4. Nitrous Oxide Emissions

Overview

U.S. Anthropogenic Nitrous Oxide Emissions, 1990-2005

	Nitrous Oxide	Carbon Dioxide Equivalent
Estimated 2005 Emissions (Thousand Metric Tons)	1,238.4	366,560
Change Compared to 2004 (Thousand Metric Tons)	22.6	6,686
Change from 2004 *(Percent)*	*1.9%*	*1.9%*
Change Compared to 1990 (Thousand Metric Tons)	111.7	33,061
Change from 1990 *(Percent)*	*9.9%*	*9.9%*

Estimated U.S. anthropogenic nitrous oxide emissions totaled 1.2 million metric tons in 2005, or 366.6 million metric tons carbon dioxide equivalent ($MMTCO_2e$), 1.9 percent more than in 2004 and 9.9 percent above 1990 levels (Table 25). The 2005 total for nitrous oxide emissions represents 5.1 percent of all U.S. greenhouse gas emissions for the year. Most of the increase in U.S. nitrous oxide emissions for 2005 can be attributed to emissions from agricultural sources, which increased by 7.0 $MMTCO_2e$.

A downward trend in U.S. nitrous oxide emissions that began in 1995, after emissions of nitrous oxide peaked at 374.5 $MMTCO_2e$ in 1994, ended in 2003. Over the past 2 years, nitrous oxide emissions have increased. In 2004, annual U.S. emissions of nitrous oxide (359.9 $MMTCO_2e$) were higher than their 1990 level (333.5 $MMTCO_2e$) for the first time since 2001, and in 2005 they were only 2.1 percent below their 1994 peak value.

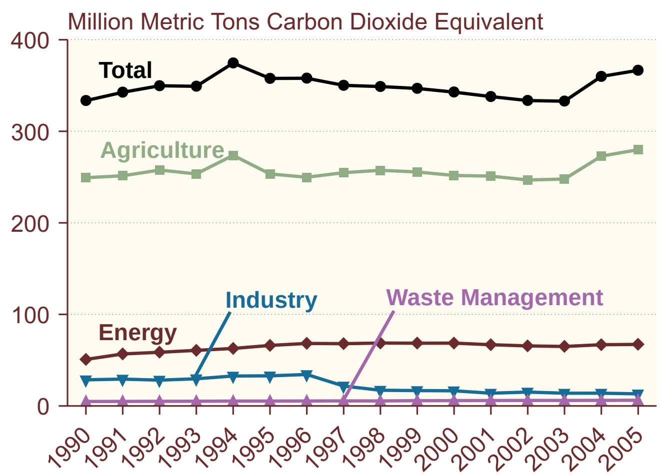
Sources of U.S. nitrous oxide emissions include energy use, agriculture, waste management, and industrial processes. The largest component of U.S. anthropogenic nitrous oxide emissions is emissions from agricultural activities, at 279.9 $MMTCO_2e$ or 76 percent of total nitrous oxide emissions in 2005. Nitrogen fertilization of agricultural soils represents 78 percent of emissions from agricultural activities. Most of the remainder (22 percent) is from the handling of animal waste in managed systems. Small quantities of nitrous oxide (0.2 percent of nitrous oxide emissions from agricultural activities) are also released from the burning of crop residues. Estimated emissions of nitrous oxide from agricultural sources in 2005 were 2.6 percent above 2004 levels and 12 percent above 1990 levels (Figure 3).

The second-largest source of anthropogenic nitrous oxide emissions is energy consumption, which includes mobile source combustion from passenger cars, buses, motorcycles, and trucks; and stationary source combustion from commercial, residential, industrial, and electric power sector energy use. Energy use was responsible for 67.3 $MMTCO_2e$ of nitrous oxide emissions in 2005 (18 percent of total U.S. nitrous oxide emissions). The 2005 level of emissions from energy sources

Sources of U.S. Anthropogenic Nitrous Oxide Emissions, 1990-2005

Source	Million Metric Tons CO_2e 1990	2005	*Percent Change* 1990-2005	2004-2005
Agriculture	249.3	279.9	*12.3%*	*2.6%*
Energy	50.8	67.3	*32.5%*	*0.6%*
Industrial Processes	28.6	13.2	*-53.6%*	*-5.3%*
Waste Management	4.9	6.2	*26.3%*	*1.1%*

Figure 3. U.S. Emissions of Nitrous Oxide by Source, 1990-2005



Source: Estimates presented in this chapter.

is 0.6 percent higher than the 2004 level and 33 percent higher than in 1990.

Industrial production of adipic and nitric acid, which releases nitrous oxide as a byproduct, accounted for emissions of 13.2 $MMTCO_2e$ in 2005 (3.6 percent of total U.S. nitrous oxide emissions), 5.3 percent lower than the 2004 level and 54 percent lower than in 1990. The large decline in emissions of nitrous oxide from adipic acid production since 1990 is a result of the continuing utilization of emissions control technology at three of the four adipic acid plants operating in the United States.

Nitrous oxide emissions from activities related to waste management in 2005 totaled 6.2 $MMTCO_2e$, or 1.7 percent of all U.S. anthropogenic nitrous oxide emissions (Table 25). During 2005, emissions from human sewage in wastewater accounted for 94 percent of estimated nitrous oxide emissions from this source, and the remainder was associated with waste combustion.

