2. Trends in Greenhouse Gas Emissions

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

In 2010, total U.S. greenhouse gas emissions were 6,821.8 Tg or million metric tons CO_2 Eq. Total U.S. emissions have increased by 10.5 percent from 1990 to 2010, and emissions increased from 2009 to 2010 by 3.2 percent (213.5 Tg CO_2 Eq.). The increase from 2009 to 2010 was primarily due to an increase in economic output resulting in an increase in energy consumption across all sectors, and, much warmer summer conditions resulting in an increase in electricity demand for air conditioning that was generated primarily by combusting coal and natural gas. Since 1990, U.S. emissions have increased at an average annual rate of 0.5 percent.

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 Annual U.S. Greenhouse Gas Emissions Relative to 1990

As the largest contributor to U.S. greenhouse gas emissions, carbon dioxide (CO_2) from fossil fuel combustion has accounted for approximately 78 percent of global warming potential (GWP) weighted emissions since 1990, from 77 percent of total GWP-weighted emissions in 1990 to 79 percent in 2010. Emissions from this source category grew by 13.7 percent (649.5 Tg CO_2 Eq.) from 1990 to 2010 and were responsible for most of the increase in national emissions during this period. From 2009 to 2010, these emissions increased by 3.5 percent (181.6 Tg CO_2 Eq.). 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 fluctuates primarily 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 in a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

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

Energy-related CO_2 emissions also depend on the type of fuel or energy consumed and its carbon (C) intensity. Producing a unit of heat or electricity using natural gas instead of coal, for example, can reduce the CO_2 emissions because of the lower C content of natural gas.

A brief discussion of the year to year variability in fuel combustion emissions is provided below, beginning with 2006.

From 2006 to 2007, emissions from fuel combustion grew at a rate slightly higher than the average growth rate since 1990. There were a number of factors contributing to this increase. More energy-intensive weather conditions in both the winter and summer resulted in an increase in consumption of heating fuels, as well as an increase in the demand for electricity. This demand for electricity was met with an increase in coal consumption of 1.7 percent, and with an increase in natural gas consumption of 9.9 percent. This increase in fossil fuel consumption, combined with a 14.4 percent decrease in hydropower generation from 2006 to 2007, resulted in an increase in emissions in 2007. The increase in emissions from the residential and commercial sectors is a result of increased electricity

consumption due to warmer summer conditions and cooler winter conditions compared to 2006. In addition to these more energy-intensive weather conditions, electricity prices remained relatively stable compared to 2006, and natural gas prices decreased slightly. Emissions from the industrial sector decreased compared to 2006 as a result of a decrease in industrial production and fossil fuels used for electricity generation. Despite an overall decrease in electricity generation from renewable energy in 2007 driven by decreases in hydropower generation, wind and solar generation increased significantly.

Emissions from fossil fuel combustion decreased from 2007 to 2008. Several factors contributed to this decrease in emissions. An increase in energy prices coupled with the economic downturn led to a decrease in energy demand and a resulting decrease in emissions from 2007 to 2008. In 2008, the price of coal, natural gas, and petroleum used to generate electricity, as well as the price of fuels used for transportation, increased significantly. As a result of this price increase, coal, natural gas, and petroleum consumption used for electricity generation decreased by 1.4 percent, 2.5 percent, and 28.8 percent, respectively. The increase in the cost of fuels to generate electricity translated into an increase in the price of electricity, leading to a decrease in electricity consumption across all sectors except the commercial sector. The increase in transportation fuel prices led to a decrease in vehicle miles traveled (VMT) and a 5.5 percent decrease in transportation fossil fuel combustion emissions from 2007 to 2008. Cooler weather conditions in the summer led to a decrease in cooling degree days by 8.7 percent and a decrease in electricity demand compared to 2007, whereas cooler winter conditions led to a 5.6 percent increase in heating degree days compared to 2007 and a resulting increase in demand for heating fuels. The increased emissions from winter heating energy demand was offset by a decrease in emissions from summer cooling related electricity demand. Lastly, renewable energy[46] consumption for electricity generation increased by 16.6 percent from 2007 to 2008, driven by a significant increase in solar and wind energy consumption (of 17.0 percent and 60.2 percent, respectively). This increase in renewable energy generation contributed to a decrease in the carbon intensity of electricity generation.

From 2008 to 2009, CO_2 from fossil fuel combustion emissions experienced a decrease of 6.6 percent, the greatest decrease of any year over the course of the twenty one-year period. Various factors contributed to this decrease in emissions. The continued economic downturn resulted in a 3.5 percent decrease in GDP, and a decrease in energy consumption across all sectors. The economic downturn also impacted total industrial production and manufacturing output, which decreased by 11.2 and 13.5 percent, respectively. In 2009, the price of coal used to generate electricity increased, while the price of natural gas used to generate electricity decreased significantly. As a result, natural gas was used for a greater share of electricity generation in 2009 than 2008, and coal was used for a smaller share. The fuel switching from coal to natural gas and additional electricity generation from other energy sources in 2009, which included a 7.3 percent increase in hydropower generation from the previous year, resulted in a decrease in carbon intensity, and in turn, a decrease in emissions from electricity generation. From 2008 to 2009, industrial sector emissions decreased significantly as a result of a decrease in output from energy-intensive industries of 23.6 percent in nonmetallic mineral and 30.3 percent in primary metal industries. The residential and commercial sectors only experienced minor decreases in emissions as summer and winter weather conditions were less energy-intensive from 2008 to 2009, and the price of electricity only increased slightly. Heating degree days decreased slightly and cooling degree days decreased by 3.8 percent from 2008 to 2009.

From 2009 to 2010, CO_2 emissions from fossil fuel combustion increased by 3.5 percent, which represents the largest annual increase in CO_2 emissions from fossil fuel combustion for the twenty one-year period.[47] This increase is primarily due to an increase in economic output 2009 to 2010, where total industrial production and manufacturing output increased by 5.3 and 5.8 percent, respectively (FRB 2011). Carbon dioxide emissions from fossil fuel combustion in the industrial sector increased by 7.0 percent, including increased emissions from the combustion of fuel oil, natural gas and coal. Overall, coal consumption increased by 5.4 percent, the largest increase in coal consumption for the twenty one-year period. In 2010, weather conditions remained fairly constant in the winter and were much hotter in the summer compared to 2009, as heating degree days decreased slightly (0.7 percent) and cooling degree days increased by 19 percent to their highest levels in the twenty one-year period. As a result of the more energy-intensive summer weather conditions, electricity sales to the residential and commercial end-use sectors in 2010 increased approximately 6.3 percent and 1.7 percent, respectively.

[46] Renewable energy, as defined in EIA's energy statistics, includes the following energy sources: hydroelectric power, geothermal energy, biofuels, solar energy, and wind energy.

[47] This increase also represents the largest absolute and percentage increase since 1988 (EIA 2011a).

Overall, from 1990 to 2010, total emissions of CO_2 increased by 605.9 Tg CO_2 Eq. (11.9 percent), while total emissions of CH_4 and N_2O decreased by 1.7 Tg CO_2 Eq. (0.3 percent), and 10.0 Tg CO_2 Eq. (3.2 percent), respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 52.5 Tg CO_2 Eq. (58.2 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF_6 are significant because many of them have extremely high GWPs and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by C sequestration in managed forests, trees in urban areas, agricultural soils, and landfilled yard trimmings. These were estimated to offset 15.8 percent of total emissions in 2010.

Table 2-1 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 2-2.

Table 2-1: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg CO_2 Eq.)

Gas/Source	1990	2005	2006	2007	2008	2009	2010
CO_2	**5,100.5**	**6,107.6**	**6,019.0**	**6,118.6**	**5,924.3**	**5,500.5**	**5,706.4**
Fossil Fuel Combustion	4,738.3	5,746.5	5,653.0	5,757.8	5,571.5	5,206.2	5,387.8
Electricity Generation	1,820.8	2,402.1	2,346.4	2,412.8	2,360.9	2,146.4	2,258.4
Transportation	1,485.9	1,896.6	1,878.1	1,893.9	1,789.8	1,727.9	1,745.5
Industrial	846.4	816.4	848.1	844.4	806.5	726.6	777.8
Residential	338.3	357.9	321.5	341.6	349.3	339.0	340.2
Commercial	219.0	223.5	208.6	218.9	225.1	224.6	224.2
U.S. Territories	27.9	50.0	50.3	46.1	39.8	41.7	41.6
Non-Energy Use of Fuels	119.6	144.1	143.8	134.9	138.6	123.7	125.1
Iron and Steel Production & Metallurgical Coke Production	99.6	66.0	68.9	71.1	66.1	42.1	54.3
Natural Gas Systems	37.6	29.9	30.8	31.0	32.8	32.2	32.3
Cement Production	33.3	45.2	45.8	44.5	40.5	29.0	30.5
Lime Production	11.5	14.4	15.1	14.6	14.3	11.2	13.2
Incineration of Waste	8.0	12.5	12.5	12.7	11.9	11.7	12.1
Limestone and Dolomite Use	5.1	6.8	8.0	7.7	6.3	7.6	10.0
Ammonia Production	13.0	9.2	8.8	9.1	7.9	7.9	8.7
Cropland Remaining Cropland	7.1	7.9	7.9	8.2	8.6	7.2	8.0
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	3.5	4.9	4.1	3.4	4.4
Soda Ash Production and Consumption	4.1	4.2	4.2	4.1	4.1	3.6	3.7
Petrochemical Production	3.3	4.2	3.8	3.9	3.4	2.7	3.3
Aluminum Production	6.8	4.1	3.8	4.3	4.5	3.0	3.0
Carbon Dioxide Consumption	1.4	1.3	1.7	1.9	1.8	1.8	2.2
Titanium Dioxide Production	1.2	1.8	1.8	1.9	1.8	1.6	1.9
Ferroalloy Production	2.2	1.4	1.5	1.6	1.6	1.5	1.7
Zinc Production	0.6	1.0	1.0	1.0	1.2	0.9	1.2
Phosphoric Acid Production	1.5	1.4	1.2	1.2	1.2	1.0	1.0
Wetlands Remaining Wetlands	1.0	1.1	0.9	1.0	1.0	1.1	1.0
Lead Production	0.5	0.6	0.6	0.6	0.5	0.5	0.5
Petroleum Systems	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.1	0.2
Land Use, Land-Use Change, and Forestry (Sink)[a]	*(881.8)*	*(1,085.9)*	*(1,110.4)*	*(1,108.2)*	*(1,087.5)*	*(1,062.6)*	*(1,074.7)*
Wood Biomass and Ethanol Consumption[b]	*218.6*	*228.6*	*233.7*	*241.1*	*252.1*	*244.1*	*266.1*
International Bunker Fuels[c]	*111.8*	*109.8*	*128.4*	*127.6*	*133.7*	*122.3*	*127.8*
CH_4	**668.3**	**625.8**	**664.6**	**656.2**	**667.9**	**672.2**	**666.5**
Natural Gas Systems	189.6	190.5	217.7	205.3	212.7	220.9	215.4
Enteric Fermentation	133.8	139.0	141.4	143.8	143.4	142.6	141.3
Landfills	147.7	112.7	111.7	111.7	113.1	111.2	107.8
Coal Mining	84.1	56.8	58.1	57.8	66.9	70.1	72.6

Manure Management	31.7	47.9	48.4	52.7	51.8	50.7	52.0
Petroleum Systems	35.2	29.2	29.2	29.8	30.0	30.7	31.0
Wastewater Treatment	15.9	16.5	16.7	16.6	16.6	16.5	16.3
Rice Cultivation	7.1	6.8	5.9	6.2	7.2	7.3	8.6
Stationary Combustion	7.5	6.6	6.2	6.5	6.6	6.3	6.3
Abandoned Underground Coal Mines	6.0	5.5	5.5	5.3	5.3	5.1	5.0
Forest Land Remaining Forest Land	2.5	8.1	17.9	14.6	8.8	5.8	4.8
Mobile Combustion	4.7	2.5	2.4	2.2	2.1	2.0	1.9
Composting	0.3	1.6	1.6	1.7	1.7	1.6	1.6
Petrochemical Production	0.9	1.1	1.0	1.0	0.9	0.8	0.9
Iron and Steel Production & Metallurgical Coke Production	1.0	0.7	0.7	0.7	0.6	0.4	0.5
Field Burning of Agricultural Residues	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.2*	*0.1*	*0.2*	*0.2*	*0.2*	*0.1*	*0.2*
N_2O	**316.2**	**331.9**	**336.8**	**334.9**	**317.1**	**304.0**	**306.2**
Agricultural Soil Management	200.0	213.1	211.1	211.1	212.9	207.3	207.8
Stationary Combustion	12.3	20.6	20.8	21.2	21.1	20.7	22.6
Mobile Combustion	43.9	37.0	33.7	29.0	25.2	22.5	20.6
Manure Management	14.8	17.6	18.4	18.5	18.3	18.2	18.3
Nitric Acid Production	17.6	16.4	16.1	19.2	16.4	14.5	16.7
Wastewater Treatment	3.5	4.7	4.8	4.8	4.9	5.0	5.0
N_2O from Product Uses	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Forest Land Remaining Forest Land	2.1	7.0	15.0	12.2	7.5	5.1	4.3
Adipic Acid Production	15.8	7.4	8.9	10.7	2.6	2.8	2.8
Composting	0.4	1.7	1.8	1.8	1.9	1.8	1.7
Settlements Remaining Settlements	1.0	1.5	1.5	1.6	1.5	1.4	1.4
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands	+	+	+	+	+	+	+
International Bunker Fuels[c]	*1.1*	*1.0*	*1.2*	*1.2*	*1.2*	*1.1*	*1.2*
HFCs	**36.9**	**115.0**	**116.0**	**120.0**	**117.5**	**112.1**	**123.0**
Substitution of Ozone Depleting Substances	0.3	99.0	101.9	102.7	103.6	106.3	114.6
HCFC-22 Production	36.4	15.8	13.8	17.0	13.6	5.4	8.1
Semiconductor Manufacture	0.2	0.2	0.3	0.3	0.3	0.3	0.3
PFCs	**20.6**	**6.2**	**6.0**	**7.5**	**6.6**	**5.6**	**5.6**
Semiconductor Manufacture	2.2	3.2	3.5	3.7	4.0	4.0	4.1
Aluminum Production	18.4	3.0	2.5	3.8	2.7	1.6	1.6
SF_6	**32.6**	**17.8**	**16.8**	**15.6**	**15.0**	**13.9**	**14.0**
Electrical Transmission and Distribution	26.7	13.9	13.0	12.2	12.2	11.8	11.8
Magnesium Production and Processing	5.4	2.9	2.9	2.6	1.9	1.1	1.3
Semiconductor Manufacture	0.5	1.0	1.0	0.8	0.9	1.0	0.9
Total	**6,175.2**	**7,204.2**	**7,159.3**	**7,252.8**	**7,048.3**	**6,608.3**	**6,821.8**
Net Emissions (Sources and Sinks)	**5,293.4**	**6,118.3**	**6,048.9**	**6,144.5**	**5,960.9**	**5,545.7**	**5,747.1**

+ Does not exceed 0.05 Tg CO_2 Eq.

