# 2. Trends in Greenhouse Gas Emissions

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

In 2006, total U.S. greenhouse gas emissions were 7,054.2 teragrams of carbon dioxide equivalents (Tg $CO_2$ Eq.).[1] Overall, total U.S. emissions have risen by 14.7 percent from 1990 to 2006, while the U.S. gross domestic product has increased by 59 percent over the same period (BEA 2007). Emissions decreased from 2005 to 2006 by 1.1 percent (75.7 Tg $CO_2$ Eq.). The following factors were primary contributors to this decrease: (1) compared to 2005, 2006 had warmer winter conditions, which decreased consumption of heating fuels, as well as cooler summer conditions, which reduced demand for electricity, (2) restraint on fuel consumption caused by rising fuel prices, primarily in the transportation sector and (3) increased use of natural gas and renewables in the electric power sector. Figure 2-1 through Figure 2-3 illustrate the overall trends in total U.S. emissions by gas,[2] annual changes, and absolute changes since 1990.

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

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

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

As the largest source of U.S. greenhouse gas emissions, carbon dioxide ($CO_2$) from fossil fuel combustion has accounted for approximately 79 percent of global warming potential (GWP) weighted emissions since 1990, growing slowly from 77 percent of total GWP-weighted emissions in 1990 to 80 percent in 2006. Emissions from this source category grew by 19.3 percent (913.8 Tg $CO_2$ Eq.) from 1990 to 2006 and were responsible for most of the increase in national emissions during this period. From 2005 to 2006, these emissions decreased by 1.6 percent (93.1 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 generally fluctuates in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than in a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

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

---

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

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

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.

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

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

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

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

From 2005 to 2006, emissions from fuel combustion decreased for the first time since 2000 to 2001. This decrease occurred primarily in the electricity generation, transportation, residential, and commercial sectors due to a number of factors. The decrease in emissions from electricity generation is a result of a smaller share of electricity by coal and a greater share generated by natural gas. Coal and natural gas consumption for electricity generation decreased by 1.3 percent and increased by 6.4 percent, respectively, in 2006, and nuclear power increased by less than 1 percent. The transportation decrease is primarily a result of the restraint on fuel consumption caused by rising fuel prices, which directly resulted in a decrease of petroleum consumption within this sector of less than one percent in 2006. The decrease in emissions from the residential sector is primarily a result of decreased electricity consumption due to increases in the price of electricity, and warmer winter weather conditions. The increase in

emissions in the industrial sector is a result of a increased emissions from fossil fuel combustion for this sector. A moderate increase in the industrial sector is a result of growth in industrial output and growth in the U.S. economy. Renewable fuels used to generate electricity increased in 2006, with the greatest growth occurring in wind.

Overall, from 1990 to 2006, total emissions of $CO_2$ increased by 914.6 Tg $CO_2$ Eq. (18 percent), while $CH_4$ and $N_2O$ emissions decreased by 50.8 Tg $CO_2$ Eq. (8 percent) and 15.5 Tg $CO_2$ Eq. (4 percent) respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and $SF_6$ rose by 57.6 Tg $CO_2$ Eq. (64 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and $SF_6$ are significant because many of them have extremely high GWPs and, in the cases of PFCs and $SF_6$, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by C sequestration in managed forests, trees in urban areas, agricultural soils, and landfilled yard trimmings, which was estimated to be 12 percent of total emissions in 2006.

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 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **5,068.5** | **5,394.2** | **5,939.7** | **5,846.2** | **5,908.6** | **5,952.7** | **6,038.2** | **6,074.3** | **5,983.1** |
| Fossil Fuel Combustion | 4,724.1 | 5,032.4 | 5,577.1 | 5,507.4 | 5,564.8 | 5,617.0 | 5,681.4 | 5,731.0 | 5,637.9 |
| Electricity Generation | 1,809.6 | 1,939.3 | 2,282.3 | 2,244.3 | 2,253.7 | 2,283.1 | 2,314.9 | 2,380.2 | 2,328.2 |
| Transportation | 1,485.1 | 1,599.4 | 1,798.2 | 1,775.6 | 1,828.9 | 1,807.6 | 1,856.4 | 1,869.8 | 1,856.0 |
| Industrial | 844.9 | 876.5 | 860.3 | 852.5 | 854.8 | 856.0 | 857.7 | 847.3 | 862.2 |
| Residential | 340.1 | 356.5 | 372.1 | 363.6 | 360.5 | 382.9 | 368.3 | 358.5 | 326.5 |
| Commercial | 216.1 | 225.8 | 228.0 | 222.3 | 222.8 | 236.5 | 230.6 | 221.9 | 210.1 |
| US Territories | 28.3 | 35.0 | 36.2 | 49.0 | 44.0 | 51.0 | 53.5 | 53.2 | 54.9 |
| Non-Energy Use of Fuels | 117.2 | 133.2 | 141.4 | 131.9 | 135.9 | 131.8 | 148.9 | 139.1 | 138.0 |
| Iron and Steel Production | 86.2 | 74.7 | 66.6 | 59.2 | 55.9 | 54.7 | 52.8 | 46.6 | 49.1 |
| Cement Manufacture | 33.3 | 36.8 | 41.2 | 41.4 | 42.9 | 43.1 | 45.6 | 45.9 | 45.7 |
| Natural Gas Systems | 33.7 | 33.8 | 29.4 | 28.8 | 29.6 | 28.4 | 28.1 | 29.5 | 28.5 |
| Municipal Solid Waste Combustion | 10.9 | 15.7 | 17.5 | 18.0 | 18.5 | 19.1 | 20.1 | 20.7 | 20.9 |
| Lime Manufacture | 12.0 | 14.0 | 14.9 | 14.3 | 13.7 | 14.5 | 15.2 | 15.1 | 15.8 |
| Ammonia Manufacture and Urea Consumption | 16.9 | 17.8 | 16.4 | 13.3 | 14.2 | 12.5 | 13.2 | 12.8 | 12.4 |
| Limestone and Dolomite Use | 5.5 | 7.4 | 6.0 | 5.7 | 5.9 | 4.8 | 6.7 | 7.4 | 8.6 |
| Cropland Remaining Cropland | 7.1 | 7.0 | 7.5 | 7.8 | 8.5 | 8.3 | 7.6 | 7.9 | 8.0 |
| Soda Ash Manufacture and Consumption | 4.1 | 4.3 | 4.2 | 4.1 | 4.1 | 4.1 | 4.2 | 4.2 | 4.2 |
| Aluminum Production | 6.8 | 5.7 | 6.1 | 4.4 | 4.5 | 4.5 | 4.2 | 4.2 | 3.9 |
| Petrochemical Production | 2.2 | 2.8 | 3.0 | 2.8 | 2.9 | 2.8 | 2.9 | 2.8 | 2.6 |
| Titanium Dioxide Production | 1.2 | 1.5 | 1.8 | 1.7 | 1.8 | 1.8 | 2.1 | 1.8 | 1.9 |
| Carbon Dioxide Consumption | 1.4 | 1.4 | 1.4 | 0.8 | 1.0 | 1.3 | 1.2 | 1.3 | 1.6 |
| Ferroalloy Production | 2.2 | 2.0 | 1.9 | 1.5 | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 |
| Phosphoric Acid Production | 1.5 | 1.5 | 1.4 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 1.2 |
| Zinc Production | 0.9 | 1.0 | 1.1 | 1.0 | 0.9 | 0.5 | 0.5 | 0.5 | 0.5 |
| Petroleum Systems | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Lead Production | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Silicon Carbide Production and Consumption | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| *Land Use, Land-Use Change, and Forestry (Sink)*[a] | *(737.7)* | *(775.3)* | *(673.6)* | *(750.2)* | *(826.8)* | *(860.9)* | *(873.7)* | *(878.6)* | *(883.7)* |
| *Wood Biomass and Ethanol Consumption*[b] | *219.3* | *236.8* | *227.3* | *203.2* | *204.4* | *209.5* | *224.8* | *227.4* | *234.7* |
| *International Bunker Fuels*[b] | *113.7* | *100.6* | *101.1* | *97.6* | *89.1* | *103.6* | *119.0* | *122.6* | *127.1* |
| **$CH_4$** | **606.1** | **598.9** | **574.3** | **558.8** | **563.5** | **559.4** | **545.6** | **539.7** | **555.3** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Enteric Fermentation | 126.9 | 132.3 | 124.6 | 123.6 | 123.8 | 124.6 | 122.4 | 124.5 | 126.2 |
| Landfills | 149.6 | 144.0 | 120.8 | 117.6 | 120.1 | 125.6 | 122.6 | 123.7 | 125.7 |
| Natural Gas Systems | 124.7 | 128.1 | 126.5 | 125.3 | 124.9 | 123.3 | 114.0 | 102.5 | 102.4 |
| Coal Mining | 84.1 | 67.1 | 60.4 | 60.3 | 56.8 | 56.9 | 59.8 | 57.1 | 58.5 |
| Manure Management | 31.0 | 35.2 | 38.8 | 40.2 | 41.3 | 40.7 | 40.1 | 41.8 | 41.4 |
| Petroleum Systems | 33.9 | 32.0 | 30.3 | 30.2 | 29.9 | 29.2 | 28.7 | 28.3 | 28.4 |
| Forest Land Remaining Forest Land | 4.5 | 4.7 | 19.0 | 9.4 | 16.4 | 8.7 | 6.9 | 12.3 | 24.6 |
| Wastewater Treatment | 23.0 | 24.3 | 24.6 | 24.2 | 24.1 | 23.9 | 24.0 | 23.8 | 23.9 |
| Stationary Combustion | 7.4 | 7.2 | 6.6 | 6.2 | 6.2 | 6.4 | 6.5 | 6.5 | 6.2 |
| Rice Cultivation | 7.1 | 7.6 | 7.5 | 7.6 | 6.8 | 6.9 | 7.6 | 6.8 | 5.9 |
| Abandoned Underground Coal Mines | 6.0 | 8.2 | 7.4 | 6.7 | 6.2 | 6.0 | 5.8 | 5.6 | 5.4 |
| Mobile Combustion | 4.7 | 4.3 | 3.4 | 3.3 | 3.0 | 2.7 | 2.6 | 2.5 | 2.4 |
| Composting | 0.3 | 0.7 | 1.3 | 1.3 | 1.3 | 1.5 | 1.6 | 1.6 | 1.6 |
| Petrochemical Production | 0.9 | 1.1 | 1.2 | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.0 |
| Iron and Steel Production | 1.3 | 1.3 | 1.2 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |
| Field Burning of Agricultural Residues | 0.7 | 0.7 | 0.8 | 0.8 | 0.7 | 0.8 | 0.9 | 0.9 | 0.8 |
| Ferroalloy Production | + | + | + | + | + | + | + | + | + |
| Silicon Carbide Production and Consumption | + | + | + | + | + | + | + | + | + |
| *International Bunker Fuels*[b] | *0.2* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.2* | *0.2* |
| **$N_2O$** | **383.4** | **395.6** | **385.9** | **392.9** | **376.1** | **356.6** | **353.5** | **370.1** | **367.9** |
| Agricultural Soil Management | 269.4 | 264.8 | 262.1 | 277.0 | 262.0 | 247.3 | 246.9 | 265.2 | 265.0 |
| Mobile Combustion | 43.5 | 53.4 | 52.5 | 49.9 | 45.9 | 42.3 | 39.7 | 36.3 | 33.1 |
| Nitric Acid Production | 17.0 | 18.9 | 18.6 | 15.1 | 16.4 | 15.4 | 15.2 | 15.8 | 15.6 |
| Stationary Combustion | 12.8 | 13.4 | 14.6 | 14.1 | 14.0 | 14.3 | 14.6 | 14.8 | 14.5 |
| Manure Management | 12.1 | 12.8 | 13.7 | 14.0 | 14.0 | 13.6 | 13.8 | 13.9 | 14.3 |
| Wastewater Treatment | 6.3 | 6.9 | 7.6 | 7.8 | 7.6 | 7.7 | 7.8 | 8.0 | 8.1 |
| Adipic Acid Production | 15.3 | 17.3 | 6.2 | 5.1 | 6.1 | 6.3 | 5.9 | 5.9 | 5.9 |
| $N_2O$ from Product Uses | 4.4 | 4.6 | 4.9 | 4.9 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 |
| Forest Land Remaining Forest Land | 0.5 | 0.6 | 2.2 | 1.3 | 2.0 | 1.2 | 1.1 | 1.6 | 2.8 |
| Composting | 0.4 | 0.8 | 1.4 | 1.4 | 1.4 | 1.6 | 1.7 | 1.7 | 1.8 |
| Settlements Remaining Settlements | 1.0 | 1.2 | 1.2 | 1.4 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 |
| Field Burning of Agricultural Residues | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 |
| Municipal Solid Waste Combustion | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| *International Bunker Fuels*[b] | *1.0* | *0.9* | *0.9* | *0.9* | *0.8* | *0.9* | *1.1* | *1.1* | *1.1* |
| **HFCs** | **36.9** | **61.8** | **100.1** | **97.9** | **106.3** | **104.5** | **116.6** | **121.4** | **124.5** |
| Substitution of Ozone Depleting Substances[c] | 0.3 | 28.5 | 71.2 | 78.0 | 85.0 | 92.0 | 99.1 | 105.4 | 110.4 |
| HCFC-22 Production | 36.4 | 33.0 | 28.6 | 19.7 | 21.1 | 12.3 | 17.2 | 15.8 | 13.8 |
| Semiconductor Manufacture | 0.2 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| **PFCs** | **20.8** | **15.6** | **13.5** | **7.0** | **8.7** | **7.1** | **6.1** | **6.2** | **6.0** |
| Semiconductor Manufacture | 2.2 | 3.8 | 4.9 | 3.5 | 3.5 | 3.3 | 3.3 | 3.2 | 3.6 |
| Aluminum Production | 18.5 | 11.8 | 8.6 | 3.5 | 5.2 | 3.8 | 2.8 | 3.0 | 2.5 |
| **$SF_6$** | **32.7** | **28.0** | **19.1** | **18.7** | **18.0** | **18.1** | **18.0** | **18.2** | **17.3** |
| Electrical Transmission and Distribution | 26.7 | 21.5 | 15.1 | 15.0 | 14.4 | 13.8 | 13.9 | 14.0 | 13.2 |
| Magnesium Production and Processing | 5.4 | 5.6 | 3.0 | 2.9 | 2.9 | 3.4 | 3.2 | 3.3 | 3.2 |
| Semiconductor Manufacture | 0.5 | 0.9 | 1.1 | 0.7 | 0.7 | 0.8 | 0.8 | 1.0 | 1.0 |
| **Total** | **6,148.3** | **6,494.0** | **7,032.6** | **6,921.3** | **6,981.2** | **6,998.2** | **7,078.0** | **7,129.9** | **7,054.2** |
| **Net Emissions (Sources and Sinks)** | **5,410.6** | **5,718.7** | **6,359.0** | **6,171.1** | **6,154.4** | **6,137.3** | **6,204.3** | **6,251.3** | **6,170.5** |

+ Does not exceed 0.05 Tg $CO_2$ Eq.

