2. Trends in Greenhouse Gas Emissions

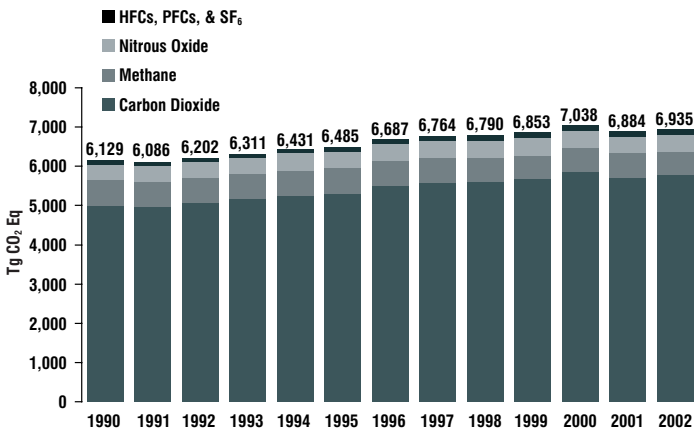
2.1. Recent Trends in U.S. Greenhouse Gas Emissions

In 2002, total U.S. greenhouse gas emissions were 6,934.6 teragrams of carbon dioxide equivalent (Tg CO_2 Eq.)[1] (13.0 percent above 1990 emissions). Emissions rose slightly from 2001 to 2002, increasing by 0.7 percent (50.7 Tg CO_2 Eq.). The following factors were primary contributors to this increase: 1) moderate economic growth in 2002, leading to increased demand for electricity and fossil fuels, 2) much hotter summer conditions in 2002—in fact, one of the hottest summers on record—causing an increase in electricity use for air conditioning. (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.

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 percent (796.3 Tg CO_2 Eq.) from 1990 to 2002 and were responsible for most of the increase in national emissions during this period. From 2001 to 2002, these emissions increased by 52.2 Tg CO_2 Eq. (0.9 percent), slightly lower than the source's average annual growth rate of 1.3 percent from 1990 through 2002. Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

Figure 2-1

U.S. Greenhouse Gas Emissions by Gas



Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures. On an annual basis, the overall consumption of fossil fuels in the United States generally fluctuates in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. 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,

[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.)

Figure 2-2

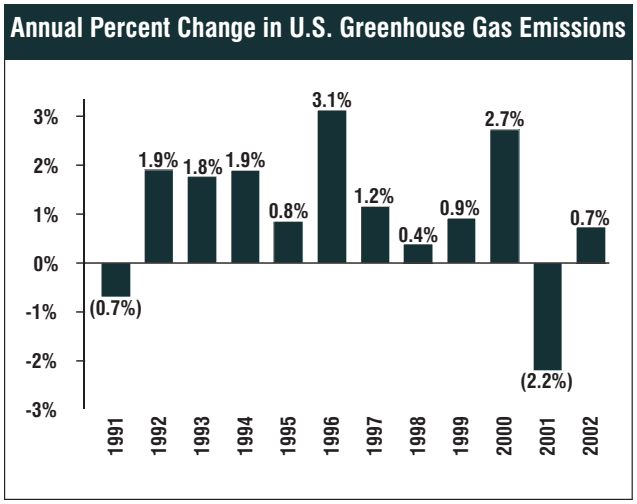
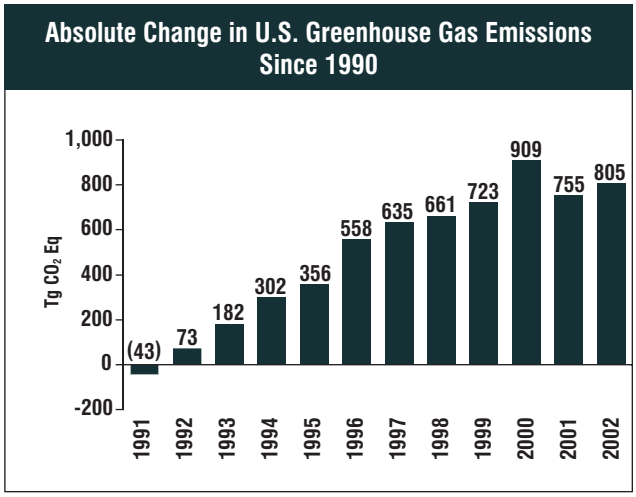


Figure 2-3



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).

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.

In 1998, warm winter temperatures contributed to a significant drop in residential and commercial natural gas consumption. This drop in emissions from natural gas used for heating was offset by two factors: 1) electric utility emissions, which increased in part due to a hot summer and its associated air conditioning demand; and 2) increased motor gasoline consumption for transportation.

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

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	1997 to 1998		1998 to 1999		1999 to 2000		2000 to 2001		2001 to 2002	
Electricity Generation	Coal	29.1	2%	5.9	0%	88.0	5%	-61.9	-3%	39.9	2%
Electricity Generation	Natural Gas	29.1	13%	11.9	5%	20.8	8%	8.4	3%	10.0	3%
Electricity Generation	Petroleum	29.8	40%	-7.6	-7%	-5.6	-6%	9.8	11%	-27.9	-28%
Transportation[a]	Petroleum	36.2	2%	57.5	4%	46.9	3%	-17.4	-1%	32.5	2%
Residential	Natural Gas	-23.7	-9%	10.0	4%	13.9	5%	-10.9	-4%	7.7	3%
Commercial	Natural Gas	-10.8	-6%	1.7	1%	9.0	5%	-9.3	-5%	4.3	3%
Industrial	Coal	-8.1	-6%	-5.5	-4%	1.6	1%	-4.9	-4%	-3.0	-2%
Industrial	Natural Gas	-11.9	-2%	-17.9	-4%	7.6	2%	-39.7	-8%	-10.4	-2%
All Sectors[b]	**All Fuels[b]**	**28.4**	**1%**	**76.4**	**1%**	**184.7**	**3%**	**-114.8**	**-2%**	**52.2**	**1%**

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

[2] Normals are based on data from 1971 through 2000 (EIA 2003b).

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 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.

