions.

Carbon dioxide 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 2003.

Figure 2-13: Emissions Allocated to Economic Sectors

Table 2-14: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq. and Percent of Total in 2003)

Sector/Source	1990	1997	1998	1999	2000	2001	2002	2003	Percent[a]
Electricity Generation	**1,841.8**	**2,104.6**	**2,186.8**	**2,197.3**	**2,299.0**	**2,254.9**	**2,269.7**	**2,296.2**	**33.3%**
CO_2 from Fossil Fuel Combustion	1,790.3	2,051.9	2,139.0	2,149.3	2,252.1	2,207.8	2,223.0	2,250.5	32.6%
Stationary Combustion[d]	8.1	9.3	9.5	9.5	10.0	9.7	9.8	10.0	0.1%
Electrical Transmission and Distribution[c]	29.2	21.7	17.1	16.4	15.6	15.4	14.7	14.1	0.2%
Waste Combustion[b]	11.3	18.1	17.4	18.0	18.3	19.2	19.2	19.2	0.3%
Limestone and Dolomite Use	2.8	3.6	3.7	4.0	3.0	2.9	2.9	2.4	+
Transportation	**1,506.8**	**1,693.0**	**1,728.7**	**1,790.0**	**1,839.6**	**1,819.8**	**1,851.6**	**1,864.4**	**27.0%**
CO_2 from Fossil Fuel Combustion	1,446.8	1,603.3	1,633.4	1,690.8	1,737.7	1,719.7	1,752.3	1,767.2	25.6%
Mobile Combustion[d]	48.1	58.7	58.7	57.7	56.1	51.6	48.1	44.3	0.6%
Substitution of ODS[e]	+	19.4	24.4	29.3	33.8	37.4	40.4	42.7	0.6%
Non-Energy Use of Fuels	11.9	11.6	12.1	12.3	12.1	11.1	10.9	10.2	0.1%
Industry	**1,446.1**	**1,509.1**	**1,470.6**	**1,427.9**	**1,431.8**	**1,371.0**	**1,365.7**	**1,331.4**	**19.3%**
CO_2 from Fossil Fuel Combustion	836.5	905.4	853.9	828.0	854.6	827.9	824.3	806.3	11.7%
Non-Energy Use of Fuels	90.4	102.6	117.0	121.8	101.7	103.7	102.6	101.9	1.5%
Stationary Combustion	5.3	5.9	5.5	5.5	5.6	5.2	5.3	5.3	0.1%

Coal Mining	81.9	62.6	62.8	58.9	56.2	55.6	52.4	53.8	0.8%
Abandoned Coal Mines	6.1	8.1	7.2	7.3	7.7	6.9	6.4	6.4	0.1%
Natural Gas Systems	128.3	133.6	131.8	127.4	132.1	131.8	130.6	125.9	1.8%
Petroleum Systems	20.0	18.8	18.5	17.8	17.6	17.4	17.1	17.1	0.2%
Natural Gas Flaring	5.8	7.9	6.6	6.9	5.8	6.1	6.2	6.0	0.1%
Titanium Dioxide Production	1.3	1.8	1.8	1.9	1.9	1.9	2.0	2.0	+
Aluminum Production[h]	24.7	16.6	14.8	14.9	14.7	8.1	9.5	8.0	0.1%
Iron and Steel Production[f]	86.7	73.1	68.6	65.5	66.9	60.0	56.1	54.8	0.8%
Ferroalloys	2.0	2.0	2.0	2.0	1.7	1.3	1.2	1.4	+
Ammonia Manufacture	19.3	20.7	21.9	20.6	19.6	16.7	18.6	15.6	0.2%
Cement Manufacture	33.3	38.3	39.2	40.0	41.2	41.4	42.9	43.0	0.6%
Lime Manufacture	11.2	13.7	13.9	13.5	13.3	12.8	12.3	13.0	0.2%
Limestone and Dolomite Use	2.8	3.6	3.7	4.0	3.0	2.9	2.9	2.4	+
Soda Ash Manufacture and Consumption	4.1	4.4	4.3	4.2	4.2	4.1	4.1	4.1	0.1%
Carbon Dioxide Consumption	0.9	0.8	0.9	0.8	1.0	0.8	1.0	1.3	+
Petrochemical Production	3.4	4.6	4.7	4.8	4.7	4.2	4.4	4.3	0.1%
Silicon Carbide Production	+	+	+	+	+	+	+	+	+
Phosphoric Acid Production	1.5	1.5	1.6	1.5	1.4	1.3	1.3	1.4	+
Adipic Acid	15.2	10.3	6.0	5.5	6.0	4.9	5.9	6.0	0.1%
Nitric Acid	17.8	21.2	20.9	20.1	19.6	15.9	17.2	15.8	0.2%
N_2O Product Usage	4.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8	0.1%
HCFC-22 Production[g]	35.0	30.0	40.1	30.4	29.8	19.8	19.8	12.3	0.2%
Semiconductor Manufacture[e]	2.9	6.3	7.1	7.2	6.3	4.5	4.4	4.3	0.1%
Magnesium Production and Processing[c]	5.4	6.3	5.8	6.0	3.2	2.6	2.6	3.0	+
Substitution of ODS[e]	0.1	4.1	5.1	6.4	7.4	8.4	9.7	11.2	0.2%
Agriculture	**473.3**	**492.0**	**508.4**	**486.9**	**495.3**	**488.6**	**485.6**	**486.4**	**7.0%**
CO_2 from Fossil Fuel Combustion	46.3	58.4	57.6	60.0	50.4	50.3	52.3	52.2	0.8%
Stationary Combustion[d]	+	+	+	+	+	+	+	+	+
Mobile Combustion[d]	0.4	0.5	0.5	0.5	0.4	0.4	0.5	0.5	+
Enteric Fermentation	117.9	118.3	116.7	116.8	115.6	114.5	114.6	115.0	1.7%
Manure Management[d]	47.4	53.7	56.2	56.2	55.9	56.9	57.3	56.7	0.8%
Rice Cultivation	7.1	7.5	7.9	8.3	7.5	7.6	6.8	6.9	0.1%
Agricultural Residue Burning[d]	1.1	1.2	1.2	1.2	1.2	1.2	1.1	1.2	+
Agricultural Soil Management	253.0	252.0	267.7	243.4	263.9	257.1	252.6	253.5	3.7%
Forest Soil Fertilization	0.1	0.3	0.4	0.5	0.4	0.4	0.4	0.4	+
Commercial	**435.4**	**445.2**	**424.2**	**426.8**	**440.7**	**431.4**	**440.2**	**453.5**	**7.0%**
CO_2 from Fossil Fuel Combustion	224.2	237.2	219.7	222.3	235.2	226.7	230.0	234.0	3.4%
Stationary Combustion[d]	1.1	1.1	1.1	1.1	1.2	1.0	1.1	1.1	+
Substitution of ODS[d]	+	13.1	17.4	20.3	23.8	27.1	30.8	34.7	0.5%
Landfills	172.2	147.4	138.5	134.0	130.7	126.2	126.8	131.2	1.9%
Human Sewage	13.0	14.7	15.0	15.4	15.6	15.6	15.7	15.9	0.2%
Wastewater Treatment	24.8	31.7	32.6	33.6	34.3	34.7	35.8	36.8	0.5%
Residential	**350.9**	**391.0**	**358.4**	**379.5**	**399.7**	**387.1**	**391.6**	**406.1**	**5.9%**
CO_2 from Fossil Fuel Combustion	339.6	370.6	338.6	359.3	379.1	367.0	371.4	385.1	5.6%