[a] The net $CO_2$ flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total. Parentheses indicate negative values or sequestration.
[b] Emissions from International Bunker Fuels and Wood Biomass and Ethanol Consumption are not included in totals.
[c] 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 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **5,068,472** | **5,939,726** | **5,846,151** | **5,908,568** | **5,952,650** | **6,038,211** | **6,074,306** | **5,983,108** |
| Fossil Fuel Combustion | 4,724,146 | 5,577,072 | 5,507,406 | 5,564,795 | 5,617,047 | 5,681,363 | 5,731,045 | 5,637,931 |
| Electricity Generation | 1,809,614 | 2,282,278 | 2,244,279 | 2,253,729 | 2,283,069 | 2,314,907 | 2,380,222 | 2,328,153 |
| Transportation | 1,485,057 | 1,798,164 | 1,775,636 | 1,828,910 | 1,807,591 | 1,856,373 | 1,869,848 | 1,856,047 |
| Industrial | 844,937 | 860,325 | 852,494 | 854,822 | 856,042 | 857,722 | 847,328 | 862,187 |
| Residential | 340,109 | 372,083 | 363,629 | 360,492 | 382,864 | 368,258 | 358,515 | 326,522 |
| Commercial | 216,144 | 228,027 | 222,341 | 222,828 | 236,452 | 230,617 | 221,921 | 210,140 |
| US Territories | 28,285 | 36,195 | 49,027 | 44,014 | 51,030 | 53,486 | 53,213 | 54,882 |
| Non-Energy Use of Fuels | 117,170 | 141,427 | 131,887 | 135,857 | 131,772 | 148,931 | 139,057 | 137,980 |
| Iron and Steel Production | 86,220 | 66,609 | 59,249 | 55,938 | 54,744 | 52,771 | 46,627 | 49,119 |
| Cement Manufacture | 33,278 | 41,190 | 41,357 | 42,898 | 43,082 | 45,603 | 45,910 | 45,739 |
| Natural Gas Systems | 33,729 | 29,390 | 28,793 | 29,629 | 28,445 | 28,122 | 29,462 | 28,504 |
| Municipal Solid Waste Combustion | 10,950 | 17,518 | 17,971 | 18,458 | 19,058 | 20,097 | 20,673 | 20,922 |
| Lime Manufacture | 12,004 | 14,872 | 14,261 | 13,652 | 14,458 | 15,154 | 15,131 | 15,825 |
| Ammonia Manufacture and Urea Consumption | 16,889 | 16,402 | 13,305 | 14,194 | 12,488 | 13,241 | 12,817 | 12,376 |
| Limestone and Dolomite Use | 5,533 | 5,960 | 5,733 | 5,885 | 4,753 | 6,702 | 7,397 | 8,615 |
| Cropland Remaining Cropland | 7,084 | 7,541 | 7,825 | 8,549 | 8,260 | 7,555 | 7,854 | 8,012 |
| Soda Ash Manufacture and Consumption | 4,141 | 4,181 | 4,147 | 4,139 | 4,111 | 4,205 | 4,228 | 4,162 |
| Aluminum Production | 6,831 | 6,086 | 4,381 | 4,490 | 4,503 | 4,231 | 4,207 | 3,923 |
| Petrochemical Production | 2,221 | 3,004 | 2,787 | 2,857 | 2,777 | 2,895 | 2,804 | 2,573 |
| Titanium Dioxide Production | 1,195 | 1,752 | 1,697 | 1,824 | 1,839 | 2,064 | 1,755 | 1,876 |
| Carbon Dioxide Consumption | 1,416 | 1,421 | 829 | 989 | 1,311 | 1,198 | 1,321 | 1,579 |
| Ferroalloy Production | 2,152 | 1,893 | 1,459 | 1,349 | 1,305 | 1,419 | 1,392 | 1,505 |
| Phosphoric Acid Production | 1,529 | 1,382 | 1,264 | 1,338 | 1,382 | 1,395 | 1,386 | 1,167 |
| Zinc Production | 949 | 1,140 | 986 | 937 | 507 | 477 | 465 | 529 |
| Petroleum Systems | 376 | 325 | 325 | 320 | 316 | 302 | 287 | 293 |
| Lead Production | 285 | 311 | 291 | 286 | 289 | 263 | 266 | 270 |
| Silicon Carbide Production and Consumption | 375 | 248 | 199 | 183 | 202 | 224 | 219 | 207 |
| *Land Use, Land-Use Change, and Forestry (Sink)[a]* | *(737,677)* | *(673,608)* | *(750,191)* | *(826,758)* | *(860,912)* | *(873,660)* | *(878,605)* | *(883,665)* |
| *Wood Biomass and Ethanol Consumption[b]* | *219,341* | *227,276* | *203,163* | *204,351* | *209,537* | *224,825* | *227,366* | *234,726* |
| *International Bunker Fuels[b]* | *113,683* | *101,125* | *97,563* | *89,101* | *103,583* | *118,975* | *122,580* | *127,097* |
| **$CH_4$** | **28,861** | **27,346** | **26,608** | **26,832** | **26,637** | **25,979** | **25,698** | **26,442** |
| Enteric Fermentation | 6,044 | 5,933 | 5,886 | 5,896 | 5,931 | 5,828 | 5,928 | 6,010 |
| Landfills | 7,124 | 5,751 | 5,598 | 5,720 | 5,981 | 5,838 | 5,890 | 5,985 |
| Natural Gas Systems | 5,937 | 6,024 | 5,968 | 5,946 | 5,874 | 5,426 | 4,880 | 4,877 |
| Coal Mining | 4,003 | 2,874 | 2,874 | 2,707 | 2,709 | 2,846 | 2,717 | 2,784 |
| Manure Management | 1,474 | 1,847 | 1,915 | 1,964 | 1,938 | 1,908 | 1,988 | 1,972 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Petroleum Systems | 1,612 | 1,442 | 1,436 | 1,422 | 1,390 | 1,368 | 1,346 | 1,354 |
| Forest Land Remaining Forest Land | 213 | 904 | 448 | 780 | 416 | 330 | 586 | 1,169 |
| Wastewater Treatment | 1,096 | 1,173 | 1,150 | 1,148 | 1,140 | 1,141 | 1,131 | 1,136 |
| Stationary Combustion | 353 | 316 | 295 | 295 | 306 | 311 | 308 | 296 |
| Rice Cultivation | 339 | 357 | 364 | 325 | 328 | 360 | 326 | 282 |
| Abandoned Underground Coal Mines | 288 | 350 | 319 | 293 | 284 | 276 | 265 | 257 |
| Mobile Combustion | 224 | 162 | 157 | 141 | 131 | 126 | 119 | 112 |
| Composting | 15 | 60 | 60 | 61 | 69 | 74 | 75 | 75 |
| Petrochemical Production | 41 | 58 | 51 | 52 | 51 | 55 | 51 | 48 |
| Iron and Steel Production | 63 | 58 | 51 | 48 | 49 | 50 | 45 | 45 |
| Field Burning of Agricultural Residues | 33 | 38 | 37 | 34 | 38 | 42 | 41 | 39 |
| Ferroalloy Production | 1 | 1 | + | + | + | + | + | + |
| Silicon Carbide Production and Consumption | 1 | 1 | + | + | + | + | + | + |
| *International Bunker Fuels*[b] | *8* | *6* | *5* | *4* | *6* | *7* | *7* | *7* |
| **$N_2O$** | **1,237** | **1,245** | **1,267** | **1,213** | **1,150** | **1,140** | **1,194** | **1,187** |
| Agricultural Soil Management | 869 | 845 | 894 | 845 | 798 | 796 | 855 | 855 |
| Mobile Combustion | 140 | 169 | 161 | 148 | 137 | 128 | 117 | 107 |
| Nitric Acid Production | 55 | 60 | 49 | 53 | 50 | 49 | 51 | 50 |
| Stationary Combustion | 41 | 47 | 46 | 45 | 46 | 47 | 48 | 47 |
| Manure Management | 39 | 44 | 45 | 45 | 44 | 44 | 45 | 46 |
| Wastewater Treatment | 20 | 24 | 25 | 25 | 25 | 25 | 26 | 26 |
| Adipic Acid Production | 49 | 20 | 16 | 20 | 20 | 19 | 19 | 19 |
| $N_2O$ from Product Uses | 14 | 16 | 16 | 14 | 14 | 14 | 14 | 14 |
| Forest Land Remaining Forest Land | 2 | 7 | 4 | 6 | 4 | 3 | 5 | 9 |
| Composting | 1 | 4 | 5 | 5 | 5 | 6 | 6 | 6 |
| Settlements Remaining Settlements | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 5 |
| Field Burning of Agricultural Residues | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Municipal Solid Waste Combustion | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *International Bunker Fuels*[b] | *3* | *3* | *3* | *3* | *3* | *3* | *4* | *4* |
| **HFCs** | **M** | **M** | **M** | **M** | **M** | **M** | **M** | **M** |
| Substitution of Ozone Depleting Substancesc | M | M | M | M | M | M | M | M |
| HCFC-22 Production | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| Semiconductor Manufacture | + | + | + | + | + | + | + | + |
| **PFCs** | **M** | **M** | **M** | **M** | **M** | **M** | **M** | **M** |
| Semiconductor Manufacture | M | M | M | M | M | M | M | M |
| Aluminum Production | M | M | M | M | M | M | M | M |
| **$SF_6$** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** |
| Electrical Transmission and Distribution | 1 | 1 | 1 | 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 International Bunker Fuels and Wood Biomass and Ethanol Consumption are not included in totals.
[c] 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 from Intergovernmental Panel on Climate Change (IPCC) guidance. Over the sixteen-year period of 1990 to 2006, total emissions in the Energy, Industrial Processes, and Agriculture sectors grew by 873.0 Tg $CO_2$ Eq. (17 percent), 21.0 Tg $CO_2$ Eq. (7 percent), and 6.6 Tg $CO_2$ Eq. (1 percent), respectively. Emissions decreased in the Waste and Solvent and Other Product Use sectors by 18.6 Tg $CO_2$ Eq. (10 percent) and less than 0.02 Tg $CO_2$ Eq. (less than 1 percent), respectively. Over the same period, estimates of net C sequestration in the Land Use, Land-Use Change, and Forestry sector increased by 122.2 Tg $CO_2$ Eq. (17 percent).

Figure 2-4: U.S. Greenhouse Gas Emissions 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** | **1995** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** |
|---|---|---|---|---|---|---|---|---|---|
| Energy | 5,203.9 | 5,529.6 | 6,067.8 | 5,982.8 | 6,036.3 | 6,078.3 | 6,150.9 | 6,174.4 | 6,076.9 |
| Industrial Processes | 299.9 | 315.7 | 326.5 | 297.9 | 308.6 | 301.2 | 315.9 | 315.5 | 320.9 |
| Solvent and Other Product Use | 4.4 | 4.6 | 4.9 | 4.9 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 |
| Agriculture | 447.5 | 453.8 | 447.9 | 463.7 | 449.0 | 434.3 | 432.1 | 453.6 | 454.1 |
| Land Use, Land-Use Change, and Forestry (Emissions) | 13.1 | 13.6 | 30.0 | 20.0 | 28.4 | 19.7 | 17.1 | 23.2 | 36.9 |
| Waste | 179.6 | 176.8 | 155.6 | 152.1 | 154.5 | 160.3 | 157.7 | 158.7 | 161.0 |
| **Total Emissions** | **6,148.3** | **6,494.0** | **7,032.6** | **6,921.3** | **6,981.2** | **6,998.2** | **7,078.0** | **7,129.9** | **7,054.2** |
| Net $CO_2$ Flux from Land Use, Land-Use Change, and Forestry (Sinks)* | (737.7) | (775.3) | (673.6) | (750.2) | (826.8) | (860.9) | (873.7) | (878.6) | (883.7) |
| **Net Emissions (Sources and Sinks)** | **5,410.6** | **5,718.7** | **6,359.0** | **6,171.1** | **6,154.4** | **6,137.3** | **6,204.3** | **6,251.3** | **6,170.5** |

* The net $CO_2$ flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total.
Note: Totals may not sum due to independent rounding.
Note: Parentheses indicate negative values or sequestration.

## Energy

Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. $CO_2$ emissions for the period of 1990 through 2006. In 2006, approximately 83 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 17 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 (37 percent and 13 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: 2006 Energy Chapter Greenhouse Gas Sources

Figure 2-6: 2006 U.S. Fossil C Flows (Tg $CO_2$ Eq.)

