Greenhouse Gases from Maryland's Landfills

Underestimated and Under Regulated

ENVIRONMENTAL INTEGRITY PROJECT

June 9, 2021

ACKNOWLEDGEMENTS:

This report was researched and written by Ryan Maher and Leah Kelly of the Environmental Integrity Project, with additional data analysis and review provided by Alexandra Shaykevich and Courtney Bernhardt. We would also like to thank the Maryland Department of the Environment for reviewing our analysis, meeting with us to provide feedback, and committing to correcting the inventory mistakes identified in this report.

THE ENVIRONMENTAL INTEGRITY PROJECT

The Environmental Integrity Project—http://www.environmentalintegrity.org—is a nonpartisan, nonprofit organization established in 2002 by former EPA enforcement attorneys to advocate for the effective enforcement of environmental laws. EIP has three goals: (1) to provide objective analyses of how the failure to enforce or implement environmental laws increases pollution and affects public health; (2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and (3) to help local communities obtain the protection of environmental laws.

For questions about this report, please contact the Environmental Integrity Project's Director of Communications, Tom Pelton, at (443) 510-2574 or tpelton@environmentalintegrity.org.

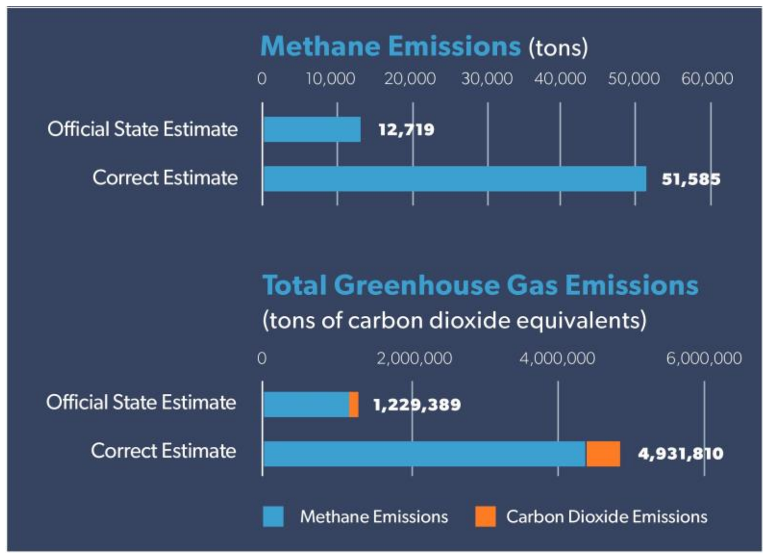
PHOTO CREDITS

Greenhouse Gas Emissions from Maryland's Landfills

Executive Summary

Methane is a potent greenhouse gas that is receiving an increasing amount of attention as a driving force behind climate change. Methane also contributes to the formation of ground-level ozone, a human health hazard and greenhouse gas in its own right. Landfills that accept municipal solid waste like food scraps, household plastics, and paper products are a significant source of greenhouse gases, particularly methane, both globally and in the United States.[1]

Figure 1. Comparison of Maryland's Estimate of Greenhouse Gas Emissions from Landfills to Actual Emissions



Greenhouse gas emissions from Maryland's municipal waste landfills in 2017 were four times higher than previously thought. In 2017, these landfills released about 500,000 tons of carbon dioxide and 51,500 tons of methane. This methane has the same greenhouse gas effect as 4.4 million tons of carbon dioxide over a 20-year period.

Maryland has 40 municipal waste landfills that produce methane, as well as carbon dioxide, another important greenhouse gas. The Environmental Integrity Project's (EIP) examination of state and federal data reveals that Maryland's municipal waste landfills release far more greenhouse gases than was previously thought, making these landfills the single largest source of methane pollution in Maryland, even larger than the natural gas industry. In total, Maryland's municipal waste landfills released about 51,500 tons of methane in 2017, the most recent year for which comprehensive data are available. That was four times greater than the Maryland Department of the Environment's (MDE) official 2017 state estimate of 12,500 tons, as shown in Figure 1. Because of methane's potency as a greenhouse gas, 51,500 tons of methane has the same impact on climate change as 4.4 million tons of carbon dioxide, if the global warming effect of the methane is considered over a 20-year period. (In response to EIP's report, MDE released an updated greenhouse gas inventory on June 9, 2021, showing that the state's municipal waste landfills emitted about 58,000 tons of methane in 2017, close to but even higher than EIP's estimate.)

It is important to consider the effects of methane on a 20-year timescale instead of a longer timeframe like a century because climate change is already causing significant harm, including through sea-level rise, flooding, wildfires and drought. Because methane is such a powerful greenhouse gas, curbing methane emissions in the near-term is a crucial part of the fight against climate change.

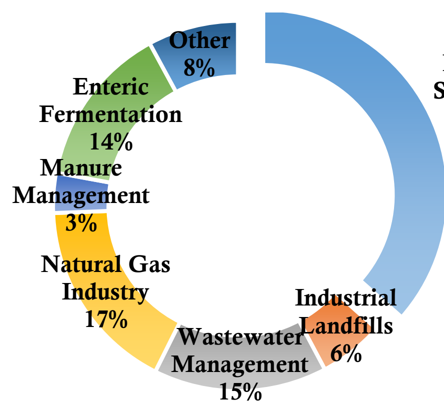
To quantify the greenhouse gases that were emitted by Maryland's municipal waste landfills, EIP reviewed MDE's most recent inventory of greenhouse gas emissions, which tabulates the state's total greenhouse gas emissions for 2017, including from landfills.[2] EIP also examined federal data on Maryland's landfills available through EPA's Greenhouse Gas Reporting Program, as well as air quality reports that landfills submit to MDE each year, and state data on the amount and type of waste at specific landfills. This analysis revealed multiple calculation and data-based errors in MDE's greenhouse gas inventory – including underestimating landfill gas emissions and excluding five landfills -- that resulted in the sizeable underestimates of total landfill emissions. EIP met with MDE staff in April 2021 to discuss our review and MDE agreed with our conclusion that methane and carbon dioxide emissions from landfills are about four times higher than the official state estimates.

EIP's analysis found that, in addition to methane, Maryland's municipal waste landfills also emitted about 500,000 tons of carbon dioxide, which is about four times more than the official state estimate of 136,000 tons. Considering methane and carbon dioxide emissions together, the state's landfills released as much greenhouse gas pollution as about 975,000 passenger vehicles driving for one year, or the equivalent of about 4.9 million tons of carbon dioxide, if the global warming impact of the methane is considered over a 20-year period.

Other key findings of EIP's review include:

- Contrary to the 2017 state estimate, landfills are the leading source of methane in Maryland relative to other sectors, emitting 37 percent of the state's human-caused methane, rather than 13 percent. Figure 2 shows the contribution of landfills to Maryland's total methane emissions relative to the contributions from other sectors. The natural gas industry had been considered the leading source of methane in Maryland based on the official state estimates, but in reality, the industry emits only 17 percent of the state's methane.

Figure 2. Contribution of Landfills to Maryland's Total 2017 Methane Emissions Relative to Other Source Categories



Contrary to the official state estimate, landfills are the leading source of methane in Maryland relative to other sectors, contributing 37 percent of the state's methane, rather than 13 percent.

- Considering the carbon dioxide and methane emissions from Maryland's landfills together, the pollution has a warming impact equivalent to that of 4.9 million tons of carbon dioxide, if the climate effects of the methane are evaluated on a 20-year timescale. That means the landfills had a greater climate impact than Maryland's largest coal-fired power plant, Brandon Shores in Anne Arundel County, in 2019, and four times the greenhouse emissions of the average Maryland coal plant.

- Prince George's County's Brown Station Road Landfill emitted more greenhouse gases than any other Maryland landfill by far—86,000 tons of carbon dioxide and 6,100 tons of methane. That has the same greenhouse gas impact of 527,000 tons of carbon dioxide over a 20-year period. Washington County's Forty West Landfill had the second highest greenhouse gas emissions, followed by Baltimore's Quarantine Road Landfill.

- Only about half (21 of 40) of the landfills operate any kind of gas collection or control systems, and only four of these must comply with any government standards to ensure that they work.

The immense load of greenhouse gases that have not been accounted for in Maryland's official state estimate underscore the need for policies that will rapidly and substantially reduce greenhouse emissions from landfills. There are two principal ways to reduce greenhouse gas emissions from landfills. First are on-site control measures, which are generally governed by environmental regulations. The federal Clean Air Act requires operators of certain landfills to install equipment that collects and destroys landfill gas. Unfortunately, those federal regulations only apply to very large landfills, and so only 10 percent of Maryland's landfills that produce gas are required to install and operate these collection and control systems. Another 17 landfills in Maryland have installed some type of system voluntarily. But the systems at these landfills range in their degree of efficacy, do not necessarily collect gas from the entirety of the landfill, and are not subject to regulations that ensure their effectiveness or their continued operation. The systems at landfills in Maryland that are subject to regulation collect gas with 76 percent efficiency, while the voluntarily installed systems at Maryland's landfills collect only 55 percent of gas.

The second general approach to reducing greenhouse gas emissions from landfills is by keeping organic waste—like food scraps, yard waste, and paper products—out of landfills. It is the breakdown of organic waste that produces methane in the landfill in the first place.[3] Food scraps, yard waste, and miscellaneous organic materials make up about 26 percent of the waste disposed of at Maryland's landfills, while paper products make up another 26 percent.[4] Food is the most prevalent type of waste in Maryland's municipal landfills.[5]

There are a variety of ways to keep organic waste out of landfills. It is possible to prevent organic materials from being wasted to begin with by redesigning food systems and directing food that would otherwise be wasted to a different beneficial use. While these approaches to eliminating organic waste are preferable,[6] once organic waste forms it can also be "recycled" rather than landfilled. There are two primary ways to recycle organic waste: composting and anaerobic digestion. Composting is generally favored by proponents of "zero waste" principles for sustainably managing waste because of the environmental and community benefits that result.[7] But both composting and anaerobic digestion break down organic material and produce byproducts that can have a beneficial use, while also drastically reducing greenhouse gas emissions when compared to a situation where the organic waste is landfilled. [8] The EPA has estimated that composting and anaerobic digestion can each reduce methane emissions by 95 percent relative to landfilling.[9]

Maryland has not gone far enough to cut landfill gas emissions through on-site control measures at landfills or diversion of organic waste away from landfills. However, there are practical, near-term solutions available to Maryland that would go a long way towards addressing this problem. Our specific recommendations are below:

1. MDE must issue strong new air quality regulations that require improved control and monitoring of greenhouse gases from the state's landfills. Maryland's rules should go well beyond the weak requirements established by the EPA's most recent set of regulations for landfills and should instead be modeled on stronger regulations issued in 2010 by California.

2. MDE should complete its rulemaking process as quickly as possible. MDE is currently in the middle of a regulatory process to develop new landfill emissions regulations. This process has been significantly delayed, beginning in March 2017 and then being put on hold for over three years. MDE recently resumed this process and should complete it without any additional delay.

3. Maryland should create financial incentives to spur on the construction of new facilities that can divert waste away from landfills and trash incinerators, which are also highly polluting. A law passed in Maryland in 2021 requiring large generators of food waste to divert that waste away from landfills and incinerators[10] will not be effective unless there are composting and organics diversion facilities that can accept the waste. Maryland must encourage the construction of such facilities and make information on existing incentives more readily available.

4. County governments should assess the feasibility of operating county-run composting facilities. Thus far, there are only two publicly-owned food composting facilities in Maryland, one in Howard County and one in Prince George's County.

5. Incinerating waste should <u>not</u> be treated as a solution to the findings discussed in this report. Trash incinerators emit very large amounts of toxic air pollution and carbon dioxide. Maryland also has a troubling history of building or attempting to site these facilities in low-income neighborhoods and communities of color. Incineration is a false solution to the problem of landfill emissions.

6. To prevent underestimation of emissions from landfills in the future, Maryland and governments across the U.S. and globally should start relying on emissions monitoring and direct measurement instead of simply modeling, which caused problems in Maryland.

Table of Contents

Background on Greenhouse Gas Emissions from Landfills

The Dangers of Climate Change

The world's leading climate scientists agree that human activities have already warmed the planet by about 1 degree Celsius relative to pre-industrial temperatures, using 1850 to 1900 as a reference period.[11] Total warming is expected to reach 1.5 degrees Celsius as early as 2030, with dire consequences for global temperatures, weather patterns, sea level rise, and natural and human systems generally.[12] Climate change has already increased the frequency of heat waves worldwide, impacting economic productivity and increasing heat-related mortality.[13] Climate change also threatens food security around the world due to the impacts of warming temperatures and more extreme weather events on crop yields and quality, livestock, and fisheries.[14] Greenhouse gas emissions must be cut dramatically in the coming years to avoid the most severe consequences of climate change.[15]

Maryland has features that make it especially vulnerable to certain aspects of climate change. Maryland's large amount of shoreline—3,100 miles—makes it the fourth most vulnerable state in the country to the effects of rising seas.[16] The unique ecosystems of the Chesapeake Bay may also be adversely impacted by climate change. Increased runoff caused by large storm events has the potential to deposit more nutrients into the Bay. Nutrient deposition leads to increased algal blooms in the Bay, which can reduce oxygen levels and ultimately cause "dead zones" where aquatic life cannot survive.[17]

The effects of climate change on communities and the built environment are already visible in Maryland. Baltimore City and nearby areas have started experiencing notable increases in precipitation and flooding.[18] 2018 was a record-breaking year for rainfall in Baltimore and several other cities on the East Coast and in the Midwest.[19] In addition, an analysis by Climate Central, an organization of journalists and scientists reporting on climate change,[20] found that in Baltimore City there was a 67 percent increase in the heaviest precipitation events from the 1950s to the 10-year period ending in 2016.[21] The Baltimore area was hit by two 1,000-year storm events in approximately two years, one on July 30, 2016, and one on May 27, 2018, both of which devastated nearby Ellicott City and caused flooding in areas of Baltimore City.[22] The Baltimore City Council has recently been conducting investigative hearings on inland flooding[23] and on backups of untreated sewage into homes.[24] Both of these problems are made worse by storms of increased frequency and severity, which overwhelm systems that are not built to handle events of this magnitude.

