2011-2020 Greenhouse Gas Reporting Program Sector Profile: Waste Sector

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WASTE SECTOR

All emissions presented here are as of 8/7/2021 and exclude biogenic carbon dioxide (CO_2). All greenhouse gas (GHG) emission data displayed in units of carbon dioxide equivalent (CO_2e) reflect the global warming potential (GWP) values from Table A-1 of 40 CFR 98, which is generally based on the Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC AR4).

Highlights

- The most prevalent greenhouse gas (GHG) emitted by the Waste Sector is methane (CH_4), and municipal solid waste (MSW) landfills are the largest emitter of CH_4 in this sector.
- Reported emissions from the Waste Sector have decreased from 2011 to 2020. Emissions in 2020 were 8.2% lower than in 2011. The decrease in emissions is primarily driven by MSW landfills. Methodological changes to the emission calculation procedures for MSW landfills were implemented in 2013 and 2016, and are a primary factor in these reported emission reductions.
- The three states with the most methane (CH_4) emissions from MSW landfills (and across the Waste Sector) are Texas, Florida, and California. The three states with the largest number of MSW landfills are Texas, California, and Illinois.
- Seventy four percent of the MSW landfills that reported have landfill gas collection and control systems (GCCSs), compared to less than 1% of industrial waste landfills.

Emissions from industrial waste landfills, industrial wastewater treatment, MSW, and solid waste combustion were lower in 2020 than in 2011, though the decrease during this time frame was not constant for any of these subsectors.

About this Sector

The Waste Sector comprises MSW landfills, industrial waste landfills, industrial wastewater treatment systems, and solid waste combustion at waste-to-energy facilities.

- **MSW landfills** are landfills that dispose or have disposed of MSW. MSW includes, among other components, solid-phase household, commercial/retail, and institutional wastes. MSW landfills may also dispose of non-MSW wastes, including construction and demolition debris and other inert materials. This subsector excludes dedicated industrial, hazardous waste, and construction and demolition landfills. An MSW landfill comprises the landfill, the landfill GCCS, and combustion devices that are used to control landfill gas emissions.

- **Industrial waste landfills** are landfills that accept or have accepted primarily industrial wastes. This subsector excludes landfills that accept hazardous waste and those that receive only construction and demolition or other inert wastes. An industrial waste landfill includes the landfill, the landfill GCCS, and combustion devices that are used to control landfill gas emissions. Less than 1% of facilities reporting under this Subpart have landfill GCCSs. The organic composition of waste streams disposed of at industrial waste landfills tends to be similar over time, leading to a relatively consistent emission rate, while the waste streams at MSW landfills may fluctuate seasonally and/or annually.

- **Industrial wastewater treatment systems** comprise anaerobic lagoons, reactors, and anaerobic sludge digesters at facilities that perform pulp and paper manufacturing, food processing, ethanol production, and petroleum refining. This subsector does not include anaerobic processes used to treat wastewater and wastewater treatment sludge at other industrial facilities. It also does not include emissions from municipal wastewater treatment plants, separate treatment of sanitary wastewater at industrial facilities, oil and/or water separators, or aerobic and anoxic treatment of industrial wastewater.
- **Solid waste combustion at waste-to-energy facilities** comprise combustors and incinerators at facilities under North American Industry Classification System (NAICS) code 562213 that burn non-hazardous solid waste either to recover energy or to reduce the volume of waste.

Who Reports?

For Reporting Year (RY) 2020, 1,465 facilities in the Waste Sector reported emissions of 105.5 million metric tons (MMT) CO_2e. In 2020, the Waste Sector represented 19.2% of the facilities reporting direct emissions to the Greenhouse Gas Reporting Program (GHGRP) and 1.6% of total U.S. direct emissions.[1] Table 1 includes details of the applicability of each source category, their corresponding reporting schedules, and estimates of the percent of facilities and emissions covered by the GHGRP.[2] Table 2 shows the number of GHGRP reporters by source category and year.

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[1] Total U.S. GHG emissions for 2019 were 6,558 MMT CO_2e, as reported in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019. EPA 430-R-21-005. U.S. Environmental Protection Agency. April 14, 2021. Available: https://www.epa.gov/ghgemissions/overview-greenhouse-gases.6456.7.

[2] Note: Values in Table 1 do not change significantly from year to year, so percentages in Table 1 are updated every five years. Table 1 was last updated in 2021.

Table 1: Waste Sector - Reporting Schedule and GHGRP Coverage by Subpart (2020)

Subpart	Source Category	Applicability	First Reporting Year	Estimated % of Industry Emissions Covered
HH	MSW Landfills	Facilities that accepted waste after January 1, 1980, and that generate methane that is equivalent to > 25,000 metric tons CO_2e/year	2010	91.5%[a]
C	Solid Waste Combustion	• Facilities that reported only under subpart C (Stationary Fuel Combustion) and reported NAICS code 562213 (Solid Waste Combustors and Incinerators) • Such facilities that emit > 25,000 metric tons CO_2e/year.	2010	78%[b]
TT	Industrial Waste Landfills	• Accepted waste after January 1, 1980, and • Design capacity > 300,000 metric tons, and • Located at a facility that emits > 25,000 metric tons CO_2e/year.	2011	53%[c]
II	Industrial Wastewater Treatment	Facilities operating an anaerobic process to treat industrial wastewater and/or industrial wastewater treatment sludge	2010	31.25%[d]

[a] *Estimate of total industry emissions is from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019. EPA 430-R-21-005. U.S. Environmental Protection Agency. April 14, 2021. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019. Emissions were estimated to be 99.4 MMT CO_2e (Table 7-3: CH_4 Emissions from Landfills (page 7-6)).*

[b] *Estimate of total U.S. solid waste combustion emissions is from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019. EPA 430-R-21-005. U.S. Environmental Protection Agency. April 14, 2021. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019. Emissions were estimated to be 11.8 MMT CO_2e (Table 3-25: CO_2, CH_4, and N_2O Emissions from the Incineration of Waste (page 3-58)).*

[c] *Estimated size of industry emissions based on the industrial waste landfill emissions estimates from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019. EPA 430-R-21-005. U.S. Environmental Protection Agency. April 14, 2021. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019. These emission estimates are based on nationwide estimated amounts of annual waste generation and are not facility-specific emission estimates. (Table 7-3: CH_4 Emissions from Landfills (page 7-6)).*

[d] *Emissions covered by the GHGRP were calculated using the U.S. GHG Inventory values for industrial wastewater (Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019. EPA 430-R-21-005. U.S. Environmental Protection Agency. April 14, 2021. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019) and RY 2019 emissions for Subpart II.*

Table 2: Waste Sector – Number of Reporters (2011–2020)[a]

Source Category	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Waste Sector	**1,645**	**1,652**	**1,638**	**1,631**	**1,548**	**1,512**	**1,503**	**1,499**	**1,473**	**1,465**
MSW Landfills	1,240	1,252	1,240	1,237	1,168	1,144	1,138	1,136	1,124	1,123
Solid Waste Combustion	68	69	68	67	64	63	62	62	61	59
Industrial Waste Landfills	176	176	176	178	174	171	171	169	168	166
Industrial Wastewater Treatment	169	162	161	156	149	141	139	139	127	124

[a] The total number of reporters may be less than the sum of the number of reporters in each individual source category because some facilities contain more than one source category.

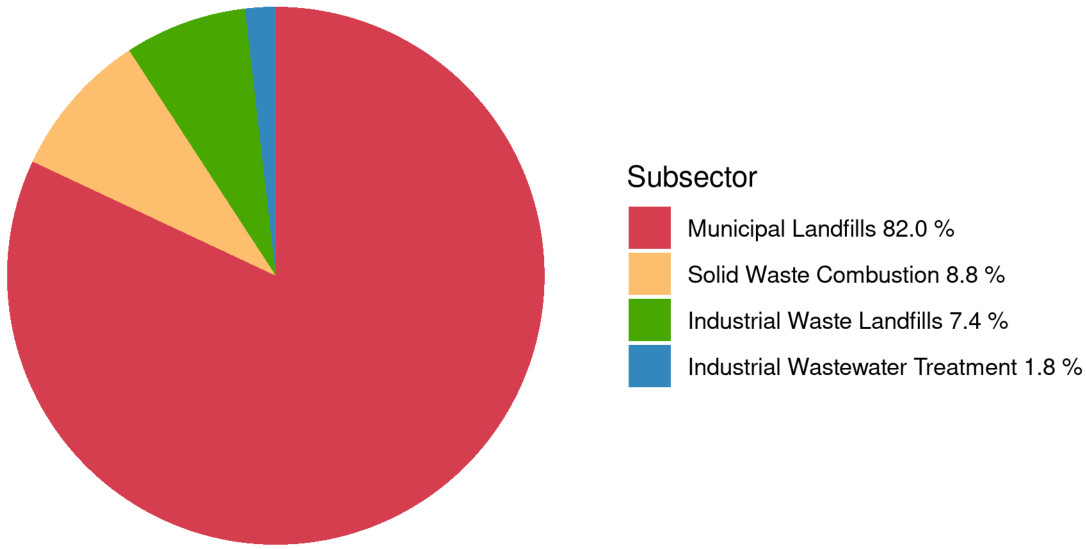
MSW landfills made up the majority of Waste Sector reporters for all reporting years. The number of reporters for MSW landfills decreased by 117 facilities between 2011 and 2020. This decrease is a result of facilities that qualified to discontinue reporting (off-ramping from the program).[3] Between 2011 and 2020, the number of reporters for industrial wastewater treatment decreased by 45. The number of reporters for industrial waste landfills had a net decrease of ten facilities from 2011 to 2020. The number of solid waste combustion facilities decreased by nine facilities from 2011 to 2020.

