Regulatory Impact Analysis for the Final Revisions to the Emission Guidelines for Existing Sources and the Final New Source Performance Standards in the Municipal Solid Waste Landfills Sector

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Regulatory Impact Analysis for the Final Revisions to the Emission Guidelines for Existing Sources and the Final New Source Performance Standards in the Municipal Solid Waste Landfills Sector

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EXECUTIVE SUMMARY

ES.1 Background

The U.S. Environmental Protection Agency (EPA) is finalizing revisions to the Emission Guidelines for existing Municipal Solid Waste Landfills (MSW landfills). The EPA is not statutorily obligated to conduct a review of the Emission Guidelines (EG), but has the discretionary authority to do so when circumstances indicate that this is appropriate. Based on changes in the landfills industry and changes in size, ownership, and age of landfills since the Emission Guidelines were promulgated in 1996, the EPA has concluded that it is appropriate to review the landfills Emission Guidelines at this time. Since the 1980s, the number of active MSW landfills in the United States has decreased by approximately 75 percent and the share of sites that are publicly owned has also decreased substantially. The overall volume of disposal capacity has remained fairly constant, indicating a trend of growing individual landfill capacity at landfill sites. Based on our review of the existing MSW landfill industry, we are finalizing a lower annual non-methane organic compound (NMOC) emissions threshold of 34 megagrams[1] per year (Mg/year) (reduced from 50 Mg/year).

In addition, the EPA is finalizing New Source Performance Standards (NSPS) for new or modified Municipal Solid Waste Landfills. On July 17, 2014, the EPA proposed a new NSPS subpart that retained the same design capacity size threshold of 2.5 million meters cubed (m^3) or 2.5 million Mg, but presented several options for revising the NMOC emission rate at which a MSW landfill must install controls. Since presenting these options, the EPA has updated its model that estimates the emission reduction and cost impacts based on public comments and new data. As a result of these data and model improvements, we `proposed to lower the annual NMOC emissions threshold from 50 Mg/year to 34 Mg/year in a supplemental proposal published August 27, 2015. This action finalizes the design capacity size threshold of 2.5 million m^3or 2.5 million Mg and the annual NMOC emission threshold of 34 Mg/year.

[1] Note that 1 megagram is equivalent to 1 metric ton. These terms may be used interchangeably in this RIA.

ES.2 Results for Final Revisions to Emission Guidelines

For the final revisions to the Emission Guidelines for existing MSW landfills, the key results of the RIA are summarized in Tables ES-1 through ES-3 and presented in more detail in chapters 3 (emission reductions and emission control costs), 4 (benefits), and 6 (comparison of benefits and costs). The analysis focuses on emission reductions, benefits and emission control costs results for the year 2025; see Table ES-1. However, additional data are provided for alternative analysis years of 2020, 2030 and 2040 for the final EG and regulatory alternatives (Table ES-2 and chapters 3, 4, and 6). In addition, a net present value analysis of the final EG is presented in chapters 3, 4, and 6 of this RIA and summarized in Table ES-3. Table ES-1 shows that the final EG result in net benefits to society in 2025. Likewise, Table ES-2 indicates that benefits exceed costs in each of the alternative years of analysis. EPA notes that the costs shown in Table ES-2 do not include testing and monitoring, and the benefits do not account for secondary CO_2 emission reductions. Table ES-3 shows the present value of annual costs, benefits and net benefits over the period 2019 through 2040 and demonstrates that benefits exceed costs for the period on a net present value basis. Methane reductions during the period of 2019 through 2040 are estimated to be approximately 6.8 million Mg (170.6 million Mg CO_2-equivalents). The net present value analysis does not include testing and monitoring costs nor does it include benefits associated with secondary CO_2 emission reductions.

Engineering Cost Analysis: To meet the final emission limits, a MSW landfill is expected to install the least cost control for combusting or controlling the landfill gas. The control costs include the costs to install and operate gas collection. For landfills where the least cost control option was an engine, the costs also include installing and operating one or more reciprocating internal combustion engines to convert the landfill gas into electricity. For this action, which tightens the emissions threshold the annualized costs represent the costs compared to no changes to the current Emission Guidelines (i.e., baseline) and include $93 million (7% discount rate) to install and operate gas collection and control systems (GCCS), as well as $0.76 million to complete the corresponding testing and monitoring. These control costs are offset by $39 million in revenue from electricity sales, which is incorporated into the net control costs for certain landfills that are expected to generate revenue by using the landfill gas to produce electricity. Revenue from electricity sales was incorporated into the net control costs using regional forecasted data on electricity prices. The EPA estimated the nationwide incremental annualized compliance cost of the EG in 2025 to be approximately $54 million (2012$) using a 7% discount rate (includes total costs of controls less revenues associated with electricity generated plus testing and monitoring costs). Using a 3% discount rate, the annualized cost prior to consideration of potential revenue from electricity sales is $84 million and these costs are offset by about $42 million in revenues expected from using landfill gas to produce electricity. With a 3% discount rate, the nationwide incremental annualized compliance cost in 2025 is estimated to be about $43 million (2012$).These costs of control also include $0.75 million in testing and monitoring costs (2012$).