Methane Contributes to Climate Change and Ozone Formation

Much of the policy discussion and scientific research on global warming has focused on carbon dioxide as the primary contributor to rising global temperatures, especially carbon dioxide from a few specific sectors that depend on fossil fuels, like transportation and coal-fired power plants.[25] There are, however, other greenhouse gases and additional sources that must be addressed in the fight against climate change. A multi-gas strategy is crucial to the effort to keep global temperatures below their most harmful levels.[26]

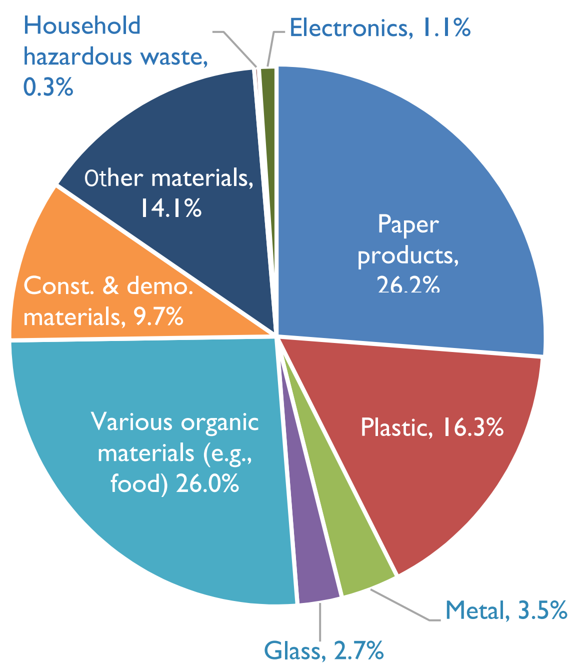
Methane is the second most powerful greenhouse gas after carbon dioxide when it comes to driving climate change. Scientists estimate that methane is responsible for about 20 percent of all human-caused global warming.[27] Methane differs from carbon dioxide as a climate pollutant in that any given amount of methane has a much larger effect on global warming than the same amount of carbon dioxide.[28] In other words, methane is a more potent greenhouse gas than carbon dioxide, so reducing methane emissions a little goes a long way. Methane also has a short lifetime in the atmosphere, lasting for about 10 years, whereas carbon dioxide can persist for hundreds of years.[29] Because of these characteristics, cutting methane emissions now can actually reduce the load of greenhouse gases in the atmosphere in the near term, and in a cost-effective way,[30] staving off the worst effects of climate change over the coming decades.[31] Some states, including Maryland, have developed a strategy that places particular emphasis on reducing "short-lived climate pollutants" like methane, recognizing that "[q]uickly cutting emissions of these potent pollutants will lead to quick climate benefits."[32]

Methane does not only present an air quality hazard as a climate pollutant. Methane that reaches the atmosphere also contributes to the formation of ozone.[33] While ozone is an important and valuable part of the upper atmosphere, it impairs human health, ecosystems, and agricultural productivity when it forms closer to the Earth's surface.[34] This ground-level ozone is also a powerful greenhouse gas in its own right.[35] Methane contributes to the formation of this harmful ground-level ozone. Parts of Maryland have long failed to meet the federal air quality standards for ozone and remain in non-compliance.[36]

Landfill Gas

Landfills that receive municipal solid waste are one of the largest sources of human-caused methane at both the global and the national level.[37] Although there are different kinds of landfills, including industrial landfills, we use the term "landfills" in this report to denote municipal solid waste landfills only. Municipal solid waste landfills primarily receive nonhazardous household waste, like food scraps, household plastics, and paper products.[38]

Figure 3. Composition of Municipal Solid Waste Disposed of at Maryland's Landfills in 2016

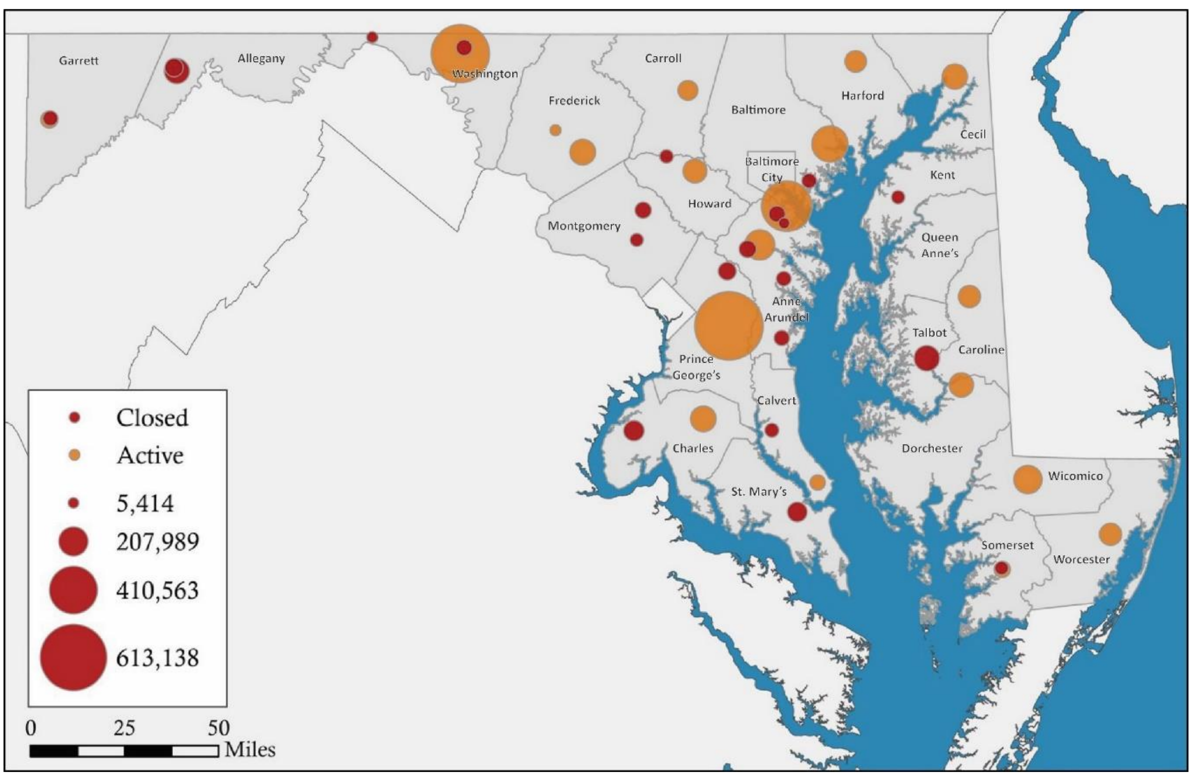


Organic materials, including food waste and paper products, make up more than half of the solid waste disposed of at Maryland's landfills.

Landfills generate gas when microorganisms in the waste pile break down food scraps and other organic materials, like paper and yard trimmings, in the waste.[39] Organic materials make up at least half of the waste disposed of at Maryland's landfills.[40] Food scraps, yard trimmings, and other miscellaneous organic materials constitute about 26 percent of the waste received by Maryland's landfills (19 percent, 3 percent, and 4 percent, respectively), while paper products make up another 26 percent (see Figure 3 above).[41] Food is the single most prevalent material disposed of in Maryland's landfills.[42] Of all the food waste generated in Maryland in 2019—927,926 tons—only 15.5 percent was recycled in some way, like through composting.[43]

The gas produced during the decomposition of organic materials is typically about half methane and half carbon dioxide.[44] The gas also contains small amounts of other compounds, including a variety of toxic air pollutants, including benzene, toluene, and xylenes, that can cause cancer, respiratory issues, and other health problems.[45] Unless a landfill has controls in place, most of the gas seeps out of the landfill and escapes into the atmosphere. Gas production lasts for decades after waste is first deposited; closed landfills can generate gas for up to 50 years after they last accept waste.[46]

Figure 4. Locations and Greenhouse Gas Emissions of Maryland's Gas-producing Landfills (Emissions Presented in Units of Tons of Carbon Dioxide Equivalents)



Of Maryland's 40 gas-producing landfills, 19 currently accept municipal solid waste on a regular basis. The remaining 21 landfills are closed and do not accept waste but still produce gas.

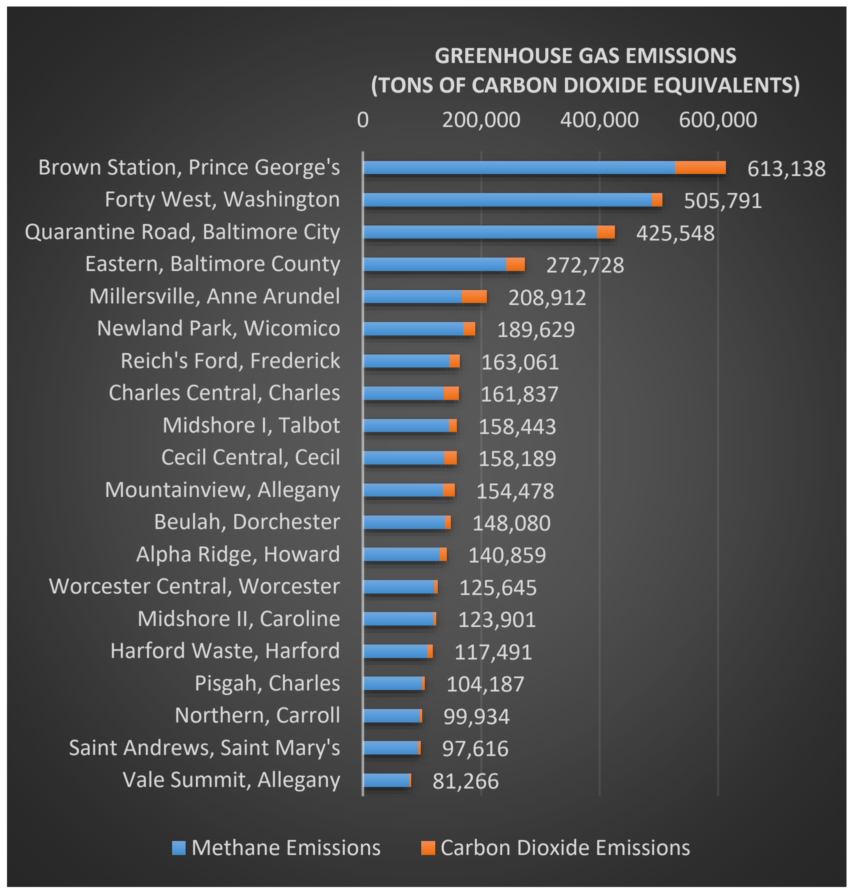
Maryland's Landfills

Maryland has 40 gas-producing landfills for which EIP could obtain comprehensive emissions data.[47] Attachment 1 of this report contains a map, reproduced above as Figure 4, which shows the locations and greenhouse gas emissions of these 40 landfills. Attachment 1 also contains a table with the names, addresses, and 2017 greenhouse gas emissions of these landfills, along with other basic information. Of these 40 landfills, 19 currently accept municipal solid waste on a regular basis. The remaining 21 landfills are closed and do not accept waste but still produce gas.

In Maryland, most landfills are owned or operated by county or city governments; 35 out of the 40 landfills in Maryland are publicly owned and operated. Only three landfills are under private ownership: the Mountainview Landfill in Allegany County, the Norris Farms Landfill in Baltimore County, and the Solley Road Landfill in Anne Arundel County. The two remaining landfills form part of two U.S. Army bases—Fort Meade and Fort Detrick—and are owned and operated by the federal government.

Figure 5 on the right shows the methane and carbon dioxide emissions from the 20 Maryland landfills with the highest greenhouse gas emissions in 2017 and the county in which each facility is located. The Brown Station Road Landfill in Prince George's County emitted the most greenhouse gases of any landfill in Maryland by far, releasing the equivalent of about 613,000 tons of carbon dioxide into the atmosphere, if the warming effects of methane are considered on a 20-year timescale. These emissions exceeded emissions from the second-highest emitting facility—the Forty West Landfill in Washington County—by the equivalent of over 100,000 tons of carbon dioxide.

Figure 5. The 20 Maryland Landfills with the Highest Greenhouse Gas Emissions in 2017



Prince George's County's Brown Station Road Landfill emits more greenhouse gases than any other landfill in Maryland, followed by Washington County's Forty West Landfill.

Greenhouse Gas Emissions from Maryland's Landfills

MDE severely underestimated the climate change impacts of Maryland's landfills. EIP discussed this conclusion with MDE in April 2021 and the agency confirmed the general results of EIP's analysis. The magnitude and nature of the underestimate is discussed in the sections that follow.

Methane and Carbon Dioxide Emissions from Maryland's Landfills are Significantly Underestimated

EIP's analysis shows that greenhouse gas emissions from Maryland's landfills in 2017 were four times higher than the official state estimate in MDE's state greenhouse gas inventory. Table 1 below shows the official state estimates for methane, carbon dioxide, and total greenhouse gases next to the actual emissions. Table 1 also shows the differences between the state and correct estimates and the extent to which methane, carbon dioxide, and total greenhouse gas emissions were underestimated by the state.

Methane emissions are expressed in terms of "carbon dioxide equivalents," or the amount of carbon dioxide that would have the same warming effect as the methane over a 20-year period. Methane has a warming effect that is 86 times that of carbon dioxide over a 20-year timescale. Climate scientists from around the world agree that humanity must take action immediately to drastically reduce greenhouse gas emissions if the worst effects of climate change are to be avoided.[48] Because immediate action is necessary to address the global crisis of climate change, it is appropriate, even imperative, to consider the impacts of landfill methane on climate change over shorter timescales.

Carbon Dioxide Equivalents and Methane's Global Warming Effect

Not all greenhouse gases are created equal. Any given amount of methane has a much larger effect on global warming than the same amount of carbon dioxide. To compare the warming effects of different greenhouse gases, the scientific community has developed the concept of "carbon dioxide equivalents," a standard unit that measures greenhouse gas emissions by converting the warming effect of any greenhouse gas into terms of the warming effect of carbon dioxide. For instance, over a 20-year period, methane has a warming effect that is 86 times that of carbon dioxide, so one ton of methane equals 86 tons of carbon dioxide equivalents of methane. Over a 100-year period, the warming effect of one ton of methane is equivalent to that of 34 tons of carbon dioxide; one ton of methane equals 34 tons of carbon dioxide equivalents of methane.

Table 1. Estimates of Greenhouse Gas Emissions from Maryland's Landfills in 2017, Corrected and Uncorrected, Considering Methane's Effects on a 20-Year Time Horizon

	Official State Estimate	Correct Estimate	Difference Between Estimates	Percent Under-estimate
Methane (tons of carbon dioxide equivalents)	1,093,852	4,436,294	3,342,442	75.3%
Carbon Dioxide (tons)	135,538	495,516	359,978	72.6%
Total Greenhouse Gases (tons of carbon dioxide equivalents)	1,229,389	4,931,810	3,702,420	75.1%

MDE estimated that landfills released about 12,500 tons of methane in 2017, or the equivalent of 1.1 million tons of carbon dioxide if the impacts of methane are considered over a 20-year period. The amount of methane Maryland's landfills actually emitted in 2017—51,500 tons—had same greenhouse gas effect as 4.4 million tons of carbon dioxide over a 20-year timeframe.

As shown in Table 1, landfills also emitted about 500,000 tons of carbon dioxide in 2017. This is nearly four times higher than the official state estimate of 136,000 tons. Considering methane and carbon dioxide emissions together, landfills emitted 4.9 million tons of carbon dioxide equivalents. The official state estimate was 1.2 million tons of carbon dioxide equivalents.