Other significant trends in emissions from additional source categories over the thirteen-year period from 1990 through 2002 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 267.1 Tg CO_2 Eq. (28 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 dropped by 29.7 Tg CO_2 Eq. (36 percent) as a result of the mining of less gassy coal from underground mines and the increased use of methane collected from degasification systems.
- Nitrous oxide emissions from agricultural soil management increased by 24.5 Tg CO_2 Eq. (9 percent) as crop and forage production, manure production, and fertilizer consumption rose.
- Aggregate hydrofluorocarbon (HFC), perfluorocarbon (PFC) emissions resulting from the substitution of ozone depleting substances increased by 91.4 Tg CO_2 Eq. This increase was significantly offset, however, by reductions in PFC emissions from aluminum production (12.9 Tg CO_2 Eq. or 71 percent), reductions in emissions of HFC-23 from the production of HCFC-22 (15.2 Tg CO_2 Eq. or 43 percent), and reductions of sulfur hexafluoride (SF_6) from electric power transmission and distribution systems (14.5 Tg CO_2 Eq. or 49 percent). Reductions in PFC emissions from aluminum production resulted from both industry emission reduction efforts and lower domestic aluminum production. HFC-23 emissions from the production of HCFC-22 decreased because a reduction in the intensity of emissions from that source offset an increase in HCFC-22 production. Reduced emissions of SF_6 from electric power transmission and distribution systems are primarily the result of higher purchase prices for SF_6 and efforts by industry to reduce emissions.

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 2002; 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 0.4 percent per year.

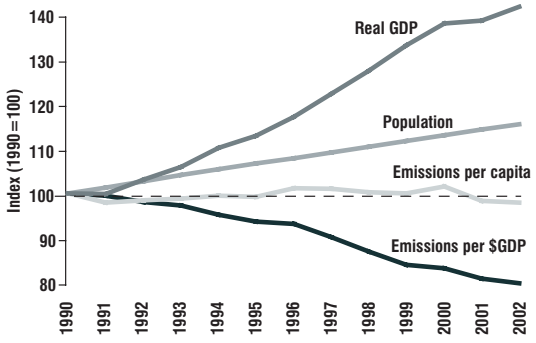
Table 2-2: Recent Trends in Various U.S. Data (Index 1990 = 100) and Global Atmospheric CO_2 Concentration

Variable	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Growth Rate[f]
Greenhouse Gas Emissions[a]	99	101	103	105	106	109	110	111	112	115	112	113	**1.0%**
Energy Consumption[b]	100	101	103	105	108	111	112	112	114	117	114	115	**1.2%**
Fossil Fuel Consumption[b]	99	102	104	106	107	111	112	113	114	117	115	115	**1.2%**
Electricity Consumption[b]	102	102	106	109	112	115	117	121	124	128	126	129	**2.2%**
GDP[c]	100	103	106	110	113	117	122	127	133	138	139	142	**3.0%**
Population[d]	101	103	104	105	107	108	109	111	112	113	114	116	**1.2%**
Atmospheric CO_2 Concentration[e]	100	101	101	101	102	102	103	104	104	104	105	105	**0.4%**

[a] GWP weighted values
[b] Energy content weighted values (EIA 2003a)
[c] Gross Domestic Product in chained 2000 dollars (BEA 2004)
[d] (U.S. Census Bureau 2003)
[e] Mauna Loa Observatory, Hawaii (Keeling and Whorf 2003)
[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 (2003), and emission estimates in this report.

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

Gas/Source	1990	1996	1997	1998	1999	2000	2001	2002
CO_2	**5,002.3**	**5,498.5**	**5,577.6**	**5,602.5**	**5,676.3**	**5,859.0**	**5,731.8**	**5,782.4**
Fossil Fuel Combustion	4,814.7	5,310.1	5,384.0	5,412.4	5,488.8	5,673.6	5,558.8	5,611.0
Iron and Steel Production	85.4	68.3	71.9	67.4	64.4	65.7	59.1	54.4
Cement Manufacture	33.3	37.1	38.3	39.2	40.0	41.2	41.4	42.9
Waste Combustion	10.9	17.2	17.8	17.1	17.6	18.0	18.8	18.8
Ammonia Production and Urea Application	19.3	20.3	20.7	21.9	20.6	19.6	16.2	17.7
Lime Manufacture	11.2	13.5	13.7	13.9	13.5	13.3	12.8	12.3
Limestone and Dolomite Use	5.5	7.8	7.2	7.4	8.1	6.0	5.7	5.8
Natural Gas Flaring	5.8	8.5	7.9	6.6	6.9	5.8	5.4	5.3
Aluminum Production	6.3	5.6	5.6	5.8	5.9	5.7	4.1	4.2
Soda Ash Manufacture and Consumption	4.1	4.2	4.4	4.3	4.2	4.2	4.1	4.1
Titanium Dioxide Production	1.3	1.7	1.8	1.8	1.9	1.9	1.9	2.0
Phosphoric Acid Production	1.5	1.6	1.5	1.6	1.5	1.4	1.3	1.3
Carbon Dioxide Consumption	0.9	0.8	0.8	0.9	0.9	1.0	0.8	1.3
Ferroalloys	2.0	2.0	2.0	2.0	2.0	1.7	1.3	1.2
Land-Use Change and Forestry (Sink)[a]	*(957.9)*	*(1,055.2)*	*(821.0)*	*(705.8)*	*(675.8)*	*(690.2)*	*(689.7)*	*(690.7)*
International Bunker Fuels[b]	*113.9*	*102.3*	*109.9*	*115.1*	*105.3*	*101.4*	*97.9*	*86.8*
Biomass Combustion[b]	*216.7*	*244.3*	*233.2*	*217.2*	*222.3*	*226.8*	*204.4*	*207.1*
CH_4	**642.7**	**637.0**	**628.8**	**620.1**	**613.1**	**614.4**	**605.1**	**598.1**
Landfills	210.0	208.8	203.4	196.6	197.8	199.3	193.2	193.0
Natural Gas Systems	122.0	127.4	126.1	124.5	120.9	125.7	124.9	121.8
Enteric Fermentation	117.9	120.5	118.3	116.7	116.6	115.7	114.3	114.4
Coal Mining	81.9	63.2	62.6	62.8	58.9	56.2	55.6	52.2
Manure Management	31.0	34.6	36.3	38.8	38.6	38.0	38.8	39.5
Wastewater Treatment	24.1	26.9	27.4	27.7	28.2	28.4	28.1	28.7
Petroleum Systems	28.9	25.6	25.5	25.0	23.7	23.5	23.5	23.2
Stationary Sources	8.2	8.8	7.8	7.2	7.5	7.7	7.2	6.9
Rice Cultivation	7.1	7.0	7.5	7.9	8.3	7.5	7.6	6.8
Mobile Sources	5.0	4.8	4.7	4.5	4.5	4.4	4.3	4.2
Abandoned Coal Mines	3.4	6.0	5.6	4.8	4.4	4.4	4.2	4.1
Petrochemical Production	1.2	1.6	1.6	1.7	1.7	1.7	1.4	1.5
Iron and Steel Production	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.0
Field Burning of Agricultural Residues	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7
Silicon Carbide Production	+	+	+	+	+	+	+	+
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**393.2**	**436.9**	**436.3**	**432.1**	**428.4**	**425.8**	**417.3**	**415.8**
Agricultural Soil Management	262.8	288.1	293.2	294.2	292.1	289.7	288.6	287.3
Mobile Sources	50.7	60.7	60.3	59.6	58.6	57.4	55.0	52.9
Manure Management	16.2	17.0	17.3	17.3	17.4	17.7	18.0	17.8
Nitric Acid	17.8	20.7	21.2	20.9	20.1	19.6	15.9	16.7
Human Sewage	12.8	14.2	14.4	14.7	15.2	15.3	15.4	15.6
Stationary Sources	12.6	13.9	14.0	13.8	13.9	14.4	13.9	14.0
Adipic Acid	15.2	17.0	10.3	6.0	5.5	6.0	4.9	5.9
N_2O Product Usage	4.3	4.5	4.8	4.8	4.8	4.8	4.8	4.8
Field Burning of Agricultural Residues	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.4
Waste Combustion	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4
International Bunker Fuels[b]	*1.0*	*0.9*	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.8*
HFCs, PFCs, and SF_6	**90.9**	**114.9**	**121.7**	**135.7**	**134.8**	**139.1**	**129.7**	**138.2**
Substitution of Ozone Depleting Substances	0.3	35.0	46.4	56.5	65.8	75.1	83.4	91.7
HCFC-22 Production	35.0	31.1	30.0	40.2	30.4	29.8	19.8	19.8
Electrical Transmission and Distribution	29.2	24.3	21.7	17.1	16.4	15.9	15.6	14.8
Aluminum Production	18.1	12.5	11.0	9.0	8.9	8.9	4.0	5.2
Semiconductor Manufacture	2.9	5.5	6.3	7.1	7.2	6.3	4.5	4.4
Magnesium Production and Processing	5.4	6.5	6.3	5.8	6.0	3.2	2.5	2.4
Total	**6,129.1**	**6,687.3**	**6,764.4**	**6,790.5**	**6,852.5**	**7,038.3**	**6,883.9**	**6,934.6**
Net Emissions (Sources and Sinks)	**5,171.3**	**5,632.1**	**5,943.5**	**6,084.7**	**6,176.8**	**6,348.2**	**6,194.1**	**6,243.8**