Reported Emissions

Methane (CH_4) is the primary GHG reported by MSW landfills, industrial waste landfills, and industrial wastewater treatment facilities. Methane is generated by the anaerobic decomposition of organic waste in landfills and in anaerobic wastewater treatment systems. Landfill gas typically contains approximately 50% methane, 50% CO_2, and less than 1% non-methane organic compounds. Industrial wastewater treatment gas contains about 65 to 70% methane, 25 to 30% CO_2, and small amounts of N_2, H_2, and other gases. Figure 1 shows the breakdown of emissions by subsector in RY 2020.

[3] See FAQ: When is a Facility Eligible to Stop Reporting? Available: http://www.ccdsupport.com/confluence/pages/viewpage.action?pageId=243139271.

Figure 1: 2020 Total Reported Emissions from Waste, by Subsector



Biogenic CO_2 emissions result primarily from the combustion of landfill gas, MSW, and other biogenic fuels in reciprocating internal engines, municipal waste combustors, and other combustion units.

Figures 2 through 6 show the location and range of emissions in the contiguous United States for the entire Waste Sector (Figure 2) and each subsector individually (Figures 3 through 6). Sizes of each circle correspond to a specified range of emissions in MT of CO_2e reported by that particular facility. Many large industrial waste landfills are in southeastern states and along the coastline of the Gulf of Mexico, which is also where numerous petroleum refineries, pulp and paper, and chemical manufacturing facilities are located. Locations of industrial wastewater treatment facilities are driven primarily by the location of ethanol facilities, which account for more than half of all industrial wastewater treatment reporters and tend to be in the Midwest. Seventy-seven percent of solid waste combustors are in the northeastern states and in Florida, and the remaining facilities are in the Midwest and western states (Figure 6).

Readers can identify the largest emitting facilities by visiting the Facility Level Information on Greenhouse Gases Tool (FLIGHT) website (https://ghgdata.epa.gov/ghgp/main.do#).

Figure 2: Waste Sector Emissions by Range and Location (2020)

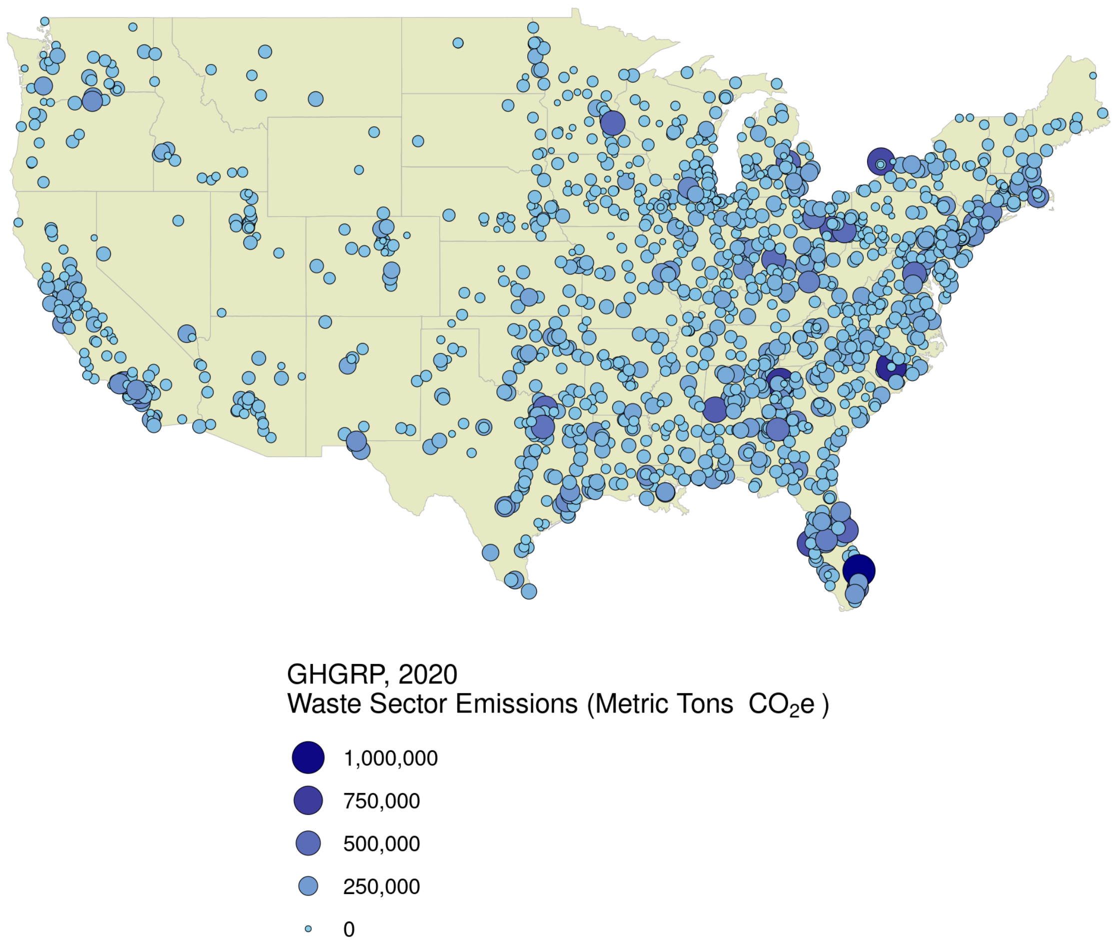


Figure 3: MSW Landfill Subsector Emissions by Range and Location (2020)

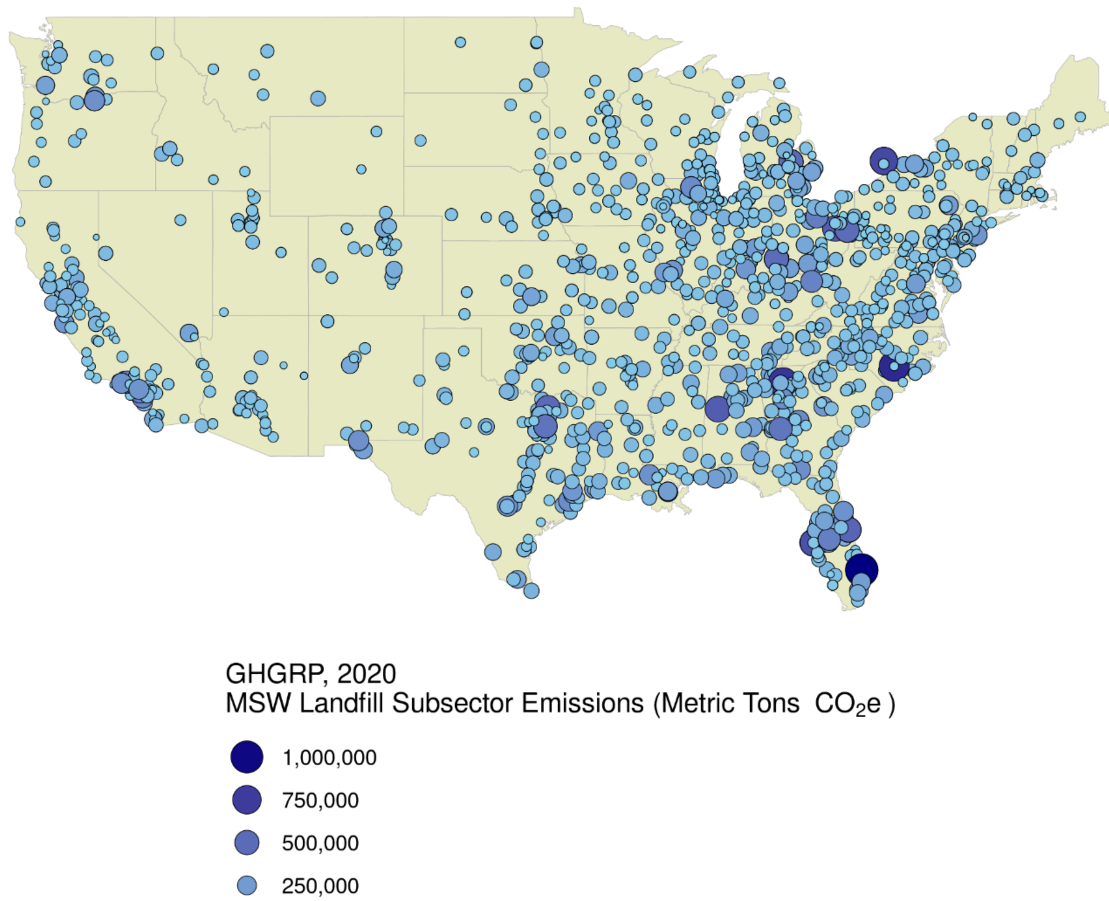


Figure 4: Solid Waste Combustion Subsector Emissions by Range and Location (2020)