[a] The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks

are only included in net emissions total. Parentheses indicate negative values or sequestration.

[b] Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry.

[c] Emissions from International Bunker Fuels are not included in totals.

[d] Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding.

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

Gas/Source	1990	2005	2006	2007	2008	2009	2010
CO_2	**5,100,499**	**6,107,587**	**6,019,033**	**6,118,566**	**5,924,259**	**5,500,517**	**5,706,370**
Fossil Fuel Combustion	4,742,080	5,757,404	5,666,588	5,771,185	5,579,548	5,214,694	5,406,848
Electricity Generation	1,820,818	2,402,143	2,346,407	2,412,827	2,360,920	2,146,415	2,258,358
Transportation	1,485,939	1,896,604	1,878,114	1,893,889	1,789,846	1,727,909	1,745,466
Industrial	846,389	816,352	848,134	844,412	806,539	726,622	777,840
Residential	338,347	357,903	321,514	341,649	349,318	338,985	340,235
Commercial	218,963	223,511	208,580	218,875	225,069	224,586	224,243
U.S. Territories	27,882	49,968	50,284	46,123	39,845	41,650	41,649
Non-Energy Use of Fuels	119,627	144,098	143,761	134,863	138,624	123,712	125,130
Iron and Steel Production & Metallurgical Coke Production	99,593	66,000	68,854	71,138	66,092	42,113	54,276
Natural Gas Systems	37,574	30,140	30,118	31,047	32,811	32,165	32,297
Cement Production	33,278	45,197	45,792	44,538	40,531	29,018	30,509
Lime Production	11,533	14,379	15,100	14,595	14,330	11,225	13,151
Incineration of Waste	7,989	12,468	12,531	12,727	11,888	11,703	12,054
Limestone and Dolomite Use	5,127	6,768	8,035	7,702	6,276	7,649	10,017
Ammonia Production	13,047	9,196	8,781	9,074	7,883	7,855	8,678
Cropland Remaining Cropland	7,084	7,854	7,875	8,222	8,638	7,245	8,050
Urea Consumption for Non-Agricultural Purposes	3,784	3,653	3,519	4,944	4,065	3,415	4,365
Soda Ash Production and Consumption	4,141	4,228	4,162	4,140	4,099	3,554	3,735
Petrochemical Production	3,311	4,181	3,837	3,931	3,449	2,735	3,336
Aluminum Production	6,831	4,142	3,801	4,251	4,477	3,009	3,009
Carbon Dioxide Consumption	1,416	1,321	1,709	1,867	1,780	1,784	2,203
Titanium Dioxide Production	1,195	1,755	1,836	1,930	1,809	1,648	1,876
Ferroalloy Production	2,152	1,392	1,505	1,552	1,599	1,469	1,663
Zinc Production	632	1,030	1,030	1,025	1,159	943	1,168
Phosphoric Acid Production	1,529	1,386	1,167	1,166	1,187	1,018	1,017
Wetlands Remaining Wetlands	1,033	1,079	879	1,012	992	1,089	983
Lead Production	516	553	560	562	547	525	542
Petroleum Systems	394	305	306	310	297	325	337
Silicon Carbide Production and Consumption	375	219	207	196	175	145	181
Land Use, Land-Use Change, and Forestry	*(881,848)*	*(1,085,929)*	*(1,110,385)*	*(1,108,249)*	*(1,087,454)*	*(1,062,559)*	*(1,074,684)*
Wood Biomass and Ethanol Consumption[b]	*218,637*	*228,614*	*233,665*	*241,128*	*252,097*	*244,078*	*266,110*
International Bunker Fuels[c]	*111,828*	*109,765*	*128,413*	*127,643*	*133,730*	*122,338*	*127,841*
CH_4	**31,822**	**29,798**	**31,649**	**31,247**	**31,804**	**32,010**	**31,740**
Natural Gas Systems	9,029	9,071	10,369	9,774	10,127	10,519	10,259
Enteric Fermentation	6,373	6,618	6,731	6,850	6,829	6,788	6,728

Landfills	7,032	5,367	5,320	5,320	5,386	5,295	5,135
Coal Mining	4,003	2,705	2,768	2,754	3,186	3,340	3,458
Manure Management	1,511	2,280	2,303	2,508	2,465	2,416	2,478
Petroleum Systems	1,677	1,390	1,389	1,420	1,427	1,460	1,478
Wastewater Treatment	758	785	794	791	792	787	779
Rice Cultivation	339	326	282	295	343	349	410
Stationary Combustion	355	315	296	311	313	298	301
Abandoned Underground Coal Mines	288	264	261	254	253	244	237
Forest Land Remaining Forest Land	120	388	854	693	419	276	231
Mobile Combustion	223	121	114	107	99	93	91
Composting	15	75	75	79	80	75	75
Petrochemical Production	41	51	48	48	43	39	44
Iron and Steel Production & Metallurgical Coke	46	34	35	33	31	17	25
Field Burning of Agricultural Residues	10	8	11	11	11	11	11
Ferroalloy Production	1	+	+	+	+	+	+
Silicon Carbide Production and Consumption	1	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[c]	*8*	*7*	*8*	*8*	*8*	*7*	*8*
N_2O	**1,020**	**1,071**	**1,087**	**1,080**	**1,023**	**981**	**988**
Agricultural Soil Management	645	687	681	681	687	669	670
Stationary Combustion	40	66	67	68	68	67	73
Mobile Combustion	142	119	109	94	81	73	66
Manure Management	48	57	59	60	59	59	59
Nitric Acid Production	57	53	52	62	53	47	54
Wastewater Treatment	11	15	15	16	16	16	16
N_2O from Product Uses	14	14	14	14	14	14	14
Forest Land Remaining Forest Land	7	23	48	39	24	16	14
Adipic Acid Production	51	24	29	34	8	9	9
Composting	1	6	6	6	6	6	6
Settlements Remaining Settlements	3	5	5	5	5	4	5
Incineration of Waste	2	1	1	1	1	1	1
Field Burning of Agricultural Residues	+	+	+	+	+	+	+
Wetlands Remaining Wetlands	+	+	+	+	+	+	+
International Bunker Fuels[c]	*3*	*3*	*4*	*4*	*4*	*4*	*4*
HFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Substitution of Ozone Depleting Substances	M	M	M	M	M	M	M
HCFC-22 Production	3	1	1	1	1	+	1
Semiconductor Manufacture	+	+	+	+	+	+	+
PFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Semiconductor Manufacture	M	M	M	M	M	M	M
Aluminum Production	M	M	M	M	M	M	M
SF_6	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Electrical Transmission and Distribution	1	1	1	1	1	+	+
Magnesium Production and Processing	+	+	+	+	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+

+ Does not exceed 0.5 Gg.

M Mixture of multiple gases

[a] The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total. Parentheses indicate negative values or sequestration.

[b] Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry

[c] Emissions from International Bunker Fuels are not included in totals.

[d] Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding.

Emissions of all gases can be summed from each source category into a set of six sectors defined by the Intergovernmental Panel on Climate Change (IPCC). Over the twenty-one-year period of 1990 to 2010, total emissions in the Energy and Agriculture sectors grew by 645.8 Tg CO_2 Eq. (12.2 percent) and 40.6 Tg CO_2 Eq. (10.5 percent), respectively. Emissions decreased in the Industrial Process, Waste and Solvent and Other Product Use sectors by 10.5 Tg CO_2 Eq. (3.4 percent), 35.2 Tg CO_2 Eq. (21.0 percent) and less than 0.1 Tg CO_2 Eq. (0.4 percent), respectively. Over the same period, estimates of net C sequestration in the Land Use, Land-Use Change, and Forestry sector increased by 192.8 Tg CO_2 Eq. (21.9 percent).

Figure 2-4: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

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

Chapter/IPCC Sector	1990	2005	2006	2007	2008	2009	2010
Energy	5,287.7	6,282.4	6,214.4	6,294.3	6,125.4	5,752.7	5,933.5
Industrial Processes	313.9	330.1	335.5	347.3	319.1	268.2	303.4
Solvent and Other Product Use	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Agriculture	387.8	424.6	425.4	432.6	433.8	426.4	428.4
Land Use, Land-Use Change, and Forestry (Emissions)	13.8	25.6	43.2	37.6	27.4	20.6	19.6
Waste	167.7	137.2	136.5	136.7	138.2	136.0	132.5
Total Emissions	**6,175.2**	**7,204.2**	**7,159.3**	**7,252.8**	**7,048.3**	**6,608.3**	**6,821.8**
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Sinks)*	(881.8)	(1085.9)	(1110.4)	(1108.2)	(1087.5)	(1062.6)	(1074.7)
Net Emissions (Sources and Sinks)	**5,293.4**	**6,118.3**	**6,048.9**	**6,144.5**	**5,960.9**	**5,545.7**	**5,747.1**

* The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total. Please refer to Table 2-9 for a breakout by source.

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 2010. In 2010, approximately 85 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 15 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure 2-5 and Figure 2-6). A discussion of specific trends related to CO_2 as well as other greenhouse gas emissions from energy consumption is presented in the Energy chapter. Energy-related activities are also responsible for CH_4 and N_2O emissions (50 percent and 14 percent of total U.S. emissions of each gas, respectively). Table 2-4 presents greenhouse gas emissions from the Energy chapter, by source and gas.

Figure 2-5: 2010 Energy Chapter Greenhouse Gas Sources

Figure 2-6: 2010 U.S. Fossil Carbon Flows (Tg CO_2 Eq.)

Table 2-4: Emissions from Energy (Tg CO_2 Eq.)

Gas/Source	1990	2005	2006	2007	2008	2009	2010
CO_2	**4,903.9**	**5,933.3**	**5,840.4**	**5,936.7**	**5,755.2**	**5,374.1**	**5,557.6**
Fossil Fuel Combustion	4,738.3	5,746.5	5,653.0	5,757.8	5,571.5	5,206.2	5,387.8
Electricity Generation	1,820.8	2,402.1	2,346.4	2,412.8	2,360.9	2,146.4	2,258.4
Transportation	1,485.9	1,896.6	1,878.1	1,893.9	1,789.8	1,727.9	1,745.5
Industrial	846.4	816.4	848.1	844.4	806.5	726.6	777.8
Residential	338.3	357.9	321.5	341.6	349.3	339.0	340.2
Commercial	219.0	223.5	208.6	218.9	225.1	224.6	224.2
U.S. Territories	27.9	50.0	50.3	46.1	39.8	41.7	41.6
Non-Energy Use of Fuels	119.6	144.1	143.8	134.9	138.6	123.7	125.1
Natural Gas Systems	37.6	29.9	30.8	31.0	32.8	32.2	32.3
Incineration of Waste	8.0	12.5	12.5	12.7	11.9	11.7	12.1
Petroleum Systems	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Biomass - Wood[a]	*214.4*	*205.7*	*202.7*	*202.2*	*197.4*	*181.8*	*191.6*
International Bunker Fuels[b]	*111.8*	*109.8*	*128.4*	*127.6*	*133.7*	*122.3*	*127.8*
Biomass - Ethanol[a]	*4.2*	*22.9*	*31.0*	*38.9*	*54.7*	*62.3*	*74.5*
CH_4	**327.1**	**291.2**	**319.1**	**307.0**	**323.5**	**335.1**	**332.3**
Natural Gas Systems	189.6	190.5	217.7	205.3	212.7	220.9	215.4
Coal Mining	84.1	56.8	58.1	57.8	66.9	70.1	72.6
Petroleum Systems	35.2	29.2	29.2	29.8	30.0	30.7	31.0
Stationary Combustion	7.5	6.6	6.2	6.5	6.6	6.3	6.3
Abandoned Underground Coal	6.0	5.5	5.5	5.3	5.3	5.1	5.0
Mobile Combustion	4.7	2.5	2.4	2.2	2.1	2.0	1.9
Incineration of Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0
International Bunker Fuels[b]	*0.2*	*0.1*	*0.2*	*0.2*	*0.2*	*0.1*	*0.2*
N_2O	**56.7**	**58.0**	**54.8**	**50.6**	**46.7**	**43.6**	**43.6**
Stationary Combustion	12.3	20.6	20.8	21.2	21.1	20.7	22.6
Mobile Combustion	43.9	37.0	33.7	29.0	25.2	22.5	20.6
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
International Bunker Fuels[b]	*1.1*	*1.0*	*1.2*	*1.2*	*1.2*	*1.1*	*1.2*
Total	**5,287.7**	**6,282.4**	**6,214.4**	**6,294.3**	**6,125.4**	**5,752.7**	**5,933.5**

+ Does not exceed 0.05 Tg CO_2 Eq.

[a] Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry

[b] Emissions from International Bunker Fuels are not included in totals.

Note: Totals may not sum due to independent rounding.

Carbon dioxide emissions from fossil fuel combustion are presented in Table 2-5 based on the underlying U.S. energy consumer data collected by EIA. Estimates of CO_2 emissions from fossil fuel combustion are calculated from these EIA "end-use sectors" based on total consumption and appropriate fuel properties (any additional analysis and refinement of the EIA data is further explained in the Energy chapter of this report). EIA's fuel consumption data for the electric power sector comprises electricity-only and combined-heat-and-power (CHP) plants within the NAICS 22 category whose primary business is to sell electricity, or electricity and heat, to the public (nonutility power producers can be included in this sector as long as they meet they electric power sector definition). EIA statistics for the industrial sector include fossil fuel consumption that occurs in the fields of manufacturing, agriculture, mining, and construction. EIA's fuel consumption data for the transportation sector consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. EIA's fuel consumption data for the industrial sector consists of all facilities and equipment used for producing, processing, or assembling goods (EIA includes generators that produce electricity and/or useful thermal output

primarily to support on-site industrial activities in this sector). EIA's fuel consumption data for the residential sector consists of living quarters for private households. EIA's fuel consumption data for the commercial sector consists of service-providing facilities and equipment from private and public organizations and businesses (EIA includes generators that produce electricity and/or useful thermal output primarily to support the activities at commercial establishments in this sector). Table 2-5, Figure 2-7, and Figure 2-8 summarize CO_2 emissions from fossil fuel combustion by end-use sector.

Table 2-5: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (Tg CO_2 Eq.)

