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Emissions of Greenhouse Gases in the United States 2006

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Energy Information Administration
Office of Integrated Analysis and Forecasting
U.S. Department of Energy
Washington, DC 20585

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For this report, activity data on coal and natural gas consumption and electricity sales and losses by sector were obtained from the October 2007 *Monthly Energy Review* (*MER*). Petroleum detail is now also available in published tables within the *MER*. Also, while generally in agreement with the *MER*, some data revisions were obtained from the *Electric Power Annual* that are not reflected in the October *MER*.

In keeping with current international practice, this report presents data on greenhouse gas emissions in million metric tons carbon dioxide equivalent. The data can be converted to carbon equivalent units by multiplying by 12/44.

Preface

Title XVI, Section 1605(a) of the Energy Policy Act of 1992 (enacted October 24, 1992) provides:

> *Not later than one year after the date of the enactment of this Act, the Secretary, through the Energy Information Administration, shall develop, based on data available to, and obtained by, the Energy Information Administration, an inventory of the national aggregate emissions of each greenhouse gas for each calendar year of the baseline period of 1987 through 1990. The Administrator of the Energy Information Administration shall annually update and analyze such inventory using available data. This subsection does not provide any new data collection authority.*

The first report in this series, *Emissions of Greenhouse Gases 1985-1990*, was published in September 1993. This report—the fifteenth annual report—presents the Energy Information Administration's latest estimates of emissions for carbon dioxide, methane, nitrous oxide, and other greenhouse gases. Most of these estimates are based on activity data and applied emissions factors and not on measured or metered emissions. A limited number of emissions estimates, such as for methane from coal mine ventilation, are obtained through direct measurement. The source of these estimates is documented in Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2006*, DOE/EIA-0638(2006) (to be published). The documentation, which according to EIA standards must be updated no later than 90 days after the publication of this report, will be available on line at www.eia.doe.gov/oiaf/1605/ggrpt.

What's New in This Report

This year's report is the first in a new, shorter format that focuses on inventory data and a summary of trends for each source category.

For combustion-related carbon dioxide emissions the partial combustion factor has been removed for all fossil fuels and sectors. This is in keeping with new international guidelines. Unless the carbon is consciously sequestered it is likely to oxidize over the next 100 years.

This is the first annual EIA emissions inventory that directly incorporates estimates of methane emissions from industrial wastewater treatment.

Whereas past inventories included chaparral ecosystems in California, much of that land fails to meet the definition of forest land and, consequently, has been removed from the estimates. As a result, the forest carbon stock estimates for California are lower than those in previous inventories, especially in the earlier years.

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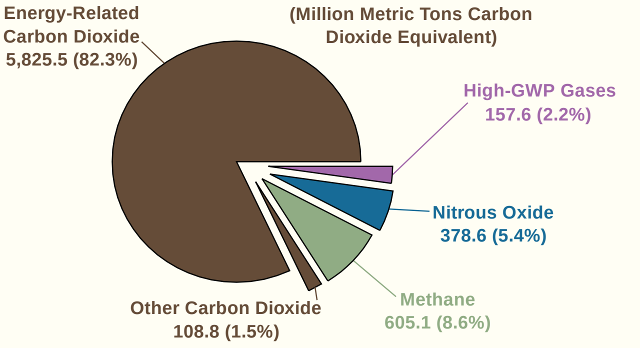
- Total U.S. greenhouse gas emissions in 2006 were 1.5 percent below the 2005 total—the first annual drop since 2001 and only the third since 1990.
- The total emissions reduction, from 7,181.4 million metric tons carbon dioxide equivalent (MMTCO$_2$e) in 2005 to 7,075.6 MMTCO$_2$e in 2006, was largely a result of reductions in carbon dioxide (CO_2) emissions. There were smaller reductions in emissions of methane (CH_4) and man-made gases with high global warming potentials (high-GWP gases) (Table 1).
- U.S. carbon dioxide emissions in 2006 were 110.6 million metric tons (MMT) below their 2005 level of 6,045.0 MMT, due to favorable weather conditions; higher energy prices; a decline in the carbon intensity of electric power generation that resulted from increased use of natural gas, the least carbon-intensive fossil fuel; and greater reliance on non-fossil energy sources.
- Methane emissions totaled 605.1 MMTCO$_2$e in 2006 (Figure 1), down by 2.3 MMTCO$_2$e from 2005, with decreases in emissions from energy sources, agriculture, and industrial processes.
- U.S. emissions of high-GWP gases, which totaled 157.6 MMTCO$_2$e in 2006, were 3.6 MMTCO$_2$e below the 2005 total, as the result of a drop in hydrofluorocarbon (HFC) emissions.
- Emissions of nitrous oxide (N_2O), unlike the other greenhouse gases, increased by 10.6 MMTCO$_2$e from 2005 to a 2006 total of 378.6 MMTCO$_2$e. The increase is attributed primarily to an increase of 9.9 MMTCO$_2$e in emissions from agricultural sources.
- In 2005, the latest year for which data are available, U.S. land use, land-use change, and forestry activities resulted in total carbon sequestration of 828.5 MMTCO$_2$e, equal to 11.5 percent of U.S. greenhouse gas emissions in 2005.

U.S. Anthropogenic Greenhouse Gas Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO$_2$e)	6,146.7	7,181.4	7,075.6
Change from 1990 (Million Metric Tons CO$_2$e)		1,034.7	928.9
(Percent)		*16.8%*	*15.1%*
Average Annual Change from 1990 *(Percent)*		*1.0%*	*0.9%*
Change from 2005 (Million Metric Tons CO$_2$e)			-105.8
(Percent)			*-1.5%*

Figure 1. U.S. Greenhouse Gas Emissions by Gas, 2006



Source: EIA estimates.

Table 1. U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990, 1995, and 1999-2006

(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Carbon Dioxide	5,017.5	5,343.4	5,703.1	5,890.5	5,806.3	5,875.9	5,940.4	6,019.9	6,045.0	5,934.4
Methane	708.4	675.9	615.8	608.0	593.9	598.6	603.7	605.9	607.3	605.1
Nitrous Oxide	333.7	357.1	346.3	341.9	336.6	332.5	331.7	358.3	368.0	378.6
High-GWP Gases[a]	87.1	94.9	133.9	138.0	128.6	137.8	136.6	149.4	161.2	157.6
Total	**6,146.7**	**6,471.2**	**6,799.1**	**6,978.4**	**6,865.4**	**6,944.9**	**7,012.4**	**7,133.5**	**7,181.4**	**7,075.6**

[a] Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: **Emissions:** EIA estimates. **Global Warming Potentials:** Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), pp. 38 and 388-389.

Greenhouse Gas Emissions Overview

U.S. Greenhouse Gas Intensity

Summary

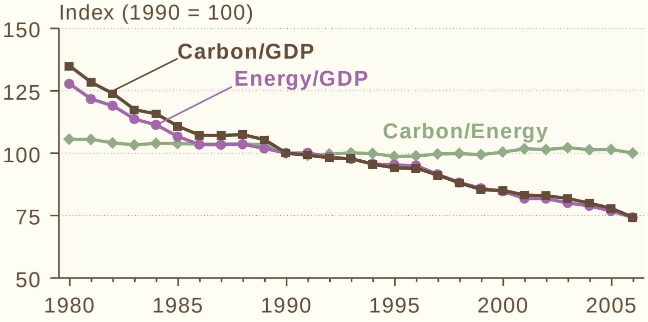
- From 2005 to 2006, the greenhouse gas intensity of the U.S. economy—measured as metric tons carbon dioxide equivalent ($MTCO_2e$) emitted per million dollars of gross domestic product (GDP)—fell by 4.2 percent, the largest annual decrease since the 1990 base year.
- Relatively robust economic growth in 2006, at 2.9 percent, coupled with a 1.5-percent drop in total greenhouse gas emissions, led to the decrease in greenhouse gas intensity (Table 2).
- Some of the factors that led to the decrease (such as weather) are variable; others (such as increased use of renewable energy for electricity generation) may indicate trends that are likely to continue.
- Since 2002, the base year for the Bush Administration's emissions intensity reduction goal of 18 percent in a decade, U.S. greenhouse gas intensity has fallen by an average of 2.5 percent per year, resulting in a total reduction of almost 10 percent from 2002 to 2006.
- The steady decrease in carbon intensity (carbon/GDP) has resulted mainly from reductions in energy use per unit of GDP (energy/GDP) rather than increased use of low-carbon fuels, as indicated by the carbon/energy ratio shown in Figure 2.

U.S. Greenhouse Gas Intensity, 1990, 2005, and 2006

	1990	2005	2006
Estimated Intensity ($MMTCO_2e$/GDP*)	864.2	652.6	625.1
Change from 1990 ($MMTCO_2e$/GDP*)		-211.6	-239.1
(Percent)		*-24.5%*	*-27.7%*
Average Annual Change from 1990 *(Percent)*		*-1.9%*	*-2.0%*
Change from 2005 ($MMTCO_2e$/GDP*)			-27.6
(Percent)			*-4.2%*

*U.S. gross domestic product (million 2000 dollars).

Figure 2. Intensity Ratios: Carbon/Energy, Energy/GDP, and Carbon/GDP, 1980-2006



Source: EIA estimates.

Table 2. U.S. Greenhouse Gas Intensity and Related Factors, 1990, 1995, and 1999-2006

	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Gross Domestic Product (Billion 2000 Dollars)	7,112.5	8,031.7	9,470.3	9,817.0	9,890.7	10,048.8	10,301.0	10,675.8	11,003.4	11,319.4
Greenhouse Gas Emissions ($MMTCO_2e$)	6,146.7	6,471.2	6,799.1	6,978.4	6,865.4	6,944.9	7,012.4	7,133.5	7,181.4	7,075.6
Greenhouse Gas Intensity ($MTCO_2e$ per Million 2000 Dollars)	864.2	805.7	717.9	710.8	694.1	691.1	680.8	668.2	652.7	625.1
Change from Previous Year (Percent)										
Gross Domestic Product	—	2.5	4.4	3.7	0.8	1.6	2.5	3.6	3.1	2.9
Greenhouse Gas Emissions	—	0.6	0.8	2.6	-1.6	1.2	1.0	1.7	0.7	-1.5
Greenhouse Gas Intensity	—	-1.9	-3.5	-1.0	-2.4	-0.4	-1.5	-1.8	-2.3	-4.2
Change from 2002 (Percent)[a]										
Cumulative	—	—	—	—	—	—	-1.5	-3.3	-5.6	-9.6
Annual Average	—	—	—	—	—	—	-1.5	-1.7	-1.9	-2.5

[a] The Bush Administration's emissions intensity goal calls for an 18-percent reduction between 2002 and 2012; achieving that goal would require an average annual reduction of slightly less than 2 percent over the entire period.

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006).

Sources: **Emissions:** EIA estimates. **GDP:** U.S. Department of Commerce, Bureau of Economic Analysis, web site www.bea.gov.

Greenhouse Gas Emissions Overview

Greenhouse Gas Emissions in the U.S. Economy

The diagram on page 4 illustrates the flow of U.S. greenhouse gas emissions in 2006, from their sources to their distribution across the U.S. end-use sectors. The left side shows CO_2 by fuel sources and quantities and other gases by quantities; the right side shows their distribution by sector. The center of the diagram indicates the split between CO_2 emissions from direct fuel combustion and electricity conversion. Adjustments indicated at the top of the diagram for U.S. territories and international bunker fuels correspond to greenhouse gas reporting requirements developed by the United Nations Framework Convention on Climate Change (UNFCCC).

CO_2. CO_2 emission sources include energy-related emissions (primarily from fossil fuel combustion) and emissions from industrial processes. The energy subtotal (5,890 $MMTCO_2e$) includes petroleum, coal, and natural gas consumption and smaller amounts from renewable sources, including municipal solid waste and geothermal power generation. The energy subtotal also includes emissions from nonfuel uses of fossil fuels, mainly as inputs to other products. Industrial process emissions (109 $MMTCO_2e$) include cement manufacture, limestone and dolomite calcination, soda ash manufacture and consumption, carbon dioxide manufacture, and aluminum production. The sum of the energy subtotal and industrial processes equals unadjusted CO_2 emissions (5,999 $MMTCO_2e$). The energy component of unadjusted emissions can be divided into direct fuel use (3,546 $MMTCO_2e$) and fuel converted to electricity (2,344 $MMTCO_2e$).

Non-CO_2 Gases. Methane (605 $MMTCO_2e$) and nitrous oxide (379 $MMTCO_2e$) sources include emissions related to energy, agriculture, waste management, and industrial processes. Other, high-GWP gases (158 $MMTCO_2e$) include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These gases have a variety of uses in the U.S. economy, including refrigerants, insulators, solvents, and aerosols; as etching, cleaning, and firefighting agents; and as cover gases in various manufacturing processes.

Adjustments. In keeping with the UNFCCC, CO_2 emissions from U.S. Territories (61 $MMTCO_2e$) are added to the U.S. total, and CO_2 emissions from fuels used for international transport (both oceangoing vessels and airplanes) (126 $MMTCO_2e$) are subtracted to derive total U.S. greenhouse gas emissions (7,076 $MMTCO_2e$).

Emissions by End-Use Sector. CO_2 emissions by end-use sectors are based on EIA's estimates of energy consumption (direct fuel use and purchased electricity) by sector and on the attribution of industrial process emissions by sector. CO_2 emissions from purchased electricity are allocated to the end-use sectors based on their shares of total electricity sales. Non-CO_2 gases are allocated by direct emissions in those sectors plus emissions in the electric power sector that can be attributed to the end-use sectors based on electricity sales.

Residential emissions (1,234 $MMTCO_2e$) include energy-related CO_2 emissions (1,217 $MMTCO_2e$); and non-CO_2 emissions (17 $MMTCO_2e$). The non-CO_2 sources include direct methane and nitrous oxide emissions from direct fuel use. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Emissions in the **commercial** sector (1,287 $MMTCO_2e$) include both energy-related CO_2 emissions (1,056 $MMTCO_2e$) and non-CO_2 emissions (231 $MMTCO_2e$). The non-CO_2 emissions include direct emissions from landfills, wastewater treatment plants, commercial refrigerants, and stationary combustion emissions of methane and nitrous oxide. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Industrial emissions (2,544 $MMTCO_2e$) include CO_2 emissions (1,777 $MMTCO_2e$)—which can be broken down between combustion (1,668 $MMTCO_2e$) and process emissions (109 $MMTCO_2e$)—and non-CO_2 emissions (767 $MMTCO_2e$). The non-CO_2 direct emissions include emissions from agriculture (methane and nitrous oxide), coal mines (methane), petroleum and natural gas pipelines (methane), industrial process emissions (methane, nitrous oxide, HFCs, PFCs and SF_6), and direct stationary combustion emissions of methane and nitrous oxide. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Transportation emissions (2,010 $MMTCO_2e$) include energy-related CO_2 emissions from mobile source combustion (1,885 $MMTCO_2e$); and non-CO_2 emissions (126 $MMTCO_2e$). The non-CO_2 emissions include methane and nitrous oxide emissions from mobile source combustion and HFC emissions from the use of refrigerants for mobile source air-conditioning units.

(continued on page 4)

Greenhouse Gas Emissions Overview

Greenhouse Gas Emissions in the U.S. Economy

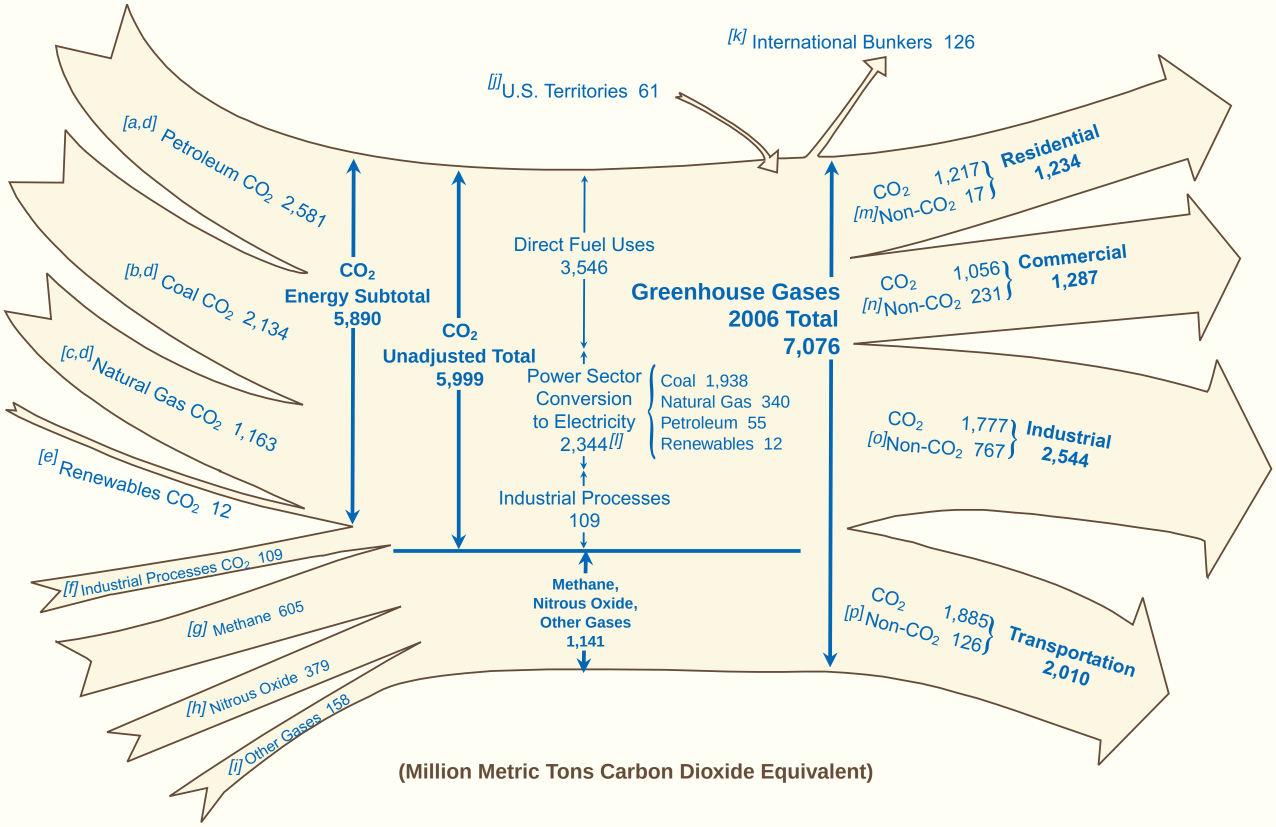


Diagram Notes

[*a*] CO_2 emissions related to petroleum consumption (includes 87.5 MMTCO$_2$ of non-fuel-related emissions).

[*b*] CO_2 emissions related to coal consumption (includes 0.5 MMTCO$_2$ of non-fuel-related emissions).

[*c*] CO_2 emissions related to natural gas consumption (includes 18.1 MMTCO$_2$ of non-fuel-related emissions).

[*d*] Excludes carbon sequestered in nonfuel fossil products.

[*e*] CO_2 emissions from the plastics portion of municipal solid waste (11.5 MMTCO$_2$) combusted for electricity generation and very small amounts (0.4 MMTCO$_2$) of geothermal-related emissions.

[*f*] Includes mainly direct process emissions. Some combustion emissions are included from waste combustion outside the electric power sector and flaring of non-marketed natural gas.

[*g*] Includes methane emissions related to energy, agriculture, waste management, and industrial processes.

[*h*] Includes nitrous oxide emissions related to agriculture, energy, industrial processes, and waste management.

[*i*] Includes hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

[*j*] Includes only energy-related CO_2 emissions from fossil fuels. Emissions are allocated to end-use sectors in proportion to U.S. ratios.

[*k*] Includes vessel bunkers and jet fuel consumed for international travel. Under the UNFCCC, these emissions are not included in country emission inventories. Emissions are subtracted from the transportation sector total.

[*l*] CO_2 emissions from electricity generation in the commercial and industrial sectors are included in those sectors.

[*m*]Non-CO_2: Direct stationary combustion emissions of methane and nitrous oxide plus indirect power sector emissions of methane, nitrous oxide, and other greenhouse gases.

[*n*] Non-CO_2: Direct stationary combustion emissions of methane and nitrous oxide plus indirect power sector emissions of methane, nitrous oxide, and other greenhouse gases. Additional direct emissions include emissions from landfills, wastewater treatment, and commercial refrigerants.

[*o*] Non-CO_2: Direct stationary combustion emissions of methane and nitrous oxide plus indirect power sector emissions of methane, nitrous oxide, and other greenhouse gases. In addition, all agricultural emissions are included in the industrial sector as well as direct process emissions of methane, nitrous oxide, and the other gases.

[*p*] Non-CO_2: Direct mobile combustion emissions of methane and nitrous oxide. Also, emissions related to transportation refrigerants are included.

Source: Estimates presented in this report. CO_2 emissions by end-use sector are based on EIA's estimates of energy consumption by sector and on industrial process emissions. CO_2 emissions from the electric power sector are allocated to the end-use sectors based on electricity sales to the sector. Non-CO_2 emissions by end-use sector are allocated by direct emissions in those sectors plus indirect emissions from the electric power sector allocated by electricity sales. Data are preliminary. Totals may not equal sum of components due to independent rounding.