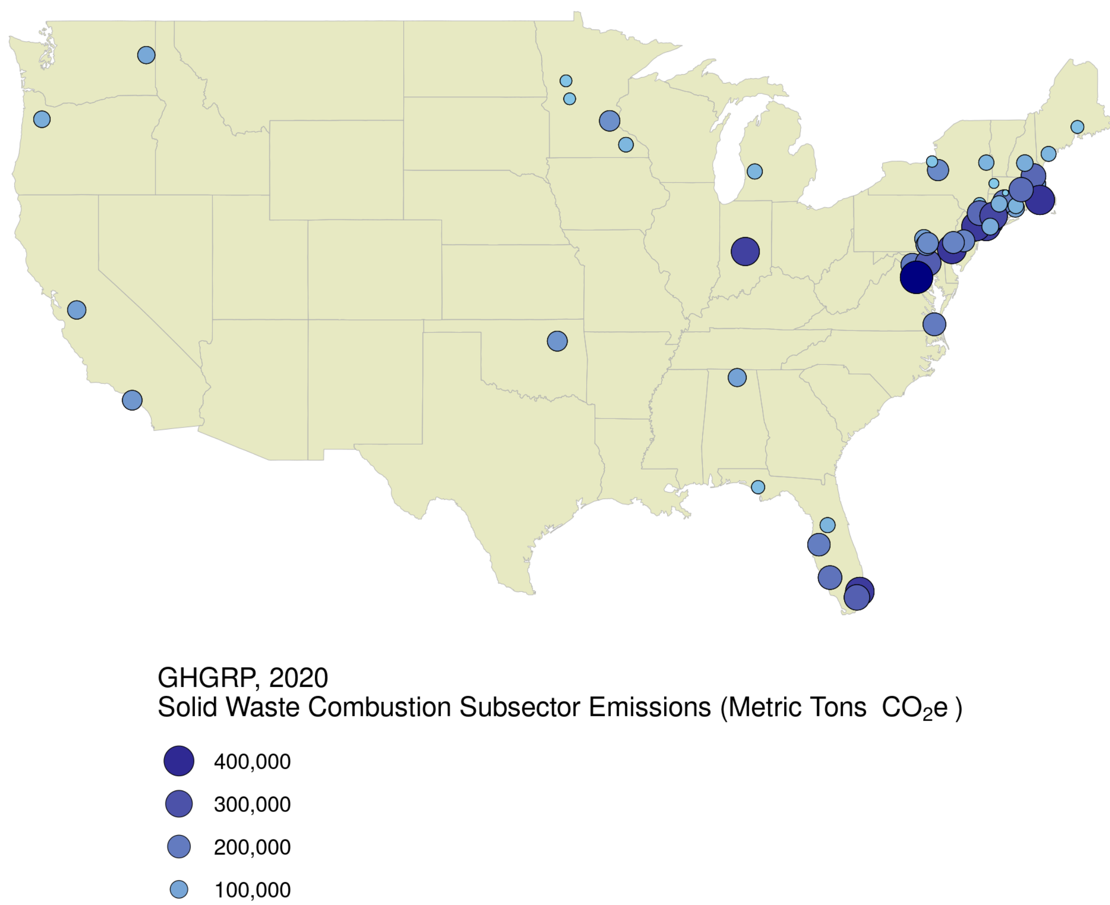


Figure 5: Industrial Waste Landfill Subsector Emissions by Range and Location (2020)

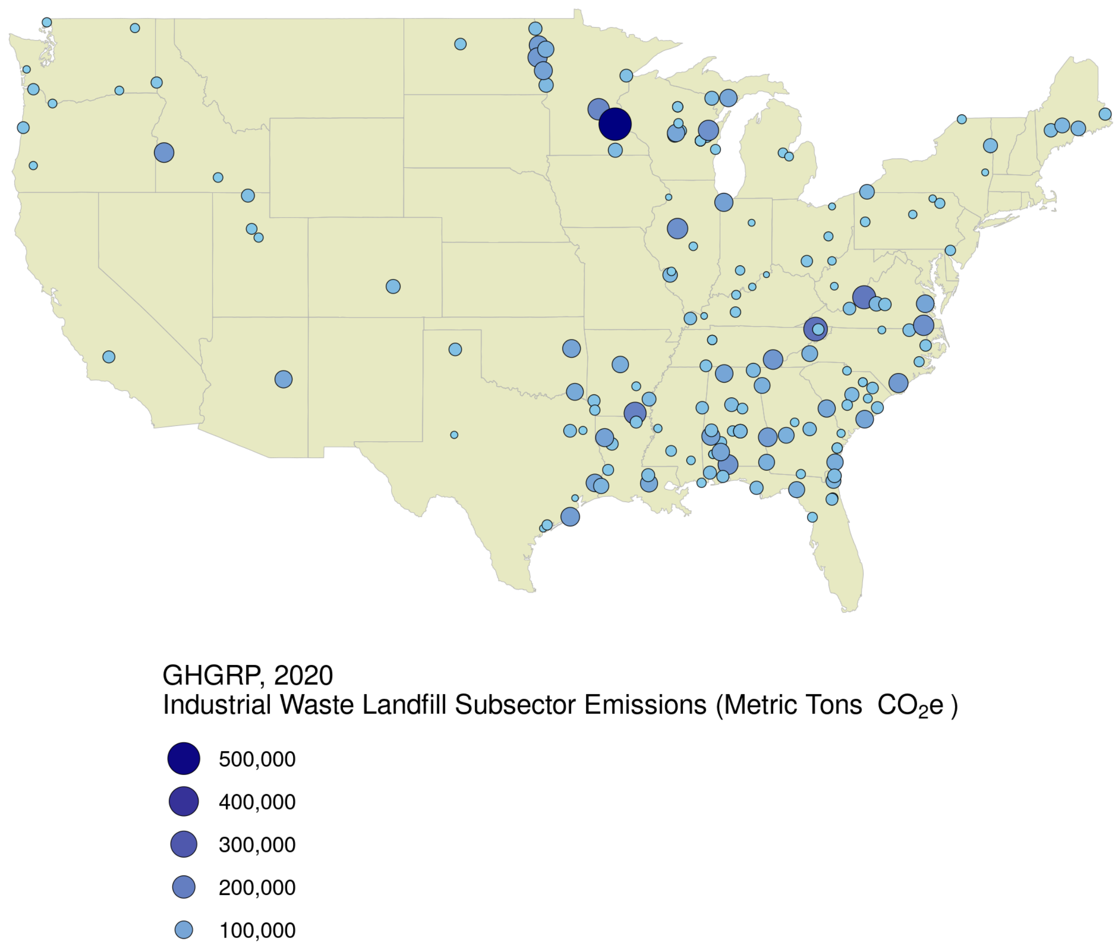
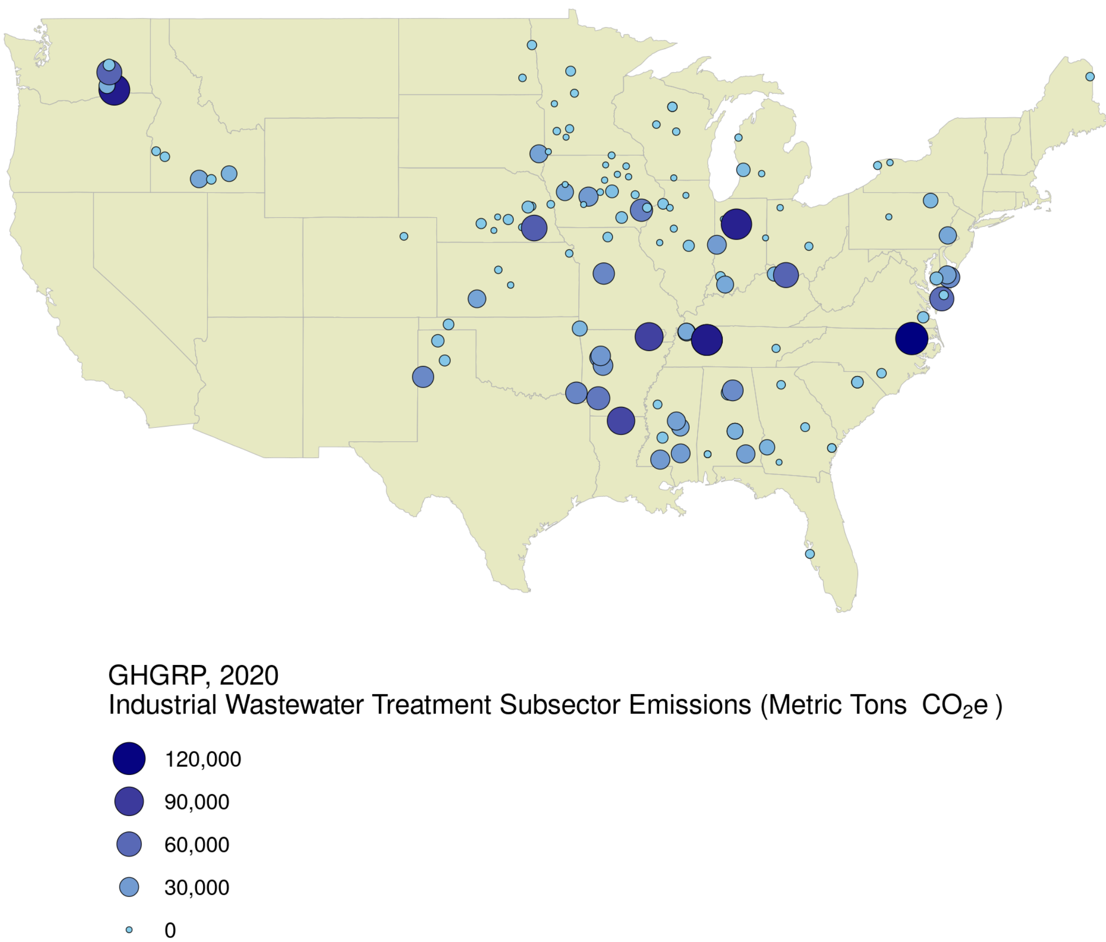


Figure 6: Industrial Wastewater Treatment Subsector Emissions by Range and Location (2020)



Waste Sector: Emissions Trends, 2011 to 2020

The waste sector consists of municipal solids waste (MSW) landfills, industrial waste landfills, solid waste combustion, and industrial wastewater treatment. Total emissions reported to the Greenhouse Gas Reporting Program by the waste sector decreased from 114.9 MMT CO_2e in 2011 to 105.5 MMT CO_2e in 2020 (8.2 percent). The decrease in emissions is likely due to the notable drop in emissions from MSW landfills.