+ 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	1996	1997	1998	1999	2000	2001	2002
CO_2	**5,002,324**	**5,498,549**	**5,577,635**	**5,602,500**	**5,676,290**	**5,858,982**	**5,731,773**	**5,782,363**
Fossil Fuel Combustion	4,814,660	5,310,067	5,384,005	5,412,394	5,488,829	5,673,575	5,558,784	5,610,976
Iron and Steel Production	85,414	68,324	71,864	67,429	64,376	65,693	59,074	54,411
Cement Manufacture	33,278	37,079	38,323	39,218	39,991	41,190	41,357	42,898
Waste Combustion	10,919	17,193	17,761	17,094	17,632	17,979	18,781	18,781
Ammonia Production and Urea Application	19,306	20,282	20,650	21,934	20,615	19,587	16,250	17,652
Lime Manufacture	11,238	13,495	13,685	13,914	13,466	13,315	12,823	12,304
Limestone and Dolomite Use	5,533	7,817	7,242	7,449	8,057	5,959	5,733	5,836
Natural Gas Flaring	5,810	8,529	7,874	6,566	6,943	5,769	5,412	5,299
Aluminum Production	6,315	5,580	5,621	5,792	5,895	5,723	4,114	4,223
Soda Ash Manufacture and Consumption	4,141	4,239	4,354	4,325	4,217	4,181	4,147	4,139
Titanium Dioxide Production	1,308	1,657	1,836	1,819	1,853	1,918	1,857	1,997
Phosphoric Acid Production	1,529	1,551	1,544	1,593	1,539	1,382	1,264	1,339
Carbon Dioxide Consumption	892	783	838	946	881	993	849	1,272
Ferroalloys	1,980	1,954	2,038	2,027	1,996	1,719	1,329	1,237
Land-Use Change and Forestry (Sink)[a]	*(957,866)*	*(1,055,222)*	*(820,955)*	*(705,786)*	*(675,753)*	*(690,150)*	*(689,747)*	*(690,723)*
International Bunker Fuels[b]	*113,866*	*102,277*	*109,889*	*115,094*	*105,297*	*101,408*	*97,869*	*86,845*
Biomass Combustion	*216,702*	*244,305*	*233,243*	*217,201*	*222,340*	*226,765*	*204,372*	*207,097*
CH_4	**30,603**	**30,333**	**29,944**	**29,530**	**29,193**	**29,259**	**28,815**	**28,482**
Landfills	9,998	9,942	9,685	9,360	9,419	9,491	9,202	9,192
Natural Gas Systems	5,811	6,065	6,005	5,929	5,757	5,985	5,946	5,801
Enteric Fermentation	5,612	5,737	5,635	5,557	5,551	5,509	5,443	5,450
Coal Mining	3,900	3,008	2,983	2,989	2,805	2,677	2,648	2,487
Manure Management	1,478	1,648	1,728	1,846	1,840	1,807	1,849	1,879
Wastewater Treatment	1,149	1,281	1,305	1,320	1,343	1,350	1,339	1,365
Petroleum Systems	1,375	1,218	1,215	1,190	1,129	1,119	1,118	1,104
Stationary Sources	391	418	369	344	355	367	344	328
Rice Cultivation	339	332	356	376	395	357	364	325
Mobile Sources	236	227	222	217	213	210	205	201
Abandoned Coal Mines	162	283	266	228	211	211	200	196
Petrochemical Production	56	76	78	80	81	80	68	72
Iron and Steel Production	63	60	60	57	56	57	51	47
Field Burning of Agricultural Residues	33	36	37	38	37	38	37	34
Silicon Carbide Production	1	1	1	1	1	1	+	+
International Bunker Fuels[b]	*8*	*6*	*7*	*7*	*6*	*6*	*5*	*4*
N_2O	**1,268**	**1,409**	**1,407**	**1,394**	**1,382**	**1,374**	**1,346**	**1,341**
Agricultural Soil Management	848	929	946	949	942	935	931	927
Mobile Sources	163	196	194	192	189	185	177	171
Manure Management	52	55	56	56	56	57	58	58
Nitric Acid	58	67	68	67	65	63	51	54
Human Sewage	41	46	47	47	49	49	50	50
Stationary Sources	41	45	45	45	45	47	45	45
Adipic Acid	49	55	33	19	18	19	16	19
N_2O Product Usage	14	14	15	15	15	15	15	15
Field Burning of Agricultural Residues	1	1	1	1	1	1	1	1
Waste Combustion	1	1	1	1	1	1	1	1
International Bunker Fuels[b]	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
HFCs, PFCs, and SF_6	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Substitution of Ozone Depleting Substances	M	M	M	M	M	M	M	M
HCFC-22 Production[c]	3	3	3	3	3	3	2	2
Electrical Transmission and Distribution[d]	1	1	1	1	1	1	1	1
Aluminum Production	M	M	M	M	M	M	M	M
Semiconductor Manufacture	M	M	M	M	M	M	M	M
Magnesium Production and Processing[d]	+	+	+	+	+	+	+	+
SO_2	**20,936**	**16,682**	**17,091**	**17,189**	**16,013**	**14,802**	**14,324**	**13,669**
NO_x	**22,860**	**22,149**	**22,284**	**21,963**	**21,199**	**20,555**	**20,048**	**19,849**
CO	**130,580**	**104,069**	**101,138**	**98,983**	**95,471**	**93,972**	**100,661**	**92,541**
NMVOCs	**20,937**	**17,184**	**16,994**	**16,403**	**16,245**	**15,418**	**15,148**	**14,996**