The 4.9 million tons of carbon dioxide equivalents emitted by Maryland's landfills in 2017 equate to the greenhouse gas emissions from about 975,000 passenger cars driven for one year, or the carbon dioxide emissions that result from generating a year's worth of electricity for 813,000 homes.[49] About 930 wind turbines would need to operate for a year to avoid this amount of greenhouse gases from a fossil fuel-based method of generating electricity. Maryland had a total of 6 coal-fired power plants operating in 2019.[50] Greenhouse gas emissions from Maryland's landfills were four times greater than the greenhouse gas emissions from the average coal-fired power plant in Maryland that year. Maryland's landfills emitted 1.7 times more greenhouse gases than the Brandon Shores power plant in Anne Arundel County, the coal plant with the largest greenhouse gas emissions in the state in 2019.[51]

Considering Landfill Emissions on a 100-Year Timescale

While it is important to consider the impacts of methane on a 20-year timescale, the EPA and MDE often evaluate methane's effects on a 100-year timescale as well.

On a 100-year timescale, the amount of methane released by Maryland's landfills in 2017 amounted to 1.8 million tons of carbon dioxide equivalents, as shown in Table 2. Since landfills also released 500,000 tons of carbon dioxide, total greenhouse gas emissions from landfills amounted to 2.2 million tons of carbon dioxide equivalents when the effects of methane are considered on a 100-year period. This large quantity of emissions is equivalent to the greenhouse gas emissions from about 445,000 passenger vehicles driving for one year, or the carbon dioxide emissions that result from generating enough electricity to power 370,000 homes for a year.

Table 2. Estimates of Greenhouse Gas Emissions from Maryland's Landfills in 2017, Corrected and Uncorrected, on a 100-Year Time Horizon

	Official State Estimate	Correct Estimate	Difference Between Estimates	Percent Under-estimate
Methane (tons of carbon dioxide equivalents)	432,453	1,753,884	1,321,431	75.3%
Carbon Dioxide (tons)	135,538	495,516	359,978	72.6%
Total Greenhouse Gases (tons of carbon dioxide equivalents)	567,991	2,249,399	1,681,409	74.7%

Over a 100-year period, greenhouse gas emissions from Maryland's landfills were nearly double the greenhouse gas emissions from the average coal plant in Maryland in 2019. Landfill emissions were also greater than the greenhouse gas emissions from 5 of the 6 coal plants that year, all but the Brandon Shores facility in Anne Arundel County. Landfill greenhouse gas emissions were 10 times those of the Dickerson Generating Station in Montgomery County, the coal plant in Maryland that emitted the least greenhouse gases in 2019.

Contribution of Maryland's Landfills to the State's Total Methane Emissions

Landfills are the leading source of human-caused methane emissions in Maryland by far, ahead of both the agricultural and natural gas sectors.

Maryland's Landfills Emitted 37 Percent of the State's Total Methane

According to MDE's original estimate, Maryland's municipal waste landfills contributed about 13 percent of the state's total methane in 2017 and all of Maryland's landfills (including landfills that accept industrial waste) caused about 18 percent of the state's total methane emissions, emitting less methane than the natural gas industry, wastewater treatment plants, and the agricultural sector (in the form of methane released from cattle).[52]

In reality, the data shows that Maryland's municipal waste landfills emitted 37 percent of the state's total methane in 2017, and all landfills combined, including industrial landfills, contributed 42 percent of the state's total methane. The second largest source of methane in Maryland was the natural gas industry, which emitted 17 percent of Maryland's total methane. The two charts presented below, Figures 6 and 7, show the uncorrected and the corrected breakdowns of where Maryland's methane comes from.

Figure 6. Official State Breakdown of Maryland's 2017 Methane Emissions

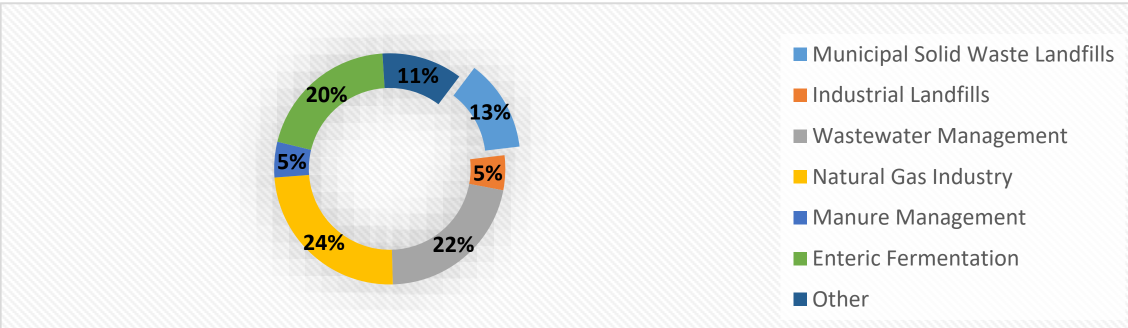
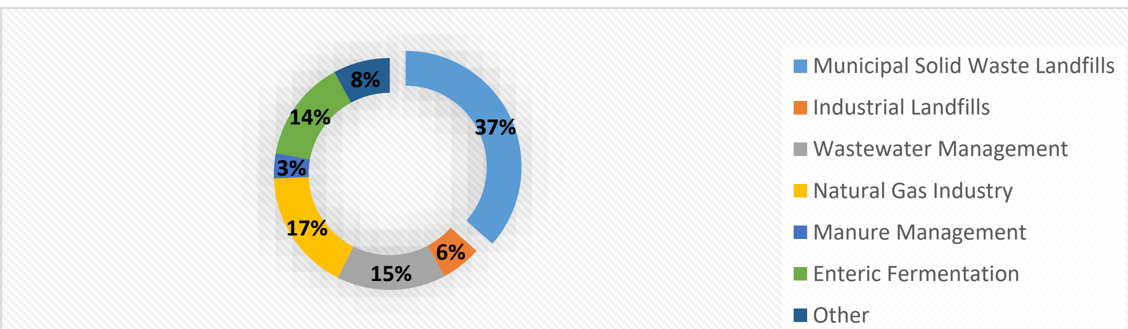


Figure 7. Correct Breakdown of Maryland's 2017 Methane Emissions by Sector



Comparing Maryland's Methane Sources to the National Picture

Maryland presents an interesting case when it comes to sector-by-sector methane emissions because MDE's official state breakdown of methane emissions presented in Figure 6 resembles the national situation much more than the corrected breakdown in Figure 7. At the national level, landfills contribute 17 percent of human-caused methane emissions.[53] This is a very large and concerning amount of methane that needs to be addressed, but the natural gas industry and agriculture (again, in the form of cattle) contribute 30 percent and 27 percent, respectively, of the nation's methane.[54] This situation clearly differs from the corrected picture of where Maryland's methane comes from. However, the overwhelming contribution of Maryland's landfills to the state's total methane emissions (42 percent) and the relatively low emissions from the natural gas industry (17 percent) and cattle (14 percent), make sense considering the circumstances that prevail on the ground in Maryland.

First, most of the methane emissions from the natural gas industry at the national level result from the extraction of the raw fossil gas from underground formations (59 percent in

2019).[55] Maryland has relatively few natural gas reserves that would be worth the cost of recovery and the little extraction that does take place in western Maryland produces a modicum of gas.[56] Accordingly, this significant source of the nation's methane emissions is effectively absent from Maryland. It is important to note that the natural gas industry in Maryland does cause methane emissions in other ways, like through leaks in the infrastructure that is used to distribute gas to consumers.[57]

Second, Maryland has a low number of cattle relative to other states. According to new data from the U.S. Department of Agriculture, Maryland ranks 41st among states in terms of cattle population and is home to just 0.19 percent of the nation's cattle.[58] Maryland ranks 43rd when it comes to its ratio of cattle to people.[59] It follows that methane emissions from this source should be low in Maryland when compared to the national picture.

Why Greenhouse Gas Emissions Were Underestimated

The official state estimate undercounted greenhouse gas emissions from landfills because of data and calculation errors related to emissions modeling. For the most part, greenhouse gas emissions from landfills in Maryland are not estimated based on direct, on-site measurement of the landfill gas. The waste heaps at landfills typically cover tens, or even hundreds, of acres. Because gas can escape from any part of these expansive areas, it is not easy or cost-effective to measure it directly. Instead, government agencies use theoretical models to estimate emissions. The models estimate emissions based on the amount of waste the landfills receive, the amount of precipitation in the area of the landfills, the age of the landfills, and other characteristics of the landfills and the areas in which they are located. Modeling in this way introduces the potential for inaccuracy because the idiosyncratic features of individual landfills are not necessarily taken into account. To avoid compounding this inherent uncertainty, it is crucial that agencies input accurate data into any model they use and apply the calculations that underlie the model correctly.

The underestimates discussed in this report primarily resulted from a calculation-based error in which methane emissions were reduced to account for a biochemical process that takes place in the soil at the surface of landfills that prevents some methane from escaping into the atmosphere. This process, which is called "surface oxidation," in reality only removes about 10 percent of methane,[60] but the State mistakenly applied a 90 percent factor instead, drastically undercutting the official estimate of methane emissions. Other errors included excluding emissions from five landfills, counting emissions from one non-existent landfill, and underestimating the amount of landfill gas produced by microorganisms in the waste of a few other landfills. Attachment 2 of this report contains a table with brief descriptions of the errors and the numerical effect of each error on the final emissions estimate.

Approaches to Estimating Greenhouse Gas Emissions from Landfills

MDE estimates greenhouse gas emissions from landfills in the state with the help of EPA's Landfill Gas Emissions Model, commonly referred to as "LandGEM." LandGEM estimates the amount of methane and carbon dioxide that a landfill generates because of the decomposition of organic materials in the waste. Users input information on the amount of waste that was deposited at the landfill year over year.

It is rare that a landfill's emissions are determined through direct measurement techniques, which may be more accurate and account for landfill-specific idiosyncrasies better than modeling approaches. However, emerging technologies may change this. EPA is currently teaming up with private companies to test and develop a variety of new methods to directly measure emissions from landfills. It appears very likely that drones, planes, and satellites are the future of estimating landfill emissions, though models like LandGEM will probably have a role to play.[61]

Federal Landfill Emissions Data and the U.S. EPA's Greenhouse Gas Reporting Program

Data from EPA's Greenhouse Gas Reporting Program generally supports EIP's conclusion that methane emissions from Maryland's landfills are much higher than the official state estimate. Like MDE's inventory of greenhouse gas emissions, the Greenhouse Gas Reporting Program database contains information on greenhouse gas emissions from Maryland's landfills. However, only 19 of Maryland's 40 gas-producing landfills reported their greenhouse gas emissions to the program in 2017 because only landfills that generated more than about 1,100 tons of methane are required to report to the program.[62] In addition, EPA primarily collects data on methane emissions from landfills in the program and gathers very little information on carbon dioxide emissions from landfills.

According to the program data, the 19 Maryland landfills that report to the program emitted about 44,000 tons of methane in 2017, or 3.8 million tons of carbon dioxide equivalents. Based on EIP's analysis of MDE's greenhouse gas inventory, the same 19 landfills emitted about 40,000 tons of methane, or 3.5 million tons of carbon dioxide equivalents. MDE's greenhouse gas inventory does not contain data on greenhouse gas emissions from individual landfills, so a direct comparison of the 19 landfills is not possible, but the official state estimate of total methane emissions from all of the state's landfills was only about 12,500 tons of methane, or 1.1 million tons of carbon dioxide equivalents.

For purposes of reporting to the program, EPA requires operators of qualifying landfills to estimate emissions using a method that is very similar to the method MDE uses, modeling methane generation based on waste disposal data.[63] However, EPA also requires operators of landfills with active gas collection systems to estimate emissions using a second method that starts with the amount of methane that was collected and destroyed by the gas collection system and then works backward to eventually determine the amount of methane that was not collected by the system and escaped into the atmosphere. Once operators of landfills with active gas collection systems derive an emissions estimate using both methods, EPA requires them to report the one value that best represents the emissions from the landfill. Neither method results in consistently higher or lower estimates relative to the other, but the two methods can produce emissions estimates that differ significantly. As indicated, MDE only takes the former, model-based approach to estimating emissions, but it does have the data necessary to estimate emissions using both methods. MDE could adopt

EPA's approach of estimating emissions using both methods for each landfill with a gas collection system and select the larger estimate to serve as the emissions value.

How Greenhouse Gas Emissions from Maryland's Landfills are Controlled

There are two primary means by which landfill gas emissions can be reduced. The first is through control measures taken on-site at the landfill. This can include equipment that is installed at the landfill and the implementation of practices at the landfill that reduce or control the amount of gas escaping into the air. The federal Clean Air Act requires that some landfills install and operate gas collection and control systems, which are described in more detail below. A separate federal law governing waste disposal requires landfill operators to employ certain cover and liner systems, which prevent some of the gas from migrating into the air. The second way in which landfill gas can be reduced is by avoiding the landfilling of organic waste, which is the source of methane and carbon dioxide in the first place.

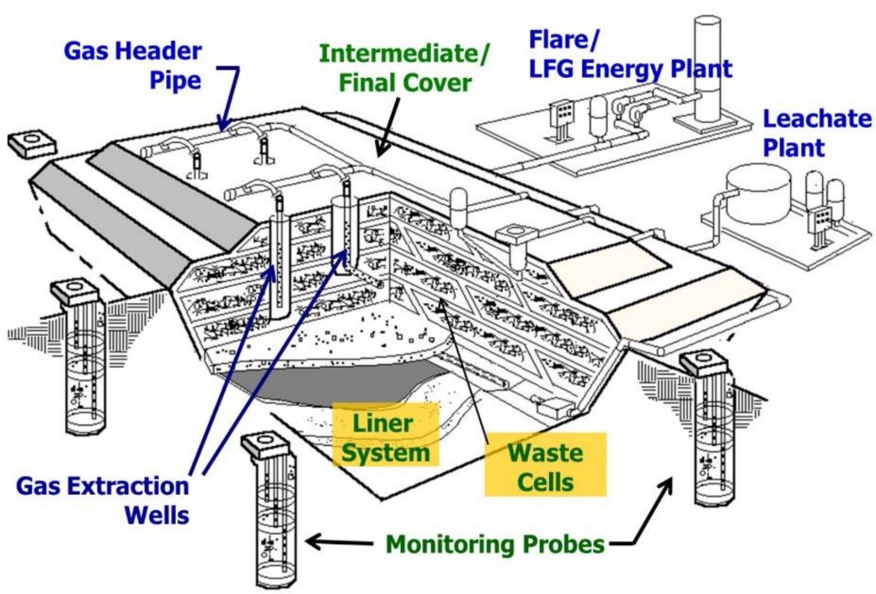
In general, the measures that have been taken in Maryland to reduce landfill gas emissions are inadequate and need to go further. The sizeable greenhouse gas emissions that have not been accounted for in the State's official estimates underscore the need for improved control of landfill gas and diversion of organic material away from landfills.

