8. Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 8-1). Landfills accounted for approximately 23 percent of total U.S. anthropogenic methane (CH_4) emissions in 2007,[1] the second largest contribution of any CH_4 source in the United States. Additionally, wastewater treatment and composting of organic waste accounted for approximately 4 percent and less than 1 percent of U.S. CH_4 emissions, respectively. Nitrous oxide (N_2O) emissions from the discharge of wastewater treatment effluents into aquatic environments were estimated, as were N_2O emissions from the treatment process itself. N_2O emissions from composting were also estimated. Together, these waste activities account for approximately 2 percent of total U.S. N_2O emissions. Nitrogen oxide (NO_x), carbon monoxide (CO), and non-CH_4 volatile organic compounds (NMVOCs) are emitted by waste activities, and are addressed separately at the end of this chapter. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 8-1 and Table 8-2.

Overall, in 2007, waste activities generated emissions of 165.6 teragrams of carbon dioxide equivalents (Tg CO_2 Eq.) or just over 2 percent of total U.S. greenhouse gas emissions.

Figure 8-1

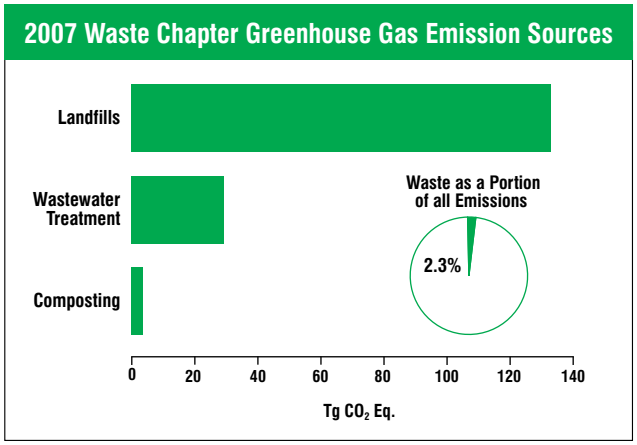

Table 8-1: Emissions from Waste (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007
CH_4	**173.0**	**169.9**	**148.8**	**153.8**	**156.5**	**158.9**
Landfills	149.2	144.3	122.3	127.8	130.4	132.9
Wastewater Treatment	23.5	24.8	25.2	24.3	24.5	24.4
Composting	0.3	0.7	1.3	1.6	1.6	1.7
N_2O	**4.0**	**4.8**	**5.8**	**6.5**	**6.6**	**6.7**
Domestic Wastewater Treatment	3.7	4.0	4.5	4.8	4.8	4.9
Composting	0.4	0.8	1.4	1.7	1.8	1.8
Total	**177.1**	**174.7**	**154.6**	**160.2**	**163.0**	**165.6**

Note: Totals may not sum due to independent rounding.

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

per capita flow	=	Wastewater flow to POTW per person per day (100 gal/person/day)
conversion to m^3	=	Conversion factor, ft^3 to m^3 (0.0283)
$FRAC\_CH_4$	=	Proportion CH_4 in biogas (0.65)
density of CH_4	=	662 (g CH_4/m^3 CH_4)
$1/10^9$	=	Conversion factor, g to Gg

U.S. population data were taken from the U.S. Census Bureau International Database (U.S. Census 2008a) and include the populations of the United States, American Samoa, Guam, Northern Mariana Islands, Puerto Rico, and the U.S. Virgin Islands. Table 8-8 presents U.S. population and total BOD_5 produced for 1990 through 2007. The proportions of domestic wastewater treated onsite versus at centralized treatment plants were based on data from the 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003, and 2005 American Housing Surveys conducted by the U.S. Census Bureau (U.S. Census 2008b), with data for intervening years obtained by linear interpolation. The wastewater flow to aerobic and anaerobic systems, and the wastewater flow to POTWs that have anaerobic digesters were obtained from the 1992, 1996, 2000, and 2004 Clean Watershed Needs Survey (EPA 1992, 1996, 2000, and 2004a).[9] Data for intervening years were obtained by linear interpolation. The BOD_5 production rate (0.09 kg/capita/day) for domestic wastewater was obtained from Metcalf and Eddy (1991 and 2003). The CH_4 emission factor (0.6 kg CH_4/kg BOD_5) and the MCFs were taken from IPCC (2006). The CH_4 destruction efficiency, 99 percent, was selected based on the range of efficiencies (98 to 100 percent) recommended for flares in *AP-42 Compilation of Air Pollutant Emission Factors, Chapter 2.4* (EPA 1998), efficiencies used to establish NSPS for landfills, and in recommendations for closed flares used by the LMOP. The cubic feet of digester gas produced per person per day (1.0 ft^3/person/day) and the proportion of CH_4 in biogas (0.65) come from Metcalf and Eddy (1991).

[9] Aerobic and anaerobic treatment were determined based on unit processes in use at the facilities. Because the list of unit processes became more extensive in the 2000 and 2004 surveys, the criteria used to identify aerobic and anaerobic treatment differ slightly across the time series. Once facilities were identified as aerobic or anaerobic, they were separated by whether or not they had anaerobic digestion in place. Once these classifications were determined, the flows associated with facilities in each category were summed.

Table 8-8: U.S. Population (Millions) and Domestic Wastewater BOD_5 Produced (Gg)

Year	Population	BOD_5
1990	254	8,350
1995	271	8,895
2000	287	9,419
2001	289	9,509
2002	292	9,597
2003	295	9,685
2004	297	9,774
2005	300	9,864
2006	303	9,954
2007	306	10,043

Source: U.S. Census Bureau (2008a); Metcalf & Eddy 1991 and 2003.

The wastewater flow to a POTW (100 gal/person/day) was taken from the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (2004), "Recommended Standards for Wastewater Facilities (Ten-State Standards)."

Industrial Wastewater CH_4 Emission Estimates

CH_4 emissions estimates from industrial wastewater were developed according to the methodology described in IPCC (2006). Industry categories that are likely to produce significant CH_4 emissions from wastewater treatment were identified. High volumes of wastewater generated and a high organic wastewater load were the main criteria. The top five industries that meet these criteria are pulp and paper manufacturing; meat and poultry processing; vegetables, fruits, and juices processing; starch-based ethanol production; and petroleum refining. Wastewater treatment emissions for these sectors for 2007 are displayed in Table 8-9.

Table 8-10 contains production data for these industries.

Table 8-9: Industrial Wastewater CH_4 Emissions by Sector for 2007

	CH_4 Emissions (Tg CO_2 Eq.)	% of Industrial Wastewater CH_4
Pulp & Paper	4.1	48%
Meat & Poultry	3.6	43%
Petroleum Refineries	0.6	7%
Fruit & Vegetables	0.1	1%
Ethanol Refineries	0.1	1%
Total	**8.5**	**100%**