(continued on page 5)

Greenhouse Gas Emissions Overview

Greenhouse Gas Emissions in the U.S. Economy

Distribution of Total U.S. Greenhouse Gas Emissions by End-Use Sector, 2006

Greenhouse Gas and Source	Sector				
	Residential	Commercial	Industrial	Transportation	Total
	Million Metric Tons Carbon Dioxide Equivalent				
Carbon Dioxide					
Energy-Related (adjusted)	1,216.8	1,056.1	1,668.0	1,884.7	**5,825.5**
Industrial Processes	—	—	108.8	—	**108.8**
Total CO_2	**1,216.8**	**1,056.1**	**1,776.8**	**1,884.7**	**5,934.4**
Methane					
Energy					
Coal Mining	—	—	64.7	—	**64.7**
Natural Gas Systems	—	—	150.8	—	**150.8**
Petroleum Systems	—	—	21.1	—	**21.1**
Stationary Combustion	8.1	0.1	0.5	—	**8.8**
Stationary Combustion: Electricity	0.1	0.1	0.1	—	**0.3**
Mobile Sources	—	—	—	4.8	**4.8**
Waste Management					
Landfills	—	146.7	—	—	**146.7**
Domestic Wastewater Treatment	—	15.9	—	—	**15.9**
Industrial Wastewater Treatment	—	—	8.5	—	**8.5**
Industrial Processes	—	—	2.4	—	**2.4**
Agricultural Sources					
Enteric Fermentation	—	—	114.6	—	**114.6**
Animal Waste	—	—	56.2	—	**56.2**
Rice Cultivation	—	—	9.1	—	**9.1**
Crop Residue Burning	—	—	1.2	—	**1.2**
Total Methane	**8.2**	**162.9**	**429.2**	**4.8**	**605.1**
Nitrous Oxide					
Agriculture					
Nitrogen Fertilization of Soils	—	—	226.7	—	**226.7**
Solid Waste of Animals	—	—	61.7	—	**61.7**
Crop Residue Burning	—	—	0.6	—	**0.6**
Energy Use					
Mobile Combustion	—	—	—	54.8	**54.8**
Stationary Combustion	0.8	0.3	4.5	—	**5.6**
Stationary Combustion: Electricity	3.3	3.2	2.5	—	**9.0**
Industrial Sources	—	—	13.8	—	**13.8**
Waste Management					
Human Sewage in Wastewater	—	5.9	—	—	**5.9**
Waste Combustion	—	—	—	—	**0.0**
Waste Combustion: Electricity	0.1	0.1	0.1	—	**0.4**
Total Nitrous Oxide	**4.3**	**9.6**	**309.9**	**54.8**	**378.6**
Hydrofluorocarbons (HFCs)					
HFC-23	—	—	14.5	—	**14.5**
HFC-32	—	0.4	—	—	**0.4**
HFC-125	—	22.1	—	—	**22.1**
HFC-134a	—	—	—	66.1	**66.1**
HFC-143a	—	23.0	—	—	**23.0**
HFC-236fa	—	2.9	—	—	**2.9**
Total HFCs	**0.0**	**48.4**	**14.5**	**66.1**	**129.0**
Perfluorocarbons (PFCs)					
CF_4	—	—	2.9	—	**2.9**
C_2F_6	—	—	3.4	—	**3.4**
NF_3, C_3F_8, and C_4F_8	—	—	0.6	—	**0.6**
Total PFCs	**0.0**	**0.0**	**6.9**	**0.0**	**6.9**
Other HFCs, PFCs/PFPEs	**—**	**6.1**	**—**	**—**	**6.1**
Sulfur Hexafluoride (SF_6)					
SF_6: Utility	4.5	4.3	3.3	—	**12.2**
SF_6: Other	—	—	3.4	—	**3.4**
Total SF_6	**4.5**	**4.3**	**6.7**	**0.0**	**15.5**
Total Non-CO_2	**17.1**	**231.3**	**767.2**	**125.6**	**1,141.2**
Total Emissions	**1,233.8**	**1,287.4**	**2,544.0**	**2,010.3**	**7,075.6**

Greenhouse Gas Emissions Overview

U.S. Emissions in a Global Perspective

Summary

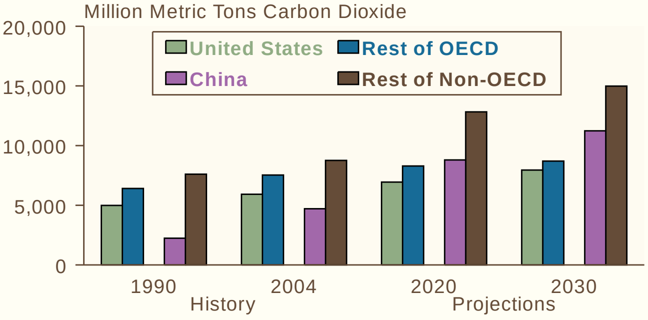
- In EIA's 2005 emissions inventory report, total U.S. energy-related carbon dioxide emissions in 2004 (including nonfuel uses of fossil fuels) were estimated at 5,923.2 MMT. With the 2004 world total for energy-related carbon dioxide emissions estimated at 26,922 MMT, U.S. emissions were about 22 percent of the world total (see Table 3 on page 7).
- Carbon dioxide emissions related to energy use in the mature economies of countries that are members of the Organization for Economic Cooperation and Development (OECD)—including OECD North America, OECD Europe, Japan, and Australia/New Zealand—are estimated at 13,457 MMT, or about one-half of the world total. With the remaining 50 percent of worldwide energy-related carbon dioxide emissions (13,465 MMT) coming from non-OECD countries, 2004 marked the first year in which global emissions were split evenly between the OECD and non-OECD economies (Figure 3).
- In EIA's *International Energy Outlook 2007* (*IEO2007*) reference case, projections of energy use and emissions are sensitive to economic growth rates and energy prices. Projections for a range of alternative growth and price scenarios are presented in *IEO2007*.
- U.S. energy-related carbon dioxide emissions are projected to increase at an average annual rate of 1.1 percent from 2004 to 2030, while emissions from the non-OECD economies are projected to grow by 2.6 percent per year. As a result, the U.S. share of world carbon dioxide emissions is projected to fall to 19 percent in 2030 (7,950 MMT out of a global total of 42,880 MMT) (Figure 4).

World Energy-Related Carbon Dioxide Emissions, 1990, 2004, and 2030

	1990	2004	2030*
Estimated Emissions (Million Metric Tons)	21,246	26,922	42,880
Change from 1990			
(Million Metric Tons)		5,676	21,634
(Percent).		*26.7%*	*101.8%*
Average Annual Change from 1990 *(Percent)*		*1.7%*	*1.8%*
Change from 2004			
(Million Metric Tons).			15,958
(Percent).			59.3%

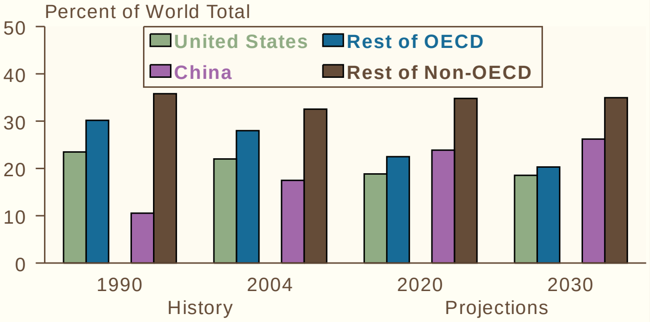
*EIA, *International Energy Outlook 2007.*

Figure 3. World Carbon Dioxide Emissions by Region, 1990, 2004, 2020, and 2030



Source: EIA, *International Energy Outlook 2007.*

Figure 4. Regional Shares of World Carbon Dioxide Emissions, 1990, 2004, 2020, and 2030



Source: EIA, *International Energy Outlook 2007.*

Greenhouse Gas Emissions Overview

U.S. Emissions in a Global Perspective

Table 3. World Energy-Related Carbon Dioxide Emissions by Region, 1990-2030
(Million Metric Tons Carbon Dioxide)

Region/Country	History[a]			Projections[a]					Average Annual Percent Change, 2004-2030
	1990	2003	2004	2010	2015	2020	2025	2030	
OECD									
OECD North America	**5,763**	**6,775**	**6,893**	**7,343**	**7,780**	**8,230**	**8,791**	**9,400**	**1.2**
United States[b]	4,989	5,800	5,923	6,214	6,589	6,944	7,425	7,950	1.1
Canada	474	589	584	648	659	694	722	750	1.0
Mexico	300	385	385	481	532	592	644	699	2.3
OECD Europe	**4,092**	**4,321**	**4,381**	**4,493**	**4,558**	**4,579**	**4,621**	**4,684**	**0.3**
OECD Asia	**1,543**	**2,129**	**2,183**	**2,269**	**2,353**	**2,423**	**2,495**	**2,569**	**0.6**
Japan	1,015	1,244	1,262	1,274	1,290	1,294	1,297	1,306	0.1
South Korea	238	475	497	523	574	614	649	691	1.3
Australia/New Zealand	291	410	424	472	490	516	549	573	1.2
Total OECD	**11,399**	**13,225**	**13,457**	**14,105**	**14,692**	**15,232**	**15,907**	**16,654**	**0.8**
Non-OECD									
Non-OECD Europe and Eurasia	**4,193**	**2,717**	**2,819**	**3,067**	**3,301**	**3,545**	**3,729**	**3,878**	**1.2**
Russia	2,334	1,602	1,685	1,809	1,908	2,018	2,114	2,185	1.0
Other	1,859	1,115	1,134	1,258	1,393	1,527	1,615	1,693	1.6
Non-OECD Asia	**3,627**	**6,479**	**7,411**	**9,711**	**11,404**	**13,115**	**14,759**	**16,536**	**3.1**
China	2,241	3,898	4,707	6,497	7,607	8,795	9,947	11,239	3.4
India	578	1,040	1,111	1,283	1,507	1,720	1,940	2,156	2.6
Other Non-OECD Asia	807	1,542	1,593	1,930	2,289	2,600	2,871	3,141	2.6
Middle East	**705**	**1,211**	**1,289**	**1,602**	**1,788**	**1,976**	**2,143**	**2,306**	**2.3**
Africa	**649**	**895**	**919**	**1,140**	**1,291**	**1,423**	**1,543**	**1,655**	**2.3**
Central and South America	**673**	**981**	**1,027**	**1,235**	**1,413**	**1,562**	**1,708**	**1,851**	**2.3**
Brazil	220	317	334	403	454	500	544	597	2.3
Other Central/South America	453	664	693	831	959	1,062	1,165	1,254	2.3
Total Non-OECD	**9,847**	**12,283**	**13,465**	**16,755**	**19,197**	**21,622**	**23,882**	**26,226**	**2.6**
Total World	**21,246**	**25,508**	**26,922**	**30,860**	**33,889**	**36,854**	**39,789**	**42,880**	**1.8**

[a] Values adjusted for nonfuel sequestration.

[b] Includes the 50 States and the District of Columbia.

Note: The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.

Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea/; and data presented in this report. **Projections:** EIA, *Annual Energy Outlook 2007*, DOE/EIA-0383(2007) (Washington, DC, February, 2007), Table 1, web site www.eia.doe.gov/oiaf/aeo; and *International Energy Outlook 2007*, DOE/EIA-0484(2007) (Washington, DC, May 2007), Table A10.

Greenhouse Gas Emissions Overview

Recent U.S. and International Developments in Global Climate Change

United States

- In December 2005, seven Northeastern and Mid-Atlantic States issued a Memorandum of Understanding to implement the Regional Greenhouse Gas Initiative (RGGI), a multi-State agreement that establishes a cap-and-trade system for carbon dioxide emissions from electric power plants.[1] RGGI aims to stabilize utilities' CO_2 emissions at current levels through 2015 and then reduce them by 10 percent by 2020. The first compliance period under RGGI begins January 1, 2009.[2] In 2007, three additional States joined RGGI: Massachusetts and Rhode Island in January and Maryland in April.
- On February 26, 2007, the Governors of Arizona, California, New Mexico, Oregon, and Washington signed an agreement establishing the Western Climate Initiative,[3] a joint effort to reduce greenhouse gas emissions and address climate change. Since then, Utah and the Canadian Provinces of Manitoba and British Columbia have joined the initiative as full partners. Five U.S. States, three Canadian Provinces, and one Mexican State are observers.[4] In August 2007, the partners released their regional greenhouse gas emissions reduction goal of 15 percent below 2005 levels by 2020.
- On April 2, 2007, the U.S. Supreme Court, in *Massachusetts v. the Environmental Protection Agency*, ruled that section 202(a)(1) of the Clean Air Act gives the U.S. Environmental Protection Agency authority to regulate tailpipe emissions of greenhouse gases.[5]
- On May 8, 2007, 31 U.S. States and one Tribal Nation signed on as charter members in the development of The Climate Registry (TCR), a voluntary, common system for entities to report greenhouse gas emissions.[6] Founding members also include those States, Provinces, and Nations that joined TCR before the May 25, 2007, press release announcing the program.[7] TCR will incorporate the California Climate Action Registry (CCAR), the Eastern Climate Registry, the Western Regional Air Partnership, and the Lake Michigan Air Directors Consortium (LADCO), making it the largest State- and Province-based effort to date to track greenhouse gas emissions.[8] States that previously had passed reporting and registry legislation plan to roll their programs into TCR. As of October 2007, 9 additional U.S. States and the District of Columbia, 1 Mexican State, and 2 additional Tribal Nations had joined the effort.[9]
- On May 14, 2007, President Bush issued a "Twenty in Ten" Executive Order, directing Federal agencies to write rules for expanding the alternative fuel mandate and boosting vehicle fuel efficiency standards. The rules are to be completed by December 2008.
- Also in May 2007, the Chicago Climate Exchange (CCX) announced the formation of a California Climate Exchange to develop and trade financial products with the aim of helping the State meet its mandatory emissions reductions goals.[10] In August 2007, Germany's foreign minister met with California Governor Arnold Schwarzenegger to promote integration of the European carbon market with the emissions trading scheme emerging in the western United States.[11]
- Washington State Governor Christine Gregoire signed Substitute Senate Bill 6001 (SSB 6001) in May 2007, imposing an emissions performance standard on

(continued on page 9)

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[1] States participating in RGGI are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. The District of Columbia, Pennsylvania, the Eastern Canadian Provinces, and New Brunswick are observers in the process.

[2] See web site www.rggi.org.

[3] See web site http://westernclimateinitiative.org.

[4] Observers to the Western Climate Initiative are: Alaska, Colorado, Kansas, Nevada, Wyoming, the Canadian Provinces of Ontario, Quebec, and Saskatchewan and the Mexican State of Sonora.

[5] Supreme Court of the United States, "Massachusetts et al. v. Environmental Protection Agency et al." No. 05-1120, Argued 11/29/06, Decided 4/22/07. See web site www.supremecourtus.gov/opinions/06pdf/05-1120.pdf.

[6] The charter member States and Tribes include Arizona, California, Colorado, Connecticut, Delaware, Florida, Hawaii, Illinois, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Utah, Vermont, Washington, Wisconsin, Wyoming, and the Campo Kumayaay Nation.

[7] Founding members include the charter members plus Alabama, Georgia, Virginia, Pueblo of Acoma and Southern Indian Tribes, British Columbia, and Manitoba.

[8] See web site www.theclimateregistry.org.

[9] Additional members as of October 2007 are Idaho, Iowa, Nevada, Oklahoma, Oregon, Tennessee, and the Mexican State of Sonora.

[10] "Chicago Climate Exchange to Form Carbon Trading Market in California," Point Carbon, web site www.pointcarbon.com/Home/News/All%20news/article22509-703.html (May 29, 2007).

[11] "Germany, California Discuss Cooperation on Carbon Markets," *Point Carbon*, web site www.pointcarbon.com/article.php?articleID=24257 (August 31, 2007).

Greenhouse Gas Emissions Overview

Recent U.S. and International Developments in Global Climate Change

United States

baseload electricity generation (similar to SB 1368 in California).[12] Oregon is considering adopting a similar emissions performance standard for long-term power purchase agreements. Also in May 2007, Montana adopted a carbon dioxide emissions performance standard for electric generating units in the State.[13] The State Public Utility Commission cannot approve generating units constructed after January 1, 2007, that are fueled primarily by coal unless a minimum of 50 percent of the carbon dioxide produced by the facilities is captured and sequestered.

- At the local level, as of September 2007, 681 mayors from the 50 States, the District of Columbia, and Puerto Rico had signed on to the Climate Protection Agreement. Originally adopted in June 2005,[14] the Agreement follows the Kyoto Protocol in setting a goal of reducing greenhouse gas emissions to 7 percent below 1990 levels by 2012.
- As of October 2007, 210 U.S. cities had joined more than 800 local governments across the world in the Cities for Climate Protection (CCP) initiative run by the International Council for Local Environmental Initiatives (ICLEI).[15] CCP assists cities in adopting policies and implementing quantifiable measures to reduce local greenhouse gas emissions, improve air quality, and enhance urban livability and sustainability.

International: United Nations Framework Convention on Climate Change and the Kyoto Protocol

COP-12 and COP/MOP-2

In November 2006, the Twelfth Conference of the Parties to the United Nation's Framework Convention on Climate Change (COP-12) and the Second Meeting of the Parties to the Kyoto Protocol (COP/MOP-2) were held in Nairobi, Kenya. Key areas included:

- Review of the implementation of the UNFCCC to inform the dialog on long-term mitigation measures (COP-12)
- Adverse effects of climate change on developing and least developed countries (COP-12)
- Financial mechanisms, national communications, technology transfer, and capacity building (COP-12)
- Long-term action on post-2012 targets under the Kyoto Protocol (COP/MOP-2)
- Russia's proposal on voluntary commitments for developing countries (COP/MOP-2)
- Review of effectiveness of commitments and implementation (COP/MOP-2)
- Increased geographic equity in the use of the Clean Development Mechanism (COP/MOP-2)
- First amendment to the Kyoto Protocol to include Belarus and Kazakhstan as Annex B countries with binding targets (COP/MOP-2).

COP-13 and CMP-3

Indonesia will host COP-13 and CMP-3 (shortened from COP/MOP) in Nusa Dua, Bali, December 3-14, 2007. Among the agenda items to be included:

- Implementation of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (COP-13)
- Financial mechanisms of the Convention (COP-13)
- National communications (COP-13)
- Development and transfer of technologies (COP-13)
- Capacity building under the Convention (COP-13)
- Implementation of the Buenos Aires program of work on adaption and response measures (COP-13)
- Reducing emissions from deforestation in developing countries (COP-13)
- Issues relating to the Clean Development Mechanism and Join Implementation (CMP-3)
- Report of the Compliance Committee and of the administrator of the Kyoto Protocol International Transaction Log (CMP-3)
- Proposal from Belarus to amend Annex B for its inclusion (CMP-3).

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[12] U.S. Department of Energy, Energy Efficiency and Renewable Energy, "Washington State Passes Climate Change Legislation," web site www.eere.energy.gov/states/news_detail.cfm/news_id=10776 (May 7, 2007).

[13] Montana Governor Brian Schweitzer, Signing Statement, House Bill 25, web site http://governor.mt.gov/news/docs/HB25SigningStatement.pdf (May 14, 2007).

[14] "U.S. Conference of Mayors Climate Protection Agreement," web site www.usmayors.org/climateprotection/agreement.htm (July 13, 2007).

[15] ICLEI was founded in 1990 as the International Council for Local Environmental Initiatives, when more than 200 local governments from 43 countries convened at the inaugural World Congress of Local Governments for a Sustainable Future at the United Nations in New York City. ICLEI began with the idea that one municipality could have a measurable effect on a global scale, which led to the realization that the cumulative effect of cities working in partnership would be profound. At the congress, ICLEI was recognized as the international environmental agency for local governments. See web site www.iclei.org/index.php?id=800.

Greenhouse Gas Emissions Overview

Units for Measuring Greenhouse Gases

Emissions data are reported here in metric units, as favored by the international scientific community. Metric tons are relatively intuitive for users of English measurement units, because 1 metric ton is only about 10 percent heavier than 1 English short ton.

Throughout this report, emissions of carbon dioxide and other greenhouse gases are given in carbon dioxide equivalents. In the case of carbon dioxide, emissions denominated in the molecular weight of the gas or in carbon dioxide equivalents are the same. Carbon dioxide equivalent data can be converted to carbon equivalents by multiplying by 12/44.

Emissions of other greenhouse gases (such as methane) can also be measured in carbon dioxide equivalent units by multiplying their emissions (in metric tons) by their global warming potentials (GWPs). Carbon dioxide equivalents are the amount of carbon dioxide by weight emitted into the atmosphere that would produce the same estimated radiative forcing as a given weight of another radiatively active gas.

Carbon dioxide equivalents are computed by multiplying the weight of the gas being measured (for example, methane) by its estimated GWP (which is 23 for methane). In 2001, the Intergovernmental Panel on Climate Change (IPCC) Working Group I released its Third Assessment Report, *Climate Change 2001: The Scientific Basis*.[16] Among other things, the Third Assessment Report updated a number of the GWP estimates that appeared in the IPCC's Second Assessment Report.[17] The GWPs published in the Third Assessment Report were used for the calculation of carbon dioxide equivalent emissions for this report. Generally, the level of total U.S. carbon dioxide equivalent emissions is 0.6 percent higher when the GWPs from the Third Assessment Report are used; however, the trends in growth of greenhouse gas emissions are similar for the two sets of GWP values. GWPs from the Second Assessment Report still are used for comparisons among countries.

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[16] Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

[17] Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996).

Carbon Dioxide Emissions

Total Emissions

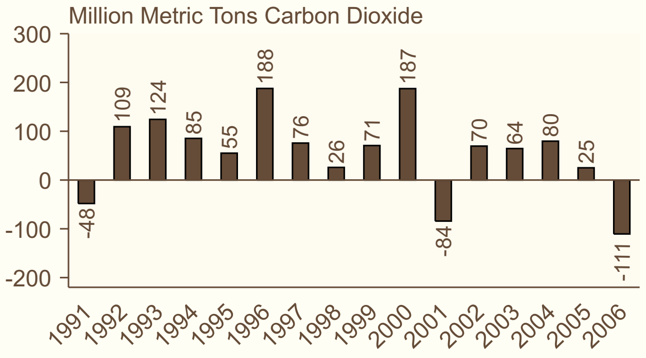
Summary

- The important factors that contributed to a drop in carbon dioxide emissions in 2006 (Figure 5) included: total energy consumption in 2006 that was 0.5 percent below the 2005 total—due in part to favorable weather conditions (both heating and cooling degree-days were below 2005 levels) and in part to higher energy prices that helped to dampen energy demand.
- A decline in the carbon intensity of electric power generation that resulted from increased use of natural gas, the least carbon-intensive fossil fuel, and greater reliance on non-fossil energy sources also contributed to the decrease.
- Relatively small increases in emissions from other sources of carbon dioxide, such as industrial processes, and from the U.S. Territories, which in total represent only a minor share of U.S. emissions, were not enough to offset the declines from major energy sources.
- Energy-related carbon dioxide, including emissions resulting from nonfuel uses of energy fuels (primarily petroleum) and adjustments for U.S. Territories and international bunker fuels, account for 98 percent of carbon dioxide emissions (Table 4).
- Emissions from other sources, such as industrial processes, account for 2 percent of carbon dioxide emissions.

U.S. Anthropogenic Carbon Dioxide Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	5,017.5	6,045.0	5,934.4
Change from 1990 (Million Metric Tons)		1,027.5	916.9
(Percent)		*20.5%*	*18.3%*
Average Annual Change from 1990 *(Percent)*		*1.2%*	*1.1%*
Change from 2005 (Million Metric Tons)			-110.6
(Percent)			*-1.8%*

Figure 5. Annual Change in U.S. Carbon Dioxide Emissions, 1990-2006



Source: EIA estimates.

Table 4. U.S. Carbon Dioxide Emissions from Energy and Industry, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide)

Fuel Type or Process	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Energy Consumption										
Petroleum	2,172.0	2,199.6	2,407.3	2,452.0	2,464.0	2,461.5	2,506.9	2,597.1	2,614.8	2,581.2
Coal	1,799.7	1,897.5	2,051.2	2,144.9	2,083.6	2,092.7	2,130.1	2,154.6	2,162.4	2,134.1
Natural Gas	1,033.6	1,193.0	1,199.2	1,239.8	1,190.3	1,245.7	1,216.7	1,194.1	1,192.8	1,163.1
Renewables[a]	6.3	10.5	10.9	10.6	11.2	13.1	11.8	11.5	11.6	11.9
Energy Subtotal	**5,011.6**	**5,300.6**	**5,668.6**	**5,847.2**	**5,749.1**	**5,813.0**	**5,865.5**	**5,957.4**	**5,981.6**	**5,890.3**
Nonfuel Use Emissions[b]	*98.8*	*105.5*	*125.0*	*110.8*	*105.8*	*106.2*	*104.2*	*112.1*	*107.3*	*111.5*
Nonfuel Use Sequestration[c]	*251.2*	*286.5*	*325.9*	*308.2*	*293.8*	*293.9*	*289.6*	*311.9*	*302.3*	*302.0*
Adjustments to Energy	-82.4	-62.4	-66.5	-59.0	-44.0	-36.4	-27.3	-42.8	-43.8	-64.8
Adjusted Energy Subtotal	**4,929.3**	**5,238.1**	**5,602.1**	**5,788.3**	**5,705.1**	**5,776.6**	**5,838.2**	**5,914.6**	**5,937.8**	**5,825.5**
Other Sources	88.2	105.2	101.1	102.2	101.2	99.3	102.2	105.3	107.1	108.8
Total	**5,017.5**	**5,343.4**	**5,703.1**	**5,890.5**	**5,806.3**	**5,875.9**	**5,940.4**	**6,019.9**	**6,045.0**	**5,934.4**

[a] Includes emissions from electricity generation using nonbiogenic municipal solid waste and geothermal energy.