Stationary Combustion[c]	5.5	4.4	4.0	4.3	4.5	4.0	3.6	3.9	0.1%
Substitution of ODS[e]	0.3	9.9	9.6	9.8	10.1	10.3	10.6	11.0	0.2%
Settlement Soil Fertilization	5.5	6.1	6.1	6.2	6.0	5.8	6.0	6.0	0.1%
U.S. Territories	**33.8**	**42.7**	**42.7**	**43.9**	**47.0**	**54.1**	**53.6**	**62.3**	**0.9%**
CO_2 from Fossil Fuel Combustion	33.8	42.7	42.7	43.9	47.0	54.1	53.6	62.3	0.9%
Total	**6,088.1**	**6,677.5**	**6,719.7**	**6,752.2**	**6,953.2**	**6,806.9**	**6,858.1**	**6,900.2**	**100.0%**
Sinks	**(1,042.0)**	**(930.0)**	**(881.0)**	**(826.1)**	**(822.4)**	**(826.9)**	**(826.5)**	**(828.0)**	**-12.0%**
Forests	(949.3)	(851.0)	(805.5)	(751.7)	(747.9)	(750.9)	(751.5)	(752.7)	-10.9%
Urban Trees	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	-0.9%
Agricultural Soils	(8.1)	(7.4)	(4.3)	(4.3)	(5.7)	(7.1)	(6.2)	(6.6)	-0.1%
Landfilled Yard Trimmings	(26.0)	(12.9)	(12.5)	(11.4)	(10.2)	(10.3)	(10.2)	(10.1)	-0.1%
Net Emissions (Sources and Sinks)	**5,046.1**	**5,747.5**	**5,838.8**	**5,926.1**	**6,130.8**	**5,980.1**	**6,031.6**	**6,072.2**	

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.
ODS (Ozone Depleting Substances)
+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05%.
- Not applicable.
[a] Percent of total emissions for year 2003.
[b] Includes both CO_2 and N_2O.
[c] SF_6 emitted.
[d] Includes both CH_4 and N_2O.
[e] May include a mixture of HFCs, PFCs, and SF_6.
[f] Includes both CH_4 and CO_2.
[g] HFC-23 emitted.
[h] Includes both CO_2 and PFCs.

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 33 percent of total U.S. greenhouse gas emissions in 2003. Emissions increased by 25 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.

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

Gas/Fuel Type or Source	1990	1997	1998	1999	2000	2001	2002	2003
CO_2	**1,804.0**	**2,073.3**	**2,159.9**	**2,171.0**	**2,273.1**	**2,229.4**	**2,244.8**	**2,271.7**
CO_2 from Fossil Fuel Combustion	1,790.3	2,051.9	2,139.0	2,149.3	2,252.1	2,207.8	2,223.0	2,250.5
Coal	*1,513.0*	*1,758.4*	*1,786.4*	*1,792.4*	*1,880.0*	*1,817.4*	*1,839.7*	*1,876.3*
Natural Gas	*176.0*	*218.9*	*248.0*	*259.9*	*280.7*	*289.1*	*305.6*	*277.6*
Petroleum	*101.0*	*74.3*	*104.3*	*96.7*	*91.0*	*100.9*	*77.4*	*96.3*
Geothermal	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.3*
Waste Combustion	10.9	17.8	17.1	17.6	18.0	18.8	18.8	18.8
Limestone and Dolomite Use	2.8	3.6	3.7	4.0	3.0	2.9	2.9	2.4
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**	**9.0**	**9.2**	**9.2**	**9.6**	**9.4**	**9.5**	**9.8**
Stationary Combustion*	7.6	8.6	8.9	8.9	9.3	9.0	9.1	9.3

Waste Combustion	0.4	0.4	0.3	0.3	0.4	0.4	0.5	0.5
SF_6	**29.2**	**21.7**	**17.1**	**16.4**	**15.6**	**15.4**	**14.7**	**14.1**
Electrical Transmission and Distribution	29.2	21.7	17.1	16.4	15.6	15.4	14.7	14.1
Total	**1,841.8**	**2,104.6**	**2,186.8**	**2,197.3**	**2,299.0**	**2,254.9**	**2,269.7**	**2,296.2**

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

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 2004a and Duffield 2004). These three source categories include CO_2 from fossil fuel combustion, CH_4 and N_2O from stationary sources, and SF_6 from electrical transmission and distribution systems.[5]

When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S. greenhouse gas emissions (30 percent). Emissions from the residential and commercial sectors also increase substantially due to their relatively large share of electricity consumption. Transportation activities remain the second largest contributor to emissions. In all sectors except agriculture, CO_2 accounts for more than 75 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 2003.