Agriculture

U.S. Nitrous Oxide Emissions from Agriculture, 1990-2005

Estimated 2005 Emissions (Million Metric Tons Carbon Dioxide Equivalent)	279.9
Change Compared to 2004 (Million Metric Tons Carbon Dioxide Equivalent)	7.0
Change from 2004 *(Percent)*	*2.6%*
Change Compared to 1990 (Million Metric Tons Carbon Dioxide Equivalent)	30.6
Change from 1990 *(Percent)*	*12.3%*

Nitrous oxide emissions from agricultural activities increased by 7.0 $MMTCO_2e$ (2.6 percent) in 2005 to a total of 279.9 $MMTCO_2e$, compared with 272.9 $MMTCO_2e$ in 2004. Since 1990, nitrous oxide emissions from agricultural activities have increased by 12.3 percent. Agricultural activities were responsible for 76 percent of U.S. nitrous oxide emissions in 2005, smaller than the 86-percent share that agricultural practices contribute to nitrous oxide emissions globally.[63] Nitrous oxide emissions from agricultural activities represent 3.9 percent of total U.S. greenhouse gas emissions.

Nitrogen fertilization of agricultural soils accounted for 78 percent of U.S. agricultural emissions of nitrous oxide in 2005. Nearly all the remaining agricultural emissions (22 percent) can be traced to the management of the solid waste of domesticated animals. The disposal of crop residues by burning also produces nitrous oxide that is released into the atmosphere; however, the amount is relatively minor, at 0.6 $MMTCO_2e$ or 0.2 percent of total U.S. emissions of nitrous oxide from agricultural sources in 2005.

Nitrogen Fertilization of Agricultural Soils

EIA estimates that 218.1 $MMTCO_2e$ of nitrous oxide was released into the atmosphere as a result of direct and indirect emissions associated with fertilization practices in 2005 (Table 26). Estimated emissions increased by 2.9 percent compared with 2004 levels and were 16.7 percent higher than in 1990.

Nitrogen uptake and nitrous oxide emissions occur naturally as a result of nitrification and denitrification processes in soil and crops, generally through bacterial action. When nitrogen compounds are added to the soil, bacterial action is stimulated, and emissions generally increase, unless the application precisely matches plant uptake and soil capture.[64] Nitrogen may be added to the soil by synthetic or organic fertilizers, nitrogen-fixing crops, and crop residues. Nitrogen-rich soils, called "histosols," may also stimulate emissions. Direct emissions in 2005 (171.0 $MMTCO_2e$) represented 78 percent of total emissions from nitrogen fertilization, with the primary components including the biological fixation of nitrogen in crops (70.7 $MMTCO_2e$), nitrogen fertilizers (58.6 $MMTCO_2e$), and crop residues (37.3 $MMTCO_2e$).

Indirect emissions from nitrogen fertilization result from adding excess nitrogen to the soil, which in turn enriches ground and surface waters, such as rivers and streams, and results in emissions of nitrous oxide. This source is referred to as "soil leaching." Additional indirect emissions occur from "atmospheric deposition," in which soils emit other nitrogen compounds that react to form nitrous oxide in the atmosphere. Indirect emissions in 2005 (47.1 $MMTCO_2e$) represented 22 percent of total emissions from nitrogen fertilization, with soil leaching accounting for 40.0 $MMTCO_2e$ and atmospheric deposition totaling 7.1 $MMTCO_2e$.

There are significant uncertainties associated with estimating the amount of emissions produced by adding nitrogen to agricultural soils. Models used to estimate

[63] U.S. Environmental Protection Agency, web site www.epa.gov/nonco2/econ-inv/international.html.

[64] A.F. Bouwman, "Exchange of Greenhouse Gases between Terrestrial Ecosystems and the Atmosphere," in A.F. Bouwman (ed.), *Soils and the Greenhouse Effect* (New York, NY: John Wiley and Sons, 1990).

the amount are based on limited sources of experimental data.[65] The uncertainty increases when moving from emissions associated with animal manure to soil mineralization and atmospheric deposition, where both estimating the amount of emissions and segmenting anthropogenic from biogenic sources become increasingly difficult.

Solid Waste of Domesticated Animals

Estimated 2005 nitrous oxide emissions from animal waste management were 61.2 $MMTCO_2e$, up by 1.4 percent from 2004 levels but 1.2 percent lower than 1990 levels (Table 27), making animal waste management the second-largest U.S. agricultural source of nitrous oxide emissions, after nitrogen fertilization of soils. Nitrous oxide emissions from animal waste are dominated by emissions from cattle waste, which in 2005 accounted for 92 percent of emissions from the solid waste of domesticated animals (a total of 56.4 $MMTCO_2e$ in 2005).

Nitrous oxide is released as part of the microbial denitrification of animal manure. The total volume of nitrous oxide emissions is a function of animal size and manure production, the amount of nitrogen in the animal waste, and the method of managing the animal waste. Waste managed by a solid storage or pasture range method may emit 20 times more nitrous oxide per unit of nitrogen content than does waste managed in anaerobic lagoon and liquid systems. Generally, solid waste from feedlot beef cattle is managed with the solid storage or pasture range method, accounting for the majority of nitrous oxide emissions. Solid waste from swine is generally managed in anaerobic lagoons and other liquid systems. Anaerobic digestion yields methane emissions but only negligible amounts of nitrous oxide. Thus, changes in estimated emissions result primarily from changes in cattle populations. For example, beef cattle populations grew during the first half of the 1990s, leading to higher emissions through 1995, but then declined slowly through 2004, lowering emissions to below 1990 levels. In 2005, U.S. cattle populations increased slightly from their 2004 level.