[b] Emissions from nonfuel uses are included in the energy subtotal.

[c] Carbon sequestered by nonfuel uses is included in the energy subtotal. Btu values are subtracted before emissions are calculated.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding. Adjusted energy subtotal includes U.S. Territories but excludes international bunker fuels.

Source: EIA estimates.

Carbon Dioxide Emissions

Residential Sector

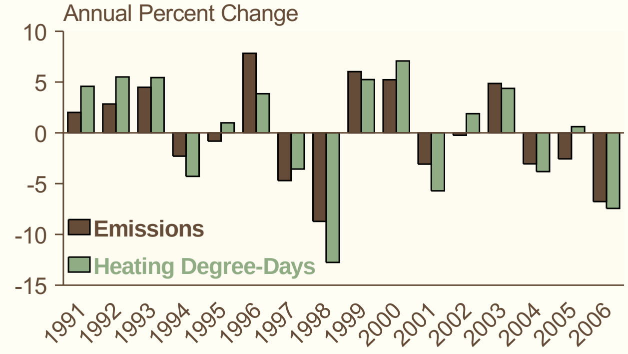
Summary

- Residential sector carbon dioxide emissions consist of:
  - Direct fuel consumption (principally natural gas) for heating and cooking
  - Electricity for cooling (and some heating), for lighting, and increasingly for televisions, computers, and other household electronic devices (Table 5).
- Weather dominates the year-to-year changes for residential energy demand and related emissions:
  - In 2006, heating degree-days declined by 7.4 percent (Figure 6), and cooling degree-days declined by almost 2 percent, from 2005 levels.
- In the longer run, residential emissions are affected by population growth and income. From 1990 to 2006:
  - U.S. population grew by an average of 1.2 percent per year
  - Residential sector carbon dioxide emissions grew by an average of 1.4 percent per year
  - Per capita income (measured in constant dollars) grew by an average of 1.8 percent per year.

Residential Sector Carbon Dioxide Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	961.6	1,253.0	1,204.2
Change from 1990 (Million Metric Tons)		291.3	242.6
(Percent)		*30.3%*	*25.2%*
Average Annual Change from 1990 *(Percent)*		*1.8%*	*1.4%*
Change from 2005 (Million Metric Tons)			-48.7
(Percent)			*-3.9%*

Figure 6. Annual Changes in U.S. Heating Degree-Days and Residential Sector CO_2 Emissions from Direct Fuel Combustion, 1990-2006



Source: EIA estimates.

Table 5. U.S. Carbon Dioxide Emissions from Residential Sector Energy Consumption, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide)

Fuel	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Petroleum										
Liquefied Petroleum Gas	22.7	25.2	33.3	35.1	33.3	33.8	35.1	33.1	31.4	31.6
Distillate Fuel	71.6	66.2	60.6	66.2	66.4	62.9	66.2	67.6	62.5	63.6
Kerosene	4.6	5.4	8.0	6.8	6.9	4.3	5.1	6.1	6.6	5.1
Petroleum Subtotal	**98.9**	**96.7**	**101.8**	**108.1**	**106.7**	**101.0**	**106.4**	**106.8**	**100.5**	**100.3**
Coal	2.9	1.7	1.3	1.0	1.0	1.1	1.2	1.2	0.9	0.6
Natural Gas	239.8	264.4	257.7	270.6	260.3	265.0	277.5	263.7	261.6	237.3
Electricity[a]	620.0	676.3	759.2	801.8	803.0	829.1	839.1	849.8	890.0	866.0
Total	**961.6**	**1,039.2**	**1,120.0**	**1,181.5**	**1,171.1**	**1,196.2**	**1,224.1**	**1,221.5**	**1,253.0**	**1,204.2**

[a] Share of total electric power sector carbon dioxide emissions weighted by sales to the residential sector.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

Carbon Dioxide Emissions

Commercial Sector

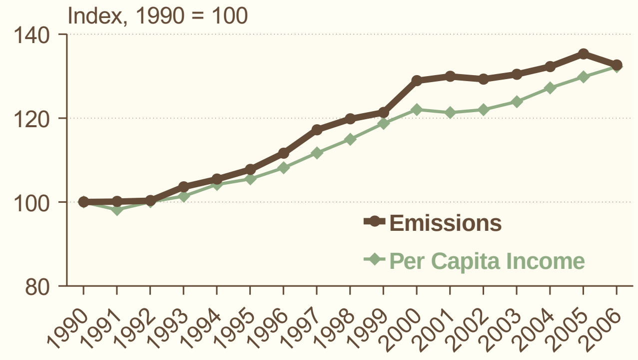
Summary

- Commercial sector emissions (Table 6) are largely the result of energy use for lighting, space heating, and space cooling in commercial structures, such as office buildings, shopping malls, schools, hospitals, and restaurants.
- Lighting accounts for a larger component of energy demand in the commercial sector (approximately 21 percent of total demand in 2005) than in the residential sector (approximately 11 percent of the total).
- Commercial sector emissions are affected less by weather than are residential sector emissions: heating and cooling accounted for approximately 40 percent of energy demand in the residential sector in 2005 but only about 22 percent in the commercial sector.[18]
- In the longer run, trends in emissions from the commercial sector parallel economic trends.
- Commercial sector emissions grew at an average annual rate of 1.8 percent from 1990 to 2006—the same rate as growth in real per capita income (Figure 7).

Commercial Sector Carbon Dioxide Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	787.5	1,065.4	1,045.2
Change from 1990			
(Million Metric Tons)		277.8	257.7
(Percent)		*35.3%*	*32.7%*
Average Annual Change from 1990 *(Percent)*		*2.0%*	*1.8%*
Change from 2005			
(Million Metric Tons)			-20.2
(Percent)			*-1.9%*

Figure 7. U.S. Commercial Sector CO_2 Emissions and Per Capita Income, 1990-2006



Source: EIA estimates.

Table 6. U.S. Carbon Dioxide Emissions from Commercial Sector Energy Consumption, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide)

Fuel	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Petroleum										
Motor Gasoline	7.9	1.3	2.0	3.2	2.7	3.2	4.2	3.4	3.5	3.5
Liquefied Petroleum Gas	4.0	4.4	5.9	6.2	5.9	6.0	6.2	5.8	5.5	5.6
Distillate Fuel	39.2	35.0	32.1	35.9	37.2	32.5	35.2	34.4	32.7	33.3
Residual Fuel	18.1	11.1	5.8	7.2	5.5	6.3	8.8	9.7	9.1	8.9
Kerosene	0.9	1.6	1.9	2.1	2.3	1.2	1.3	1.5	1.6	1.2
Petroleum Subtotal	**70.1**	**53.5**	**47.7**	**54.6**	**53.5**	**49.1**	**55.8**	**54.8**	**52.5**	**52.6**
Coal	11.8	11.1	9.7	8.2	8.4	8.4	7.9	9.7	9.2	6.2
Natural Gas	143.1	165.4	166.2	172.7	165.1	171.0	174.7	169.6	168.8	154.6
Electricity[a]	562.5	618.4	731.9	779.6	796.2	789.5	788.7	807.4	834.9	831.9
Total	**787.5**	**848.4**	**955.5**	**1,015.1**	**1,023.3**	**1,018.1**	**1,027.1**	**1,041.6**	**1,065.4**	**1,045.2**

[a] Share of total electric power sector carbon dioxide emissions weighted by sales to the commercial sector.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

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[18] Energy Information Administration, *Annual Energy Outlook 2007*, DOE/EIA-0383(2006) (Washington, DC, February 2007), Table A5, web site www.eia.doe.gov/oiaf/aeo/excel/aeo_base.xls.

Carbon Dioxide Emissions

Industrial Sector

Summary

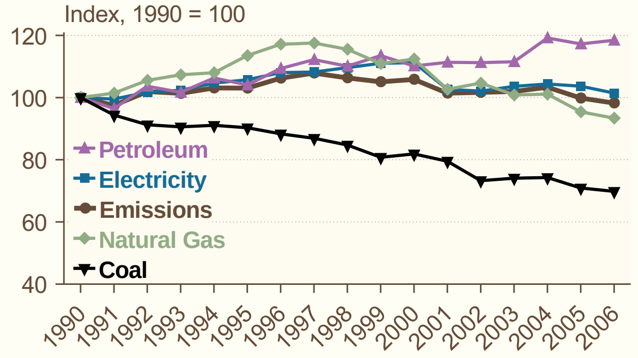
- Unlike commercial sector emissions, trends in U.S. industrial sector emissions (Table 7) have not followed the trends in economic growth.
- Decreases in industrial sector carbon dioxide emissions have resulted largely from erosion of the older energy-intensive (specifically coal-intensive) U.S. industrial base.
- Coke plants consumed 23.0 million short tons of coal in 2006, down from 38.9 million short tons in 1990.
- Other industrial coal consumption declined from 76.3 million short tons in 1990 to 60.5 million short tons in 2006.
- Total industrial coal use dropped by more than 27 percent from 1990 to 2006 (Figure 8).
- The share of manufacturing activity represented by less energy-intensive industries, such as computer chip and electronic component manufacturing, has increased, while the share represented by the more energy-intensive industries has fallen.

Industrial Sector Carbon Dioxide Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	1,679.9	1,677.1	1,650.8
Change from 1990 (Million Metric Tons)		-2.8	-29.1
(Percent)		*0.2%*	*-1.7%*
Average Annual Change from 1990 *(Percent)*		*	*-0.1%*
Change from 2005 (Million Metric Tons)			-26.3
(Percent)			*-1.6%*

*Less than 0.05 percent.

Figure 8. U.S. Industrial Sector CO_2 Emissions and Major Industrial Fuel Use, 1990-2006



Source: EIA estimates.

Table 7. U.S. Carbon Dioxide Emissions from Industrial Sector Energy Consumption, 1990, 1996, and 1999-2006
(Million Metric Tons Carbon Dioxide)

Fuel	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Petroleum										
Motor Gasoline	13.2	14.2	10.8	10.7	20.9	21.9	23.0	26.4	26.5	26.7
Liquefied Petroleum Gas	40.1	46.6	49.6	58.2	50.4	56.1	51.7	57.1	54.7	54.1
Distillate Fuel	83.9	82.4	86.4	87.4	94.7	87.7	82.7	88.4	92.0	93.4
Residual Fuel	30.6	24.5	14.1	16.7	13.8	13.2	15.6	17.9	20.4	20.3
Asphalt and Road Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lubricants	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kerosene	0.9	1.1	0.9	1.1	1.7	1.0	1.7	2.0	2.2	1.7
Petroleum Coke	63.8	66.9	81.1	74.1	77.0	76.2	76.0	82.8	79.1	81.9
Other Petroleum	125.4	112.5	128.4	115.9	130.3	127.6	137.7	140.3	137.5	143.3
Petroleum Subtotal	**358.0**	**348.2**	**371.2**	**364.1**	**388.7**	**383.7**	**388.4**	**414.9**	**412.4**	**421.4**
Coal	**250.3**	**225.9**	**208.0**	**214.1**	**215.3**	**205.2**	**205.8**	**208.1**	**184.6**	**183.8**
Coal Coke Net Imports	**0.5**	**5.7**	**6.6**	**6.1**	**2.7**	**5.7**	**4.7**	**12.9**	**4.1**	**5.7**
Natural Gas	**436.7**	**494.0**	**477.3**	**478.1**	**438.9**	**464.5**	**447.4**	**430.8**	**408.7**	**399.2**
Electricity[a]	**634.5**	**657.0**	**701.8**	**715.6**	**658.2**	**648.7**	**666.4**	**669.1**	**667.3**	**640.7**
Total[b]	**1,679.9**	**1,730.9**	**1,764.8**	**1,778.1**	**1,703.8**	**1,707.8**	**1,712.8**	**1,735.7**	**1,677.1**	**1,650.8**

[a] Share of total electric power sector carbon dioxide emissions weighted by sales to the industrial sector.

[b] Includes emissions from nonfuel uses of fossil fuels. See Table 10 for details by fuel category.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

Carbon Dioxide Emissions

Transportation Sector

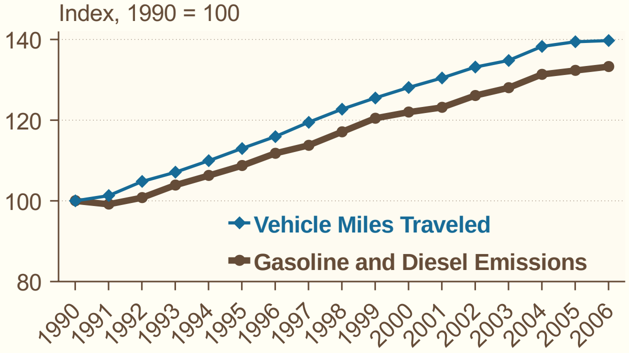
Summary

- Transportation sector carbon dioxide emissions in 2006 were 407.5 million metric tons higher than in 1990 (Table 8), an increase that represents 46.4 percent of the growth in unadjusted energy-related carbon dioxide emissions from all sectors over the period.
- Since 1999, the transportation sector has led all U.S. end-use sectors in emissions of carbon dioxide.
- Petroleum combustion is the largest source of carbon dioxide emissions in the transportation sector, as opposed to electricity-related emissions in the other end-use sectors.
- Increases in ethanol fuel consumption in recent years have mitigated the growth in transportation sector emissions somewhat (emissions from energy inputs to ethanol production plants are counted in the industrial sector).
- Transportation sector emissions from gasoline and diesel fuel combustion generally parallel total vehicle miles traveled (Figure 9).

Transportation Sector Carbon Dioxide Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	1,582.6	1,986.2	1,990.1
Change from 1990			
(Million Metric Tons)		403.6	407.5
(Percent)		*25.5%*	*25.8%*
Average Annual Change from 1990 *(Percent)*		*1.5%*	*1.4%*
Change from 2005			
(Million Metric Tons)			3.9
(Percent)			*0.2%*

Figure 9. U.S. Vehicle Miles Traveled and CO_2 Emissions from Gasoline and Diesel Transportation Fuel Use, 1990-2006



Source: EIA estimates.

Table 8. U.S. Carbon Dioxide Emissions from Transportation Sector Energy Consumption, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide)

Fuel	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Petroleum										
Motor Gasoline	961.7	1,029.7	1,115.1	1,121.9	1,127.1	1,155.8	1,159.5	1,180.8	1,182.2	1,186.2
Liquefied Petroleum Gas	1.3	1.0	0.8	0.7	0.8	0.8	1.0	1.1	1.1	1.1
Jet Fuel	222.6	222.1	245.4	253.8	242.8	236.8	231.5	239.8	246.3	239.5
Distillate Fuel	267.8	306.9	365.8	377.8	387.1	394.5	414.5	433.9	444.4	452.2
Residual Fuel	80.1	71.7	52.4	69.9	46.1	53.3	45.0	58.3	66.0	65.6
Lubricants[a]	6.5	6.2	6.8	6.7	6.1	6.0	5.6	5.6	5.6	5.5
Aviation Gasoline	3.1	2.7	2.7	2.5	2.4	2.3	2.1	2.2	2.4	2.3
Petroleum Subtotal	**1,543.2**	**1,640.4**	**1,789.1**	**1,833.3**	**1,812.5**	**1,849.5**	**1,859.1**	**1,921.7**	**1,948.1**	**1,952.4**
Coal	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Natural Gas	**36.2**	**38.6**	**35.8**	**35.6**	**34.8**	**37.7**	**37.8**	**32.2**	**33.2**	**32.5**
Electricity[b]	**3.2**	**3.2**	**3.4**	**3.6**	**3.7**	**3.6**	**4.6**	**4.7**	**4.9**	**5.2**
Total	**1,582.6**	**1,682.2**	**1,828.3**	**1,872.6**	**1,851.0**	**1,890.9**	**1,901.4**	**1,958.6**	**1,986.2**	**1,990.1**

[a] Includes emissions from nonfuel uses of fossil fuels. See Table 10 for details by fuel category.

[b] Share of total electric power sector carbon dioxide emissions weighted by sales to the transportation sector.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

Carbon Dioxide Emissions

Electric Power Sector

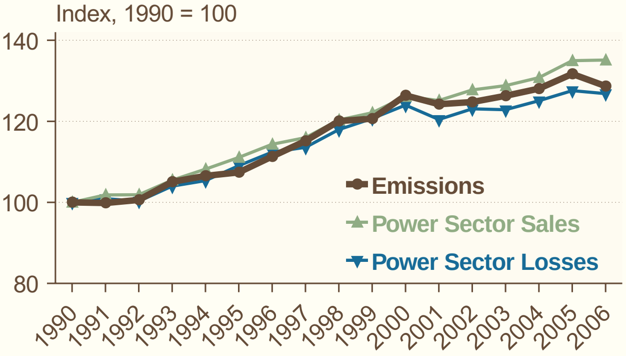
Summary

- The electric power sector transforms primary energy inputs into electricity. The sector consists of companies whose primary business is the generation of electricity.
- From 2005 to 2006, electricity demand was essentially flat and the carbon intensity of the electricity supply fell, leading to a drop in electric power sector emissions (Table 9).
- From 2000 to 2006, as the overall efficiency of U.S. electricity generation has increased, there has been a decline in electric power sector energy losses[19] relative to total sales, which has helped to mitigate the sector's carbon dioxide emissions (Figure 10).
- From year to year, demand for electricity can be affected by the number of cooling degree-days.
- All the end-use sectors except transportation have increasingly relied on electricity as an energy source, displacing other fuels.
- Carbon dioxide emissions from electricity generation in the commercial and industrial sectors are counted in those sectors.

Electric Power Sector Carbon Dioxide Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	1,820.2	2,397.1	2,343.9
Change from 1990			
(Million Metric Tons)		576.9	523.7
(Percent)		*31.7%*	*28.8%*
Average Annual Change from 1990 *(Percent)*		*1.9%*	*1.6%*
Change from 2005			
(Million Metric Tons)			-53.3
(Percent)			*-2.2%*

Figure 10. U.S. Electric Power Sector Energy Sales and Losses and CO_2 Emissions from Primary Fuel Combustion, 1990-2006



Source: EIA estimates.

Table 9. U.S. Carbon Dioxide Emissions from Electric Power Sector Energy Consumption, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide)

Fuel	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Petroleum										
Heavy Fuel Oil	91.9	45.0	76.5	69.5	80.1	52.3	69.0	69.8	69.8	28.7
Light Fuel Oil	7.1	7.9	10.2	12.8	12.5	9.3	11.7	8.1	8.4	5.4
Petroleum Coke	2.9	7.8	10.8	9.6	10.1	16.6	16.5	21.1	23.2	20.5
Petroleum Subtotal	**101.9**	**60.7**	**97.5**	**91.8**	**102.6**	**78.2**	**97.2**	**99.0**	**101.3**	**54.5**
Coal	**1,534.2**	**1,653.2**	**1,825.6**	**1,915.5**	**1,856.1**	**1,872.2**	**1,910.5**	**1,922.7**	**1,963.7**	**1,937.9**
Natural Gas	**177.7**	**230.6**	**262.2**	**282.8**	**291.1**	**307.4**	**279.3**	**297.7**	**320.5**	**339.5**
Municipal Solid Waste	**5.9**	**10.1**	**10.5**	**10.2**	**10.9**	**12.7**	**11.4**	**11.2**	**11.2**	**11.5**
Geothermal	**0.4**	**0.4**	**0.4**	**0.4**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Total	**1,820.2**	**1,955.0**	**2,196.3**	**2,300.7**	**2,261.1**	**2,270.9**	**2,298.8**	**2,331.0**	**2,397.1**	**2,343.9**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Emissions for total fuel consumption are allocated to end-use sectors in proportion to electricity sales. Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

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[19] Electrical system energy losses are calculated as the difference between total primary consumption by the electric power sector and the total energy content of retail electricity sales.

Carbon Dioxide Emissions

Nonfuel Uses of Energy Inputs

Summary

- The use of fossil fuels for purposes other than the energy value of the fuel creates emissions and also sequesters carbon in nonfuel products. Both the emissions and sequestration are included in the total for energy-related carbon dioxide emissions:
  - In 2006, carbon dioxide emissions from nonfuel uses of energy inputs totaled 111.5 MMT—almost 4 percent above the 2005 total (Table 10).
  - Carbon sequestration from nonfuel uses of energy inputs in 2006 included 302 MMTCO$_2$e that was embedded in plastics and other nonfuel products rather than emitted to the atmosphere (see Table 11 on page 18).
  - The 2006 sequestration total was about the same as the 2005 total.

Carbon Dioxide Emissions from Nonfuel Uses of Energy Inputs, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	98.8	107.3	111.5
Change from 1990 (Million Metric Tons)		8.4	12.7
(Percent)		*8.5%*	*12.8%*
Average Annual Change from 1990 *(Percent)*		*0.5%*	*0.8%*
Change from 2005 (Million Metric Tons)			4.2
(Percent)			*3.9%*

Carbon Sequestration from Nonfuel Uses of Energy Inputs, 1990, 2005, and 2006

	1990	2005	2006
Estimated Sequestration (Million Metric Tons CO$_2$e)	251.2	302.3	302.0
Change from 1990 (Million Metric Tons CO$_2$e)		51.1	50.8
(Percent)		*20.3%*	*20.2%*
Average Annual Change from 1990 *(Percent)*		*1.2%*	*1.2%*
Change from 2005 (Million Metric Tons CO$_2$e)			-0.3
(Percent)			*-0.1%*

Table 10. U.S. Carbon Dioxide Emissions from Nonfuel Use of Energy Fuels, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide)

End Use and Type	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Industrial										
Petroleum										
Liquefied Petroleum Gases	14.8	19.6	22.5	20.5	19.2	20.0	19.1	19.4	18.3	18.7
Distillate Fuel	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Residual Fuel	1.9	2.1	2.2	2.2	2.2	1.7	1.7	1.7	1.7	1.7
Asphalt and Road Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lubricants	6.9	6.6	7.2	7.0	6.5	6.4	5.9	6.0	5.9	5.8
Other *(Subtotal)*	*51.6*	*52.0*	*66.8*	*54.2*	*51.9*	*53.1*	*52.9*	*60.3*	*56.6*	*60.8*
Pentanes Plus	1.1	4.1	3.5	3.2	2.7	2.3	2.3	2.3	2.0	1.4
Petrochemical Feed	33.6	36.0	38.2	36.8	32.9	33.5	36.5	41.8	38.4	41.0
Petroleum Coke	9.1	6.8	14.5	7.2	10.6	9.8	8.2	12.6	11.7	13.3
Special Naphtha	7.8	5.2	10.6	7.1	5.7	7.5	5.9	3.7	4.6	5.1
Waxes and Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petroleum Subtotal	*75.5*	*80.6*	*99.1*	*84.5*	*80.2*	*81.6*	*80.0*	*87.9*	*83.1*	*87.5*
Coal	0.5	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
Natural Gas	16.3	18.0	18.6	19.1	18.9	18.1	18.1	18.1	18.1	18.1
Industrial Subtotal	**92.3**	**99.2**	**118.2**	**104.2**	**99.7**	**100.2**	**98.6**	**106.5**	**101.6**	**106.0**
Transportation										
Lubricants	6.5	6.2	6.8	6.7	6.1	6.0	5.6	5.6	5.6	5.5
Total	**98.8**	**105.5**	**125.0**	**110.8**	**105.8**	**106.2**	**104.2**	**112.1**	**107.3**	**111.5**

P = preliminary data.