Figure 2-14: Emissions with Electricity Distributed to Economic Sectors

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 2003

Sector/Gas	1990	1997	1998	1999	2000	2001	2002	2003	Percent[a]
Industry	**2,075.7**	**2,247.3**	**2,223.2**	**2,190.1**	**2,207.7**	**2,074.0**	**2,062.9**	**2,040.1**	**29.6%**
Direct Emissions	**1,446.1**	**1,509.1**	**1,470.6**	**1,427.9**	**1,431.8**	**1,371.0**	**1,365.7**	**1,331.4**	19.3%
CO_2	1,103.0	1,183.2	1,143.2	1,118.6	1,123.7	1,086.7	1,081.7	1,059.0	15.3%
CH_4	240.9	228.4	225.3	216.5	218.7	216.4	211.2	207.9	3.0%
N_2O	40.5	39.8	34.9	33.6	33.7	28.7	31.1	29.8	0.4%
HFCs, PFCs, and SF_6	61.7	57.7	67.2	59.1	55.6	39.3	41.8	34.6	0.5%
Electricity-Related	**629.6**	**738.2**	**752.5**	**762.2**	**775.9**	**702.9**	**697.2**	**708.7**	10.3%
CO_2	616.7	727.2	743.3	753.1	767.2	695.0	689.5	701.2	10.2%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.7	3.2	3.2	3.2	3.3	2.9	2.9	3.0	+
SF_6	10.0	7.6	5.9	5.7	5.3	4.8	4.5	4.4	0.1%
Transportation	**1,509.9**	**1,696.1**	**1,731.8**	**1,793.2**	**1,843.0**	**1,823.2**	**1,854.8**	**1,867.6**	**27.1%**
Direct Emissions	**1,506.8**	**1,693.0**	**1,728.7**	**1,790.0**	**1,839.6**	**1,819.8**	**1,851.6**	**1,864.4**	27.0%
CO_2	1,458.7	1,614.9	1,645.6	1,703.0	1,749.8	1,730.8	1,763.2	1,777.4	25.8%
CH_4	4.4	3.5	3.4	3.1	2.9	2.6	2.4	2.2	+
N_2O	43.7	55.2	55.3	54.6	53.2	49.0	45.6	42.1	0.6%
HFCs[b]	+	19.4	24.4	29.3	33.8	37.4	40.4	42.7	0.6%

[5] 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.

Electricity-Related	**3.1**	**3.1**	**3.1**	**3.1**	**3.3**	**3.4**	**3.1**	**3.2**	+
CO_2	3.0	3.0	3.0	3.1	3.3	3.3	3.1	3.2	+
CH_4	+	+	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+	+	+
SF_6	+	+	+	+	+	+	+	+	+
Commercial	**981.6**	**1,083.8**	**1,093.5**	**1,104.9**	**1,161.8**	**1,170.6**	**1,178.5**	**1,196.8**	**17.3%**
Direct Emissions	**435.4**	**445.2**	**424.2**	**426.8**	**440.7**	**431.4**	**440.2**	**453.5**	6.6%
CO_2	224.2	237.2	219.7	222.3	235.2	226.7	230.0	234.0	3.4%
CH_4	197.8	179.8	171.8	168.5	165.8	161.6	163.4	168.7	2.4%
N_2O	13.4	15.0	15.3	15.8	15.9	16.0	16.0	16.2	0.2%
HFCs	+	13.1	17.4	20.3	23.8	27.1	30.8	34.7	0.5%
Electricity-Related	**546.2**	**638.7**	**669.3**	**678.1**	**721.1**	**739.2**	**738.3**	**743.3**	10.8%
CO_2	535.0	629.2	661.0	670.0	713.0	730.9	730.2	735.3	10.7%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.4	2.7	2.8	2.8	3.0	3.1	3.1	3.2	+
SF_6	8.7	6.6	5.2	5.1	4.9	5.1	4.8	4.6	0.1%
Residential	**953.0**	**1,060.3**	**1,060.0**	**1,082.9**	**1,141.4**	**1,129.6**	**1,159.5**	**1,183.7**	**17.2%**
Direct Emissions	**350.9**	**391.0**	**358.4**	**379.5**	**399.7**	**387.1**	**391.6**	**406.1**	5.9%
CO_2	339.6	370.6	338.6	359.3	379.1	367.0	371.4	385.1	5.6%
CH_4	4.4	3.5	3.1	3.4	3.5	3.1	2.8	3.1	+
N_2O	6.6	7.1	7.0	7.1	6.9	6.7	6.8	6.9	0.1%
HFCs	0.3	9.9	9.6	9.8	10.1	10.3	10.6	11.0	0.2%
Electricity-Related	**602.1**	**669.3**	**701.6**	**703.4**	**741.7**	**742.5**	**767.9**	**777.6**	11.3%
CO_2	589.7	659.3	693.0	695.0	733.3	734.1	759.4	769.3	11.2%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.6	2.9	3.0	2.9	3.1	3.1	3.2	3.3	+
SF_6	9.6	6.9	5.5	5.2	5.0	5.1	5.0	4.8	0.1%
Agriculture	**534.1**	**547.4**	**568.6**	**537.3**	**552.3**	**555.5**	**548.8**	**549.8**	**8.0%**
Direct Emissions	**473.3**	**492.0**	**508.4**	**486.9**	**495.3**	**488.6**	**485.6**	**486.4**	7.0%
CO_2	46.3	58.4	57.6	60.0	50.4	50.3	52.3	52.2	0.8%
CH_4	157.0	163.1	164.4	164.8	162.1	162.0	161.6	162.0	2.3%
N_2O	270.0	270.5	286.3	262.1	282.8	276.3	271.7	272.2	3.9%
Electricity-Related	**60.8**	**55.4**	**60.2**	**50.4**	**57.0**	**66.9**	**63.2**	**63.4**	**0.9%**
CO_2	59.6	54.6	59.5	49.8	56.3	66.2	62.5	62.7	0.9%
CH_4	+	+	+	+	+	+	+	+	+
N_2O	0.3	0.2	0.3	0.2	0.2	0.3	0.3	0.3	+
SF_6	1.0	0.6	0.5	0.4	0.4	0.5	0.4	0.4	+
U.S. Territories	**33.8**	**42.7**	**42.7**	**43.9**	**47.0**	**54.1**	**53.6**	**62.3**	**0.9%**
CO_2	33.8	42.7	42.7	43.9	47.0	54.1	53.6	62.3	0.9%
Total	**6,088.1**	**6,677.5**	**6,719.7**	**6,752.2**	**6,953.2**	**6,806.9**	**6,858.1**	**6,900.2**	**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%.
[a] Percents for year 2003.
[b] Includes primarily HFC-134a.