End-Use Sector	1990	2005	2006	2007	2008	2009	2010
Transportation	**1,489.0**	**1,901.3**	**1,882.6**	**1,899.0**	**1,794.5**	**1,732.4**	**1,750.0**
Combustion	1,485.9	1,896.6	1,878.1	1,893.9	1,789.8	1,727.9	1,745.5
Electricity	3.0	4.7	4.5	5.1	4.7	4.5	4.5
Industrial	**1,533.1**	**1,553.3**	**1,560.2**	**1,559.8**	**1,503.8**	**1,328.6**	**1,415.4**
Combustion	846.4	816.4	848.1	844.4	806.5	726.6	777.8
Electricity	686.8	737.0	712.0	715.4	697.3	602.0	637.6
Residential	**931.4**	**1,214.7**	**1,152.4**	**1,205.2**	**1,192.2**	**1,125.5**	**1,183.7**
Combustion	338.3	357.9	321.5	341.6	349.3	339.0	340.2
Electricity	593.0	856.7	830.8	863.5	842.9	786.5	843.5
Commercial	**757.0**	**1,027.2**	**1,007.6**	**1,047.7**	**1,041.1**	**978.0**	**997.1**
Combustion	219.0	223.5	208.6	218.9	225.1	224.6	224.2
Electricity	538.0	803.7	799.0	828.8	816.0	753.5	772.9
U.S. Territories	**27.9**	**50.0**	**50.3**	**46.1**	**39.8**	**41.7**	**41.6**
Total	**4,738.3**	**5,746.5**	**5,653.0**	**5,757.8**	**5,571.5**	**5,206.2**	**5,387.8**
Electricity Generation	**1,820.8**	**2,402.1**	**2,346.4**	**2,412.8**	**2,360.9**	**2,146.4**	**2,258.4**

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 2-7: 2010 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Figure 2-8: 2010 End-Use Sector Emissions from Fossil Fuel Combustion

The main driver of emissions in the Energy sector is CO_2 from fossil fuel combustion. Electricity generation is the largest emitter of CO_2, and electricity generators consumed 36 percent of U.S. energy from fossil fuels and emitted 42 percent of the CO_2 from fossil fuel combustion in 2010. Electricity generation emissions can also be allocated to the end-use sectors that are consuming that electricity, as presented in Table 2-5. The transportation end-use sector accounted for 1,750.0 Tg CO_2 Eq. in 2010, or approximately 32 percent of total CO_2 emissions from fossil fuel combustion. The industrial end-use sector accounted for 26 percent of CO_2 emissions from fossil fuel combustion. The residential and commercial end-use sectors accounted for 22 and 19 percent, respectively, of CO_2 emissions from fossil fuel combustion. Both of these end-use sectors were heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances contributing 71 and 78 percent of emissions from the residential and commercial end-use sectors, respectively. Significant trends in emissions from energy source categories over the twenty one-year period from 1990 through 2010 included the following:

- Total CO_2 emissions from fossil fuel combustion increased from 4,738.3 Tg CO_2 Eq. to 5,387.8 Tg CO_2 Eq.—a 13.7 percent total increase over the twenty one-year period. From 2009 to 2010, these emissions increased by 181.6 Tg CO_2 Eq. (3.5 percent).
- CO_2 emissions from non-energy use of fossil fuels increased 5.5 Tg CO_2 Eq. (4.6 percent) from 1990 through 2010. Emissions from non-energy uses of fossil fuels were 125.1 Tg CO_2 Eq. in 2010, which constituted 2.2 percent of total national CO_2 emissions.
- CO_2 emissions from incineration of waste (12.1 Tg CO_2 Eq. in 2010) increased by 4.1 Tg CO_2 Eq. (50.9 percent) from 1990 through 2010, as the volume of plastics and other fossil carbon-containing materials in

municipal solid waste grew.

- N_2O emissions from stationary combustion increased 10.3 Tg CO_2 Eq. (84.4 percent) from 1990 through 2010. N_2O emissions from this source increased primarily as a result of an increase in the number of coal fluidized bed boilers in the electric power sector.
- CH_4 emissions from coal mining were 72.6 Tg CO_2 Eq. in 2010, a decline in emissions of 11.5 Tg CO_2 Eq. (13.6 percent) from 1990. This occurred as a result of the mining of less gassy coal from underground mines and the increased use of CH_4 collected from degasification systems.
- CH_4 emissions from natural gas systems were 215.4 Tg CO_2 Eq. in 2010; emissions have increased by 25.8Tg CO_2 Eq. (13.6 percent) since 1990.
- In 2010, N_2O emissions from mobile combustion were 20.6 Tg CO_2 Eq. (approximately 6.7 percent of U.S. N_2O emissions). From 1990 to 2010, N_2O emissions from mobile combustion decreased by 53.1 percent. However, from 1990 to 1998 emissions increased by 26 percent, due to control technologies that reduced NO_x emissions while increasing N_2O emissions. Since 1998, newer control technologies have led to a steady decline in N_2O from this source.

Industrial Processes

Greenhouse gas emissions are produced as the by-products of many non-energy-related industrial activities. For example, industrial processes can chemically transform raw materials, which often release waste gases such as CO_2, CH_4, and N_2O. These processes include iron and steel production and metallurgical coke production, cement production, ammonia production, urea consumption, lime production, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and consumption, titanium dioxide production, phosphoric acid production, ferroalloy production, CO_2 consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production (see Figure 2-9). Industrial processes also release HFCs, PFCs and SF_6. In addition to their use as ODS substitutes, HFCs, PFCs, SF_6, and other fluorinated compounds are employed and emitted by a number of other industrial sources in the United States. These industries include aluminum production, HCFC-22 production, semiconductor manufacture, electric power transmission and distribution, and magnesium metal production and processing. Table 2-6 presents greenhouse gas emissions from industrial processes by source category.

Figure 2-9: 2010 Industrial Processes Chapter Greenhouse Gas Sources

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

Gas/Source	1990	2005	2006	2007	2008	2009	2010
CO_2	**188.5**	**165.4**	**169.9**	**172.6**	**159.5**	**118.1**	**139.7**
Iron and Steel Production & Metallurgical	99.6	66.0	68.9	71.1	66.1	42.1	54.3
Iron and Steel Production	*97.1*	*64.0*	*66.9*	*69.1*	*63.8*	*41.2*	*52.2*
Metallurgical Coke Production	*2.5*	*2.0*	*1.9*	*2.1*	*2.3*	*1.0*	*2.1*
Cement Production	33.3	45.2	45.8	44.5	40.5	29.0	30.5
Lime Production	11.5	14.4	15.1	14.6	14.3	11.2	13.2
Limestone and Dolomite Use	5.1	6.8	8.0	7.7	6.3	7.6	10.0
Ammonia Production	13.0	9.2	8.8	9.1	7.9	7.9	8.7
Urea Consumption for Non-Agriculture Purposes	3.8	3.7	3.5	4.9	4.1	3.4	4.4
Soda Ash Production and Consumption	4.1	4.2	4.2	4.1	4.1	3.6	3.7
Petrochemical Production	3.3	4.2	3.8	3.9	3.4	2.7	3.3
Aluminum Production	6.8	4.1	3.8	4.3	4.5	3.0	3.0
Carbon Dioxide Consumption	1.4	1.3	1.7	1.9	1.8	1.8	2.2
Titanium Dioxide Production	1.2	1.8	1.8	1.9	1.8	1.6	1.9
Ferroalloy Production	2.2	1.4	1.5	1.6	1.6	1.5	1.7

Zinc Production	0.6	1.0	1.0	1.0	1.2	0.9	1.2
Phosphoric Acid Production	1.5	1.4	1.2	1.2	1.2	1.0	1.0
Lead Production	0.5	0.6	0.6	0.6	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.1	0.2
CH_4	**1.9**	**1.8**	**1.7**	**1.7**	**1.6**	**1.2**	**1.5**
Petrochemical Production	0.9	1.1	1.0	1.0	0.9	0.8	0.9
Iron and Steel Production & Metallurgical	1.0	0.7	0.7	0.7	0.6	0.4	0.5
Iron and Steel Production	1.0	0.7	0.7	0.7	0.6	0.4	0.5
Metallurgical Coke Production	+	+	+	+	+	+	+
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
N_2O	**33.4**	**23.9**	**25.0**	**29.8**	**18.9**	**17.3**	**19.5**
Nitric Acid Production	17.6	16.4	16.1	19.2	16.4	14.5	16.7
Adipic Acid Production	15.8	7.4	8.9	10.7	2.6	2.8	2.8
HFCs	**36.9**	**115.0**	**116.0**	**120.0**	**117.5**	**112.1**	**123.0**
Substitution of Ozone Depleting Substances[a]	0.3	99.0	101.9	102.7	103.6	106.3	114.6
HCFC-22 Production	36.4	15.8	13.8	17.0	13.6	5.4	8.1
Semiconductor Manufacture	0.2	0.2	0.3	0.3	0.3	0.3	0.3
PFCs	**20.6**	**6.2**	**6.0**	**7.5**	**6.6**	**5.6**	**5.6**
Semiconductor Manufacture	2.2	3.2	3.5	3.7	4.0	4.0	4.1
Aluminum Production	18.4	3.0	2.5	3.8	2.7	1.6	1.6
SF_6	**32.6**	**17.8**	**16.8**	**15.6**	**15.0**	**13.9**	**14.0**
Electrical Transmission and Distribution	26.7	13.9	13.0	12.2	12.2	11.8	11.8
Magnesium Production and Processing	5.4	2.9	2.9	2.6	1.9	1.1	1.3
Semiconductor Manufacture	0.5	1.0	1.0	0.8	0.9	1.0	0.9
Total	**313.9**	**330.1**	**335.5**	**347.3**	**319.1**	**268.2**	**303.4**

+ Does not exceed 0.05 Tg CO_2 Eq.

[a] Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding.

Overall, emissions from the Industrial Processes sector decreased by 3.4 percent from 1990 to 2010, as emission decreases from some sources have been offset by increases from other sources. Significant trends in emissions from industrial processes source categories over the twenty-one-year period from 1990 through 2010 included the following:

- Combined CO_2 and CH_4 emissions from iron and steel production and metallurgical coke production increased by 29 percent to 54.8 Tg CO_2 Eq. from 2009 to 2010, but have declined overall by 45.8 Tg CO_2 Eq. (45.5 percent) from 1990 through 2010, due to restructuring of the industry, technological improvements, and increased scrap steel utilization.
- CO_2 emissions from ammonia production (8.7 Tg CO_2 Eq. in 2010) decreased by 4.4 Tg CO_2 Eq. (33.5 percent) since 1990. This is due to a decrease in domestic ammonia production primarily attributed to market fluctuations. Urea consumption for non-agricultural purposes (4.4 Tg CO_2 Eq. in 2010) increased by 0.6 Tg CO_2 Eq. (15.3 percent) since 1990.
- N_2O emissions from adipic acid production were 2.8 Tg CO_2 Eq. in 2010, and have decreased significantly in recent years due to the widespread installation of pollution control measures. Emissions from adipic acid production have decreased by 82.2 percent since 1990 and by 84.0 percent since a peak in 1995.
- HFC emissions from ODS substitutes have been increasing from small amounts in 1990 to 114.6 Tg CO_2 Eq. in 2010. This increase results from efforts to phase out CFCs and other ODSs in the United States. In the short term, this trend is expected to continue, and will likely accelerate over the next decade as HCFCs—which are interim substitutes in many applications—are phased out under the provisions of the Copenhagen Amendments to the Montreal Protocol.
- PFC emissions from aluminum production decreased by about 91.5 percent (16.9 Tg CO_2 Eq.) from 1990 to 2010, due to both industry emission reduction efforts and lower domestic aluminum production.

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, N_2O Emissions from Product Uses, the only source of greenhouse gas emissions from this sector, accounted for 4.4 Tg CO_2 Eq., or less than 0.1 percent of total U.S. greenhouse gas emissions in 2010 (see Table 2-7).

Table 2-7: N_2O Emissions from Solvent and Other Product Use (Tg CO_2 Eq.)

Gas/Source	1990	2005	2006	2007	2008	2009	2010
N_2O	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**
N_2O from Product Uses	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Total	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**

In 2010, N_2O emissions from product uses constituted 1.4 percent of U.S. N_2O emissions. From 1990 to 2010, emissions from this source category decreased by just under 0.4 percent, though slight increases occurred in intermediate years.

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 2010, agricultural activities were responsible for emissions of 428.4 Tg CO_2 Eq., or 6.3 percent of total U.S. greenhouse gas emissions. CH_4 and N_2O were the primary greenhouse gases emitted by agricultural activities. CH_4 emissions from enteric fermentation and manure management represented about 21.2 percent and 7.8 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2010. Agricultural soil management activities, such as fertilizer application and other cropping practices, were the largest source of U.S. N_2O emissions in 2010, accounting for 67.9 percent.

Figure 2-10: 2010 Agriculture Chapter Greenhouse Gas Sources

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

Gas/Source	1990	2005	2006	2007	2008	2009	2010
CH_4	**172.9**	**193.9**	**195.9**	**202.9**	**202.6**	**200.8**	**202.2**
Enteric Fermentation	133.8	139.0	141.4	143.8	143.4	142.6	141.3
Manure Management	31.7	47.9	48.4	52.7	51.8	50.7	52.0
Rice Cultivation	7.1	6.8	5.9	6.2	7.2	7.3	8.6
Field Burning of Agricultural Residues	0.2	0.2	0.2	0.2	0.2	0.2	0.2
N_2O	**214.9**	**230.7**	**229.6**	**229.7**	**231.3**	**225.6**	**226.2**
Agricultural Soil Management	200.0	213.1	211.1	211.1	212.9	207.3	207.8
Manure Management	14.8	17.6	18.4	18.5	18.3	18.2	18.3
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**387.8**	**424.6**	**425.4**	**432.6**	**433.8**	**426.4**	**428.4**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from Agriculture source categories include the following:

- Agricultural soils produced approximately 67.9 percent of N_2O emissions in the United States in 2010. Estimated emissions from this source in 2010 were 207.8 Tg CO_2 Eq. Annual N_2O emissions from agricultural soils fluctuated between 1990 and 2010, although overall emissions were 3.9 percent higher in

2010 than in 1990. Nitrous oxide emissions from this source have not shown any significant long-term trend, as their estimation is highly sensitive to the amount of N applied to soils, which has not changed significantly over the time-period, and to weather patterns and crop type.

- Enteric fermentation was the second largest source of CH_4 emissions in the United States in 2010, at 141.3 Tg CO_2 Eq. Generally, emissions decreased from 1995 to 2003, though with a slight increase in 2002. This trend was mainly due to decreasing populations of both beef and dairy cattle and increased digestibility of feed for feedlot cattle. Emissions increased from 2004 through 2007, as both dairy and beef populations increased and the literature for dairy cow diets indicated a trend toward a decrease in feed digestibility for those years. Emissions decreased again in 2008, 2009, and 2010 as beef cattle populations decreased. During the timeframe of this analysis, populations of sheep have decreased 51 percent since 1990 while horse populations have increased over 87 percent, mostly since 1999. Goat and swine populations have increased 25 percent and 20 percent, respectively, during this timeframe.
- Overall, emissions from manure management increased 51.2 percent between 1990 and 2010. This encompassed an increase of 64.0 percent for CH_4, from 31.7 Tg CO_2 Eq. in 1990 to 52.0 Tg CO_2 Eq. in 2010; and an increase of 23.7 percent for N_2O, from 14.8 Tg CO_2 Eq. in 1990 to 18.3 Tg CO_2 Eq. in 2010. The majority of this increase was from swine and dairy cow manure, since the general trend in manure management is one of increasing use of liquid systems, which tends to produce greater CH_4 emissions.

