3. Methane Emissions

Overview

U.S. Anthropogenic Methane Emissions, 1990-2000

	Methane	Carbon Equivalent
Estimated 2000 Emissions (Million Metric Tons)	28.2	176.8
Change Compared to 1999 (Million Metric Tons)	*-0.5*	*-3.0*
Change from 1999 *(Percent)*	*-1.6%*	*-1.6%*
Change Compared to 1990 (Million Metric Tons)	-3.5	-21.8
Change from 1990 *(Percent)*	*-11.0%*	*-11.0%*

U.S. anthropogenic methane emissions totaled 28.2 million metric tons in 2000, a decline of about 0.5 million metric tons from 1999 levels (Table 13). The decline is primarily the result of increased methane recovery at U.S. landfills, and to a lesser extent reductions in emissions from coal mining. Methane recovery for energy at U.S. landfills rose from 2.2 to 2.5 million metric tons due to the lingering effects of the expiration of Section 29 of the Windfall Profits Tax Act of 1980. To be eligible for the tax credit included in that section, methane recovery systems at landfills must have been operational by June 30, 1998. The last recovery projects installed by the tax credit deadline continued to ramp up in 2000. Meanwhile, methane recovered and flared at landfills rose from 2.0 million metric tons to 2.4 million metric tons. This increase is likely the result of attempts by landfill owners and operators to comply with the New Source Performance Standards and Emissions Guidelines issued by the U.S. Environmental Protection Agency (EPA). In addition, for the first time in 40 years, U.S. coal production fell for a second consecutive year, as coal imports increased by 37 percent and electric utilities drew down stocks to meet increasing demand.[52]

Estimated U.S. emissions of methane in 2000 were 3.5 million metric tons below the 1990 level, a decrease equivalent to almost 22 million metric tons of carbon, or roughly 1.1 percent of total U.S. anthropogenic greenhouse gas emissions.[53] In addition to a 3.4 million metric ton decrease in methane emissions from landfills since 1990, there has also been a 1.3 million metric ton decrease in methane emissions from coal mines during the same period (Table 13). The 32-percent decline in emissions from coal mining is the result of a threefold increase in methane recovery from coal mines and a shift in production away from gassy mines. Overall, methane emissions account for about 8.5 percent of total U.S. greenhouse gas emissions weighted by global warming potential.

Methane emissions estimates are much more uncertain than carbon dioxide emissions estimates. Methane emissions usually are accidental or incidental to biological processes and may not be metered in any systematic way.[54] Thus, methane emission estimates must often rely on proxy measurements. Considerable effort has been devoted to improving estimation methods. However, with very little additional sample or activity data being gathered, the marginal improvements associated with revised methods are severely limited.

Estimated U.S. anthropogenic methane emissions for 2000 also include preliminary data for several key sources; thus, the overall estimate is preliminary. Emissions from three of these sources—coal mining, natural gas systems, and landfills—represent more than three-fifths of all U.S. methane emissions. Thus, comparisons between 1999 and 2000 numbers are more likely to be valid in the context of directional change rather than magnitude of change. For example, because 2000 data on

[52]Energy Information Administration, *U.S. Coal Supply and Demand: 2000 Review*, web site www.eia.doe.gov/cneaf/coal/page/special/feature.html.

[53]Using the new estimated global warming potential of 23 for methane. For an expanded discussion of global warming potentials, see Chapter 1.

[54]Wherever possible, estimates of methane emissions are based on measured data. In some cases, however, measured data are incomplete or unavailable. In the absence of measured data, emissions are calculated by multiplying some known activity data, such as coal production or natural gas throughput, by an emissions factor derived from a small sample of the relevant emissions source or through laboratory experiments. For a more detailed discussion of where measured data were used and how emissions factors were developed, see Appendix A, "Estimation Methods." The absence of measured emissions data for most sources of methane emissions and the reliance on emissions factors represent a source of uncertainty (further details are available in Appendix C, "Uncertainty in Emissions Estimates").

waste generation are not yet available, waste generation has been scaled to economic output as a proxy. Less critical but still important data are also unavailable for coal mines and natural gas systems, such as emissions from coal mine degasification systems and miles of gas transmission and distribution pipeline.

Energy Sources

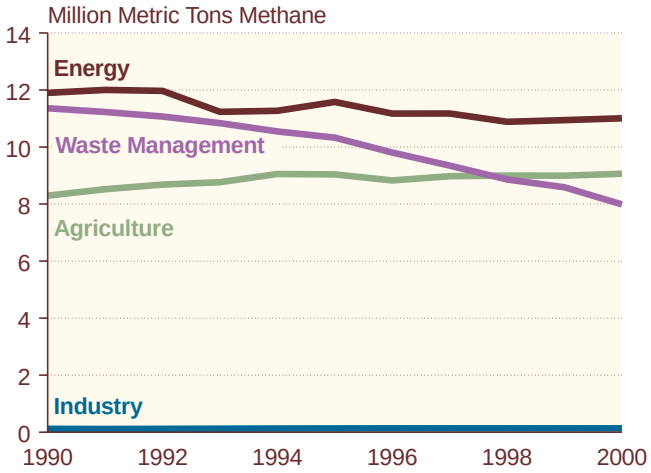
Principal Sources of U.S. Anthropogenic Methane Emissions, 1990-2000

Source	Million Metric Tons Methane 1990	2000	Percent Change 1990-2000	1999-2000
Energy	11.9	11.0	*-7.5%*	*0.6%*
Waste Management	11.4	8.0	*-29.7%*	*-7.0%*
Agriculture	8.3	9.1	*9.3%*	*0.8%*
Industrial Processes	0.1	0.1	*15.2%*	*1.2%*

U.S. methane emissions from energy sources were estimated at 11.0 million metric tons in 2000, nearly unchanged from 1999 levels and 0.9 million metric tons below 1990 levels (Figure 3). In 2000, an estimated decline of 0.14 million metric tons in emissions from coal mines was offset by a increase of 0.2 million metric tons in emissions from natural gas systems. The drop in methane emissions from energy sources since 1990 can be traced primarily to decreased emissions from coal mines and, to a lesser extent, to lower emissions from petroleum systems and stationary combustion.