Over 80 percent of emissions from the waste sector come from municipal solid waste (MSW) landfills. Reported emissions from MSW landfills decreased from 94 MMT CO_2e in 2011 to 86 MMT CO_2e in 2020 (7.9 percent). The decrease in reported emissions is due to changes to the rule for calculating methane emissions from MSW landfills. Starting in reporting year 2013, MSW landfills are allowed to assume that a higher percentage of methane generated by the landfill is oxidized to CO_2 as it passes through the landfill soil cover, resulting in lower reported methane emissions. Landfills are provided two equations for calculating methane emissions and are given the choice of which results to report. Landfills choosing to report the lower of the two estimates is likely contributing to lower reported emissions. In 2020, annual reported waste disposal as well as annual emissions from MSW landfills decreased by 5 percent and 4.2 percent, respectively. Since 2011, waste disposal had been slightly increasing year to year.

In addition to MSW landfills, reported emissions also decreased from the other waste subsectors. Emissions reported by industrial waste landfills decreased 12.7 percent between 2011 and 2020 while emissions reported by solid waste combustors decreased 2.9 percent during this time, and wastewater treatment facilities dropped 24.2 percent.

Table 3: Waste Sector – Emissions by Subsector (2011–2020)[a,b]

Source Category	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Waste Sector	**114.9**	**115.0**	**111.3**	**111.9**	**110.3**	**107.5**	**105.6**	**108.3**	**109.6**	**105.5**
MSW Landfills	93.8	94.4	91.2	90.8	89.6	86.8	86.3	88.6	90.2	86.5
Solid Waste Combustion	9.6	9.8	10.0	9.9	10.1	10.2	9.2	9.5	9.2	9.3
Industrial Waste Landfills	8.9	8.7	8.0	8.5	8.5	8.6	8.1	8.2	8.1	7.8
Industrial Wastewater Treatment	2.6	2.1	2.2	2.6	2.1	2.0	1.9	2.0	2.1	1.9

[a] *Biogenic emissions of CO_2 are not included in the CO_2e emissions in this table. As landfill gas recovered from MSW landfills and industrial waste landfills is considered biogenic, CO_2 emissions from the combustion of landfill gas are not included in the CO_2e emissions in this table. Biogenic CO_2 emissions from the combustion of the biogenic fraction of MSW are also not included in the CO_2e emissions in this table.*
[b] *Totals may not sum due to independent rounding.*

Table 4: Waste Sector - Biogenic CO_2 Emissions (2011-2020)[a]

Waste Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total biogenic CO_2 emissions	**18.8**	**18.5**	**18.2**	**17.8**	**17.6**	**17.5**	**17.7**	**17.8**	**17.7**	**17.3**
MSW Landfills	4.1	4.1	3.9	3.8	3.9	4.0	4.0	4.0	4.2	4.0
Solid Waste Combustion	14.7	14.4	14.3	14.0	13.7	13.5	13.7	13.7	13.5	13.3

[a] *Totals may not sum due to independent rounding.*

Figure 7: Direct Emissions by State from the Waste Sector (2020)[a]

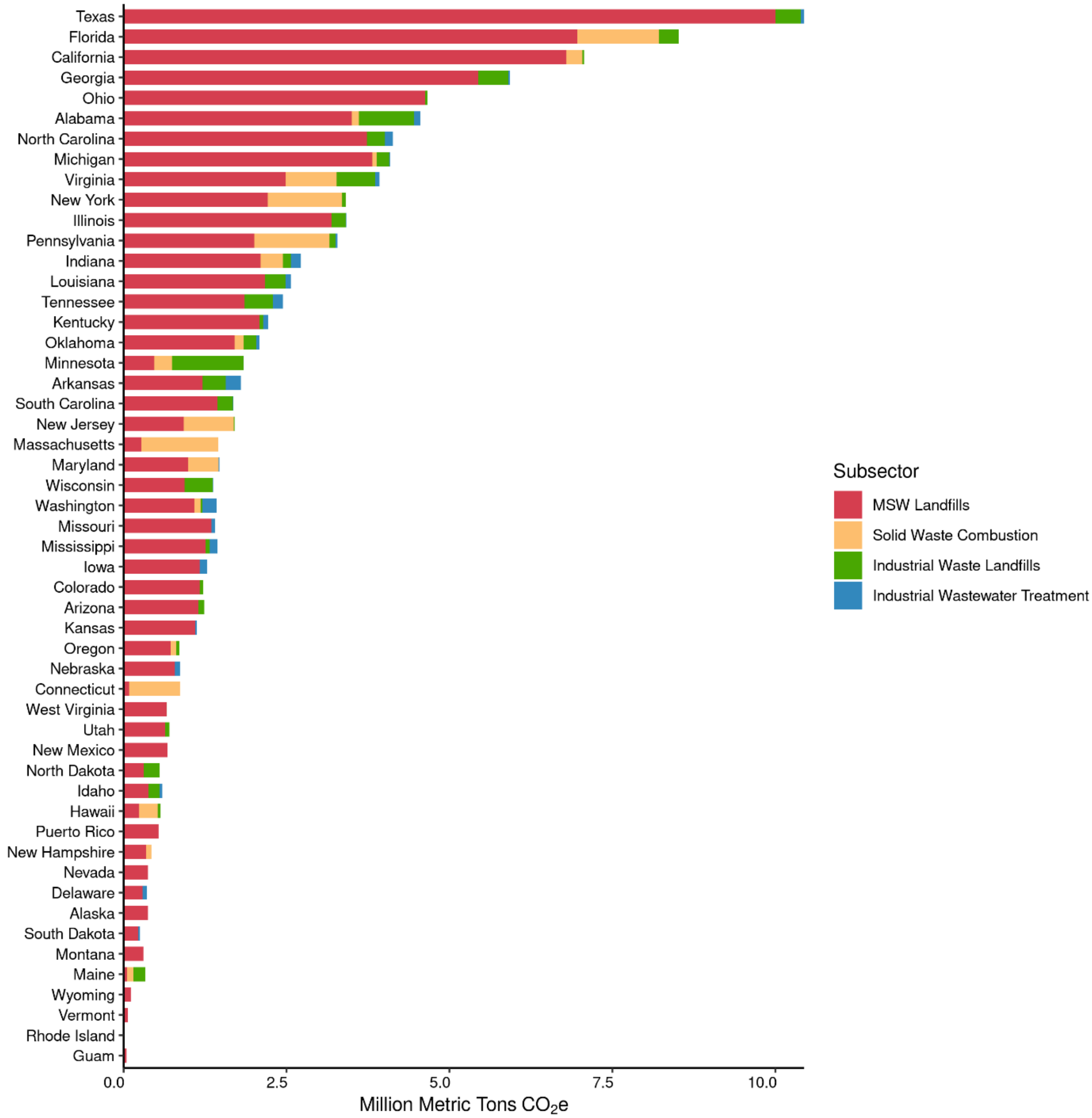


Table 5 shows the emissions by GHG emitted. Table 6 breaks down emissions by Waste Sector processes and fuel combustion.

Table 5: Waste Sector - Emissions by GHG (MMT CO_2e)[a]

Waste Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of Facilities	**1,645**	**1,652**	**1,638**	**1,631**	**1,547**	**1,512**	**1,502**	**1,499**	**1,473**	**1,465**
Total Emissions	**114.9**	**115.0**	**111.3**	**111.9**	**110.3**	**107.5**	**105.6**	**108.3**	**109.6**	**105.5**
Carbon Dioxide										
MSW Landfills	1.0	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.4	1.5
Solid Waste Combustion	9.1	9.3	9.4	9.4	9.6	9.7	8.7	9.0	8.8	8.8
Methane										
MSW Landfills	92.8	93.4	90.0	89.6	88.3	85.3	84.9	87.1	88.8	84.9
Solid Waste Combustion	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Industrial Waste Landfills	8.9	8.7	8.0	8.5	8.5	8.6	8.1	8.2	8.1	7.8
Industrial Wastewater Treatment	2.6	2.1	2.2	2.6	2.1	2.0	1.9	2.0	2.1	1.9
Nitrous Oxide										
MSW Landfills[b]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Solid Waste Combustion	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

[a] *Totals may not sum due to independent rounding.*
[b] *Emissions shown for CO_2 and N_2O result from the combustion of fossil fuels and the non-biogenic portion of MSW that is combusted.*

Table 6: Waste Sector – Emissions from Waste Sector Processes and Fuel Combustion[a,b,c]

Waste Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MSW Landfills	**93.8**	**94.4**	**91.2**	**90.8**	**89.6**	**86.8**	**86.3**	**88.6**	**90.2**	**86.5**
Fuel combustion	1.1	1.0	1.2	1.2	1.3	1.5	1.4	1.5	1.4	1.6
Waste Sector processes	92.7	93.3	90.0	89.6	88.3	85.3	84.9	87.1	88.8	84.9
Solid Waste combustion	**9.6**	**9.8**	**10.0**	**9.9**	**10.1**	**10.2**	**9.2**	**9.5**	**9.2**	**9.3**
Fuel combustion	9.6	9.8	10.0	9.9	10.1	10.2	9.2	9.5	9.2	9.3
Industrial Waste Landfills	**8.9**	**8.7**	**8.0**	**8.5**	**8.5**	**8.6**	**8.1**	**8.2**	**8.1**	**7.8**
Waste sector processes	8.9	8.7	8.0	8.5	8.5	8.6	8.1	8.2	8.1	7.8
Industrial Wastewater Treatment	**2.6**	**2.1**	**2.2**	**2.6**	**2.1**	**2.0**	**1.9**	**2.0**	**2.1**	**1.9**
Waste Sector processes	2.6	2.1	2.2	2.6	2.1	2.0	1.9	2.0	2.1	1.9

[a] *These values represent total emissions reported to the GHGRP in these industry sectors. Additional emissions may occur at facilities that have not reported (e.g., those below the reporting threshold).*
[b] *Totals may not sum due to independent rounding. Emission values presented may differ slightly from other publicly available GHGRP data due to minor differences in the calculation methodology.*
[c] *Emissions from fuel combustion are defined here as emissions reported under Subpart C.*

Figure 8 shows the average emissions per reporter from the waste subsectors compared with average emissions from all GHGRP reporters. Figure 9 and Table 7 show the percentage and number of reporters within each emission range, respectively.