On-Site Emissions Controls

Gas Collection Systems Required by Air Quality Regulations

In general, air quality regulations require that certain landfills install and operate gas collection systems. These systems suck gas out of the waste heap through a network of pipes in the waste, typically with the help of a vacuum, and route it to a control device of some kind. The systems at these landfills route collected gas to equipment that removes the methane in the gas through combustion. This equipment includes flares, which simply combust the methane in the gas, and devices like boilers, internal

Figure 8. Simplified Depiction of the Pollution Control Systems at a Modern Landfill



In Maryland, only 4 out of 40 gas-producing landfills are required by regulation to operate a gas collection and control system.

combustion engines, and gas turbines, which burn the gas to produce electricity or heat. Gas collection systems and combustion devices do not remove the carbon dioxide in landfill gas. While methane is burned, the carbon dioxide in the gas simply passes through the combustion device and escapes into the atmosphere. In addition, combusting methane in these devices generates carbon dioxide as a byproduct.

Twenty-one of the 40 landfills that produce gas in Maryland have a gas collection system that collects gas from at least part of the landfill. Ten of the 21 landfills with gas collection systems have only a flare. The remaining 11 have devices that convert all or a portion of the collected gas into heat or electricity. In addition, it is important to note that gas collection systems never collect and combust all of the gas generated by a landfill. The EPA estimates that the average collection system harnesses 75 percent of the gas generated in the waste heap.[64] Most of the landfills in Maryland with gas collection systems gather site-specific data on collection system efficiencies, which ranged from 5 percent to 95 percent in 2017, the most recent year for which we have complete data. The average collection efficiency of Maryland's systems was 59 percent. The specific collection efficiencies of the systems at Maryland's landfills are presented in Attachment 1.

The landfill air quality regulations currently in effect in Maryland are federal regulations that the EPA issued in 1996 pursuant to the Clean Air Act.[65] These regulations are relatively weak and only require 4 of the 40 landfills that produce gas in Maryland to install and operate gas collection systems. These landfills are: (1) Eastern Landfill in Baltimore County; (2) Millersville Landfill in Anne Arundel County; (3) Brown Station Road Landfill in Prince George's County; and (4) the closed Sandy Hill Landfill, which is also located in Prince George's County. Per the federal regulations, these systems must collect gas from almost all of the areas where waste is disposed of at the landfills.[66]

The EPA most recently updated its landfill air quality regulations in 2016. These regulations will take effect in Maryland on June 21, 2021, the effective date of the EPA's federal plan that implements the regulations.[67] However, even when these regulations do take effect, they will not apply to any additional landfills in Maryland beyond the 4 that are already covered.[68] Nor will the updated regulations require the operators of these 4 landfills to make meaningful changes to the way they control landfill gas.

Gas Collection Systems Operated Voluntarily

In Maryland, there are 17 gas-producing landfills that have installed gas collection and control systems voluntarily, without a regulatory mandate. Landfill operators install gas collection systems voluntarily to monetize energy generated by burning landfill gas, or to harness the energy for use on-site to heat and power buildings.[69] There are also financial incentives available at the federal and state levels that promote the collection and use of landfill gas.[70] Operators may also install systems to control odors, or to prevent landfill gas from reaching levels that present an explosive hazard, as discussed further below.

Of the 17 landfills in Maryland that have voluntarily installed collection systems, EIP found data on system efficiency for 16. The gas collection systems at these 16 landfills had an average reported collection efficiency of 55 percent in 2017, which is significantly lower than the 76 percent average collection efficiency achieved by the systems subject to federal requirements. The difference in the system efficiency of collection systems that are required by regulations versus those that are installed voluntarily is even more pronounced when considering landfills that continue to accept waste. Systems at closed landfills generally collect gas with a higher efficiency because, as discussed in the section that follows, landfill operators need to add a final cover to closed landfills, which slows the escape of some of the gas, making it easier to collect. Gas is harder to collect at active landfills. Gas is collected with 69 percent efficiency at the 3 active landfills that are subject to the federal regulations, while systems at the 10 active landfills that installed the systems voluntarily only collect gas with 39 percent efficiency.

In addition, voluntarily installed systems are not subject to the monitoring, operating, and reporting requirements in the federal rule. The landfill operators do not need to monitor the systems to ensure that they are preventing landfill gas from escaping from the surface of the landfill, nor are they under an obligation to make sure that these systems collect gas from all (or any) of the landfill. Further, operators at these landfills do not need to keep the control devices that destroy the collected gas running consistently, or at all.

Caps and Liners Required by Solid Waste Regulations

Landfill gas is also regulated under the federal Resource Conservation and Recovery Act, which governs the disposal of solid and hazardous waste.[71] The EPA has issued regulations under this statute that are specific to municipal waste.[72] MDE implements these regulations in Maryland.[73]

These regulations require landfill operators to cover newly deposited waste at the end of each operating day, which slows the escape of landfill gas into the atmosphere, and potentially facilitates the breakdown of methane in the soil through the biological process known as surface oxidation.[74] The regulations also require operators to install liners before waste is deposited.[75] Liners can mitigate the subsurface migration of gas.[76] In addition, the regulations require operators to install final cover systems, or "caps," on landfills that close.[77] Daily cover, liners, and final cover systems all serve to slow the escape of landfill gas and, to some degree, improve the efficiency of gas collection systems.[78]

Because methane is a flammable gas, the regulations also provide for "[e]xplosive gases control" at landfills.[79] Landfill operators must ensure that methane emitted from the landfill does not collect in concentrations that could lead to an explosion.[80] To do so, landfill operators establish and follow a program of routine monitoring of methane in buildings at the landfill and at the property boundary.[81] There are also requirements that apply after a landfill closes and the final cover system is in place. Pursuant to these requirements, operators must ensure that the gas monitoring program and final cover system remain effective for up to 30 years after closure.[82]

To a certain extent, these measures slow the escape of landfill gas and improve the operation of gas collection systems, but they are not meant to provide for the control of methane as a climate pollutant. Instead, they are meant to reduce the chance that methane will cause an explosion, and any pollution control benefits are secondary.[83] While all measures that contribute to the mitigation of greenhouse gas emissions from landfills should be encouraged, and strict enforcement of the regulations under the Resource Conservation and Recovery Act is necessary to secure their benefits, the regulations alone do not require sufficient control of greenhouse gas emissions from landfills.[84] In particular, the measures required by these regulations may slow the escape of landfill gas, but they do not prevent gas emissions and the gas will ultimately escape into the atmosphere if landfills do not install well-functioning gas collection systems.

Keeping Organic Waste Out of Landfills

Stronger regulation of greenhouse gases from landfills is necessary, especially to reduce emissions from existing landfills where the organic materials that cause greenhouse gases to form cannot now be removed. However, because landfill gas derives from the decomposition of organic material in the waste at landfills, the optimal approach to reducing greenhouse gases from landfills is keeping organic material, like yard waste and food scraps, out of landfills in the first place. This is often referred to as "organics diversion." The benefits of organics diversion are discussed below, as is the state of organics diversion in Maryland. It is important to note that burning waste, which is a highly polluting activity, is not considered an acceptable organics diversion method by EIP and most other environmental organizations.

Benefits of Organics Diversion

The Zero Waste International Alliance ("ZWIA"), a network of advocates who promote positive alternatives to landfilling and burning waste, has ranked different methods of managing waste by preference in what is called the Zero Waste Hierarchy, shown below in Figure 9. The hierarchy identifies the three best ways of reducing waste as rethink/redesign, reduce, and reuse, in that order. Recycling and composting of waste are fourth in the hierarchy in terms of preferred management methods but are the best ways of disposing of waste once it is no longer possible to rethink/redesign, reduce, or reuse it.

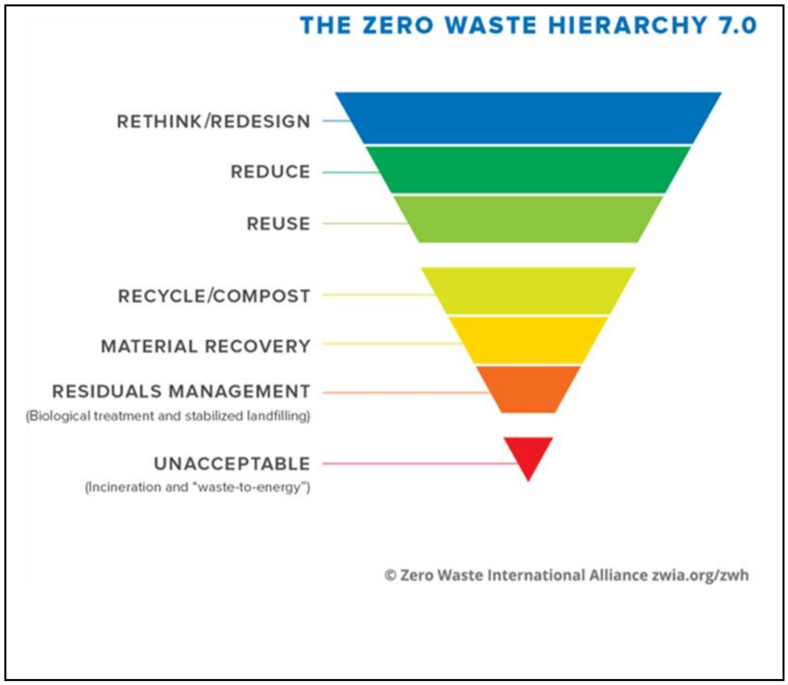
The two methods of "recycling" organic waste that are most widely recognized are composting and anaerobic digestion.[85] Composting is a process that allows organic waste to decompose in the presence of oxygen and does not produce methane.[86] The greenhouse gas reductions that can be achieved by composting rather than landfilling organic waste largely depend on how effectively the method of composting avoids anaerobic (oxygen-free) conditions, which lead to the formation of methane.[87] However, composting in general is a particularly effective way of largely avoiding methane emissions.[88] Anaerobic digestion is a process in which microorganisms break down waste in the absence of oxygen to produce biogas that can be used to generate electricity.[89] It also produces a wet leftover mixture called "digestate" that can be nutrient-rich and used as a soil amendment,[90] though ZWIA recommends composting of the digestate before mixing it with soil in order to prevent the release of harmful compounds produced during the anaerobic digestion process.[91] The EPA has estimated that composting and anaerobic digestion each achieve a 95 percent methane reduction efficiency when compared to landfilling organic waste.[92]

Composting—particularly at the smaller, more local scale—is considered preferable to anaerobic digestion by ZWIA and most zero waste advocates.[93] Composting has many benefits for the climate, ecosystems, and communities. The composting process creates nutrient-rich soil that reduces erosion and stormwater pollution and sequesters carbon.[94] By removing waste from landfills, composting avoids taking up landfill space, which extends the life of those landfills and reduces their need to expand by creating space for the disposal of other materials.[95] In addition, composting facilities can employ significantly more people per ton of waste than landfills, or incinerator facilities. A report recently released by the Global Alliance for Incinerator Alternatives found that composting creates 6.6 jobs per 10,000 tons per year of waste handled, which is almost four times the number of jobs created by landfilling and incineration (1.8 and 1.7 per 10,000 tons of waste respectively).[96]

Organics Diversion in Maryland

Maryland already has some measures in place to prevent the landfilling of organic materials but must go further. Maryland has long prohibited landfill and trash incinerator operators from accepting yard waste that is disposed of and collected separately from other waste.[97] In addition, the Maryland Recycling Act, which was passed in 1988, establishes recycling rates that must be met by each of Maryland's 24 counties.[98] The rates apply to the entire household waste stream, but the law does not set independent requirements or targets for organic materials. Based on the most recent report in 2018, 5 counties were not meeting these "mandatory" recycling rates.[99] In a 2019 report on organics diversion, MDE found that "Maryland generally has fewer composting and anaerobic digestion facilities than the [five] other states surveyed, proportionate to its population."[100]

Figure 9. Zero Waste Hierarchy



Composting, particularly at the local scale, is considered preferable to anaerobic digestion by the Zero Waste Hierarchy and most zero waste advocates.

In 2021, Maryland took an important step to address organic waste directly by passing a law[101] that requires large generators of food waste to divert that waste from landfills, incinerators, and solid waste processing facilities. Facilities that constitute large food scrap generators include supermarkets, convenience stores, certain individual school facilities, and cafeterias at businesses and institutions.[102] Restaurants are exempt from the law's requirements and other facilities may apply for a waiver based on financial hardship.[103] In 2019, the Johns Hopkins University Center for a Livable Future estimated that there are 3,961 large food scrap generators, defined as facilities generating at least 1 ton of food waste per week, operating in Maryland, of which 51 were fast food restaurants.[104] Under the new law, food scrap generators have several options for achieving compliance, including sending the food to a composting or anaerobic digestion facility, reducing food waste, donating servable food, and providing it for agricultural use such as animal feed. The requirements take effect on January 1, 2023, for facilities generating 2 tons a week or more of food residuals and on January 1, 2024, for facilities generating 1 ton a week or more of food residuals.[105]

However, a significant impediment to this law's potential effectiveness is the fact that food scrap generators are not required to comply unless there is a sufficiently large organics recycling facility, which includes composting and anaerobic digestion facilities, within 30 miles.[106] Based on MDE's January 2021 written testimony on the law, there are currently only 7 facilities in the state permitted to compost food waste and MDE is aware of 5 planned or operational "Maryland-based anaerobic digestion facilities designed to accept food scraps."[107] Further, the fiscal and policy note for the new law expressly acknowledges that the dearth of organics diversion facilities will likely limit the bill's effectiveness, stating that "only a small number of food scrap generators are likely affected by the bill initially, [but] additional composting and anaerobic digestion facilities will likely be established over time as the demand for food residuals recycling increases."[108]

Recommendations

Maryland must take steps as quickly as possible to curb greenhouse gas emissions from landfills. Our specific recommendations follow.

1. Maryland Should Issue Strong New Air Pollution Regulations for Landfills

MDE is currently in the process of developing new air quality regulations to limit emissions from landfills.[109] The agency is conducting this rulemaking for two reasons. First, under the EPA's 2016 air quality regulations for landfills, states must either develop state rules setting standards at least as strong as the EPA's[110] or accept coverage under a federal plan.[111] The EPA has issued a federal plan that will become effective in Maryland on June 21, 2021, but that plan explicitly contemplates that states may continue developing their own regulations.[112] Second, Maryland is required to reduce greenhouse gases by at least 40 percent by the year 2030 (using 2006 emissions as a baseline) under a state law called the Maryland Greenhouse Gas Reduction Act.[113] Reducing methane emissions has been identified as a priority by the Maryland Commission on Climate Change, an advisory body that recommends strategies for meeting these reduction requirements.[114]

MDE should issue very strong regulations for controlling and monitoring landfill emissions. Presently, the strongest landfill emission regulations in the country are the ones that were issued in 2010 by the State of California. These are even more protective than the EPA's 2016 regulations. California's regulations require installation of gas collection and control systems at more landfills than EPA's because California's rules are based on whether a landfill produces enough gas to operate a flare. EPA's rules, by contrast, require installation of systems at landfills based on size and emissions thresholds. If MDE were to adopt California's standards for requiring installation of a system, EIP's analysis shows that 28 landfills in Maryland would be required to install such systems. Under EPA's regulations, only 4 landfills are required to do so.