Methane emissions from coal mines dropped by 32 percent (1.3 million metric tons) between 1990 and 2000. This decline resulted from the increased capture and use of methane from coal mine degasification systems and a shift in production away from some of the Nation's gassiest underground mines in Central Appalachia. Between 1990 and 2000, the share of coal production represented by underground mines declined from 41 percent to 35 percent. Methane emissions from petroleum systems dropped from 1.29 million metric tons in 1990 to 1.03 million metric tons in 2000. A decrease of 0.12 million metric tons in estimated emissions from stationary combustion made a smaller contribution to the overall

Figure 3. U.S. Emissions of Methane by Source, 1990-2000



Source: Estimates presented in this chapter.

drop in emissions from energy sources between 1990 and 2000. Together, the declines in emissions from coal mining, petroleum systems and stationary combustion more than compensated for the increase of 0.82 million metric tons in emissions from the natural gas system, attributed to increasing U.S. consumption of natural gas between 1990 and 2000.

Coal Mining

U.S. Methane Emissions from Coal Mining, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Methane)	2.9
Change Compared to 1999 (Million Metric Tons Methane)	-0.1
Change from 1999 *(Percent)*	*-4.5%*
Change Compared to 1990 (Million Metric Tons Methane)	-1.3
Change from 1990 *(Percent)*	*-31.5%*

The preliminary estimate of methane emissions from coal mines for 2000 is 2.89 million metric tons (Table 14), a decrease of 4.5 percent from the 1999 level.[55] This decrease can be traced to coal production levels, which fell for a second consecutive year for the first time in 40 years. U.S. coal production dropped from 1.12 billion short tons in 1998 to 1.07 billion short tons in 2000. The

[55]Further details on emissions from abandoned coal mines are available in Appendix D "Emissions Sources Excluded."

decline was due primarily to a 41 million ton drawdown of coal stocks and the use of 12.5 million tons of imported low-sulfur coal to meet stricter environmental regulations.[56]

Between 1990 and 2000, methane emissions from coal mines dropped by 32 percent from the 1990 level of 4.22 million metric tons. The decline is attributed to three important trends: (1) methane recovery from active coal mines for use as an energy resource increased from 0.29 million metric tons in 1990 to about 0.83 million metric tons in 2000; (2) methane drainage from degasification in active mines decreased by more than 0.33 million metric tons between 1990 and 2000; and (3) methane emissions from ventilation systems at gassy mines dropped by about 0.46 million metric tons between 1990 and 2000 (Table 14).[57]

Natural Gas Production, Processing, and Distribution

U.S. Methane Emissions from Natural Gas Systems, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Methane)	6.4
Change Compared to 1999 (Million Metric Tons Methane)	0.2
Change from 1999 *(Percent)*	*3.2%*
Change Compared to 1990 (Million Metric Tons Methane)	0.8
Change from 1990 *(Percent)*	*14.7%*

At 6.4 million metric tons, 2000 estimated methane emissions from natural gas production, processing, and distribution were up from the revised estimate of 6.2 million metric tons for 1999 (Table 15). The 3.2-percent increase in emissions levels can be traced to a 3.7-percent rise in gross withdrawals of natural gas and a 24-percent jump in withdrawals from storage; however, the 2000 estimate is preliminary, because gas processing and pipeline data for 2000 had not been finalized as of the publication of this report. The estimated 2000 emissions level is 14.7 percent above 1990 levels, with about two-fifths of the increase attributable to increased mileage of distribution pipelines and one-third attributable to increases in gas withdrawals.[58]

Petroleum Systems

U.S. Methane Emissions from Petroleum Systems, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Methane)	1.0
Change Compared to 1999 (Million Metric Tons Methane)	*
Change from 1999 *(Percent)*	*-1.0%*
Change Compared to 1990 (Million Metric Tons Methane)	-0.3
Change from 1990 *(Percent)*	*-20.5%*

*Less than 0.05 million metric tons.

Approximately 97 percent of all emissions from petroleum systems occur during exploration and production. Of the 1.0 million metric tons of emissions annually from this source, 91 percent can be traced to venting, of which nearly half is attributable to venting from oil tanks (Table 16). A much smaller portion of methane emissions from petroleum systems can be traced to refineries and transportation of crude oil. Overall, methane emissions from petroleum systems are estimated at 1.03 million metric tons in 2000, down slightly from 1.04 million metric tons in 1999 and more significantly from 1.29 million metric tons in 1990. Domestic oil production in 2000 was approximately 79 percent of the 1990 level, accounting for the decline in methane emissions from this source.