Emissions Analysis: In 2025, these final guidelines would achieve reductions of approximately 1,810 Mg NMOC and 0.29 million Mg methane (7.1 million metric tons CO_2-equivalents[2]) compared to the baseline. In addition, the action is expected to result in the net reduction of 277,000 Mg CO_2, due to reduced demand for electricity from the grid as landfills generate electricity from landfill gas.[3] These pollutants are associated with substantial health, welfare and climate effects.

Benefits: The monetized benefits in this RIA include those from reducing 0.29 million Mg methane in 2025, which are valued using the social cost of methane (SC-CH_4), and the secondary reductions in CO_2, which are valued using the social cost of carbon (SC-CO_2). The EPA estimates that, in 2025, the methane reductions from the final guidelines will yield monetized climate benefits of $200 million (2012$) to approximately $1.2 billion (2012$)[4]; the mean SC-CH_4 at the 3% discount rate results in an estimate of about $430 million (2012$) in 2025. The secondary climate benefits associated with the reduction of 277,000 Mg CO_2 are estimated to be $14 million (2012$) in 2025. In addition to these secondary CO_2 impacts, there is a small increase in CO_2 emissions resulting from flaring of methane but they have not been quantified or

[2] A global warming potential of 25 is used to convert methane to CO_2-equivalents.
[3] The reduced demand for electricity from the grid more than offsets the additional energy demand required to operate the control system and the by-product emissions from the combustion of LFG.
[4] The range of estimates reflects four SC-CH_4 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

monetized. Both the CO_2 generated directly from aerobic decomposition in MSW landfills and that created as a result of methane oxidation in the atmosphere would have been generated anyway as a result of natural decomposition of the organic waste materials if they had not been deposited in the landfill (EPA, 2015a) See sections 2.5.2 and 4.2.1 for a detailed qualitative discussion of this impact. The benefits from reducing some air pollutants have not been monetized in this analysis due to data, resource, and methodological limitations, including reducing 1,810 Mg NMOC in 2025 (that includes undetermined amounts of HAPs). We assessed the benefits of these emission reductions qualitatively in sections 4.3, 4.4, and 4.5 of this RIA.

Small Entity Analysis: The EPA certifies that the final Emission Guidelines will not have a Significant Impact on a Substantial Number of Small Entities (SISNOSE) because the guidelines will not impose any requirements on small entities. Specifically, Emission Guidelines established under CAA section 111(d) do not impose any requirements on regulated entities and, thus, will not have a significant economic impact upon a substantial number of small entities.

Economic Impacts: Because of the relatively low net compliance cost of the final guidelines compared to the overall size of the MSW landfill industry, as well as the lack of appropriate economic parameters or models, the EPA is unable to estimate the impacts of the final guidelines on the supply and demand for MSW landfill services. However, the EPA does not believe the guidelines will lead to changes in supply and demand for landfill services or waste disposal costs, tipping fees, or the amount of waste disposed in landfills. Hence, the overall economic impact of the guidelines should be minimal on the affected industries and their consumers.

Table ES-1 Summary of the Monetized Benefits, Costs, and Net Benefits for the Final Emission Guidelines for Existing MSW Landfills in 2025 (millions of 2012$) [1]

	3% Discount Rate	7% Discount Rate
Monetized CH_4 Benefits[2]	**$430**	
Monetized Secondary CO_2 Benefits[1]	**$14**	
Total Compliance Costs[3]	**$43**	**$54**
Compliance expenditures	*$84*	*$93*
Revenues from electricity sales produced with captured LFG	*$42*	*$39*
Net Benefits	**$400**	**$ 390**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient PM2.5, ozone, and HAP concentrations resulting from reduction of 1,810 Mg of NMOC/yr	

[1] Estimates may not sum due to rounding.