Figure 8: Average Emissions per Reporter from the Waste Sector (2020)

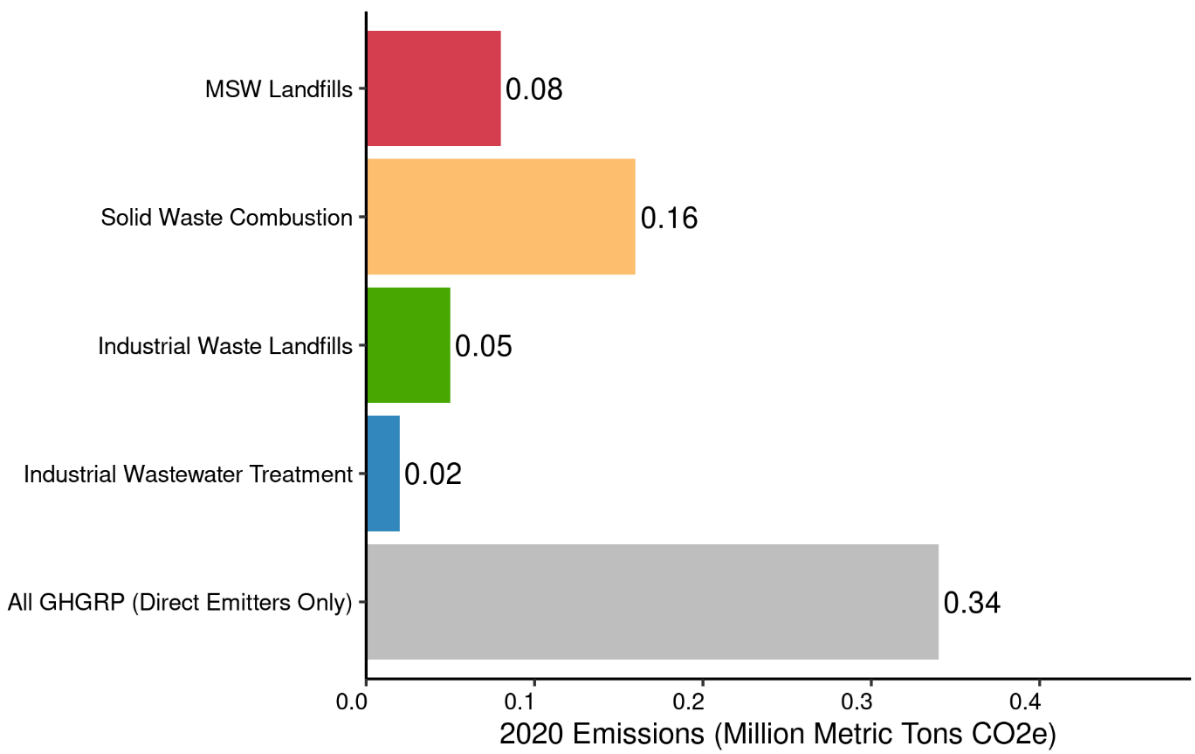


Figure 9: Percentage of Facilities in the Waste Sector at Various Emissions Ranges (2020)

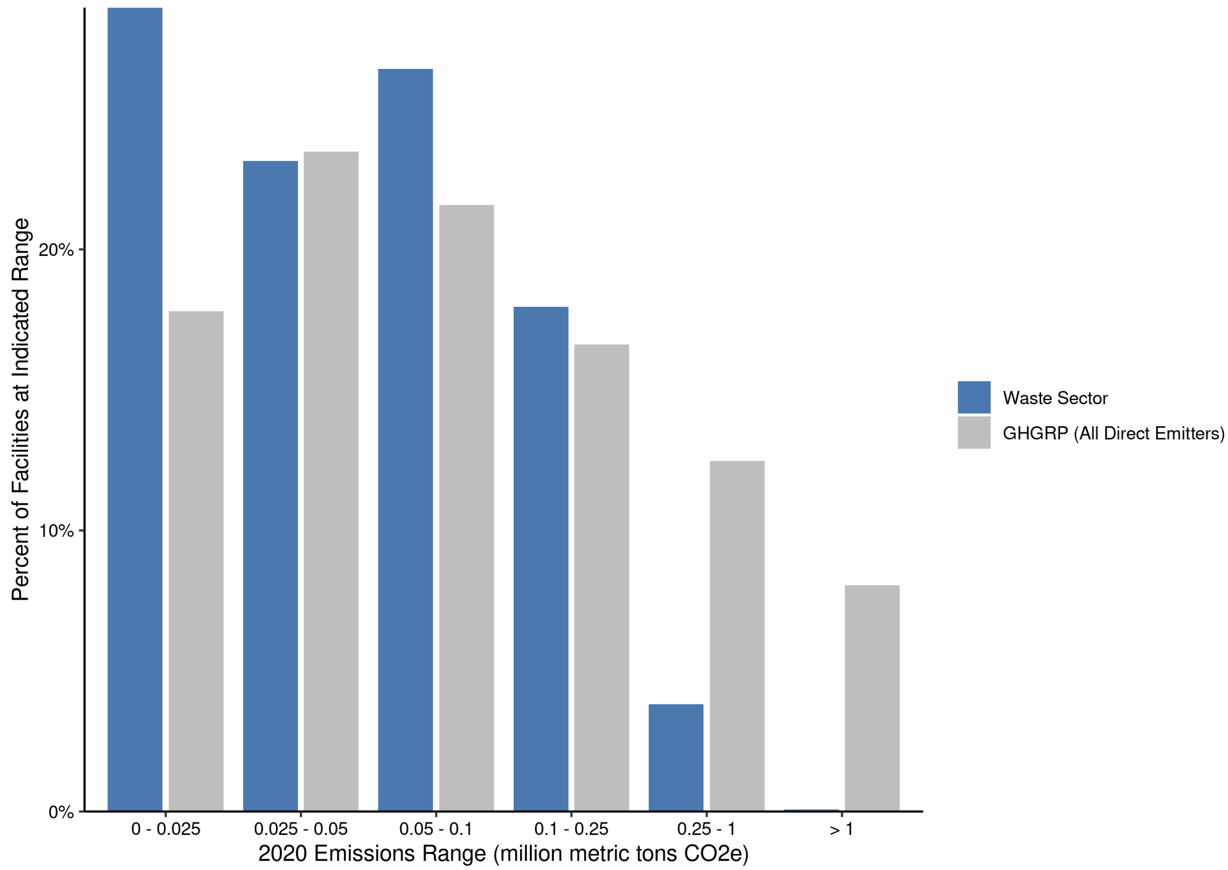


Table 7: Waste Sector – Number of Facilities by Emissions Range in MMT CO_2e (2020)[a]

Waste Sector	0 - 0.025	0.025 - 0.05	0.05 - 0.1	0.1 - 0.25	0.25 - 1	> 1
MSW Landfills	250	278	341	209	44	1
Solid Waste Combustion	2	7	13	26	11	0
Industrial Waste Landfills	78	38	25	24	1	0
Industrial Wastewater Treatment	96	17	7	4	0	0

[a] Within this table, the total number of facilities shown in the Total Waste Sector row represents the number of unique facilities. The totals in this row may not equal the sum of the rows below due to facilities reporting under multiple industry types.

MSW Landfill Details

Table 8 shows the characteristics of MSW landfills in 2020, and Table 9 shows emissions by type of MSW landfill.

Table 8: Characteristics of MSW Landfills in 2011-2020

Operational Characteristic	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of reporting facilities	**1,240**	**1,252**	**1,240**	**1,237**	**1,168**	**1,144**	**1,138**	**1,136**	**1,124**	**1,123**
Number of open landfills	958	964	968	969	945	939	941	943	941	939
Number of closed landfills	282	288	272	268	223	205	197	193	183	184
Number of landfills with gas collection	914	926	926	923	864	849	846	848	830	835
Number of landfills without gas collection	326	326	314	314	304	295	292	288	294	288

Facilities are required to report under Subpart HH if their methane generation value meets or exceeds 25,000 MT of CO_2e. However, these facilities can cease reporting if their emissions are under 25,000 MT CO_2e for five consecutive years, or under 15,000 MT CO_2e for three consecutive years.