Stationary Combustion

U.S. methane emissions from stationary combustion in 2000 were 0.44 million metric tons, up by 4.5 percent from the 1999 level but 22 percent below 1990 levels (Table 17). Residential wood consumption typically accounts for about 87 percent of methane emissions from stationary combustion. Methane emissions are the result of incomplete combustion, and residential woodstoves and fireplaces provide much less efficient combustion than industrial or utility boilers. Estimates

[56]Energy Information Administration, *U.S. Coal Supply and Demand: 2000 Review*, web site www.eia.doe.gov/cneaf/coal/page/special/feature.html.

[57]The EPA believes that a significant portion of methane recovery from coal mines should not be deducted from current-year emissions, because the gas is being drained from coal seams that will be mined only in future years, if at all. The relationship between estimates of emissions from degasification and estimates of gas recovery is under review and may be revised in the future.

[58]The EPA estimates that the companies participating in the Natural Gas STAR program together avoided more than 575,000 metric tons in 1999 and 729,000 metric tons in 2000. Program participants report annually on emissions reductions achieved through such activities as equipment replacement, enhanced inspection and maintenance, and improved operations management. Participating companies may either use their own techniques to estimate reductions achieved or employ default values developed by the EPA and the Gas Technology Institue (formerly the Gas Research Institute).

U.S. Methane Emissions from Stationary Combustion, 1990-2000	
Estimated 2000 Emissions (Million Metric Tons Methane)	0.44
Change Compared to 1999 (Million Metric Tons Methane)	0.02
Change from 1999 *(Percent)*	*4.5%*
Change Compared to 1990 (Million Metric Tons Methane)	-0.12
Change from 1990 *(Percent)*	*-21.9%*

of residential wood combustion are, however, very uncertain (for further details, see Appendix C). The universe of wood consumers is large and heterogeneous, and wood for residential consumption is typically obtained from sources outside the documented economy. EIA relies on its Residential Energy Consumption Survey (RECS) to estimate residential wood consumption. Residential wood consumption data are derived from the 1990, 1994, and 1997 RECS. Intervening and subsequent years are scaled to heating degree-days. For the first time in 4 years, U.S. winter temperatures were near average rather than warmer than normal. As a result, the estimated level of residential wood consumption in 2000 was higher than in previous years, although it was well below the levels seen between 1990 and 1996.

Mobile Combustion

U.S. Methane Emissions from Mobile Combustion, 1990-2000	
Estimated 2000 Emissions (Million Metric Tons Methane)	0.25
Change Compared to 1999 (Million Metric Tons Methane)	-0.01
Change from 1999 *(Percent)*	*-3.9%*
Change Compared to 1990 (Million Metric Tons Methane)	*
Change from 1990 *(Percent)*	*1.6%*

*Less than 0.05 million metric tons.

Estimated U.S. methane emissions from mobile combustion in 2000 were 0.25 million metric tons, down by 3.9 percent from 1999 levels but 1.6 percent higher than the 1990 level (Table 18). Emissions from passenger cars have declined since 1990 as older cars with catalytic converters that are less efficient at destroying methane have been taken off the road. However, from 1993 to 1999, rapid growth in the fleet of light-duty trucks and the related increase in methane emissions offset the declines from passenger cars. In 2000, emissions from passenger cars and light-duty trucks declined simultaneously, if only incrementally, as overall vehicle miles traveled dropped in both classes for the first time since 1995.

Waste Management

Methane emissions from waste management account for 28 percent of U.S. anthropogenic methane emissions (Figure 3). This portion has been declining from its 1990 level of 36 percent due to a 3.4 million metric ton drop in emissions from landfills. Landfills represent 98 percent of the 8.0 million metric tons of methane emissions from waste management and remain the single largest source of U.S. anthropogenic methane emissions (Table 13). The remainder of emissions from waste management are associated with domestic wastewater treatment. Estimated emissions from waste management would increase if sufficient information were available to estimate emissions from industrial wastewater treatment (for further details, see Appendix D).

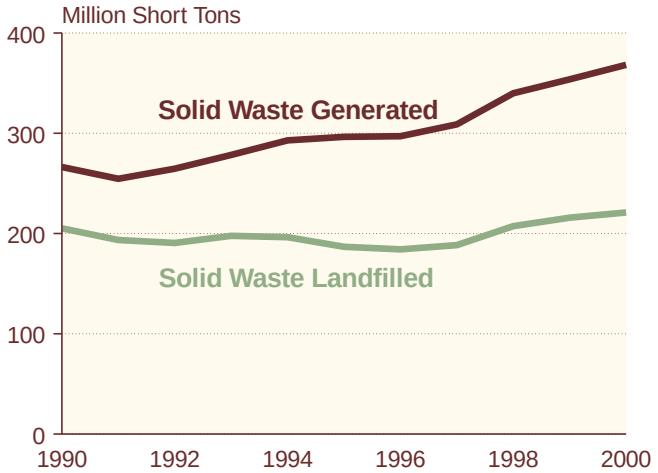
Landfills

U.S. Methane Emissions from Landfills, 1990-2000	
Estimated 2000 Emissions (Million Metric Tons Methane)	7.8
Change Compared to 1999 (Million Metric Tons Methane)	-0.6
Change from 1999 *(Percent)*	*-7.2%*
Change Compared to 1990 (Million Metric Tons Methane)	-3.4
Change from 1990 *(Percent)*	*-30.2%*

Despite a record level of municipal solid waste reaching U.S. landfills in 2000 (Figure 4),[59] estimated methane emissions from landfills dropped to 7.82 million metric tons, 7.2 percent below the 1999 level of 8.42 million metric tons and 3.4 million metric tons or 30 percent below 1990 levels (Table 19). This dramatic decrease is directly attributable to a 3.9 million metric ton increase in methane captured that otherwise would have been emitted to the atmosphere. Of the 4.9 million metric tons of methane believed to be captured from this source, 2.5 million metric tons were recovered for energy use, and 2.4 million metric tons were recovered and flared. While

[59] "Nationwide Survey: The State of Garbage in America, 1999," *Biocycle* (April 2000) for years before 2000. Waste generation for 2000 estimated on the basis of annual economic growth.