Notes: Emissions from nonfuel use of energy fuels are included in the energy consumption tables in this chapter. Data in this table are revised from unpublished data used to produce the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: EIA estimates.

Carbon Dioxide Emissions

Nonfuel Uses of Energy Inputs

Table 11. U.S. Carbon Sequestered by Nonfuel Use of Energy Fuels, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

End Use and Type	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Industrial										
Petroleum										
Liquefied Petroleum Gases	59.3	78.5	89.9	82.1	76.7	79.9	76.3	77.7	73.4	74.7
Distillate Fuel	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Residual Fuel	1.9	2.1	2.2	2.2	2.2	1.7	1.7	1.7	1.7	1.7
Asphalt and Road Oil	88.5	89.1	100.1	96.4	95.0	93.7	92.2	98.6	100.0	95.3
Lubricants	6.9	6.6	7.2	7.0	6.5	6.4	5.9	6.0	5.9	5.8
Other *(Subtotal)*	*72.1*	*83.1*	*95.0*	*88.8*	*84.0*	*86.5*	*88.1*	*101.5*	*94.6*	*97.8*
Pentanes Plus	4.4	16.2	14.0	12.7	10.8	9.2	9.0	9.1	8.0	5.7
Petrochemical Feed	46.0	50.0	55.5	57.7	50.7	55.1	59.2	69.2	64.2	66.7
Petroleum Coke	9.1	6.8	14.5	7.2	10.6	9.8	8.2	12.6	11.7	13.3
Special Naphtha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waxes and Miscellaneous	12.6	10.2	11.0	11.2	11.9	12.3	11.6	10.7	10.7	12.0
Petroleum Subtotal	*228.9*	*259.7*	*294.9*	*277.0*	*264.8*	*268.7*	*264.7*	*286.0*	*276.2*	*275.7*
Coal	1.4	2.1	1.8	1.8	1.7	1.5	1.5	1.5	1.5	1.4
Natural Gas	14.3	18.4	22.5	22.6	21.2	17.7	17.9	18.9	19.0	19.4
Industrial Subtotal	**244.7**	**280.2**	**319.1**	**301.5**	**287.7**	**287.8**	**284.1**	**306.3**	**296.7**	**296.5**
Transportation										
Lubricants	6.5	6.2	6.8	6.7	6.1	6.0	5.6	5.6	5.6	5.5
Total	**251.2**	**286.5**	**325.9**	**308.2**	**293.8**	**293.9**	**289.6**	**311.9**	**302.3**	**302.0**

P = preliminary data.

Notes: Emissions from nonfuel use of energy fuels are included in the energy consumption tables in this chapter. Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: EIA estimates.

Carbon Dioxide Emissions

Adjustments to Energy Consumption

Summary

- EIA's greenhouse gas emissions inventory includes two “adjustments to energy consumption” (Table 12):
  - Carbon dioxide emissions data in this report and the energy consumption data upon which they are based correspond to EIA's coverage of energy consumption, which includes the 50 States and the District of Columbia. Under the UNFCCC, however, the United States is also responsible for counting emissions emanating from its Territories. Therefore, their emissions are added to the U.S. total.
  - Because the definition of energy consumption by the IPCC excludes international bunker fuels from the statistics of all countries, emissions from international bunker fuels are subtracted from the U.S. total. Similarly, because the IPCC excludes emissions from military bunker fuels from national totals, they are subtracted from the U.S. total.

Carbon Dioxide Emissions from U.S. Territories, 1990, 2005, and 2006*

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	31.1	59.5	61.3
Change from 1990 (Million Metric Tons)		28.4	30.2
(Percent)		*91.3%*	*97.2%*
Average Annual Change from 1990 *(Percent)*		*4.4%*	*4.3%*
Change from 2005 (Million Metric Tons)			1.8
(Percent)			*3.1%*

*Added to total U.S. emissions.

Carbon Dioxide Emissions from International Bunker Fuels, 1990, 2005, and 2006*

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	113.5	103.3	126.1
Change from 1990 (Million Metric Tons)		-10.2	12.7
(Percent)		*-9.0%*	*11.2%*
Average Annual Change from 1990 *(Percent)*		*-0.6%*	*0.7%*
Change from 2005 (Million Metric Tons)			22.9
(Percent)			*22.1%*

*Subtracted from total U.S. emissions.

Table 12. U.S. Carbon Dioxide Emissions: Adjustments for U.S. Territories and International Bunker Fuels, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide)

Fuel	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Emissions from U.S. Territories										
Puerto Rico.	20.2	24.1	26.2	27.6	34.3	34.9	37.2	37.9	39.0	40.4
U.S. Virgin Islands	7.0	8.5	8.8	9.8	14.2	13.7	15.2	18.1	16.1	16.4
American Samoa	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Guam	1.8	3.6	3.4	2.9	3.1	2.1	2.4	2.0	2.2	2.3
U.S. Pacific Islands	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wake Island	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4
Subtotal[a]	**31.1**	**38.4**	**40.6**	**42.4**	**53.8**	**52.9**	**57.0**	**60.1**	**59.5**	**61.3**
Emissions from Bunker Fuels										
Marine Bunkers *(Subtotal)*	*62.0*	*46.6*	*41.3*	*37.6*	*35.3*	*24.2*	*19.8*	*29.3*	*29.5*	*49.8*
Distillate Fuel	6.2	5.8	3.1	2.9	2.0	1.6	1.4	1.7	2.4	3.1
Residual Fuel	55.8	40.8	38.2	34.6	33.2	22.6	18.3	27.6	27.1	46.7
Aviation Bunkers *(Subtotal)*	*38.1*	*45.3*	*56.1*	*55.9*	*54.3*	*57.0*	*55.3*	*63.5*	*66.1*	*68.7*
U.S. Carriers.	18.5	21.0	24.8	25.9	24.8	23.6	23.2	26.5	28.3	28.5
Foreign Carriers	19.5	24.3	31.3	30.0	29.5	33.3	32.1	37.0	37.9	40.2
Military Bunkers *(Subtotal)*	*13.4*	*8.9*	*9.8*	*7.9*	*8.2*	*8.1*	*9.2*	*10.1*	*7.6*	*7.6*
Subtotal[b]	**113.5**	**100.8**	**107.2**	**101.4**	**97.8**	**89.3**	**84.2**	**102.8**	**103.3**	**126.1**
Net Adjustment.	**-82.4**	**-62.4**	**-66.5**	**-59.0**	**-44.0**	**-36.4**	**-27.3**	**-42.8**	**-43.8**	**-64.8**

P = preliminary data.

[a] Added to total U.S. emissions.

[b] Subtracted from total U.S. emissions.

Note: Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

Carbon Dioxide Emissions

Other Sources

Summary

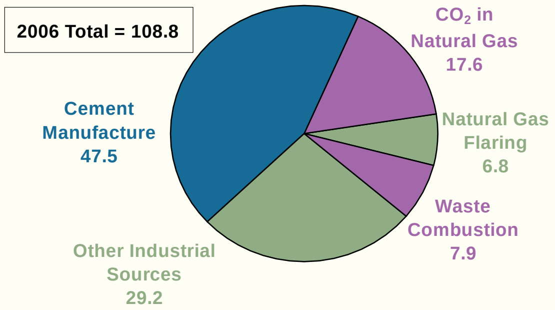
- "Other emissions sources" in total accounted for 1.8 percent (108.8 MMT) of all U.S. carbon dioxide emissions in 2006 (Figure 11).
- The largest source of U.S. carbon dioxide emissions other than fossil fuel consumption is cement manufacture (Table 13), where most emissions result from the production of clinker (consisting of calcium carbonate sintered with silica in a cement kiln to produce calcium silicate).
- Limestone consumption, especially for lime manufacture, is the source of 15 to 20 million metric tons of carbon dioxide emissions per year.
- In addition, "other sources" include: soda ash manufacture and consumption; carbon dioxide manufacture; aluminum manufacture; flaring of natural gas at the wellhead; carbon dioxide scrubbed from natural gas; and waste combustion.

Carbon Dioxide Emissions from Other Sources, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons)	88.2	107.1	108.8
Change from 1990 (Million Metric Tons)		18.9	20.6
(Percent)		*21.4%*	*23.3%*
Average Annual Change from 1990 *(Percent)*		*1.3%*	*1.3%*
Change from 2005 (Million Metric Tons)			1.7
(Percent)			*1.6%*

Figure 11. U.S. Carbon Dioxide Emissions from Other Sources, 2006

(Million Metric Tons)



Source: EIA estimates.

Table 13. U.S. Carbon Dioxide Emissions from Other Sources, 1990, 1995, and 1999-2006

(Million Metric Tons Carbon Dioxide)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Cement Manufacture	***33.3***	***36.9***	***40.1***	***41.3***	***41.5***	***43.0***	***43.2***	***45.7***	***46.1***	***47.5***
Clinker Production	32.6	36.1	39.2	40.4	40.5	42.0	42.2	44.7	45.1	46.4
Masonry Cement	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cement Kiln Dust	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9
Limestone Consumption	***15.9***	***17.8***	***18.3***	***18.6***	***18.1***	***17.0***	***18.0***	***18.9***	***18.9***	***19.7***
Lime Manufacture	12.4	14.5	15.5	15.4	14.8	14.1	15.1	15.7	15.7	16.5
Iron Smelting	1.7	1.2	1.0	1.1	1.0	0.9	0.9	1.0	0.8	0.9
Steelmaking	0.3	0.5	0.3	0.5	0.6	0.5	0.4	0.4	0.4	0.4
Copper Refining	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Glass Manufacture	0.1	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2
Flue Gas Desulfurization	0.7	0.9	1.1	1.2	1.4	1.3	1.3	1.4	1.5	1.5
Dolomite Manufacture	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Other										
Soda Ash Manufacture	3.4	3.8	3.7	3.6	3.6	3.5	3.6	3.8	3.9	3.9
Soda Ash Consumption	0.5	0.8	0.6	0.6	0.5	0.4	0.6	0.6	0.6	0.6
Carbon Dioxide Manufacture	0.9	1.0	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.6
Aluminum Manufacture	5.9	4.9	5.5	5.4	3.9	4.0	4.0	3.7	3.6	3.4
Shale Oil Production	0.2	*	*	*	*	*	*	*	*	*
Natural Gas Flaring	9.1	17.2	6.7	5.5	5.9	6.0	5.9	5.8	7.2	6.8
Carbon Dioxide in Natural Gas	14.0	16.7	17.8	18.2	18.6	17.9	18.1	17.6	17.1	17.6
Waste Combustion	5.0	6.1	7.1	7.8	7.9	6.1	7.4	7.6	8.2	7.9
Total	**88.2**	**105.2**	**101.1**	**102.2**	**101.2**	**99.3**	**102.2**	**105.3**	**107.1**	**108.8**

P = preliminary data.

*Less than 0.05 million metric tons.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

Methane Emissions

Total Emissions

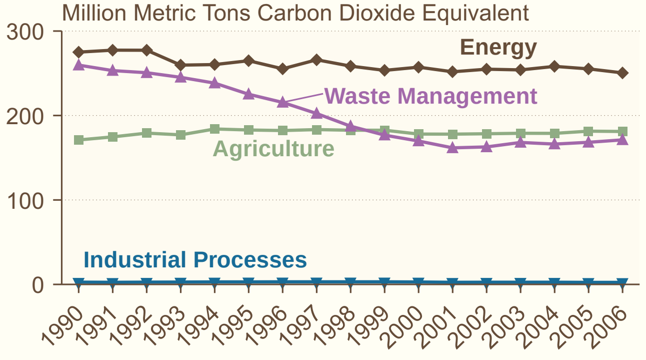
Summary

- The major sources of U.S. methane emissions are energy production, distribution, and use; agriculture; and waste management (Figure 12).
- U.S. methane emissions in 2006 totaled 605 million metric tons carbon dioxide equivalent (MMTCO$_2$e), down slightly from the 2005 total (Table 14).
- Methane emissions declined steadily from 1990 to 2001, as emissions from energy sources and waste management fell.
- Emissions rose from 2001 to 2005, as emissions from waste management increased in every year except 2004.
- The energy sector—including coal mining, natural gas systems, petroleum systems, and stationary and mobile combustion—is the largest source of U.S. methane emissions.
- Agriculture (primarily livestock management) and waste management (primarily landfills) also are large contributors to U.S. methane emissions.
- This is the first annual EIA emissions inventory that directly incorporates estimates of methane emissions from industrial wastewater treatment in the waste management category.

U.S. Anthropogenic Methane Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO$_2$e)	708.4	607.3	605.1
Change from 1990 (Million Metric Tons CO$_2$e)		-101.0	-103.3
(Percent)		*-14.3%*	*-14.6%*
Average Annual Change from 1990 *(Percent)*		*-1.0%*	*-1.0%*
Change from 2005 (Million Metric Tons CO$_2$e)			-2.3
(Percent)			*-0.4%*

Figure 12. U.S. Methane Emissions by Source, 1990-2006



Source: EIA estimates.

Table 14. U.S. Methane Emissions from Anthropogenic Sources, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Energy Sources	275.0	264.8	253.4	257.2	251.8	254.8	254.0	258.2	255.1	250.4
Agricultural Sources	171.1	182.9	182.5	178.1	177.9	178.4	178.9	178.9	181.5	181.1
Waste Management	259.6	225.1	176.8	169.8	161.7	162.8	168.1	166.2	168.3	171.2
Industrial Processes	2.7	3.0	3.1	2.9	2.6	2.7	2.6	2.6	2.5	2.4
Total	**708.4**	**675.9**	**615.8**	**608.0**	**593.9**	**598.6**	**603.7**	**605.9**	**607.3**	**605.1**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: Published and unpublished data used to produce *Emissions of Greenhouse Gases in the United States 2005.* Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: IPCC Guidelines for National Greenhouse Gas Inventories* (2006 and revised 1996 guidelines), web site www.ipcc-nggip.iges.or.jp/public/public.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Methane Emissions

Energy Use

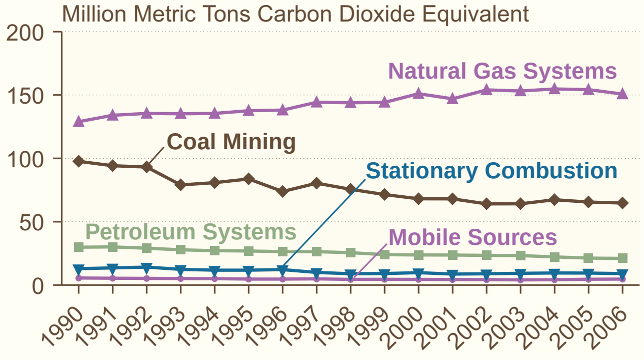
Summary

- Natural gas systems and coal mines are the major sources of methane emissions in the energy sector.
- Methane emissions from natural gas systems grew between 1990 and 2000, in parallel with increases in U.S. natural gas consumption, then leveled off from 2000 to 2006 (Figure 13 and Table 15).
- Emissions from coal mines declined from 1990 to 2002 and have remained low since then, because production increases have been largely from surface mines that produce relatively little methane.
- Methane emissions from petroleum systems have declined as domestic oil production has dropped by more than 30 percent since 1990.
- Residential wood consumption accounts for almost 90 percent of methane emissions from stationary combustion.
- Methane emissions from passenger cars, which declined from 1990 to 2003 as more efficient catalytic converters were added on newer models, have rebounded with increases in total vehicle miles traveled.

Energy-Related Methane Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	275.0	255.1	250.4
Change from 1990 (Million Metric Tons CO_2e)		-19.9	-24.6
(Percent)		*-7.2%*	*-8.9%*
Average Annual Change from 1990 *(Percent)*		*-0.5%*	*-0.6%*
Change from 2005 (Million Metric Tons CO_2e)			-4.7
(Percent)			*-1.8%*

Figure 13. U.S. Methane Emissions from Energy Sources, 1990-2006



Source: EIA estimates.

Table 15. U.S. Methane Emissions from Energy Sources, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Natural Gas Systems	***128.9***	***137.6***	***144.2***	***151.0***	***147.0***	***154.0***	***153.2***	***154.8***	***154.2***	***150.8***
Production	33.8	36.1	37.3	39.9	42.0	42.4	42.9	43.6	44.3	43.3
Processing	14.9	16.5	16.1	16.4	16.0	15.5	14.4	14.8	14.6	14.6
Transmission and Storage	48.3	49.3	52.8	55.4	49.0	55.6	54.7	53.7	53.5	51.0
Distribution	32.0	35.7	38.0	39.3	40.0	40.5	41.2	42.6	41.8	41.8
Coal Mining	***97.7***	***83.8***	***71.5***	***68.1***	***68.0***	***64.1***	***64.2***	***67.3***	***65.5***	***64.7***
Surface	10.7	11.2	12.5	12.4	13.2	13.0	12.7	13.1	13.5	14.2
Underground	87.0	72.5	58.9	55.7	54.9	51.1	51.5	54.2	52.1	50.5
Petroleum Systems	***29.9***	***26.9***	***24.0***	***23.8***	***23.7***	***23.5***	***23.3***	***22.3***	***21.3***	***21.1***
Refineries	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7
Exploration and Production	29.0	26.1	23.2	22.9	22.9	22.6	22.4	21.4	20.4	20.3
Crude Oil Transportation	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
Stationary Combustion	***12.9***	***11.8***	***9.1***	***9.8***	***8.7***	***8.9***	***9.3***	***9.5***	***9.5***	***9.1***
Mobile Sources	***5.6***	***4.7***	***4.6***	***4.5***	***4.3***	***4.3***	***4.1***	***4.2***	***4.6***	***4.8***
Total	**275.0**	**264.8**	**253.4**	**257.2**	**251.8**	**254.8**	**254.0**	**258.2**	**255.1**	**250.4**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: Published and unpublished data used to produce *Emissions of Greenhouse Gases in the United States 2005.* Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: IPCC Guidelines for National Greenhouse Gas Inventories* (2006 and revised 1996 guidelines), web site www.ipcc-nggip.iges.or.jp/public/public.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Methane Emissions

Agriculture

Summary

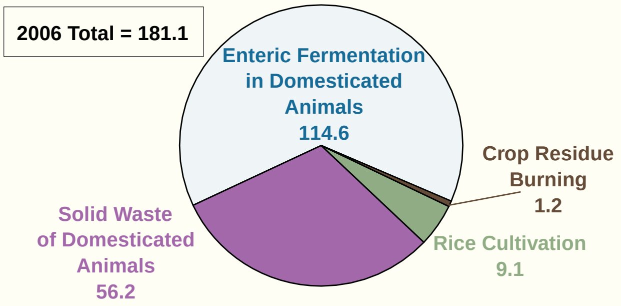
- Livestock management—including emissions from enteric fermentation (two-thirds) and management of animal wastes (one-third)—accounts for most of the U.S. methane emissions from agricultural activities (Table 16).
- Since 1990, there has been a shift in livestock management to larger facilities that are more likely to manage waste in liquid systems, which increase the amounts of methane generated from livestock waste.
- Because 95 percent of all methane emissions from enteric fermentation (digestion in ruminant animals) are attributable to cattle, trends in emissions are correlated with trends in the size of the U.S. cattle population.
- Decreases in U.S. rice production—particularly in Louisiana, Mississippi, and Arkansas—have reduced the estimated emissions from rice cultivation.
- Crop residue burning remains the smallest contributor to methane emissions from agriculture, representing less than 1 percent of total U.S. methane emissions (Figure 14).

Methane Emissions from Agricultural Sources, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	171.1	181.5	181.1
Change from 1990 (Million Metric Tons CO_2e)		10.4	10.0
(Percent)		*6.1%*	*5.8%*
Average Annual Change from 1990 *(Percent)*		*0.4%*	*0.4%*
Change from 2005 (Million Metric Tons CO_2e)			-0.4
(Percent)			*-0.2%*

Figure 14. U.S. Methane Emissions from Agriculture by Source, 2006

(Million Metric Tons Carbon Dioxide Equivalent)



Source: EIA estimates.

Table 16. U.S. Methane Emissions from Agricultural Sources, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Enteric Fermentation in Domesticated Animals	117.3	121.8	117.3	113.9	112.7	113.4	113.8	112.0	113.9	114.6
Solid Waste of Domesticated Animals	43.5	49.9	52.7	52.8	53.3	53.7	54.2	54.7	55.5	56.2
Rice Cultivation	9.3	10.2	11.5	10.2	10.7	10.2	9.8	10.9	10.9	9.1
Crop Residue Burning	1.0	1.0	1.1	1.1	1.1	1.0	1.2	1.3	1.2	1.2
Total	**171.1**	**182.9**	**182.5**	**178.1**	**177.9**	**178.4**	**178.9**	**178.9**	**181.5**	**181.1**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: Published and unpublished data used to produce *Emissions of Greenhouse Gases in the United States 2005.* Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: IPCC Guidelines for National Greenhouse Gas Inventories* (2006 and revised 1996 guidelines), web site www.ipcc-nggip.iges.or.jp/public/public.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Methane Emissions

Waste Management

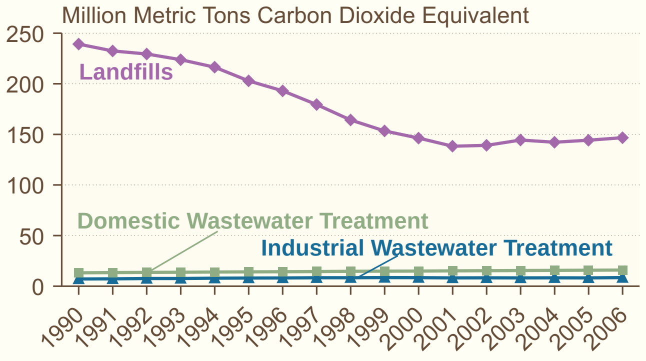
Summary

- Decomposition of solid waste in municipal and industrial landfills is the largest source of U.S. methane emissions from waste management (Table 17).
- Emissions from landfills declined substantially from 1990 to 2001 as a result of increases in recycling and in the recovery of landfill methane for energy; since 2001, annual increases in the total amount of waste deposited in landfills have resulted in increasing methane emissions (Figure 15).
- Rapid growth in methane recovery during the 1990s can be traced in part to the Federal Section 29 tax credit for alternative energy sources, which provided a subsidy of approximately 1 cent per kilowatthour for electricity generated from landfill gas before June 1998.
- Methane recovery may also have been increased by the U.S. EPA's New Source Performance Standards and Emission Guidelines, which require large landfills to collect and burn landfill gas.
- As part of the American Jobs Creation Act of 2004, a tax credit for electricity generation from landfill gas was added to Section 45 of the Internal Revenue Code. The credit was augmented under the Energy Policy Act of 2005, providing a 10-year tax credit valued at 0.9 cents per kilowatthour for landfill gas-to-energy projects placed in service between October 22, 2004, and December 31, 2007.
- About 14 percent of methane emissions from waste management are attributable to wastewater treatment, including both domestic wastewater (two-thirds) and industrial wastewater (one-third).