[2] Monetized benefits include the climate-related benefits associated with the reduction of 0.29 million Mg/yr methane in 2025 ($430 million, valued using the central value of the social cost of methane, SC-CH_4) and the net reduction of 277,000 Mg/yr of CO_2 ($14 million, valued using the central value of the social cost of carbon, SC-CO_2). For summary purposes, this table shows benefits as the central value of the SC-CH_4 and central value of the SC-CO_2. However, we emphasize the importance and value of considering all four estimates of the SC-CH_4 and the four SC-CO_2 estimates. The SC-CH_4 and SC-CO_2 estimates are calculated with four different values of a one ton reduction (model average at 2.5 percent discount rate, 3 percent, and 5 percent; 95th percentile at 3 percent). The full range of methane and CO_2 benefits is $200 million - $1.2 billion for the final option. We provide climate benefit estimates based on additional discount rates in Section 4.2.

[3] The engineering compliance cost estimates are annualized capital costs plus annual operation and maintenance expenses and are offset by the estimated revenue from electricity sales generated using captured landfill gas. Compliance expenditures also include testing and monitoring costs. Engineering costs are considered a proxy for the social costs of the regulation.

[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

Table ES-2 Summary of the Monetized CH_4–Related Benefits, Costs, and Net Benefits for the Final Emission Guidelines Option 2.5/34 in 2020, 2025, 2030 and 2040 (7% Discount Rate, millions of 2012$)[1]

	2020	2025	2030	2040
Monetized Methane-related Benefits[2]	**$410**	**$430**	**$520**	**$770**
Total Compliance Costs[3]	**$46**	**$53**	**$47**	**$70**
Compliance expenditures	*$110*	*$92*	*$84*	*$123*
Revenues from electricity sales produced with captured LFG	*$64*	*$39*	*$37*	*$53*
Net Benefits	**$360**	**$380**	**$470**	**$700**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient $PM_{2.5}$, ozone, and HAP concentrations resulting from reduction of Mg of NMOC per year[5]			

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of methane in 2020, 2025, 2030 and 2040, valued using the social cost of methane. The social costs of methane estimates are shown at the 3% discount rate. See Chapter 4 for a range of social costs of methane estimates for the four SC-CH_4: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.7 for a complete discussion. Benefits associated with secondary CO_2 emission reductions are not reflected in this table.
[3] The engineering compliance cost estimates are annualized capital costs plus annual operation and maintenance expenses and are reduced by the estimated revenue from electricity sales generated using captured landfill gas. Compliance expenditures do not include testing and monitoring costs. Engineering costs are considered a proxy for the social costs of the regulation.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.
[5] Annual NMOC reductions in Mg/yr are estimated to be approximately 1,990, 1,810, 1,900, and 2,250 for 2020, 2025, 2030 and 2040 respectively.

Table ES-3 Summary of the Net Present Value of Monetized CH_4-Related Benefits, Costs, and Net Benefits for the Final Emission Guidelines for 2019 through 2040 (millions of 2012$)[1]

	Monetized CH_4 Related Benefits 3% Discount Rate[2]	Total Compliance Costs 3% Discount Rate[3]	Total Compliance Costs 7% Discount Rate[3]	Net Benefits 3% Discount Rate	Net Benefits 7% Discount Rate
Net Present Value	$8,400	$680	$620	$7,800	$7,800
Equivalent Annualized Value	$510	$41	$52	$470	$460

[1] Totals may not sum due to rounding.
[2] Monetized methane-related benefits refer to climate-related benefits from methane emission reductions, which are valued using the central SC-CH_4 estimate (average SC-CH_4 at 3 percent). SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years.
[3] Compliance costs represent estimates of the annual operation and maintenance expenses plus the annualized portion of capital costs associated with installation and operation of GCCS to meet the EG for 2019 through 2040. These costs are reduced by estimated electricity sales generated with landfill gas. See section 3.7 and Table 3-17 for a discussion of the components of compliance costs for each year. Estimates of compliance costs shown do not include testing and monitoring.

ES.3 Results for Final New Source Performance Standards

For the New Source Performance Standards for new or modified MSW landfills, the key results of the RIA are summarized in Tables ES-4 through ES-6 and are presented in more detail in chapter 7 (emission reductions, benefits and emission control costs). The analysis focuses on emission reductions, benefits, and emission controls cost results for the year 2025; see Table ES-4. However, additional data are provided for alternative analysis years of 2020, 2030 and 2040 for the final NSPS and regulatory alternatives in Table ES-5 and chapter 7. EPA notes that the costs shown in Table ES-5 do not include testing and monitoring and the benefits do not account for secondary CO_2 emission impacts. In addition, a net present value analysis of the final NSPS is presented in chapter 7 of this RIA and summarized in Table ES-6. The net present value analysis shown in Table ES-6 does not include testing and monitoring nor does it include secondary CO_2 emission impacts. Benefits exceed costs for the NSPS in all of the years evaluated.