Figure 4. U.S. Solid Waste Generated and Landfilled, 1990-2000



Source: "Nationwide Survey: The State of Garbage in America, 1999," *Biocycle* (April 2000) for years before 2000. Waste generation for 2000 estimated on the basis of annual economic growth.

estimates of methane recovered and disposed of in both manners are drawn from data collected by the EPA's Landfill Methane Outreach Program,[60] there is less uncertainty in the estimate of methane recovered and used for energy. It is likely that estimates of methane flared are biased downward due to a lack of comprehensive industry data.

The rapid growth in methane recovery has resulted from a combination of regulatory and tax policy. The Federal Section 29 (of the Internal Revenue Code) tax credit for alternative energy sources, added to the tax code as part of the Crude Oil Windfall Profits Act of 1980, provided a subsidy roughly equivalent to 1 cent per kilowatthour for electricity generated from landfill gas. However, this tax credit expired on June 30, 1998, and, absent a similar subsidy, the number of additional landfill gas-to-energy projects that are commercially viable is limited. The energy policy proposed by President George W. Bush and recently passed by the U.S. House of Representatives includes provisions for resurrecting the Section 29 tax credit under Section 45 of the Internal Revenue Code, which currently contains a provision for a tax credit, valued at approximately 1.7 cents per kilowatthour, for electricity generated from wind, closed-loop biomass, or poultry waste. The ultimate outcome of this initiative is uncertain.[61]

Increases in methane recovery have also resulted from the implementation of the EPA's New Source Performance Standards and Emission Guidelines. These regulations require all landfills with more than 2.5 million metric tons of waste in place and annual emissions of nonmethane volatile organic compounds (NMVOCs) exceeding 50 metric tons to collect and burn their landfill gas, either by flaring or as an energy resource.

Domestic and Commercial Wastewater Treatment

U.S. Methane Emissions from Domestic and Commercial Wastewater Treatment, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Methane)	0.17
Change Compared to 1999 (Million Metric Tons Methane)	*
Change from 1999 *(Percent)*	*0.8%*
Change Compared to 1990 (Million Metric Tons Methane)	0.02
Change from 1990 *(Percent)*	*10.2%*

*Less than 0.05 million metric tons.

Methane emissions from domestic and commercial wastewater treatment are a function of the share of organic matter in the wastewater stream and the conditions under which it decomposes. Wastewater may be treated aerobically or anaerobically. If it is treated aerobically, methane emissions will be low. Under anaerobic conditions, methane emissions will be high. There is little information available on wastewater treatment methods. Data on flaring or energy recovery from methane generated by wastewater are also sparse. EIA believes that emissions from this source are relatively small, representing on the order of 0.6 percent of all U.S. methane emissions. Thus, emissions are estimated using a default per-capita emissions factor and U.S. population data.

With the U.S. population growing slowly, methane emissions from domestic and commercial wastewater treatment are estimated to have grown by 0.8 percent between 1999 and 2000 to 0.17 million metric tons. This is about 10.2 percent above the 1990 level of 0.15 million metric tons (Table 13). The EPA is conducting research in this area. If additional information becomes available, EIA will review it and revise the estimation method accordingly.

Agricultural Sources

At an estimated 9.1 million metric tons, methane emissions from agricultural activities represent 32 percent of total U.S. anthropogenic methane emissions (Table 13). Ninety-five percent of methane emissions from

[60]See web site www.epa.gov/lmop.
[61]See web site www.swana.org/whypolicy.asp.

agricultural activities result from livestock management. About 65 percent of these emissions can be traced to enteric fermentation in ruminant animals, and the remainder is attributable to the anaerobic decomposition of livestock wastes. A small portion of U.S. methane emissions result from crop residue burning and wetland rice cultivation. Estimated agricultural methane emissions increased slightly between 1999 and 2000 due mainly to an increase in emissions from enteric fermentation associated with continued growth in average cattle size.

Enteric Fermentation in Domesticated Animals

U.S. Methane Emissions from Enteric Fermentation in Domesticated Animals, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Methane)	5.5
Change Compared to 1999 (Million Metric Tons Methane)	0.1
Change from 1999 *(Percent)*	*1.9%*
Change Compared to 1990 (Million Metric Tons Methane)	0.4
Change from 1990 *(Percent)*	*7.3%*

In 2000, estimated methane emissions from enteric fermentation in domesticated animals rose by 1.9 percent to 5.5 million metric tons (Table 20). Because cattle account for about 96 percent of all emissions from enteric fermentation, trends in emissions correlate with trends in cattle populations. While cattle populations were flat or somewhat declining in 2000 (with the exception of cattle on feed), average cattle size (excluding calves) reached a 21-year high in 2000. Animal size is a principal determinant of energy intake requirements, which relate directly to methane emissions. Emissions remain 7.3 percent above 1990 levels, principally due to 7.3-percent growth in average cattle size between 1990 and 2000.[62] Meanwhile, cattle populations have fluctuated in a cyclical pattern, settling in 2000 at levels very similar to those seen in 1990.