Crop Residue Burning

In 2005, estimated emissions of nitrous oxide from crop residue burning were 0.6 $MMTCO_2e$, 3.0 percent below the 2004 level (Table 25). The decrease is attributable to a nearly across-the-board decrease in U.S. crop production. Emissions from this source remain very small, at 0.2 percent of all U.S. nitrous oxide emissions. When crop residues are burned, the incomplete combustion of agricultural waste results in the production of nitrous oxide, as well as methane (discussed in Chapter 3).

Energy Use

U.S. Nitrous Oxide Emissions from Energy, 1990-2005

Estimated 2005 Emissions (Million Metric Tons Carbon Dioxide Equivalent)	67.3
Change Compared to 2004 (Million Metric Tons Carbon Dioxide Equivalent)	0.4
Change from 2004 *(Percent)*	*0.6%*
Change Compared to 1990 (Million Metric Tons Carbon Dioxide Equivalent)	16.5
Change from 1990 *(Percent)*	*32.5%*

The energy use category includes nitrous oxide emissions from both mobile and stationary sources as byproducts of fuel combustion. Estimated 2005 energy-related emissions were 67.3 $MMTCO_2e$, or 18 percent of total U.S. anthropogenic nitrous oxide emissions (Table 25). Emissions from energy use are dominated by mobile combustion (78 percent of nitrous oxide emissions from energy use in 2005).

Mobile Combustion

Nitrous oxide emissions from mobile source combustion in 2005 were 52.6 $MMTCO_2e$, an increase of 1.0 percent from the 2004 level of 52.0 $MMTCO_2e$ (Table 28). In addition to emissions from passenger cars and light-duty trucks, emissions from air, rail, and marine transportation and from farm and construction equipment are also included in the estimates. Motor vehicles, however, are the predominant source, accounting for 92 percent of nitrous oxide emissions from mobile combustion.

Nitrous oxide emissions from motor vehicles are caused primarily by the conversion of nitrogen oxides (NO_x) into nitrous oxide (N_2O) by vehicle catalytic converters. The normal operating temperature of catalytic converters is high enough to cause the thermal decomposition of nitrous oxide. Consequently, it is probable that nitrous oxide emissions result primarily from "cold starts" of motor vehicles and from catalytic converters that are defective or operating under abnormal conditions. This implies that the primary determinant of the level of emissions is motor vehicle operating conditions; however, different types of catalytic converters appear to differ systematically in their emissions, and emissions

[65]Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.87-4.100, web site www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm.

probably vary with engine size. Thus, emissions also depend on the “mix” of vehicle age and type on the road.

Nitrous oxide emissions from mobile sources grew rapidly from 1990 to 1996 due to increasing motor vehicle use, the shifting composition of the light-duty vehicle fleet toward light trucks that have lower fuel economy and higher per-mile emission factors, and the gradual replacement of low emitting pre-1983 vehicles that did not use catalytic converters with higher emitting post-1983 vehicles that do use catalytic converters. This growth moderated between 1996 and 1999 due to the introduction of more advanced, lower-emitting catalytic converters. After peaking in 1999, U.S. emissions of nitrous oxide from mobile sources declined slowly through 2002, as vehicle turnover led to a fleet dominated by the more advanced catalytic converters. Since 2002, emissions have increased as both the number of motor vehicles on U.S. roadways and emissions from other mobile sources have grown.

Stationary Combustion

In 2005, estimated nitrous oxide emissions from stationary combustion sources were 14.7 MMTCO_2e, 1.1 percent (0.2 MMTCO_2e) lower than in 2004 and 9.9 percent (1.3 MMTCO_2e) higher than in 1990 (Table 29). The increase in emissions from this source from 1990 to 2005 can be attributed principally to coal-fired combustion systems. Nitrous oxide emissions from coal-fired combustion systems increased by 19 percent over the period, from 8.0 MMTCO_2e in 1990 to 9.5 MMTCO_2e in 2005.

Coal-fired combustion systems produced 65 percent of the 2005 emissions of nitrous oxide from stationary combustion. Other fuels—including fuel oil (2.3 MMTCO_2e), wood (2.2 MMTCO_2e), and natural gas (0.6 MMTCO_2e) —accounted for the balance. During combustion, nitrous oxide is produced as a result of chemical interactions between nitrogen oxides (mostly NO_2) and other combustion products. With most conventional stationary combustion systems, high temperatures destroy almost all nitrous oxide, limiting the quantity that escapes; therefore, emissions from these systems typically are low.

Industrial Sources

Emissions of nitrous oxide from industrial sources were 13.2 MMTCO_2e in 2005, a decrease of 0.7 MMTCO_2e (5.3 percent) from 2004 and a decrease of 15.3 MMTCO_2e (54 percent) since 1990. Nitrous oxide is emitted as a byproduct of certain chemical production processes. Table 30 provides estimates of emissions from the production of adipic acid and nitric acid, the two principal known sources.