Land Use, Land-Use Change, and Forestry

When humans alter the terrestrial biosphere through land use, changes in land use, and land management practices, they also alter the background carbon fluxes between biomass, soils, and the atmosphere. Forest management practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings and food scraps have resulted in an uptake (sequestration) of carbon in the United States, which offset about 16 percent of total U.S. greenhouse gas emissions in 2010. Forests (including vegetation, soils, and harvested wood) accounted for approximately 86 percent of total 2010 net CO_2 flux, urban trees accounted for 9 percent, mineral and organic soil carbon stock changes accounted for 4 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total net flux in 2010. The net forest sequestration is a result of net forest growth, increasing forest area, and a net accumulation of carbon stocks in harvested wood pools. The net sequestration in urban forests is a result of net tree growth and increased urban forest size. In agricultural soils, mineral and organic soils sequester approximately 5.9 times as much C as is emitted from these soils through liming and urea fertilization. The mineral soil C sequestration is largely due to the conversion of cropland to hay production fields, the limited use of bare-summer fallow areas in semi-arid areas, and an increase in the adoption of conservation tillage practices. The landfilled yard trimmings and food scraps net sequestration is due to the long-term accumulation of yard trimming and food scraps carbon in landfills.

Land use, land-use change, and forestry activities in 2010 resulted in a net C sequestration of 1,074.7 Tg CO_2 Eq. (293.1 Tg C) (Table 2-9). This represents an offset of approximately 19 percent of total U.S. CO_2 emissions, or 16 percent of total greenhouse gas emissions in 2010. Between 1990 and 2010, total land use, land-use change, and forestry net C flux resulted in a 21.9 percent increase in CO_2 sequestration.

Table 2-9: Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Sink Category	1990	2005	2006	2007	2008	2009	2010
Forest Land Remaining Forest Land	(701.4)	(940.9)	(963.5)	(959.2)	(938.3)	(910.6)	(921.8)
Cropland Remaining Cropland	(29.4)	(18.3)	(19.1)	(19.7)	(18.1)	(17.4)	(15.6)
Land Converted to Cropland	2.2	5.9	5.9	5.9	5.9	5.9	5.9
Grassland Remaining Grassland	(52.2)	(8.9)	(8.8)	(8.6)	(8.5)	(8.3)	(8.3)
Land Converted to Grassland	(19.8)	(24.4)	(24.2)	(24.0)	(23.8)	(23.6)	(23.6)
Settlements Remaining Settlements	(57.1)	(87.8)	(89.8)	(91.9)	(93.9)	(95.9)	(98.0)
Other (Landfilled Yard Trimmings and Food Scraps)	(24.2)	(11.6)	(11.0)	(10.9)	(10.9)	(12.7)	(13.3)
Total	**(881.8)**	**(1,085.9)**	**(1,110.4)**	**(1,108.2)**	**(1,087.5)**	**(1,062.6)**	**(1,074.7)**

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

Land use, land-use change, and forestry source categories also resulted in emissions of CO_2, CH_4, and N_2O that are not included in the net CO_2 flux estimates presented in Table 2-9. The application of crushed limestone and dolomite to managed land (i.e., soil liming) and urea fertilization resulted in CO_2 emissions of 8.0 Tg CO_2 Eq. in 2010, an increase of about 13.6 percent relative to 1990. Lands undergoing peat extraction resulted in CO_2 emissions of 1.0 Tg CO_2 Eq. (983 Gg), and N_2O emissions of less than 0.05 Tg CO_2 Eq. N_2O emissions from the application of synthetic fertilizers to forest soils have increased from 0.1 Tg CO_2 Eq. in 1990 to 0.4 Tg CO_2 Eq. in 2010. Settlement soils in 2010 resulted in direct N_2O emissions of 1.4 Tg CO_2 Eq., a 43 percent increase relative to 1990. Emissions from forest fires in 2010 resulted in CH_4 emissions of 4.8 Tg CO_2 Eq., and in N_2O emissions of 4.0 Tg CO_2 Eq. (Table 2-10).

Table 2-10: Emissions from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Source Category	1990	2005	2006	2007	2008	2009	2010
CO_2	**8.1**	**8.9**	**8.8**	**9.2**	**9.6**	**8.3**	**9.0**
Cropland Remaining Cropland:							
Liming of Agricultural Soils	4.7	4.3	4.2	4.5	5.0	3.7	3.9
Cropland Remaining Cropland: Urea							
Fertilization	2.4	3.5	3.7	3.8	3.6	3.6	4.1
Wetlands Remaining Wetlands:							
Peatlands Remaining Peatlands	1.0	1.1	0.9	1.0	1.0	1.1	1.0
CH_4	**2.5**	**8.1**	**17.9**	**14.6**	**8.8**	**5.8**	**4.8**
Forest Land Remaining Forest Land:							
Forest Fires	2.5	8.1	17.9	14.6	8.8	5.8	4.8
N_2O	**3.1**	**8.5**	**16.5**	**13.8**	**9.0**	**6.5**	**5.7**
Forest Land Remaining Forest Land:							
Forest Fires	2.1	6.6	14.6	11.9	7.2	4.7	4.0
Forest Land Remaining Forest Land:							
Forest Soils	0.1	0.4	0.4	0.4	0.4	0.4	0.4
Settlements Remaining Settlements:							
Settlement Soils	1.0	1.5	1.5	1.6	1.5	1.4	1.4
Wetlands Remaining Wetlands:							
Peatlands Remaining Peatlands	+	+	+	+	+	+	+
Total	**13.8**	**25.6**	**43.2**	**37.6**	**27.4**	**20.6**	**19.6**

+ Less than 0.05 Tg CO_2 Eq.

Note: Totals may not sum due to independent rounding.

Other significant trends from 1990 to 2010 in emissions from land use, land-use change, and forestry source categories include:

- Net C sequestration by forest land has increased by approximately 31 percent. This is primarily due to increased forest management and the effects of previous reforestation. The increase in intensive forest management resulted in higher growth rates and higher biomass density. The tree planting and conservation efforts of the 1970s and 1980s continue to have a significant impact on sequestration rates. Finally, the forested area in the United States increased over the past 20 years, although only at an average rate of 0.22 percent per year.
- Net sequestration of C by urban trees has increased by 71.8 percent over the period from 1990 to 2010. This is primarily due to an increase in urbanized land area in the United States.
- Annual C sequestration in landfilled yard trimmings and food scraps has decreased by 44.9 percent since 1990. This is due in part to a decrease in the amount of yard trimmings and food scraps generated. In addition, the proportion of yard trimmings and food scraps landfilled has decreased, as there has been a significant rise in the number of municipal composting facilities in the United States.

Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-11). In 2010, landfills were the third largest source of U.S. anthropogenic CH_4 emissions, accounting for 16.2 percent of total U.S. CH_4 emissions.[48] Additionally, wastewater treatment accounts for 2.5 percent of U.S. CH_4 emissions, and 1.6 percent of N_2O emissions. Emissions of CH_4 and N_2O from composting grew from 1990 to 2010, and resulted in emissions of 3.3 Tg CO_2 Eq. in 2010. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 2-11.

Figure 2-11: 2010 Waste Chapter Greenhouse Gas Sources

Overall, in 2010, waste activities generated emissions of 132.5 Tg CO_2 Eq., or 1.9 percent of total U.S. greenhouse gas emissions.

Table 2-11: Emissions from Waste (Tg CO_2 Eq.)

Gas/Source	1990	2005	2006	2007	2008	2009	2010
CH_4	**163.9**	**130.8**	**130.0**	**130.0**	**131.4**	**129.3**	**125.8**
Landfills	147.7	112.7	111.7	111.7	113.1	111.2	107.8
Wastewater Treatment	15.9	16.5	16.7	16.6	16.6	16.5	16.3
Composting	0.3	1.6	1.6	1.7	1.7	1.6	1.6
N_2O	**3.8**	**6.4**	**6.5**	**6.7**	**6.8**	**6.7**	**6.8**
Wastewater Treatment	3.5	4.7	4.8	4.8	4.9	5.0	5.0
Composting	0.4	1.7	1.8	1.8	1.9	1.8	1.7
Total	**167.7**	**137.2**	**136.5**	**136.7**	**138.2**	**136.0**	**132.5**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from waste source categories include the following:

- From 1990 to 2010, net CH_4 emissions from landfills decreased by 39.8 Tg CO_2 Eq. (27 percent), with small increases occurring in interim years. This downward trend in overall emissions is the result of increases in the amount of landfill gas collected and combusted,[49] which has more than offset the additional CH_4 emissions resulting from an increase in the amount of municipal solid waste landfilled.
- Combined CH_4 and N_2O emissions from composting have generally increased since 1990, from 0.7 Tg CO_2 Eq. to 3.3 Tg CO_2 Eq. in 2010, which represents slightly less than a five-fold increase over the time series.
- From 1990 to 2010, CH_4 and N_2O emissions from wastewater treatment increased by 0.4 Tg CO_2 Eq. (2.7 percent) and 1.6 Tg CO_2 Eq. (46 percent), respectively.

2.2. Emissions by Economic Sector

Throughout this report, emission estimates are grouped into six sectors (i.e., chapters) defined by the IPCC and detailed above: Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land Use, Land-Use Change, and Forestry; and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories. This section reports emissions by the following U.S. economic sectors: residential, commercial, industry, transportation, electricity generation, and agriculture, as well as U.S. territories.

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

[48] Landfills also store carbon, due to incomplete degradation of organic materials such as wood products and yard trimmings, as described in the Land Use, Land-Use Change, and Forestry chapter.

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

U.S. greenhouse gas emissions in 2010. Transportation activities, in aggregate, accounted for the second largest portion (27 percent). Emissions from industry accounted for about 20 percent of U.S. greenhouse gas emissions in 2010. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade. The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. The remaining 19 percent of U.S. greenhouse gas emissions were contributed by the residential, agriculture, and commercial sectors, plus emissions from U.S. territories. The residential sector accounted for 5.4 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; unlike other economic sectors, agricultural sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation, rather than CO_2 from fossil fuel combustion. The commercial sector accounted for roughly 6 percent of emissions, while U.S. territories accounted for less than 1 percent.

CO_2 was also emitted and sequestered (in the form of C) 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 2-12 presents a detailed breakdown of emissions from each of these economic sectors by source category, as they are defined in this report. Figure 2-12 shows the trend in emissions by sector from 1990 to 2010.

Figure 2-12: Emissions Allocated to Economic Sectors

Table 2-12: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq. and Percent of Total in 2010)

Sector/Source	1990	2005	2006	2007	2008	2009	2010	Percent[a]
Electric Power Industry	**1,866.2**	**2,448.8**	**2,393.0**	**2,459.1**	**2,405.8**	**2,191.4**	**2,306.5**	**33.8%**
CO_2 from Fossil Fuel Combustion	1,820.8	2,402.1	2,346.4	2,412.8	2,360.9	2,146.4	2,258.4	33.1%
Stationary Combustion – N_2O and CH_4	7.7	16.5	16.7	17.2	17.3	17.2	18.9	0.3%
Incineration of Waste	8.5	12.9	12.9	13.1	12.3	12.1	12.4	0.2%
Electrical Transmission and Distribution	26.7	13.9	13.0	12.2	12.2	11.8	11.8	0.2%
Limestone and Dolomite Use	2.6	3.4	4.0	3.9	3.1	3.8	5.0	0.1%
Transportation	**1,545.2**	**2,017.5**	**1,994.5**	**2,002.4**	**1,889.8**	**1,819.3**	**1,834.0**	**26.9%**
CO_2 from Fossil Fuel Combustion	1,485.9	1,896.6	1,878.1	1,893.9	1,789.8	1,727.9	1,745.5	25.6%
Substitution of Ozone Depleting Substances	+	72.9	72.2	68.8	64.9	60.2	58.4	0.9%
Mobile Combustion	47.4	37.8	34.3	29.4	25.5	22.6	20.6	0.3%
Non-Energy Use of Fuels	11.8	10.2	9.9	10.2	9.5	8.5	9.5	0.1%
Industry	**1,564.8**	**1,438.1**	**1,499.8**	**1,489.6**	**1,448.5**	**1,317.2**	**1,394.2**	20.4%
CO_2 from Fossil Fuel Combustion	815.3	769.5	799.1	796.0	761.1	680.0	730.2	10.7%
Natural Gas Systems	227.2	228.6	229.6	236.6	240.8	252.6	247.3	3.6%
Non-Energy Use of Fuels	102.1	125.9	125.0	117.5	120.7	111.5	111.9	1.6%
Coal Mining	84.1	56.8	58.1	57.8	66.9	70.1	72.6	1.1%
Iron and Steel Production	100.5	66.7	69.6	71.8	66.7	42.5	54.8	0.8%
Petroleum Systems	35.6	29.5	29.5	30.1	30.3	31.0	31.4	0.5%
Cement Production	33.3	45.2	45.8	44.5	40.5	29.0	30.5	0.4%
Nitric Acid Production	17.6	16.4	16.1	19.2	16.4	14.5	16.7	0.2%
Substitution of Ozone Depleting Substances	+	6.4	7.1	7.8	8.5	10.9	13.5	0.2%
Lime Production	11.5	14.4	15.1	14.6	14.3	11.2	13.2	0.2%
Ammonia Production	13.0	9.2	8.8	9.1	7.9	7.9	8.7	0.1%
HCFC-22 Production	36.4	15.8	13.8	17.0	13.6	5.4	8.1	0.1%
Semiconductor Manufacture	2.9	4.4	4.7	4.8	5.1	5.3	5.4	0.1%
Limestone and Dolomite Use	2.6	3.4	4.0	3.9	3.1	3.8	5.0	0.1%
Abandoned Underground Coal Mines	6.0	5.5	5.5	5.3	5.3	5.1	5.0	0.1%
Aluminum Production	25.3	7.1	6.3	8.1	7.2	4.6	4.6	0.1%
N_2O from Product Uses	4.4	4.4	4.4	4.4	4.4	4.4	4.4	0.1%
Urea Consumption for Non-Agricultural	3.8	3.7	3.5	4.9	4.1	3.4	4.4	0.1%