Transportation

Transportation activities accounted for 27 percent of U.S. greenhouse gas emissions in 2003. 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 2003, transportation emissions rose by 24 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 35 percent from 1990 to 2003) 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 and freight transportation by both air and road modes during the 1990s.

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 22 percent from 1990 to 2003. This rise in CO_2 emissions, combined with an increase of 42.7 Tg CO_2 Eq. in HFC emissions over the same period, led to an increase in overall emissions from transportation activities of 24 percent.

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

Gas/Vehicle Type	1990		1997	1998	1999	2000	2001	2002	2003
CO_2	**1,461.7**		**1,618.0**	**1,648.7**	**1,706.2**	**1,753.1**	**1,734.2**	**1,766.4**	**1,780.7**
Passenger Cars	612.5		595.5	613.8	622.4	623.4	625.7	639.5	633.7
Light-Duty Trucks	312.2		421.6	432.1	449.2	452.1	456.2	468.1	478.8
Other Trucks	217.0		279.9	290.4	304.3	320.4	327.5	327.5	341.2
Buses	7.8		9.1	9.3	10.4	10.2	9.6	9.1	8.9
Aircraft[a]	177.2		179.0	181.3	186.7	193.2	183.4	174.9	171.3
Ships and Boats	49.2		38.7	32.4	42.3	63.1	42.7	57.2	57.5
Locomotives	36.3		40.0	40.5	41.7	41.8	42.8	41.0	42.8
Other[b]	49.4		54.2	48.7	49.3	48.9	46.1	49.0	46.6
International Bunker Fuels[c]	*93.6*		*106.1*	*103.3*	*102.7*	*102.2*	*98.5*	*89.5*	*84.2*
CH_4	**4.6**		**3.8**	**3.7**	**3.4**	**3.2**	**2.9**	**2.7**	**2.4**
Passenger Cars	2.6		1.9	1.8	1.7	1.5	1.4	1.2	1.1
Light-Duty Trucks	1.4		1.3	1.3	1.1	1.0	0.9	0.9	0.8
Other Trucks and Buses	0.3		0.3	0.3	0.3	0.2	0.2	0.2	0.2
Aircraft	0.2		0.2	0.1	0.2	0.2	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*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**42.9**		**54.2**	**54.4**	**53.7**	**52.2**	**47.9**	**44.5**	**40.9**
Passenger Cars	25.5		26.7	26.7	25.9	24.7	23.1	21.6	19.9
Light-Duty Trucks	14.1		23.7	23.7	23.6	23.0	20.6	18.6	16.8
Other Trucks and Buses	0.9		1.4	1.6	1.7	1.7	1.7	1.8	1.8
Aircraft	1.7		1.7	1.8	1.8	1.9	1.8	1.7	1.7
Ships and Boats	0.4		0.3	0.3	0.3	0.5	0.3	0.5	0.5
Locomotives	0.3		0.3	0.3	0.3	0.3	0.3	0.3	0.3
Motorcycles	+		+	+	+	+	+	+	+
International Bunker Fuels[c]	*1.0*		*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*	*0.8*
HFCs	**+**		**19.4**	**24.4**	**29.3**	**33.8**	**37.4**	**40.4**	**42.7**
Mobile Air Conditioners[d]	+		13.8	17.4	20.8	24.0	26.7	28.8	30.3
Refrigerated Transport	+		5.5	7.0	8.5	9.8	10.8	11.5	12.3
Total	**1,509.3**		**1,695.4**	**1,731.1**	**1,792.5**	**1,842.2**	**1,822.4**	**1,853.9**	**1,866.7**

+ 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.

[BEGIN TEXT BOX]

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 2004) and fuel sales data (EIA 1991 through 2004). To avoid double-counting, emission estimates of CO_2 from fossil fuel combustion and non-CO_2 from stationary and mobile sources 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, Wastewater Treatment, and Human Sewage.* CH_4 emissions from landfills and wastewater treatment, as well as N_2O emissions from human sewage, were allocated to the commercial sector.

- *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 used in 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, mobile and transport refrigeration/air-conditioning systems 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.

[END TEXT BOX]

2.3. Ambient Air Pollutant Emissions

In the United States, carbon monoxide (CO), nitrogen oxides (NO_x), nonmethane volatile organic compounds (NMVOCs), and sulfur dioxide (SO_2) are referred to as "ambient air pollutants," and are regulated under the Clean Air Act in an effort to protect human health and the environment. These pollutants 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 pollutants may react with other chemical compounds in the 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 nitrous oxide (N_2O). NMVOCs—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 t 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 ambient air pollutant formation into greenhouse gases is carbon monoxide's interaction with the hydroxyl radical—the major atmospheric sink for methane emissions—to form CO_2. Therefore, increased atmospheric concentrations of CO limit the number of hydroxyl molecules (OH) available to destroy methane.

Since 1970, the United States has published estimates of annual emissions of ambient air pollutants (EPA 2004).[6] Table 2-18 shows that fuel combustion accounts for the majority of emissions of these 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.