Solid Waste of Domesticated Animals

Estimated methane emissions from the solid waste of domesticated animals increased from 3.03 million metric tons in 1999 to 3.05 million metric tons in 2000 (Table 21). This small increase was the result of a small increase in the populations of cattle on feed and dairy cattle in several States, combined with a return of calve sizes to levels not seen since 1997. In the absence of these factors, general decreases in animal populations would have resulted in a small drop in overall methane emissions from the waste of domesticated animals. There has also been a shift of swine populations to larger livestock operations, which are believed to be more likely to manage waste using liquid systems that tend to promote methane generation.[63] EIA does not have sufficient data to substantiate that belief at this time. If true, however, it would likely change the trend in emissions from this source from flat to slightly positive. Estimated 2000 emission levels were approximately 0.36 million metric tons above 1990 levels due to a general increase in the size of cattle over the past decade and a 12-percent increase in the population of market swine.

U.S. Methane Emissions from Solid Waste of Domesticated Animals, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Methane)	3.0
Change Compared to 1999 (Million Metric Tons Methane)	*
Change from 1999 *(Percent)*	*0.7%*
Change Compared to 1990 (Million Metric Tons Methane)	0.4
Change from 1990 *(Percent)*	*13.4%*

*Less than 0.05 million metric tons.

Rice Cultivation

Estimated methane emissions from U.S. rice cultivation dropped to 0.43 million metric tons in 2000 from 0.49 million metric tons in 1999. This was the first decrease since 1996 and was the result of a 13-percent drop in the number of acres harvested. Arkansas, Mississippi, Louisiana, and Texas all saw substantial drops in acres harvested. Despite these declines, annual emissions remained 6.7 percent above 1990 levels (Table 13).

Burning of Crop Residues

Crop residue burning, being the smallest contributor to agricultural greenhouse gas emissions, represents on the order of 0.2 percent of total U.S. methane emissions. Estimated 2000 methane emissions from the burning of crop residues were 0.05 million metric tons, up by 3.5 percent from 1999 levels and 11 percent above 1990 levels (Table 13). The small increase is attributable mainly

[62] U.S. Department of Agriculture, National Agricultural and Statistics Service, Livestock, web site www.nass.usda.gov:81/ipedb.

[63] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April, 2001), p. 5-6, web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

to rising corn, soybean, and potato production. This estimate reflects a small modification to the estimation method. Dry matter content, carbon content, combustion efficiency, and methane conversion rates have been revised, and rice combustion rates have been annualized to reflect new EPA data.[64]

Industrial Sources

U.S. Methane Emissions from Industrial Sources, 1990-2000

Estimated 2000 Emissions (Million Metric Tons Methane)	0.14
Change Compared to 1999 (Million Metric Tons Methane)	*
Change from 1999 *(Percent)*	*1.2%*
Change Compared to 1990 (Million Metric Tons Methane)	0.02
Change from 1990 *(Percent)*	*15.2%*

*Less than 0.05 million metric tons.

Chemical Production

The preliminary estimate of methane emissions from U.S. chemical production in 2000 is 0.080 million metric tons, 0.024 million metric tons higher than in 1990 (Table 22). The 2000 number remains preliminary pending updated production data for five chemicals: methanol, carbon black, ethylene, ethylene dichloride, and styrene. Methane emissions from chemical production grew between 1998 and 1999, and a continued robust economy in 2000 suggests potential additional emissions growth from this source.

Iron and Steel Production

With production of pig iron and coke recovering some of production that was lost in 1999, estimated methane emissions from iron and steel production rose by 3.1 percent to 0.55 million metric tons in 2000, despite continued declines in sinter production. Emissions remained 10.5 percent below the 1990 level of 0.062 million metric tons (Table 22). A general pattern of reduced iron and steel production has resulted in flat or declining methane emissions from this source over the past decade.

[64]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April 2001), p. 5-24, web site www.epa.gov/globalwarming/publications/emissions/us2001/index.html.

Table 13. U.S. Methane Emissions from Anthropogenic Sources, 1990-2000
(Million Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Energy Sources											
Coal Mining	4.22	4.08	3.99	3.41	3.47	3.63	3.24	3.24	3.20	3.03	2.89
Natural Gas Systems	5.58	5.80	5.86	5.85	5.86	5.95	5.97	6.12	5.94	6.20	6.40
Petroleum Systems	1.29	1.30	1.26	1.20	1.17	1.16	1.14	1.14	1.10	1.04	1.03
Stationary Combustion	0.56	0.59	0.62	0.54	0.53	0.58	0.58	0.44	0.40	0.42	0.44
Mobile Sources	0.25	0.23	0.24	0.24	0.24	0.25	0.24	0.24	0.24	0.26	0.25
Total Energy Sources	**11.90**	**12.00**	**11.97**	**11.24**	**11.27**	**11.58**	**11.17**	**11.18**	**10.88**	**10.94**	**11.01**
Waste Management											
Landfills	11.21	11.07	10.91	10.68	10.39	10.17	9.65	9.19	8.70	8.42	7.82
Wastewater Treatment	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17
Total Waste Management	**11.36**	**11.23**	**11.07**	**10.84**	**10.55**	**10.33**	**9.81**	**9.35**	**8.86**	**8.59**	**7.99**
Agricultural Sources											
Enteric Fermentation	5.16	5.30	5.39	5.46	5.59	5.61	5.46	5.42	5.41	5.43	5.54
Animal Waste	2.69	2.79	2.81	2.87	2.95	2.95	2.92	3.07	3.09	3.03	3.05
Rice Paddies	0.40	0.40	0.44	0.40	0.47	0.44	0.40	0.44	0.46	0.49	0.43
Crop Residue Burning	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05
Total Agricultural Sources	**8.29**	**8.52**	**8.68**	**8.77**	**9.06**	**9.04**	**8.83**	**8.98**	**9.00**	**9.00**	**9.06**
Industrial Processes	**0.12**	**0.11**	**0.12**	**0.12**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.14**
Total	**31.67**	**31.86**	**31.84**	**30.96**	**31.00**	**31.08**	**29.94**	**29.64**	**28.88**	**28.66**	**28.19**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). Totals may not equal sum of components due to independent rounding.