Purposes								
Petrochemical Production	4.2	5.3	4.8	4.9	4.3	3.6	4.3	0.1%
Stationary Combustion	4.9	4.6	4.7	4.6	4.3	3.7	4.1	0.1%
Soda Ash Production and Consumption	4.1	4.2	4.2	4.1	4.1	3.6	3.7	0.1%
Adipic Acid Production	15.8	7.4	8.9	10.7	2.6	2.8	2.8	+
Carbon Dioxide Consumption	1.4	1.3	1.7	1.9	1.8	1.8	2.2	+
Titanium Dioxide Production	1.2	1.8	1.8	1.9	1.8	1.6	1.9	+
Ferroalloy Production	2.2	1.4	1.5	1.6	1.6	1.5	1.7	+
Mobile Combustion	0.9	1.3	1.3	1.3	1.3	1.3	1.4	+
Magnesium Production and Processing	5.4	2.9	2.9	2.6	1.9	1.1	1.3	+
Zinc Production	0.6	1.0	1.0	1.0	1.2	0.9	1.2	+
Phosphoric Acid Production	1.5	1.4	1.2	1.2	1.2	1.0	1.0	+
Lead Production	0.5	0.6	0.6	0.6	0.6	0.5	0.5	+
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2	+
Agriculture	**431.9**	**496.0**	**516.7**	**517.6**	**505.8**	**492.8**	**494.8**	**7.3%**
N_2O from Agricultural Soil Management	200.0	213.1	211.1	211.1	212.9	207.3	207.8	3.0%
Enteric Fermentation	133.8	139.0	141.4	143.8	143.4	142.6	141.3	2.1%
Manure Management	46.5	65.5	66.7	71.1	70.0	68.9	70.4	1.0%
CO_2 from Fossil Fuel Combustion	31.0	46.8	49.0	48.4	45.4	46.7	47.6	0.7%
CH_4 and N_2O from Forest Fires	4.6	14.8	32.6	26.4	16.0	10.5	8.8	0.1%
Rice Cultivation	7.1	6.8	5.9	6.2	7.2	7.3	8.6	0.1%
Liming of Agricultural Soils	4.7	4.3	4.2	4.5	5.0	3.7	3.9	0.1%
Urea Fertilization	2.4	3.5	3.7	3.8	3.6	3.6	4.1	0.1%
CO_2 and N_2O from Managed Peatlands	1.0	1.1	0.9	1.0	1.0	1.1	1.0	+
Mobile Combustion	0.3	0.5	0.5	0.5	0.5	0.5	0.5	+
N_2O from Forest Soils	0.1	0.4	0.4	0.4	0.4	0.4	0.4	+
Field Burning of Agricultural Residues	0.3	0.2	0.3	0.3	0.3	0.3	0.3	+
Stationary Combustion	+	+	+	+	+	+	+	+
Commercial	**388.0**	**374.3**	**359.9**	**372.2**	**381.8**	**382.0**	**381.7**	**5.6%**
CO_2 from Fossil Fuel Combustion	219.0	223.5	208.6	218.9	225.1	224.6	224.2	3.3%
Landfills	147.7	112.7	111.7	111.7	113.1	111.2	107.8	1.6%
Substitution of Ozone Depleting Substances	+	12.3	13.6	15.4	17.2	20.1	23.6	0.3%
Wastewater Treatment	15.9	16.5	16.7	16.6	16.6	16.5	16.3	0.2%
Human Sewage	3.5	4.7	4.8	4.8	4.9	5.0	5.0	0.1%
Composting	0.7	3.3	3.3	3.5	3.5	3.3	3.3	+
Stationary Combustion	1.3	1.3	1.2	1.3	1.3	1.3	1.3	+
Residential	**345.4**	**371.3**	**336.1**	**358.4**	**368.4**	**360.0**	**365.2**	**5.4%**
CO_2 from Fossil Fuel Combustion	338.3	357.9	321.5	341.6	349.3	339.0	340.2	5.0%
Substitution of Ozone Depleting Substances	0.3	7.3	8.9	10.7	12.9	15.1	19.1	0.3%
Stationary Combustion	5.7	4.6	4.1	4.5	4.7	4.5	4.4	0.1%
Settlement Soil Fertilization	1.0	1.5	1.5	1.6	1.5	1.4	1.4	+
U.S. Territories	**33.7**	**58.2**	**59.3**	**53.5**	**48.4**	**45.5**	**45.5**	**0.7%**
CO_2 from Fossil Fuel Combustion	27.9	50.0	50.3	46.1	39.8	41.7	41.6	0.6%
Non-Energy Use of Fuels	5.7	8.1	8.8	7.2	8.4	3.7	3.7	0.1%
Stationary Combustion	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
Total Emissions	**6,175.2**	**7,204.2**	**7,159.3**	**7,252.8**	**7,048.3**	**6,608.3**	**6,821.8**	**100.0%**
Sinks	**(881.8)**	**(1,085.9)**	**(1,110.4)**	**(1,108.2)**	**(1,087.5)**	**(1,062.6)**	**(1,074.7)**	**-15.8%**
CO_2 Flux from Forests[b]	(701.4)	(940.9)	(963.5)	(959.2)	(938.3)	(910.6)	(921.8)	-13.5%
Urban Trees	(57.1)	(87.8)	(89.8)	(91.9)	(93.9)	(95.9)	(98.0)	-1.4%
CO_2 Flux from Agricultural Soil Carbon Stocks	(99.2)	(45.6)	(46.1)	(46.3)	(44.4)	(43.4)	(41.6)	-0.6%
Landfilled Yard Trimmings and Food Scraps	(24.2)	(11.6)	(11.0)	(10.9)	(10.9)	(12.7)	(13.3)	-0.2%
Net Emissions	**5,293.4**	**6,118.3**	**6,048.9**	**6,144.5**	**5,960.9**	**5,545.7**	**5,747.1**	**84.2%**

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 percent.

[a] Percent of total emissions for year 2010.

[b] Includes the effects of net additions to stocks of carbon stored in harvested wood products.

Emissions with Electricity Distributed to Economic Sectors

It can also be useful to view greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). The generation, transmission, and distribution of electricity, which is the largest economic sector in the United States, accounted for 34 percent of total U.S. greenhouse gas emissions in 2010. Emissions increased by 24 percent since 1990, as electricity demand grew and fossil fuels remained the dominant energy source for generation. Electricity generation-related emissions increased from 2009 to 2010 by 5.3 percent, primarily due to increased CO_2 emissions from fossil fuel combustion. The increase in electricity-related emissions was due to increased economic output and the resulting increase in electricity demand. Electricity-related emissions also increased due to an increase in the carbon intensity of fuels used to generate electricity. This was caused by fuel switching as the price of coal increased only slightly while the price of natural gas increased significantly. The fuel switching from coal to natural gas and the decrease in electricity generation from other energy sources in 2010, which included a 6 percent decline in hydropower generation from the previous year, resulted in an increase in carbon intensity, and in turn, an increase in emissions from electricity 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 non-utility 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 2-13 provides a detailed summary of emissions from electricity generation-related activities.

Table 2-13: Electricity Generation-Related Greenhouse Gas Emissions (Tg CO_2 Eq.)

Gas/Fuel Type or Source	1990	2005	2006	2007	2008	2009	2010
CO_2	**1,831.4**	**2,418.0**	**2,363.0**	**2,429.4**	**2,375.9**	**2,161.9**	**2,275.4**
Fossil Fuel Combustion	1,820.8	2,402.1	2,346.4	2,412.8	2,360.9	2,146.4	2,258.4
Coal	*1,547.6*	*1,983.8*	*1,953.7*	*1,987.3*	*1,959.4*	*1,740.9*	*1,827.3*
Natural Gas	*175.3*	*318.8*	*338.0*	*371.3*	*361.9*	*372.2*	*399.4*
Petroleum	*97.5*	*99.2*	*54.4*	*53.9*	*39.2*	*33.0*	*31.3*
Geothermal	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Incineration of Waste	8.0	12.5	12.5	12.7	11.9	11.7	12.1
Limestone and Dolomite Use	2.6	3.4	4.0	3.9	3.1	3.8	5.0
CH_4	**0.3**	**0.5**	**0.5**	**0.5**	**0.5**	**0.4**	**0.5**
Stationary Combustion*	0.3	0.5	0.5	0.5	0.5	0.4	0.5
Incineration of Waste	+	+	+	+	+	+	+
N_2O	**7.8**	**16.4**	**16.6**	**17.1**	**17.2**	**17.2**	**18.8**
Stationary Combustion*	7.4	16.0	16.2	16.7	16.8	16.8	18.5
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
SF_6	**26.7**	**13.9**	**13.0**	**12.2**	**12.2**	**11.8**	**11.8**
Electrical Transmission and Distribution	26.7	13.9	13.0	12.2	12.2	11.8	11.8
Total	**1,866.2**	**2,448.8**	**2,393.0**	**2,459.1**	**2,405.8**	**2,191.4**	**2,306.5**

Note: Totals may not sum due to independent rounding.

* Includes only stationary combustion emissions related to the generation of electricity.

+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05 percent.

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 each economic sector's share of retail sales of electricity consumption (EIA 2011 and Duffield 2006). These source categories include CO_2 from Fossil Fuel Combustion, CH_4 and N_2O from Stationary Combustion, Incineration of Waste, Limestone and Dolomite Use, and SF_6 from Electrical Transmission and Distribution Systems. Note that only 33 percent of the Limestone and Dolomite Use emissions

were associated with electricity generation and distributed as described; the remainder of Limestone and Dolomite Use emissions were attributed to the industrial processes economic end-use sector.[50]

When emissions from electricity are distributed among these sectors, industry activities account for the largest share of total U.S. greenhouse gas emissions (29.6 percent), followed closely by emissions from transportation (27.0 percent). Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included. In all sectors except agriculture, CO_2 accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

Table 2-14 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electricity generation distributed to them. Figure 2-13 shows the trend in these emissions by sector from 1990 to 2010.

Figure 2-13: Emissions with Electricity Distributed to Economic Sectors

Table 2-14: U.S. Greenhouse Gas Emissions by Economic Sector and Gas with Electricity-Related Emissions Distributed (Tg CO_2 Eq.) and Percent of Total in 2010

Sector/Gas	1990	2005	2006	2007	2008	2009	2010	Percent[a]
Industry	**2,237.7**	**2,159.9**	**2,198.5**	**2,185.9**	**2,131.5**	**1,905.8**	**2.019.0**	**29.6%**
Direct Emissions	1,564.8	1,438.1	1,499.8	1,489.6	1,448.5	1,317.2	1,394.2	20.4%
CO_2	1,141.3	1,087.6	1,121.1	1,113.5	1,071.3	938.2	1,009.5	14.8%
CH_4	318.5	285.5	314.0	301.6	318.0	329.4	327.1	4.8%
N_2O	41.8	32.5	33.7	38.4	27.4	25.4	27.9	0.4%
HFCs, PFCs, and SF_6	63.2	32.5	31.0	36.0	31.9	24.2	29.7	0.4%
Electricity-Related	672.9	721.8	698.7	696.3	683.0	588.6	624.9	9.2%
CO_2	660.3	712.7	689.9	687.9	674.5	580.6	616.4	9.0%
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	+
N_2O	2.8	4.8	4.9	4.8	4.9	4.6	5.1	0.1%
SF_6	9.6	4.1	3.8	3.4	3.5	3.2	3.2	+
Transportation	**1,548.3**	**2,022.3**	**1,999.1**	**2,007.6**	**1,894.6**	**1,823.9**	**1,838.6**	**27.0%**
Direct Emissions	1,545.2	2,017.5	1,994.5	2,002.4	1,889.8	1,819.3	1,834.0	26.9%
CO_2	1,497.8	1,906.8	1,888.0	1,904.1	1,799.4	1,736.5	1,755.0	25.7%
CH_4	4.5	2.2	2.1	1.9	1.8	1.6	1.6	+
N_2O	42.95	35.53	32.18	27.49	23.73	20.99	19.02	0.3%
HFCs[b]	+	72.9	72.2	68.8	64.9	60.2	58.4	0.9%
Electricity-Related	3.1	4.8	4.6	5.2	4.8	4.6	4.6	0.1%
CO_2	3.1	4.8	4.6	5.1	4.7	4.5	4.5	0.1%
CH_4	+	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+	+
SF_6	+	+	+	+	+	+	+	+
Commercial	**939.4**	**1,193.6**	**1,174.8**	**1,216.9**	**1,213.3**	**1,151.3**	**1,171.0**	**17.2%**
Direct Emissions	388.0	374.3	359.9	372.2	381.8	382.0	381.7	5.6%
CO_2	219.0	223.5	208.6	218.9	225.1	224.6	224.2	3.3%
CH_4	164.8	131.7	130.8	130.9	132.4	130.3	126.7	1.9%
N_2O	4.2	6.8	6.8	7.0	7.1	7.1	7.1	0.1%
HFCs	+	12.3	13.6	15.4	17.2	20.1	23.6	0.3%
Electricity-Related	551.4	819.3	814.9	844.7	831.6	769.2	789.3	11.6%
CO_2	541.1	809.0	804.7	834.5	821.2	758.9	778.7	11.4%

[50] 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.

CH_4	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.3	5.5	5.7	5.9	5.9	6.0	6.4	0.1%
SF_6	7.9	4.7	4.4	4.2	4.2	4.2	4.0	0.1%
Residential	**953.2**	**1,244.6**	**1,183.4**	**1,238.5**	**1,227.3**	**1,162.9**	**1,226.6**	**18.0%**
Direct Emissions	345.4	371.3	336.1	358.4	368.4	360.0	365.2	5.4%
CO_2	338.3	357.9	321.5	341.6	349.3	339.0	340.2	5.0%
CH_4	4.6	3.6	3.3	3.6	3.7	3.6	3.5	0.1%
N_2O	2.1	2.4	2.4	2.5	2.4	2.3	2.3	+
HFCs	0.3	7.3	8.9	10.7	12.9	15.1	19.1	0.3%
Electricity-Related	607.8	873.4	847.4	880.1	858.9	803.0	861.4	12.6%
CO_2	596.5	862.4	836.7	869.4	848.3	792.2	849.8	12.5%
CH_4	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.6	5.8	5.9	6.1	6.1	6.3	7.0	0.1%
SF_6	8.7	5.0	4.6	4.4	4.3	4.3	4.4	0.1%
Agriculture	**462.9**	**525.5**	**544.2**	**550.5**	**533.3**	**518.9**	**521.1**	**7.6%**
Direct Emissions	431.9	496.0	516.7	517.6	505.8	492.8	494.8	7.3%
CO_2	39.2	55.7	57.8	57.7	55.1	55.0	56.7	0.8%
CH_4	175.5	202.2	214.0	217.6	211.5	206.8	207.2	3.0%
N_2O	217.2	238.1	245.0	242.3	239.2	231.0	230.9	3.4%
Electricity-Related	31.0	29.5	27.5	32.9	27.5	26.0	26.3	0.4%
CO_2	30.4	29.1	27.1	32.5	27.2	25.7	25.9	0.4%
CH_4	+	+	+	+	+	+	+	+
N_2O	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
SF_6	0.4	0.2	0.1	0.2	0.1	0.1	0.1	+
U.S. Territories	**33.7**	**58.2**	**59.3**	**53.5**	**48.4**	**45.5**	**45.5**	**0.7%**
Total	**6,175.2**	**7,204.2**	**7,159.3**	**7,252.8**	**7,048.3**	**6,608.3**	**6,821.8**	**100%**

Note: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector.