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

| Gas/Source | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **4,886.4** | **5,215.5** | **5,765.7** | **5,686.4** | **5,749.1** | **5,796.6** | **5,878.8** | **5,920.5** | **5,825.6** |
| Fossil Fuel Combustion | 4,724.1 | 5,032.4 | 5,577.1 | 5,507.4 | 5,564.8 | 5,617.0 | 5,681.4 | 5,731.0 | 5,637.9 |
| Electricity Generation | 1,809.6 | 1,939.3 | 2,283.1 | 2,314.9 | 2,380.2 | 2,328.2 | 2,283.1 | 2,314.9 | 2,380.2 |
| Transportation | 1,473.5 | 1,590.2 | 1,801.5 | 1,849.3 | 1,862.6 | 1,848.7 | 1,801.5 | 1,849.3 | 1,862.6 |
| Industrial | 849.9 | 880.6 | 858.8 | 861.0 | 850.9 | 866.1 | 858.8 | 861.0 | 850.9 |
| Residential | 344.4 | 359.9 | 385.0 | 370.8 | 360.9 | 328.7 | 385.0 | 370.8 | 360.9 |
| Commercial | 218.5 | 227.5 | 237.6 | 231.9 | 223.2 | 211.4 | 237.6 | 231.9 | 223.2 |
| US Territories | 28.3 | 35.0 | 51.0 | 53.5 | 53.2 | 54.9 | 51.0 | 53.5 | 53.2 |
| Non-Energy Use of Fuels | 117.2 | 133.2 | 141.4 | 131.9 | 135.9 | 131.8 | 148.9 | 139.1 | 138.0 |
| Natural Gas Systems | 33.7 | 33.8 | 29.4 | 28.8 | 29.6 | 28.4 | 28.1 | 29.5 | 28.5 |
| Municipal Solid Waste Combustion | 10.9 | 15.7 | 17.5 | 18.0 | 18.5 | 19.1 | 20.1 | 20.7 | 20.9 |
| Petroleum Systems | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| *Biomass—Wood** | *215.2* | *229.1* | *218.1* | *193.5* | *192.8* | *193.8* | *205.1* | *204.8* | *204.4* |
| *International Bunker Fuels** | *113.7* | *100.6* | *101.1* | *97.6* | *89.1* | *103.6* | *119.0* | *122.6* | *127.1* |
| *Biomass—Ethanol** | *4.2* | *7.7* | *9.2* | *9.7* | *11.5* | *15.7* | *19.7* | *22.6* | *30.3* |
| **$CH_4$** | **260.7** | **246.8** | **234.5** | **232.0** | **226.9** | **224.6** | **217.4** | **202.3** | **203.3** |
| Natural Gas Systems | 124.7 | 128.1 | 126.5 | 125.3 | 124.9 | 123.3 | 114.0 | 102.5 | 102.4 |
| Coal Mining | 84.1 | 67.1 | 60.4 | 60.3 | 56.8 | 56.9 | 59.8 | 57.1 | 58.5 |
| Petroleum Systems | 33.9 | 32.0 | 30.3 | 30.2 | 29.9 | 29.2 | 28.7 | 28.3 | 28.4 |
| Stationary Combustion | 7.4 | 7.2 | 6.6 | 6.2 | 6.2 | 6.4 | 6.5 | 6.5 | 6.2 |
| Abandoned Underground Coal Mines | 6.0 | 8.2 | 7.4 | 6.7 | 6.2 | 6.0 | 5.8 | 5.6 | 5.4 |
| Mobile Combustion | 4.7 | 4.3 | 3.4 | 3.3 | 3.0 | 2.7 | 2.6 | 2.5 | 2.4 |
| *International Bunker Fuels** | *0.2* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.2* | *0.2* |
| **$N_2O$** | **56.8** | **67.3** | **67.5** | **64.4** | **60.4** | **57.1** | **54.7** | **51.5** | **48.0** |
| Mobile Combustion | 43.5 | 53.4 | 52.5 | 49.9 | 45.9 | 42.3 | 39.7 | 36.3 | 33.1 |
| Stationary Combustion | 12.8 | 13.4 | 14.6 | 14.1 | 14.0 | 14.3 | 14.6 | 14.8 | 14.5 |
| Municipal Solid Waste Combustion | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| *International Bunker Fuels** | *1.0* | *0.9* | *0.9* | *0.9* | *0.8* | *0.9* | *1.1* | *1.1* | *1.1* |
| **Total** | **5,203.9** | **5,529.6** | **6,067.8** | **5,982.8** | **6,036.3** | **6,078.3** | **6,150.9** | **6,174.4** | **6,076.9** |

* These values are presented for informational purposes only and are not included in totals or are already accounted for in other source categories.

Note: Totals may not sum due to independent rounding.

$CO_2$ 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 electricity generation sector consists of privately and publicly owned establishments that generate, transmit, distribute, or sell electricity primarily for use by the public and that meet EIA's definition of an electric utility (EIA does not include nonutility power producers in this sector). 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 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **Transportation** | **1,488.1** | **1,602.5** | **1,801.6** | **1,779.2** | **1,832.3** | **1,811.8** | **1,860.9** | **1,874.5** | **1,861.0** |
| Combustion | 1,485.1 | 1,599.4 | 1,798.2 | 1,775.6 | 1,828.9 | 1,807.6 | 1,856.4 | 1,869.8 | 1,856.0 |
| Electricity | 3.0 | 3.0 | 3.4 | 3.6 | 3.4 | 4.2 | 4.5 | 4.7 | 4.9 |
| **Industrial** | **1,527.5** | **1,589.5** | **1,645.1** | **1,583.9** | **1,572.5** | **1,592.1** | **1,596.8** | **1,579.6** | **1,567.1** |
| Combustion | 844.9 | 876.5 | 860.3 | 852.5 | 854.8 | 856.0 | 857.7 | 847.3 | 862.2 |
| Electricity | 682.5 | 713.1 | 784.7 | 731.4 | 717.7 | 736.1 | 739.0 | 732.3 | 704.9 |
| **Residential** | **929.5** | **995.5** | **1,129.7** | **1,121.8** | **1,145.6** | **1,178.3** | **1,173.1** | **1,206.4** | **1,151.9** |
| Combustion | 340.1 | 356.5 | 372.1 | 363.6 | 360.5 | 382.9 | 368.3 | 358.5 | 326.5 |
| Electricity | 589.4 | 639.0 | 757.6 | 758.1 | 785.1 | 795.4 | 804.9 | 847.9 | 825.4 |
| **Commercial** | **750.8** | **810.0** | **964.6** | **973.5** | **970.3** | **983.8** | **997.1** | **1,017.3** | **1,003.0** |
| Combustion | 216.1 | 225.8 | 228.0 | 222.3 | 222.8 | 236.5 | 230.6 | 221.9 | 210.1 |
| Electricity | 534.7 | 584.2 | 736.6 | 751.1 | 747.5 | 747.3 | 766.5 | 795.4 | 792.9 |
| **U.S. Territories** | **28.3** | **35.0** | **36.2** | **49.0** | **44.0** | **51.0** | **53.5** | **53.2** | **54.9** |
| **Total** | **4,724.1** | **5,032.4** | **5,577.1** | **5,507.4** | **5,564.8** | **5,617.0** | **5,681.4** | **5,731.0** | **5,637.9** |
| **Electricity Generation** | **1,809.6** | **1,939.3** | **2,282.3** | **2,244.3** | **2,253.7** | **2,283.1** | **2,314.9** | **2,380.2** | **2,328.2** |

Note: Totals may not sum due to independent rounding. Combustion-related emissions from electricity generation are allocated based on aggregate national electricity consumption by each end-use sector.

Figure 2-7: 2006 $CO_2$ Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Figure 2-8: 2006 End-Use Sector Emissions of $CO_2$ from Fossil Fuel Combustion

The main driver of emissions in the energy sector is $CO_2$ from fossil fuel combustion. The transportation end-use sector accounted for 1,861.0 Tg $CO_2$ Eq. in 2006, or approximately 33 percent of total $CO_2$ emissions from fossil fuel combustion, the largest share of any end-use economic sector.[3] The industrial end-use sector accounted for 28 percent of $CO_2$ emissions from fossil fuel combustion. The residential and commercial end-use sectors accounted for an average 20 and 18 percent, respectively, of $CO_2$ emissions from fossil fuel combustion. Both end-use sectors were heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances contributing to about 72 and 79 percent of emissions from the residential and commercial end-use sectors, respectively. Significant trends in emissions from energy source categories over the sixteen-year period from 1990 through 2006 included the following:

- Total $CO_2$ emissions from fossil fuel combustion increased from 4,724.1 Tg $CO_2$ Eq. to 5,637.9 Tg $CO_2$ Eq.—a 19.3 percent total increase over the sixteen-year period. From 2005 to 2006, these emissions decreased by 93.1 Tg $CO_2$ Eq. (1.6 percent).
- $CO_2$ emissions from non-energy use of fossil fuels have increased 20.8 Tg $CO_2$ Eq. (18 percent) from 1990 through 2006. Emissions from non-energy uses of fossil fuels were 138.0 Tg $CO_2$ Eq. in 2006, which constituted 2.4 percent of overall fossil fuel $CO_2$ emissions and 2.3 percent of total national $CO_2$ emissions,

[3] Note that electricity generation is the largest emitter of $CO_2$ when electricity is not distributed among end-use sectors.

approximately the same proportion as in 1990.

- $CH_4$ emissions from natural gas systems were 102.4 Tg $CO_2$ Eq. in 2006; emissions have declined by 22.3 Tg $CO_2$ Eq. (18 percent) since 1990. This decline has been due to improvements in technology and management practices, as well as some replacement of old equipment.

- $CH_4$ emissions from coal mining were 58.5 Tg $CO_2$ Eq. This decline of 25.6 Tg $CO_2$ Eq. (30 percent) from 1990 results from the mining of less gassy coal from underground mines and the increased use of $CH_4$ collected from degasification systems.

- In 2006, $N_2O$ emissions from mobile combustion were 33.1 Tg $CO_2$ Eq. (approximately 9 percent of U.S. $N_2O$ emissions). From 1990 to 2006, $N_2O$ emissions from mobile combustion decreased by 24 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.

- $CO_2$ emissions from municipal solid waste combustion (20.9 Tg $CO_2$ Eq. in 2006) increased by 10.0 Tg $CO_2$ Eq. (91 percent) from 1990 through 2006, as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.

## Industrial Processes

Emissions are produced as a by-product of many non-energy-related industrial process activities. For example, industrial processes can chemically transform raw materials, which often release waste gases such as $CO_2$, $CH_4$, and $N_2O$. These processes include iron and steel production, cement manufacture, ammonia manufacture and urea consumption, lime manufacture, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash manufacture and use, titanium dioxide production, phosphoric acid production, ferroalloy production, $CO_2$ 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). Additionally, emissions from industrial processes release HFCs, PFCs and $SF_6$. Table 2-6 presents greenhouse gas emissions from industrial processes by source category.

Figure 2-9: 2006 Industrial Processes Chapter Greenhouse Gas Sources

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

| Gas/Source | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **175.0** | **171.6** | **166.5** | **151.9** | **151.0** | **147.8** | **151.8** | **145.9** | **149.5** |
| Iron and Steel Production | 86.2 | 74.7 | 66.6 | 59.2 | 55.9 | 54.7 | 52.8 | 46.6 | 49.1 |
| Cement Manufacture | 33.3 | 36.8 | 41.2 | 41.4 | 42.9 | 43.1 | 45.6 | 45.9 | 45.7 |
| Lime Manufacture | 12.0 | 14.0 | 14.9 | 14.3 | 13.7 | 14.5 | 15.2 | 15.1 | 15.8 |
| Ammonia Manufacture & Urea Consumption | 16.9 | 17.8 | 16.4 | 13.3 | 14.2 | 12.5 | 13.2 | 12.8 | 12.4 |
| Limestone and Dolomite Use | 5.5 | 7.4 | 6.0 | 5.7 | 5.9 | 4.8 | 6.7 | 7.4 | 8.6 |
| Soda Ash Manufacture and Consumption | 4.1 | 4.3 | 4.2 | 4.1 | 4.1 | 4.1 | 4.2 | 4.2 | 4.2 |
| Aluminum Production | 6.8 | 5.7 | 6.1 | 4.4 | 4.5 | 4.5 | 4.2 | 4.2 | 3.9 |
| Petrochemical Production | 2.2 | 2.8 | 3.0 | 2.8 | 2.9 | 2.8 | 2.9 | 2.8 | 2.6 |
| Titanium Dioxide Production | 1.2 | 1.5 | 1.8 | 1.7 | 1.8 | 1.8 | 2.1 | 1.8 | 1.9 |
| Carbon Dioxide Consumption | 1.4 | 1.4 | 1.4 | 0.8 | 1.0 | 1.3 | 1.2 | 1.3 | 1.6 |
| Ferroalloy Production | 2.2 | 2.0 | 1.9 | 1.5 | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 |
| Phosphoric Acid Production | 1.5 | 1.5 | 1.4 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 1.2 |
| Zinc Production | 0.9 | 1.0 | 1.1 | 1.0 | 0.9 | 0.5 | 0.5 | 0.5 | 0.5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lead Production | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Silicon Carbide Production and Consumption | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| **$CH_4$** | **2.2** | **2.4** | **2.5** | **2.2** | **2.1** | **2.1** | **2.2** | **2.0** | **2.0** |
| Petrochemical Production | 0.9 | 1.1 | 1.2 | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.0 |
| Iron and Steel Production | 1.3 | 1.3 | 1.2 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |
| Ferroalloy Production | + | + | + | + | + | + | + | + | + |
| Silicon Carbide Production and Consumption | + | + | + | + | + | + | + | + | + |
| **$N_2O$** | **32.3** | **36.2** | **24.8** | **20.2** | **22.4** | **21.7** | **21.2** | **21.7** | **21.6** |
| Nitric Acid Production | 17.0 | 18.9 | 18.6 | 15.1 | 16.4 | 15.4 | 15.2 | 15.8 | 15.6 |
| Adipic Acid Production | 15.3 | 17.3 | 6.2 | 5.1 | 6.1 | 6.3 | 5.9 | 5.9 | 5.9 |
| **HFCs** | **36.9** | **61.8** | **100.1** | **97.9** | **106.3** | **104.5** | **116.6** | **121.4** | **124.5** |
| Substitution of Ozone Depleting Substances | 0.3 | 28.5 | 71.2 | 78.0 | 85.0 | 92.0 | 99.1 | 105.4 | 110.4 |
| HCFC-22 Production | 36.4 | 33.0 | 28.6 | 19.7 | 21.1 | 12.3 | 17.2 | 15.8 | 13.8 |
| Semiconductor Manufacture | 0.2 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| **PFCs** | **20.8** | **15.6** | **13.5** | **7.0** | **8.7** | **7.1** | **6.1** | **6.2** | **6.0** |
| Semiconductor Manufacture | 2.2 | 3.8 | 4.9 | 3.5 | 3.5 | 3.3 | 3.3 | 3.2 | 3.6 |
| Aluminum Production | 18.5 | 11.8 | 8.6 | 3.5 | 5.2 | 3.8 | 2.8 | 3.0 | 2.5 |
| **$SF_6$** | **32.7** | **28.0** | **19.1** | **18.7** | **18.0** | **18.1** | **18.0** | **18.2** | **17.3** |
| Electrical Transmission and Distribution | 26.7 | 21.5 | 15.1 | 15.0 | 14.4 | 13.8 | 13.9 | 14.0 | 13.2 |
| Magnesium Production and Processing | 5.4 | 5.6 | 3.0 | 2.9 | 2.9 | 3.4 | 3.2 | 3.3 | 3.2 |
| Semiconductor Manufacture | 0.5 | 0.9 | 1.1 | 0.7 | 0.7 | 0.8 | 0.8 | 1.0 | 1.0 |
| **Total** | **299.9** | **315.7** | **326.5** | **297.9** | **308.6** | **301.2** | **315.9** | **315.5** | **320.9** |

+ 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 industrial processes increased by 7.0 percent from 1990 to 2006 despite decreases in emissions from several industrial processes, such as iron and steel, aluminum production, HCFC-22 production, and electrical transmission and distribution. The increase in overall emissions was driven by a rise in the emissions originating from cement manufacture and, primarily, the emissions from the use of substitutes for ozone depleting substances. Significant trends in emissions from industrial processes source categories over the sixteen-year period from 1990 through 2006 included the following:

- HFC emissions from ODS substitutes have been increasing from small amounts in 1990 to 110.4 Tg $CO_2$ Eq. in 2006. 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*.

- $CO_2$ and $CH_4$ emissions from iron and steel production increased by 5.2 percent to 50.1 Tg $CO_2$ Eq. in 2006, but have declined overall by 37.5 Tg $CO_2$ Eq. (42.8 percent) from 1990 through 2006, due to restructuring of the industry, technological improvements, and increased scrap utilization.

- PFC emissions from aluminum production decreased by 87 percent (16.1 Tg $CO_2$ Eq.) from 1990 to 2006, due to both industry emission reduction efforts and lower domestic aluminum production.