+ 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).

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	1996	1997	1998	1999	2000	2001	2002
Energy	5,144.5	5,646.4	5,716.6	5,738.6	5,806.1	5,991.4	5,871.9	5,914.8
Industrial Processes	297.4	318.3	324.1	331.9	326.2	329.3	301.9	310.7
Solvent and Other Product Use	4.3	4.5	4.8	4.8	4.8	4.8	4.8	4.8
Agriculture	436.0	468.3	473.8	476.2	474.2	469.9	468.6	467.1
Land-Use Change and Forestry (Sink)*	(957.9)	(1,055.2)	(821.0)	(705.8)	(675.8)	(690.2)	(689.7)	(690.7)
Waste	246.9	249.9	245.2	239.0	241.2	243.0	236.8	237.2
Total	**6,129.1**	**6,687.3**	**6,764.4**	**6,790.5**	**6,852.5**	**7,038.3**	**6,883.9**	**6,934.6**
Net Emissions (Sources and Sinks)	**5,171.3**	**5,632.1**	**5,943.5**	**6,084.7**	**6,176.8**	**6,348.2**	**6,194.1**	**6,243.8**

* 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).

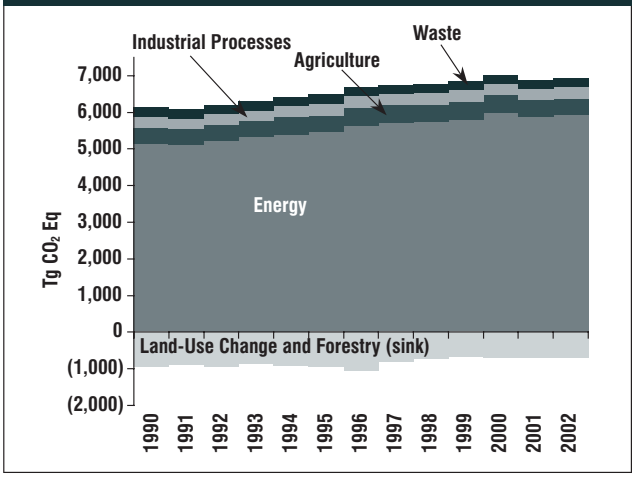
Overall, from 1990 to 2002, total emissions of CO_2 and N_2O increased by 780.0 Tg CO_2 Eq. (16 percent) and 22.7 Tg CO_2 Eq. (6 percent), respectively, while CH_4 emissions decreased by 44.6 Tg CO_2 Eq. (7 percent). During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 47.3 Tg CO_2 Eq. (52 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 10 percent of total emissions in 2002.

As an alternative, emissions of all gases can be totaled for each of the IPCC sectors. Over the thirteen year period of 1990 to 2002, total emissions in the Energy, Agriculture, Industrial Processes, and Solvent and Other Product Use sectors climbed by 770.3 Tg CO_2 Eq. (15 percent), 31.0 Tg CO_2 Eq. (7 percent), 13.3 Tg CO_2 Eq. (4 percent), and 0.5 Tg CO_2 Eq. (11 percent), respectively, while emissions from the Waste sector decreased 9.6 Tg CO_2 Eq. (4 percent). Over the same period, estimates of net carbon sequestration in the Land-Use Change and Forestry sector declined by 267.1 Tg CO_2 Eq. (28 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.

Figure 2-5

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



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 2002. Transportation activities, in aggregate, accounted for the

Table 2-6: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq. and Percent of Total in 2002)