Totals may not sum due to independent rounding.

+ Does not exceed 0.05 Tg CO_2 Eq. or 0.05 percent.

[a] Percent of total emissions for year 2010.

[b] Includes primarily HFC-134a.

Industry

The industrial end-use sector includes CO_2 emissions from fossil fuel combustion from all manufacturing facilities, in aggregate. This sector also includes emissions that are produced as a by-product of the non-energy-related industrial process activities. The variety of activities producing these non-energy-related emissions includes methane emissions from petroleum and natural gas systems, fugitive CH_4 emissions from coal mining, by-product CO_2 emissions from cement manufacture, and HFC, PFC, and SF_6 by-product emissions from semiconductor manufacture, to name a few. Since 1990, industrial sector emissions have declined. The decline has occurred both in direct emissions and indirect emissions associated with electricity use. However, the decline in direct emissions has been sharper. In theory, emissions from the industrial end-use sector should be highly correlated with economic growth and industrial output, but heating of industrial buildings and agricultural energy consumption are also affected by weather conditions. In addition, structural changes within the U.S. economy that lead to shifts in industrial output away from energy-intensive manufacturing products to less energy-intensive products (e.g., from steel to computer equipment) also have a significant effect on industrial emissions.

Transportation

When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 27 percent of U.S. greenhouse gas emissions in 2010. The largest sources of transportation greenhouse gases in 2010 were passenger cars (43 percent), light duty trucks, which include sport utility vehicles, pickup trucks, and minivans (19 percent), freight trucks (22 percent) and commercial aircraft (6 percent). These figures include direct

emissions from fossil fuel combustion, as well as HFC emissions from mobile air conditioners and refrigerated transport allocated to these vehicle types. Although average fuel economy over this period increased slightly due primarily to the retirement of older vehicles, average fuel economy among new vehicles sold annually gradually declined from 1990 to 2004. The decline in new vehicle fuel economy between 1990 and 2004 reflected the increasing market share of light duty trucks, which grew from about one-fifth of new vehicle sales in the 1970s to slightly over half of the market by 2004. Increasing fuel prices have since decreased the momentum of light duty truck sales, and average new vehicle fuel economy has improved since 2005 as the market share of passenger cars increased. Over the 1990s through early this decade, growth in vehicle travel substantially outweighed improvements in vehicle fuel economy; however, the rate of Vehicle Miles Traveled (VMT) growth slowed considerably starting in 2005 (and declined rapidly in 2008) while average vehicle fuel economy increased. However, in 2010, fuel VMT grew by 0.3 percent, while average fuel economy decreased slightly. Among new vehicles sold annually, average fuel economy gradually declined from 1990 to 2004, reflecting substantial growth in sales of light-duty trucks—in particular, growth in the market share of sport utility vehicles—relative to passenger cars. Gasoline fuel consumption increased slightly, while consumption of diesel fuel continued to decrease, due in part to a decrease in commercial activity and freight trucking as a result of the economic recession.

Table 2-15 provides a detailed summary of greenhouse gas emissions from transportation-related activities with electricity-related emissions included in the totals.

From 1990 to 2010, transportation emissions rose by 19 percent due, in large part, to increased demand for travel and the stagnation of fuel efficiency across the U.S. vehicle fleet. The number of vehicle miles traveled by light-duty motor vehicles (passenger cars and light-duty trucks) increased 34 percent from 1990 to 2010, as a result of a confluence of factors including population growth, economic growth, urban sprawl, and low fuel prices over much of this period.

From 2008 to 2009, CO_2 emissions from the transportation end-use sector declined 4 percent. The decrease in emissions can largely be attributed to decreased economic activity in 2009 and an associated decline in the demand for transportation. Modes such as medium- and heavy-duty trucks were significantly impacted by the decline in freight transport. Similarly, increased jet fuel prices were a factor in the 17 percent decrease in commercial aircraft emissions since 2007. From 2009 to 2010, CO_2 emissions from the transportation end-use sector increased by 1 percent as economic activity rebounded slightly in 2010.

Almost all of the energy consumed for transportation was supplied by petroleum-based products, with more than half 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 17 percent from 1990 to 2010. This rise in CO_2 emissions, combined with an increase in HFCs from close to zero emissions in 1990 to 58.4 Tg CO_2 Eq. in 2010, led to an increase in overall emissions from transportation activities of 19 percent.

Although average fuel economy over this period increased slightly due primarily to the retirement of older vehicles, average fuel economy among new vehicles sold annually gradually declined from 1990 to 2004. The decline in new vehicle fuel economy between 1990 and 2004 reflected the increasing market share of light duty trucks, which grew from about one-fifth of new vehicle sales in the 1970s to slightly over half of the market by 2004. Increasing fuel prices have since decreased the momentum of light duty truck sales, and average new vehicle fuel economy has improved since 2005 as the market share of passenger cars increased. Over the 1990s through early this decade, growth in vehicle travel substantially outweighed improvements in vehicle fuel economy; however, the rate of Vehicle Miles Traveled (VMT) growth slowed considerably starting in 2005 (and declined rapidly in 2008) while average vehicle fuel economy increased. However, in 2010, fuel VMT grew by 0.3 percent, while average fuel economy decreased slightly. Among new vehicles sold annually, average fuel economy gradually declined from 1990 to 2004, reflecting substantial growth in sales of light-duty trucks—in particular, growth in the market share of sport utility vehicles—relative to passenger cars. Gasoline fuel consumption increased slightly, while consumption of diesel fuel continued to decrease, due in part to a decrease in commercial activity and freight trucking as a result of the economic recession.

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

Gas/Vehicle	1990	2005	2006	2007	2008	2009	2010
Passenger Cars	**657.4**	**709.6**	**682.9**	**847.4**	**807.0**	**798.7**	**787.9**
CO_2	629.3	662.3	639.1	804.4	769.3	766.0	757.5
CH_4	2.6	1.1	1.0	1.1	1.0	0.9	0.9
N_2O	25.4	17.8	15.7	17.3	14.7	12.4	10.9
HFCs	+	28.4	27.1	24.6	22.1	19.3	18.6
Light-Duty Trucks	**336.6**	**551.3**	**564.0**	**366.4**	**347.0**	**349.5**	**346.4**
CO_2	321.1	505.9	519.5	330.1	312.8	317.4	316.0
CH_4	1.4	0.7	0.7	0.3	0.3	0.3	0.3
N_2O	14.1	13.7	12.6	5.9	5.2	5.2	4.7
HFCs	+	31.0	31.2	30.1	28.6	26.6	25.4
Medium- and Heavy-Duty Trucks	**231.1**	**408.5**	**418.7**	**444.7**	**427.1**	**389.3**	**402.3**
CO_2	230.1	396.0	406.0	431.6	413.9	376.3	389.3
CH_4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
N_2O	0.8	1.2	1.1	1.5	1.4	1.2	1.1
HFCs	+	11.1	11.4	11.5	11.6	11.6	11.6
Buses	**8.4**	**12.0**	**12.3**	**18.0**	**17.5**	**16.6**	**16.5**
CO_2	8.4	11.8	12.0	17.6	17.1	16.2	16.0
CH_4	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+
HFCs	+	0.2	0.3	0.3	0.4	0.4	0.4
Motorcycles	**1.8**	**1.7**	**1.9**	**4.3**	**4.5**	**4.3**	**3.8**
CO_2	1.7	1.6	1.9	4.3	4.4	4.2	3.7
CH_4	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+
Commercial Aircraft[a]	**136.8**	**162.8**	**138.5**	**139.5**	**123.4**	**112.5**	**115.2**
CO_2	135.4	161.2	137.1	138.1	122.2	111.4	114.0
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	1.3	1.5	1.3	1.3	1.2	1.1	1.1
Other Aircraft[b]	**44.4**	**35.8**	**35.0**	**33.1**	**35.2**	**30.4**	**28.7**
CO_2	43.9	35.5	34.7	32.8	34.8	30.1	28.4
CH_4	0.1	0.1	0.1	0.1	0.1	+	+
N_2O	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Ships and Boats[c]	**45.1**	**45.2**	**48.4**	**55.2**	**37.1**	**34.0**	**43.3**
CO_2	44.5	44.5	47.7	54.4	36.6	33.5	42.6
CH_4	+	+	+	+	+	+	+
N_2O	0.6	0.6	0.7	0.8	0.5	0.5	0.6
HFCs	+	+	+	+	+	+	+
Rail	**39.0**	**53.0**	**55.1**	**54.4**	**50.7**	**43.4**	**46.3**
CO_2	38.5	50.3	52.4	51.6	47.9	40.7	43.5
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.3	0.4	0.4	0.4	0.4	0.3	0.3
HFCs	+	2.2	2.2	2.2	2.3	2.3	2.3
Other Emissions from Electricity Generation[d]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Pipelines[e]	**36.0**	**32.2**	**32.3**	**34.2**	**35.6**	**36.6**	**38.8**
CO_2	36.0	32.2	32.3	34.2	35.6	36.6	38.8
Lubricants	**11.8**	10.2	9.9	10.2	9.5	8.5	9.5
CO_2	11.8	10.2	9.9	10.2	9.5	8.5	9.5
Total Transportation	**1,548.3**	**2,022.3**	**1,999.1**	**2,007.6**	**1,894.6**	**1,823.9**	**1,838.6**
International Bunker Fuels[f]	*113.0*	*110.9*	*129.8*	*129.0*	*135.1*	*123.6*	*129.2*

Note: Totals may not sum due to independent rounding. Passenger cars and light-duty trucks include vehicles typically used for personal travel and less than 8500 lbs; medium- and heavy-duty trucks include vehicles

larger than 8500 lbs. HFC emissions primarily reflect HFC-134a.
+ Does not exceed 0.05 Tg CO_2 Eq.
[a] Consists of emissions from jet fuel consumed by domestic operations of commercial aircraft (no bunkers).
[b] Consists of emissions from jet fuel and aviation gasoline consumption by general aviation and military aircraft.
[c] Fluctuations in emission estimates are associated with fluctuations in reported fuel consumption, and may reflect data collection problems.
[d] Other emissions from electricity generation are a result of waste incineration (as the majority of municipal solid waste is combusted in "trash-to-steam" electricity generation plants), electrical transmission and distribution, and a portion of limestone and dolomite use (from pollution control equipment installed in electricity generation plants).
[e] CO_2 estimates reflect natural gas used to power pipelines, but not electricity. While the operation of pipelines produces CH_4 and N_2O, these emissions are not directly attributed to pipelines in the US Inventory.
[f] Emissions from International Bunker Fuels include emissions from both civilian and military activities; these emissions are not included in the transportation totals.

Commercial

The commercial sector is heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Energy-related emissions from the residential and commercial sectors have generally been increasing since 1990, and are often correlated with short-term fluctuations in energy consumption caused by weather conditions, rather than prevailing economic conditions. Landfills and wastewater treatment are included in this sector, with landfill emissions decreasing since 1990 and wastewater treatment emissions increasing slightly.

Residential

The residential sector is heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Emissions from the residential sectors have generally been increasing since 1990, and are often correlated with short-term fluctuations in energy consumption caused by weather conditions, rather than prevailing economic conditions. In the long-term, this sector is also affected by population growth, regional migration trends, and changes in housing and building attributes (e.g., size and insulation).

Agriculture

The agriculture sector includes a variety of processes, including enteric fermentation in domestic livestock, livestock manure management, and agricultural soil management. In 2010, agricultural soil management was the largest source of N_2O emissions, and enteric fermentation was the second largest source of CH_4 emissions in the United States. This sector also includes small amounts of CO_2 emissions from fossil fuel combustion by motorized farm equipment like tractors. The agriculture sector relies less heavily on electricity than the other sectors.

[BEGIN BOX]

Box 2-1: Methodology for Aggregating Emissions by Economic Sector

In presenting the Economic Sectors in the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks, the Inventory expands upon the standard IPCC sectors common for UNFCCC reporting. Discussing greenhouse gas emissions relevant to U.S.-specific sectors improves communication of the report's findings.

In the Electricity Generation economic sector, CO_2 emissions from the combustion of fossil fuels included in the EIA electric utility fuel consuming sector are apportioned to this economic sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA electric utility sector. Additional sources include CO_2, CH_4, and N_2O from waste incineration, as the majority of municipal solid waste is combusted in "trash-to-steam" electricity generation plants. The Electricity Generation economic sector also includes SF_6 from Electrical Transmission and Distribution, and a portion of CO_2 from Limestone and Dolomite Use (from pollution control equipment installed in electricity generation plants).

In the Transportation economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA transportation fuel consuming sector are apportioned to this economic sector (additional analyses and refinement of the EIA data is further explained in the Energy chapter of this report). Additional emissions are apportioned from the CH_4 and N_2O from Mobile Combustion, based on the EIA transportation sector. Substitutes of Ozone Depleting Substitutes are apportioned based on their specific end-uses within the source category, with emissions from transportation refrigeration/air-conditioning systems to this economic sector. Finally, CO_2 emissions from Non-Energy Uses of Fossil Fuels identified as lubricants for transportation vehicles are included in the Transportation economic sector.

For the Industry economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA industrial fuel consuming sector, minus the agricultural use of fuel explained below, are apportioned to this economic sector. Stationary and mobile combustion emissions of CH_4 and N_2O are also based on the EIA industrial sector, minus emissions apportioned to the Agriculture economic sector described below. Substitutes of Ozone Depleting Substitutes are apportioned based on their specific end-uses within the source category, with most emissions falling within the Industry economic sector (minus emissions from the other economic sectors). Additionally, all process-related emissions from sources with methods considered within the IPCC Industrial Process guidance have been apportioned to this economic sector. This includes the process-related emissions (i.e., emissions from the actual process to make the material, not from fuels to power the plant) from such activities as Cement Production, Iron and Steel Production and Metallurgical Coke Production, and Ammonia Production. Additionally, fugitive emissions from energy production sources, such as Natural Gas Systems, Coal Mining, and Petroleum Systems are included in the Industry economic sector. A portion of CO_2 from Limestone and Dolomite Use (from pollution control equipment installed in large industrial facilities) are also included in the Industry economic sector. Finally, all remaining CO_2 emissions from Non-Energy Uses of Fossil Fuels are assumed to be industrial in nature (besides the lubricants for transportation vehicles specified above), and are attributed to the Industry economic sector.