Nitric Acid Production

The 6.3 million metric tons of nitric acid manufactured in 2005[66] resulted in estimated nitrous oxide emissions of 10.3 MMTCO_2e (Table 30). This estimate was 5.6 percent lower than 2004 levels and 12 percent lower than 1990 levels. The emissions factor used to estimate nitrous oxide emissions from the production of nitric acid was based on measurements at a single DuPont plant, which indicated an emissions factor of 2 to 9 grams of nitrous oxide emitted per kilogram of nitric acid manufactured, suggesting a significant range of uncertainty.[67] Nitric acid, a primary ingredient in fertilizers, usually is manufactured by oxidizing ammonia (NH_3) with a platinum catalyst. Nitrous oxide emissions are a direct result of the oxidation.

Adipic Acid Production

Emissions from adipic acid production in 2005 were 2.9 MMTCO_2e, 4.2 percent lower than in 2004. Nitrous oxide emissions from this source in 2005 were 83 percent (13.9 MMTCO_2e) lower than in 1990.

Adipic acid is a fine white powder that is used primarily in the manufacture of nylon fibers and plastics, such as carpet yarn, clothing, and tire cord. Other uses of adipic acid include production of plasticizer for polyvinyl chloride and polyurethane resins, lubricants, insecticides, and dyes. In the United States, three companies, which

U.S. Nitrous Oxide Emissions from Industrial Sources, 1990-2005

Estimated 2005 Emissions (Million Metric Tons Carbon Dioxide Equivalent)	13.2
Change Compared to 2004 (Million Metric Tons Carbon Dioxide Equivalent)	-0.7
Change from 2004 *(Percent)*	*-5.3%*
Change Compared to 1990 (Million Metric Tons Carbon Dioxide Equivalent)	-15.3
Change from 1990 *(Percent)*	*-53.6%*

[66]U.S. Department of Commerce, Bureau of Census, *Current Industrial Reports: Fertilizer Materials and Related Products, Fourth Quarter 2005*, MQ325B(05)-4 (Washington, DC, March 2006), Table 1, web site www.census.gov/industry/1/mq325b054.pdf.
[67]Intergovernmental Panel on Climate Change, *IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual*, Vol. 3 (Paris, France, 1997), Table 2-7, web site www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch2ref1.pdf.

operate four plants, manufacture adipic acid by oxidizing a ketone-alcohol mixture with nitric acid. Nitrous oxide is an intrinsic byproduct of this chemical reaction. For every metric ton of adipic acid produced, 0.3 metric ton of nitrous oxide is created.[68] Emissions from adipic acid manufacture grew by 23 percent from 1990 to 1996, reaching 20.7 $MMTCO_2e$ before dropping sharply to 7.8 $MMTCO_2e$ in 1997.

Before 1997, two of the four plants that manufacture adipic acid controlled emissions by thermally decomposing the nitrous oxide. This technique eliminates 98 percent of potential nitrous oxide emissions from the process.[69] During the first quarter of 1997, a third plant installed emissions controls, increasing the share of adipic acid production employing emissions abatement controls from 74 percent in 1996 to 92 percent in 1997. In 1998, with emissions controls in place for the full year, 97 percent of emissions from U.S. adipic acid production were controlled.[70]

Estimated emissions of nitrous oxide from uncontrolled adipic acid production decreased from 19.6 $MMTCO_2e$ in 1996 to 2.0 $MMTCO_2e$ in 1998 and remained fairly stable through 2002, before dropping to 1.4 $MMTCO_2e$ per year in 2003 (Table 30). Emissions of nitrous oxide from controlled plants have remained relatively constant from 1998 through 2005, in a range of 1.4 to 1.6 $MMTCO_2e$. With the share of adipic acid production employing abatement controls now at 98 percent, future changes in nitrous oxide emissions from this source are expected to result primarily from changes in plant production levels in response to market demand.

Waste Management

Nitrous oxide emissions from waste management in 2005 are estimated at 6.2 $MMTCO_2e$, or 1.7 percent of all U.S. anthropogenic nitrous oxide emissions (Table 25). During 2005, emissions from human sewage in wastewater were responsible for 94 percent of the estimated emissions from this source, and the remainder was associated with waste combustion. Estimated emissions from waste management increased by 1.1 percent from 2004 to 2005 and by 26 percent from 1990 to 2005. Because of the lack of reliable data and an effective estimation method, no estimate of emissions from industrial wastewater was calculated, leaving estimated emissions from waste management lower than they otherwise would be had a viable estimation method been available.

Human Sewage in Wastewater

In 2005, nitrous oxide emissions from wastewater were 5.8 $MMTCO_2e$, a 1.0-percent increase from 2004 levels and a 27-percent increase from the 1990 level (Table 25). Estimates of nitrous oxide emissions from human waste are scaled to population size and per capita protein intake. U.S. population has grown by 19 percent since 1990.[71] U.S. per capita protein intake rose steadily from 1990 to 1999, then declined from 2000 to 2002. U.S. per capita protein intake in 2002 was 6.5 percent above the 1990 level.[72]

Nitrous oxide is emitted from wastewater that contains nitrogen-based organic materials, such as those found in human or animal waste. Two natural processes—nitrification and denitrification—combine to produce nitrous oxide. Nitrification, an aerobic process, converts ammonia into nitrate; denitrification, an anaerobic process, converts nitrate to nitrous oxide. Factors that influence the amount of nitrous oxide generated from wastewater include temperature, acidity, biochemical oxygen demand (BOD),[73] and nitrogen concentration.