Table 2-18: Emissions of NO_x, CO, NMVOCs, and SO_2 (Gg)

Gas/Activity	1990		1997	1998	1999	2000	2001	2002	2003
NO_x	**22,860**		**22,284**	**21,964**	**20,530**	**20,288**	**19,414**	**18,850**	**18,573**
Stationary Fossil Fuel Combustion	9,884		9,578	9,419	8,344	8,002	7,667	7,523	7,222
Mobile Fossil Fuel Combustion	12,134		11,768	11,592	11,300	11,395	10,823	10,389	10,418
Oil and Gas Activities	139		130	130	109	111	113	135	124
Waste Combustion	82		140	145	143	114	114	134	121
Industrial Processes	591		629	637	595	626	656	630	648
Solvent Use	1		3	3	3	3	3	5	4
Field Burning of Agricultural Residues	28		34	35	34	35	35	33	33
Waste	0		3	3	3	2	2	2	2
CO	**130,580**		**101,138**	**98,984**	**94,361**	**92,895**	**89,329**	**87,451**	**85,077**
Stationary Fossil Fuel Combustion	4,999		3,927	3,927	5,024	4,340	4,377	4,020	4,454
Mobile Fossil Fuel Combustion	119,482		90,284	87,940	83,484	83,680	79,972	78,574	75,526
Oil and Gas Activities	302		333	332	145	146	147	116	125
Waste Combustion	978		2,668	2,826	2,725	1,670	1,672	1,672	1,674
Industrial Processes	4,124		3,153	3,163	2,156	2,217	2,339	2,308	2,431
Solvent Use	4		1	1	46	46	45	46	65
Field Burning of Agricultural Residues	689		767	789	767	790	770	707	794
Waste	1		5	5	13	8	8	8	8
NMVOCs	**20,937**		**16,994**	**16,403**	**15,869**	**15,228**	**15,048**	**14,222**	**13,939**
Stationary Fossil Fuel Combustion	912		1,016	1,016	1,045	1,077	1,080	926	1,007
Mobile Fossil Fuel Combustion	10,933		7,928	7,742	7,586	7,230	6,872	6,560	6,351
Oil and Gas Activities	555		442	440	414	389	400	340	345

[6] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2004).

Waste Combustion	222	313	326	302	257	258	281	263
Industrial Processes	2,426	2,038	2,047	1,813	1,773	1,769	1,725	1,711
Solvent Use	5,217	5,100	4,671	4,569	4,384	4,547	4,256	4,138
Field Burning of Agricultural Residues	NA	NA	NA	NA	NA	NA	NA	NA
Waste	673	157	161	140	119	122	133	125
SO_2	**20,936**	**17,091**	**17,189**	**15,917**	**14,829**	**14,452**	**13,928**	**14,463**
Stationary Fossil Fuel Combustion	18,407	15,104	15,191	13,915	12,848	12,461	11,946	12,477
Mobile Fossil Fuel Combustion	793	659	665	704	632	624	631	634
Oil and Gas Activities	390	312	310	283	286	289	315	293
Waste Combustion	39	29	30	30	29	30	24	28
Industrial Processes	1,306	985	991	984	1,031	1,047	1,009	1,029
Solvent Use	0	1	1	1	1	1	2	2
Field Burning of Agricultural Residues	NA	NA	NA	NA	NA	NA	NA	NA
Waste	0	1	1	1	1	1	1	1

Source: (EPA 2004) except for estimates from field burning of agricultural residues.
+ Does not exceed 0.5 Gg
NA (Not Available)
Note: Totals may not sum due to independent rounding.

[BEGIN BOX]

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 69 percent in 2003. 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.

[END BOX]