Methane Emissions from Waste Management, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	259.6	168.3	171.2
Change from 1990 (Million Metric Tons CO_2e)		-91.4	-88.4
(Percent)		*-35.2%*	*-34.1%*
Average Annual Change from 1990 *(Percent)*		*-2.8%*	*-2.6%*
Change from 2005 (Million Metric Tons CO_2e)			2.9
(Percent)			*1.7%*

Figure 15. U.S. Methane Emissions from Waste Management by Source, 1990-2006



Source: EIA estimates.

Table 17. U.S. Methane Emissions from Waste Management, 1990, 1995, and 1999-2006

(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Landfills	239.2	202.9	153.4	146.3	138.3	139.2	144.4	142.2	144.2	146.7
Domestic Wastewater Treatment	13.2	14.2	14.8	15.0	15.2	15.3	15.5	15.6	15.8	15.9
Industrial Waste Water Treatment	7.2	8.1	8.5	8.5	8.2	8.3	8.2	8.3	8.2	8.5
Total.	**259.6**	**225.1**	**176.8**	**169.8**	**161.7**	**162.8**	**168.1**	**166.2**	**168.3**	**171.2**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: Published and unpublished data used to produce *Emissions of Greenhouse Gases in the United States 2005.* Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: IPCC Guidelines for National Greenhouse Gas Inventories* (2006 and revised 1996 guidelines), web site www.ipcc-nggip.iges.or.jp/public/public.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Methane Emissions

Industrial Processes

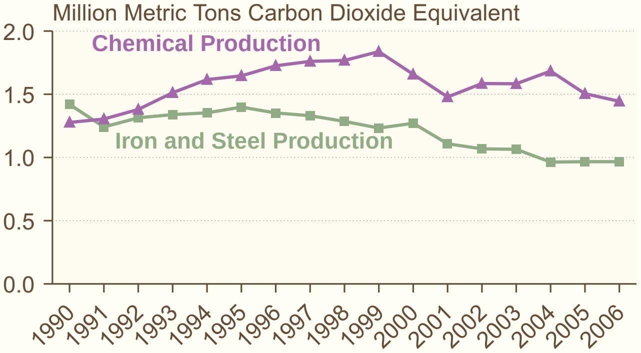
Summary

- Methane emissions are generated by industrial processes in the production of iron and steel and in chemical production (Figure 16 and Table 18).
- The slight growth in methane emissions from U.S. chemical production from 1990 to 2006 (0.2 $MMTCO_2e$) has been more than offset by declines in emissions from iron and steel production (0.5 $MMTCO_2e$) over the same period, leading to a net decline of 0.3 $MMTCO_2e$ in methane emissions from industrial processes.

Methane Emissions from Industrial Processes, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	2.7	2.5	2.4
Change from 1990 (Million Metric Tons CO_2e)		-0.2	-0.3
(Percent)		*-8.4%*	*-10.6%*
Average Annual Change from 1990 *(Percent)*		*-0.6%*	*-0.7%*
Change from 2005 (Million Metric Tons CO_2e)			-0.1
(Percent)			*-2.4%*

Figure 16. U.S. Methane Emissions from Industrial Processes by Source, 1990-2006



Source: EIA estimates.

Table 18. U.S. Methane Emissions from Industrial Processes, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Chemical Production										
Ethylene	0.4	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ethylene Dichloride	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Styrene	0.3	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4
Methanol.	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.1	*
Carbon Black	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Subtotal	**1.3**	**1.6**	**1.8**	**1.7**	**1.5**	**1.6**	**1.6**	**1.7**	**1.5**	**1.4**
Iron and Steel Production										
Coke[a]	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Sinter	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Pig Iron	1.0	1.1	1.0	1.0	0.9	0.8	0.8	0.8	0.8	0.8
Subtotal	**1.4**	**1.4**	**1.2**	**1.3**	**1.1**	**1.1**	**1.1**	**1.0**	**1.0**	**1.0**
Total	**2.7**	**3.0**	**3.1**	**2.9**	**2.6**	**2.7**	**2.6**	**2.6**	**2.5**	**2.4**

*Less than 0.05 $MMTCO_2e$.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

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Nitrous Oxide Emissions

Total Emissions

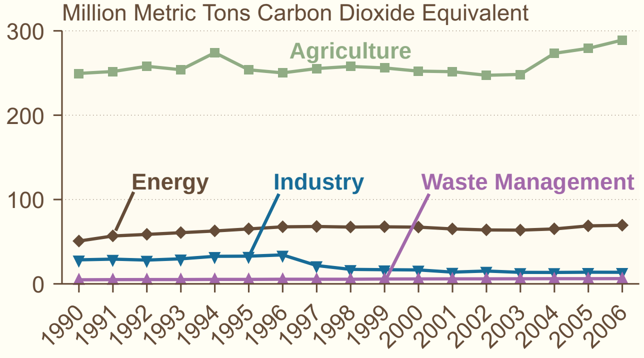
Summary

- Nitrous oxide emissions represent about 5 percent of all U.S. greenhouse gas emissions.
- The major sources of U.S. nitrous oxide emissions are agriculture and energy use, with industrial processes and waste management making smaller contributions (Table 19). The largest source is agricultural activities (Figure 17), including nitrogen fertilization of soils and disposal of animal wastes.
- Annual U.S. nitrous oxide emissions rose from 1990 to 1994, then fell from 1994 to 2003. They began rising sharply from 2003 to 2006, largely as a result of increases in the application of synthetic fertilizers.

U.S. Anthropogenic Nitrous Oxide Emissions, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e). . . .	333.7	368.0	378.6
Change from 1990 (Million Metric Tons CO_2e)		34.2	44.9
(Percent)		*10.3%*	*13.4%*
Average Annual Change from 1990 *(Percent)*		*0.7%*	*0.8%*
Change from 2005 (Million Metric Tons CO_2e).			10.6
(Percent)			*2.9%*

Figure 17. Nitrous Oxide Emissions by Source, 1990-2006



Source: EIA estimates.

Table 19. Estimated U.S. Emissions of Nitrous Oxide, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Agriculture										
Nitrogen Fertilization of Soils	187.1	187.7	193.1	189.8	189.6	185.6	187.1	212.5	217.4	226.7
Solid Waste of Domesticated Animals . .	61.9	65.6	62.3	61.8	61.4	61.1	60.7	60.3	61.2	61.7
Crop Residue Burning	0.5	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.6	0.6
Subtotal.	**249.5**	**253.7**	**256.0**	**252.2**	**251.5**	**247.3**	**248.3**	**273.4**	**279.2**	**289.1**
Energy Use										
Mobile Combustion	37.4	51.2	53.0	52.2	50.6	49.6	49.2	50.3	53.8	54.8
Stationary Combustion.	13.3	13.9	14.6	15.1	14.6	14.3	14.5	14.9	14.9	14.7
Subtotal.	**50.8**	**65.2**	**67.7**	**67.2**	**65.1**	**64.0**	**63.7**	**65.2**	**68.7**	**69.5**
Industrial Sources	**28.6**	**32.9**	**16.8**	**16.6**	**14.0**	**15.2**	**13.6**	**13.6**	**13.9**	**13.8**
Waste Management										
Human Sewage in Wastewater	4.6	5.1	5.5	5.6	5.6	5.7	5.7	5.8	5.8	5.9
Waste Combustion	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Subtotal.	**4.9**	**5.4**	**5.8**	**5.8**	**6.0**	**6.0**	**6.1**	**6.1**	**6.2**	**6.3**
Total	**333.7**	**357.1**	**346.3**	**341.9**	**336.6**	**332.5**	**331.7**	**358.3**	**368.0**	**378.6**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: Estimates presented in this chapter. Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: IPCC Guidelines for National Greenhouse Gas Inventories* (2006 and revised 1996 guidelines), web site www.ipcc-nggip.iges.or.jp/public/public.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Nitrous Oxide Emissions

Agriculture

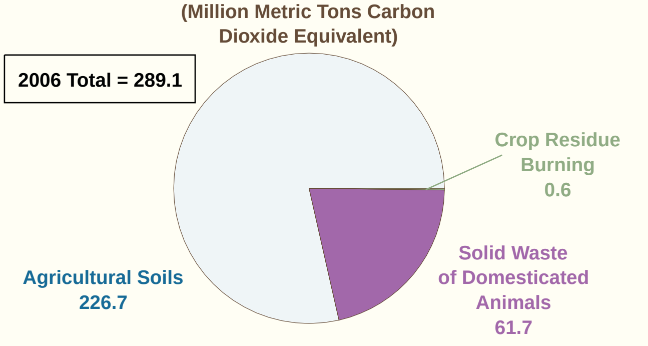
Summary

- Agricultural soils—both direct and indirect emissions—account for more than three-quarters of all U.S. emissions of nitrous oxide from agriculture (Figure 18 and Table 20).
- When nitrogen compounds are added to the soil, bacterial action is stimulated, leading to increased emissions of nitrous oxide unless the application precisely matches plant uptake and soil capture.
- Nitrous oxide is also released as part of the microbial denitrification of animal manure. Emissions are a function of animal size and manure production, the amount of nitrogen in the animal waste, and the method of managing the waste. Waste managed by solid storage or pasture range methods may emit 20 times as much nitrous oxide per unit of nitrogen content as waste managed in anaerobic lagoon and liquid systems.

U.S. Anthropogenic Nitrous Oxide Emissions from Agriculture, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	249.5	279.2	289.1
Change from 1990 (Million Metric Tons CO_2e)		29.7	39.6
(Percent)		*11.9%*	*15.9%*
Average Annual Change from 1990 *(Percent)*		*0.8%*	*0.9%*
Change from 2005 (Million Metric Tons CO_2e)			9.9
(Percent)			*3.5%*

Figure 18. Nitrous Oxide Emissions from Agriculture by Source, 2006



Source: EIA estimates.

Table 20. U.S. Nitrous Oxide Emissions from Agricultural Sources, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Agricultural Soils										
Direct Emissions										
Biological Fixation in Crops	58.6	62.1	68.2	67.9	69.5	65.3	62.5	71.0	70.7	71.2
Nitrogen Fertilizers	53.1	51.2	47.7	45.6	44.4	45.6	48.0	54.3	57.9	63.0
Crop Residues	28.2	28.1	33.8	34.6	34.7	32.9	32.8	38.5	37.3	36.9
Other	4.5	4.7	4.7	4.6	4.7	4.7	4.8	4.8	4.8	4.8
Total Direct Emissions	***144.4***	***146.2***	***154.5***	***152.9***	***153.5***	***148.7***	***148.2***	***168.7***	***170.9***	***176.2***
Indirect Emissions										
Soil Leaching	36.3	35.2	32.8	31.3	30.6	31.4	33.0	37.1	39.5	43.0
Atmospheric Deposition	6.5	6.3	5.8	5.6	5.5	5.6	5.9	6.6	7.0	7.6
Total Indirect Emissions	***42.8***	***41.4***	***38.6***	***36.9***	***36.0***	***37.0***	***38.8***	***43.7***	***46.5***	***50.6***
Solid Waste of Domesticated Animals										
Cattle	57.5	61.1	57.9	57.4	56.9	56.7	56.3	55.8	56.4	56.8
Swine	1.5	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7
Poultry	0.9	1.2	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4
Horses	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Sheep	1.0	0.8	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5
Goats	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.5
Total Solid Waste	***61.9***	***65.6***	***62.3***	***61.8***	***61.4***	***61.1***	***60.7***	***60.3***	***61.2***	***61.7***
Crop Residue Burning	***0.5***	***0.5***	***0.5***	***0.6***	***0.6***	***0.5***	***0.5***	***0.6***	***0.6***	***0.6***
Total Agricultural Sources	**249.5**	**253.7**	**256.0**	**252.2**	**251.5**	**247.3**	**248.3**	**273.4**	**279.2**	**289.1**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

Nitrous Oxide Emissions

Energy Use

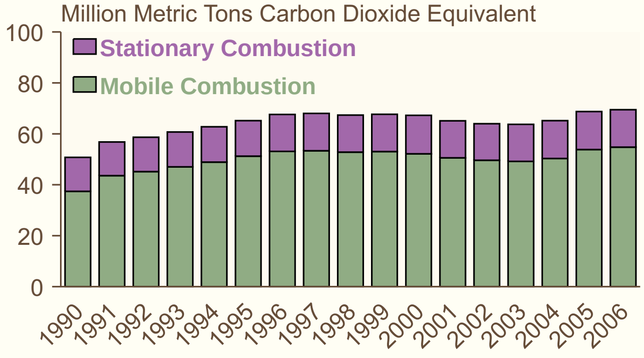
Summary

- Nitrous oxide is a byproduct of fuel combustion in mobile and stationary sources (Figure 19).
- More than three-quarters of U.S. nitrous oxide emissions from energy use can be traced to motor vehicles, primarily passenger cars and light trucks (Table 21). Emissions from passenger cars did not increase from 2005 to 2006, emissions from light trucks showed the largest increase, and the rest of the increase in vehicle emissions of nitrous oxide is attributed to off-road vehicles (included in "Other Mobile Sources").
- Nitrous oxide emissions from motor vehicles are caused by the conversion of nitrogen oxides into nitrous oxide by catalytic converters. Because the normal operating temperature of catalytic converters is high enough to cause the thermal decomposition of nitrous oxide, emissions in this category result primarily from "cold starts" and defective catalytic converters.
- Nitrous oxide emissions from stationary combustion sources are dominated by coal-fired generation at electric power plants.

U.S. Anthropogenic Nitrous Oxide Emissions from Energy Use, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	50.8	68.7	69.5
Change from 1990 (Million Metric Tons CO_2e)		18.0	18.7
(Percent)		*35.4%*	*36.8%*
Average Annual Change from 1990 *(Percent)*		*2.0%*	*2.0%*
Change from 2005 (Million Metric Tons CO_2e)			0.7
(Percent)			*1.1%*

Figure 19. Nitrous Oxide Emissions from Energy Use by Source, 1990-2006



Source: EIA estimates.

Table 21. U.S. Nitrous Oxide Emissions from Energy Use, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Item	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Mobile Combustion										
Motor Vehicles	***33.9***	***47.6***	***49.3***	***48.3***	***46.9***	***46.0***	***45.8***	***46.6***	***49.6***	***50.2***
Passenger Cars	21.6	28.5	28.4	27.6	26.7	25.6	24.9	24.6	25.6	25.6
Light-Duty Trucks	10.4	16.9	18.4	18.1	17.7	17.8	18.2	19.1	21.2	21.8
Other Motor Vehicles	1.8	2.2	2.5	2.6	2.6	2.7	2.7	2.8	2.8	2.8
Other Mobile Sources	***3.6***	***3.6***	***3.7***	***3.9***	***3.6***	***3.6***	***3.4***	***3.7***	***4.2***	***4.6***
Total	**37.4**	**51.2**	**53.0**	**52.2**	**50.6**	**49.6**	**49.2**	**50.3**	**53.8**	**54.8**
Stationary Combustion										
Residential and Commercial	1.4	1.4	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.2
Industrial	4.7	4.9	4.9	4.9	4.6	4.4	4.3	4.6	4.5	4.5
Electric Power	7.2	7.7	8.6	8.9	8.7	8.8	9.0	9.0	9.2	9.1
Total	**13.3**	**13.9**	**14.6**	**15.1**	**14.6**	**14.3**	**14.5**	**14.9**	**14.9**	**14.7**
Total from Energy Use	**50.8**	**65.2**	**67.7**	**67.2**	**65.1**	**64.0**	**63.7**	**65.2**	**68.7**	**69.5**

*Less than 50,000 metric tons carbon dioxide equivalent.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Sources: Calculations based on vehicle miles traveled from U.S. Department of Transportation, *Federal Highway Statistics* (various years), Table VM-1, and current year preliminary estimates calculated using growth rates from EIA, *Short-Term Energy Outlook* (various years). Other Mobile Sources calculations based on Oak Ridge National Laboratory, *Transportation Energy Data Book*; EIA, *Fuel Oil and Kerosene Sales*, *State Energy Data Report*, and *Petroleum Supply Annual* (various years). Passenger car and light-duty truck emissions coefficients from U.S. Environmental Protection Agency, Office of Air and Radiation, *Emissions of Nitrous Oxide From Highway Mobile Sources: Comments on the Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-1996*, EPA-420-R-98-009 (Washington DC, August 1998). Emissions coefficients from Intergovernmental Panel on Climate Change, Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: IPCC Guidelines for National Greenhouse Gas Inventories* (2006 and revised 1996 guidelines), web site www.ipcc-nggip.iges.or.jp/public/public.htm.

Nitrous Oxide Emissions

Industrial Sources

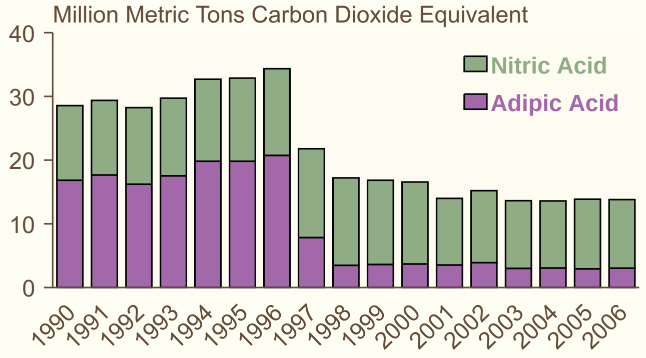
Summary

- Production of adipic acid and nitric acid releases nitrous oxide as a byproduct (Table 22).
- Adipic acid is a fine white powder used primarily in the manufacture of nylon fibers and plastics. Three companies operate four U.S. plants that manufacture adipic acid by oxidizing a ketone-alcohol mixture with nitric acid. This chemical reaction causes nitrous oxide emissions.
- A large decline in nitrous oxide emissions from industrial processes since 1996 (Figure 20) is the result of emissions control technology installed at three of the four adipic acid plants in the United States.
- Nitric acid, a primary ingredient in fertilizers, usually is manufactured by oxidizing ammonia with a platinum catalyst. This oxidation causes nitrous oxide emissions.

U.S. Anthropogenic Nitrous Oxide Emissions from Industrial Sources, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	28.6	13.9	13.8
Change from 1990			
(Million Metric Tons CO_2e)		-14.7	-14.8
(Percent)		*-51.5%*	*-51.7%*
Average Annual Change from 1990 *(Percent)*		*-4.7%*	*-4.4%*
Change from 2005			
(Million Metric Tons CO_2e)			-0.1
(Percent)			*-0.4%*

Figure 20. Nitrous Oxide Emissions from Industry by Source, 1990-2006



Source: EIA estimates.

Table 22. U.S. Nitrous Oxide Emissions from Industrial Sources, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Adipic Acid										
Controlled Sources	1.0	1.1	1.5	1.6	1.4	1.6	1.6	1.6	1.6	1.6
Uncontrolled Sources	15.9	18.7	2.1	2.1	2.1	2.3	1.4	1.4	1.4	1.4
Subtotal	**16.8**	**19.8**	**3.6**	**3.7**	**3.5**	**3.9**	**3.0**	**3.1**	**2.9**	**3.0**
Nitric Acid	**11.7**	**13.1**	**13.2**	**12.9**	**10.4**	**11.3**	**10.6**	**10.5**	**10.9**	**10.8**
Total Known Industrial Sources	**28.6**	**32.9**	**16.8**	**16.6**	**14.0**	**15.2**	**13.6**	**13.6**	**13.9**	**13.8**

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

Nitrous Oxide Emissions

Waste Management

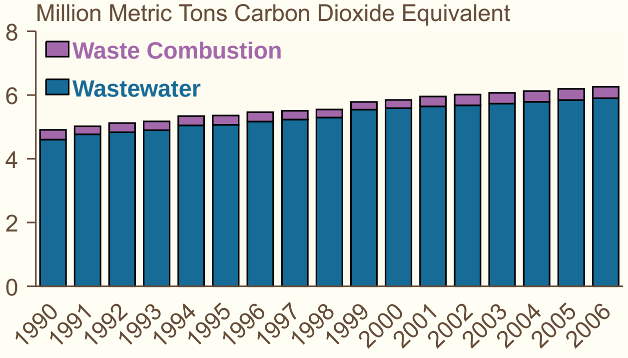
Summary

- Emissions from human sewage account for nearly all U.S. nitrous oxide emissions from waste management. The remainder is associated with waste combustion (Figure 21 and Table 23).
- Estimates of nitrous oxide emissions from human waste are scaled to population size and per-capita intake of protein.
- Nitrous oxide is emitted from wastewater that contains nitrogen-based organic materials, such as those found in human or animal waste. Factors that influence the amount of nitrous oxide generated from wastewater include temperature, acidity, biochemical oxygen demand, and nitrogen concentration.

U.S. Anthropogenic Nitrous Oxide Emissions from Waste Management, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	4.9	6.2	6.3
Change from 1990 (Million Metric Tons CO_2e)		1.3	1.4
(Percent)		*26.2%*	*27.6%*
Average Annual Change from 1990 *(Percent)*		*1.6%*	*1.5%*
Change from 2005 (Million Metric Tons CO_2e)			0.1
(Percent)			*1.1%*

Figure 21. Nitrous Oxide Emissions from Waste Management by Source, 1990-2006



Source: EIA estimates.

Table 23. U.S. Nitrous Oxide Emissions from Waste Management, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Domestic and Commercial Wastewater	4.6	5.1	5.5	5.6	5.6	5.7	5.7	5.8	5.8	5.9
Waste Combustion	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Total	**4.9**	**5.4**	**5.8**	**5.8**	**6.0**	**6.0**	**6.1**	**6.1**	**6.2**	**6.3**

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0573(2005) (Washington, DC, November 2006). Totals may not equal sum of components due to independent rounding.

Source: EIA estimates.

High-GWP Gases

Total Emissions

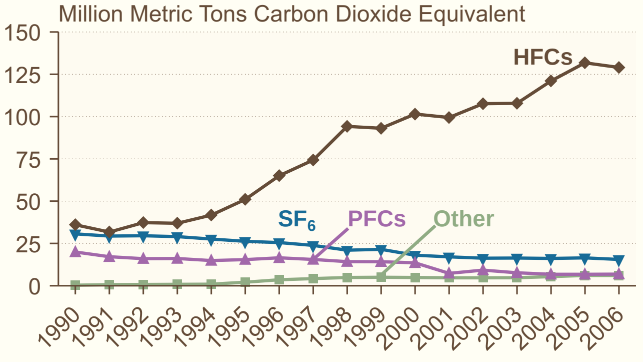
Summary

- Greenhouse gases with high global warming potential (high-GWP gases) are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), which together represented just over 2 percent of U.S. greenhouse gas emissions in 2006.
- Emissions estimates for the high-GWP gases are provided to EIA by the EPA's Office of Air and Radiation. The estimates are derived from the EPA Vintaging Model.
- Emissions of high-GWP gases have increased steadily since 1990 (Figure 22 and Table 24), largely because HFCs are being used to replace chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and other ozone-depleting substances that are being phased out under the terms of the Montreal Protocol, which entered into force on January 1, 1989.
- PFC emissions have declined since 1990 as a result of production declines in the U.S. aluminum industry as well as industry efforts to lower emissions per unit of output.