Engineering Cost Analysis: To meet the emission limits, a MSW landfill is expected to install the least cost control for controlling or combusting the landfill gas. The control costs include the costs to install and operate gas collection. For landfills where the least cost control option was an engine, the costs also include installing and operating one or more reciprocating internal combustion engines to convert the landfill gas into electricity. Revenue from electricity sales was incorporated into the net control costs using regional forecasted data on electricity prices. The annualized costs also include testing and monitoring costs. For this final action, which tightens the emissions threshold, the annualized costs represent the costs compared to no changes to the current NSPS (i.e., baseline) and include $11 million to install and operate a GCCS, as well as $0.08 million to complete the corresponding testing and monitoring assuming a 7% discount rate. These control costs are offset by $5.1 million in revenue from electricity sales, which is incorporated into the net control costs for certain landfills that are expected to generate revenue by using the landfill gas to produce electricity. The EPA estimated the nationwide incremental annualized compliance cost of the NSPS in 2025 to be $6.0 million (2012$) using a 7% discount rate (includes total costs of control offset by revenues from electricity sales plus testing and monitoring costs). Using a 3% discount rate, the nationwide incremental annualized compliance cost in 2025 is estimated to be $4.8 million (2012$).

Emissions Analysis: In 2025, this final action would achieve reductions of 280 Mg NMOC and 44,000 Mg methane (1.1 Mg CO_2-equivalents[5]) compared to the baseline. This action is also expected to result in secondary air benefits, specifically a decrease of 26,000 Mg CO_2 emissions due to reduced demand for electricity from the grid as new landfills generate electricity from landfill gas.[6] Because less energy is required to operate the GCCS at some landfills than is produced by these landfills through the burning of LFG in engines. These pollutants are associated with substantial health, welfare and climate effects.

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[5] A global warming potential of 25 is used to convert methane to CO_2-equivalents.

[6] The reduced demand for electricity from the grid more than offsets the additional energy demand required to operate the control system and the by-product emissions from the combustion of LFG.

Benefits: The monetized benefits in this RIA include those from reducing 44,000 Mg methane in 2025, which are valued using the social cost of methane (SC-CH_4), and the reductions in CO_2, which are valued using the social cost of carbon (SC-CO_2). The EPA estimates that, in 2025, the final NSPS will yield monetized climate benefits of $31 million (2012$) to approximately $180 million (2012$)[7] from the methane reductions; the mean SC-CH_4 at the 3% discount rate results in an estimate of about $67 million (2012$) in 2025. The climate benefits associated with the reduction of 26,000 Mg CO_2 are estimated to be $1.3 million (2012$) in 2025. In addition to these secondary CO_2 impacts, there is a small increase in CO_2 emissions resulting from flaring of methane but they have not been quantified or monetized. Both the CO_2 generated directly from aerobic decomposition in MSW landfills and that created as a result of methane oxidation in the atmosphere would have been generated anyway as a result of natural decomposition of the organic waste materials if they had not been deposited in the landfill (EPA, 2015a) See sections 2.5.2 and 4.2.1 for a detailed qualitative discussion of this impact. The benefits from reducing some air pollutants have not been monetized in this analysis due to data, resource, and methodological limitations, including reducing 280 Mg NMOC (containing undetermined amounts of HAPs). We assessed the benefits of these emission reductions qualitatively in this RIA.

Small Entity Analysis: The EPA performed a small business impacts analysis for the final NSPS, for the Supplemental Proposed New Source Performance Standards for new or modified MSW landfills, and for the July 2014 proposed NSPS. The EPA certifies that the final rule will not have a Significant Impact on a Substantial Number of Small Entities (SISNOSE). The final standards do not impact a substantial number of small entities, and the impact to these entities are not significant. This topic is discussed in greater detail in Section 7.4.

Economic Impacts: Because of the relatively low net compliance cost of this final standards compared to the overall size of the MSW landfill industry, as well as the lack of appropriate

[7] The range of estimates reflects four SC-CH_4 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

economic parameters or models, the EPA is unable to estimate the impacts of the final standards on the supply and demand for MSW landfill services. However, the EPA does not believe the final standards will lead to changes in supply and demand for landfill services or waste disposal costs, tipping fees, or the amount of waste disposed in landfills. Hence, the overall economic impact of the final standards should be minimal on the affected industries and their consumers.