As agriculture equipment is included in EIA's industrial fuel consuming sector surveys, additional data is used to extract the fuel used by agricultural equipment, to allow for accurate reporting in the Agriculture economic sector from all sources of emissions, such as motorized farming equipment. Energy consumption estimates are obtained from Department of Agriculture survey data, in combination with separate EIA fuel sales reports. This supplementary data is used to apportion CO_2 emissions from fossil fuel combustion, and CH_4 and N_2O emissions from stationary and mobile combustion (all data is removed from the Industrial economic sector, to avoid double-counting). The other emission sources included in this economic sector are intuitive for the agriculture sectors, such as N_2O emissions from Agricultural Soils, CH_4 from Enteric Fermentation (i.e., exhalation from the digestive tracts of domesticated animals), CH_4 and N_2O from Manure Management, CH_4 from Rice Cultivation, CO_2 emissions from Liming of Agricultural Soils and Urea Application, and CH_4 and N_2O from Forest Fires. N_2O emissions from the Application of Fertilizers to tree plantations (termed "forest land" by the IPCC) are also included in the Agriculture economic sector.

The Residential economic sector includes the CO_2 emissions from the combustion of fossil fuels reported for the EIA residential sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA residential fuel consuming sector. Substitutes of Ozone Depleting Substitutes are apportioned based on their specific end-uses within the source category, with emissions from residential air-conditioning systems to this economic sector. N_2O emissions from the Application of Fertilizers to developed land (termed "settlements" by the IPCC) are also included in the Residential economic sector.

The Commercial economic sector includes the CO_2 emissions from the combustion of fossil fuels reported in the EIA commercial fuel consuming sector data. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA commercial sector. Substitutes of Ozone Depleting Substitutes are apportioned based on their specific end-uses within the source category, with emissions from commercial refrigeration/air-conditioning systems to this economic

sector. Public works sources including direct CH_4 from Landfills and CH_4 and N_2O from Wastewater Treatment and Composting are included in this economic sector.

[END BOX]

[BEGIN BOX]

Box 2-2: Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and non-utilities combined—was the largest source of U.S. greenhouse gas emissions in 2010; (4) emissions per unit of total gross domestic product as a measure of national economic activity; or (5) emissions per capita.

Table 2-16 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 0.5 percent since 1990. This rate is slightly slower than that for total energy consumption and growth in national population since 1990 and much slower than that for electricity consumption and overall gross domestic product, respectively. Total U.S. greenhouse gas emissions are growing at a rate similar to that of fossil fuel consumption since 1990 (see Table 2-16).

Table 2-16: Recent Trends in Various U.S. Data (Index 1990 = 100)

Variable	1990		2005	2006	2007	2008	2009	2010	Growth
GDP[b]	100		157	161	165	164	158	163	2.5%
Electricity Consumption[c]	100		134	135	137	136	131	137	1.6%
Fossil Fuel Consumption[c]	100		119	117	119	116	109	113	0.6%
Energy Consumption[c]	100		119	118	121	119	113	117	0.8%
Population[d]	100		118	120	121	122	123	123	1.1%
Greenhouse Gas Emissions[e]	100		117	116	117	114	107	111	0.5%

[a] Average annual growth rate

[b] Gross Domestic Product in chained 2005 dollars (BEA 2011)

[c] Energy-content-weighted values (EIA 2011)

[d] U.S. Census Bureau (2011)

[e] GWP-weighted values

Figure 2-14: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product
Source: BEA (2011), U.S. Census Bureau (2011), and emission estimates in this report.

[END BOX]

2.3. Indirect Greenhouse Gas Emissions (CO, NOx, NMVOCs, and SO2)

The reporting requirements of the UNFCCC[51] request that information be provided on indirect greenhouse gases, which include CO, NO_x, NMVOCs, and SO_2. These gases do not have a direct global warming effect, but indirectly

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

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

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

Since 1970, the United States has published estimates of annual emissions of CO, NO_x, NMVOCs, and SO_2 (EPA 2010, EPA 2009),[52] which are regulated under the Clean Air Act. Table 2-17 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Table 2-17: Emissions of NO_x, CO, NMVOCs, and SO_2 (Gg)

Gas/Activity	1990	2005	2006	2007	2008	2009	2010
NO_x	**21,707**	**15,900**	**15,039**	**14,380**	**13,547**	**11,468**	**11,468**
Mobile Fossil Fuel Combustion	10,862	9,012	8,488	7,965	7,441	6,206	6,206
Stationary Fossil Fuel Combustion	10,023	5,858	5,545	5,432	5,148	4,159	4,159
Industrial Processes	591	569	553	537	520	568	568
Oil and Gas Activities	139	321	319	318	318	393	393
Incineration of Waste	82	129	121	114	106	128	128
Agricultural Burning	8	6	7	8	8	8	8
Solvent Use	1	3	4	4	4	3	3
Waste	+	2	2	2	2	2	2
CO	**130,038**	**70,809**	**67,238**	**63,625**	**60,039**	**51,452**	**51,452**
Mobile Fossil Fuel Combustion	119,360	62,692	58,972	55,253	51,533	43,355	43,355
Stationary Fossil Fuel Combustion	5,000	4,649	4,695	4,744	4,792	4,543	4,543
Industrial Processes	4,125	1,555	1,597	1,640	1,682	1,549	1,549
Incineration of Waste	978	1,403	1,412	1,421	1,430	1,403	1,403
Agricultural Burning	268	184	233	237	270	247	247
Oil and Gas Activities	302	318	319	320	322	345	345
Waste	1	7	7	7	7	7	7
Solvent Use	5	2	2	2	2	2	2
NMVOCs	**20,930**	**13,761**	**13,594**	**13,423**	**13,254**	**9,313**	**9,313**
Mobile Fossil Fuel Combustion	10,932	6,330	6,037	5,742	5,447	4,151	4,151
Solvent Use	5,216	3,851	3,846	3,839	3,834	2,583	2,583
Industrial Processes	2,422	1,997	1,933	1,869	1,804	1,322	1,322
Stationary Fossil Fuel Combustion	912	716	918	1,120	1,321	424	424
Oil and Gas Activities	554	510	510	509	509	599	599
Incineration of Waste	222	241	238	234	230	159	159
Waste	673	114	113	111	109	76	76
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA

[52] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2009) and EPA (2010).

SO_2	**20,935**	**13,466**	**12,388**	**11,799**	**10,368**	**8,599**	**8,599**
Stationary Fossil Fuel Combustion	18,407	11,541	10,612	10,172	8,891	7,167	7,167
Industrial Processes	1,307	831	818	807	795	798	798
Mobile Fossil Fuel Combustion	793	889	750	611	472	455	455
Oil and Gas Activities	390	181	182	184	187	154	154
Incineration of Waste	38	24	24	24	23	24	24
Waste	+	1	1	1	1	1	1
Solvent Use	+	+	+	+	+	+	+
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA

Source: (EPA 2010, EPA 2009) except for estimates from field burning of agricultural residues.

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 60 percent in 2010. 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]

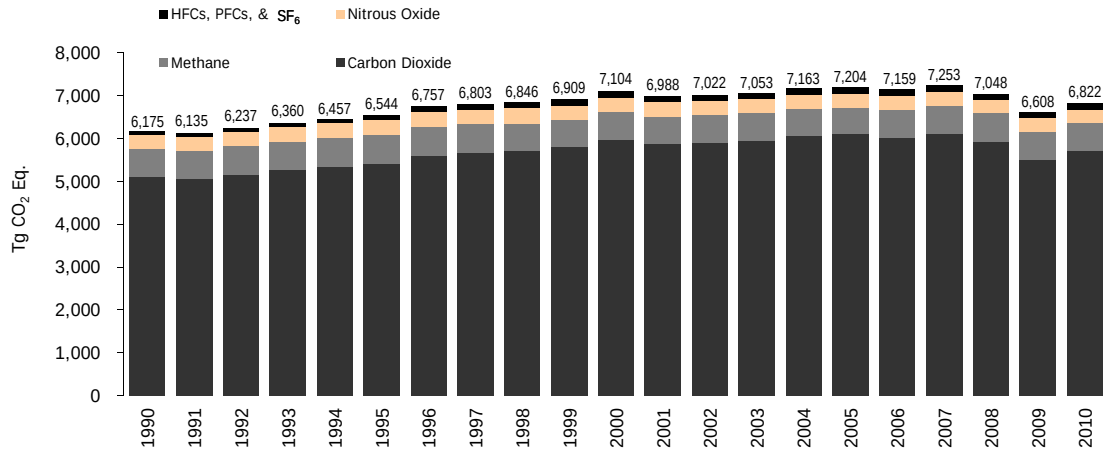


Figure 2-1: U.S. Greenhouse Gas Emissions by Gas

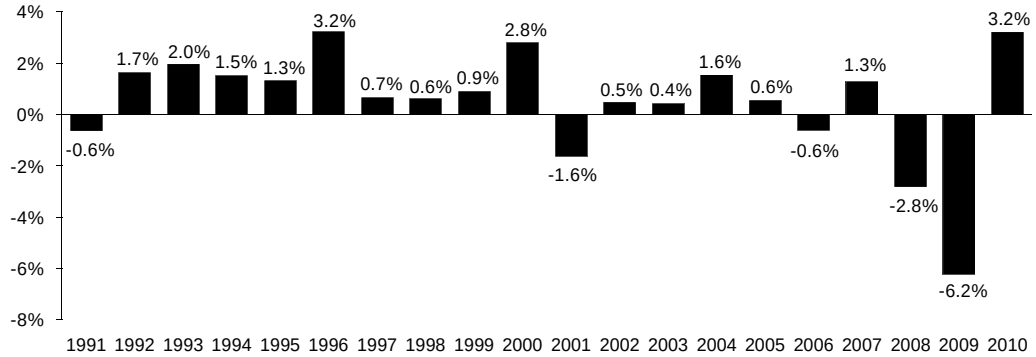


Figure 2-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

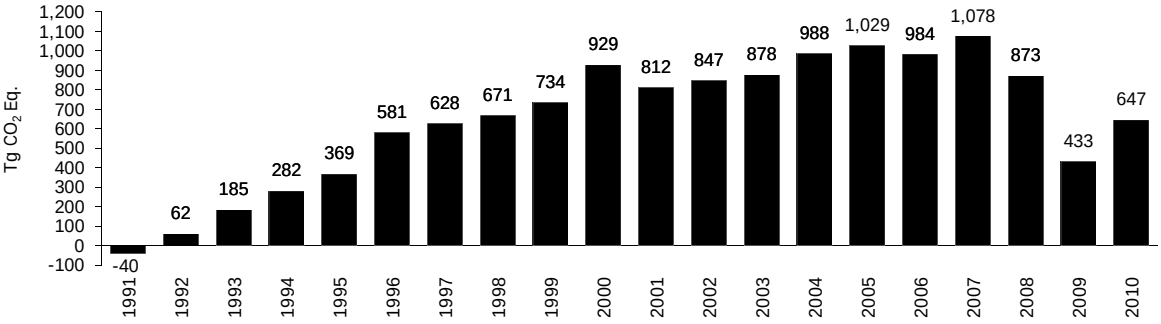
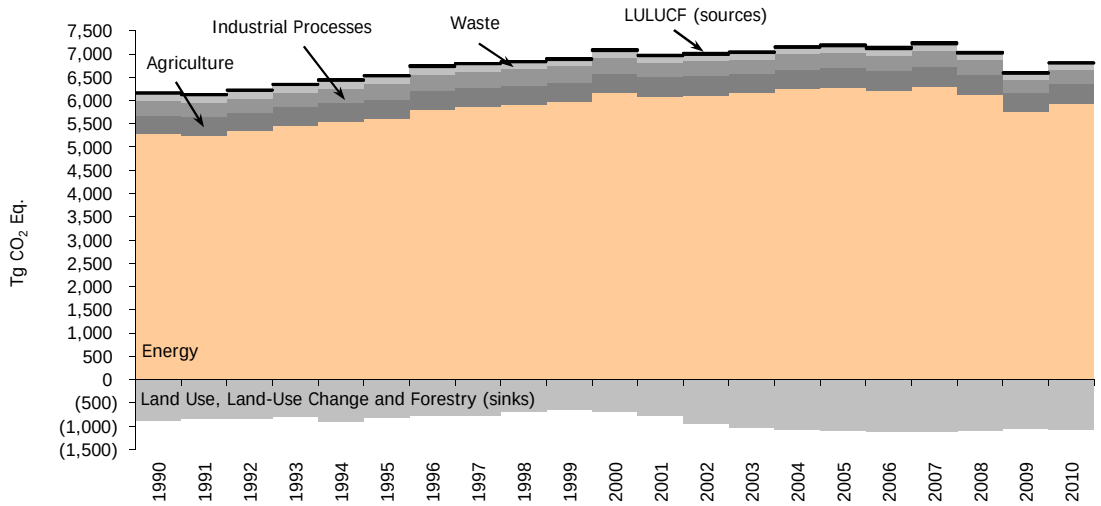


Figure 2-3: Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1990



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

Figure 2-4: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

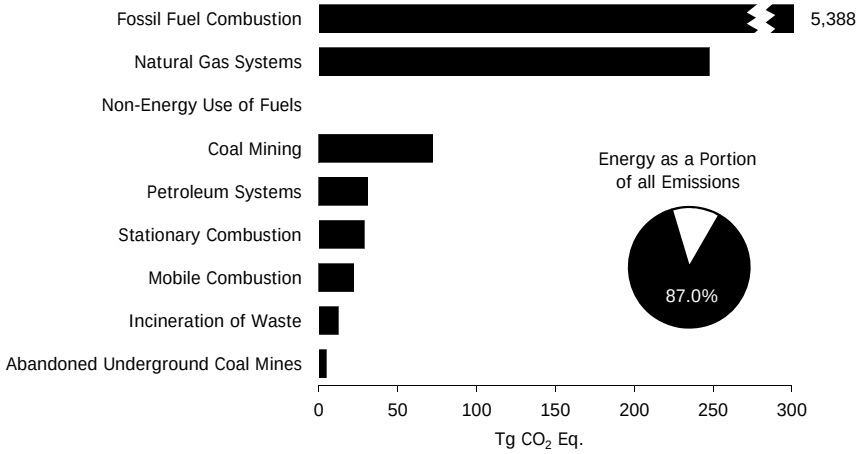


Figure 2-5: 2010 Energy Sector Greenhouse Gas Sources

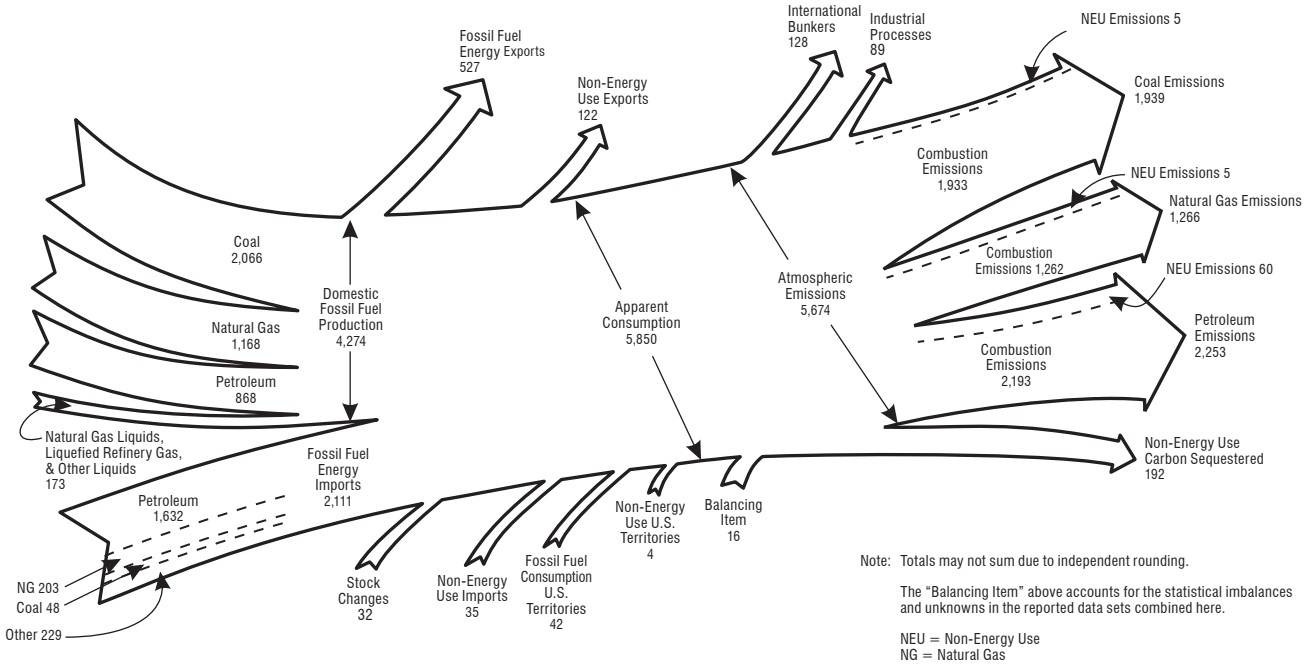


Figure 2-6 2010 U.S. Fossil Carbon Flows (Tg CO_2 Eq.)