At minimum, MDE should adopt California's thresholds for requiring installation of a collection and control system, and MDE should strongly consider going beyond what California has done. California's flare-based applicability standards were issued in 2010. EIP recently completed an assessment of current flare technology that can be used at landfills.[115] Based on this assessment, EIP believes that modern landfills can operate a flare using smaller amounts of landfill gas than was possible when California issued its regulations. Using lower thresholds based on modern flare technology, 38, not 28, landfills in Maryland could be required to install collection and control systems.

In addition, simply requiring installation of a gas collection and control system is not enough. California's regulations are also stronger than the EPA's when it comes to requirements for operating the system and monitoring emissions. California is more selective than EPA when it comes to the type of collection system that must be installed.[116] California requires monitoring of a system for equipment leaks,[117] an approach that is also used for controlling emissions from the oil and gas industry. EPA's regulations include no leak detection and repair requirements. In addition, California's requirements are stronger than EPA's when it comes to the requirements that surround monitoring of methane emissions at the landfill's surface, operating flares as control devices, and reporting of information about the landfill to regulators.

MDE should model its landfill regulations on California's and should take all other steps necessary to ensure that as many landfills as possible in Maryland must install collection and control systems and operate them as effectively as possible.

2. MDE Should Finalize Its New Landfill Emissions Regulations as Quickly as Possible

In addition to issuing a strong rule, MDE should also move forward as quickly as possible with completing its rulemaking process. MDE first held a public stakeholder meeting to discuss its development of new regulations to limit landfill emissions in March 2017.[118] After that, MDE did not hold another meeting on the rule for over three years. A second meeting on the process was held in September 2020, and a third has been scheduled on June 23, 2021. During the three and a half-year gap between the first and second meetings, MDE was contending with mixed messages coming from the EPA, but that is not a sufficient excuse for the delay. The EPA's regulations were finalized in 2016, and MDE has always unquestionably had authority to issue stronger regulations that the federal requirements.

Given the new information on the magnitude of landfills' contribution to greenhouse gas emissions in Maryland, particularly methane emissions, MDE should now move forward as quickly as possible in order to finalize a strong rule that will reduce greenhouse gas emissions from landfills.

3. Maryland Should Create New Incentives to Spur on the Construction of More Organics Diversion Facilities and Make Information on Existing Incentives More Widely Available

As discussed above, additional composting and anaerobic digestion facilities must be built in Maryland in order to ensure that the state's new food scraps diversion law increases the amount of food waste that is diverted from landfills and incinerators. Maryland should create more incentives in order to ensure that these facilities do in fact begin operating. A lengthy 2019 report issued by MDE on organics diversion identifies several existing state-level incentives that might possibly be applied to these projects.[119] However, it appears that the work group whose discussions resulted in the report generally regarded the existing incentives as insufficient, particularly for small-scale composting operations.[120] MDE also acknowledges in the report that "it can be difficult [for project developers] to locate incentives from multiple sources and determine eligibility for particular projects."[121] One of the recommendations in the report is that MDE "create a sector-specific publication listing economic incentives and assistance potentially applicable to organics recycling projects, as well as contact information for more assistance."[122] Based on a review of the materials posted on MDE's Organics Diversion and Composting website, it does not appear that this has been created.[123]

MDE should finalize this list of state incentives and contact information, supplement it with information on available federal incentives programs for composting and anaerobic digestion businesses in Maryland, and make it available on its Organics Diversion and Composting website. In addition, the State of Maryland should create a dedicated fund to provide assistance to companies building new organics diversion facilities, focusing on composting businesses and businesses offering employment to residents of communities with high unemployment where the need for jobs is greatest.

4. County Governments in Maryland Should Assess the Feasibility of Operating Their Own Composting Facilities

County governments in Maryland should also seek to increase local composting capacity, especially food composting capacity, by assessing the feasibility of operating a county-owned composting site. This feasibility assessment should include conducting surveys of public land on which a composting facility could be sited. As stated above in this report, 35 out of 40 landfills in the state are publicly owned. Other essential disposal services in Maryland are publicly owned and operated, including many sanitary sewer systems and wastewater treatment plants. In addition, Howard County already operates a food composting facility at its Alpha Ridge landfill[124] and a publicly owned and operated food composting facility is also located in Prince George's County.[125]

Given the urgency of addressing climate change, the importance of diverting organic waste from both landfills and incinerators, and the jobs creation potential of composting, county governments that do not currently operate a composting facility should immediately begin assessing the feasibility of operating a publicly-owned composting facility within their county.

5. Maryland Should Not Treat Burning Trash as a Solution to the Problem of Landfill Emissions

Incinerating municipal solid waste rather than landfilling it is sometimes presented as a favorable approach for reducing landfill methane.[126] Trash incinerators, which are extremely polluting, have a particularly sordid and environmentally unjust history in the State of Maryland. In 2010, a company called Energy Answers proposed to build the largest trash incinerator in the United States in Baltimore City, approximately four miles from the city's existing trash incinerator, which is the largest in the state. Fortunately, the Energy Answers incinerator was never built, due in large part to local opposition led by college and high school students.[127] However, until the students began voicing their objections, the project had political support from top officials at the state and local levels.[128] This was the case despite the clear injustice of proposing to site two large trash incinerators within four miles of one another in the low-income and industrialized southern area of a majority-Black city like Baltimore.

EIP unequivocally opposes treating waste incinerators (sometimes referred to as "waste-to-energy" facilities) as a solution to the problem of landfill methane. Multiple analyses have shown that burning trash emits higher rates of toxic air pollutants, particularly the neurotoxins lead and mercury, per unit of energy generated than burning coal.[129] Trash incinerators are also large sources of carbon dioxide themselves. In addition, incinerators generate a byproduct, toxic incinerator ash, which must be disposed of, often at a landfill. Baltimore City's Quarantine Road Landfill houses not only the City's municipal solid waste but also incinerator ash from the Wheelabrator Baltimore trash incinerator.

Maryland must reduce landfill methane, but it must do so without poisoning the air that people breathe and without further putting the health of low-income communities and communities of color at risk. Waste diversion and improved pollution controls are solutions to the problem of landfill methane. Incineration is not a solution; it is exchanging one problem for another.

6. Maryland, Other States, and EPA Should Promote and Make Use of Direct Measurement Techniques and Emissions Monitoring at the Nation's Landfills

As discussed above, even when government regulators use models correctly to estimate emissions from landfills there is the potential for erroneous estimates. Models are based on theoretical conditions at a non-existent, "average" landfill. In reality, each landfill possesses unique attributes that influence the production and release of landfill gas and affect the effectiveness of any gas control system. Rainfall, the type and depth of waste cover, and waste composition are just a few examples of variables that can cause a landfill to generate and release more or less landfill gas. Models typically cannot take all of this into account.

State and federal regulators, including MDE, should promote and make use of direct measurement and monitoring techniques to gain a better understanding of what is really happening at the nation's landfills. This is not to say that modeling does not have a place in the regulation of landfills. The two approaches complement each other. Direct measurement and monitoring techniques produce data that can be used to improve models and can independently corroborate results of models, which protects against error. Moving forward, Maryland should embrace the emerging technologies that the EPA has teamed up with private companies to develop, which include drone, flyover, and satellite measurement technologies. MDE should also undertake pilot monitoring projects to continue clarifying the picture of what is really coming out of Maryland's landfills.

Endnotes

[1] EPA, Greenhouse Gas Emissions, Global Greenhouse Gas Emissions Data (Mar. 25, 2021), *available at* https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.
[2] MDE, Climate Change, Greenhouse Gas Inventory (last accessed May 25, 2021), *available at* https://mde.maryland.gov/programs/Air/ClimateChange/Pages/GreenhouseGasInventory.aspx.
[3] Agency for Toxic Substances and Disease Registry ("ATSDR"), Landfill Gas Primer: An Overview for Environmental Health Professionals, at 3, 5–6 (Nov. 2001); EPA, LFG Energy Project Development Handbook, Ch. 1, at 2 (Mar. 2020).
[4] MDE, 2016 Maryland Statewide Waste Characterization Study, Final Report, at ES-3–ES-4, 3-1–3-7 (July 14, 2017), *available at* https://mde.maryland.gov/programs/LAND/SolidWaste/Documents/2016%20Maryland%20Statewide%20WCS%20Study.pdf (evaluating the composition of Maryland's municipal solid waste in 2016).
[5] Ibid, 3-2.
[6] Zero Waste International Alliance, Composting and Anaerobic Digestion Policy (last accessed May 15, 2021), *available at* https://zwia.org/composting-and-anaerobic-digestion-policy/.
[7] Ibid.
[8] EPA, Basic Information about Anaerobic Digestion (AD) (July 3, 2021), *available at* https://www.epa.gov/anaerobic-digestion/basic-information-about-anaerobic-digestion-ad.
[9] EPA, Global Mitigation of Non-CO2 GHGs Report: 2010-2030, Landfills, at III-6–III-10 (2013), *available at* https://www.epa.gov/sites/production/files/2016-06/documents/mac_report_2013-iii_waste.pdf (the entire report is available at https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases/global-mitigation-non-co2-ghgsreport-2010-2030).
[10] Letter from Maryland Governor Lawrence Hogan to Adrienne Jones, Speaker of the House of Delegates, at 3 (May 28, 2021), *available at* https://governor.maryland.gov/wp-content/uploads/2021/05/EWS-House-Bills-FINAL-2021-1.pdf.
[11] Intergovernmental Panel on Climate Change ("IPCC"), Global warming of 1.5ºC, at 51, 57 (2018), *available at* https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_Low_Res.pdf.
[12] Ibid, 51–52.
[13] Ibid, 240; Kevin Trenberth, Climate change caused by human activities is happening and it already has major consequences, Vol. 36, Issue 4, Journal of Energy and Natural Resources Law (June 1, 2018).
[14] IPCC, *supra* note 11, at 238–240.
[15] *See, e.g.*, U.S. Global Change Research Program, Fourth National Climate Assessment, Summary Findings (Nov. 2018), at https://nca2018.globalchange.gov/.
[16] MDE, Climate Change Program (last accessed May 2, 2021), *available at* https://mde.maryland.gov/programs/Air/ClimateChange/Pages/index.aspx#:~:text=The%20effects%20of%20climate%20change,livelihoods%2C%20and%20the%20state's%20economy.
[17] MDE, The 2030 Greenhouse Gas Emissions Reduction Act Plan, at 11 (Feb. 19, 2021), *available at* https://mde.maryland.gov/programs/Air/ClimateChange/Documents/2030%20GGRA%20Plan/2030%20MD%20Greenhouse%20Gas%20Reduction%20Act%20Plan.pdf.
[18] Ron Cassie, Baltimore Magazine, Hell and High Water (last accessed May 3, 2021), *available at* https://www.baltimoremagazine.com/section/historypolitics/climate-change-wreaking-havoc-baltimore-infrastructure-public-health/.
[19] Jonathan Erdman, The Weather Channel, 2018 Was Wettest Year on Record in Over Two Dozen Cities in the East, Midwest, Including Washington D.C. and Pittsburgh (Jan. 3, 2019), *available at* https://weather.com/news/news/2018-12-15-record-wet-year-2018-washington-dc-baltimore.
[20] Climate Central, What We Do (last accessed June 1, 2021), *available at* https://www.climatecentral.org/what-we-do.
[21] Climate Central, Across U.S. Heaviest Downpours on the Rise (May 27, 2015), *available at* http://www.climatecentral.org/news/across-us-heaviest-downpours-on-the-rise-18989.
[22] *See* Plaintiff's Complaint, *Mayor and City Council of Baltimore City v. BP*, Baltimore City Circuit Court, at 44-45. (2018) *available at* https://mayor.baltimorecity.gov/sites/default/files/Climate%20Change%20Complaint.pdf.
[23] Baltimore City Council, Investigative Hearing – Inland Flood Mitigation (Mar. 8, 2021), *available at* https://baltimore.legistar.com/LegislationDetail.aspx?From=RSS&ID=4749302&GUID=7B564A5E-6D44-4435-9AD7-1C6E260D3C52.

[24] Baltimore City Council, Investigative Hearing – Building Backups of Untreated Sewage (Apr. 5, 2021), *available at* https://baltimore.legistar.com/LegislationDetail.aspx?From=RSS&ID=4793140&GUID=4E3A5912-69EB-4747-9F1A-8DA2E6DBE5F3.

[25] *See* Kirk Smith, et al., Joint CO2 and CH4 accountability for global warming, Proceedings of the National Academy of Sciences of the United States of America, at E2865 (July 11, 2013), *available at* https://www.pnas.org/content/pnas/110/31/E2865.full.pdf; *see generally* IPCC, Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Ch. 15, at 1151–55 (2014); *see also* EPA, Inventory of US Greenhouse Gas Emissions and Sinks, 1990-2019, at 2-1–2-16 (Apr. 14, 2021); Stephanie Waldhoff, The Marginal Damage Costs of Different Greenhouse Gases: An Application of FUND, Economics, at Abstract, 1 (Oct. 1, 2014), *available at* https://www.degruyter.com/document/doi/10.5018/economics-ejournal.ja.2014-31/html.

[26] IPCC, *supra* note 11, at 12, 42, 66–68, 101–02, 106–08, 115–16 (2018); John Reilly, et al., Pew Center on Global Climate Change, Multi-Gas Contributors to Global Climate Change: Climate Impacts and Mitigation Costs of Non-CO2 Gases, at iii, 1, 41 (Feb. 2003), *available at* https://www.c2es.org/site/assets/uploads/2003/02/multi-gas-contributors-global-climate-change.pdf; IPCC, Climate Change 2014: Synthesis Report, at 82–84 (2014), *available at* https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf.

[27] EPA, Global Methane Initiative, Importance of Methane (Oct. 22, 2020), *available at* https://www.epa.gov/gmi/importance-methane; *see also* IPCC, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, at 675-82 (2013); EPA, Global Greenhouse Gas Emissions Data, Greenhouse Gas Emissions (Sept. 13, 2019), *available at* https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

[28] EPA, Understanding Global Warming Potentials, Greenhouse Gas Emissions (Feb. 14, 2017), *available at* https://www.epa.gov/ghgemissions/understanding-global-warming-potentials; *see also* IPCC, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, at 710–20 (2013).

[29] EPA, *supra* note 28.

[30] Reilly, *supra* note 26, at 16–20, 41; *see, e.g.*, Joint Institute for Strategic Energy Analysis, Potential Cost-Effective Opportunities for Methane Emission Abatement, at vii–x, 12–19 (Aug. 2015), *available at* https://www.nrel.gov/docs/fy16osti/62818.pdf.

[31] *See* United Nations Environment Programme, Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers, at x, 3, 6, 24 (Nov. 2011).

[32] MDE, Methane, HFCs and Other Short-Lived Climate Pollutants, at 14 (Mar. 16, 2020), *available at* https://mde.maryland.gov/programs/workwithmde/Documents/SLCP_AQCAC03162020.pdf.