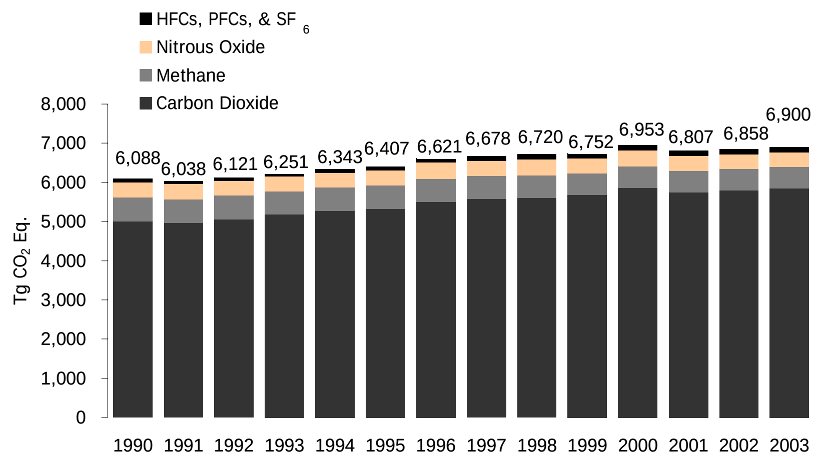


Figure 2-1: U.S. Greenhouse Gas Emissions by Gas

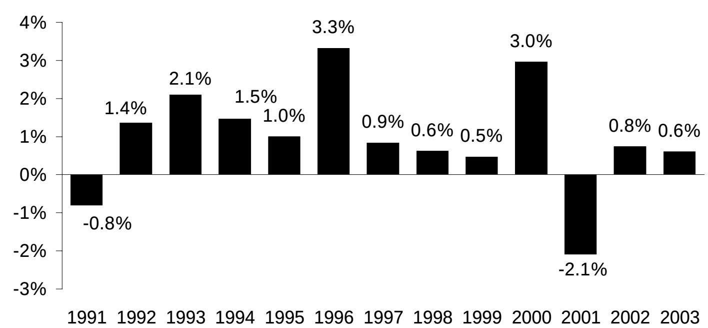


Figure 2-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

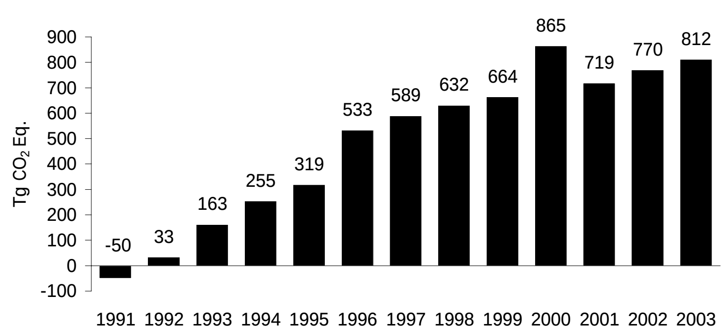


Figure 2-3: Cumulative Change in U.S. Greenhouse Gas Emissions Relative to 1990

Figure 2-4: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product

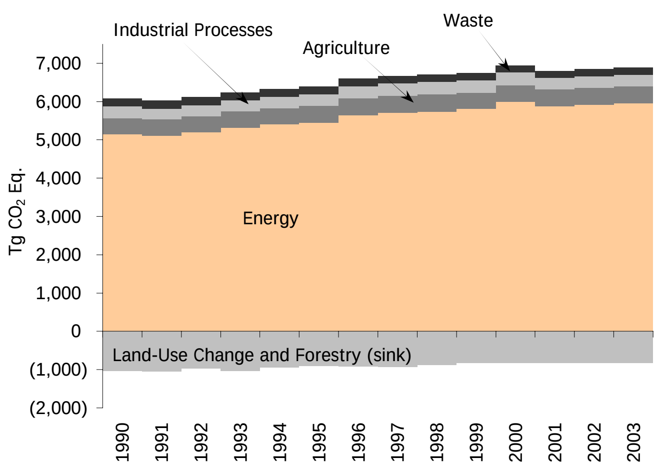


Figure 2-5: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

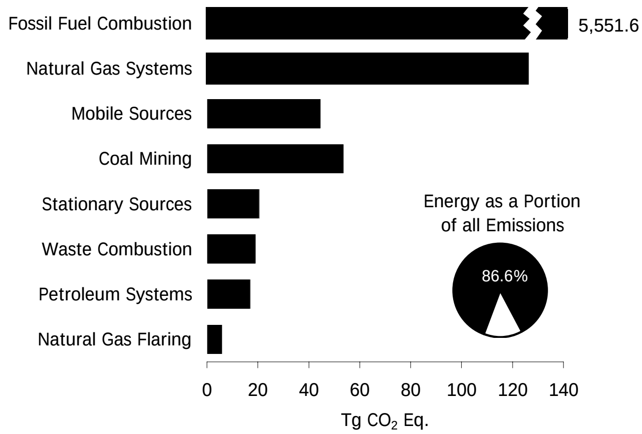
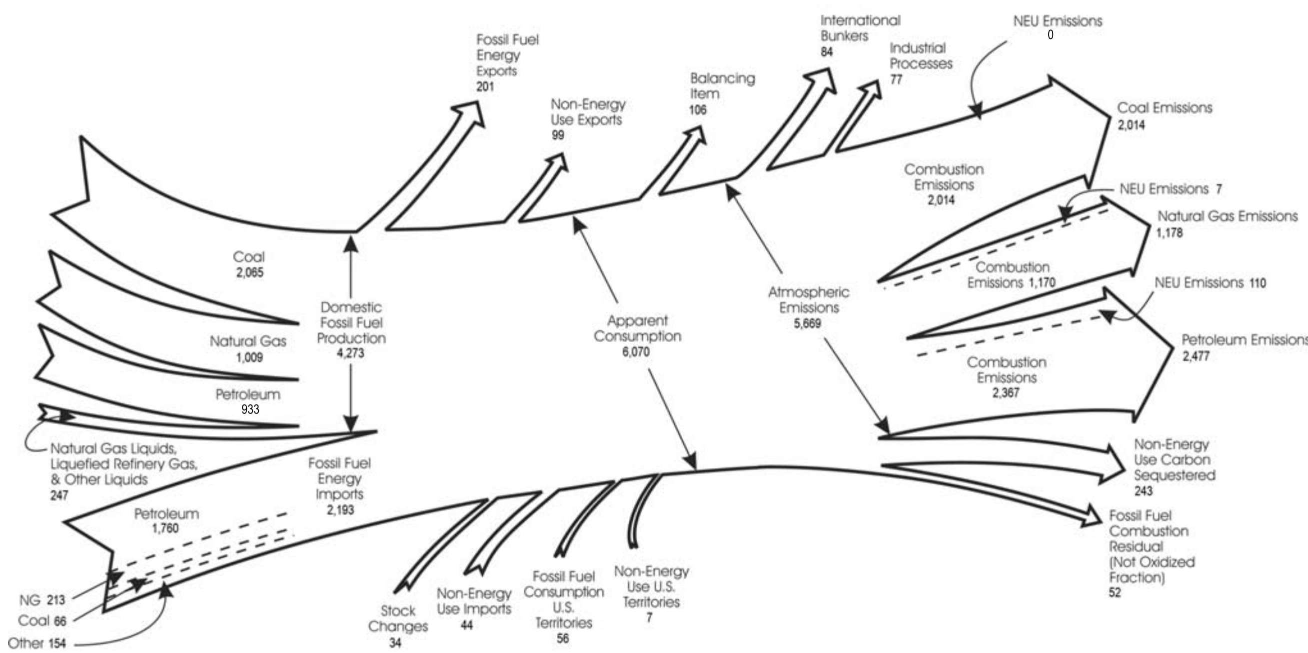


Figure 2-6: 2003 Energy Sector Greenhouse Gas Sources

Figure 2-7

2003 U.S. Fossil Carbon Flows (Tg CO_2 Eq.)



Note: Totals may not sum due to independent rounding.

The "Balancing Item" above accounts for statistical imbalances and unknowns in the reported data sets combined here.