U.S. Nitrous Oxide Emissions from Waste Management, 1990-2005

Estimated 2005 Emissions (Million Metric Tons Carbon Dioxide Equivalent)	6.2
Change Compared to 2004 (Million Metric Tons Carbon Dioxide Equivalent)	0.1
Change from 2004 *(Percent)*	*1.1%*
Change Compared to 1990 (Million Metric Tons Carbon Dioxide Equivalent)	1.3
Change from 1990 *(Percent)*	*26.3%*

[68] M.H. Thiemens and W.C. Trogler, "Nylon Production: An Unknown Source of Atmospheric Nitrous Oxide," *Science*, Vol. 251, No. 4996 (February 1991).
[69] Radian Corporation, *Nitrous Oxide Emissions from Adipic Acid Manufacturing* (Rochester, NY, January 1992), p. 10.
[70] R.A. Reimer, R.A. Parrett, and C.S. Slaten, "Abatement of N_2O Emissions Produced in Adipic Acid," in *Proceedings of the Fifth International Workshop on Nitrous Oxide Emissions* (Tsukuba, Japan, July 1992).
[71] U.S. Census Bureau, web site www.census.gov. For 1990 population, see www.census.gov/population/cen2000/phc-t1/tab04.xls; for 2005 population estimate, see www.census.gov/popest/states/tables/NST-EST2005-01.xls.
[72] Data on protein intake are taken from the United Nations Food and Agriculture Organization (FAO), statistical databases, web site www.fao.org/statistics/yearbook/vol_1_1/site_en.asp?page=consumption.
[73] Biochemical oxygen demand (BOD) is a measure of the organic content of wastewater that is subject to decomposition.

Waste Combustion

In 2005, estimated nitrous oxide emissions from waste combustion were 0.3 $MMTCO_2e$, up by 2.8 percent from the 2004 level and 15 percent above the 1990 level. Data on the amount of waste generated in the United States in 2005 were not available in time for this report; therefore, EIA scaled the 2005 estimate for waste combustion to the growth in U.S. gross domestic product. The share of waste burned is estimated to have remained nearly stable between 1998 and 2005, but the total volume of waste generated is estimated to have risen steadily. The total volume of waste generated in the United States increased by 79 percent from 1990 to 2005; however, the share of waste burned in 2005 was just 7.4 percent, compared with 12 percent in 1990.[74]

[74] *Biocycle*, "The State of Garbage in America" (April 2006).

Table 25. Estimated U.S. Emissions of Nitrous Oxide, 1990, 1995, and 1998-2005

Source	1990	1995	1998	1999	2000	2001	2002	2003	2004	P2005
Million Metric Tons Carbon Dioxide Equivalent										
Agriculture										
Nitrogen Fertilization of Soils	186.9	187.3	194.0	192.7	189.4	189.1	185.1	186.6	211.9	218.1
Solid Waste of Domesticated Animals	61.9	65.6	62.8	62.3	61.8	61.4	61.1	60.7	60.3	61.2
Crop Residue Burning	0.5	0.5	0.6	0.5	0.6	0.6	0.5	0.5	0.6	0.6
Subtotal	**249.3**	**253.4**	**257.4**	**255.6**	**251.8**	**251.1**	**246.8**	**247.8**	**272.9**	**279.9**
Energy Use										
Mobile Combustion	37.4	52.2	54.3	54.0	53.6	52.4	51.2	50.5	52.0	52.6
Stationary Combustion	13.3	13.9	14.4	14.6	15.0	14.5	14.3	14.5	14.8	14.7
Subtotal	**50.8**	**66.1**	**68.7**	**68.6**	**68.6**	**66.9**	**65.6**	**65.0**	**66.9**	**67.3**
Industrial Sources	**28.6**	**32.9**	**17.2**	**16.8**	**16.6**	**14.0**	**15.2**	**14.0**	**14.0**	**13.2**
Waste Management										
Human Sewage in Wastewater	4.6	5.1	5.3	5.5	5.6	5.6	5.7	5.7	5.8	5.8
Waste Combustion	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Subtotal	**4.9**	**5.4**	**5.5**	**5.8**	**5.8**	**6.0**	**6.0**	**6.1**	**6.1**	**6.2**
Total	**333.5**	**357.7**	**348.8**	**346.8**	**342.8**	**337.9**	**333.6**	**332.9**	**359.9**	**366.6**
Thousand Metric Tons Nitrous Oxide										
Agriculture										
Nitrogen Fertilization of Soils	631	633	655	651	640	639	625	630	716	737
Solid Waste of Domesticated Animals	209	222	212	211	209	207	207	205	204	207
Crop Residue Burning	2	2	2	2	2	2	2	2	2	2
Subtotal	**842**	**856**	**869**	**864**	**851**	**848**	**834**	**837**	**922**	**946**
Energy Use										
Mobile Combustion	126	176	183	183	181	177	173	170	176	178
Stationary Combustion	45	47	49	49	51	49	48	49	50	50
Subtotal	**172**	**223**	**232**	**232**	**232**	**226**	**222**	**220**	**226**	**227**
Industrial Sources	**96**	**111**	**58**	**57**	**56**	**47**	**51**	**47**	**47**	**45**
Waste Management										
Human Sewage in Wastewater	16	17	18	19	19	19	19	19	20	20
Waste Combustion	1	1	1	1	1	1	1	1	1	1
Subtotal	**17**	**18**	**19**	**20**	**20**	**20**	**20**	**20**	**21**	**21**
Total	**1,127**	**1,208**	**1,178**	**1,172**	**1,158**	**1,141**	**1,127**	**1,125**	**1,216**	**1,238**

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 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005). 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: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.81-4.94, web site www.ipcc.ch/pub/guide.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004*, EPA-430-R-06-002 (Washington, DC, April 2006), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenter PublicationsGHGEmissionsUSEmissionsInventory2006.html.