Sector/Source	1990	1996	1997	1998	1999	2000	2001	2002	Percent[a]
Electricity Generation	**1,843.9**	**2,047.0**	**2,113.2**	**2,196.3**	**2,206.7**	**2,309.1**	**2,265.5**	**2,286.8**	**33.0%**
CO_2 from Fossil Fuel Combustion	1,792.4	1,992.2	2,060.5	2,148.5	2,158.7	2,261.9	2,218.2	2,240.1	32.3%
Waste Combustion[b]	11.3	17.6	18.1	17.4	18.0	18.3	19.1	19.1	0.3%
Transmission & Distribution[c]	29.2	24.3	21.7	17.1	16.4	15.9	15.6	14.8	0.2%
Stationary Combustion[d]	8.2	9.1	9.3	9.6	9.6	10.0	9.8	9.9	0.1%
Limestone and Dolomite Use	2.8	3.9	3.6	3.7	4.0	3.0	2.9	2.9	0.0%
Transportation	**1,513.4**	**1,683.7**	**1,698.6**	**1,732.9**	**1,794.7**	**1,844.8**	**1,827.0**	**1,861.4**	**26.8%**
CO_2 from Fossil Fuel Combustion	1,458.2	1,604.8	1,614.8	1,644.9	1,702.9	1,749.6	1,730.6	1,764.4	25.4%
Mobile Combustion[d]	55.2	65.0	64.4	63.6	62.6	61.4	58.9	56.7	0.8%
Substitution of ODS[e]	+	13.9	19.4	24.4	29.3	33.8	37.4	40.4	0.6%
Industry	**1,437.4**	**1,493.2**	**1,495.5**	**1,454.6**	**1,414.0**	**1,418.5**	**1,353.1**	**1,331.9**	**19.2%**
CO_2 from Fossil Fuel Combustion	920.3	993.9	1,000.1	960.5	942.0	949.3	920.5	903.6	13.0%
Natural Gas Systems	122.0	127.4	126.1	124.5	120.9	125.7	124.9	121.8	1.8%
Iron and Steel Production[f]	86.7	69.6	73.1	68.6	65.5	66.9	60.1	55.4	0.8%
Coal Mining	81.9	63.2	62.6	62.8	58.9	56.2	55.6	52.2	0.8%
Cement Manufacture	33.3	37.1	38.3	39.2	40.0	41.2	41.4	42.9	0.6%
Petroleum Systems	28.9	25.6	25.5	25.0	23.7	23.5	23.5	23.2	0.3%
HCFC-22 Production[g]	35.0	31.1	30.0	40.2	30.4	29.8	19.8	19.8	0.3%
Ammonia Manufacture	19.3	20.3	20.7	21.9	20.6	19.6	16.2	17.7	0.3%
Nitric Acid	17.8	20.7	21.2	20.9	20.1	19.6	15.9	16.7	0.2%
Lime Manufacture	11.2	13.5	13.7	13.9	13.5	13.3	12.8	12.3	0.2%
Substitution of ODS[e]	+	2.8	4.0	5.1	6.4	7.5	8.5	9.9	0.1%
Aluminum Production[h]	24.4	18.0	16.6	14.8	14.8	14.6	8.1	9.4	0.1%
Adipic Acid	15.2	17.0	10.3	6.0	5.5	6.0	4.9	5.9	0.1%
Stationary Combustion[b]	5.7	6.3	6.4	6.0	6.0	6.0	5.6	5.7	0.1%
Natural Gas Flaring	5.8	8.5	7.9	6.6	6.9	5.8	5.4	5.3	0.1%
N_2O Product Usage	4.3	4.5	4.8	4.8	4.8	4.8	4.8	4.8	0.1%
Semiconductor Manufacture[e]	2.9	5.5	6.3	7.1	7.2	6.3	4.5	4.4	0.1%
Soda Ash Manufacture and Consumption	4.1	4.2	4.4	4.3	4.2	4.2	4.1	4.1	0.1%
Abandoned Coal Mines	3.4	6.0	5.6	4.8	4.4	4.4	4.2	4.1	0.1%
Limestone and Dolomite Use	2.8	3.9	3.6	3.7	4.0	3.0	2.9	2.9	0.0%
Magnesium Production and Processing[c]	5.4	6.5	6.3	5.8	6.0	3.2	2.5	2.4	0.0%
Titanium Dioxide Production	1.3	1.7	1.8	1.8	1.9	1.9	1.9	2.0	0.0%
Petrochemical Production	1.2	1.6	1.6	1.7	1.7	1.7	1.4	1.5	0.0%
Phosphoric Acid Production	1.5	1.6	1.5	1.6	1.5	1.4	1.3	1.3	0.0%
Carbon Dioxide Consumption	0.9	0.8	0.8	0.9	0.9	1.0	0.8	1.3	0.0%
Ferroalloys	2.0	2.0	2.0	2.0	2.0	1.7	1.3	1.2	0.0%
Silicon Carbide Production	+	+	+	+	+	+	+	+	0.0%
Agriculture	**482.8**	**520.8**	**532.6**	**534.3**	**534.7**	**520.7**	**519.3**	**519.8**	**7.5%**
Agricultural Soil Management	262.8	288.1	293.2	294.2	292.1	289.7	288.6	287.3	4.1%
Enteric Fermentation	117.9	120.5	118.3	116.7	116.6	115.7	114.3	114.4	1.7%
Manure Management[d]	47.2	51.6	53.6	56.1	56.0	55.7	56.8	57.3	0.8%
CO_2 from Fossil Fuel Combustion	46.3	52.0	58.3	57.6	59.9	50.4	50.2	52.2	0.8%
Rice Cultivation	7.1	7.0	7.5	7.9	8.3	7.5	7.6	6.8	0.1%
Field Burning of Agricultural Residues[d]	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.1	0.0%
Mobile Combustion[d]	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.5	0.0%
Stationary Combustion[d]	+	+	+	+	+	+	+	+	0.0%
Commercial	**472.2**	**497.4**	**496.7**	**477.2**	**484.9**	**505.1**	**492.2**	**500.4**	**7.2%**
CO_2 from Fossil Fuel Combustion	224.2	237.0	237.2	219.7	222.3	237.1	227.3	231.2	3.3%
Stationary Combustion[d]	1.1	1.2	1.2	1.1	1.2	1.2	1.1	1.1	0.0%
Substitution of ODS[e]	+	9.3	13.1	17.4	20.3	23.8	27.1	30.8	0.4%
Landfills	210.0	208.8	203.4	196.6	197.8	199.3	193.2	193.0	2.8%

Table 2-6: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq. and Percent of Total in 2002) (Continued)

Sector/Source	1990	1996	1997	1998	1999	2000	2001	2002	Percent[a]
Human Sewage	12.8	14.2	14.4	14.7	15.2	15.3	15.4	15.6	0.2%
Wastewater Treatment	24.1	26.9	27.4	27.7	28.2	28.4	28.1	28.7	0.4%
Residential	**345.6**	**403.8**	**385.1**	**352.4**	**373.6**	**394.0**	**381.7**	**387.7**	**5.6%**
CO_2 from Fossil Fuel Combustion	339.6	388.9	370.6	338.6	359.3	379.3	366.9	373.1	5.4%
Stationary Combustion[c]	5.7	5.9	4.6	4.2	4.5	4.7	4.4	4.0	0.1%
Substitution of ODS[e]	0.3	9.0	9.9	9.6	9.8	10.1	10.3	10.6	0.2%
U.S. Territories	**33.8**	**41.4**	**42.7**	**42.8**	**43.8**	**46.1**	**45.2**	**46.6**	**0.7%**
CO_2 from Fossil Fuel Combustion	33.8	41.4	42.7	42.8	43.8	46.1	45.2	46.6	0.7%
Total	**6,129.1**	**6,687.3**	**6,764.4**	**6,790.5**	**6,852.5**	**7,038.3**	**6,883.9**	**6,934.6**	**100.0%**
Sinks	**(957.9)**	**(1,055.2)**	**(821.0)**	**(705.8)**	**(675.8)**	**(690.2)**	**(689.7)**	**(690.7)**	**-10.0%**
Forests	(846.6)	(964.1)	(730.1)	(617.8)	(588.4)	(602.3)	(600.2)	(600.8)	-8.7%
Urban Trees	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	(58.7)	-0.8%
Agricultural Soils	(26.5)	(19.0)	(19.3)	(16.9)	(17.3)	(19.0)	(20.7)	(21.2)	-0.3%
Landfilled Yard Trimmings	(26.0)	(13.4)	(12.9)	(12.4)	(11.3)	(10.1)	(10.2)	(10.1)	-0.1%
Net Emissions (Sources and Sinks)	**5,171.3**	**5,632.1**	**5,943.5**	**6,084.7**	**6,176.8**	**6,348.2**	**6,194.1**	**6,243.8**	**90.0%**

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 2002.
[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.

second largest portion (27 percent). Additional discussion and data on these two economic sectors is provided below.