Sources: EIA 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. 4.83-4.84, web site www.ipcc.ch/pub/guide.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (Washington, DC, various years), web site www.epa.gov/globalwarming/ publications/emissions/index.html.

Table 14. U.S. Methane Emissions from Coal Mining and Post-Mining Activities, 1990-2000
(Million Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Surface Mining											
Mining	0.43	0.42	0.42	0.42	0.45	0.45	0.46	0.47	0.49	0.50	0.50
Post-Mining	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Underground Mining											
Ventilation (Gassy Mines)	2.13	2.04	2.10	1.82	1.85	1.91	1.71	1.79	1.80	1.76	1.66
Ventilation (Nongassy Mines)	0.03	0.03	0.02	0.02	0.03	0.03	0.04	0.04	0.03	0.04	0.04
Degasification	1.26	1.23	1.17	1.05	1.06	1.21	1.02	1.06	1.04	0.92	0.92
Post-Mining	0.64	0.61	0.61	0.53	0.60	0.60	0.62	0.63	0.63	0.59	0.56
Methane Recovery for Energy (-)	0.29	0.29	0.37	0.47	0.56	0.60	0.65	0.80	0.84	0.83	0.83
Net Emissions	**4.22**	**4.08**	**3.99**	**3.41**	**3.47**	**3.63**	**3.24**	**3.24**	**3.20**	**3.03**	**2.89**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). Totals may not equal sum of components due to independent rounding.

Sources: Coal production numbers from Energy Information Administration, *Coal Production*, DOE/EIA-0118 (Washington, DC, various years), and *Coal Industry Annual*, DOE/EIA-0584 (Washington, DC, 1995-1999). Methane recovery rates from U.S. Environmental Protection Agency, Office of Air and Radiation, Climate Protection Partnerships Division, Coalbed Methane Outreach Program. Ventilation data for 1985, 1988, and 1990 provided by G. Finfinger, U.S. Department of the Interior, Bureau of Mines, Pittsburgh Research Center. Ventilation data for all other years provided by U.S. Environmental Protection Agency, Office of Air and Radiation, Climate Protection Partnerships Division, Coalbed Methane Outreach Program.

Table 15. U.S. Methane Emissions from Natural Gas Systems, 1990-2000
(Million Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Production	1.47	1.49	1.49	1.51	1.55	1.57	1.58	1.65	1.66	1.65	1.71
Gas Processing	0.65	0.71	0.70	0.71	0.71	0.72	0.73	0.71	0.70	0.71	0.73
Transmission and Storage	2.10	2.21	2.23	2.15	2.11	2.14	2.11	2.20	1.98	2.11	2.24
Distribution	1.36	1.39	1.44	1.48	1.49	1.52	1.55	1.55	1.59	1.72	1.72
Total	**5.58**	**5.80**	**5.86**	**5.85**	**5.86**	**5.95**	**5.97**	**6.12**	**5.94**	**6.20**	**6.40**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). Totals may not equal sum of components due to independent rounding.

Sources: National Risk Management Research Laboratory, *Methane Emissions From the Natural Gas Industry*, Vol. 2, Technical Report, GRI-94/0257.1 and EPA-600-R-96-08 (Research Triangle Park, NC, June 1996), Appendix A; American Gas Association, *Gas Facts* (various years); Energy Information Administration, *Natural Gas Annual,* DOE/EIA-0131 (various years); Energy Information Administration, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, DC, July 2001); Energy Information Administration, *Petroleum Supply Annual*, DOE/EIA-0340 (Washington, DC, various years).

Table 16. U.S. Methane Emissions from Petroleum Systems, 1990-2000
(Million Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Refineries	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Exploration and Production	1.26	1.27	1.23	1.17	1.14	1.13	1.11	1.11	1.07	1.01	1.00
Crude Oil Transportation	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	**1.29**	**1.30**	**1.26**	**1.20**	**1.17**	**1.16**	**1.14**	**1.14**	**1.10**	**1.04**	**1.03**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). Totals may not equal sum of components due to independent rounding.

Sources: U.S. Environmental Protection Agency, Office of Air and Radiation, *Draft Estimates of Methane Emissions from the U.S. Oil Industry* (Draft Report, Washington, DC); Energy Information Administration, *Petroleum Supply Annual*, DOE/EIA-0340 (Washington, DC, various years); and *Oil and Gas Journal*, Worldwide Refining Issue and Pipeline Economics Issue (various years).