- $N_2O$ emissions from adipic acid production were 5.9 Tg $CO_2$ Eq. in 2006, and have decreased significantly in recent years from the widespread installation of pollution control measures. Emissions from adipic acid production have decreased 61 percent since 1990, and emissions from adipic acid production have fluctuated by less than 1 Tg $CO_2$ Eq. annually since 1998.

- $CO_2$ emissions from ammonia manufacture and urea consumption (12.4 Tg $CO_2$ Eq. in 2006) have decreased by 4.5 Tg $CO_2$ Eq. (27 percent) since 1990, due to a decrease in domestic ammonia manufacture. This decrease in ammonia manufacture can be attributed to market fluctuations and high natural gas prices.

## 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. emissions in 2006 (see Table 2-7).

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

| Gas/Source | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$N_2O$** | **4.4** | **4.6** | **4.9** | **4.9** | **4.4** | **4.4** | **4.4** | **4.4** | **4.4** |
| $N_2O$ from Product Uses | 4.4 | 4.6 | 4.9 | 4.9 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 |
| **Total** | **4.4** | **4.6** | **4.9** | **4.9** | **4.4** | **4.4** | **4.4** | **4.4** | **4.4** |

- In 2006, $N_2O$ emissions from product uses constituted 1 percent of U.S. $N_2O$ emissions. From 1990 to 2006, emissions from this source category decreased by less than 1 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 2006, agricultural activities were responsible for emissions of 454.1 Tg $CO_2$ Eq., or 6.4 percent of total U.S. greenhouse gas emissions. $CH_4$ and $N_2O$ were the primary greenhouse gases emitted by agricultural activities. $CH_4$ emissions from enteric fermentation and manure management represented about 23 percent and 7 percent of total $CH_4$ emissions from anthropogenic activities, respectively, in 2006. Agricultural soil management activities, such as fertilizer application and other cropping practices, were the largest source of U.S. $N_2O$ emissions in 2006, accounting for 72 percent.

Figure 2-10: 2006 Agriculture Chapter Greenhouse Gas Sources

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

| Gas/Source | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$CH_4$** | **165.7** | **175.8** | **171.7** | **172.2** | **172.6** | **173.0** | **170.9** | **174.0** | **174.4** |
| Enteric Fermentation | 126.9 | 132.3 | 124.6 | 123.6 | 123.8 | 124.6 | 122.4 | 124.5 | 126.2 |
| Manure Management | 31.0 | 35.2 | 38.8 | 40.2 | 41.3 | 40.7 | 40.1 | 41.8 | 41.4 |
| Rice Cultivation | 7.1 | 7.6 | 7.5 | 7.6 | 6.8 | 6.9 | 7.6 | 6.8 | 5.9 |
| Field Burning of Agricultural Residues | 0.7 | 0.7 | 0.8 | 0.8 | 0.7 | 0.8 | 0.9 | 0.9 | 0.8 |
| **$N_2O$** | **281.8** | **278.0** | **276.3** | **291.5** | **276.4** | **261.3** | **261.2** | **279.6** | **279.8** |
| Agricultural Soil Management | 269.4 | 264.8 | 262.1 | 277.0 | 262.0 | 247.3 | 246.9 | 265.2 | 265.0 |
| Manure Management | 12.1 | 12.8 | 13.7 | 14.0 | 14.0 | 13.6 | 13.8 | 13.9 | 14.3 |
| Field Burning of Agricultural Residues | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 |
| **Total** | **447.5** | **453.8** | **447.9** | **463.7** | **449.0** | **434.3** | **432.1** | **453.6** | **454.1** |

Note: Totals may not sum due to independent rounding.

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

- Agricultural soils produced approximately 72 percent of $N_2O$ emissions in the United States in 2006. Estimated emissions from this source in 2006 were 265.0 Tg $CO_2$ Eq. Annual $N_2O$ emissions from agricultural soils fluctuated between 1990 and 2006, although overall emissions were 1.6 percent lower in 2006 than in 1990.

- Enteric fermentation was the largest source of $CH_4$ emissions in 2006, at 126.2 Tg $CO_2$ Eq. Although emissions from enteric fermentation have decreased by less than 1 percent between 1990 and 2006, emissions increased about 2 percent between 1990 and 1994 and decreased 8 percent 1995 to 2004, mainly due to decreasing populations of both beef and dairy cattle and improved feed quality for feedlot cattle. The last two years have shown an increase in emissions. During this timeframe, populations of sheep have decreased 45 percent since 1990 while horse populations have increased over 80 percent, mostly over the last 5 years. Goat and swine populations have increased 1 percent and 14 percent, respectively, during this timeframe.

- Overall, emissions from manure management increased 29 percent between 1990 and 2006. This encompassed an increase of 34 percent for $CH_4$, from 31.0 Tg $CO_2$ Eq. in 1990 to 41.4 Tg $CO_2$ Eq. in 2006; and an increase of 18 percent for $N_2O$, from 12.1 Tg $CO_2$ Eq. in 1990 to 14.3 Tg $CO_2$ Eq. in 2006. 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 13 percent of total U.S. greenhouse gas emissions in 2006. Forests (including vegetation, soils, and harvested wood) accounted for approximately 84 percent of total 2006 net $CO_2$ flux, urban trees accounted for 11 percent, mineral and organic soil carbon stock changes accounted for 5 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total net flux in 2006. 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 70 percent more C than is emitted through these soils, liming, and urea fertilization, combined. 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 carbon and food scraps in landfills.

Land use, land-use change, and forestry activities in 2006 resulted in a net C flux of -883.7 Tg $CO_2$ Eq. (Table 2-9). This represents an offset of approximately 14.8 percent of total U.S. $CO_2$ emissions, or 12.5 percent of total greenhouse gas emissions in 2006. Between 1990 and 2006, total land use, land-use change, and forestry net C flux resulted in a 20 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 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| Forest Land Remaining Forest Land | (621.7) | (659.9) | (550.7) | (623.4) | (697.3) | (730.9) | (741.4) | (743.6) | (745.1) |
| Cropland Remaining Cropland | (30.1) | (39.4) | (38.4) | (40.0) | (40.3) | (40.5) | (40.9) | (41.0) | (41.8) |
| Land Converted to | 14.7 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cropland Grassland Remaining Grassland | (1.9) | 16.6 | 16.4 | 16.4 | 16.4 | 16.4 | 16.3 | 16.3 | 16.2 |
| Land Converted to Grassland | (14.3) | (16.3) | (16.3) | (16.3) | (16.3) | (16.3) | (16.3) | (16.3) | (16.3) |
| Settlements Remaining Settlements | (60.6) | (71.5) | (82.4) | (84.6) | (86.8) | (88.9) | (91.1) | (93.3) | (95.5) |
| Other (Landfilled Yard Trimmings and Food Scraps) | (23.9) | (14.1) | (11.5) | (11.6) | (11.8) | (10.0) | (9.6) | (10.0) | (10.5) |
| **Total** | **(737.7)** | **(775.3)** | **(673.6)** | **(750.2)** | **(826.8)** | **(860.9)** | **(873.7)** | **(878.6)** | **(883.7)** |

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 2006, and increase of 13 percent relative to 1990. The application of synthetic fertilizers to forest and settlement soils in 2006 resulted in direct $N_2O$ emissions of 1.8 Tg $CO_2$ Eq. Direct $N_2O$ emissions from fertilizer application increased by approximately 74 percent between 1990 and 2006. Emissions of $CH_4$ and $N_2O$ from forest fires fluctuate widely from year to year, but overall increased by 449 percent between 1990 and 2006 (Table 2-10).

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

| Source Category | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **7.1** | **7.0** | **7.5** | **7.8** | **8.5** | **8.3** | **7.6** | **7.9** | **8.0** |
| Cropland Remaining Cropland: Liming of Agricultural Soils & Urea Fertilization | 7.1 | 7.0 | 7.5 | 7.8 | 8.5 | 8.3 | 7.6 | 7.9 | 8.0 |
| **$CH_4$** | **4.5** | **4.7** | **19.0** | **9.4** | **16.4** | **8.7** | **6.9** | **12.3** | **24.6** |
| Forest Land Remaining Forest Land: Forest Fires | 4.5 | 4.7 | 19.0 | 9.4 | 16.4 | 8.7 | 6.9 | 12.3 | 24.6 |
| **$N_2O$** | **1.5** | **1.8** | **3.5** | **2.7** | **3.5** | **2.7** | **2.6** | **3.1** | **4.3** |
| Forest Land Remaining Forest Land: Forest Fires | 0.5 | 0.5 | 1.9 | 1.0 | 1.7 | 0.9 | 0.7 | 1.2 | 2.5 |
| Forest Land Remaining Forest Land: Forest Soils | 0.1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Settlements Remaining Settlements: Settlement Soils | 1.0 | 1.2 | 1.2 | 1.4 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 |
| **Total** | **13.1** | **13.6** | **30.0** | **20.0** | **28.4** | **19.7** | **17.1** | **23.2** | **36.9** |

Note: Totals may not sum due to independent rounding.

Other significant trends from 1990 to 2006 in land use, land-use change, and forestry emissions include:

- Net C sequestration by forest land has increased 20 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 16 years, although only at an average rate of 0.1 percent per year.

- Net sequestration of C by urban trees has increased by 57 percent over this sixteen-year period. 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 56 percent. 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 2006, landfills were the second largest source of anthropogenic $CH_4$ emissions, accounting for 23 percent of total U.S. $CH_4$ emissions.[4] Additionally, wastewater treatment accounts for 4 percent of U.S. $CH_4$ emissions, and 2 percent of $N_2O$ emissions. Emissions of $CH_4$ and $N_2O$ from composting grew from 1990 to 2006, and resulted in emissions of 3.3 Tg $CO_2$ Eq. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 2-11.

Figure 2-11: 2006 Waste Chapter Greenhouse Gas Sources

Overall, in 2006, waste activities generated emissions of 161.0 Tg $CO_2$ Eq., or 2.3 percent of total U.S. greenhouse gas emissions.

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

| Gas/Source | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$CH_4$** | **172.9** | **169.1** | **146.7** | **143.0** | **145.5** | **151.0** | **148.1** | **149.0** | **151.1** |
| Landfills | 149.6 | 144.0 | 120.8 | 117.6 | 120.1 | 125.6 | 122.6 | 123.7 | 125.7 |
| Wastewater Treatment | 23.0 | 24.3 | 24.6 | 24.2 | 24.1 | 23.9 | 24.0 | 23.8 | 23.9 |
| Composting | 0.3 | 0.7 | 1.3 | 1.3 | 1.3 | 1.5 | 1.6 | 1.6 | 1.6 |
| **$N_2O$** | **6.6** | **7.7** | **8.9** | **9.2** | **9.0** | **9.3** | **9.6** | **9.7** | **9.9** |
| Wastewater Treatment | 6.3 | 6.9 | 7.6 | 7.8 | 7.6 | 7.7 | 7.8 | 8.0 | 8.1 |
| Composting | 0.4 | 0.8 | 1.4 | 1.4 | 1.4 | 1.6 | 1.7 | 1.7 | 1.8 |
| **Total** | **179.6** | **176.8** | **155.6** | **152.1** | **154.5** | **160.3** | **157.7** | **158.7** | **161.0** |

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from Waste include the following:

- From 1990 to 2006, net $CH_4$ emissions from landfills decreased by 23.9 Tg $CO_2$ Eq. (16 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,[5] which has more than offset the additional $CH_4$ emissions resulting from an increase in the amount of municipal solid waste landfilled.

- From 1990 to 2006, $CH_4$ and $N_2O$ emissions from wastewater treatment increased by 0.8 Tg $CO_2$ Eq. (4 percent) and 1.8 Tg $CO_2$ Eq. (29 percent), respectively.

- $CH_4$ and $N_2O$ emissions from composting each increased by less than 0.1 Tg $CO_2$ Eq. (1 percent) from 2005 to 2006. Emissions from composting have been continually increasing since 1990, from 0.7 Tg $CO_2$ Eq. to 3.3 Tg $CO_2$ Eq. in 2006, a four-fold increase over the time series.

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

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

## 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 U.S. greenhouse gas emissions in 2006. Transportation activities, in aggregate, accounted for the second largest portion (28 percent). Emissions from industry accounted for about 19 percent of U.S. greenhouse gas emissions in 2006. 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 percent, and primarily consisted of $CO_2$ emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 8 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions were dominated by $N_2O$ emissions from agricultural soil management and $CH_4$ emissions from enteric fermentation, rather than $CO_2$ from fossil fuel combustion. The commercial sector accounted for roughly 6 percent of emissions, while U.S. territories accounted for about 1 percent.

$CO_2$ was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Table 2-12 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 2006.

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 2006)