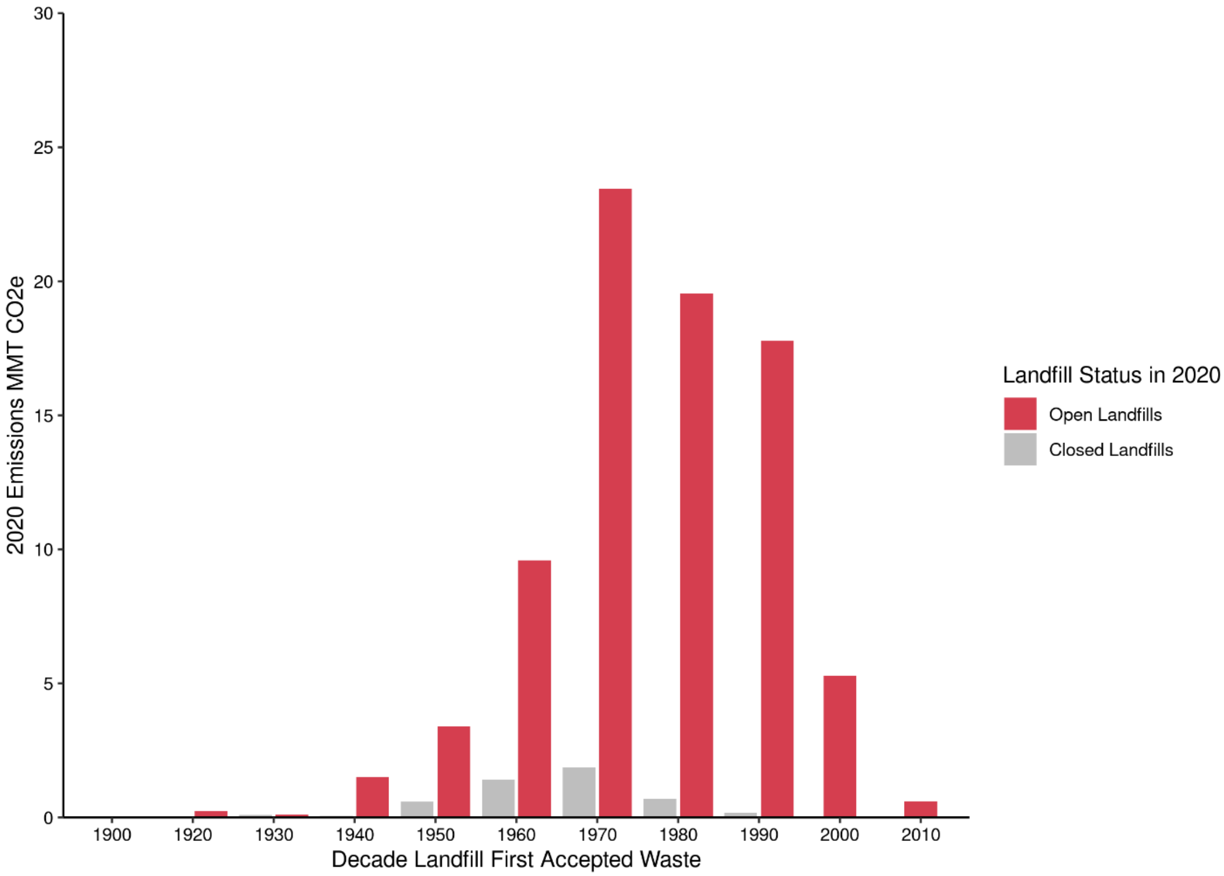
Table 9: Methane Emissions by Type of MSW Landfill in 2011–2020 (MMT CO_2e)[a]

Operational Characteristics	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Emissions	**93.8**	**94.4**	**91.2**	**90.8**	**89.6**	**86.8**	**86.3**	**88.6**	**90.2**	**86.5**
Total emissions for closed landfills	9.3	9.3	8.5	8.4	7.7	6.8	5.7	5.3	5.1	4.9
Total emissions for open landfills	84.5	85.1	82.6	82.4	81.9	80.0	80.6	83.3	85.1	81.5
Emissions for landfills without gas collection	23.6	23.5	22.0	21.7	21.6	21.1	20.3	20.7	21.3	21.2
Emissions for landfills with gas collection	70.2	70.9	69.2	69.2	68.0	65.6	66.0	67.9	69.0	65.3

[a] *Totals may not sum due to independent rounding.*

Figure 10 displays total methane emissions (in MMT CO_2e) and the operational status of the landfill (i.e., open and closed) in 2020, grouped by the decade the landfill first accepted waste. The Waste Sector is unique because emissions in the current RY are heavily impacted by the quantity of waste already in place at the landfills and the age of that waste (i.e., the year, or decade in this case, that the waste was first disposed of in the landfill). Figure 11 shows that most emissions in the current RY result from landfills that first accepted waste between the 1970s and 1990s, and are still open in 2020. The largest number of reporting landfills first opened and started accepting waste in the 1970s. More than 300 of these landfills still accept waste in 2020, which explains why the 1970s era landfills contributed the most to current methane emissions.

Figure 10: MSW Landfill Emissions (2020)



Industrial Wastewater Treatment Details

Tables 10 shows details of the industrial wastewater subsector. Table 10 shows facility counts and emissions by NAICS codes. Tables 13 and 14 show additional details on the industrial waste landfills subsector.

Table 10: Major NAICS Codes and Emissions for Industrial Wastewater Treatment in 2020

Major NAICS Code	Industry	Facility Count	Facility Percent	Emissions (MMT CO_2e)	Emissions Percent
3114	Fruits and vegetables	14	11.0%	0.2	8.0%
3116, 112340	Meat and poultry	60	48.0%	1.5	79.0%
221112, 311221, 311222, 312120, 312140, 325193, 325199	Ethanol	37	30.0%	<0.05	1.0%
322110, 322121, 322130	Pulp and paper	11	9.0%	0.2	12.0%
311512	Creamery Butter Manufacturing	1	1.0%	<0.05	0.0%
311224	Soybean and Other Oilseed Processing	1	1.0%	<0.05	0.0%
Total	**-**	**124**	**100%**	**1.94**	**100%**

Industrial Waste Landfill Details

Table 11 shows the characteristics of industrial waste landfills and Table 12 shows emissions by type of industrial waste landfills.

Table 11: Characteristics of Industrial Waste Landfills in 2011–2020

Data	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of reporting facilities	**176**	**176**	**176**	**178**	**174**	**171**	**171**	**169**	**168**	**166**
Number of open landfills	144	142	140	143	141	140	139	136	139	135
Number of closed landfills	32	34	36	35	33	31	32	33	29	31
Number of landfills with gas collection	2	2	2	2	1	1	1	1	1	1
Number of landfills without gas collection	174	174	174	176	173	170	170	168	167	165

Table 12: Methane Emissions for Industrial Waste Landfills in 2011–2020 (MMT CO_2e)[a]

Data	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Emissions	**8.9**	**8.7**	**8.0**	**8.5**	**8.5**	**8.6**	**8.1**	**8.2**	**8.1**	**7.8**
Total emissions for closed landfills	0.8	0.7	0.7	0.6	0.6	0.5	0.6	0.6	0.5	0.5
Total emissions for open landfills	8.1	8.0	7.4	7.9	7.9	8.0	7.5	7.6	7.6	7.3
Total emissions for landfills without gas collection	8.5	8.3	7.6	8.0	8.2	8.3	7.9	7.9	8.1	7.7
Total emissions for landfills with gas collection	0.4	0.4	0.4	0.5	0.3	0.3	0.2	0.2	0.0	0.0

[a] *Totals may not sum due to independent rounding.*

Figure 11: Industrial Waste Landfill Emissions (2020)

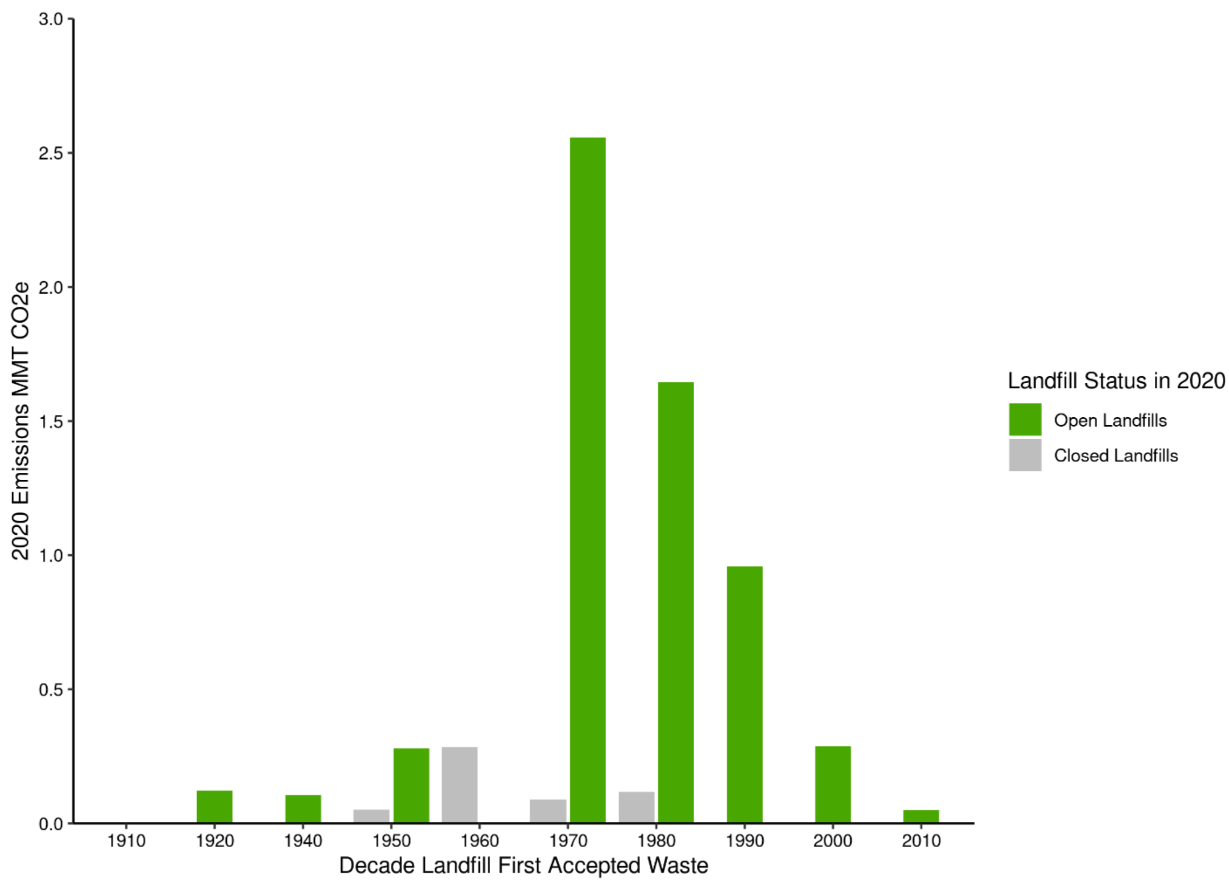


Figure 11 displays total methane emissions (in MMT CO_2e) and the operational status of industrial waste landfills in 2020 (i.e., open and closed) by the decade the landfill first accepted waste. The majority of 2020 emissions result from landfills that first accepted waste between the 1960s and 1980s, and are still open in 2020. There are significantly more open landfills than closed landfills contributing to total emissions in the current RY. Forty-seven of the landfills that opened in the 1960s were still accepting waste in 2020, which is why emissions from landfills that opened in that decade are higher than in other decades.