NEU = Non-Energy Use
NG = Natural Gas

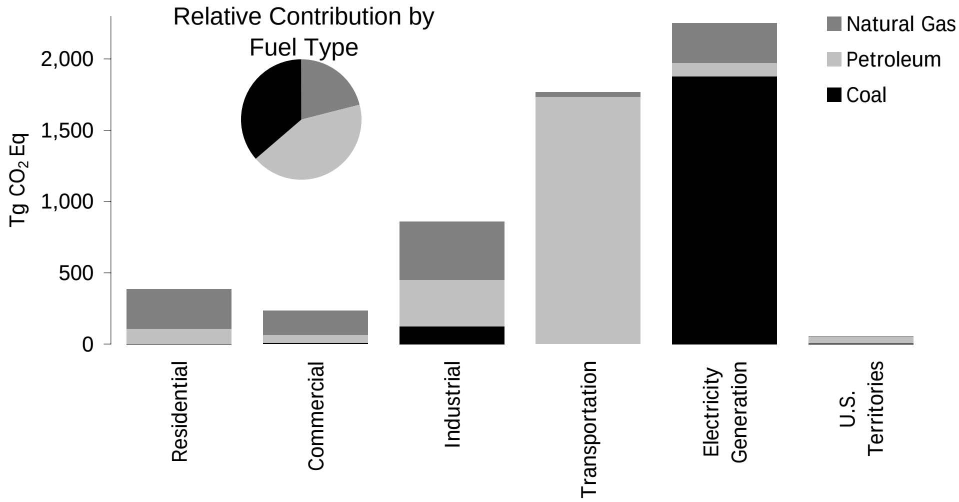


Figure 2-8: 2003 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type
Note: Electricity generation also includes emissions of less than 1 Tg CO_2 Eq. from geothermal-based electricity generation.