Table 17. U.S. Methane Emissions from Stationary Combustion Sources, 1990-2000

(Thousand Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Residential											
Coal	*	*	*	*	*	*	*	*	*	*	*
Distillate Fuel	4	4	4	5	4	4	5	5	4	4	4
Natural Gas	4	4	5	5	5	5	5	5	4	5	5
LPG	*	*	*	*	*	*	1	1	1	1	1
Wood	512	541	569	483	474	526	525	382	341	365	382
Total	**521**	**550**	**578**	**493**	**483**	**535**	**535**	**392**	**350**	**374**	**392**
Commercial											
Coal	1	1	1	1	1	1	1	1	1	1	1
Distillate Fuel	1	1	1	1	1	1	1	*	*	*	*
Natural Gas	3	3	3	3	3	4	4	4	4	4	4
LPG	*	*	*	*	*	*	*	*	*	*	*
Wood	*	*	*	*	*	*	*	*	*	*	*
Total	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Industrial											
Coal	7	6	6	6	6	6	6	6	5	5	5
Distillate Fuel	1	1	1	1	1	1	1	1	1	1	1
Natural Gas	11	12	12	13	13	14	14	14	14	14	15
LPG	2	2	3	2	3	3	3	3	3	3	3
Wood	4	3	4	4	4	5	5	5	5	5	5
Total	**26**	**25**	**26**	**27**	**28**	**28**	**29**	**29**	**28**	**29**	**30**
Electric Power											
Coal	10	10	10	10	10	10	11	11	12	12	12
Distillate Fuel	1	1	1	1	1	*	*	*	1	1	*
Natural Gas	*	*	*	*	*	*	*	*	*	*	*
Wood	*	*	*	*	*	*	*	*	*	*	*
Total	**11**	**11**	**11**	**11**	**11**	**11**	**12**	**12**	**13**	**13**	**13**
Total All Fuels											
Coal	17	17	17	17	17	17	18	18	18	18	18
Distillate Fuel	7	7	7	7	7	7	7	7	6	6	6
Natural Gas	19	20	20	21	21	22	23	23	22	22	24
LPG	3	3	3	3	3	3	4	4	3	4	4
Wood	517	544	573	487	478	530	530	387	346	371	387
Total	**563**	**590**	**620**	**536**	**527**	**580**	**581**	**438**	**395**	**421**	**439**

*Less than 500 metric tons of methane.

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). Totals may not equal sum of components due to independent rounding.

Sources: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, *Compilation of Air Pollutant Emission Factors*, AP-42, web site www.epa.gov/ttn/chief; Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), web site www.ipcc.ch/pub/guide.htm; and Energy Information Administration, *State Energy Data Report 1998*, DOE/EIA-0214(98) (Washington, DC, September 2000), *Monthly Energy Review*, DOE/EIA-0035(01/07) (Washington, DC, July 2001), and *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, DC, July 2001).

Table 18. U.S. Methane Emissions from Mobile Sources, 1990-2000
(Thousand Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Motor Vehicles											
Passenger Cars	142	132	131	126	117	109	107	105	105	106	101
Buses	1	1	1	1	1	1	1	1	1	1	1
Motorcycles	4	4	4	4	4	4	4	4	4	4	4
Light-Duty Trucks	63	63	63	75	85	99	92	91	91	108	100
Other Trucks	12	12	12	13	14	14	15	15	16	16	16
Total	**222**	**212**	**212**	**219**	**221**	**228**	**219**	**217**	**217**	**236**	**223**
Other Transport	23	23	24	22	22	23	23	21	22	24	26
Total Transport	**245**	**235**	**235**	**241**	**243**	**250**	**242**	**238**	**239**	**259**	**249**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000).

Sources: Calculations based on vehicle miles traveled from U.S. Department of Transportation, *Federal Highway Statistics*, various years, Table VM-1. Vehicle 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. 1.65-1.75, web site www.ipcc.ch/pub/guide.htm. Distribution of passenger car and light duty truck fleet model years for 1983, 1985, 1988, 1991, and 1994 according to data in the Energy Information Administration's "Residential Transportation Energy Consumption Surveys" for those years. Distribution for passenger cars and light duty trucks in other years computed by interpolation. Distribution of bus and other truck fleet according to model year computed assuming 10-percent attrition per annum of pre-1983 fleet for each year after 1984.

Table 19. U.S. Methane Emissions from Landfills, 1990-2000
(Million Metric Tons Methane)

Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Gross Emissions from Landfills	12.2	12.4	12.5	12.5	12.6	12.6	12.6	12.6	12.6	12.6	12.7
Methane Recovered for Energy (-)	0.8	0.8	0.9	0.9	1.1	1.1	1.3	1.6	1.9	2.2	2.5
Methane Assumed Flared (-)	0.2	0.4	0.7	0.9	1.1	1.3	1.7	1.8	2.0	2.0	2.4
Net Emissions	**11.2**	**11.1**	**10.9**	**10.7**	**10.4**	**10.2**	**9.6**	**9.2**	**8.7**	**8.4**	**7.8**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000).