Table 13 shows total emissions in the industrial waste landfill subsector and the number of facilities (unique and combined) grouped by major NAICS code.

Table 13: Major NAICS Code Groups Represented by Reporting Industrial Waste Landfills (2020)[a]

Major NAICS Code	NAICS Code Description	Combined Facility Count[a]	Unique Facility Count	Percent of Total Facilities	Emissions (MMT CO_2e)[b]	Percent of Total Emissions
212	Mining (except oil and gas)	1	1	0.6%	<0.05	0.2%
221	Utilities	8	7	4.1%	0.2	2.4%
311	Food manufacturing	11	11	6.4%	0.7	9.0%
321	Wood product manufacturing	4	2	1.2%	<0.05	0.1%
322	Paper manufacturing	119	89	51.5%	4.2	54.6%
324	Petroleum and coal products manufacturing	4	4	2.3%	<0.05	0.6%
325	Chemical manufacturing	29	19	11.0%	0.5	6.9%
327	Nonmetallic mineral product manufacturing	1	1	0.6%	NA	NA%
331	Primary metal manufacturing	19	19	11.0%	0.6	7.6%
332	Fabricated metal product manufacturing	2	2	1.2%	<0.05	<0.05%
531	Real Estate	2	2	1.2%	<0.05	0.6%
562	Waste management and remediation services	17	16	9.3%	1.4	18.1%
Total	**-**	**217**	**166**	**100%**	**7.75**	**100%**

[a] *Facilities may report multiple NAICS codes based on operations conducted at their facilities. The counts presented in this column include all facilities that reported the relevant NAICS code as a primary, secondary, or additional NAICS code.*
[b] *The data presented in this column represent the total emissions for facilities that reported the relevant NAICS code as their primary code so as not to double-count emissions. This column does not sum emissions from facilities that reported their respective NAICS codes as secondary or additional.*

The majority of industrial facilities that report emissions under the industrial waste landfill subsector have dedicated onsite landfills. These landfills are presumed to only accept waste generated by that particular facility. Some industrial waste landfills are not associated with any particular industrial sector (i.e., NAICS code 562), and these facilities accept mixed industrial waste from various industries.

Paper manufacturing facilities contributed the majority of industrial waste landfill emissions in 2020 (4.23 MMT CO_2e or 54.6%). Waste management and remediation services facilities (1.4 MMT CO_2e or 18%) and Food manufacturing sector facilities (0.69 MMT CO_2e or 8.9%) comprise the next largest shares.

Calculation Methods Available for Use

Facilities in the Waste Sector emit methane from the decomposition of organic matter in wastes and emit CO_2, methane, and nitrous oxide from the combustion of solid wastes, captured methane, and other fuels.

Emission Calculation Methodology from Stationary Fuel Combustion Units

For MSW and industrial waste landfills, emissions from the combustion of any collected biogas are included with emissions for the landfill facility if the landfill is not co-located with a process in another industry sector that is covered by the reporting rule (e.g., a petroleum refinery or pulp and paper facility). If the landfill is co-located, then the combustion emissions are included with the emissions from the co-located industry sector. For industrial wastewater, combustion emissions are included with the emissions from the pulp and paper, ethanol manufacturing, food processing, or petroleum refining industry sector, as appropriate. The calculation methodology for stationary fuel combustion sources (Subpart C) is explained here.

Emission Calculation Methodologies for Process Emissions Sources

MSW Landfill Emission Calculation Methodology Because there is no internationally agreed-upon and cost-effective approach to directly measure the amount of CH_4 emitted from landfills, the emission estimation methodology uses a combination of gas measurements, models, and calculations. The calculation procedure for MSW landfills depends on whether the landfill has an active landfill GCCS.

- **Landfills without a GCCS.** MSW landfills without an active landfill GCCS must calculate CH_4 generation using a first-order decay model for CH_4 generation in the landfill (Equation HH-1 of the rule, which is based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5). Equation HH-1 uses the quantities and types of wastes disposed in the landfill, a default or measured CH_4 fraction in the landfill gas, and other characteristics of the landfill as model inputs. The CH_4 generation is corrected using Equation HH-5 to account for CH_4 that oxidizes (and therefore is not emitted) as it passes through the landfill cover material.

- **Landfills with an active GCCS.** MSW landfills with an active GCCS must calculate emissions using Equations HH-6 and HH-8 of the rule, and specify which method they consider most accurate for their facility. FLIGHT displays emissions from both methods but uses the facility-specified value to calculate total emissions from the MSW landfills subsector. If the facility does not specify which equation to use, FLIGHT uses the higher value.

- Equation HH-6 estimates emissions using the modeled CH_4 generation rate (Equation HH-1, described above) minus the measured amount of CH_4 recovered and destroyed. CH_4

generated in excess of the measured CH_4 recovery is corrected to account for CH4 oxidation in the landfill cover material.

- Equation HH-8 estimates emissions based on the measured quantity of methane recovered for destruction and an estimated landfill gas collection efficiency, which varies by type of landfill cover material used. This equation back-calculates the quantity of uncollected gas, which is then corrected to account for methane oxidation in the landfill cover material. Emissions from the gas collected and intended for destruction are estimated based on the CH_4 destruction efficiency of the combustion device.

The values resulting from Equations HH-6 and HH-8 may vary significantly, depending on the characteristics of the landfill. For example, the amount of recovered methane can vary by year, and the landfill gas collection efficiency will change yearly for open landfills. The collection efficiency will change yearly because it is estimated using an area-weighted approach that is dependent on the surface area of each stage of cover (daily, intermediate, or final). While Equation HH-8 incorporates more site-specific information, it might not provide the most accurate GHG emission estimate for every landfill due to the many variables that affect landfill GHG emissions.

Until 2013, all landfills were required to use a methane oxidation fraction of 0.10 in their methane emission equations. In 2013, a rule change allowed for the use of different default methane oxidation fractions each year if the facility opted to calculate its landfill methane flux using the provided methodology. A default value of 0.10 must be used if the facility chooses not to calculate landfill methane flux. The results of the methane flux calculations, combined with the extent of soil cover at the landfill, direct the reporter to the appropriate oxidation fraction to use. The methane oxidation fraction values available for use are 0.0, 0.10, 0.25, and 0.35. Using a higher oxidation fraction value results in lower methane emissions than when a lower oxidation fraction value is used.

Beginning in 2013, facilities were required to report the oxidation fraction used for each relevant emission equation. Table 17 shows the oxidation fraction value used in each equation. Approximately 42% of facilities without a GCCS used the higher oxidation fractions of 0.25 or 0.35, and 3% used a value of zero. A larger percentage of facilities with landfill gas collection (51–71%) used the higher oxidation values (25–35%), while approximately 1% used a value of zero.

Table 14: MSW Landfills – Methane Oxidation Fraction Values Used by MSW Landfills (2020)[a]

	Without GCCS				With GCCS					
	HH-5		HH-5[a]		HH-6		HH-7[b]		HH-8	
Oxidation Factor Default Value	Count	%	Count	%	Count	%	Count	%	Count	%
0	7	2.4%	14	1.7%	14	1.7%	14	1.7%	14	1.7%
0.1	151	52.4%	364	43.6%	220	26.3%	313	37.5%	187	22.4%
0.25	121	42%	444	53.2%	458	54.9%	451	54%	381	45.6%
0.35	9	3.1%	13	1.6%	143	17.1%	57	6.8%	253	30.3%
Total	**288**	**100%**	**835**	**100%**	**835**	**100%**	**835**	**100%**	**835**	**100%**

[a] *Totals may not sum due to independent rounding.*

[b] *Landfills with GCCSs must report landfill gas generation using both Equations HH-5 and HH-7, in addition to calculating emissions using both Equations HH-6 and HH-8.*

Table 15 presents the number of facilities with a GCCS and the calculation method used (either Equation HH-6 or HH-8) for each RY. Facilities may use the equation they feel is most appropriate based on their facility operations. Facilities are not required to use the same equation across RYs, but most facilities did use the same equation for multiple years. Most facilities used Equation HH-8 for all five reporting years. Equation HH-8 is based on the measured quantity of recovered methane, while Equation HH-6 is based on the amount of modeled methane generation.