[33] Arlene Fiore, et al., Characterizing the tropospheric ozone response to methane emission controls and the benefits to climate and air quality, Journal of Geophysical Research, at 1 (Apr. 30, 2008), *available at* https://www.gfdl.noaa.gov/bibliography/related_files/aff0801.pdf; Marcus Sarofim, et al., Valuing the Ozone-Related Health Benefits of Methane Emission Controls, Environmental Resource Economics, at 46 (June 29, 2015), *available at* https://link.springer.com/content/pdf/10.1007/s10640-015-9937-6.pdf; EPA, *supra* note 28; MDE, Annual Climate Change Report, at 9 (Dec. 31, 2020), *available at* https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Publications/2020%20MDE%20Agency%20Report.pdf; IPCC, *supra* note 27, at 670–71, 677, 680.

[34] EPA, Ground-level Ozone Pollution, Ground-level Ozone Basics (Apr. 28, 2021), *available at* https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics; EPA, Ground-level Ozone Pollution, Health Effects of Ozone Pollution (Jan. 14, 2021), *available at* https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution; California Air Resources Board, Ozone Effects: Overview of the harmful health effects of ground level ozone (Nov. 3, 2016), *available at* https://ww2.arb.ca.gov/resources/fact-sheets/ozone-effects.

[35] IPCC, Climate Change 2001, The Scientific Basis, at 43, 241 (2001), *available at* https://www.ipcc.ch/site/assets/uploads/2018/03/WGI_TAR_full_report.pdf; Sarofim, *supra* note 33, at 46; Climate and Clean Air Coalition, What are short-lived climate pollutants? Tropospheric ozone (last accessed Apr. 29, 2021), *available at* https://www.ccacoalition.org/en/slcps/tropospheric-ozone.

[36] MDE, Clean Air Progress Report 2019, at 3 (2019), *available at* https://mde.state.md.us/programs/Air/Documents/GoodNewsReport/GoodNews2019.pdf.

[37] EPA, Overview of Greenhouse Gases: Methane Emissions, Greenhouse Gas Emissions (Mar. 16, 2020), *available at* https://www.epa.gov/ghgemissions/overview-greenhouse-gases#CH4-reference.

[38] EPA, Municipal Solid Waste Landfills (Jan. 6, 2021), *available at* https://www.epa.gov/landfills/municipal-solid-waste-landfills.
[39] ATSDR, *supra* note 3, at 3, 5–6; EPA, LFG Energy Project Development Handbook, Ch. 1, at 2 (Mar. 2020).
[40] MDE, *supra* note 4, at 4-1.
[41] Ibid, ES-3–ES-4, 3-1–3-7. EIP drew these percentages from MDE's "adjusted waste composition" analysis on pages 3-5 to 3-7, which adjusts the conclusions of its study to factor in the results of third-party waste composition studies for Montgomery and Prince George's County. Ibid, 3-1, 3-5. Also, the breakdown presented here accounts for the effects of Maryland's yard trimmings disposal ban, which prohibits landfill operators from collecting truckloads of separately collected yard waste unless the operator provides for the recycling of the yard waste. Maryland Code, Environmental Article, § 9-1723(a).
[42] MDE, *supra* note 4, at 3-2.
[43] MDE, Waste Diversion, Food Scraps Management (last accessed May 6, 2021), *available at* https://mde.maryland.gov/programs/land/recyclingandoperationsprogram/pages/foodscraps.aspx#:~:text=In%20Maryland%2C%20an%20estimated%201.86,food%20waste%20generated%20each%20year.&text=The%20disposal%20of%20food%20scrap,%25)%20Marylanders%20is%20food%20insecure.
[44] EPA, Basic Information about Landfill Gas, Landfill Methane Outreach Program ("LMOP") (Mar. 10, 2020), *available at* https://www.epa.gov/lmop/basic-information-about-landfill-gas; see also ATSDR, *supra* note 3, at 3-4. Some landfills emit nitrous oxide, another greenhouse gas. However, because information is lacking on nitrous oxide emissions from landfills, and these emissions may be negligible, official estimates of greenhouse gases from landfills do not usually account for this compound and nitrous oxide is not considered in this report. Ming-Sheng Jia, Nitrous Oxide Emissions from Municipal Solid Waste Landfills and its Measuring Methodology: A Review, 1815–24 (June 2014).
[45] EPA, Office of Air and Radiation, Regulatory Impact Analysis for the Proposed Revisions to the Emission Guidelines for Existing Sources and Supplemental Proposed New Source Performance Standards in the Municipal Solid Waste Landfills Sector, EPA-452, at Ch. 2, 21-24, Ch. 4, 1-35 (Aug. 2015); *see also* Environmental and Energy Study Institute, Fact Sheet – Landfill Methane (Apr. 26, 2013), *available at* https://www.eesi.org/papers/view/fact-sheet-landfill-methane.
[46] EPA, LFG Energy Project Development Handbook, Ch. 1, at 5 (Mar. 2020); ATSDR, *supra* note 3, at 5 (citing John F. Crawford and Paul G. Smith, Landfill Technology (1985)).
[47] There are at least 23 other closed municipal waste landfills in Maryland that are not included in MDE's greenhouse gas inventory. Based on their dates of closure, it does not appear that these facilities emit landfill gas in significant quantities. MDE, Closed Solid Waste Acceptance Facilities Contact List, at 1–5 (Oct. 24, 2019), *available at* https://mde.maryland.gov/programs/LAND/SolidWaste/Documents/Closed_Facilities_Contact_List.pdf. The New Cut Landfill in Howard County is excluded from the count of 40 and information for this landfill is not shown in Attachment 1. It is possible that this landfill still produces small amounts of landfill gas, but EIP was not able to acquire the data necessary to estimate this landfill's total greenhouse gas emissions.
[48] *See, e.g.*, U.S. Global Change Research Program, Fourth National Climate Assessment, Summary Findings (Nov. 2018), at https://nca2018.globalchange.gov/.
[49] EIP calculated these equivalencies using the EPA's Greenhouse Gas Equivalencies Calculator, *available at* https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.
[50] EIP obtained data on Maryland's coal-fired power plants through the EPA's Greenhouse Gas Reporting Program using the Facility Level Information on Greenhouse Gases Tool (FLIGHT), *available at* https://ghgdata.epa.gov/ghgrp/main.do#.
[51] Ibid.
[52] MDE, 2017 Periodic Greenhouse Gas Emissions Inventory (last accessed May 2, 2021), *available at* https://mde.maryland.gov/programs/Air/ClimateChange/Pages/GreenhouseGasInventory.aspx.
[53] EPA, Greenhouse Gas Emissions, Overview of Greenhouse Gases (Apr. 14, 2021), *available at* https://www.epa.gov/ghgemissions/overview-greenhouse-gases.
[54] Ibid.
[55] EPA, Inventory of U.S. Greenhouse Gas Emissions and Sink: 1990–2019, Chapter 3. Energy, at 3-90 (2021), *available at* https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-chapter-3-energy.pdf; *see also* EPA, Natural Gas STAR Program, Estimates of Methane Emissions by Segment in the United States (Apr. 22, 2021), *available at* https://www.epa.gov/natural-gas-star-program/estimates-methane-emissions-segment-united-states.

[56] United States Energy Information Administration, Maryland State Profile and Energy Estimates (Oct. 15, 2020), *available at* https://www.eia.gov/state/analysis.php?sid=MD#:~:text=Maryland%20has%20few%20economically%20recoverable,feet%20of%20natural%20gas%20annually.
[57] *See, e.g.*, Scott Dance, Baltimore Sun, Baltimore's natural gas system is increasingly leaky, raising concerns about safety and global warming (Sept. 18, 2019), *available at* https://www.baltimoresun.com/news/environment/bs-md-gas-leaks-20190918-shpuu5b5efajnipe37sbv64e3i-story.html.
[58] United States Department of Agriculture, Cattle Report, at 5 (Jan. 29, 2021), *available at* https://downloads.usda.library.cornell.edu/usda-esmis/files/h702q636h/n009ww19g/9880wj45t/catl0121.pdf.
[59] Beef2Live, Cattle Inventory vs Human Population by State (May 7, 2021), *available at* https://beef2live.com/story-cattle-inventory-vs-human-population-state-0-114255.
[60] EPA, Climate Leaders Greenhouse Gas Inventory Protocol, Core Module Guidance: Direct Emissions from Municipal Solid Waste Landfilling, at 14 (Oct. 2004), *available at* https://nepis.epa.gov/Exe/ZyPDF.cgi/P1004NAU.PDF?Dockey=P1004NAU.PDF (citing Peter Czepiel, et al., Quantifying the Effect of Oxidation on Landfill Methane Emissions, Journal of Geophysical Research, at 16,712–16,729 (1996). The assumption that surface oxidation removes 10 percent of the methane that is flowing through the landfill's surface is heavily controverted but is still the default assumption that the EPA prescribes for states inventorying landfill greenhouse gas emissions. EPA, User's Guide for Estimating Emissions from Municipal Solid Waste Using the State Inventory Tool, at 1.13 (Sept. 2020), *available at* https://www.epa.gov/sites/production/files/2020-10/documents/solid_waste_users_guide.pdf; *see also* EPA, Summary of Expert Review Comments and Responses: Draft Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2017, at 22–23, 27–28 (Apr. 2019), *available at* https://www.epa.gov/sites/production/files/2019-04/documents/2019-ghgi-expert-review-comment-response.pdf.
[61] EPA, Municipal Solid Waste Landfills: New Source Performance Standards (NSPS), Emission Guidelines (EG) and Compliance Times, Additional Resources (May 24, 2021), *available at* https://www.epa.gov/stationary-sources-air-pollution/municipal-solid-waste-landfills-new-source-performance-standards.
[62] 40 C.F.R. § 98.341.
[63] 40 C.F.R. § 98.343; *see also* EPA, Municipal Solid Waste Landfills, Subpart HH, Greenhouse Gas Reporting Program, at 1 (Feb. 2018), *available at* https://www.epa.gov/sites/production/files/2018-02/documents/hh_infosheet_2018.pdf.
[64] EPA, AP-42, 5th Ed., Vol. I, Ch. 2.4, Municipal Solid Waste Landfills, at 2.4-6 (Nov. 1998), *available at* https://www3.epa.gov/ttn/chief/ap42/ch02/final/c02s04.pdf. This estimate is highly contested, with representatives of industry typically asserting a higher default collection efficiency and environmental groups asserting a lower. Despite this disagreement, the default value of 75 percent has remained in place for over two decades.
[65] Code of Maryland Regulations ("COMAR") 26.11.19.20; 40 C.F.R. Part 60, Subparts WWW and Cc.
[66] 40 C.F.R. § 60.752(b).
[67] Federal Plan Requirements for Municipal Solid Waste Landfills That Commenced Construction On or Before July 17, 2014, and Have Not Been Modified or Reconstructed Since July 17, 2014, 86 Fed. Reg. 27,756 (May 21, 2021).
[68] 40 C.F.R. Part 60, Subparts Cf and XXX. The updated regulations will obligate these 4 landfills to change certain monitoring and reporting practices but will not significantly impact emissions from these landfills.
[69] EPA, Landfill Methane Outreach Program, Benefits of Landfill Gas Energy Projects (Apr. 15, 2021), *available at* https://www.epa.gov/lmop/benefits-landfill-gas-energy-projects.
[70] EPA, Landfill Methane Outreach Program, Resources for Funding Landfill Gas Energy Projects (Aug. 28, 2020), *available at* https://www.epa.gov/lmop/resources-funding-landfill-gas-energy-projects; Regional Greenhouse Gas Initiative, Offsets, Landfill Methane (last accessed May 14, 2021), *available at* https://www.rggi.org/allowance-tracking/offsets/offset-categories/landfill-methane.
[71] 42 U.S.C. §§ 6901-6992k.
[72] *See* 40 C.F.R. pt. 258.
[73] Maryland Manual On-Line, Department of the Environment, Functions (last accessed May 14, 2021), *available at* https://msa.maryland.gov/msa/mdmanual/14doe/html/14agen.html.
[74] 40 C.F.R. § 258.21.
[75] 40 C.F.R. § 258.40.
[76] ATSDR, *supra* note 3, at 55-56, 60-61.
[77] Ibid; 40 C.F.R. §§ 258.40, 258.60.