Sources: Municipal solid waste landfilled from "Nationwide Survey: The State of Garbage in America, 1999," *Biocycle* (April 2000) for years before 2000. Waste generation for 2000 estimated on the basis of annual economic growth. Emissions calculations based on S.A. Thorneloe et al., "Estimate of Methane Emissions from U.S. Landfills," Prepared for the U.S. Environmental Protection Agency, Office of Research and Development (April 1994), and D. Augenstein, "The Greenhouse Effect and U.S. Landfill Methane," *Global Environmental Change* (December 1992), pp. 311-328. Methane recovered and flared from U.S. Environmental Protection Agency, Office of Air and Radiation, Climate Protection Partnerships Division, Landfill Methane Outreach Program, web site www.epa.gov/lmop/.

Table 20. U.S. Methane Emissions from Enteric Fermentation in Domesticated Animals, 1990-2000
(Million Metric Tons Methane)

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Cattle	4.87	5.01	5.10	5.18	5.31	5.35	5.20	5.16	5.15	5.19	5.30
Sheep	0.15	0.15	0.14	0.13	0.13	0.12	0.11	0.10	0.10	0.09	0.09
Pigs	0.08	0.09	0.09	0.09	0.09	0.09	0.08	0.09	0.09	0.09	0.09
Goats	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
Horses	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
Total	**5.16**	**5.30**	**5.39**	**5.46**	**5.59**	**5.61**	**5.46**	**5.42**	**5.41**	**5.43**	**5.54**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). Totals may not equal sum of components due to independent rounding.

Sources: Cattle, sheep, and pig population data provided by the U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Service. Goat and horse population figures extrapolated from U.S. Department of Commerce, Bureau of the Census, *Census of Agriculture*, 1982, 1987, 1992, and 1997. Emissions calculations based on U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1998*, EPA-236-R-00-001 (Washington, DC, April 2000), web site www.epa.gov/globalwarming/publications/emissions/us2000/index.html; and P.J. Crutzen, I. Aselmann, and W.S. Seiler, "Methane Production by Domestic Animals, Wild Ruminants, Other Herbivorous Fauna, and Humans," *Tellus*, Vol. 38B (1986), pp. 271-284.

Table 21. U.S. Methane Emissions from the Solid Waste of Domesticated Animals, 1990-2000
(Thousand Metric Tons Methane)

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Cattle											
Beef Cattle	249	264	271	278	284	286	275	275	273	275	280
Dairy Cattle	917	923	927	964	1,011	1,045	1,073	1,105	1,112	1,119	1,137
Swine											
Market Swine	861	912	924	919	954	931	896	981	1,005	961	960
Breeding Swine	487	515	506	510	498	482	468	495	476	445	446
Poultry											
Caged Layers	83	84	86	88	90	91	92	94	97	100	96
Broilers	73	77	81	91	95	100	102	105	106	110	111
Other Animals											
Sheep	5	5	5	5	4	4	4	4	3	3	3
Goats	1	1	1	1	1	1	1	1	1	1	1
Horses	12	11	11	11	12	12	13	13	13	14	14
Total	**2,688**	**2,792**	**2,812**	**2,867**	**2,949**	**2,951**	**2,923**	**3,071**	**3,086**	**3,026**	**3,048**

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). Totals may not equal sum of components due to independent rounding.

Sources: 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. Population data for all other animals from U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Branch. Typical animal sizes from U.S. Environmental Protection Agency, Office of Air and Radiation, *Anthropogenic Methane Emissions in the United States: Estimates for 1990, Report to Congress* (Washington, DC, April 1993), p. 6-8. Cattle sizes adjusted by annual slaughter weight from U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Branch. Maximum methane 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: U.S. Environmental Protection Agency, February 1992), pp. 24-27, and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1998*, EPA-230-00-001 (Washington, DC, April 2000). General methane conversion factors 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. 4.25, web site www.ipcc.ch/pub/guide.htm. State methane conversion factors for dairy cattle from U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1998*, EPA-236-R-00-001 (Washington, DC, April 2001), web site www.epa.gov/globalwarming/publications/emissions/ us2000/index.html.

Table 22. U.S. Methane Emissions from Industrial Processes, 1990-2000

(Thousand Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	P2000
Chemical Production											
Ethylene	17	18	19	19	20	21	22	23	23	25	25
Ethylene Dichloride	3	2	3	3	3	3	3	4	4	4	4
Styrene	15	15	16	18	20	21	22	21	21	22	22
Methanol	8	8	7	10	10	10	11	12	11	11	11
Carbon Black	14	13	15	16	16	17	17	17	18	18	18
Total	**56**	**57**	**60**	**66**	**70**	**72**	**75**	**77**	**77**	**80**	**80**
Iron and Steel Production											
Coke[a]	11	9	9	9	8	9	8	7	7	6	7
Sinter	6	5	6	6	6	6	6	6	5	6	5
Pig Iron	45	40	43	43	44	46	44	45	43	42	43
Total	**62**	**54**	**57**	**58**	**59**	**61**	**59**	**58**	**56**	**54**	**55**
Total Industrial Processes	**117**	**111**	**117**	**124**	**129**	**132**	**134**	**134**	**133**	**133**	**135**

[a]Based on total U.S. production of metallurgical coke, including non-iron and steel uses.

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 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000). Totals may not equal sum of components due to independent rounding.

Sources: American Iron and Steel Institute, *Annual Statistical Report* (Washington, DC, various years); American Chemical Council (formerly the Chemical Manufacturers Association), *U.S. Chemical Industry Statistical Handbook* (Washington, DC, various years); and 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. 2.23, web site www.ipcc/pub/guide.htm.