| Sector/Source | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Percent[a] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Electricity Generation** | **1,859.1** | **1,989.7** | **2,328.9** | **2,290.9** | **2,300.4** | **2,329.4** | **2,363.4** | **2,430.0** | **2,377.8** | **33.7%** |
| CO2 from Fossil Fuel Combustion | 1,809.6 | 1,939.3 | 2,282.3 | 2,244.3 | 2,253.7 | 2,283.1 | 2,314.9 | 2,380.2 | 2,328.2 | 33.0% |
| Stationary Combustion | 8.6 | 9.1 | 10.6 | 10.4 | 10.4 | 10.7 | 10.8 | 11.0 | 10.8 | 0.2% |
| Electrical Transmission and Distribution | 26.7 | 21.5 | 15.1 | 15.0 | 14.4 | 13.8 | 13.9 | 14.0 | 13.2 | 0.2% |
| Municipal Solid Waste Combustion | 11.4 | 16.2 | 17.9 | 18.4 | 18.9 | 19.5 | 20.5 | 21.1 | 21.3 | 0.3% |
| Limestone and Dolomite Use | 2.8 | 3.7 | 3.0 | 2.9 | 2.9 | 2.4 | 3.4 | 3.7 | 4.3 | 0.1% |
| **Transportation** | **1,544.1** | **1,685.8** | **1,917.5** | **1,895.8** | **1,948.5** | **1,925.9** | **1,975.4** | **1,987.2** | **1,969.5** | **27.9%** |
| $CO_2$ from Fossil Fuel Combustion | 1,485.1 | 1,599.4 | 1,798.2 | 1,775.6 | 1,828.9 | 1,807.6 | 1,856.4 | 1,869.8 | 1,856.0 | 26.3% |
| Mobile Combustion | 47.2 | 56.5 | 54.7 | 51.9 | 47.5 | 43.8 | 40.9 | 37.5 | 34.1 | 0.5% |
| Substitution of Ozone Depleting Substances | + | 18.6 | 52.6 | 57.2 | 61.1 | 64.4 | 67.8 | 69.7 | 69.5 | 1.0% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Non-Energy Use of Fuels | 11.9 | 11.3 | 12.1 | 11.1 | 10.9 | 10.1 | 10.2 | 10.2 | 9.9 | 0.1% |
| **Industry** | **1,460.3** | **1,478.0** | **1,432.9** | **1,384.3** | **1,384.9** | **1,375.5** | **1,388.9** | **1,354.3** | **1,371.5** | **19.4%** |
| $CO_2$ from Fossil Fuel Combustion | 798.2 | 819.1 | 809.4 | 801.8 | 801.9 | 811.0 | 806.6 | 801.8 | 818.6 | 11.6% |
| Non-Energy Use of Fuels | 99.6 | 115.9 | 118.4 | 115.5 | 115.8 | 113.2 | 131.4 | 121.8 | 120.8 | 1.7% |
| Stationary Combustion | 4.7 | 5.0 | 4.9 | 4.6 | 4.4 | 4.3 | 4.6 | 4.5 | 4.6 | 0.1% |
| Mobile Combustion | 0.6 | 0.7 | 0.8 | 0.9 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 0.0% |
| Coal Mining | 84.1 | 67.1 | 60.4 | 60.3 | 56.8 | 56.9 | 59.8 | 57.1 | 58.5 | 0.8% |
| Abandoned Underground Coal Mines | 6.0 | 8.2 | 7.4 | 6.7 | 6.2 | 6.0 | 5.8 | 5.6 | 5.4 | 0.1% |
| Natural Gas Systems | 158.4 | 161.9 | 155.9 | 154.1 | 154.5 | 151.8 | 142.1 | 132.0 | 130.9 | 1.9% |
| Petroleum Systems | 34.2 | 32.3 | 30.6 | 30.5 | 30.2 | 29.5 | 29.0 | 28.6 | 28.7 | 0.4% |
| Titanium Dioxide Production | 1.2 | 1.5 | 1.8 | 1.7 | 1.8 | 1.8 | 2.1 | 1.8 | 1.9 | 0.0% |
| Aluminum Production | 25.4 | 17.5 | 14.7 | 7.8 | 9.7 | 8.3 | 7.1 | 7.2 | 6.4 | 0.1% |
| Iron and Steel Production | 87.5 | 76.0 | 67.8 | 60.3 | 57.0 | 55.8 | 53.8 | 47.6 | 50.1 | 0.7% |
| Ferroalloy Production | 2.2 | 2.0 | 1.9 | 1.5 | 1.4 | 1.3 | 1.4 | 1.4 | 1.5 | 0.0% |
| Ammonia Manufacture and Urea Consumption | 16.9 | 17.8 | 16.4 | 13.3 | 14.2 | 12.5 | 13.2 | 12.8 | 12.4 | 0.2% |
| Cement Manufacture | 33.3 | 36.8 | 41.2 | 41.4 | 42.9 | 43.1 | 45.6 | 45.9 | 45.7 | 0.6% |
| Lime Manufacture | 12.0 | 14.0 | 14.9 | 14.3 | 13.7 | 14.5 | 15.2 | 15.1 | 15.8 | 0.2% |
| Limestone and Dolomite Use | 2.8 | 3.7 | 3.0 | 2.9 | 2.9 | 2.4 | 3.4 | 3.7 | 4.3 | 0.1% |
| Soda Ash Manufacture and Consumption | 4.1 | 4.3 | 4.2 | 4.1 | 4.1 | 4.1 | 4.2 | 4.2 | 4.2 | 0.1% |
| Carbon Dioxide Consumption | 1.4 | 1.4 | 1.4 | 0.8 | 1.0 | 1.3 | 1.2 | 1.3 | 1.6 | 0.0% |
| Silicon Carbide Production and Consumption | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.0% |
| Lead Production | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.0% |
| Zinc Production | 0.9 | 1.0 | 1.1 | 1.0 | 0.9 | 0.5 | 0.5 | 0.5 | 0.5 | 0.0% |
| Petrochemical Production | 3.1 | 3.8 | 4.2 | 3.9 | 4.0 | 3.9 | 4.1 | 3.9 | 3.6 | 0.1% |
| Phosphoric Acid Production | 1.5 | 1.5 | 1.4 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 1.2 | 0.0% |
| Adipic Acid Production | 15.3 | 17.3 | 6.2 | 5.1 | 6.1 | 6.3 | 5.9 | 5.9 | 5.9 | 0.1% |
| Nitric Acid Production | 17.0 | 18.9 | 18.6 | 15.1 | 16.4 | 15.4 | 15.2 | 15.8 | 15.6 | 0.2% |
| N2O Product Uses | 4.4 | 4.6 | 4.9 | 4.9 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 0.1% |
| HCFC-22 Production | 36.4 | 33.0 | 28.6 | 19.7 | 21.1 | 12.3 | 17.2 | 15.8 | 13.8 | 0.2% |
| Semiconductor Manufacture | 2.9 | 5.0 | 6.3 | 4.5 | 4.3 | 4.3 | 4.3 | 4.4 | 4.8 | 0.1% |
| Magnesium Production and Processing | 5.4 | 5.6 | 3.0 | 2.9 | 2.9 | 3.4 | 3.2 | 3.3 | 3.2 | 0.0% |
| Substitution of Ozone Depleting Substances | + | 1.2 | 3.1 | 3.1 | 3.7 | 4.4 | 4.8 | 5.2 | 5.7 | 0.1% |
| **Agriculture** | **506.8** | **524.1** | **528.0** | **533.4** | **529.3** | **498.0** | **499.2** | **521.3** | **533.6** | **7.6%** |
| $CO_2$ from Fossil Fuel | 46.76 | 57.32 | 50.88 | 50.69 | 52.89 | 45.02 | 51.12 | 45.52 | 43.60 | 0.6% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Combustion | | | | | | | | | | |
| Stationary Combustion | + | + | + | + | + | + | + | + | + | 0.0% |
| Mobile Combustion | 0.4 | 0.5 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.0% |
| Enteric Fermentation | 126.9 | 132.3 | 124.6 | 123.6 | 123.8 | 124.6 | 122.4 | 124.5 | 126.2 | 1.8% |
| Manure Management | 43.0 | 48.0 | 52.5 | 54.2 | 55.2 | 54.3 | 53.9 | 55.7 | 55.7 | 0.8% |
| Rice Cultivation | 7.1 | 7.6 | 7.5 | 7.6 | 6.8 | 6.9 | 7.6 | 6.8 | 5.9 | 0.1% |
| Field Burning of Agricultural Residues | 1.1 | 1.0 | 1.3 | 1.2 | 1.1 | 1.2 | 1.4 | 1.4 | 1.3 | 0.0% |
| $N_2O$ from Agricultural Soil Management | 269.4 | 264.8 | 262.1 | 277.0 | 262.0 | 247.3 | 246.9 | 265.2 | 265.0 | 3.8% |
| Liming of Agricultural Soils | 4.7 | 4.4 | 4.3 | 4.4 | 5.0 | 4.6 | 3.9 | 4.3 | 4.4 | 0.1% |
| Urea Fertilization | 2.4 | 2.7 | 3.2 | 3.4 | 3.6 | 3.7 | 3.7 | 3.5 | 3.6 | 0.1% |
| $CH_4$ and $N_2O$ from Forest Fires | 4.9 | 5.2 | 20.9 | 10.4 | 18.0 | 9.6 | 7.6 | 13.6 | 27.0 | 0.4% |
| $N_2O$ from Forest Soils | 0.1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.0% |
| **Commercial** | **396.9** | **404.5** | **390.3** | **383.0** | **388.1** | **410.2** | **404.6** | **400.4** | **394.6** | **5.6%** |
| $CO_2$ from Fossil Fuel Combustion | 216.1 | 225.8 | 228.0 | 222.3 | 222.8 | 236.5 | 230.6 | 221.9 | 210.1 | 3.0% |
| Stationary Combustion | 1.2 | 1.3 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.2 | 1.2 | 0.0% |
| Substitution of Ozone Depleting Substances | + | 0.7 | 5.5 | 7.4 | 9.6 | 12.1 | 15.0 | 18.5 | 22.4 | 0.3% |
| Landfills | 149.6 | 144.0 | 120.8 | 117.6 | 120.1 | 125.6 | 122.6 | 123.7 | 125.7 | 1.8% |
| Human Sewage | 6.3 | 6.9 | 7.6 | 7.8 | 7.6 | 7.7 | 7.8 | 8.0 | 8.1 | 0.1% |
| Wastewater Treatment | 23.0 | 24.3 | 24.6 | 24.2 | 24.1 | 23.9 | 24.0 | 23.8 | 23.9 | 0.3% |
| Composting | 0.7 | 1.5 | 2.6 | 2.7 | 2.7 | 3.1 | 3.3 | 3.3 | 3.3 | 0.0% |
| **Residential** | **346.9** | **370.9** | **387.7** | **379.3** | **376.6** | **399.6** | **385.5** | **376.0** | **344.8** | **4.9%** |
| $CO_2$ from Fossil Fuel Combustion | 340.1 | 356.5 | 372.1 | 363.6 | 360.5 | 382.9 | 368.3 | 358.5 | 326.5 | 4.6% |
| Stationary Combustion | 5.5 | 5.0 | 4.3 | 3.9 | 4.0 | 4.2 | 4.3 | 4.2 | 3.9 | 0.1% |
| Substitution of Ozone Depleting Substances | 0.3 | 8.1 | 10.1 | 10.3 | 10.7 | 11.0 | 11.4 | 11.9 | 12.9 | 0.2% |
| Settlement Soil Fertilization | 1.0 | 1.2 | 1.2 | 1.4 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 | 0.0% |
| **U.S. Territories** | **34.1** | **41.1** | **47.3** | **54.5** | **53.3** | **59.7** | **61.0** | **60.5** | **62.4** | **0.9%** |
| $CO_2$ from Fossil Fuel Combustion | 34.1 | 41.1 | 47.3 | 54.5 | 53.3 | 59.7 | 61.0 | 60.5 | 62.4 | 0.9% |
| **Total Emissions** | **6,148.3** | **6,494.0** | **7,032.6** | **6,921.3** | **6,981.2** | **6,998.2** | **7,078.0** | **7,129.9** | **7,054.2** | **100.0%** |
| **Sinks** | **(737.7)** | **(775.3)** | **(673.6)** | **(750.2)** | **(826.8)** | **(860.9)** | **(873.7)** | **(878.6)** | **(883.7)** | **-12.5%** |
| $CO_2$ Flux from Forests | (621.7) | (659.9) | (550.7) | (623.4) | (697.3) | (730.9) | (741.4) | (743.6) | (745.1) | -10.6% |
| Urban Trees | (60.6) | (71.5) | (82.4) | (84.6) | (86.8) | (88.9) | (91.1) | (93.3) | (95.5) | -1.4% |
| $CO_2$ Flux from Agricultural Soil Carbon Stocks | (31.5) | (29.7) | (29.0) | (30.6) | (30.9) | (31.1) | (31.5) | (31.7) | (32.6) | -0.5% |
| Landfilled Yard Trimmings and Food Scraps | (23.9) | (14.1) | (11.5) | (11.6) | (11.8) | (10.0) | (9.6) | (10.0) | (10.5) | -0.1% |
| **Net Emissions (Sources and Sinks)** | **5,410.6** | **5,718.7** | **6,359.0** | **6,171.1** | **6,154.4** | **6,137.3** | **6,204.3** | **6,251.3** | **6,170.5** | **87.5%** |

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%.

[a] Percent of total emissions for year 2006.

## 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 2006. Emissions increased by 28 percent since 1990, as electricity demand grew and fossil fuels remained the dominant energy source for generation. Electricity generation-related emissions decreased from 2005 to 2006 by 2 percent, primarily due to reduced $CO_2$ emissions from fossil fuel combustion. 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 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **1,823.3** | **1,958.6** | **2,302.8** | **2,265.1** | **2,275.1** | **2,304.5** | **2,338.4** | **2,404.6** | **2,353.4** |
| $CO_2$ from Fossil Fuel Combustion | 1,809.6 | 1,939.3 | 2,282.3 | 2,244.3 | 2,253.7 | 2,283.1 | 2,314.9 | 2,380.2 | 2,328.2 |
| *Coal* | *1,531.3* | *1,648.7* | *1,909.6* | *1,852.3* | *1,868.3* | *1,906.2* | *1,917.6* | *1,958.4* | *1,932.4* |
| *Natural Gas* | *176.2* | *229.5* | *280.9* | *289.6* | *306.0* | *278.3* | *296.8* | *319.1* | *339.6* |
| *Petroleum* | *101.8* | *60.7* | *91.5* | *102.0* | *79.1* | *98.1* | *100.1* | *102.3* | *55.7* |
| *Geothermal* | *0.4* | *0.3* | *0.4* | *0.4* | *0.4* | *0.4* | *0.4* | *0.4* | *0.4* |
| Municipal Solid Waste Combustion | 10.9 | 15.7 | 17.5 | 18.0 | 18.5 | 19.1 | 20.1 | 20.7 | 20.9 |
| Limestone and Dolomite Use | 2.8 | 3.7 | 3.0 | 2.9 | 2.9 | 2.4 | 3.4 | 3.7 | 4.3 |
| **$CH_4$** | **0.6** | **0.6** | **0.7** | **0.7** | **0.7** | **0.7** | **0.7** | **0.7** | **0.7** |
| Stationary Combustion* | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| **$N_2O$** | **8.5** | **9.0** | **10.4** | **10.1** | **10.1** | **10.4** | **10.5** | **10.7** | **10.5** |
| Stationary Combustion* | 8.1 | 8.6 | 10.0 | 9.7 | 9.7 | 10.0 | 10.0 | 10.3 | 10.1 |
| Municipal Solid Waste Combustion | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| **$SF_6$** | **26.7** | **21.5** | **15.1** | **15.0** | **14.4** | **13.8** | **13.9** | **14.0** | **13.2** |
| Electrical Transmission and Distribution | 26.7 | 21.5 | 15.1 | 15.0 | 14.4 | 13.8 | 13.9 | 14.0 | 13.2 |
| **Total** | **1,859.1** | **1,989.7** | **2,328.9** | **2,290.9** | **2,300.4** | **2,329.4** | **2,363.4** | **2,430.0** | **2,377.8** |

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

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

When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S. greenhouse gas emissions (29 percent), followed closely by emissions from transportation activities, which account for 28 percent of total emissions. Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption. In all sectors except agriculture, $CO_2$ accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

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

Table 2-14 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 2006.