Table 26. U.S. Nitrous Oxide Emissions from Nitrogen Fertilization of Agricultural Soils, 1990, 1995, and 1998-2005

Source	1990	1995	1998	1999	2000	2001	2002	2003	2004	P2005
Million Metric Tons Carbon Dioxide Equivalent										
Direct Emissions										
Biological Fixation in Crops	58.6	62.1	68.7	68.2	67.9	69.5	65.3	62.5	71.0	70.7
Nitrogen Fertilizers	53.1	51.2	47.5	47.7	45.6	44.4	45.6	48.0	54.3	58.6
Crop Residues	28.2	28.1	34.8	33.8	34.6	34.7	32.9	32.8	38.5	37.3
Soil Mineralization	3.0	3.1	3.1	3.1	3.1	3.1	3.1	3.2	3.2	3.2
Animal Manure	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Sewage Sludge	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.4	0.4
Total Direct Emissions	**144.1**	**145.9**	**155.5**	**154.1**	**152.4**	**153.0**	**148.2**	**147.7**	**168.2**	**171.0**
Indirect Emissions										
Soil Leaching	36.3	35.2	32.6	32.8	31.3	30.6	31.4	33.0	37.1	40.0
Atmospheric Deposition	6.5	6.3	5.8	5.8	5.6	5.5	5.6	5.9	6.6	7.1
Total Indirect Emissions	**42.8**	**41.4**	**38.5**	**38.6**	**36.9**	**36.0**	**37.0**	**38.8**	**43.7**	**47.1**
Total	**186.9**	**187.3**	**194.0**	**192.7**	**189.4**	**189.1**	**185.1**	**186.6**	**211.9**	**218.1**
Thousand Metric Tons Nitrous Oxide										
Direct Emissions										
Biological Fixation in Crops	198	210	232	230	229	235	221	211	240	239
Nitrogen Fertilizers	179	173	161	161	154	150	154	162	183	198
Crop Residues	95	95	118	114	117	117	111	111	130	126
Soil Mineralization	10	10	10	10	11	11	11	11	11	11
Animal Manure	4	5	4	4	4	4	4	4	4	4
Sewage Sludge	1	1	1	1	1	1	1	1	1	1
Total Direct Emissions	**487**	**493**	**525**	**521**	**515**	**517**	**501**	**499**	**568**	**578**
Indirect Emissions										
Soil Leaching	123	119	110	111	106	103	106	111	125	135
Atmospheric Deposition	22	21	20	20	19	18	19	20	22	24
Total Indirect Emissions	**144**	**140**	**130**	**130**	**125**	**122**	**125**	**131**	**148**	**159**
Total	**631**	**633**	**655**	**651**	**640**	**639**	**625**	**630**	**716**	**737**

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 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005). Totals may not equal sum of components due to independent rounding.

Sources: Estimates presented in this chapter. Emissions coefficients from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.89-4.107, web site www.ipcc.ch/pub/guide.htm. Total nitrogen content of U.S. commercial fertilizer consumption—1988-1994, Tennessee Valley Authority; 1995-2002, Association of American Plant Food Control Officials, *Commercial Fertilizers* (Washington, DC, various years). Manure application based on cattle population data provided by the U.S. Department of Agriculture, National Agricultural Statistics Service, web sites www.usda.gov/nass/pubs/histdata.htm and www.nass.usda.gov/ipedb/. Typical animal sizes from U.S. Environmental Protection Agency, Office of Air and Radiation, *Anthropogenic Methane Emissions in the United States: Estimates for 1990* (Washington, DC, April 1993), p. 6-8. Manure production and waste management systems used from L.M. Safley, M.E. Casada et al., *Global Methane Emissions From Livestock and Poultry Manure* (Washington, DC, February 1992), and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004*, EPA-430-R-06-002 (Washington, DC, April 2006), web site http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html.

Table 27. U.S. Nitrous Oxide Emissions from Solid Waste of Domesticated Animals, 1990, 1995, and 1998-2005

Source	1990	1995	1998	1999	2000	2001	2002	2003	2004	P2005
Million Metric Tons Carbon Dioxide Equivalent										
Cattle	57.5	61.1	58.3	57.9	57.4	56.9	56.7	56.3	55.8	56.4
Swine	1.5	1.6	1.7	1.6	1.6	1.6	1.6	1.7	1.7	1.7
Poultry	0.9	1.2	1.3	1.3	1.3	1.3	1.3	1.3	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	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5
Goats	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4
Total	**61.9**	**65.6**	**62.8**	**62.3**	**61.8**	**61.4**	**61.1**	**60.7**	**60.3**	**61.2**
Thousand Metric Tons Nitrous Oxide										
Cattle	194	206	197	195	194	192	192	190	189	191
Swine	5	5	6	6	5	6	6	6	6	6
Poultry	3	4	4	4	4	4	4	4	5	5
Horses	2	2	2	2	2	2	2	2	2	2
Sheep	3	3	2	2	2	2	2	2	2	2
Goats	1	1	1	1	1	1	1	1	1	1
Total	**209**	**222**	**212**	**211**	**209**	**207**	**207**	**205**	**204**	**207**

P = preliminary data.