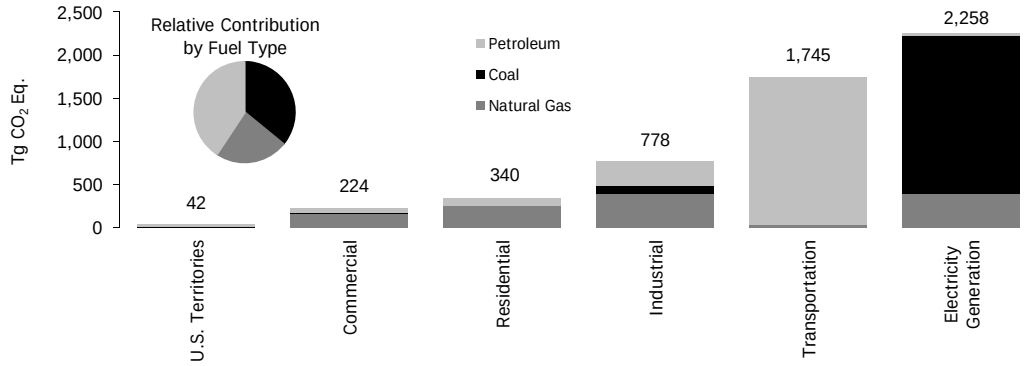


Figure 2-7: 2010 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Note: Electricity generation also includes emissions of less than 0.5 Tg CO_2 Eq. from geothermal-based electricity generation.

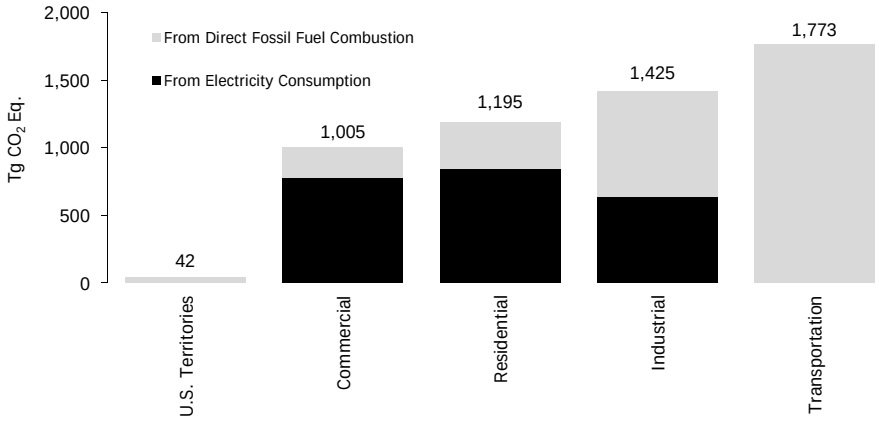


Figure 2-8: 2010 End-Use Sector Emissions from Fossil Fuel Combustion

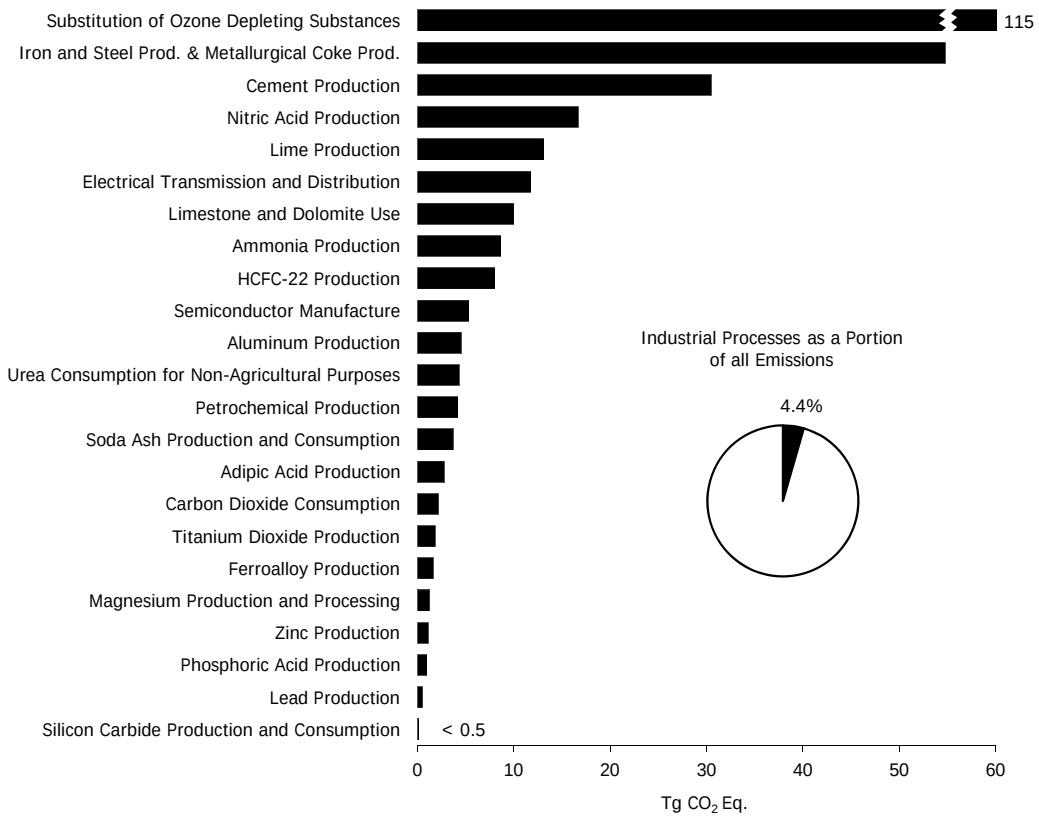


Figure 2-9: 2010 Industrial Processes Chapter Greenhouse Gas Sources

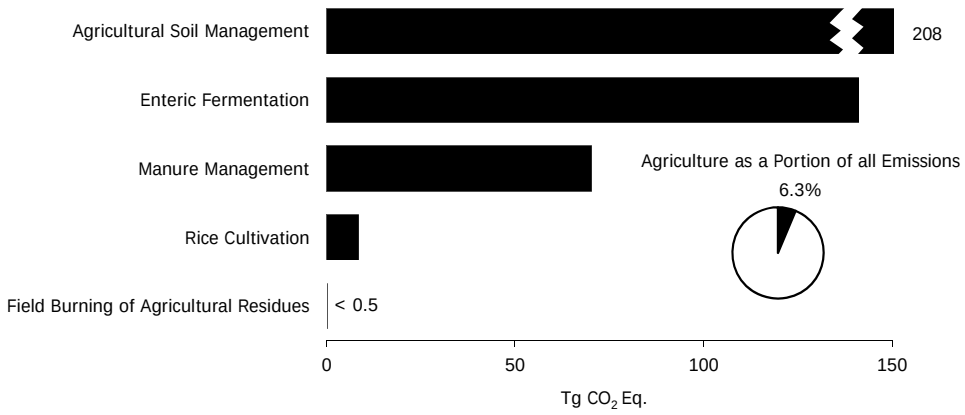


Figure 2-10: 2010 Agriculture Chapter Greenhouse Gas Sources

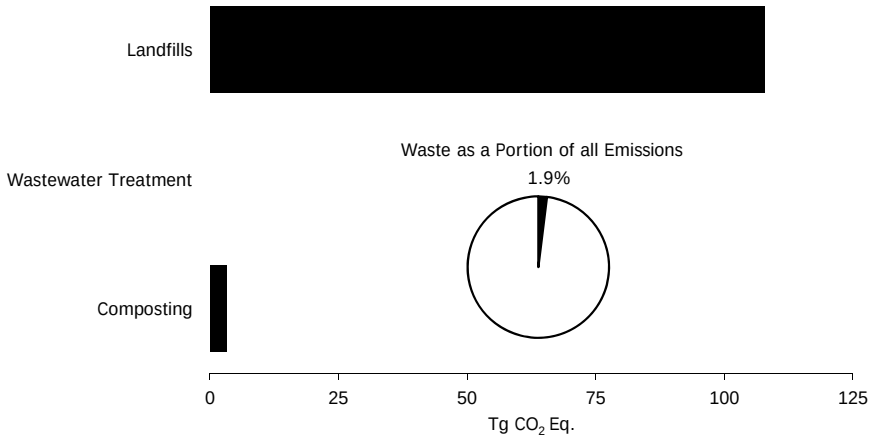


Figure 2-11: 2010 Waste Chapter Greenhouse Gas Sources

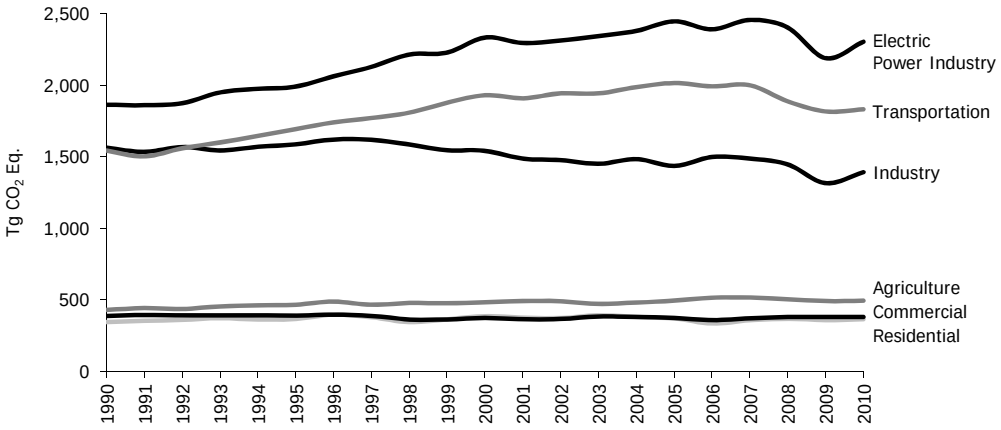


Figure 2-12: Emissions Allocated to Economic Sectors

Note: Does not include U.S. Territories.

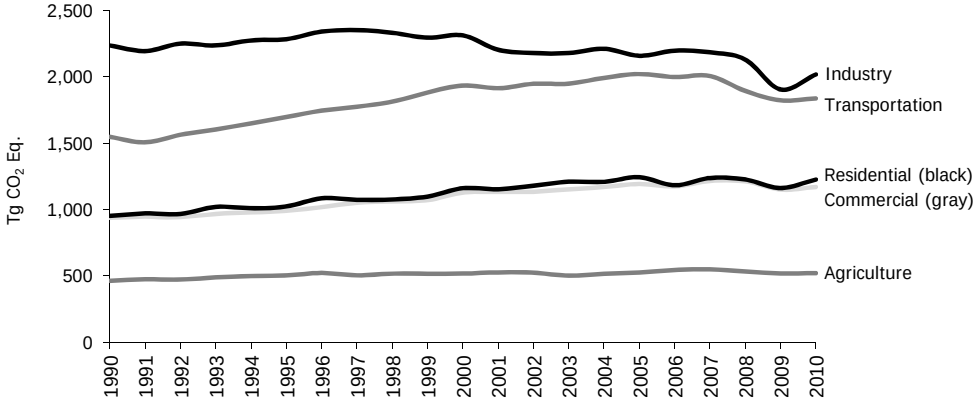


Figure 2-13: Emissions with Electricity Distributed to Economic Sectors

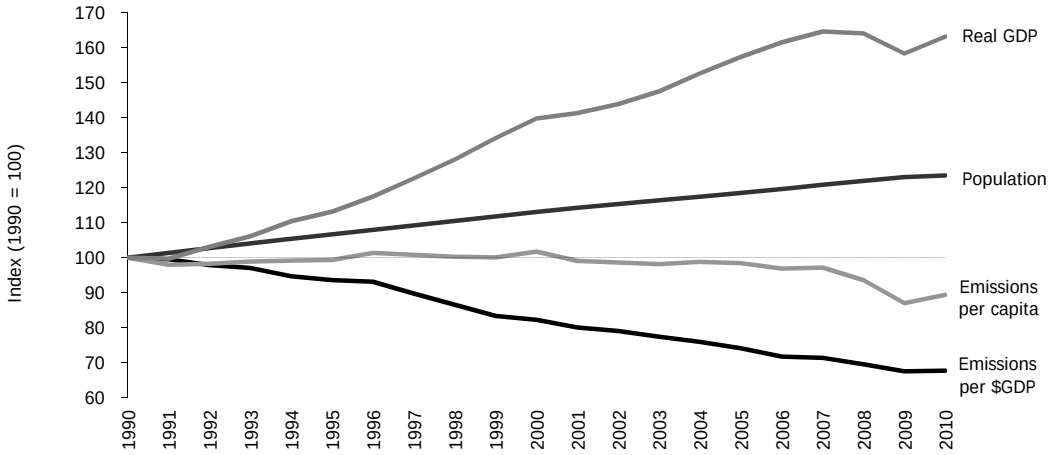


Figure 2-14: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product