U.S. Anthropogenic Emissions of High-GWP Gases, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	87.1	161.2	157.6
Change from 1990 (Million Metric Tons CO_2e)		74.1	70.5
(Percent)		*85.1%*	*81.0%*
Average Annual Change from 1990 *(Percent)*		*4.2%*	*3.8%*
Change from 2005 (Million Metric Tons CO_2e)			-3.6
(Percent)			*-2.2%*

Figure 22. U.S. Anthropogenic Emissions of High-GWP Gases, 1990-2006



Source: U.S. EPA estimates.

Table 24. U.S. Emissions of Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Hydrofluorocarbons	36.1	51.0	93.1	101.5	99.4	107.6	107.8	121.1	131.8	129.0
Perfluorocarbons	20.0	15.5	14.2	13.6	7.4	9.3	7.7	6.8	6.8	6.9
Other HFCs, PFCs/PFPEs	0.4	2.1	5.0	4.9	4.7	4.7	4.7	5.4	6.1	6.1
Sulfur Hexafluoride	30.7	26.3	21.6	18.1	17.1	16.3	16.4	16.2	16.5	15.6
Total Emissions	**87.1**	**94.9**	**133.9**	**138.0**	**128.6**	**137.8**	**136.6**	**149.4**	**161.2**	**157.6**

P = preliminary data.

Notes: Other HFCs, PFCs/PFPEs include HFC-152a, HFC-227ea, HFC-245fa, HFC-4310mee, and a variety of PFCs and perfluoropolyethers (PFPEs). They are grouped together to protect confidential data. Totals may not equal sum of components due to independent rounding.

Source: U.S. Environmental Protection Agency, Office of Air and Radiation, web site www.epa.gov/globalwarming/ (preliminary estimates, September and October 2007).

High-GWP Gases

Hydrofluorocarbons

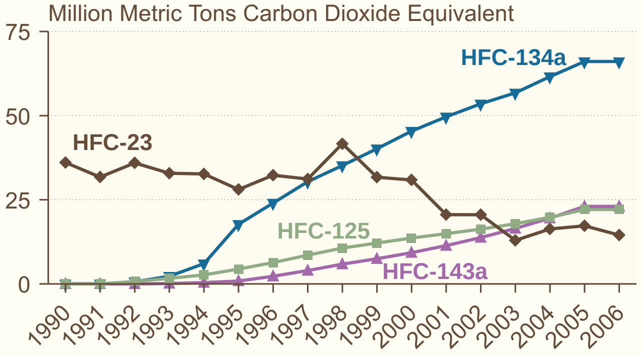
Summary

- HFCs are compounds that contain carbon, hydrogen, and fluorine. Although they do not destroy stratospheric ozone, they are powerful greenhouse gases.
- HFCs are used in many applications, such as solvents, residential and commercial refrigerants, firefighting agents, and propellants for aerosols.
- Emissions of substitutes for ozone-depleting substances, including HFC-32, HFC-125, HFC-134a, and HFC-236fa, have grown from trace amounts in 1990 to more than 110 MMTCO$_2$e in 2006 (Figure 23).
- Nearly 90 percent of the growth in HFC emissions since 1990 can be attributed to the use of HFCs as replacements for ozone-depleting substances. The market is expanding, with HFCs used in fire protection applications to replace Halon 1301 and Halon 1211.
- Since 1999, HFC-134a—used as a replacement for CFCs in air conditioners for passenger cars, trucks, trains, and buses—has accounted for the largest share of HFC emissions (Table 25).

U.S. Anthropogenic Emissions of HFCs, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO$_2$e)	36.1	131.8	129.0
Change from 1990 (Million Metric Tons CO$_2$e)		95.7	93.0
(Percent)		*265.4%*	*257.8%*
Average Annual Change from 1990 *(Percent)*		*9.0%*	*8.3%*
Change from 2005 (Million Metric Tons CO$_2$e)			-2.7
(Percent)			*-2.1%*

Figure 23. U.S. Anthropogenic Emissions of HFCs, 1990-2006



Source: U.S. EPA estimates.

Table 25. U.S. Emissions of Hydrofluorocarbons, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
HFC-23	36.1	28.1	31.7	30.9	20.6	20.6	12.9	16.3	17.3	14.5
HFC-32	0.0	0.0	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4
HFC-125	0.0	4.4	12.1	13.6	14.9	16.3	17.9	19.8	22.1	22.1
HFC-134a	0.0	17.7	40.2	45.4	49.7	53.5	56.8	61.6	66.1	66.1
HFC-143a	0.0	0.9	7.5	9.3	11.4	13.8	16.5	19.5	23.0	23.0
HFC-236fa	0.0	0.0	1.3	2.0	2.6	3.2	3.5	3.5	2.9	2.9
Total HFCs	**36.1**	**51.0**	**93.1**	**101.5**	**99.4**	**107.6**	**107.8**	**121.1**	**131.8**	**129.0**

P = preliminary data.

Note: Totals may not equal sum of components due to independent rounding.

Source: U.S. Environmental Protection Agency, Office of Air and Radiation, web site www.epa.gov/globalwarming/ (preliminary estimates, September and October 2007).

High-GWP Gases

Perfluorocarbons

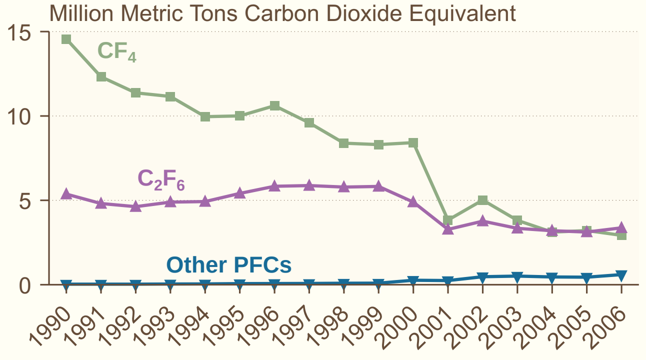
Summary

- The two principal sources of PFC emissions are domestic aluminum production and semiconductor manufacture, which yield perfluoromethane (CF_4) and perfluoroethane (C_2F_6) (Figure 24 and Table 26).
- While PFC emissions from aluminum production have declined markedly since 1990, the decline has been offset in part by increased emissions from semiconductor manufacturing.
- Emissions from process inefficiencies during aluminum production (known as "anode effects") have been greatly reduced; in addition, high costs for alumina and energy have led to production cutbacks.
- Perfluoroethane is used as an etchant and cleaning agent in semiconductor manufacturing. The portion of the gas that does not react with the materials is emitted to the atmosphere.

U.S. Anthropogenic Emissions of PFCs, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	20.0	6.8	6.9
Change from 1990 (Million Metric Tons CO_2e)		-13.2	-13.1
(Percent)		*-66.0%*	*-65.5%*
Average Annual Change from 1990 *(Percent)*		*-6.9%*	*-6.4%*
Change from 2005 (Million Metric Tons CO_2e)			0.1
(Percent)			*1.8%*

Figure 24. U.S. Anthropogenic Emissions of PFCs, 1990-2006



Source: U.S. EPA estimates.

Table 26. U.S. Emissions of Perfluorocarbons, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
CF_4	14.6	10.0	8.3	8.4	3.8	5.0	3.8	3.1	3.2	2.9
C_2F_6	5.4	5.4	5.8	4.9	3.3	3.8	3.3	3.2	3.1	3.4
NF_3	*	0.1	0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.4
C_3F_8	*	*	*	0.1	0.1	0.1	0.1	*	*	*
C_4F_8	*	*	*	*	*	0.1	0.1	0.1	0.1	*
Total HFCs	**20.0**	**15.5**	**14.2**	**13.6**	**7.4**	**9.3**	**7.7**	**6.8**	**6.8**	**6.9**

*Less than 0.05 million metric tons carbon dioxide equivalent.
P = preliminary data.
Note: Totals may not equal sum of components due to independent rounding.
Source: U.S. Environmental Protection Agency, Office of Air and Radiation, web site www.epa.gov/globalwarming/ (preliminary estimates, September and October 2007).

High-GWP Gases

Sulfur Hexafluoride

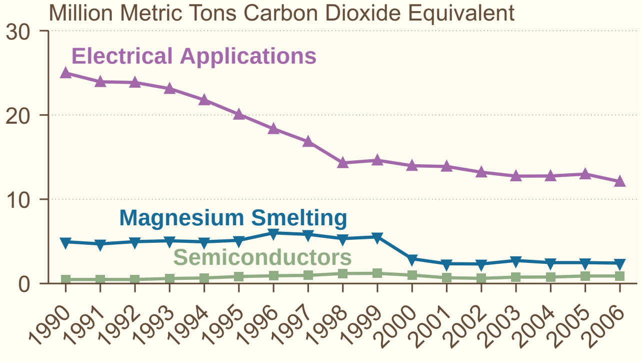
Summary

- SF_6, an excellent dielectric gas for high-voltage applications, is used primarily in electrical applications—as an insulator and arc interrupter for circuit breakers, switch gear, and other equipment in electricity transmission and distribution systems.
- SF_6 is also used in magnesium metal casting, as a cover gas during magnesium production, and as an atmospheric tracer for experimental purposes.
- Other, minor applications of SF_6 include leak detection and the manufacture of loudspeakers and lasers.
- Industry efforts to reduce emissions of SF_6 from electrical power systems have led to a decline in emissions since 1990 (Figure 25 and Table 27).

U.S. Anthropogenic Emissions of SF_6, 1990, 2005, and 2006

	1990	2005	2006
Estimated Emissions (Million Metric Tons CO_2e)	30.7	16.5	15.6
Change from 1990 (Million Metric Tons CO_2e)		-14.2	-15.1
(Percent)		*-46.2%*	*-49.3%*
Average Annual Change from 1990 *(Percent)*		*-4.1%*	*-4.2%*
Change from 2005 (Million Metric Tons CO_2e)			-0.9
(Percent)			*-5.7%*

Figure 25. U.S. Anthropogenic Emissions of SF_6 by Source, 1990-2006



Source: U.S. EPA estimates.

Table 27. U.S. Emissions of Sulfur Hexafluoride by Source, 1990, 1995, and 1999-2006
(Million Metric Tons Carbon Dioxide Equivalent)

Source	1990	1995	1999	2000	2001	2002	2003	2004	2005	P2006
Electrical Applications	25.2	20.3	14.8	14.1	14.0	13.3	12.9	12.9	13.1	12.2
Magnesium Smelting	5.0	5.2	5.6	3.0	2.4	2.3	2.8	2.5	2.5	2.4
Semiconductors	0.5	0.8	1.2	1.0	0.7	0.6	0.8	0.8	0.9	0.9
Total SF_6	**30.7**	**26.3**	**21.6**	**18.1**	**17.1**	**16.3**	**16.4**	**16.2**	**16.5**	**15.6**

P = preliminary data.

Note: Totals may not equal sum of components due to independent rounding.

Source: U.S. Environmental Protection Agency, Office of Air and Radiation, web site www.epa.gov/globalwarming/ (preliminary estimates, September and October 2007).

Land Use

Overview

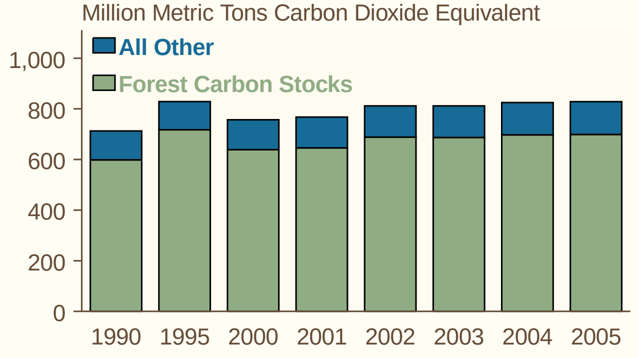
Summary

- Land use, land-use change, and forestry activities in 2005 resulted in net sequestration of 828.5 million metric tons CO_2 equivalent (Table 28), equal to 11.5 percent of U.S. greenhouse gas emissions in 2005, which totaled 7,181.4 $MMTCO_2e$.
- Net carbon sequestration from land use, land-use change, and forestry activities in 2005 was 16 percent greater than in 1990 (Figure 26). The increase resulted primarily from a higher rate of net carbon accumulation in forest carbon stocks.
- Net carbon accumulation in Cropland Remaining Cropland, Land Converted to Grassland, and Settlements Remaining Settlements increased from 1990 to 2005.
- Net carbon accumulation in landfilled yard trimmings and food scraps decreased from 1990 to 2005. Grassland Remaining Grassland had net carbon emissions in 1990 and 1991, became a net carbon sink from 1992 to 1994, and since then has remained a fairly constant emissions source.
- Emissions from Land Converted to Cropland declined from 1990 to 2005.

Total U.S. Carbon Sequestration from Land-Use Change and Forests, 1990, 2004, and 2005

	1990	2004	2005
Estimated Sequestration (Million Metric Tons)	712.8	824.8	828.5
Change from 1990			
(Million Metric Tons)		112.0	115.7
(Percent)		*15.7%*	*16.2%*
Average Annual Change from 1990 *(Percent)*		*1.1%*	*1.0%*
Change from 2004			
(Million Metric Tons)			0.45
(Percent)			*-1.3%*

Figure 26. Carbon Sequestration from Land Use and Land-Use Change, 1990, 1995, and 2000-2005



Source: U.S. EPA estimates.

Table 28. Net Carbon Dioxide Sequestration from U.S. Land-Use Change and Forestry, 1990, 1995, and 2000-2005
(Million Metric Tons Carbon Dioxide Equivalent)

Component	1990	1995	2000	2001	2002	2003	2004	2005
Forest Land Remaining Forest Land:								
Changes in Forest Carbon Stocks	598.5	717.5	638.7	645.7	688.1	687.0	697.3	698.7
Cropland Remaining Cropland:								
Changes in Agricultural Soil Carbon Stocks and Liming Emissions[a]	28.1	37.4	36.5	38.0	37.8	38.3	39.4	39.4
Land Converted to Cropland:								
Changes in Agricultural Soil Carbon Stocks	-8.7	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2
Grassland Remaining Grassland:								
Changes in Agricultural Soil Carbon Stocks	-0.1	-16.4	-16.3	-16.2	-16.2	-16.2	-16.1	-16.1
Land Converted to Grassland:								
Changes in Agricultural Soil Carbon Stocks	14.6	16.3	16.3	16.3	16.3	16.3	16.3	16.3
Settlements Remaining Settlements:								
Urban Trees[b]	57.5	67.8	78.2	80.2	82.3	84.4	86.4	88.5
Other:								
Landfilled Yard Trimmings and Food Scraps	22.8	13.3	10.5	10.6	10.8	9.3	8.7	8.8
Total Net Flux	**712.8**	**828.8**	**756.7**	**767.5**	**811.9**	**811.9**	**824.8**	**828.5**

[a] Estimates include carbon stock changes in mineral soils and organic soils on Cropland Remaining Cropland and liming emissions from all Cropland, Grassland, and Settlement categories.

[b] Estimates include C stock changes on both Settlements Remaining Settlements, and Land Converted to Settlements.

Note: Totals may not equal sum of components due to independent rounding.

Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Land Use

Forest Lands and Harvested Wood Pools

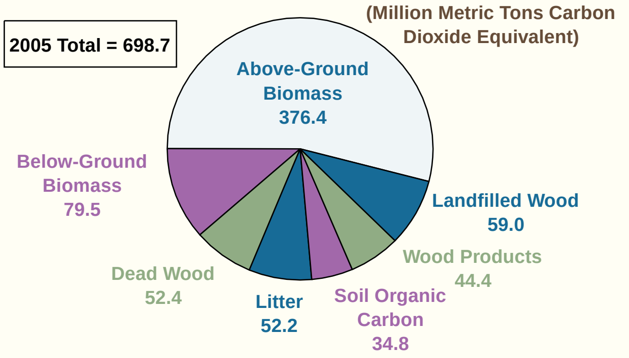
Summary

- Carbon sequestration attributed to forest land remaining forest land in 2005 totaled 698.7 million metric tons carbon dioxide equivalent (Figure 27 and Table 29).
- The calculation methods for this year's annualized estimates of forest ecosystem carbon stocks differ from those used in previous inventories, as a result of efforts to improve the consistency of national, State, and sub-State data sets. The new estimate of carbon stocks sequestered in forest land in 1990 is 23 percent lower, and the estimate for 2004 is 9 percent higher, than the values in last year's inventory.
- The chaparral ecosystem fails to meet the definition of forest, and more current forest data omit this vegetation type; however, it has been discovered that older forest survey data included it. To ensure consistency, chaparral has been removed from the older estimates in this year's inventory, resulting in lower estimates of carbon stocks for California, especially in the earlier years.
- The sequestration estimates for harvested wood products have also been revised, based on more detailed product and trade data and updated parameters for discard and decay. As a result, the estimates for average annual sequestration for harvested wood products from 1990 through 2004 are about 47 percent less than in last year's inventory. Virtually all of the decrease is in the estimates of annual additions to landfills and dumps.

Carbon Sequestration from Forest Lands and Harvested Wood Pools, 1990, 2004, and 2005

	1990	2004	2005
Estimated Sequestration (Million Metric Tons)	598.5	697.3	698.7
Change from 1990			
(Million Metric Tons)		98.8	100.2
(Percent)		*16.5%*	*16.7%*
Average Annual Change from 1990 *(Percent)*		*1.0%*	*1.0%*
Change from 2004			
(Million Metric Tons)			1.4
(Percent)			*0.2%*

Figure 27. Carbon Sequestration from Forest Lands and Harvested Wood Pools, 2005



Source: U.S. EPA estimates.

Table 29. Net Carbon Dioxide Sequestration in U.S. Forests and Harvested Wood Pools, 1990, 1995, and 2000-2005
(Million Metric Tons Carbon Dioxide Equivalent)

Carbon Pool	1990	1995	2000	2001	2002	2003	2004	2005
Forests	**466.5**	**602.0**	**529.4**	**555.5**	**595.3**	**595.3**	**595.3**	**595.3**
Above-Ground Biomass	251.8	331.0	347.1	360.4	376.4	376.4	376.4	376.4
Below-Ground Biomass.	63.9	69.8	73.9	76.4	79.5	79.5	79.5	79.5
Dead Wood	36.7	60.9	48.2	50.0	52.4	52.4	52.4	52.4
Litter.	65.6	49.5	35.8	47.1	52.2	52.2	52.2	52.2
Soil Organic Carbon	48.5	90.8	24.5	21.6	34.8	34.8	34.8	34.8
Harvested Wood	**132.0**	**115.5**	**109.3**	**90.2**	**92.8**	**91.7**	**101.9**	**103.4**
Wood Products	63.1	53.5	46.2	31.2	34.1	33.4	43.3	44.4
Landfilled Wood.	68.9	62.0	63.1	59.0	58.7	58.3	58.7	59.0
Total	**598.5**	**717.5**	**638.7**	**645.7**	**688.1**	**687.0**	**697.3**	**698.7**

Notes: The sums of the annual net stock changes in this table (shown in the "Total" row) represent estimates of the actual net flux between the total forest carbon pool and the atmosphere. Forest estimates are based on periodic measurements; harvested wood estimates are based on annual surveys and models. Totals may not equal sum of components due to independent rounding.

Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Land Use

Croplands and Grasslands

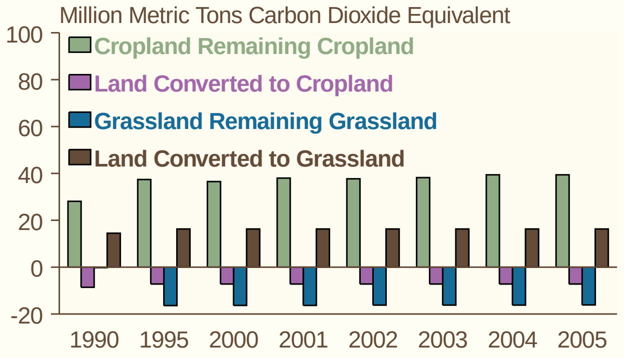
Summary

- Annual carbon dioxide emissions from organic cropland soils are subdivided between Cropland Remaining Cropland and Land Converted to Cropland (Table 30); in last year's inventory they were reported only for Cropland Remaining Cropland. The reapportionment resulted in an average annual increase in emissions of 71.4 percent for soil carbon stock changes in Land Converted to Cropland from 1990 to 2004 and a shift of this category to an overall source (Figure 28) from an overall sink in the previous report.
- The adjustments for Cropland and Grassland categories, applied to Grassland Remaining Grassland, resulted in an average annual increase in emissions of 46.2 percent for soil carbon stock changes from 1990 to 2004. Applied to Land Converted to Grassland, the adjustments resulted in an average annual decrease in sinks of 21.1 percent from 1990 to 2004.

Total U.S. Carbon Sequestration from Croplands and Grasslands, 1990, 2004, and 2005

	1990	2004	2005
Estimated Sequestration (Million Metric Tons)	33.8	32.3	32.4
Change from 1990 (Million Metric Tons)		-1.5	-1.4
(Percent)		*-4.4%*	*-4.1%*
Average Annual Change from 1990 *(Percent)*		*-0.3%*	*-0.3%*
Change from 2004 (Million Metric Tons)			0.1
(Percent)			*0.3%*

Figure 28. Carbon Sequestration from Croplands and Grasslands, 1990, 1995, and 2000-2005



Source: U.S. EPA estimates.

Table 30. Net Carbon Dioxide Sequestration from Croplands and Grasslands, 1990, 1995, and 2000-2005
(Million Metric Tons Carbon Dioxide Equivalent)

Carbon Pool	1990	1995	2000	2001	2002	2003	2004	2005
Cropland Remaining Cropland.	**28.1**	**37.4**	**36.5**	**38.0**	**37.8**	**38.3**	**39.4**	**39.4**
Mineral Soils	60.2*	69.5	68.5	70.1	70.4	70.5	71.0	71.1
Organic Soils	-27.4*	-27.7	-27.7	-27.7	-27.7	-27.7	-27.7	-27.7
Liming of Soils	-4.7*	-4.4*	-4.3*	-4.4*	-5.0*	-4.6*	-3.9*	-4.0*
Land Converted to Cropland	**-8.7**	**-7.2**	**-7.2**	**-7.2**	**-7.2**	**-7.2**	**-7.2**	**-7.2**
Mineral Soils	-6.2*	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6
Organic Soils	-2.4*	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6
Liming of Soils	—*	—	—	—	—	—	—	—
Grassland Remaining Grassland.	**0.1**	**-16.4**	**-16.3**	**-16.2**	**-16.2**	**-16.2**	**-16.1**	**-16.1**
Mineral Soils	3.7*	-12.7	-12.6	-12.6	-12.5	-12.5	-12.5	-12.4
Organic Soils	-3.9*	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7
Liming of Soils	—*	—	—	—	—	—	—	—
Land Converted to Grassland	**14.6**	**16.3**	**16.3**	**16.3**	**16.3**	**16.3**	**16.3**	**16.3**
Mineral Soils	15.0*	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Organic Soils	-0.5*	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Liming of Soils	—*	—	—	—	—	—	—	—

*Values based on a combination of historical data and projections. All other values based on historical data only.

Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Land Use

Urban Trees, Yard Trimmings, and Food Scraps

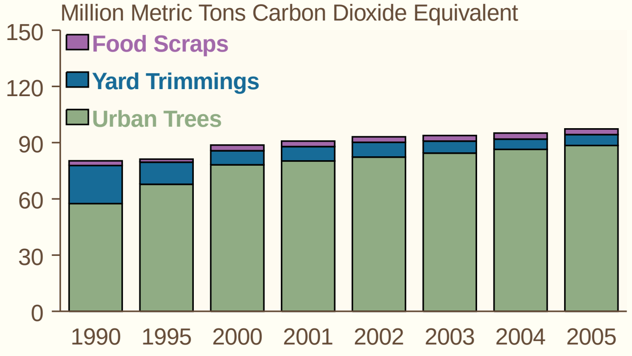
Summary

- Urban trees accounted for nearly all (91 percent) of the carbon sequestration attributed to urban trees, yard trimmings, and food scraps in 2005 (Figure 29 and Table 31).
- For yard trimmings and food scrap carbon stocks in landfills, the value for the initial carbon content of leaves was updated for the current inventory based on updated experimental results. This recalculation had the effect of reducing both the stocks of carbon from leaves and the annual flux for yard trimmings and food scraps.
- In last year's inventory, changes in yard trimming and food scrap carbon stocks in landfills were included under Settlements Remaining Settlements. Although carbon stock changes in yard trimmings and food scraps are associated with settlements, removals do not occur within settlements. Therefore, yard trimming and food scrap carbon storage is now reported under "Other."

Total U.S. Carbon Sequestration from Urban Trees, Yard Trimmings, and Food Scraps, 1990, 2004, and 2005

	1990	2004	2005
Estimated Sequestration (Million Metric Tons)	80.3	95.1	97.3
Change from 1990 (Million Metric Tons)		14.8	16.9
(Percent)		*18.4%*	*21.0%*
Average Annual Change from 1990 *(Percent)*		*1.1%*	*1.3%*
Change from 2004 (Million Metric Tons)			2.2
(Percent)			*2.3%*

Figure 29. Carbon Sequestration from Urban Trees, Yard Trimmings, and Food Scraps, 1990, 1995, and 2000-2005



Source: U.S. EPA estimates.

Table 31. Net Carbon Dioxide Sequestration in U.S. Urban Trees, Yard Trimmings, and Food Scraps, 1990, 1995, and 2000-2005
(Million Metric Tons Carbon Dioxide Equivalent)

Carbon Pool	1990	1995	2000	2001	2002	2003	2004	2005
Urban Trees	**57.5**	**67.8**	**78.2**	**80.2**	**82.3**	**84.4**	**86.4**	**88.5**
Yard Trimmings	**20.3**	**11.8**	**7.5**	**7.7**	**7.9**	**6.4**	**5.5**	**5.8**
Grass	2.4	1.2	0.8	0.9	0.9	0.7	0.6	0.7
Leaves	8.2	4.7	2.9	3.0	3.1	2.5	2.1	2.2
Branches	9.7	5.8	3.7	3.8	3.9	3.2	2.8	2.9
Food Scraps	**2.5**	**1.6**	**3.0**	**2.9**	**2.9**	**3.0**	**3.2**	**3.0**
Total Net Flux	**80.3**	**81.2**	**88.7**	**90.8**	**93.1**	**93.8**	**95.1**	**97.3**

Note: Totals may not equal sum of components due to independent rounding.

Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, EPA 430-R-07-002 (Washington, DC, April 2007), web site www.epa.gov/climatechange/emissions/usinventoryreport.html.

Land Use

Tree Planting and Surface Albedo

Surface albedo is a measure of the extent to which the Earth's surface reflects or absorbs sunlight. Lighter surfaces, such as bare ground covered with snow, have a relatively *high albedo* and *reflect* almost all the energy (heat) of incoming solar radiation. Darker surfaces, such as deep oceans and dense forests, have a relatively *low albedo* and *absorb* almost all the heat of incoming solar radiation. Consequently, when changing conditions cause a decrease in surface albedo—for example, when trees are planted on lands that receive substantial winter snowfall—they can increase the capacity of the affected area to absorb heat from the sun, with an overall warming effect.

Afforestation and reforestation to increase carbon sequestration are permitted activities under the Clean Development Mechanism of the Kyoto Protocol and other climate change mitigation programs. Project developers can earn carbon credits or offsets for the amounts of carbon sequestered by the trees they plant. Recent research, however, has shown the importance of changes in surface albedo caused by tree planting, which should be considered in tandem with the increases in carbon sequestration achieved by such projects.[20, 21, 22, 23, 24] Tree planting increases carbon sequestration; but, depending on local and regional conditions, it can also decrease surface albedo.[25]

The recent scientific studies cited above have shown that, in the Earth's middle and high latitudes, the warming effect of lower surface albedo that results from afforestation or reforestation can have an unintended net warming effect. Before the advent of industrialization, humans were already affecting the climate by clearing forests to plant crops, an activity that increased surface albedo.[26] Thus, the net result of preindustrial changes in land use was negative climate forcing (cooling). According to one recent study,[27] the rate of cooling induced by preindustrial deforestation was similar in magnitude to the current rate of positive climate forcing (warming) caused by anthropogenic emissions of ozone (O_3), nitrous oxide (N_2O), and halocarbons.

Researchers have also compared the magnitude of the positive climate forcing caused by modern-day tree planting (as a result of lowered albedo) with the negative forcing that results from increased carbon sequestration by newly planted trees. Their results indicate that, in the middle and high latitudes, the warming effects of afforestation and reforestation activities could partially or completely offset the cooling effects—especially in snow-covered areas, where the difference in albedo between snow-covered bare ground and partially snow-covered forested areas is greatest. This finding has policy implications in general for climate change mitigation efforts and specifically for the valuation of carbon credits earned through reforestation and afforestation activities.

The albedo effect is less significant in tropical zones, where research models indicate that deforestation causes warming.[28] In tropical forest areas, loss of tree cover reduces leafy surface area and, as a result, slows the release of water vapor into the atmosphere. Slower evaporation rates, in turn, have a negative effect on cloud formation above tropical rain forests. Because the clouds reflect incoming solar radiation, they lower surface temperatures. With less cloud cover, more incoming solar radiation reaches the Earth's surface, and temperatures rise.

(continued on page 42)

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[20] R.A. Betts, P. D. Falloon, K.K. Goldewijk, and N. Ramankutty, "Biogeophysical Effects of Land Use on Climate: Model Simulations of Radiative Forcing and Large-Scale Temperature Change," *Agricultural and Forest Meteorology*, Vol. 142 (2007), pp. 216-233.

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[22] J.J. Feddema, K.W. Oleson, G.B. Bonan, L.O. Mearns, L.E. Buja, G.A. Meehl, and W.M. Washington, "The Importance of Land-Cover Change in Simulating Future Climates," *Science*, Vol. 310, No. 5754 (December 9, 2005), pp. 1674-1678.

[23] A. Fischlin, G.F. Midgley, J.T. Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, and A.A. Velichko, "Ecosystems, Their Properties, Goods, and Services," in *Climate Change 2007: Impacts, Adaptation and Vulnerability* (M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, eds. (Cambridge, UK: Cambridge University Press, 2007), pp. 211-272, web site www.ipcc.ch/ipccreports/ar4-wg2.htm.

[24] S.G. Gibbard, K. Caldeira, G. Bala, T.J. Philips, and M. Wickett, "Climate Effects of Global Land Cover Change," *Geophysical Research Letters*, Vol. 32 (2005), p. L23705, web site www.llnl.gov/tid/lof/documents/pdf/324200.pdf.

[25] It is important to note that the planting of trees often has other ecological and societal benefits, which are not discussed here.

[26] S.G. Gibbard et al., "Climate Effects of Global Land Cover Change" (2005).

[27] R.A. Betts et al., "Biogeophysical Effects of Land Use on Climate: Model Simulations of Radiative Forcing and Large-Scale Temperature Change" (2007).

[28] J.J. Feddema et al., "The Importance of Land-Cover Change in Simulating Future Climates" (2005).

Land Use

Tree Planting and Surface Albedo

At the National Center for Atmospheric Research, researchers using the Parallel Climate Model (sponsored by the U.S. Department of Energy) have modeled climate change for three future periods—2000-2033, 2033-2066, and 2066-2100—considering in one case only the effects of atmospheric forcing and in another case the combined effects of atmospheric forcing and changes in land cover.[29] They found that forest-to-agriculture conversion in the Amazon rain forest causes significant warming, although the effects are not uniform across all tropical forests. (For example, in Indonesia, temperature changes from forest loss are minor in future scenarios, because the Asian monsoon compensates for the decrease in cloud formation relative to that over undisturbed forests.)

In the middle and, especially, high latitudes, there is increasing evidence that the radiative cooling effect derived from carbon sequestration by newly planted trees could be partially or completely offset by the radiative warming effect of reduced albedo. For example, the IPCC in its latest assessment notes that replacement of tundra vegetation by coniferous evergreen trees is likely to reduce regional albedo significantly and lead to a warming effect greater than the cooling effect of increased carbon sequestration.[30] In contrast, tree planting in tropical latitudes, where vegetation and cloud formation are linked, can double the radiative cooling benefit by reducing incoming solar radiation while also increasing carbon sequestration.

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[29] J.J. Feddema et al., “The Importance of Land-Cover Change in Simulating Future Climates” (2005).

[30] Intergovernmental Panel on Climate Change, *Climate Change 2007—The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the IPCC (Cambridge, UK: Cambridge University Press, 2007).

Glossary

Acid stabilization: A circumstance where the pH of the waste mixture in an animal manure management system is maintained near 7.0, optimal conditions for methane production.

Aerobic bacteria: Microorganisms living, active, or occurring only in the presence of oxygen.

Aerobic decomposition: The breakdown of a molecule into simpler molecules or atoms by microorganisms under favorable conditions of oxygenation.

Aerosols: Airborne particles.

Afforestation: Planting of new forests on lands that have not been recently forested.

Agglomeration: The clustering of disparate elements.

Airshed: An area or region defined by settlement patterns or geology that results in discrete atmospheric conditions.

Albedo: The fraction of incident light or electromagnetic radiation that is reflected by a surface or body. See *Planetary albedo*.

Anaerobes: Organisms that live and are active only in the absence of oxygen.

Anaerobic bacteria: Microorganisms living, active, or occurring only in the absence of oxygen.

Anaerobic decomposition: The breakdown of molecules into simpler molecules or atoms by microorganisms that can survive in the partial or complete absence of oxygen.

Anaerobic lagoon: A liquid-based manure management system, characterized by waste residing in water to a depth of at least six feet for a period ranging between 30 and 200 days.

Anode: A positive electrode, as in a battery, radio tube, etc.

Anthracite: The highest rank of coal; used primarily for residential and commercial space heating. It is a hard, brittle, and black lustrous coal, often referred to as hard coal, containing a high percentage of fixed carbon and a low percentage of volatile matter. The moisture content of fresh-mined anthracite generally is less than 15 percent. The heat content of anthracite ranges from 22 to 28 million Btu per ton on a moist, mineral-matter-free basis. The heat content of anthracite coal consumed in the United States averages 25 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter). Note: Since the 1980's, anthracite refuse or mine waste has been used for steam electric power generation. This fuel typically has a heat content of 15 million Btu per ton or less.

Anthropogenic: Made or generated by a human or caused by human activity. The term is used in the context of global climate change to refer to gaseous emissions that are the result of human activities, as well as other potentially climate-altering activities, such as deforestation.

API Gravity: American Petroleum Institute measure of specific gravity of crude oil or condensate in degrees. An arbitrary scale expressing the gravity or density of liquid petroleum products. The measuring scale is calibrated in terms of degrees API; it is calculated as follows: Degrees API = (141.5/sp.gr.60 deg.F/60 deg.F) - 131.5.

Asphalt: A dark brown-to-black cement-like material obtained by petroleum processing and containing bitumens as the predominant component; used primarily for road construction. It includes crude asphalt as well as the following finished products: cements, fluxes, the asphalt content of emulsions (exclusive of water), and petroleum distillates blended with asphalt to make cutback asphalts. Note: The conversion factor for asphalt is 5.5 barrels per short ton.

Associated natural gas: See *Associated-dissolved natural gas* and *Natural gas*.

Associated-dissolved natural gas: Natural gas that occurs in crude oil reservoirs either as free gas (associated) or as gas in solution with crude oil (dissolved gas). See *Natural gas*.

Aviation gasoline (finished): A complex mixture of relatively volatile hydrocarbons with or without small quantities of additives, blended to form a fuel suitable for use in aviation reciprocating engines. Fuel specifications are provided in ASTM Specification D 910 and Military Specification MIL-G-5572. Note: Data on blending components are not counted in data on finished aviation gasoline.

Balancing item: Represents differences between the sum of the components of natural gas supply and the sum of the components of natural gas disposition. These differences may be due to quantities lost or to the effects of data reporting problems. Reporting problems include differences due to the net result of conversions of flow data metered at varying temperature and pressure bases and converted to a standard temperature and pressure base; the effect of variations in company accounting and billing practices; differences between billing cycle and calendar period time frames; and imbalances resulting from the merger of data reporting systems that vary in scope, format, definitions, and type of respondents.

Biofuels: Liquid fuels and blending components produced from biomass (plant) feedstocks, used primarily for transportation.

Biogas: The gas produced from the anaerobic decomposition of organic material in a landfill.

Biogenic: Produced by the actions of living organisms.

Biomass: Organic nonfossil material of biological origin constituting a renewable energy source.

Biosphere: The portion of the Earth and its atmosphere that can support life. The part of the global carbon cycle that includes living organisms and biogenic organic matter.

Bituminous coal: A dense coal, usually black, sometimes dark brown, often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make coke. Bituminous coal is the most abundant coal in active U.S. mining regions. Its moisture content usually is less than 20 percent. The heat content of bituminous coal ranges from 21 to 30 million Btu per ton on a moist, mineral-matter-free basis. The heat content of bituminous coal consumed in the United States averages 24 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter).

BOD_5: The biochemical oxygen demand of wastewater during decomposition occurring over a 5-day period. A measure of the organic content of wastewater.

Bromofluorocarbons (halons): Inert, nontoxic chemicals that have at least one bromine atom in their chemical makeup. They evaporate without leaving a residue and are used in fire extinguishing systems, especially for large computer installations.

Bunker fuel: Fuel supplied to ships and aircraft, both domestic and foreign, consisting primarily of residual and distillate fuel oil for ships and kerosene-based jet fuel for aircraft. The term "international bunker fuels" is used to denote the consumption of fuel for international transport activities. *Note*: For the purposes of greenhouse gas emissions inventories, data on emissions from combustion of international bunker fuels are subtracted from national emissions totals. Historically, bunker fuels have meant only ship fuel. See *Vessel bunkering*.

Calcination: A process in which a material is heated to a high temperature without fusing, so that hydrates, carbonates, or other compounds are decomposed and the volatile material is expelled.

Calcium sulfate: A white crystalline salt, insoluble in water. Used in Keene's cement, in pigments, as a paper filler, and as a drying agent.

Calcium sulfite: A white powder, soluble in dilute sulfuric acid. Used in the sulfite process for the manufacture of wood pulp.

Capital stock: Property, plant and equipment used in the production, processing and distribution of energy resources.

Carbon black: An amorphous form of carbon, produced commercially by thermal or oxidative decomposition of hydrocarbons and used principally in rubber goods, pigments, and printer's ink.

Carbon budget: Carbon budget: The balance of the exchanges (incomes and losses) of carbon between carbon sinks (e.g., atmosphere and biosphere) in the carbon cycle. See *Carbon cycle* and *Carbon sink*.

Carbon cycle: All carbon sinks and exchanges of carbon from one sink to another by various chemical, physical, geological, and biological processes. See *Carbon sink* and *Carbon budget*.

Carbon dioxide (CO_2): A colorless, odorless, nonpoisonous gas that is a normal part of Earth's atmosphere. Carbon dioxide is a product of fossil-fuel combustion as well as other processes. It is considered a greenhouse gas as it traps heat (infrared energy) radiated by the Earth into the atmosphere and thereby contributes to the potential for global warming. The global warming potential (GWP) of other greenhouse gases is measured in relation to that of carbon dioxide, which by international scientific convention is assigned a value of one (1). See *Global warming potential (GWP)* and *Greenhouse gases*.

Carbon dioxide equivalent: The amount of carbon dioxide by weight emitted into the atmosphere that would produce the same estimated radiative forcing as a given weight of another radiatively active gas. Carbon dioxide equivalents are computed by multiplying the weight of the gas being measured (for example, methane) by its estimated global warming potential (which is 21 for methane). "Carbon equivalent units" are defined as carbon dioxide equivalents multiplied by the carbon content of carbon dioxide (i.e., 12/44).

Carbon flux: See *Carbon budget*.

Carbon intensity: The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per British thermal unit (Btu) of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels. See *Emissions coefficient* and *Carbon output rate*.

Carbon output rate: The amount of carbon by weight per kilowatthour of electricity produced.

Carbon sequestration: The fixation of atmospheric carbon dioxide in a carbon sink through biological or physical processes.

Carbon sink: A reservoir that absorbs or takes up released carbon from another part of the carbon cycle. The four sinks, which are regions of the Earth within which carbon behaves in a systematic manner, are the atmosphere, terrestrial biosphere (usually including freshwater systems), oceans, and sediments (including fossil fuels).

Catalytic converter: A device containing a catalyst for converting automobile exhaust into mostly harmless products.

Catalytic hydrocracking: A refining process that uses hydrogen and catalysts with relatively low temperatures and high pressures for converting middle boiling or residual material to high octane gasoline, reformer charge stock, jet fuel, and/or high grade fuel oil. The process uses one or more catalysts, depending on product output, and can handle high sulfur feedstocks without prior desulfurization.

Cesspool: An underground reservoir for liquid waste, typically household sewage.

Chlorofluorocarbon (CFC): Any of various compounds consisting of carbon, hydrogen, chlorine, and fluorine used as refrigerants. CFCs are now thought to be harmful to the earth's atmosphere.

Clean Development Mechanism (CDM): A Kyoto Protocol program that enables industrialized countries to finance emissions-avoiding projects in developing countries and receive credit for reductions achieved against their own emissions limitation targets. See *Kyoto Protocol*.

Climate: The average course or condition of the weather over a period of years as exhibited by temperature, humidity, wind velocity, and precipitation.

Climate change: A term used to refer to all forms of climatic inconsistency, but especially to significant change from one prevailing climatic condition to another. In some cases, "climate change" has been used synonymously with the term "global warming"; scientists, however, tend to use the term in a wider sense inclusive of natural changes in climate, including climatic cooling.

Clinker: Powdered cement, produced by heating a properly proportioned mixture of finely ground raw materials (calcium carbonate, silica, alumina, and iron oxide) in a kiln to a temperature of about 2,700ºF.

Cloud condensation nuclei: Aerosol particles that provide a platform for the condensation of water vapor, resulting in clouds with higher droplet concentrations and increased albedo.

Coal coke: See *Coke (coal)*.

Coalbed methane: Methane is generated during coal formation and is contained in the coal microstructure. Typical recovery entails pumping water out of the coal to allow the gas to escape. Methane is the principal component of natural gas. Coalbed methane can be added to natural gas pipelines without any special treatment.

Coke (coal): A solid carbonaceous residue derived from low-ash, low-sulfur bituminous coal from which the volatile constituents are driven off by baking in an oven at temperatures as high as 2,000 degrees Fahrenheit so that the fixed carbon and residual ash are fused together. Coke is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace. Coke from coal is grey, hard, and porous and has a heating value of 24.8 million Btu per ton.

Coke (petroleum): A residue high in carbon content and low in hydrogen that is the final product of thermal decomposition in the condensation process in cracking. This product is reported as marketable coke or catalyst coke. The conversion is 5 barrels (of 42 U.S. gallons each) per short ton. Coke from petroleum has a heating value of 6.024 million Btu per barrel.

Combustion: Chemical oxidation accompanied by the generation of light and heat.

Combustion chamber: An enclosed vessel in which chemical oxidation of fuel occurs.

Conference of the Parties (COP): The collection of nations that have ratified the Framework Convention on Climate Change (FCCC). The primary role of the COP is to keep implementation of the FCCC under review and make the decisions necessary for its effective implementation. See *Framework Convention on Climate Change (FCCC)*.

Cracking: The refining process of breaking down the larger, heavier, and more complex hydrocarbon molecules into simpler and lighter molecules.

Criteria pollutant: A pollutant determined to be hazardous to human health and regulated under EPA's National Ambient Air Quality Standards. The 1970 amendments to the Clean Air Act require EPA to describe the health and welfare impacts of a pollutant as the "criteria" for inclusion in the regulatory regime.

Crop residue: Organic residue remaining after the harvesting and processing of a crop.

Cultivar: A horticulturally or agriculturally derived variety of a plant.

Deforestation: The net removal of trees from forested land.

Degasification system: The methods employed for removing methane from a coal seam that could not otherwise be removed by standard ventilation fans and thus would pose a substantial hazard to coal miners. These systems may be used prior to mining or during mining activities.

Degradable organic carbon: The portion of organic carbon present in such solid waste as paper, food waste, and yard waste that is susceptible to biochemical decomposition.

Desulfurization: The removal of sulfur, as from molten metals, petroleum oil, or flue gases.

Diffusive transport: The process by which particles of liquids or gases move from an area of higher concentration to an area of lower concentration.

Distillate fuel: A general classification for one of the petroleum fractions produced in conventional distillation operations. It includes diesel fuels and fuel oils. Products known as No. 1, No. 2, and No. 4 diesel fuel are used in on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines, such as those in railroad locomotives and agricultural machinery. Products known as No. 1, No. 2, and No. 4 fuel oils are used primarily for space heating and electric power generation.

Efflux: An outward flow.

Electrical generating capacity: The full-load continuous power rating of electrical generating facilities, generators, prime movers, or other electric equipment (individually or collectively).

EMCON Methane Generation Model: A model for estimating the production of methane from municipal solid waste landfills.

Emissions: Anthropogenic releases of gases to the atmosphere. In the context of global climate change, they consist of radiatively important greenhouse gases (e.g., the release of carbon dioxide during fuel combustion).

Emissions coefficient: A unique value for scaling emissions to activity data in terms of a standard rate of emissions per unit of activity (e.g., pounds of carbon dioxide emitted per Btu of fossil fuel consumed).

Enteric fermentation: A digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal.

Eructation: An act or instance of belching.

ETBE (ethyl tertiary butyl ether): $(CH_3)_3COC_2H$: An oxygenate blend stock formed by the catalytic etherification of isobutylene with ethanol.

Ethylene: An olefinic hydrocarbon recovered from refinery processes or petrochemical processes. Ethylene is used as a petrochemical feedstock for numerous chemical applications and the production of consumer goods.