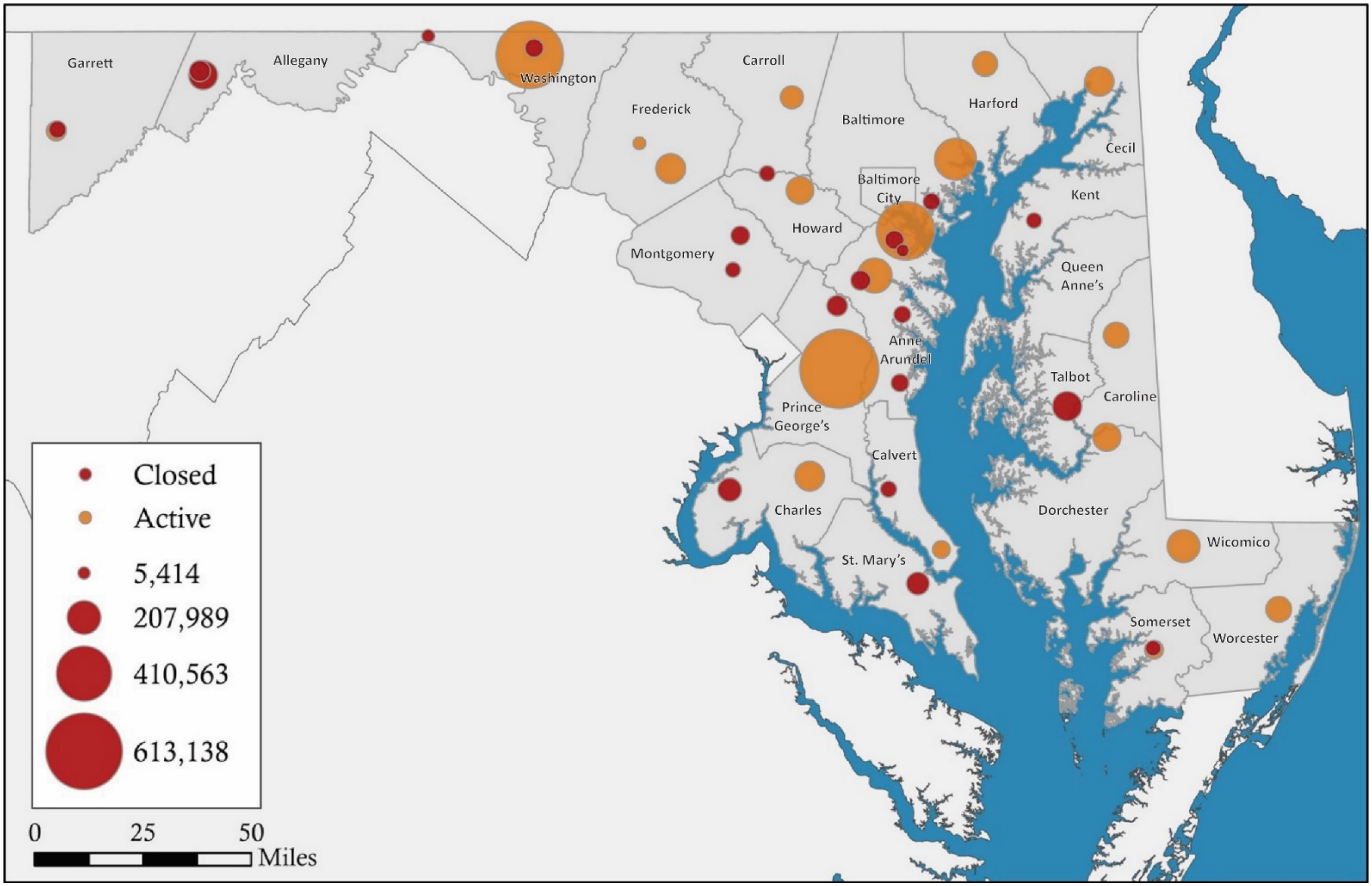
[78] EPA, LFG Energy Project Development Handbook, Ch. 7, at 14, 17 (Mar. 2020), *available at* https://www.epa.gov/sites/production/files/2020-03/documents/pdh_chapter7.pdf.
[79] 40 C.F.R. § 258.23.
[80] 40 C.F.R. § 258.23(a)(1), (2).
[81] 40 C.F.R. § 258.23(b).
[82] 40 C.F.R. § 258.61.
[83] Environmental and Energy Study Institute, Fact Sheet, Landfill Methane (Apr. 26, 2013), *available at* https://www.eesi.org/papers/view/fact-sheet-landfill-methane; *see also* 40 C.F.R. § 258.23.
[84] Joseph A. Davis, Society of Environmental Journalists, To-Do List for Climate Change Gas Methane Is Long, Challenging (May 12, 2021), *available at* https://www.sej.org/publications/backgrounders/do-list-climate-change-gas-methane-long-challenging-and-newsy.
[85] *See e.g.*, Zero Waste International Alliance, Zero Waste Hierarchy of Highest and Best Use (June 21, 2018), *available at* https://zwia.org/zwh/; MDE, Yard Waste, Food Residuals, and Other Organic Materials Diversion and Infrastructure Study Group, Final Report, at 8-10 (July 2019), *available at* https://mde.maryland.gov/programs/LAND/RMP/Documents/HB%20171%20final%20report.pdf.
[86] EPA, *supra* note 9, at III-10.
[87] Ibid, III-11; California EPA, Method for Estimating Greenhouse Gas Emission Reductions from Diversion of Organic Waste from Landfills to Compost Facilities, at 3 (May 2017), *available at* https://ww2.arb.ca.gov/sites/default/files/classic/cc/waste/cerffinal.pdf.
[88] EPA, *supra* note 9, at III-11.
[89] Ibid, III-11.
[90] EPA, *supra* note 8.
[91] Zero Waste International Alliance, Composting and Anaerobic Digestion Policy (last accessed June 1, 2021), *available at* https://zwia.org/composting-and-anaerobic-digestion-policy/.
[92] EPA, *supra* note 9, at III-6.
[93] Zero Waste International Alliance, *supra* note 91.
[94] Baltimore Office of Sustainability, Baltimore Food Waste and Recovery Strategy, at 7 (2018), *available at* https://mayor.baltimorecity.gov/sites/default/files/BaltimoreFoodWaste&RecoveryStrategy_Sept2018.pdf.
[95] Ibid, 10.
[96] John Ribeiro-Broomhead, Neil Tangri, Global Alliance for Incinerator Alternatives, ZeroWaste and Economic Recovery: The Job Creation Potential of Zero Waste Solutions., at 13-14 (2021), *available at* https://zerowasteworld.org/zerowastejobs/.
[97] Maryland Code, Environmental Article, § 9-1723.
[98] Maryland Code, Environmental Article, §§ 9-505, 9-1701–9-1730.
[99] MDE, County Recyclables by Commodity in Tons for Calendar Year 2018, *available at* https://mde.maryland.gov/programs/LAND/RecyclingandOperationsprogram/Documents/2018%20County%20MRA%20Data.pdf.
[100] MDE, *supra* note 85, at 15–16.
[101] See Letter from Lawrence J. Hogan, Jr., Governor, to Hon. Adrienne A. Jones, Speaker of the House of Delegates listing Maryland bills passed by the legislature that will become law without the Governor's signature, including HB 264 (May 28, 2021), *available at* https://governor.maryland.gov/wpcontent/uploads/2021/05/EWS-House-Bills-FINAL-2021-1.pdf.
[102] The text of House Bill 264 is available at http://mgaleg.maryland.gov/2021RS/bills/hb/hb0264e.pdf.
[103] Ibid.
[104] MDE, *supra* note 85, at Appendix E, 229, 231.
[105] MDE is tasked with enforcing the law, including issuing penalties for violations and reporting on the program to the Maryland legislature.
[106] *Supra* note 102.
[107] Letter from Tyler Abbott, MDE, to the Honorable Kumar P. Barve, House Environment and Transportation Committee (Jan 27, 2021) *available at* http://mgaleg.maryland.gov/cmte_testimony/2021/ent/1NrBtkZeZ2OLsWfdLiELFiMCEmXgaRogI.pdf.
[108] Department of Legislative Services, Maryland General Assembly, Fiscal and Policy Note for House Bill 264, 2021 Session, *available at* http://mgaleg.maryland.gov/2021RS/fnotes/bil_0004/hb0264.pdf.
[109] *See generally*, MDE, Updating Maryland's Municipal Solid Waste (MSW) Landfill Regulations (Sept. 21, 2020), *available at* https://mde.maryland.gov/programs/Regulations/air/Documents/MSWLandfillsPresentation092120.pdf.

[110] 42 U.S.C. § 7411(d)(1); *cf.* § 7410 (requiring states to submit implementation plans for setting, monitoring, and enforcing national ambient air quality standards).
[111] 42 U.S.C. § 7411(d)(2)(A).
[112] Federal Plan Requirements for Municipal Solid Waste Landfills That Commenced Construction On or Before July 17, 2014, and Have Not Been Modified or Reconstructed Since July 17, 2014, 86 Fed. Reg. 27,756, 27,759 (May 21, 2021).
[113] Maryland Code, Environmental Article, § 2-1204.1.
[114] MDE, *supra* note 109, at 17–18.
[115] See the EIP report prepared by Benjamin Kunstman, Staff Engineer, On Municipal Solid Waste Landfill Flaring Survey And Appendices A-C (October 9, 2020), Attachment B to EIP's October 15, 2020 Comments to MDE on the landfill methane regulation process, *available at* https://mde.maryland.gov/programs/Regulations/air/Documents/MWC_Comment_Letters_092020/FINAL%20EIP%20Landfill%20Methane%20Comments%20to%20MDE%20w%20attachments%2010.15.20.pdf.
[116] Specifically, the EPA allows use of "passive" gas collection systems, which rely on gravity and do not use vacuum technology to suck gas into the pipes, under certain circumstances. *See, e.g.*, 40 C.F.R. § 60.33f(b)(3). California does not allow such systems and requires that a vacuum be created. 17 C.C.R. § 95464(b)(1)(C).
[117] 17 C.C.R. § 95464(b)(1)(B) (requiring that the system be operated "so that there is no landfill gas leak that exceeds 500 ppm[] [of methane]"; 17 C.C.R. § 95469(b)(3) (requiring that system components under positive pressure must be monitored quarterly for leaks and leaks must be repaired within 10 days).
[118] *See* MDE, Addressing Methane from Landfills, at 14 (Mar. 31, 2017), *available at* https://mde.maryland.gov/programs/Regulations/air/Documents/LandfillPresentation03312017.pdf.
[119] MDE, *supra* note 85, Appendix G.
[120] Ibid, 48.
[121] Ibid, 57.
[122] Ibid.
[123] MDE, Organics Diversion and Composting (last accessed June 1,2021), *available at* https://mde.maryland.gov/programs/LAND/RecyclingandOperationsprogram/Pages/composting.aspx.
[124] Howard County, Composting Facility (last accessed May 31, 2021), *available at* https://www.howardcountymd.gov/Departments/Public-Works/Bureau-Of-Environmental-Services/Alpha-Ridge-Landfill/Pilot-Compost-Facility.
[125] Prince George's County, Prince George's Organics Composting Facility (last accessed May 31, 2021), *available at* https://www.princegeorgescountymd.gov/583/Yard-Waste-Composting-Facility.
[126] Wheelabrator Technologies, Wheelabrator Baltimore (last accessed May 31, 2021), *available at* https://www.wtienergy.com/plant-locations/energy-from-waste/wheelabrator-baltimore.
[127] Darryl Fears, Washington Post, This Baltimore 20-year-old just won a huge international award for taking out a giant trash incinerator, (April 18, 2016), *available at* https://www.washingtonpost.com/news/energy-environment/wp/2016/04/18/this-baltimore-20-year-old-just-won-a-huge-international-award-for-taking-out-a-giant-trash-incinerator/.
[128] Fern Shen, Baltimore Brew, Battle over South Baltimore trash incinerator re-igniting (Aug 30, 2012), *available at* https://www.baltimorebrew.com/2012/08/30/battle-over-proposed-south-baltimore-trash-incinerator-re-igniting/.
[129] EIP, Waste-to-Energy: Dirtying Maryland's Air by Seeking a Quick Fix on Renewable Energy?, at i–10 (Oct. 2011), *available at* https://environmentalintegrity.org/wp-content/uploads/2016/11/FINALWTEINCINERATORREPORT-101111.pdf.

Attachment 1

Greenhouse Gas Emissions and Characteristics of Maryland's Landfills[1]

Locations and Greenhouse Gas Emissions of Maryland's Gas-Producing Landfills
(Emissions Presented in Units of Tons of Carbon Dioxide Equivalents)



Summary of Individual Landfill Locations, Characteristics, and Greenhouse Gas Emissions

Landfill	County	Address	Active or Closed	Ownership Status	Gas Collection System Efficiency	Carbon Dioxide Emissions (tons)	Methane Emissions (tons)	20-Year Effect of Methane (GWP of 86)		100-Year Effect of Methane (GWP of 34)	
								Methane Emissions (tons CO2e)	Total GHGs (tons CO2e)	Methane Emissions (tons CO2e)	Total GHGs (tons CO2e)
Alpha Ridge	Howard	2350 Marriottsville Rd, Marriottsville	Active	County	41%	10,728	1,513	130,131	140,859	51,447	62,175
Annapolis	Anne Arundel	North River Rd, Annapolis	Closed	City	No system	1,485	487	41,889	43,374	16,561	18,046
Appeal	Calvert	401 Sweetwater Rd, Lusby	Active	County	No system	1,714	562	48,344	50,058	19,113	20,827
Barstow	Calvert	350 Stafford Rd, Prince Frederick	Closed	County	No system	1,271	417	35,859	37,130	14,177	15,448
Beulah, 1 & 2	Dorchester	6815 East New Market-Ellwood Rd, Hurlock	Active	County	30%[2]	9,097	1,616	138,983	148,080	54,947	64,044
Brown Station, A & B[3]	Prince George's	3500 Brown Station Rd, Upper Marlboro	Active	County	67%	86,066	6,129	527,072	613,138	208,377	294,443
Cecil County	Cecil	758 East Old Philadelphia Rd, Elkton	Active	County	63%	20,383	1,602	137,805	158,189	54,481	74,864
Charles County	Charles	12305 Billingsley Rd, Waldorf	Active	County	70%	25,104	1,590	136,733	161,837	54,057	79,161
Eastern	Baltimore County	6259 Days Cove Rd, White Marsh	Active	County	64%	29,709	2,826	243,018	272,728	96,077	125,786
Fort Detrick	Frederick	Rocky Springs Rd, Frederick	Active	Federal	No system	185	61	5,228	5,414	2,067	2,252
Fort Meade	Anne Arundel	Lokus Rd, Odenton	Closed	Federal	No system	2,419	794	68,251	70,670	26,983	29,402
Forty West	Washington	12630 Earth Care Rd, Hagerstown	Active	County	No system	17,320	5,680	488,471	505,791	193,117	210,437

Landfill	County	Address	Active or Closed	Ownership Status	Gas Collection System Efficiency	Carbon Dioxide Emissions (tons)	Methane Emissions (tons)	20-Year Effect of Methane (GWP of 86)		100-Year Effect of Methane (GWP of 34)	
								Methane Emissions (tons CO2e)	Total GHGs (tons CO2e)	Methane Emissions (tons CO2e)	Total GHGs (tons CO2e)
Garrett County	Garrett	3118 Oakland Sang Run Rd, Oakland	Active	County	No system	2,435	799	68,693	71,128	27,158	29,593
Glen Burnie	Anne Arundel	100 Dover Rd NE, Glen Burnie	Closed	County	No system	4,544	673	57,859	62,402	22,874	27,418
Gude	Montgomery	600 East Gude Dr, Rockville	Closed	County	95%	12,472	192	16,499	28,970	6,523	18,995
Hancock	Washington	6502 Hess Rd, Hancock	Closed	County	No system	244	80	6,877	7,121	2,719	2,963
Harford	Harford	3241 Scarboro Rd, Street	Active	County	38%	8,425	1,268	109,066	117,491	43,119	51,544
Hoods Mill	Carroll	7901 Kabik Ct, Woodbine	Closed	County	No system	1,138	373	32,098	33,236	12,690	13,828
Midshore I Regional	Talbot	7341 Barkers Landing Rd, Easton	Closed	County	45%	13,036	1,691	145,407	158,443	57,487	70,523
Midshore II Regional	Caroline	12236 River Rd, Ridgely	Active	County	No system	4,241	1,391	119,660	123,901	47,308	51,549
Millersville	Anne Arundel	389 Burns Crossing Rd, Severn	Active	County	77%	41,239	1,950	167,672	208,912	66,289	107,528
Mountainview	Allegany	13300 New George's Creek Rd, Frostburg	Closed	Private	62%	19,134	1,574	135,344	154,478	53,508	72,642
Newland Park	Wicomico	6948 Brick Kiln Rd, Salisbury	Active	County	55%	19,657	1,976	169,973	189,629	67,199	86,855
Nicholson	Kent	23750 Earl Nicholson Rd, Chestertown	Closed	County	No system	1,014	333	28,615	29,629	11,313	12,327
Norris Farms	Baltimore County	101 Norris Ln, Baltimore	Closed	Private	95%	24,180	246	21,159	45,339	8,365	32,545