Table 15: MSW Landfills – Use of Equation HH-6 versus HH-8 by RY

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Facilities with a GCCS	926	926	923	864	849	846	848	830	835
Facilities that used Equation HH-6	271	274	285	274	270	265	282	259	246
Facilities that used Equation HH-8	640	650	633	583	578	579	566	571	589

Industrial Wastewater Treatment Calculation Methodology The calculation procedure of industrial wastewater treatment depends on whether biogas is recovered from the anaerobic reactor(s) or lagoon(s) operating at the facility. All anaerobic sludge digesters are assumed to recover biogas. The methodology for sludge digesters does not include calculating CH4 generation using chemical oxygen demand (COD) or the five-day biochemical oxygen demand (BOD5), because it is assumed that all generated methane is recovered.

- **No biogas recovery.** All facilities with anaerobic reactors or lagoons calculate emissions using measurements of the volume of wastewater, measurements of the average weekly concentration of either COD or BOD5, and a default methane conversion factor. All methane generated during the process is emitted (Equation II-3).

- **With biogas recovery.** All facilities with anaerobic reactors, lagoons, or sludge digesters that recover biogas calculate emissions using measurements of the flow of recovered biogas; methane concentration, temperature, pressure, and moisture; and default values for biogas collection efficiency and methane destruction efficiency. Equation II-4 determines the amount of methane recovered in the process and Equation II-5 uses the collection efficiency to estimate the amount of methane that leaks out of equipment. Equation II-6 determines total methane emissions by summing methane leakage and methane not destroyed in the destruction device.

Solid waste combustion facilities must report under Subpart C, and the reporter generally must use one of four calculation methodologies (tiers) to calculate CO_2 emissions depending on fuel type and unit size. The calculation methodologies for Subpart C are explained in more detail here. Units that are not subject to Subpart D but are required by states to monitor emissions according to Part 75 can report CO_2 emissions under Subpart C using Part 75 calculation methods and monitoring data that they already collect under Part 75 (e.g., heat input and fuel use). Methane and nitrous oxide mass emissions are also required to be reported for fuels that are included in Table C-2 of Part 98 and are calculated using either an estimated or measured fuel quantity, default or measured HHV, and default emission factors.

Data Verification and Analysis

As a part of the reporting and verification process, EPA evaluates annual GHG reports with electronic checks and staff review as needed. EPA contacts facilities regarding potential substantive errors and facilities resubmit reports as errors are identified. Additional information on EPA's verification process is available here.

Other Information

EPA's Landfill Methane Outreach Program (LMOP) is a voluntary assistance program that promotes the reduction of CH4 emissions from landfills by encouraging the recovery and beneficial use of landfill gas as an energy resource. By joining LMOP, companies, state agencies, organizations, landfill operators, and communities gain access to a vast network of industry experts and practitioners, as well as various technical and marketing resources that can help with landfill gas energy project development. LMOP maintains a list of candidate landfills where available data indicate that installing a landfill gas-to-energy project is likely to provide financial benefits. LMOP defines a candidate landfill as one that is accepting waste or has been closed for five years or less; has at least one million tons of waste; and does not have an operational, under-construction, or planned landfill gas-to-energy project.

EPA's U.S. Greenhouse Gas Inventory (hereafter referred to as the Inventory) estimates total U.S. GHG emissions from Waste Sector sources. National-level emissions presented in the Inventory report differ from the total emissions reported to the GHGRP for several reasons:

- The Inventory accounts for emissions from all facilities in a given sector. The GHGRP, on the other hand, includes only those facilities that meet the reporting thresholds. The coverage and the emissions methodologies differ between the two programs (see Table 3 for estimated coverage across the Waste Sector).
- The Inventory estimates for MSW landfills are a combination of top-down and bottom-up estimates for certain years in the Inventory time series, representing national emissions that are intended to be inclusive of all facilities within a given sector. The 1990–2017 Inventory for MSW landfills incorporated directly reported CH4 emissions from facilities

reporting to the GHGRP (for years 2010 to 2017), with a scale-up factor to account for emissions from MSW landfills that do not meet GHGRP's reporting threshold.[4]

- The Inventory estimate for industrial waste landfill emissions includes only the pulp and paper and food and beverage sector facilities, whereas subpart TT of the GHGRP covers many more industries. Due to a lack of industrial waste disposal data for all facilities within each industrial sector, the inventory uses proxy data (i.e., annual production data multiplied by a disposal factor) to estimate the amount of waste disposed of by the pulp and paper and food and beverage sectors. The GHGRP uses a bottom-up calculation approach and requires facilities to report the amount of waste disposed.
- The Inventory estimate for industrial wastewater treatment includes aerobic ponds with anaerobic portions, but under the GHGRP, only emissions from strictly anaerobic processes are required to be reported.
- The Inventory does not capture emissions from wastewater sludge digesters or CH4 recovered from anaerobic treatment processes, while the GHGRP does.

Glossary

Anaerobic process refers to a procedure in which organic matter in wastewater, wastewater treatment sludge, or other material is degraded by micro-organisms in the absence of oxygen, resulting in the generation of CO_2 and CH_4. This source category consists of the following: anaerobic reactors, anaerobic lagoons, anaerobic sludge digesters, and biogas destruction devices (e.g., burners, boilers, turbines, flares, or other devices) (40 CFR Part 98.350).

Biogenic CO_2 emissions means carbon dioxide released from the combustion or decomposition of biologically based materials other than fossil fuels.

Continuous emission monitoring system or CEMS means the total equipment required to sample, analyze, measure, and provide, by means of readings recorded at least once every 15 minutes, a permanent record of gas concentrations, pollutant emission rates, or gas volumetric flow rates from stationary sources (40 CFR Part 98.6).

Ethanol production means an operation that produces ethanol from the fermentation of sugar, starch, grain, or cellulosic biomass feedstocks; or the production of ethanol synthetically from petrochemical feedstocks, such as ethylene or other chemicals.

FLIGHT refers to EPA's GHG data publication tool, named the Facility Level Information on Greenhouse Gases Tool (https://ghgdata.epa.gov/ghgp/main.do#).

Food processing means an operation used to manufacture or process meat, poultry, fruits, and/or vegetables as defined under NAICS 3116 (Meat Product Manufacturing) or NAICS 3114 (Fruit and Vegetable Preserving and Specialty Food Manufacturing). For information on NAICS codes, see http://www.census.gov/eos/www/naics/.

GCCS means a landfill's gas collection and control system.

[4] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017. EPA 430-R-19-001. U.S. Environmental Protection Agency. April 14, 2021. Available: https://www.epa.gov/ghgemissions/overview-greenhouse-gases.6456.7.

GHGRP means EPA's Greenhouse Gas Reporting Program (40 CFR Part 98).

GHGRP vs. GHG Inventory: EPA's Greenhouse Gas Reporting Program (GHGRP) collects and disseminates annual GHG data from individual facilities and suppliers across the U.S. economy. EPA also develops the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks (GHG Inventory) to track total national emissions of GHGs to meet U.S. government commitments to the United Nations Framework Convention on Climate Change. The GHGRP and Inventory datasets are complementary; however, there are also important differences in the data and approach. For more information, please see https://www.epa.gov/ghgreporting/greenhouse-gas-reporting-program-and-usinventory-greenhouse-gas-emissions-and-sinks.

IPCC AR4 refers to the Fourth Assessment Report by the Intergovernmental Panel on Climate Change. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K. and A. Reisinger. (eds.)]. IPCC, Geneva, Switzerland, 2007. The AR4 values also can be found in the current version of Table A-1 in Subpart A of 40 CFR Part 98.

Industrial wastewater means water containing wastes from an industrial process. Industrial wastewater includes water that comes into direct contact with or results from the storage, production, or use of any raw material, intermediate product, finished product, by-product, or waste product. Examples of industrial wastewater include, but are not limited to, paper mill white water, wastewater from equipment cleaning, wastewater from air pollution control devices, rinse water, contaminated stormwater, and contaminated cooling water.

Industrial waste landfill means any landfill other than a MSW landfill, a Resource Conservation and Recovery Act (RCRA) Subtitle C hazardous waste landfill, or a Toxic Substances Control Act hazardous waste landfill, in which industrial solid waste, such as RCRA Subtitle D wastes (nonhazardous industrial solid waste, defined in §257.2 of this chapter), commercial solid wastes, or conditionally exempt small quantity generator wastes, is placed. An industrial waste landfill includes all disposal areas at the facility.

Industrial wastewater treatment sludge means solid or semi-solid material resulting from the treatment of industrial wastewater, including, but not limited to, biosolids, screenings, grit, scum, and settled solids.

Landfill Methane Outreach Program or LMOP is a voluntary assistance program run by EPA to help reduce CH4 emissions from landfills by encouraging the recovery and beneficial use of landfill gas as an energy resource (http://www.epa.gov/lmop/).

MT means metric tons.

MMT means million metric tons.

Municipal solid waste landfill, as defined by the GHGRP, means an entire disposal facility in a contiguous geographical space where household waste is placed in or on land. An MSW landfill may also receive other types of RCRA Subtitle D wastes (40 CFR 257.2) such as commercial solid waste, nonhazardous sludge, conditionally exempt small quantity generator waste, and industrial solid waste. Portions of an MSW landfill may be separated by access roads, public roadways, or other public right-of-ways. An MSW landfill may be publicly or privately owned (40 CFR Part 98.6).

NAICS means the North American Industry Classification System, the standard used by federal statistical agencies to classify business establishments into industrial categories for collecting and publishing statistical data related to the U.S. economy.

Wastewater treatment systems are the collection of all processes that treat or remove pollutants and contaminants, such as soluble organic matter, suspended solids, pathogenic organisms, and chemicals from wastewater prior to its reuse or discharge from the facility.