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 2006

| Sector/Gas | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Percent[a] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Industry** | **2,100.4** | **2,141.1** | **2,174.3** | **2,061.1** | **2,051.6** | **2,064.0** | **2,075.4** | **2,038.3** | **2,029.2** | **28.5%** |
| Direct Emissions | 1,460.3 | 1,478.0 | 1,432.9 | 1,384.3 | 1,384.9 | 1,375.5 | 1,388.9 | 1,354.3 | 1,371.5 | 19.2% |
| $CO_2$ | 1,070.1 | 1,103.0 | 1,091.3 | 1,066.4 | 1,065.7 | 1,069.6 | 1,086.5 | 1,065.8 | 1,084.6 | 15.2% |
| $CH_4$ | 286.5 | 273.6 | 258.3 | 255.4 | 251.3 | 247.8 | 240.5 | 226.7 | 227.1 | 3.2% |
| $N_2O$ | 40.4 | 44.8 | 33.7 | 28.9 | 30.6 | 29.8 | 29.5 | 30.0 | 29.9 | 0.4% |
| HFCs, PFCs, and $SF_6$ | 63.3 | 56.6 | 49.6 | 33.6 | 37.3 | 28.2 | 32.4 | 31.7 | 30.0 | 0.4% |
| Electricity-Related | 640.1 | 663.1 | 741.4 | 676.8 | 666.7 | 688.5 | 686.5 | 683.9 | 657.7 | 9.2% |
| $CO_2$ | 627.7 | 652.8 | 733.1 | 669.2 | 659.4 | 681.1 | 679.2 | 676.8 | 650.9 | 9.1% |
| $CH_4$ | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.0% |
| $N_2O$ | 2.9 | 3.0 | 3.3 | 3.0 | 2.9 | 3.1 | 3.0 | 3.0 | 2.9 | 0.0% |
| $SF_6$ | 9.2 | 7.2 | 4.8 | 4.4 | 4.2 | 4.1 | 4.0 | 3.9 | 3.6 | 0.1% |
| **Transportation** | **1,547.2** | **1,688.9** | **1,921.0** | **1,899.4** | **1,952.0** | **1,930.2** | **1,980.0** | **1,992.0** | **1,974.5** | **27.7%** |
| Direct Emissions | 1,544.1 | 1,685.8 | 1,917.5 | 1,895.8 | 1,948.5 | 1,925.9 | 1,975.4 | 1,987.2 | 1,969.5 | 27.6% |
| $CO_2$ | 1,496.9 | 1,610.7 | 1,810.2 | 1,786.7 | 1,839.8 | 1,817.7 | 1,866.6 | 1,880.0 | 1,865.9 | 26.2% |
| $CH_4$ | 4.5 | 4.1 | 3.2 | 3.1 | 2.7 | 2.5 | 2.4 | 2.3 | 2.1 | 0.0% |
| $N_2O$ | 42.67 | 52.46 | 51.53 | 48.80 | 44.82 | 41.26 | 38.51 | 35.20 | 31.96 | 0.4% |
| HFCs[b] | + | 18.6 | 52.57 | 57.20 | 61.13 | 64.41 | 67.84 | 69.74 | 69.46 | 1.0% |
| Electricity-Related | 3.1 | 3.1 | 3.49 | 3.69 | 3.49 | 4.33 | 4.59 | 4.78 | 5.03 | 0.1% |
| $CO_2$ | 3.1 | 3.1 | 3.4 | 3.6 | 3.5 | 4.3 | 4.5 | 4.7 | 5.0 | 0.1% |
| $CH_4$ | + | + | + | + | + | + | + | + | + | 0.0% |
| $N_2O$ | + | + | + | + | + | + | + | + | + | 0.0% |
| $SF_6$ | + | + | + | + | + | + | + | + | + | 0.0% |
| **Commercial** | **946.3** | **1,003.8** | **1,141.9** | **1,149.8** | **1,151.1** | **1,172.7** | **1,187.2** | **1,212.5** | **1,204.4** | **16.9%** |
| Direct Emissions | 396.9 | 404.5 | 390.3 | 383.0 | 388.1 | 410.2 | 404.6 | 400.4 | 394.6 | 5.5% |
| $CO_2$ | 216.1 | 225.8 | 228.0 | 222.3 | 222.8 | 236.5 | 230.6 | 221.9 | 210.1 | 2.9% |
| $CH_4$ | 173.8 | 170.0 | 147.6 | 143.8 | 146.4 | 151.9 | 149.0 | 149.9 | 152.0 | 2.1% |
| $N_2O$ | 7.0 | 8.0 | 9.3 | 9.5 | 9.4 | 9.7 | 9.9 | 10.1 | 10.2 | 0.1% |
| HFCs | + | 0.7 | 5.5 | 7.4 | 9.6 | 12.1 | 15.0 | 18.5 | 22.4 | 0.3% |
| Electricity-Related | 549.3 | 599.4 | 751.6 | 766.7 | 763.0 | 762.5 | 782.6 | 812.0 | 809.8 | 11.4% |
| $CO_2$ | 538.7 | 590.0 | 743.2 | 758.1 | 754.6 | 754.4 | 774.3 | 803.5 | 801.5 | 11.2% |
| $CH_4$ | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.0% |
| $N_2O$ | 2.5 | 2.7 | 3.3 | 3.4 | 3.4 | 3.4 | 3.5 | 3.6 | 3.6 | 0.1% |
| $SF_6$ | 7.9 | 6.5 | 4.9 | 5.0 | 4.8 | 4.5 | 4.6 | 4.7 | 4.5 | 0.1% |
| **Residential** | **952.4** | **1,026.5** | **1,160.7** | **1,153.2** | **1,178.0** | **1,211.2** | **1,207.2** | **1,241.7** | **1,187.8** | **16.7%** |
| Direct Emissions | 346.9 | 370.9 | 387.7 | 379.3 | 376.6 | 399.6 | 385.5 | 376.0 | 344.8 | 4.8% |
| $CO_2$ | 340.1 | 356.5 | 372.1 | 363.6 | 360.5 | 382.9 | 368.3 | 358.5 | 326.5 | 4.6% |
| $CH_4$ | 4.4 | 4.0 | 3.4 | 3.1 | 3.1 | 3.3 | 3.3 | 3.3 | 3.1 | 0.0% |
| $N_2O$ | 2.1 | 2.2 | 2.1 | 2.3 | 2.3 | 2.4 | 2.5 | 2.4 | 2.3 | 0.0% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HFCs | 0.3 | 8.1 | 10.1 | 10.3 | 10.7 | 11.0 | 11.4 | 11.9 | 12.9 | 0.2% |
| Electricity-Related | 605.5 | 655.6 | 773.0 | 773.9 | 801.4 | 811.6 | 821.7 | 865.6 | 843.0 | 11.8% |
| $CO_2$ | 593.8 | 645.4 | 764.4 | 765.2 | 792.6 | 802.9 | 813.0 | 856.6 | 834.4 | 11.7% |
| $CH_4$ | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.0% |
| $N_2O$ | 2.8 | 3.0 | 3.4 | 3.4 | 3.5 | 3.6 | 3.6 | 3.8 | 3.7 | 0.1% |
| $SF_6$ | 8.7 | 7.1 | 5.0 | 5.1 | 5.0 | 4.8 | 4.8 | 5.0 | 4.7 | 0.1% |
| **Agriculture** | **567.9** | **592.5** | **587.4** | **603.2** | **595.1** | **560.5** | **567.2** | **584.9** | **595.8** | **8.4%** |
| Direct Emissions | 506.8 | 524.1 | 528.0 | 533.4 | 529.3 | 498.0 | 499.2 | 521.3 | 533.6 | 7.5% |
| $CO_2$ | 53.8 | 64.4 | 58.4 | 58.5 | 61.4 | 53.3 | 58.7 | 53.4 | 51.6 | 0.7% |
| $CH_4$ | 170.3 | 180.7 | 190.8 | 181.8 | 189.1 | 181.8 | 178.0 | 186.4 | 199.1 | 2.8% |
| $N_2O$ | 282.6 | 279.0 | 278.8 | 293.1 | 278.8 | 262.9 | 262.6 | 281.5 | 282.9 | 4.0% |
| Electricity-Related | 61.2 | 68.5 | 59.4 | 69.8 | 65.8 | 62.5 | 68.1 | 63.6 | 62.3 | 0.9% |
| $CO_2$ | 60.0 | 67.4 | 58.7 | 69.0 | 65.1 | 61.9 | 67.3 | 63.0 | 61.6 | 0.9% |
| $CH_4$ | + | + | + | + | + | + | + | + | + | 0.0% |
| $N_2O$ | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.0% |
| $SF_6$ | 0.9 | 0.7 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.0% |
| **U.S. Territories** | **34.1** | **41.1** | **47.3** | **54.5** | **53.3** | **59.7** | **61.0** | **60.5** | **62.4** | **0.9%** |
| **Total** | **6,148.3** | **6,494.0** | **7,032.6** | **6,921.3** | **6,981.2** | **6,998.2** | **7,078.0** | **7,129.9** | **7,054.2** | **100.0%** |

Note: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector. Totals may not sum due to independent rounding.

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

[a] Percent of total emissions for year 2006.

[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, to name a few includes 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. Overall, direct industry sector emissions have declined since 1990, while electricity-related emissions have risen. 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 affect on industrial emissions.

## Transportation

When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 28 percent of U.S. greenhouse gas emissions in 2006. The largest sources of transportation GHGs in 2006 were passenger cars (34 percent), light duty trucks, which include sport utility vehicles, pickup trucks, and minivans (28 percent), freight trucks (20 percent) and commercial aircraft (7 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. 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 2006, transportation emissions rose by 28 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 39 percent from 1990 to 2006, as a result of a confluence of factors including population growth, economic growth, urban sprawl, and low fuel prices over much of this period. A similar set of social and economic trends has led to a significant increase in air travel and freight

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

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 reflects an increasing market share of light duty trucks, which have grown 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 improved in 2005 and 2006 as the market share of passenger cars increased. VMT growth among all passenger vehicles has also been impacted, growing an average annual rate of 0.8 percent from 2004 to 2006, compared to an annual rate of 2.7 percent over the period 1990 to 2004.

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 25 percent from 1990 to 2006. This rise in $CO_2$ emissions, combined with an increase in HFCs from virtually no emissions in 1990 to 69.5 Tg $CO_2$ Eq. in 2006, led to an increase in overall emissions from transportation activities of 28 percent.

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

| Gas/Vehicle Type | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **Passenger Cars** | 656.9 | 644.1 | 694.6 | 699.1 | 713.7 | 692.4 | 689.5 | 705.8 | 678.4 |
| $CO_2$ | 628.8 | 604.9 | 643.5 | 647.9 | 662.6 | 642.1 | 640.0 | 658.4 | 634.5 |
| $CH_4$ | 2.6 | 2.1 | 1.6 | 1.5 | 1.4 | 1.3 | 1.2 | 1.1 | 1.0 |
| $N_2O$ | 25.4 | 26.9 | 25.2 | 23.8 | 22.5 | 21.0 | 19.5 | 17.8 | 15.6 |
| HFCs | + | 10.1 | 24.3 | 25.9 | 27.2 | 28.0 | 28.8 | 28.5 | 27.2 |
| **Light-Duty Trucks** | **336.2** | **434.7** | **508.1** | **513.3** | **525.1** | **560.4** | **583.0** | **544.0** | **556.6** |
| $CO_2$ | 320.7 | 405.0 | 466.0 | 470.3 | 483.2 | 518.8 | 540.8 | 501.9 | 514.9 |
| $CH_4$ | 1.4 | 1.4 | 1.1 | 1.1 | 0.9 | 0.8 | 0.7 | 0.7 | 0.7 |
| $N_2O$ | 14.1 | 22.1 | 22.4 | 21.3 | 18.5 | 16.6 | 15.3 | 13.7 | 12.7 |
| HFCs | + | 6.1 | 18.6 | 20.6 | 22.5 | 24.2 | 26.1 | 27.7 | 28.3 |
| **Medium- and Heavy-Duty Trucks** | **228.6** | **272.5** | **344.3** | **343.6** | **357.9** | **354.4** | **367.4** | **395.2** | **404.6** |
| $CO_2$ | 227.8 | 271.2 | 341.5 | 340.6 | 354.8 | 351.2 | 364.1 | 391.9 | 401.3 |
| $CH_4$ | + | + | + | + | + | + | + | + | + |
| $N_2O$ | 0.8 | 1.0 | 1.2 | 1.2 | 1.2 | 1.3 | 1.2 | 1.2 | 1.1 |
| HFCs | + | 0.3 | 1.6 | 1.7 | 1.8 | 1.9 | 2.1 | 2.1 | 2.2 |
| **Buses** | **8.5** | **9.3** | **11.2** | **10.3** | **10.0** | **10.8** | **15.1** | **12.1** | **12.5** |
| $CO_2$ | 8.3 | 9.0 | 10.9 | 10.0 | 9.6 | 10.5 | 14.7 | 11.8 | 12.1 |
| $CH_4$ | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| $N_2O$ | + | + | + | + | + | + | + | + | + |
| HFCs | + | + | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| **Motorcycles** | **1.8** | **1.8** | **1.9** | **1.7** | **1.7** | **1.7** | **1.8** | **1.6** | **1.9** |
| $CO_2$ | 1.7 | 1.8 | 1.8 | 1.7 | 1.7 | 1.6 | 1.7 | 1.6 | 1.9 |
| $CH_4$ | + | + | + | + | + | + | + | + | + |
| $N_2O$ | + | + | + | + | + | + | + | + | + |
| **Commercial Aircraft - Domestic[a]** | **138.1** | **144.6** | **165.9** | **154.4** | **147.6** | **145.4** | **144.4** | **152.0** | **143.6** |
| $CO_2$ | 136.7 | 143.1 | 164.2 | 152.9 | 146.1 | 143.9 | 142.9 | 150.4 | 142.1 |
| $CH_4$ | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| $N_2O$ | 1.3 | 1.4 | 1.6 | 1.5 | 1.4 | 1.4 | 1.4 | 1.5 | 1.4 |
| **Other Aircraft – Domestic[b]** | **43.8** | **31.9** | **32.6** | **34.1** | **32.2** | **31.1** | **34.5** | **31.1** | **28.8** |
| $CO_2$ | 43.3 | 31.5 | 32.2 | 33.7 | 31.9 | 30.8 | 34.1 | 30.8 | 28.5 |
| $CH_4$ | 0.1 | 0.1 | 0.1 | 0.1 | 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 | 0.3 | 0.3 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ships and Boats – Domestic[c]** | **47.0** | **56.6** | **65.1** | **47.4** | **65.4** | **38.3** | **47.1** | **50.8** | **47.7** |
| $CO_2$ | 46.5 | 55.5 | 61.0 | 43.2 | 60.8 | 33.6 | 42.1 | 45.6 | 42.4 |
| $CH_4$ | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| $N_2O$ | 0.4 | 0.4 | 0.5 | 0.3 | 0.5 | 0.3 | 0.4 | 0.4 | 0.4 |
| HFCs | + | 0.6 | 3.4 | 3.7 | 4.0 | 4.3 | 4.6 | 4.7 | 4.9 |
| **Rail** | **38.5** | **44.0** | **50.1** | **50.8** | **50.7** | **52.8** | **55.8** | **56.6** | **57.9** |
| $CO_2$ | 38.1 | 42.2 | 45.1 | 45.4 | 44.9 | 46.6 | 49.2 | 49.8 | 51.0 |
| $CH_4$ | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| $N_2O$ | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 |
| HFCs | + | 1.4 | 4.6 | 5.0 | 5.4 | 5.8 | 6.1 | 6.4 | 6.5 |
| **Pipelines[d]** | **36.1** | **38.2** | **35.2** | **33.6** | **36.6** | **32.7** | **31.2** | **32.3** | **32.4** |
| $CO_2$ | 36.1 | 38.2 | 35.2 | 33.6 | 36.6 | 32.7 | 31.2 | 32.3 | 32.4 |
| **Lubricants** | **11.9** | **11.3** | **12.1** | **11.1** | **10.9** | **10.1** | **10.2** | **10.2** | **9.9** |
| $CO_2$ | 11.9 | 11.3 | 12.1 | 11.1 | 10.9 | 10.1 | 10.2 | 10.2 | 9.9 |
| **Other Transportation (Unspecified)[e]** | **+** | **+** | **+** | **+** | **+** | **0.1** | **0.1** | **0.2** | **0.2** |
| **Total Transportation** | **1,547.2** | **1,688.9** | **1,921.0** | **1,899.4** | **1,952.0** | **1,930.2** | **1,980.0** | **1,992.0** | **1,974.5** |
| *International Bunker Fuels[f]* | *114.8* | *101.6* | *102.2* | *98.6* | *90.0* | *104.6* | *120.2* | *123.8* | *128.4* |

+ Does not exceed 0.05 Tg $CO_2$ Eq.