Ethylene dichloride: A colorless, oily liquid used as a solvent and fumigant for organic synthesis, and for ore flotation.

Facultative bacteria: Bacteria that grow equally well under aerobic and anaerobic conditions.

Flange: A rib or a rim for strength, for guiding, or for attachment to another object (e.g., on a pipe).

Flared: Gas disposed of by burning in flares usually at the production sites or at gas processing plants.

Flatus: Gas generated in the intestines or the stomach of an animal.

Flue gas desulfurization: Equipment used to remove sulfur oxides from the combustion gases of a boiler plant before discharge to the atmosphere. Also referred to as scrubbers. Chemicals such as lime are used as scrubbing media.

Fluidized-bed combustion: A method of burning particulate fuel, such as coal, in which the amount of air required for combustion far exceeds that found in conventional burners. The fuel particles are continually fed into a bed of mineral ash in the proportions of 1 part fuel to 200 parts ash, while a flow of air passes up through the bed, causing it to act like a turbulent fluid.

Flux material: A substance used to promote fusion, e.g., of metals or minerals.

Fodder: Coarse food for domestic livestock.

Forestomach: See *Rumen*.

Fossil fuel: An energy source formed in the earths crust from decayed organic material. The common fossil fuels are petroleum, coal, and natural gas.

Framework Convention on Climate Change (FCCC): An agreement opened for signature at the “Earth Summit” in Rio de Janeiro, Brazil, on June 4, 1992, which has the goal of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent significant anthropogenically forced climate change. See *Climate change*.

Fuel cycle: The entire set of sequential processes or stages involved in the utilization of fuel, including extraction, transformation, transportation, and combustion. Emissions generally occur at each stage of the fuel cycle.

Fugitive emissions: Unintended leaks of gas from the processing, transmission, and/or transportation of fossil fuels.

Gasification: A method for converting coal, petroleum, biomass, wastes, or other carbon-containing materials into a gas that can be burned to generate power or processed into chemicals and fuels.

Gate station: Location where the pressure of natural gas being transferred from the transmission system to the distribution system is lowered for transport through small diameter, low pressure pipelines.

Geothermal: Pertaining to heat within the Earth.

Global climate change: See *Climate change*.

Global warming: An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is today most often used to refer to the warming that some scientists predict will occur as a result of increased anthropogenic emissions of greenhouse gases. See *Climate change*.

Global warming potential (GWP): An index used to compare the relative radiative forcing of different gases without directly calculating the changes in atmospheric concentrations. GWPs are calculated as the ratio of the radiative forcing that would result from the emission of one kilogram of a greenhouse gas to that from the emission of one kilogram of carbon dioxide over a fixed period of time, such as 100 years.

Greenhouse effect: The result of water vapor, carbon dioxide, and other atmospheric gases trapping radiant (infrared) energy, thereby keeping the earth's surface warmer than it would otherwise be. Greenhouse gases within the lower levels of the atmosphere trap this radiation, which would otherwise escape into space, and subsequent re-radiation of some of this energy back to the Earth maintains higher surface temperatures than would occur if the gases were absent. See *Greenhouse gases*.

Greenhouse gases: Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving the Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface.

Gross gas withdrawal: The full-volume of compounds extracted at the wellhead, including nonhydrocarbon gases and natural gas plant liquids.

Gypsum: Calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$), a sludge constituent from the conventional lime scrubber process, obtained as a byproduct of the dewatering operation and sold for commercial use.

Halogenated substances: A volatile compound containing halogens, such as chlorine, fluorine or bromine.

Halons: See *Bromofluorocarbons*.

Heating degree-days (HDD): A measure of how cold a location is over a period of time relative to a base temperature, most commonly specified as 65 degrees Fahrenheit. The measure is computed for each day by subtracting the average of the day's high and low temperatures from the base temperature (65 degrees), with negative values set equal to zero. Each day's heating degree-days are summed to create a heating degree-day measure for a specified reference period. Heating degree-days are used in energy analysis as an indicator of space heating energy requirements or use.

Herbivore: A plant-eating animal.

Hydrocarbon: An organic chemical compound of hydrogen and carbon in either gaseous, liquid, or solid phase. The molecular structure of hydrocarbon compounds varies from the simple (e.g., methane, a constituent of natural gas) to the very heavy and very complex.

Hydrochlorofluorocarbons (HCFCs): Chemicals composed of one or more carbon atoms and varying numbers of hydrogen, chlorine, and fluorine atoms.

Hydrofluorocarbons (HFCs): A group of man-made chemicals composed of one or two carbon atoms and varying numbers of hydrogen and fluorine atoms. Most HFCs have 100-year Global Warming Potentials in the thousands.

Hydroxyl radical (OH): An important chemical scavenger of many trace gases in the atmosphere that are greenhouse gases. Atmospheric concentrations of OH affect the atmospheric lifetimes of greenhouse gases, their abundance, and, ultimately, the effect they have on climate.

Intergovernmental Panel on Climate Change (IPCC): A panel established jointly in 1988 by the World Meteorological Organization and the United Nations Environment Program to assess the scientific information relating to climate change and to formulate realistic response strategies.

International bunker fuels: See *Bunker fuels*.

Jet fuel: A refined petroleum product used in jet aircraft engines. It includes kerosene-type jet fuel and naphtha-type jet fuel.

Joint Implementation (JI): Agreements made between two or more nations under the auspices of the Framework Convention on Climate Change (FCCC) whereby a developed country can receive "emissions reduction units" when it helps to finance projects that reduce net emissions in another developed country (including countries with economies in transition).

Kerosene: A light petroleum distillate that is used in space heaters, cook stoves, and water heaters and is suitable for use as a light source when burned in wick-fed lamps. Kerosene has a maximum distillation temperature of 400 degrees Fahrenheit at the 10-percent recovery point, a final boiling point of 572 degrees Fahrenheit, and a minimum flash point of 100 degrees Fahrenheit. Included are No. 1-K and No. 2-K, the two grades recognized by ASTM Specification D 3699 as well as all other grades of kerosene called range or stove oil, which have properties similar to those of No. 1 fuel oil. See *Kerosene-type jet fuel*.

Kerosene-type jet fuel: A kerosene-based product having a maximum distillation temperature of 400 degrees Fahrenheit at the 10-percent recovery point and a final maximum boiling point of 572 degrees Fahrenheit and meeting ASTM Specification D 1655 and Military Specifications MIL-T-5624P and MIL-T-83133D (Grades JP-5 and JP-8). It is used for commercial and military turbojet and turboprop aircraft engines.

Kyoto Protocol: The result of negotiations at the third Conference of the Parties (COP-3) in Kyoto, Japan, in December of 1997. The Kyoto Protocol sets binding greenhouse gas emissions targets for countries that sign and ratify the agreement. The gases covered under the Protocol include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride.

Ketone-alcohol (cyclohexanol): An oily, colorless, hygroscopic liquid with a camphor-like odor. Used in soapmaking, dry cleaning, plasticizers, insecticides, and germicides.

Leachate: The liquid that has percolated through the soil or other medium.

Lignite: The lowest rank of coal, often referred to as brown coal, used almost exclusively as fuel for steam-electric power generation. It is brownish-black and has a high inherent moisture content, sometimes as high as 45 percent The heat content of lignite ranges from 9 to 17 million Btu per ton on a moist, mineral-matter-free basis. The heat content of lignite consumed in the United States averages 13 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter).

Liquefied petroleum gases: A group of hydrocarbon-based gases derived from crude oil refining or natural gas fractionation. They include ethane, ethylene, propane, propylene, normal butane, butylene, isobutane, and isobutylene. For convenience of transportation, these gases are liquefied through pressurization.

Lubricants: Substances used to reduce friction between bearing surfaces, or incorporated into other materials used as processing aids in the manufacture of other products, or used as carriers of other materials. Petroleum lubricants may be produced either from distillates or residues. Lubricants include all grades of lubricating oils, from spindle oil to cylinder oil to those used in greases.

Methane: A colorless, flammable, odorless hydrocarbon gas (CH4) which is the major component of natural gas. It is also an important source of hydrogen in various industrial processes. Methane is a greenhouse gas. See also *Greenhouse gases*.

Methanogens: Bacteria that synthesize methane, requiring completely anaerobic conditions for growth.

Methanol: A light alcohol that can be used for gasoline blending. See oxygenate.

Methanotrophs: Bacteria that use methane as food and oxidize it into carbon dioxide.

Methyl chloroform (trichloroethane): An industrial chemical (CH_3CCl_3) used as a solvent, aerosol propellant, and pesticide and for metal degreasing.

Methyl tertiary butyl ether (MTBE): A colorless, flammable, liquid oxygenated hydrocarbon containing 18.15 percent oxygen.

Methylene chloride: A colorless liquid, nonexplosive and practically nonflammable. Used as a refrigerant in centrifugal compressors, a solvent for organic materials, and a component in nonflammable paint removers.

Mole: The quantity of a compound or element that has a weight in grams numerically equal to its molecular weight. Also referred to as gram molecule or gram molecular weight.

Montreal Protocol: The Montreal Protocol on Substances that Deplete the Ozone Layer (1987). An international agreement, signed by most of the industrialized nations, to substantially reduce the use of chlorofluorocarbons (CFCs). Signed in January 1989, the original document called for a 50-percent reduction in CFC use by 1992 relative to 1986 levels. The subsequent London Agreement called for a complete elimination of CFC use by 2000. The Copenhagen Agreement, which called for a complete phaseout by January 1, 1996, was implemented by the U.S. Environmental Protection Agency.

Motor gasoline (finished): A complex mixture of relatively volatile hydrocarbons with or without small quantities of additives, blended to form a fuel suitable for use in spark-ignition engines. Motor gasoline, as defined in ASTM Specification D 4814 or Federal Specification VV-G-1690C, is characterized as having a boiling range of 122 to 158 degrees Fahrenheit at the 10 percent recovery point to 365 to 374 degrees Fahrenheit at the 90 percent recovery point. “Motor Gasoline” includes conventional gasoline; all types of oxygenated gasoline, including gasohol; and reformulated gasoline, but excludes aviation gasoline. Note: Volumetric data on blending components, such as oxygenates, are not counted in data on finished motor gasoline until the blending components are blended into the gasoline.

Multiple cropping: A system of growing several crops on the same field in one year.

Municipal solid waste: Residential solid waste and some nonhazardous commercial, institutional, and industrial wastes.

Naphtha less than 401 degrees Fahrenheit: A naphtha with a boiling range of less than 401 degrees Fahrenheit that is intended for use as a petrochemical feedstock. Also see *Petrochemical feedstocks*.

Naphtha-type jet fuel: A fuel in the heavy naphtha boiling range having an average gravity of 52.8 degrees API, 20 to 90 percent distillation temperatures of 290 degrees to 470 degrees Fahrenheit, and meeting Military Specification MIL-T-5624L (Grade JP-4). It is used primarily for military turbojet and turboprop aircraft engines because it has a lower freeze point than other aviation fuels and meets engine requirements at high altitudes and speeds.

Natural gas: A mixture of hydrocarbons and small quantities of various nonhydrocarbons in the gaseous phase or in solution with crude oil in natural underground reservoirs.

Natural gas liquids (NGLs): Those hydrocarbons in natural gas that are separated as liquids from the gas. Includes natural gas plant liquids and lease condensate.

Natural gas, pipeline quality: A mixture of hydrocarbon compounds existing in the gaseous phase with sufficient energy content, generally above 900 Btu, and a small enough share of impurities for transport through commercial gas pipelines and sale to end-users.

Nitrogen oxides (NO_x): Compounds of nitrogen and oxygen produced by the burning of fossil fuels.

Nitrous oxide (N_2O): A colorless gas, naturally occurring in the atmosphere. Nitrous oxide has a 100-year Global Warming Potential of 310.

Nonmethane volatile organic compounds (NMVOCs): Organic compounds, other than methane, that participate in atmospheric photochemical reactions.

Octane: A flammable liquid hydrocarbon found in petroleum. Used as a standard to measure the antiknock properties of motor fuel.

Oil reservoir: An underground pool of liquid consisting of hydrocarbons, sulfur, oxygen, and nitrogen trapped within a geological formation and protected from evaporation by the overlying mineral strata.

Organic content: The share of a substance that is of animal or plant origin.

Organic waste: Waste material of animal or plant origin.

Oxidize: To chemically transform a substance by combining it with oxygen.

Oxygenates: Substances which, when added to gasoline, increase the amount of oxygen in that gasoline blend. Ethanol, Methyl Tertiary Butyl Ether (MTBE), Ethyl Tertiary Butyl Ether (ETBE), and methanol are common oxygenates.

Ozone: A molecule made up of three atoms of oxygen. Occurs naturally in the stratosphere and provides a protective layer shielding the Earth from harmful ultraviolet radiation. In the troposphere, it is a chemical oxidant, a greenhouse gas, and a major component of photochemical smog.

Ozone precursors: Chemical compounds, such as carbon monoxide, methane, nonmethane hydrocarbons, and nitrogen oxides, which in the presence of solar radiation react with other chemical compounds to form ozone.

Paraffinic hydrocarbons: Straight-chain hydrocarbon compounds with the general formula C_nH_{2n+2}.

Perfluorocarbons (PFCs): A group of man-made chemicals composed of one or two carbon atoms and four to six fluorine atoms, containing no chlorine. PFCs have no commercial uses and are emitted as a byproduct of aluminum smelting and semiconductor manufacturing. PFCs have very high 100-year Global Warming Potentials and are very long-lived in the atmosphere.

Perfluoromethane: A compound (CF_4) emitted as a byproduct of aluminum smelting.

Petrochemical feedstocks: Chemical feedstocks derived from petroleum principally for the manufacture of chemicals, synthetic rubber, and a variety of plastics.

Petroleum: A broadly defined class of liquid hydrocarbon mixtures. Included are crude oil, lease condensate, unfinished oils, refined products obtained from the processing of crude oil, and natural gas plant liquids. Note: Volumes of finished petroleum products include nonhydrocarbon compounds, such as additives and detergents, after they have been blended into the products.

Petroleum coke: See *Coke (petroleum)*.

Photosynthesis: The manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll, with sunlight as the energy source. Carbon is sequestered and oxygen and water vapor are released in the process.

Pig iron: Crude, high-carbon iron produced by reduction of iron ore in a blast furnace.

Pipeline, distribution: A pipeline that conveys gas from a transmission pipeline to its ultimate consumer.

Pipeline, gathering: A pipeline that conveys gas from a production well/field to a gas processing plant or transmission pipeline for eventual delivery to end-use consumers.

Pipeline, transmission: A pipeline that conveys gas from a region where it is produced to a region where it is to be distributed.

Planetary albedo: The fraction of incident solar radiation that is reflected by the Earth-atmosphere system and returned to space, mostly by backscatter from clouds in the atmosphere.

Pneumatic device: A device moved or worked by air pressure.

Polystyrene: A polymer of styrene that is a rigid, transparent thermoplastic with good physical and electrical insulating properties, used in molded products, foams, and sheet materials.

Polyvinyl chloride (PVC): A polymer of vinyl chloride. Tasteless. odorless, insoluble in most organic solvents. A member of the family vinyl resin, used in soft flexible films for food packaging and in molded rigid products, such as pipes, fibers, upholstery, and bristles.

Post-mining emissions: Emissions of methane from coal occurring after the coal has been mined, during transport or pulverization.

Radiative forcing: A change in average net radiation at the top of the troposphere (known as the tropopause) because of a change in either incoming solar or exiting infrared radiation. A positive radiative forcing tends on average to warm the earth's surface; a negative radiative forcing on average tends to cool the earth's surface. Greenhouse gases, when emitted into the atmosphere, trap infrared energy radiated from the earth's surface and therefore tend to produce positive radiative forcing. See *Greenhouse gases*.

Radiatively active gases: Gases that absorb incoming solar radiation or outgoing infrared radiation, affecting the vertical temperature profile of the atmosphere. See *Radiative forcing*.

Ratoon crop: A crop cultivated from the shoots of a perennial plant.

Redox potential: A measurement of the state of oxidation of a system.

Reflectivity: The ratio of the energy carried by a wave after reflection from a surface to its energy before reflection.

Reforestation: Replanting of forests on lands that have recently been harvested or otherwise cleared of trees.

Reformulated gasoline: Finished motor gasoline formulated for use in motor vehicles, the composition and properties of which meet the requirements of the reformulated gasoline regulations promulgated by the U.S. Environmental Protection Agency under Section 211(k) of the Clean Air Act. Note: This category includes oxygenated fuels program reformulated gasoline (OPRG) but excludes reformulated gasoline blendstock for oxygenate blending (RBOB).

Renewable energy resources: Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include: biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

Residual fuel oil: A general classification for the heavier oils, known as No. 5 and No. 6 fuel oils, that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. It conforms to ASTM Specifications D 396 and D 975 and Federal Specification VV-F-815C. No. 5, a residual fuel oil of medium viscosity, is also known as Navy Special and is defined in Military Specification MIL-F-859E, including Amendment 2 (NATO Symbol F-770). It is used in steam-powered vessels in government service and inshore powerplants. No. 6 fuel oil includes Bunker C fuel oil and is used for the production of electric power, space heating, vessel bunkering, and various industrial purposes.

Rumen: The large first compartment of the stomach of certain animals in which cellulose is broken down by the action of bacteria.

Sample: A set of measurements or outcomes selected from a given population.

Sequestration: See *Carbon sequestration*.

Septic tank: A tank in which the solid matter of continuously flowing sewage is disintegrated by bacteria.

Sinter: A chemical sedimentary rock deposited by precipitation from mineral waters, especially siliceous sinter and calcareous sinter.

Sodium silicate: A grey-white powder soluble in alkali and water, insoluble in alcohol and acid. Used to fireproof textiles, in petroleum refining and corrugated paperboard manufacture, and as an egg preservative. Also referred to as liquid gas, silicate of soda, sodium metasilicate, soluble glass, and water glass.

Sodium tripolyphosphate: A white powder used for water softening and as a food additive and texturizer.

Stabilization lagoon: A shallow artificial pond used for the treatment of wastewater. Treatment includes removal of solid material through sedimentation, the decomposition of organic material by bacteria, and the removal of nutrients by algae.

Still gas (refinery gas): Any form or mixture of gases produced in refineries by distillation, cracking, reforming, and other processes. The principal constituents are methane, ethane, ethylene, normal butane, butylene, propane, propylene, etc. Still gas is used as a refinery fuel and a petrochemical feedstock. The conversion factor is 6 million Btu per fuel oil equivalent barrel.

Stratosphere: The region of the upper atmosphere extending from the tropopause (8 to 15 kilometers altitude) to about 50 kilometers. Its thermal structure, which is determined by its radiation balance, is generally very stable with low humidity.

Stripper well: An oil or gas well that produces at relatively low rates. For oil, stripper production is usually defined as production rates of between 5 and 15 barrels of oil per day. Stripper gas production would generally be anything less than 60 thousand cubic feet per day.

Styrene: A colorless, toxic liquid with a strong aromatic aroma. Insoluble in water, soluble in alcohol and ether; polymerizes rapidly; can become explosive. Used to make polymers and copolymers, polystyrene plastics, and rubber.

Subbituminous coal: A coal whose properties range from those of lignite to those of bituminous coal and used primarily as fuel for steam-electric power generation. It may be dull, dark brown to black, soft and crumbly, at the lower end of the range, to bright, jet black, hard, and relatively strong, at the upper end. Subbituminous coal contains 20 to 30 percent inherent moisture by weight. The heat content of subbituminous coal ranges from 17 to 24 million Btu per ton on a moist, mineral-matter-free basis. The heat content of subbituminous coal consumed in the United States averages 17 to 18 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter).

Sulfur dioxide (SO_2): A toxic, irritating, colorless gas soluble in water, alcohol, and ether. Used as a chemical intermediate, in paper pulping and ore refining, and as a solvent.

Sulfur hexafluoride (SF_6): A colorless gas soluble in alcohol and ether, and slightly less soluble in water. It is used as a dielectric in electronics. It possesses the highest 100-year Global Warming Potential of any gas (23,900).

Sulfur oxides (SO_x): Compounds containing sulfur and oxygen, such as sulfur dioxide (SO_2) and sulfur trioxide (SO_3).

Tertiary amyl methyl ether ($(CH_3)_2(C_2H_5)COCH_3$): An oxygenate blend stock formed by the catalytic etherification of isoamylene with methanol.

Troposphere: The inner layer of the atmosphere below about 15 kilometers, within which there is normally a steady decrease of temperature with increasing altitude. Nearly all clouds form and weather conditions manifest themselves within this region. Its thermal structure is caused primarily by the heating of the earth's surface by solar radiation, followed by heat transfer through turbulent mixing and convection.

Uncertainty: A measure used to quantify the plausible maximum and minimum values for emissions from any source, given the biases inherent in the methods used to calculate a point estimate and known sources of error.

Vapor displacement: The release of vapors that had previously occupied space above liquid fuels stored in tanks. These releases occur when tanks are emptied and filled.

Ventilation system: A method for reducing methane concentrations in coal mines to non-explosive levels by blowing air across the mine face and using large exhaust fans to remove methane while mining operations proceed.

Vessel bunkering: Includes sales for the fueling of commercial or private boats, such as pleasure craft, fishing boats, tugboats, and ocean-going vessels, including vessels operated by oil companies. Excluded are volumes sold to the U.S. Armed Forces.

Volatile organic compounds (VOCs): Organic compounds that participate in atmospheric photochemical reactions.

Volatile solids: A solid material that is readily decomposable at relatively low temperatures.

Waste flow: Quantity of a waste stream generated by an activity.

Wastewater: Water that has been used and contains dissolved or suspended waste materials.

Wastewater, domestic and commercial: Wastewater (sewage) produced by domestic and commercial establishments.

Wastewater, industrial: Wastewater produced by industrial processes.

Water vapor: Water in a vaporous form, especially when below boiling temperature and diffused (e.g., in the atmosphere).

Wax: A solid or semi-solid material derived from petroleum distillates or residues by such treatments as chilling, precipitating with a solvent, or de-oiling. It is a light-colored, more-or-less translucent crystalline mass, slightly greasy to the touch, consisting of a mixture of solid hydrocarbons in which the paraffin series predominates. Includes all marketable wax, whether crude scale or fully refined. The three grades included are microcrystalline, crystalline-fully refined, and crystalline-other. The conversion factor is 280 pounds per 42 U.S. gallons per barrel.

Weanling system: A cattle management system that places calves on feed starting at 165 days of age and continues until the animals have reached slaughter weight.

Wellhead: The point at which the crude (and/or natural gas) exits the ground. Following historical precedent, the volume and price for crude oil production are labeled as “wellhead,” even though the cost and volume are now generally measured at the lease boundary. In the context of domestic crude price data, the term “wellhead” is the generic term used to reference the production site or lease property.

Wetlands: Areas regularly saturated by surface or groundwater and subsequently characterized by a prevalence of vegetation adapted for life in saturated-soil conditions.

Wood energy: Wood and wood products used as fuel, including roundwood (cordwood), limbwood, wood chips, bark, sawdust, forest residues, charcoal, pulp waste, and spent pulping liquor..

Yearling system: A cattle management system that includes a stocker period from 165 days of age to 425 days of age followed by a 140-day feedlot period.