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

Sources: Estimates presented in this chapter. Nitrogen content of waste by species, manure management systems, and emissions coefficients from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.89-4.107, web site www.ipcc.ch/pub/guide.htm. Population data for horses and goats extrapolated from U.S. Department of Commerce, Bureau of the Census, *Census of Agriculture* (1982, 1987, 1992, and 1997). All other animal populations from U.S. Department of Agriculture, National Agricultural Statistics Service, web sites www.usda.gov/nass/pubs/histdata.htm and www.nass.usda.gov/ipedb/. Typical animal sizes from U.S. Environmental Protection Agency, Office of Air and Radiation, *Anthropogenic Methane Emissions in the United States: Estimates for 1990* (Washington, DC, April 1993), p. 6-8. Cattle sizes adjusted by annual slaughter weight from U.S. Department of Agriculture, National Agricultural Statistics Service.

Table 28. U.S. Nitrous Oxide Emissions from Mobile Combustion, 1990, 1995, and 1998-2005

Item	1990	1995	1998	1999	2000	2001	2002	2003	2004	P2005
Million Metric Tons Carbon Dioxide Equivalent										
Motor Vehicles										
Passenger Cars	21.6	29.2	29.3	28.9	28.3	27.4	26.1	25.1	25.0	24.5
Light-Duty Trucks	10.4	17.2	19.0	18.9	18.9	18.8	18.9	19.2	20.5	21.2
Other Trucks	1.7	2.1	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.7
Buses	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Motorcycles	*	*	*	*	*	*	*	*	*	*
Subtotal	**33.9**	**48.6**	**50.7**	**50.3**	**49.7**	**48.8**	**47.7**	**47.1**	**48.3**	**48.5**
Other Mobile Sources	**3.6**	**3.6**	**3.5**	**3.7**	**3.9**	**3.6**	**3.6**	**3.4**	**3.7**	**4.1**
Total	**37.4**	**52.2**	**54.3**	**54.0**	**53.6**	**52.4**	**51.2**	**50.5**	**52.0**	**52.6**
Thousand Metric Tons Nitrous Oxide										
Motor Vehicles										
Passenger Cars	73	98	99	98	96	92	88	85	85	83
Light-Duty Trucks	*	*	*	*	*	*	*	*	*	*
Other Trucks	*	*	*	*	*	*	*	*	*	*
Buses	35	58	64	64	64	64	64	65	69	72
Motorcycles	6	7	8	8	8	8	9	9	9	9
Subtotal	**114**	**164**	**171**	**170**	**168**	**165**	**161**	**159**	**163**	**164**
Other Mobile Sources	**12**	**12**	**12**	**12**	**13**	**12**	**12**	**11**	**13**	**14**
Total	**126**	**176**	**183**	**183**	**181**	**177**	**173**	**170**	**176**	**178**

*Less than 50,000 metric tons carbon dioxide equivalent or less than 500 metric tons nitrous oxide.

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 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005). 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, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 1.64-1.68, web site www.ipcc.ch/pub/guide.htm.

Table 29. U.S. Nitrous Oxide Emissions from Stationary Combustion, 1990, 1995, and 1998-2005

Source	1990	1995	1998	1999	2000	2001	2002	2003	2004	P2005
					Thousand Metric Tons Carbon Dioxide Equivalent					
Residential										
Coal	13	7	5	6	4	5	5	5	6	5
Fuel Oil[a]	251	247	235	263	279	275	261	268	277	274
Natural Gas	128	142	133	138	145	139	143	149	143	142
Wood	676	606	443	466	501	431	443	466	478	489
Total	**1,068**	**1,002**	**815**	**873**	**929**	**850**	**852**	**888**	**903**	**911**
Commercial										
Coal	52	48	42	42	36	38	38	34	42	42
Fuel Oil[a]	170	131	118	118	135	132	122	134	135	138
Natural Gas	77	89	88	89	92	89	92	93	92	89
Wood	77	84	75	78	83	78	80	83	82	82
Total	**375**	**352**	**323**	**328**	**346**	**337**	**332**	**344**	**351**	**351**
Industrial										
Coal	1,129	1,020	925	905	940	913	841	851	853	818
Fuel Oil[a]	1,606	1,668	1,680	1,743	1,690	1,694	1,644	1,655	1,750	1,701
Natural Gas	242	274	279	268	271	248	252	243	244	224
Wood	1,680	1,924	1,867	1,887	1,906	1,681	1,626	1,588	1,719	1,442
Total	**4,657**	**4,886**	**4,752**	**4,803**	**4,807**	**4,536**	**4,363**	**4,336**	**4,566**	**4,185**
Electric Power										
Coal	6,770	7,278	8,008	8,034	8,426	8,205	8,244	8,411	8,446	8,635
Fuel Oil[a]	228	135	233	216	204	229	216	215	213	216
Natural Gas	94	123	133	140	151	153	164	150	156	165
Wood	150	146	160	161	156	147	175	195	192	196
Total	**7,242**	**7,682**	**8,534**	**8,551**	**8,937**	**8,733**	**8,799**	**8,971**	**9,008**	**9,212**
Total All Sectors										
Coal	**7,963**	**8,354**	**8,980**	**8,987**	**9,406**	**9,161**	**9,128**	**9,301**	**9,347**	**9,501**
Fuel Oil[a]	**2,256**	**2,180**	**2,266**	**2,341**	**2,308**	**2,330**	**2,242**	**2,272**	**2,375**	**2,329**
Natural Gas	**541**	**627**	**633**	**634**	**659**	**629**	**651**	**635**	**634**	**621**
Wood	**2,583**	**2,760**	**2,544**	**2,592**	**2,646**	**2,337**	**2,324**	**2,331**	**2,471**	**2,209**
Total	**13,343**	**13,921**	**14,424**	**14,554**	**15,020**	**14,457**	**14,346**	**14,539**	**14,827**	**14,659**