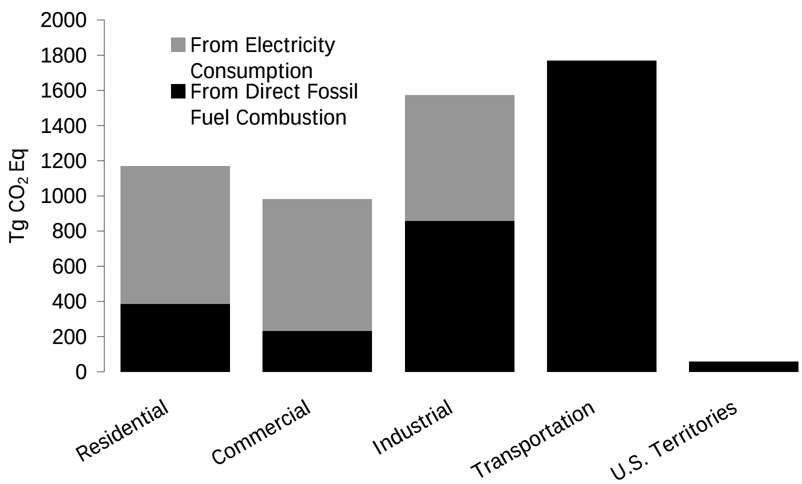


Figure 2-9: 2003 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion

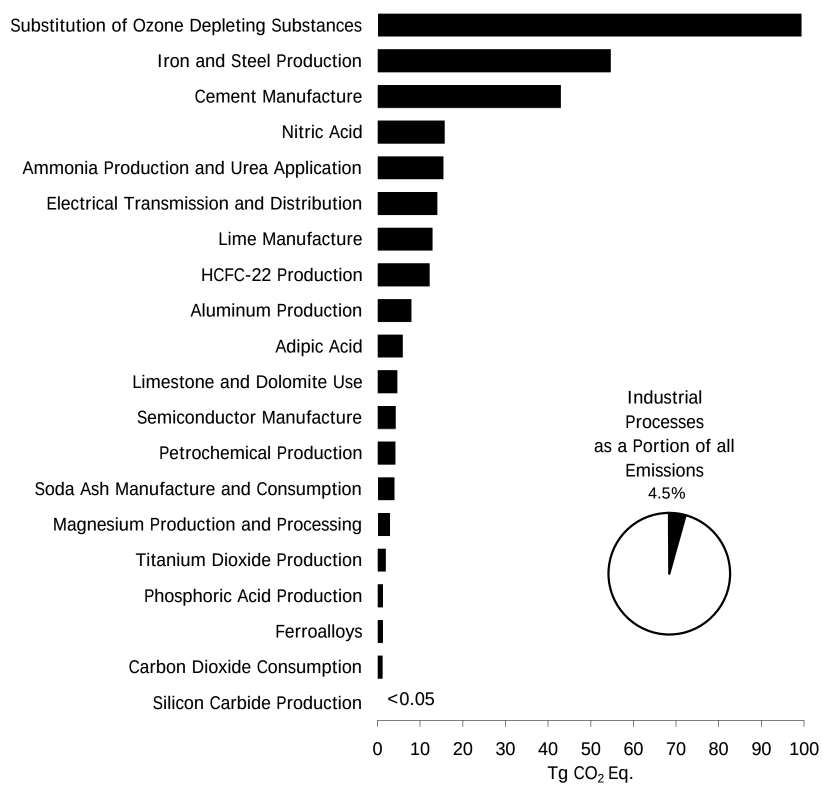


Figure 2-10: 2003 Industrial Processes Chapter Greenhouse Gas Sources

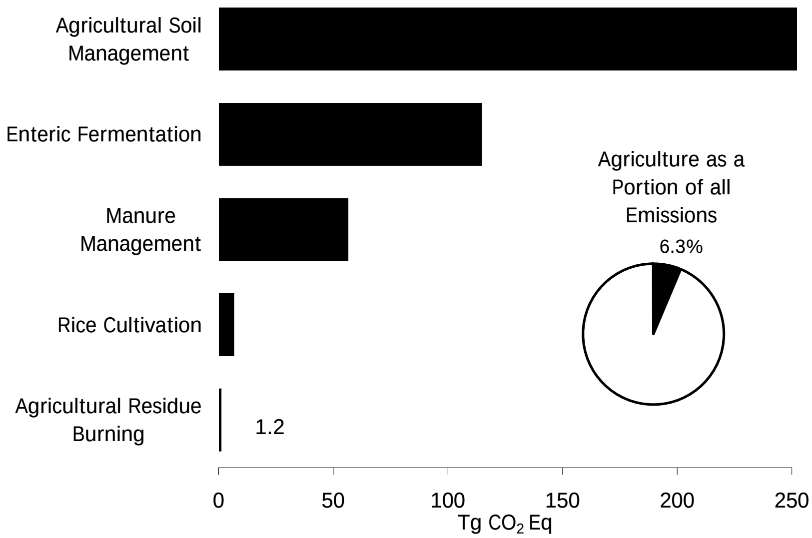


Figure 2-11: 2003 Agriculture Chapter GHG Sources

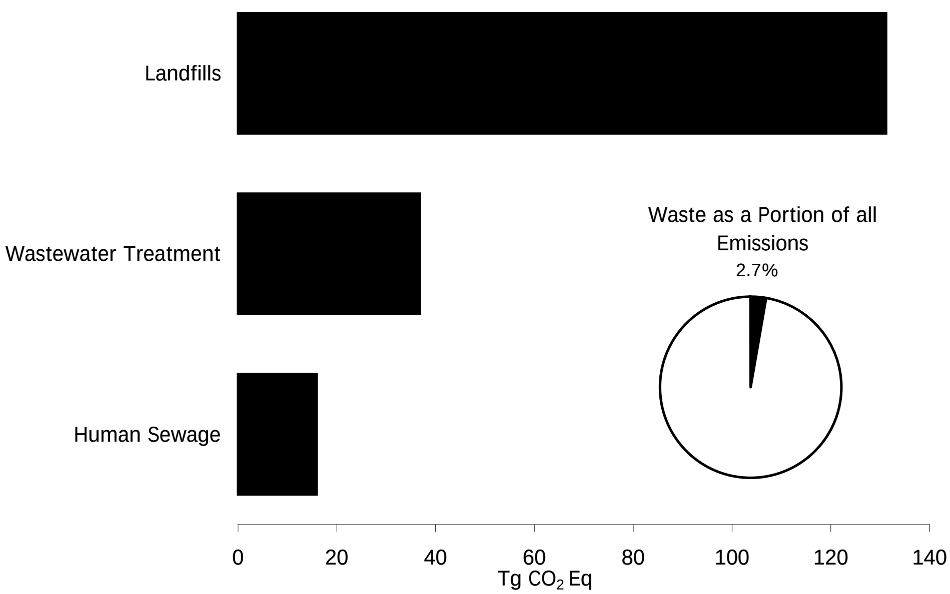


Figure 2-12: 2003 Waste Chapter Greenhouse Gas Sources

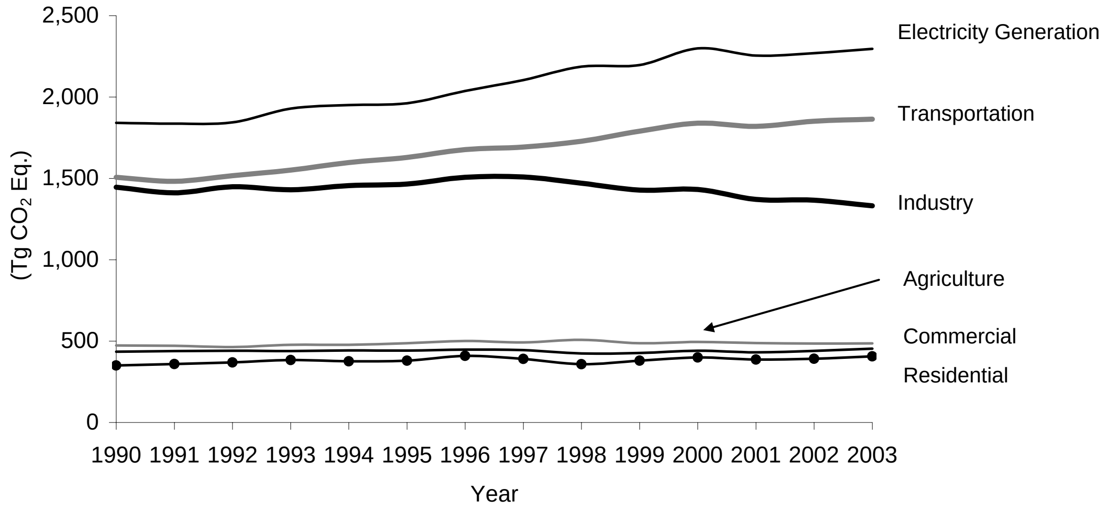


Figure 2-13: Emissions Allocated to Economic Sectors

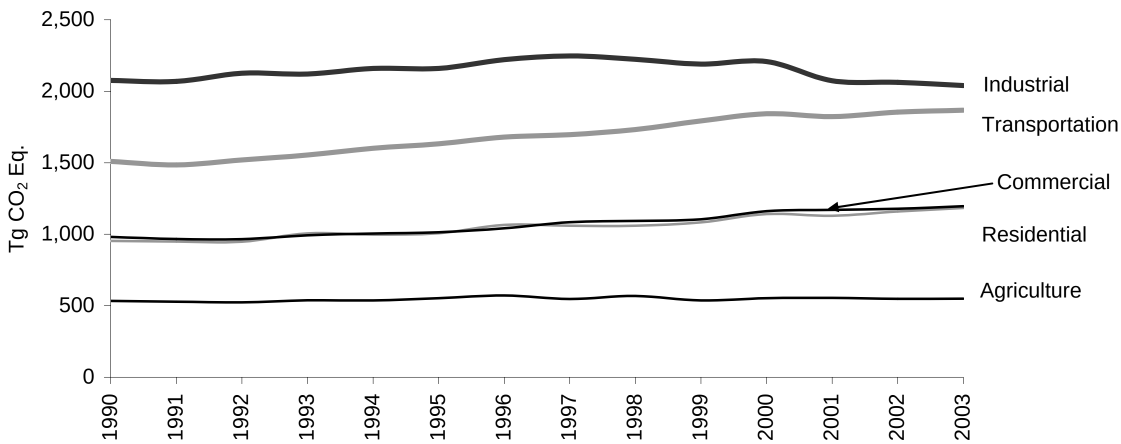


Figure 2-14: Emissions with Electricity Distributed to Economic Sectors