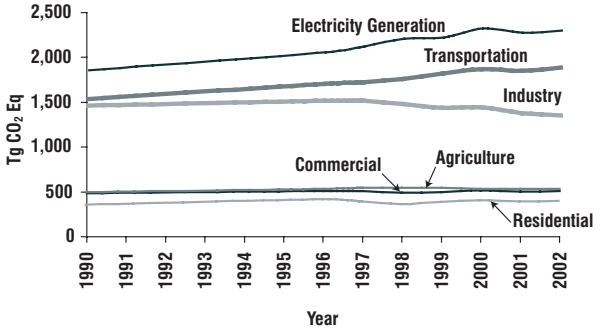
Emissions from industry accounted for 19 percent of U.S. greenhouse gas emissions in 2002. In contrast to electricity generation and transportation, emissions from industry have declined over the past decade, as structural changes have occurred in the U.S. economy (i.e., shifts from a manufacturing base 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 21 percent of emissions. Residences 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 2-6 presents a detailed breakdown of emissions from each of these economic sectors by source category, as

Figure 2-6

Emissions Allocated to Economic Sectors



Note: Does not include territories.

they are defined in this report. Figure 2-6 shows the trend in emissions by sector from 1990 to 2002.

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 2002. Emissions increased by 24 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 2-7 provides a detailed summary of emissions from electricity generation-related activities.

To distribute electricity emissions among economic end-use sectors, emissions from the source categories assigned to the electricity generation sector were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity (EIA 2003a 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.[3]

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 2-7: Electricity Generation-Related Greenhouse Gas Emissions (Tg CO_2 Eq.)

Gas/Fuel Type or Source	1990	1996	1997	1998	1999	2000	2001	2002
CO_2	**1,806.1**	**2,013.3**	**2,081.9**	**2,169.3**	**2,180.4**	**2,282.9**	**2,239.8**	**2,261.8**
CO_2 from Fossil Fuel Combustion	1,792.4	1,992.2	2,060.5	2,148.5	2,158.7	2,261.9	2,218.2	2,240.1
Coal	1,515.9	1,722.2	1,767.4	1,796.6	1,802.5	1,890.5	1,828.6	1,868.4
Natural Gas	176.0	204.9	218.9	248.0	259.9	280.7	289.1	299.1
Petroleum	100.1	64.7	73.7	103.5	95.9	90.4	100.1	72.2
Geothermal	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
Waste Combustion	10.9	17.2	17.8	17.1	17.6	18.0	18.8	18.8
Limestone and Dolomite Use	2.8	3.9	3.6	3.7	4.0	3.0	2.9	2.9
CH_4	**0.6**	**0.6**	**0.6**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
Stationary Combustion*	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7
N_2O	**8.0**	**8.9**	**9.1**	**9.3**	**9.3**	**9.7**	**9.4**	**9.6**
Stationary Combustion*	7.6	8.5	8.7	8.9	8.9	9.3	9.1	9.2
Waste Combustion	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4
SF_6	**29.2**	**24.3**	**21.7**	**17.1**	**16.4**	**15.9**	**15.6**	**14.8**
Electrical Transmission and Distribution	29.2	24.3	21.7	17.1	16.4	15.9	15.6	14.8
Total	**1,843.9**	**2,047.0**	**2,113.2**	**2,196.3**	**2,206.7**	**2,309.1**	**2,265.5**	**2,286.8**

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

[3] Emissions were not distributed to U.S. territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

Table 2-8: U.S Greenhouse Gas Emissions by "Economic Sector" and Gas with Electricity-Related Emissions Distributed (Tg CO_2 Eq.) and percent of total in 2002