Note: Totals may not sum due to independent rounding. Emissions estimates for passenger cars, light-duty trucks and heavy-duty trucks are calculated using fuel consumption data from FHWA's Highway Statistics, which used an updated methodology to develop the 2006 estimates. In the most recent Highway Statistics, FHWA also updated 2005 fuel consumption estimates, but did not revise other prior years. This causes some discontinuity in the emissions estimates between 2004 and 2005.

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 8501 lbs and above.

HFC emissions primarily reflect HFC-134a.

[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] $CO_2$ 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.

[e] Combination of gases; balancing item for transportation emissions not specifically identified in table but which are included in transportation economic sector emissions identified in Table 2-14.

[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, while wastewater treatment emissions have increases 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 agricultural sector includes a variety of processes, including enteric fermentation in domestic livestock, livestock manure management, and agricultural soil management. In 2006, enteric fermentation was the largest source of $CH_4$ emissions in the U.S., and agricultural soil management was the largest source of $N_2O$ emissions in the U.S. This sector also includes small amounts of $CO_2$ emissions from fossil fuel combustion by motorized farm equipment like tractors.

## Electricity Generation

The process of generating electricity, for consumption in the above sectors, is the single largest source of greenhouse gas emissions in the United States, representing 33 percent of total U.S. emissions. Electricity generation also accounted for the largest share of $CO_2$ emissions from fossil fuel combustion, approximately 41 percent in 2006. Electricity was consumed primarily in the residential, commercial, and industrial end-use sectors for lighting, heating, electric motors, appliances, electronics, and air conditioning.

[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*, EPA expands upon the standard IPCC sectors common for UNFCCC reporting. EPA believes that 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 $CO_2$ and $N_2O$ from Municipal Solid Waste Combustion, 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 ammonia manufacture. 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 2006; (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 0.9 percent

since 1990. This rate is slightly slower than that for total energy or fossil fuel consumption and much slower than that for either electricity consumption or overall gross domestic product. Total U.S. greenhouse gas emissions have also grown slightly slower than national population since 1990 (see Table 2-16).

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

| Variable | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Growth Rate[a] |
|---|---|---|---|---|---|---|---|---|---|---|
| GDP[b] | 100 | 113 | 138 | 139 | 141 | 145 | 150 | 155 | 159 | 3.0% |
| Electricity Consumption[c] | 100 | 112 | 127 | 125 | 128 | 129 | 131 | 134 | 135 | 1.9% |
| Fossil Fuel Consumption[c] | 100 | 107 | 117 | 115 | 116 | 116 | 119 | 119 | 117 | 1.0% |
| Energy Consumption[c] | 100 | 108 | 116 | 112 | 115 | 115 | 118 | 118 | 117 | 1.0% |
| Population[d] | 100 | 107 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 1.1% |
| Greenhouse Gas Emissions[e] | 100 | 106 | 114 | 113 | 114 | 114 | 115 | 116 | 115 | 0.9% |

[a] Average annual growth rate
[b] Gross Domestic Product in chained 2000 dollars (BEA 2007)
[c] Energy-content-weighted values (EIA 2007b)
[d] U.S. Census Bureau (2007)
[e] GWP-weighted values

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

Source: BEA (2007), U.S. Census Bureau (2007), and emission estimates in this report.

[END BOX]

## 2.3. Indirect Greenhouse Gas Emissions (CO, NOx, NMVOCs, and $SO_2$)

The reporting requirements of the UNFCCC[7] request that information be provided on indirect greenhouse gases, which include CO, $NO_x$, NMVOCs, and $SO_2$. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of $SO_2$, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the 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 $CH_4$.

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

Since 1970, the United States has published estimates of annual emissions of CO, $NO_x$, NMVOCs, and $SO_2$ (EPA 2005),[8] which are regulated under the Clean Air Act. Table 2-17 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 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| **$NO_x$** | **21,645** | **21,272** | **19,203** | **18,410** | **17,938** | **17,043** | **16,177** | **15,569** | **14,869** |
| Mobile Fossil Fuel Combustion | 10,920 | 10,622 | 10,310 | 9,819 | 10,154 | 9,642 | 9,191 | 8,739 | 8,287 |
| Stationary Fossil Fuel Combustion | 9,883 | 9,821 | 8,002 | 7,667 | 6,791 | 6,419 | 6,004 | 5,853 | 5,610 |
| Industrial Processes | 591 | 607 | 626 | 656 | 534 | 528 | 524 | 519 | 515 |
| Oil and Gas Activities | 139 | 100 | 111 | 113 | 321 | 316 | 316 | 316 | 315 |
| Municipal Solid Waste Combustion | 82 | 88 | 114 | 114 | 98 | 97 | 97 | 97 | 97 |
| Agricultural Burning | 28 | 29 | 35 | 35 | 33 | 34 | 39 | 39 | 38 |
| Solvent Use | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 5 | 5 |
| Waste | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **CO** | **130,461** | **109,032** | **92,777** | **89,212** | **84,609** | **80,221** | **76,342** | **72,365** | **68,372** |
| Mobile Fossil Fuel Combustion | 119,360 | 97,630 | 83,559 | 79,851 | 75,421 | 71,038 | 67,096 | 63,154 | 59,213 |
| Stationary Fossil Fuel Combustion | 5,000 | 5,383 | 4,340 | 4,377 | 4,965 | 4,893 | 4,876 | 4,860 | 4,844 |
| Industrial Processes | 4,125 | 3,959 | 2,217 | 2,339 | 1,744 | 1,724 | 1,724 | 1,724 | 1,724 |
| Municipal Solid Waste Combustion | 978 | 1,073 | 1,670 | 1,672 | 1,439 | 1,437 | 1,437 | 1,437 | 1,437 |
| Agricultural Burning | 691 | 663 | 792 | 774 | 709 | 800 | 879 | 860 | 825 |
| Oil and Gas Activities | 302 | 316 | 146 | 147 | 323 | 321 | 321 | 321 | 322 |
| Waste | 1 | 2 | 8 | 8 | 7 | 7 | 7 | 7 | 7 |
| Solvent Use | 5 | 5 | 46 | 45 | 1 | 1 | 1 | 1 | 1 |
| **NMVOCs** | **20,930** | **19,520** | **15,228** | **15,048** | **15,640** | **15,170** | **14,807** | **14,444** | **14,082** |
| Mobile Fossil Fuel Combustion | 10,932 | 8,745 | 7,230 | 6,872 | 7,235 | 6,885 | 6,587 | 6,289 | 5,991 |
| Solvent Use | 5,216 | 5,609 | 4,384 | 4,547 | 3,881 | 3,862 | 3,854 | 3,846 | 3,839 |
| Industrial Processes | 2,422 | 2,642 | 1,773 | 1,769 | 2,036 | 1,972 | 1,931 | 1,890 | 1,849 |
| Stationary Fossil Fuel Combustion | 912 | 973 | 1,077 | 1,080 | 1,585 | 1,560 | 1,553 | 1,545 | 1,538 |
| Oil and Gas Activities | 554 | 582 | 389 | 400 | 545 | 538 | 533 | 528 | 523 |
| Municipal Solid Waste Combustion | 222 | 237 | 257 | 258 | 243 | 239 | 237 | 235 | 232 |
| Waste | 673 | 731 | 119 | 122 | 115 | 114 | 112 | 111 | 110 |
| Agricultural Burning | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **$SO_2$** | **20,935** | **16,891** | **14,829** | **14,452** | **13,403** | **13,631** | **13,232** | **13,114** | **12,258** |
| Stationary Fossil Fuel Combustion | 18,407 | 14,724 | 12,848 | 12,461 | 11,613 | 11,956 | 11,625 | 11,573 | 10,784 |
| Industrial Processes | 1,307 | 1,117 | 1,031 | 1,047 | 850 | 804 | 800 | 797 | 793 |

[8] $NO_x$ and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2008).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mobile Fossil Fuel Combustion | 793 | 672 | 632 | 624 | 683 | 621 | 564 | 508 | 451 |
| Oil and Gas Activities | 390 | 335 | 286 | 289 | 233 | 226 | 220 | 213 | 207 |
| Municipal Solid Waste Combustion | 38 | 42 | 29 | 30 | 23 | 22 | 22 | 22 | 22 |
| Waste | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Solvent Use | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Agricultural Burning | NA | NA | NA | NA | NA | NA | NA | NA | NA |

Source: (EPA 2005) except for estimates from field burning of agricultural residues.
NA (Not Available)
Note: Totals may not sum due to independent rounding.

[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 71 percent in 2006. Coal combustion contributes nearly all of those emissions (approximately 92 percent). Sulfur dioxide emissions have decreased in recent years, primarily as a result of electric power generators switching from high-sulfur to low-sulfur coal and installing flue gas desulfurization equipment.

[END BOX]

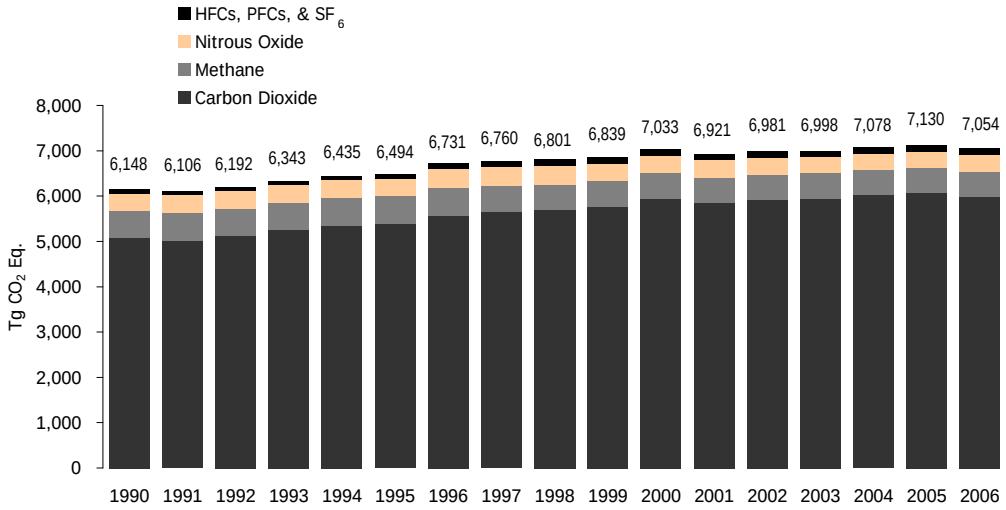



Figure 2-1: U.S. Greenhouse Gas Emissions by Gas

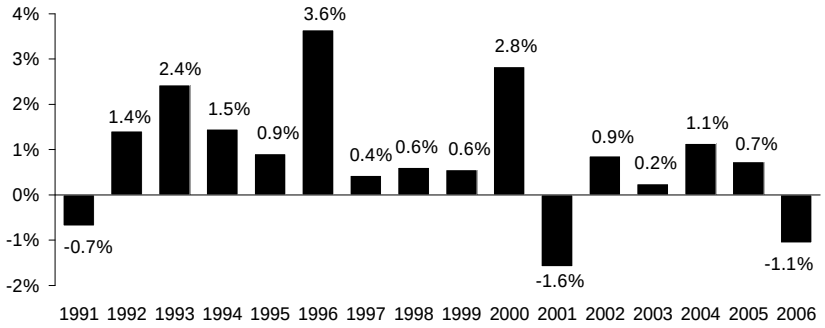



Figure 2-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

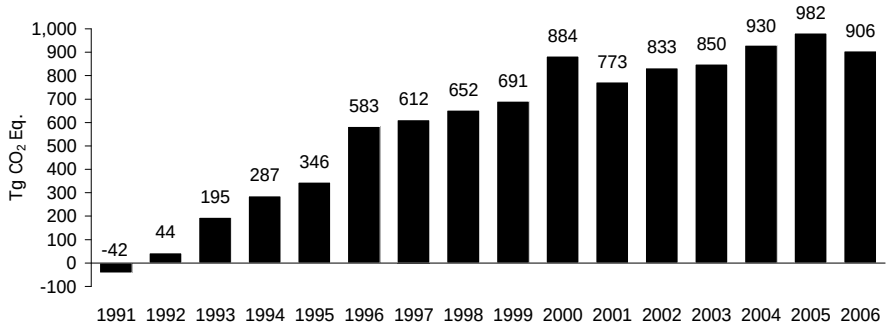
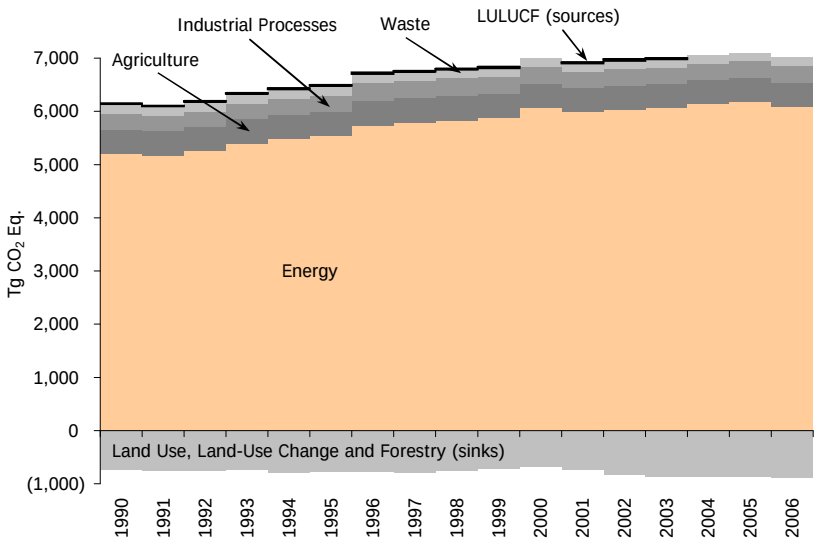