[a]Fuel oil use in the residential sector consists of distillate fuel only. In the other sectors it includes both distillate and residual fuel oil.
P = preliminary data. See notes and sources at end of table.

Table 29. U.S. Nitrous Oxide Emissions from Stationary Combustion, 1990, 1995, and 1998-2005 (Continued)

Source	1990	1995	1998	1999	2000	2001	2002	2003	2004	P2005
	Thousand Metric Tons Nitrous Oxide									
Residential										
Coal	*	*	*	*	*	*	*	*	*	*
Fuel Oil[a]	1	1	1	1	1	1	1	1	1	1
Natural Gas	*	*	*	*	*	*	*	1	*	*
Wood	2	2	1	2	2	1	1	2	2	2
Subtotal	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Commercial										
Coal	*	*	*	*	*	*	*	*	*	*
Fuel Oil[a]	1	*	*	*	*	*	*	*	*	*
Natural Gas	*	*	*	*	*	*	*	*	*	*
Wood	*	*	*	*	*	*	*	*	*	*
Subtotal	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Industrial										
Coal	4	3	3	3	3	3	3	3	3	3
Fuel Oil[a]	5	6	6	6	6	6	6	6	6	6
Natural Gas	1	1	1	1	1	1	1	1	1	1
Wood	6	7	6	6	6	6	5	5	6	5
Subtotal	**16**	**17**	**16**	**16**	**16**	**15**	**15**	**15**	**15**	**14**
Electric Power										
Coal	23	25	27	27	28	28	28	28	29	29
Fuel Oil[a]	1	*	1	1	1	1	1	1	1	1
Natural Gas	*	*	*	*	1	1	1	1	1	1
Wood	1	*	1	1	1	*	1	1	1	1
Total	**24**	**26**	**29**	**29**	**30**	**30**	**30**	**30**	**30**	**31**
Total All Sectors										
Coal	**27**	**28**	**30**	**30**	**32**	**31**	**31**	**31**	**32**	**32**
Fuel Oil[a]	**8**	**7**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**
Natural Gas	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Wood	**9**	**9**	**9**	**9**	**9**	**8**	**8**	**8**	**8**	**7**
Total	**45**	**47**	**49**	**49**	**51**	**49**	**48**	**49**	**50**	**50**

[a]Fuel oil use in the residential sector consists of distillate fuel only. In the other sectors it includes both distillate and residual fuel oil.

*Less than 500 metric tons nitrous oxide.

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 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005). Totals may not equal sum of components due to independent rounding.

Sources: Emissions coefficients from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), p. 1.50, web site www.ipcc.ch/pub/guide.htm. Energy consumption data from Energy Information Administration, *State Energy Data Report 1998*, DOE/EIA-0214(98) (Washington, DC, September 2003); and *Monthly Energy Review*, DOE/EIA-0035(2003/08) (Washington, DC, August 2003).

Table 30. U.S. Nitrous Oxide Emissions from Industrial Sources, 1990, 1995, and 1998-2005

Source	1990	1995	1998	1999	2000	2001	2002	2003	2004	P2005
Million Metric Tons Carbon Dioxide Equivalent										
Adipic Acid										
Controlled Sources	1.0	1.1	1.5	1.5	1.6	1.4	1.6	1.6	1.6	1.6
Uncontrolled Sources	15.9	18.7	2.0	2.1	2.1	2.1	2.3	1.4	1.4	1.4
Subtotal	**16.8**	**19.8**	**3.5**	**3.6**	**3.7**	**3.5**	**3.9**	**3.0**	**3.1**	**2.9**
Nitric Acid	**11.7**	**13.1**	**13.7**	**13.2**	**12.9**	**10.4**	**11.3**	**11.0**	**10.9**	**10.3**
Total Known Industrial Sources	**28.6**	**32.9**	**17.2**	**16.8**	**16.6**	**14.0**	**15.2**	**14.0**	**14.0**	**13.2**
Thousand Metric Tons Nitrous Oxide										
Adipic Acid										
Controlled Sources	3	4	5	5	5	5	5	5	6	5
Uncontrolled Sources	54	63	7	7	7	7	8	5	5	5
Subtotal	**57**	**67**	**12**	**12**	**13**	**12**	**13**	**10**	**10**	**10**
Nitric Acid	**40**	**44**	**46**	**45**	**43**	**35**	**38**	**37**	**37**	**35**
Total Known Industrial Sources	**96**	**111**	**58**	**57**	**56**	**47**	**51**	**47**	**47**	**45**

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 2004*, DOE/EIA-0573(2004) (Washington, DC, December 2005). Totals may not equal sum of components due to independent rounding.

Sources: Data sources and methods documented in Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0638(2004) (Washington, DC, November 2006), and *Documentation for Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0638(2005) (to be published).