Sector/Gas	1990	1996	1997	1998	1999	2000	2001	2002	Percent[a]
Industry	**2,067.7**	**2,210.8**	**2,236.7**	**2,210.4**	**2,179.5**	**2,197.9**	**2,063.4**	**2,047.9**	**29.5%**
Direct Emissions	1,437.4	1,493.2	1,495.5	1,454.6	1,414.0	1,418.5	1,353.1	1,331.9	19.2%
CO_2	1,094.3	1,161.3	1,172.4	1,129.8	1,107.8	1,113.8	1,071.9	1,053.2	15.2%
CH_4	240.9	227.5	225.3	222.3	213.2	215.1	212.9	206.1	3.0%
N_2O	40.8	46.0	40.2	35.2	34.0	34.0	29.0	30.9	0.4%
HFCs, PFCs, and SF_6	61.4	58.4	57.6	67.2	59.0	55.6	39.3	41.7	0.6%
Electricity-Related	630.3	717.6	741.2	755.8	765.5	779.3	710.3	716.0	10.3%
CO_2	617.4	705.8	730.2	746.5	756.4	770.5	702.3	708.1	10.2%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.7	3.1	3.2	3.2	3.2	3.3	3.0	3.0	+
SF_6	10.0	8.5	7.6	5.9	5.7	5.4	4.9	4.6	0.1%
Transportation	**1,516.5**	**1,686.7**	**1,701.6**	**1,736.0**	**1,797.9**	**1,848.1**	**1,830.4**	**1,864.5**	**26.9%**
Direct Emissions	1,513.4	1,683.7	1,698.6	1,732.9	1,794.7	1,844.8	1,827.0	1,861.4	26.8%
CO_2	1,458.2	1,604.8	1,614.8	1,644.9	1,702.9	1,749.6	1,730.6	1,764.4	25.4%
CH_4	4.5	4.3	4.2	4.0	3.9	4.0	3.9	3.8	0.1%
N_2O	50.7	60.7	60.3	59.6	58.6	57.4	55.0	52.9	0.8%
HFCs[b]	+	13.9	19.4	24.4	29.3	33.8	37.4	40.4	0.6%
Electricity-Related	3.1	3.0	3.1	3.1	3.2	3.4	3.5	3.1	+
CO_2	3.0	2.9	3.0	3.1	3.1	3.3	3.4	3.1	+
CH_4	+	+	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+	+	+
SF_6	+	+	+	+	+	+	+	+	+
Commercial	**1,019.0**	**1,093.7**	**1,138.0**	**1,149.4**	**1,166.0**	**1,229.3**	**1,232.9**	**1,234.3**	**17.8%**
Direct Emissions	472.2	497.4	496.7	477.2	484.9	505.1	492.2	500.4	7.2%
CO_2	224.2	237.0	237.2	219.7	222.3	237.1	227.3	231.2	3.3%
CH_4	234.9	236.5	231.6	225.1	226.8	228.5	222.1	222.5	3.2%
N_2O	13.2	14.5	14.8	15.0	15.5	15.7	15.7	15.9	0.2%
HFCs	+	9.3	13.1	17.4	20.3	23.8	27.1	30.8	0.4%
Electricity-Related	546.8	596.3	641.3	672.2	681.0	724.3	740.7	733.9	10.6%
CO_2	535.6	586.4	631.8	663.9	672.9	716.0	732.3	725.9	10.5%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.4	2.6	2.8	2.8	2.9	3.0	3.1	3.1	+
SF_6	8.7	7.1	6.6	5.2	5.1	5.0	5.1	4.7	0.1%
Residential	**948.4**	**1,062.4**	**1,057.1**	**1,057.1**	**1,080.0**	**1,139.0**	**1,125.6**	**1,158.1**	**16.7%**
Direct Emissions	345.6	403.8	385.1	352.4	373.6	394.0	381.7	387.7	5.6%
CO_2	339.6	388.9	370.6	338.6	359.3	379.3	366.9	373.1	5.4%
CH_4	4.6	4.7	3.7	3.3	3.5	3.7	3.5	3.1	+
N_2O	1.1	1.2	1.0	0.9	0.9	1.0	1.0	0.9	+
HFCs	0.3	9.0	9.9	9.6	9.8	10.1	10.3	10.6	0.2%
Electricity-Related	602.8	658.6	672.0	704.7	706.4	744.9	744.0	770.4	11.1%
CO_2	590.4	647.7	662.1	696.0	698.0	736.5	735.5	762.0	11.0%
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.6	2.9	2.9	3.0	3.0	3.1	3.1	3.2	+
SF_6	9.6	7.8	6.9	5.5	5.2	5.1	5.1	5.0	0.1%
Agriculture	**543.7**	**592.4**	**588.3**	**594.8**	**585.3**	**577.9**	**586.3**	**583.1**	**8.4%**
Direct Emissions	482.8	520.8	532.6	534.3	534.7	520.7	519.3	519.8	7.5%
CO_2	46.3	52.0	58.3	57.6	59.9	50.4	50.2	52.2	0.8%
CH_4	156.8	162.9	163.0	164.3	164.4	162.1	161.7	161.6	2.3%
N_2O	279.7	305.8	311.3	312.4	310.3	308.3	307.4	306.0	4.4%
Electricity-Related	60.9	71.6	55.6	60.5	50.6	57.2	67.1	63.4	0.9%

Table 2-8: U.S Greenhouse Gas Emissions by "Economic Sector" and Gas with Electricity-Related Emissions Distributed (Tg CO_2 Eq.) and percent of total in 2002 (continued)

Sector/Gas	1990	1996	1997	1998	1999	2000	2001	2002	Percent[a]
CO_2	59.6	70.4	54.8	59.8	50.0	56.6	66.3	62.7	0.9%
CH_4	+	+	+	+	+	+	+	+	+
N_2O	0.3	0.3	0.2	0.3	0.2	0.2	0.3	0.3	+
SF_6	1.0	0.8	0.6	0.5	0.4	0.4	0.5	0.4	+
U.S. Territories	**33.8**	**41.4**	**42.7**	**42.8**	**43.8**	**46.1**	**45.2**	**46.6**	**0.7%**
CO_2	33.8	41.4	42.7	42.8	43.8	46.1	45.2	46.6	0.7%
Total	**6,129.1**	**6,687.3**	**6,764.4**	**6,790.5**	**6,852.5**	**7,038.3**	**6,883.9**	**6,934.6**	**100.0%**

Note: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector.
Totals may not sum due to independent rounding.
+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05 percent.
[a] Percents for year 2002.
[b] Includes primarily HFC-134a.

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, then, were 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 2003). 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.

Table 2-8 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electricity generation distributed to them. Figure 2-7 shows the trend in these emissions by sector from 1990 to 2002.

Transportation

Transportation activities accounted for 27 percent of U.S. greenhouse gas emissions in 2002. Table 2-9 provides a detailed summary of greenhouse gas emissions from

Table 2-9: Transportation-Related Greenhouse Gas Emissions (Tg CO_2 Eq.)

Gas/Vehicle Type	1990	1996	1997	1998	1999	2000	2001	2002
CO_2	**1,461.2**	**1,607.8**	**1,617.8**	**1,648.0**	**1,706.1**	**1,753.0**	**1,734.1**	**1,767.5**
Passenger Cars	599.9	590.1	588.2	608.0	619.1	621.7	623.3	636.9
Light-Duty Trucks	306.3	404.0	416.2	427.8	446.4	450.1	453.4	465.5
Other Trucks	196.6	242.5	254.3	264.3	276.2	286.6	289.2	292.4
Buses	7.2	8.1	8.4	8.6	9.6	9.5	8.9	8.3
Aircraft[a]	176.9	180.2	178.9	180.8	186.7	193.2	183.4	177.6
Ships and Boats	48.0	47.8	33.4	27.1	38.1	59.1	37.2	52.4
Locomotives	27.7	32.3	32.2	32.8	34.1	34.0	34.6	33.5
Other[b]	98.7	102.9	106.3	98.6	95.8	98.8	104.2	101.0
International Bunker Fuels[c]	93.9	99.3	106.1	103.8	102.7	102.2	98.5	86.8
CH_4	**5.0**	**4.8**	**4.7**	**4.5**	**4.5**	**4.4**	**4.3**	**4.2**
Passenger Cars	2.4	2.0	2.0	2.0	1.9	1.9	1.9	1.8
Light-Duty Trucks	1.6	1.8	1.7	1.7	1.6	1.5	1.5	1.4
Other Trucks and Buses	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Aircraft	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.1
Ships and Boats	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
Other[d]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
International Bunker Fuels[c]	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
N_2O	**50.7**	**60.7**	**60.3**	**59.6**	**58.6**	**57.4**	**55.0**	**52.9**
Passenger Cars	31.0	33.1	32.6	32.3	31.2	30.2	28.8	27.4
Light-Duty Trucks	14.1	21.1	21.1	20.6	20.4	19.9	19.1	18.2
Other Trucks and Buses	2.5	3.4	3.6	3.7	3.9	3.9	4.0	4.0
Aircraft	1.7	1.8	1.7	1.8	1.8	1.9	1.8	1.7
Ships and Boats	0.4	0.4	0.3	0.2	0.3	0.5	0.3	0.4
Locomotives	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Other[d]	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7
International Bunker Fuels[c]	1.0	0.9	1.0	1.0	0.9	0.9	0.9	0.8
HFCs	**+**	**13.9**	**19.4**	**24.4**	**29.3**	**33.8**	**37.4**	**40.4**
Mobile Air Conditioners[e]	+	10.1	13.8	17.4	20.8	24.0	26.7	28.8
Refrigerated Transport	+	3.8	5.5	7.0	8.5	9.8	10.8	11.5
Total	**1,516.8**	**1,687.1**	**1,702.2**	**1,736.6**	**1,798.4**	**1,848.6**	**1,830.9**	**1,865.0**