Figure 2-3: Cumulative Change in U.S. Greenhouse Gas Emissions Relative to 1990




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

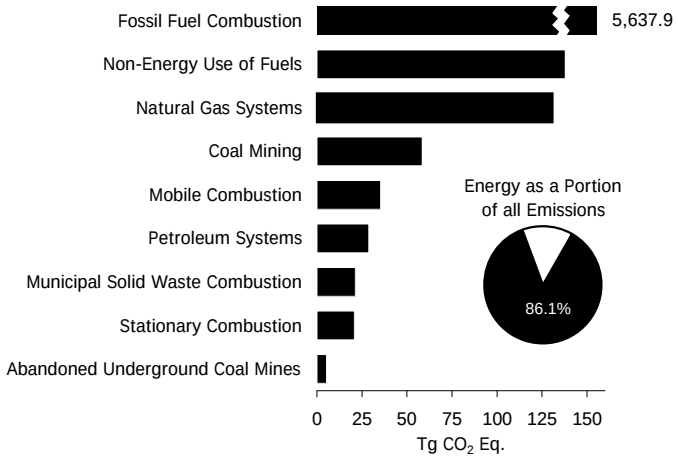



Figure 2-5: 2006 Energy Sector Greenhouse Gas Sources

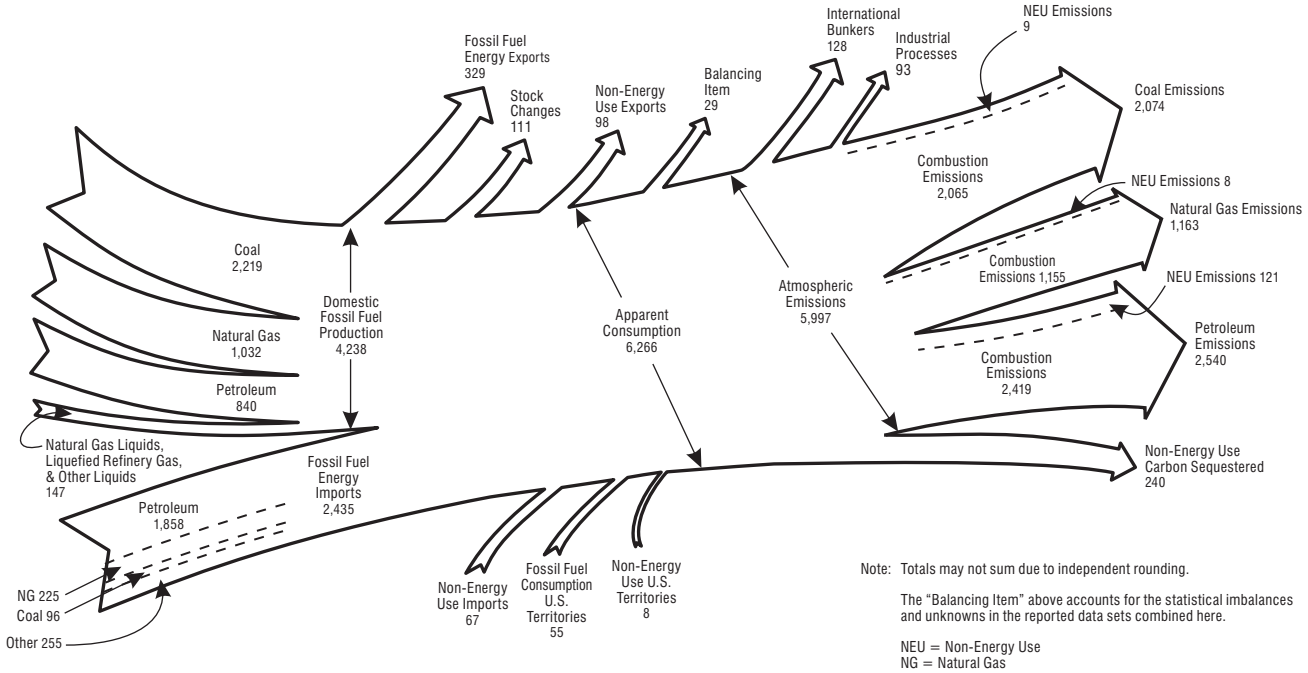



**Figure 2-6 2006 U.S. Fossil Carbon Flows (Tg $CO_2$ Eq.)**

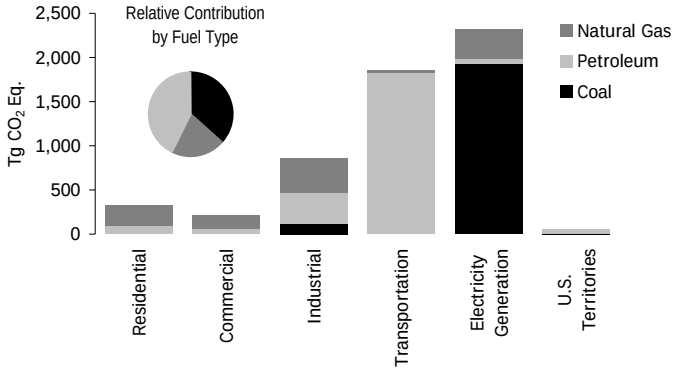



Figure 2-7: 2006 $CO_2$ Emissions from Fossil Fuel Combustion by Sector and Fuel Type

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

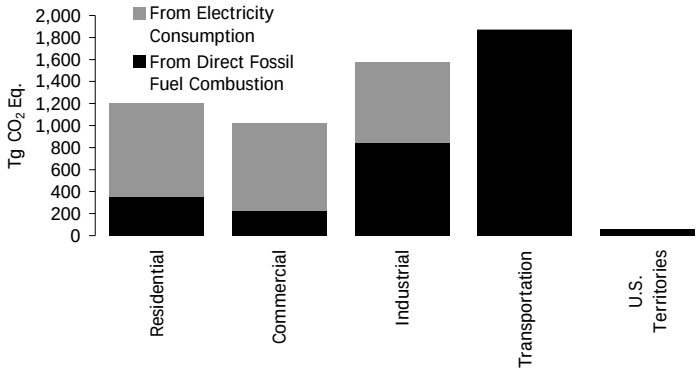



Figure 2-8: 2006 End-Use Sector Emissions of $CO_2$ from Fossil Fuel Combustion

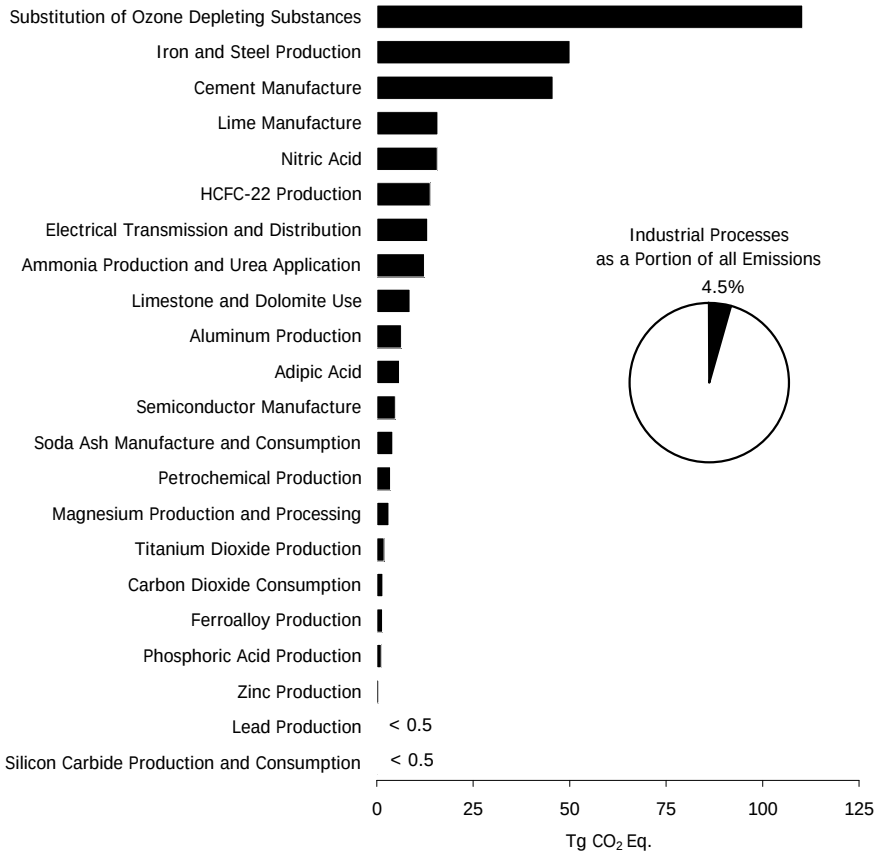



Figure 2-9: 2006 Industrial Processes Chapter Greenhouse Gas Sources

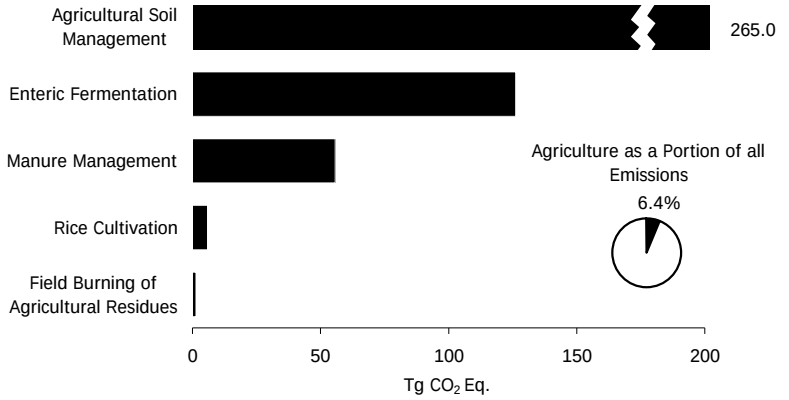



Figure 2-10: 2006 Agriculture Chapter GHG Sources

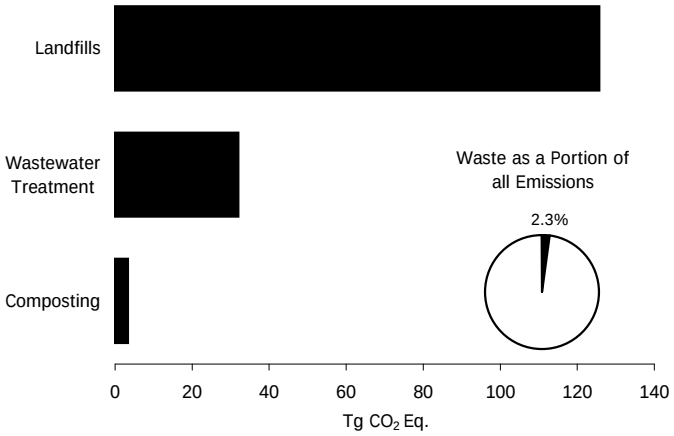



Figure 2-11: 2006 Waste Chapter Greenhouse Gas Sources

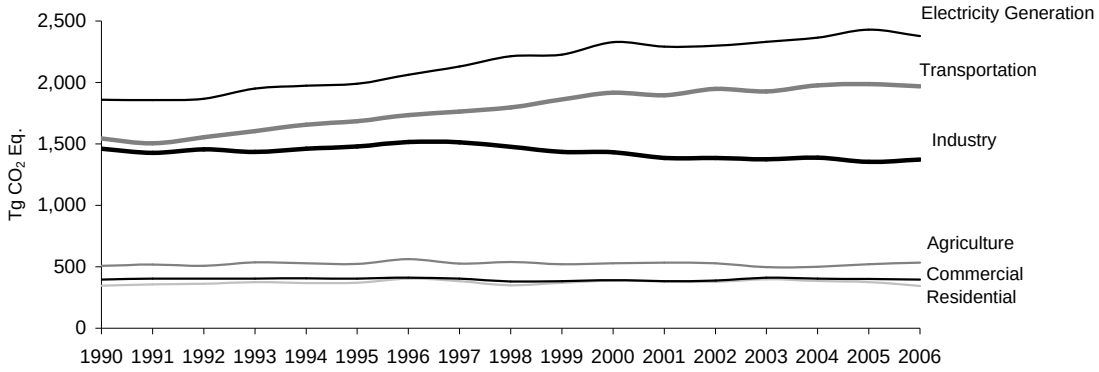



Figure 2-12: Emissions Allocated to Economic Sectors

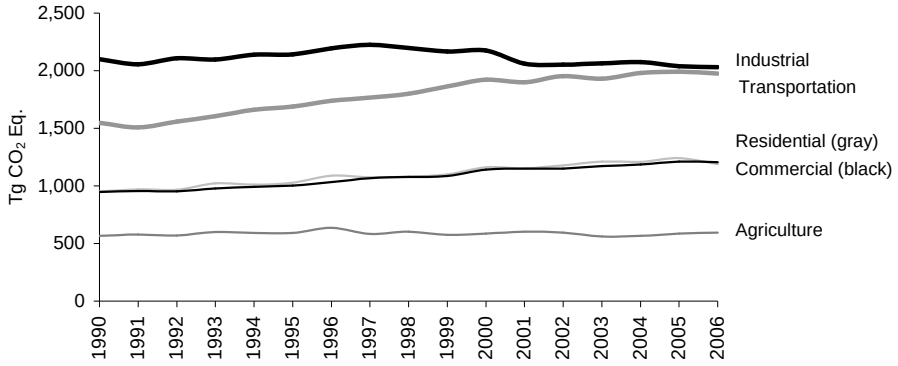



Figure 2-13: Emissions with Electricity Distributed to Economic Sectors

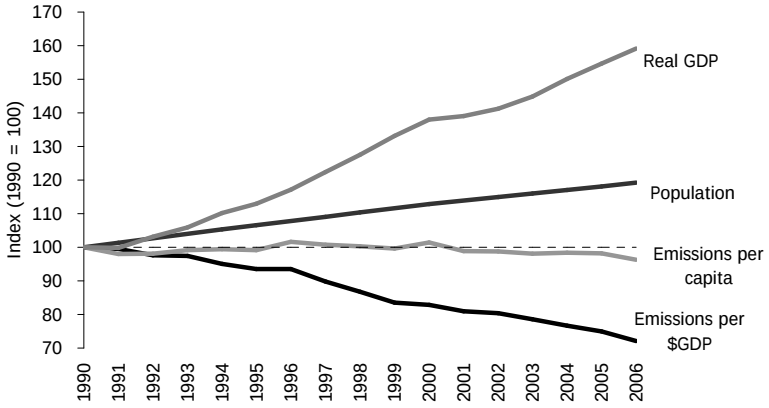



Figure 2-14: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product