Landfill	County	Address	Active or Closed	Ownership Status	Gas Collection System Efficiency	Carbon Dioxide Emissions (tons)	Methane Emissions (tons)	20-Year Effect of Methane (GWP of 86)		100-Year Effect of Methane (GWP of 34)	
								Methane Emissions (tons CO2e)	Total GHGs (tons CO2e)	Methane Emissions (tons CO2e)	Total GHGs (tons CO2e)
Northern	Carroll	1400 Baltimore Blvd, Westminster	Active	County	5%	3,743	1,118	96,191	99,934	38,029	41,772
Oaks	Montgomery	6001 Olney Laytonsville Rd, Gaithersburg	Closed	County	93%	23,870	454	39,051	62,921	15,439	39,309
Pisgah	Charles	6645 Mason Springs Rd, La Plata	Closed	County	Unknown efficiency[4]	3,567	1,170	100,620	104,187	39,780	43,347
Quarantine Road	Baltimore City	6100 Quarantine Rd, Baltimore	Active	City	38%	30,344	4,595	395,204	425,548	156,243	186,588
Reich's Ford, A & B	Frederick	9031 Reichs Ford Rd, Frederick	Active	County	53%[5]	16,426	1,705	146,634	163,061	57,972	74,398
Resh Road	Washington	13300 Greencastle Pike, Hagerstown	Closed	County	No system	1,996	655	56,316	58,312	22,265	24,261
Round Glade	Garrett	3118 Oakland Sang Run Rd, Oakland	Closed	County	No system	1,619	531	45,666	47,285	18,054	19,673
Saint Andrews	Saint Mary's	44825 St. Andrews Church Rd, California	Closed	County	No system	3,343	1,096	94,273	97,616	37,271	40,614
Sandy Hill	Prince George's	9500 Old Laurel Bowie Rd, Bowie	Closed	County	94%	38,148	463	39,777	77,925	15,726	53,874
Solley Road	Anne Arundel	7890 Solley Rd, Glen Burnie	Closed	Private	95%	3,131	32	2,740	5,871	1,083	4,215
Somerset County	Somerset	8716 James Ring Rd, Westover	Active	County	No system	2,124	697	59,915	62,039	23,687	25,811
Sudley Road	Anne Arundel	5400 Nutwell Sudley Rd, Deale	Closed	County	No system	1,754	575	49,466	51,220	19,556	21,310
Vale Summit	Allegany	Junction of Cabin Run Rd & Rt. 36, Frostburg	Closed	County	No system	2,782	913	78,484	81,266	31,028	33,810

Landfill	County	Address	Active or Closed	Ownership Status	Gas Collection System Efficiency	Carbon Dioxide Emissions (tons)	Methane Emissions (tons)	20-Year Effect of Methane (GWP of 86)		100-Year Effect of Methane (GWP of 34)	
								Methane Emissions (tons CO2e)	Total GHGs (tons CO2e)	Methane Emissions (tons CO2e)	Total GHGs (tons CO2e)
Westover	Somerset	8716 James Ring Rd, Westover	Closed	County	No system	1,062	348	29,969	31,031	11,848	12,910
Worcester County	Worcester	7091 Central Site Ln, Newark	Active	County	0.77%[6]	4,366	1,410	121,279	125,645	47,948	52,314
TOTALS[7]					**59% (avg.)**	**495,516**	**51,585**	**4,436,294**	**4,931,810**	**1,753,884**	**2,249,399**

[1] All of the information presented here is from 2017, the most recent year for comprehensive data is available.
[2] The gas collection system at the Beulah Landfill only covers the "New Beulah" or "Beulah 2" section of the landfill, which opened in 1996. The collection efficiency presented here accounts for this.
[3] The four landfills highlighted in orange (Brown Station Road, Eastern, Millersville, and Sandy Hill) are the only landfills in Maryland that are required to operate gas collection systems under EPA's federal landfill regulations.
[4] The Pisgah Landfill has a gas collection system that routes gas to a flare. EIP was not able to obtain information on the collection efficiency of this system. MDE's 2017 inventory of greenhouse gases does not contain any information on the system.
[5] The Reich's Ford gas collection system does not collect gas from Cell B-3 of the landfill, which is currently accepting waste. It does cover Cell A and the other parts of Cell B. The collection efficiency presented here accounts for this.
[6] The gas collection system at the Worcester County Central Landfill only collects gas from Cells 2 and 3 of the landfill, which are much smaller and produce much less gas than Cells 1 and 4, from which gas is not collected. The collection efficiency presented here accounts for this.
[7] Totals do not match the sum of the values in each column exactly due to independent rounding. This in no way affects the accuracy of the results presented here.

Attachment 2

Errors Affecting the Official State Estimates of Methane and Carbon Dioxide Emissions from Maryland's Landfills[1]

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
All landfills	When calculating the amount of methane that was eliminated by surface oxidation at each landfill, MDE inverted the relevant values and estimated that 90% of the methane that could be eliminated by surface oxidation was eliminated, when instead surface oxidation only eliminates an estimated 10% of methane.	0	-28,629 [3]	-2,462,110	-2,462,110
All landfills with gas collection systems	MDE calculated the total amount of methane eliminated by surface oxidation by determining the amount of methane eliminated at individual landfills and then adding these amounts together. Even if MDE had not made the error described above. MDE should have added together the methane eliminated at every individual landfill to get the total. Instead, MDE excluded landfills that have a gas collection system when it added the methane removed via surface oxidation at individual landfills.[4]	0	2,632	226,378	226,378

[1] All values expressed in units of carbon dioxide equivalents ("CO2e") in this table were calculated using a global warming potential ("GWP") of 86 for methane to account for the warming effects of methane over a 20-year period.

[2] CO2e values do not match the values presented in tons multiplied by the GWP of 86 exactly because the values presented in tons are independently rounded for purposes of this table and EIP did not round the tonnage values in its calculations of CO2e. This does not affect the accuracy of the values presented.

[3] This value isolates the effect of the 90%/10% oxidation inversion error and assumes that all other numbers in the Maryland Department of the Environment's (MDE's) 2017 Greenhouse Gas Inventory (2017 Inventory) are correct.

[4] The 11 landfills with gas collection systems that MDE excluded were Alpha Ridge; Brown Station Road; Cecil County; Eastern; Millersville; Mountainview; Newland Park; Northern; Quarantine Road; Reich's Ford, Cells A and B; and Worcester County, Cells 1 and 4. In addition, MDE did not

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
All landfills with gas collection systems	When estimating the amount of carbon dioxide emitted by control devices, MDE failed to add in the carbon dioxide emitted by non-boiler landfill-gas-to-energy devices.	-149,327	0	0	-149,327
All landfills	MDE failed to include carbon dioxide that was generated by the decomposition of organic materials in the landfills.	-270,381	0	0	-270,381
All landfills	MDE should have calculated the amount of carbon dioxide that was produced from the combustion of methane in control devices using a different method. MDE should have multiplied the amount of methane that was combusted by 2.75 (the molar ratio of methane to carbon dioxide) to reach this value.	125,919	0	0	125,919
Oaks, Kent County	MDE included a landfill in the 2017 Inventory that does not appear to exist: the Oaks Landfill in Kent County.	19,410	6,366	547,450	566,860
Midshore I	MDE failed to include a landfill that does exist: Midshore I Regional Landfill in Talbot County. There are two landfills that form part of the Midshore Regional Solid Waste System, Midshore I and Midshore II. In the 2017 Inventory, MDE mislabeled Midshore II as Midshore I and omitted the real Midshore I, along with its gas collection system, from its calculations altogether.[5]	-13,036	-1,691	-145,407	-158,443

exclude the Sandy Hill Landfill from consideration, even though this landfill has a gas control system. This appears to have been an oversight. Finally, MDE included some landfills that have gas collection systems when aggregating the methane that was eliminated by surface oxidation at individual landfills. Those mistakes and their impacts are addressed in the list of landfill-specific errors below.

[5] All available information indicates that Midshore I is still emitting methane and carbon dioxide. MDE's 2014 GHGs inventory shows that the landfill was still a large source of methane emissions that year. LandGEM, in combination with facility-specific waste disposal data from EPA's Greenhouse Gas Reporting Program, indicates that the landfill was still generating large amounts of methane (3,117.1 tons) and carbon dioxide (8,552.7 tons) in 2017; and

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
Glen Burnie	MDE failed to include this facility in the 2017 Inventory.	-4,544	-673	-57,859	-62,402
Norris Farms	MDE failed to include this facility and its gas collection system in the 2017 Inventory.	-24,180	-246	-21,159	-45,339
Solley Road	MDE failed to include this facility and its gas collection system in the 2017 Inventory.	-3,131	-32	-2,740	-5,871
Oaks, Montgomery County	MDE failed to include methane and carbon dioxide generated by the real Oaks landfill in Montgomery County. MDE did, however, factor the impacts of this landfill's gas collection system into its emissions estimates.	-12,430	-4,499	-386,915	-399,345
	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	10	861	861
Gude	MDE failed to include methane and carbon dioxide generated by the Gude landfill. As with the Oaks Landfill, MDE did factor the impacts of this landfill's gas collection system into its emissions estimates.	-6,443	-2,336	-200,860	-207,303
	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the	0	1	127	127

the ECR for the LFGTE project that combusts gas from the landfill, the Easton Utilities facility, shows that the LFGTE project continued to receive significant amounts of gas in 2017.

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
	landfill-specific emission factors in EPA's AP-42 factors.				
Cecil County Central	MDE underestimated the amount of methane and carbon dioxide that the landfill generated using EPA's LandGEM model. It is not clear why EIP obtained different values using LandGEM than MDE did for this landfill, though MDE may have only included methane and carbon dioxide generated by the horizontal expansion of the landfill that was completed in 2017 and excluded methane and carbon dioxide generated by the rest of the landfill.	-12,492	-4,388	-377,342	-389,834
	MDE overestimated the amount of gas that was collected by the landfill's gas collection system. It mistakenly treated the amount of gas flowing through the system, 538 cubic feet per minute, as if the value were expressed in units of million cubic feet per year.[6] The correct flow rate is 282.7728 million cubic feet per year, not 538 million cubic feet per year.	7,088	-2,526	-217,229	-210,141
Reich's Ford, Cells A & B	MDE underestimated the amount of methane and carbon dioxide that the landfill generated using EPA's LandGEM model.	-6,088	-2,040	-175,439	-181,527
	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	5	446	446

[6] Cecil County Department of Public Works, 2017 Emissions Certification Report, at 42 (Calculation Worksheet, Sheet 1 of 4) (Mar. 2018).

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
	The control device at the landfill destroys methane with an estimate efficiency of 98.2%. MDE should have accounted for this in its calculations	0	21	1,774	1,774
Reich's Ford, Cell B-3	MDE underestimated the amount of carbon dioxide that the landfill generated using EPA's LandGEM model.	-83	0	0	-83
Millersville	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	80	6,858	6,858
Fort Meade	MDE underestimated the amount of methane and carbon dioxide that the landfill generated using EPA's LandGEM model. It is not clear to us why EIP obtained a different value using LandGEM than MDE did for this landfill.	-1,580	-518	-44,575	-46,155
Charles County	MDE did not factor in the landfill's gas collection system when calculating the amount of methane that was eliminated by surface oxidation.	0	-379	-32,568	-32,568
	Although MDE mistakenly treated this landfill as if it lacked a gas collection system when calculating methane eliminated via surface oxidation, it did factor in the collection system for purposes of subtracting methane removed by the collection system and for estimating the amount of carbon dioxide that the system emitted. However, at this step, MDE's estimate of the amount of gas collected by the landfill's collection system was too high. MDE treated the total methane generated by the landfill as if it was the amount of methane that was collected by the gas collection system.	-2,933	1,045	89,877	86,944

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
New Beulah (or "Beulah 2")	MDE underestimated the amount of methane and carbon dioxide that the landfill generated using EPA's LandGEM model.	-967	-317	-27,245	-28,212
	MDE did not factor in the landfill's gas collection system when calculating the amount of methane that was eliminated by surface oxidation.	0	-78	-6,703	-6,703
	MDE did not factor in the landfill's gas collection system when calculating the total amount of methane that was eliminated by gas collection systems, or the carbon dioxide that resulted.	-2,112	753	64,734	62,622
Harford	MDE underestimated the amount of methane and carbon dioxide that the landfill generated using EPA's LandGEM model. It is not clear why EIP obtained a different value using LandGEM than MDE did for this landfill.	-283	-93	-7,972	-8,255
	MDE did not factor in the landfill's gas collection system when calculating the amount of methane that was eliminated by surface oxidation.	0	-85	-7,325	-7,325
	MDE did not factor in the landfill's gas collection system when calculating the total amount of methane that was eliminated by gas collection systems, or the carbon dioxide that resulted.	-2,310	823	70,783	68,473
Worcester County Central	MDE failed to account for methane and carbon dioxide emissions from Cells 2 and 3 of the Worcester County Central Landfill, and also failed to account for the gas collection system at these cells.	-71	-2	-148	-219
	MDE treated Cells 1 and 4 of the landfill, which generate large amounts of methane and carbon dioxide, as if they had a gas collection system operating at 80% efficiency. There is not a gas collection system operating at those cells. This affected MDE's estimate of the amount of	0	125	10,767	10,767

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
	methane that surface oxidation eliminated at Cells 1 and 4. It also affected the estimate of the amount of carbon dioxide that was not collected and emitted from the landfill's surface.				
Newland Park	MDE did not factor in the landfill's gas collection system when calculating the amount of methane that was eliminated by surface oxidation. MDE did factor in the collection system when estimating the amount of methane that was collected and sent to control devices.	0	-254	-21,882	-21,882
	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	27	2,348	2,348
Northern	MDE did not factor in the landfill's gas collection system when calculating the amount of methane that was eliminated by surface oxidation. MDE did factor in the collection system when estimating the amount of methane that was collected and sent to control devices.	0	-6	-533	-533
Quarantine Road	MDE used incorrect values to represent the amount of landfill gas that was flowing to the flare and the landfill-gas-to-energy ("LFGTE") project fueled by the landfill's gas. 8.38 million cubic feet of gas flowed to the flare in 2017 and 215.6 million cubic feet per year flowed to the LFGTE project,[7]	-5	1	92	87

[7] Baltimore City Department of Public Works, 2017 Emission Certification Report, Quarantine Road Sanitary Landfill, at 18 (Page 1 of the 2017 Emissions Calculations) (Mar. 2018).

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
	but MDE used values of 12.81 and 211.04, respectively. It is not clear where MDE obtained these values.				
	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	36	3,113	3,113
Sandy Hill	MDE underestimated the amount of methane generated by the landfill.	0	-2,315	-199,104	-199,104
	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	185	15,889	15,889
Eastern	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	40	3,431	3,431
Brown Station Road	To calculate the methane that escaped from the control devices at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	88	7,555	7,555

Facility Affected	Error	Effect of Error on Carbon Dioxide Estimate (tons)	Effect of Error on Methane Estimate (tons)	Effect of Error on Methane Estimate (tons of carbon dioxide equivalents)[2]	Effect of Error on Total GHGs Estimate (tons of carbon dioxide equivalents)
Alpha Ridge	To calculate the methane that escaped from the control device at this landfill, MDE used an emission factor from EPA's AP-42 factors that only applies to lean-burn, four-stroke engines that burn natural gas. MDE should have used the landfill-specific emission factors in EPA's AP-42 factors.	0	2	202	202
TOTALS[8]		**- 359,978**	**- 38,866**	**- 3,342,442**	**- 3,702,420**

[8] These totals do not match the sum of each column exactly because the values presented in the table are independently rounded. This does not affect the accuracy of the values presented here.