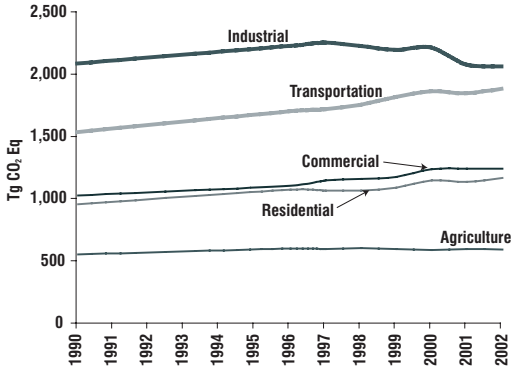
+ Does not exceed 0.05 Tg CO_2 Eq.
Note: Totals may not sum due to independent rounding.
[a] Aircraft emissions consist of emissions from all jet fuel (less bunker fuels) and aviation gas consumption.
[b] "Other" CO_2 emissions include motorcycles, construction equipment, agricultural machinery, pipelines, and lubricants.
[c] Emissions from International Bunker Fuels include emissions from both civilian and military activities, but are not included in totals.
[d] "Other" CH_4 and N_2O emissions include motorcycles, construction equipment, agricultural machinery, industrial equipment, and snowmobiles.
[e] Includes primarily HFC-134a.

transportation-related activities. Total emissions in Table 2-9 differ slightly from those shown in Table 2-8 primarily because the table below includes all transportation activities, including those that had been counted under the Agriculture economic sector.

From 1990 to 2002, transportation emissions rose by 23 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 33 percent from 1990 to 2002) 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

Figure 2-7

Emissions with Electricity Distributed to Economic Sectors



Note: Does not include territories.

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 21 percent from 1990 to 2002. This rise in CO_2 emissions, combined with increases of 40.4 Tg CO_2 Eq. in HFC emissions and 2.3 Tg CO_2 Eq. in N_2O emissions over the same period, led to an increase in overall emissions from transportation activities of 23 percent.

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," as termed in the Clean Air Act. 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. 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

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 68 percent in 2002. 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.

Table 2-10: Emissions of NO_x, CO, NMVOCs, and SO_2 (Gg)

Gas/Activity	1990	1996	1997	1998	1999	2000	2001	2002
NO_x	**23,037**	**22,360**	**22,289**	**21,961**	**21,341**	**20,917**	**20,141**	**19,849**
Stationary Fossil Fuel Combustion	9,884	9,540	9,578	9,419	8,716	8,226	7,826	7,542
Mobile Fossil Fuel Combustion	12,134	11,714	11,768	11,592	11,582	11,395	11,254	11,352
Oil and Gas Activities	139	126	130	130	113	115	117	118
Waste Combustion	82	135	140	145	142	149	149	149
Industrial Processes	769	808	634	635	748	992	755	649
Solvent Use	1	3	3	3	3	3	3	3
Field Burning of Agricultural Residues	28	32	34	35	34	35	35	33
Waste	0	3	3	3	3	3	3	3
CO	**130,575**	**104,063**	**101,132**	**98,976**	**95,464**	**93,965**	**100,653**	**92,541**
Stationary Fossil Fuel Combustion	4,999	3,935	3,927	3,927	4,941	4,163	4,169	3,961
Mobile Fossil Fuel Combustion	119,482	93,409	90,284	87,940	84,574	83,680	90,268	82,063
Oil and Gas Activities	302	321	333	332	152	152	153	153
Waste Combustion	978	2,628	2,668	2,826	2,833	2,914	2,916	3,294
Industrial Processes	4,124	3,016	3,153	3,163	2,145	2,214	2,327	2,304
Solvent Use	4	1	1	1	46	45	44	44
Field Burning of Agricultural Residues	685	747	761	781	760	784	762	706
Waste	1	5	5	5	14	14	14	15
NMVOCs	**20,937**	**17,184**	**16,994**	**16,403**	**16,245**	**15,418**	**15,148**	**14,996**
Stationary Fossil Fuel Combustion	912	1,018	1,016	1,016	1,312	1,088	1,087	1,147
Mobile Fossil Fuel Combustion	10,933	8,306	7,928	7,742	7,658	7,230	6,800	6,771
Oil and Gas Activities	555	433	442	440	376	348	357	348
Waste Combustion	222	304	313	326	326	332	333	333
Industrial Processes	2,426	1,997	2,038	2,047	1,890	1,845	1,829	1,818
Solvent Use	5,217	4,969	5,100	4,671	4,533	4,422	4,584	4,420
Field Burning of Agricultural Residues	NA	NA	NA	NA	NA	NA	NA	NA
Waste	673	158	157	161	151	153	158	158
SO_2	**20,936**	**16,682**	**17,091**	**17,189**	**16,013**	**14,802**	**14,324**	**13,669**
Stationary Fossil Fuel Combustion	18,407	14,746	15,104	15,191	14,073	12,883	12,367	11,805
Mobile Fossil Fuel Combustion	793	649	659	665	701	632	636	634
Oil and Gas Activities	390	304	312	310	275	279	281	268
Waste Combustion	39	29	29	30	29	29	30	30
Industrial Processes	1,306	953	985	991	933	977	1,008	930
Solvent Use	0	1	1	1	1	1	1	1
Field Burning of Agricultural Residues	NA	NA	NA	NA	NA	NA	NA	NA
Waste	0	1	1	1	1	1	1	1

Source: (EPA 2003) 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.

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.

Ambient air pollutants are regulated under the Clean Air Act in an effort to protect human health and the environment. These gases also indirectly affect the global climate by either acting as short-lived greenhouse gases or reacting with other chemical compounds in the atmosphere to form compounds that are greenhouse gases. Unlike the other ambient air pollutants, sulfur-containing compounds emitted into the atmosphere affect the Earth's radiative budget negatively; therefore, it is 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 2003).[4] Table 2-10 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.

[4] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2003).