Table ES-4 Summary of the Monetized Benefits, Costs, and Net Benefits for the Final New Source Performance Standards for MSW Landfills in 2025 (millions of 2012$)[1]

	3% Discount Rate	7% Discount Rate
Monetized Methane-related Benefits[2]	**$67**	
Monetized Secondary CO_2 Benefits[2]	**$1.3**	
Total Costs[3]	**$4.8**	**$6.0**
Compliance expenditures	*$9.3*	*$11*
Revenues from electricity sales produced with captured LFG	*$4.6*	*$5.1*
Net Benefits	**$63**	**$62**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient PM2.5, ozone, and HAP concentrations from reducing 280 Mg of NMOC/yr	

[1] Estimates may not add due to rounding.

[2] Monetized benefits include the climate-related benefits associated with the reduction of 44,000 Mg methane in 2025 ($67 million, valued using the central value of the social cost of methane, SC-CH_4) and the net reduction of 26,000 Mg/yr of CO_2 ($1.3 million, valued using the central value of the social cost of carbon, SC-CO_2). For summary purposes, this table shows benefits as the central value of the SC-CH_4 and central value of the SC-CO_2. However, we emphasize the importance and value of considering all four estimates of the SC-CH_4 and the four SC-CO_2 estimates. The SC-CH_4 and SC-CO_2 estimates are calculated with four different values of a one ton reduction (model average at 2.5 percent discount rate, 3 percent, and 5 percent; 95th percentile at 3 percent). The full range of methane and CO_2 benefits is $31 million - $180 million for the final standards. We provide climate benefit estimates based on additional discount rates in Section 4.2.

[3] The engineering compliance cost estimates are annualized capital costs plus annual operation and maintenance expenses and are offset by the estimated revenue from electricity sales generated using captured landfill gas. Compliance expenditures also include testing and monitoring costs. Engineering costs are considered a proxy for the social costs of the regulation.

[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

Table ES-5 Summary of the Monetized CH_4–Related Benefits, Costs, and Net Benefits for the Final NSPS 2.5/34 in 2020, 2025, 2030 and 2040 (7% Discount Rate, millions of 2012$)[1]

	2020	2025	2030	2040
Monetized Methane-related Benefits[2]	**$64**	**$67**	**$84**	**$130**
Total Costs[3]	**$4.7**	**$6.0**	**$5.8**	**$11.2**
Compliance expenditures	*$14.6*	*$11.0*	*$12.8*	*$15.7*
Revenues from electricity sales produced with captured LFG	*$9.9*	*$5.1*	*$7.0*	*$4.5*
Net Benefits	**$59**	**$61**	**$78**	**$120**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient $PM_{2.5}$, ozone, and HAP concentrations resulting from reduction of Mg of NMOC per year[5]			

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of methane in 2020, 2025, 2030 and 2040, valued using the social cost of methane. The social costs of methane estimates are shown at the 3% discount rate. See Chapter 7 for a range of social costs of methane estimates for the four SC-CH_4: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 7.10.for a complete discussion. Benefits associated with secondary CO_2 emission reductions are not reflected in this table.
[3] The engineering compliance cost estimates are annualized capital costs plus annual operation and maintenance expenses and are offset by the estimated revenue from electricity sales generated using captured landfill gas. Compliance expenditures do not include testing and monitoring costs. Engineering costs are considered a proxy for the social costs of the regulation.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.
[5] Annual NMOC reductions in are estimated to be approximately 310, 280, 310, and 370 Mg/year for 2020, 2025, 2030 and 2040, respectively.

Table ES-6 Estimated Monetized CH_4-Related Benefits, Costs, and Net Benefits of the Final NSPS Option (2.5/34) and Net Present Value (in millions, 2012$)[1]

Year	Monetized CH_4–Related Benefits 3% Discount Rate[2]	Total Costs 3% Discount Rate[3]	Total Costs 7% Discount Rate[3]	Net Benefits 3% Discount Rate	Net Benefits 7% Discount Rate
Net Present Value	$1,300	$84	$73	$1,200	$1,200
Equivalent Annualized Value	$80	$5.1	$6.2	$75	$74

[1] Totals may not sum due to rounding.
[2] Monetized methane-related benefits refer to climate-related benefits from methane emission reductions, which are valued using the central SC-CH_4 estimate (average SC-CH_4 at 3 percent). The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values are shown for the 3% discount central estimate and represent only a partial accounting of climate impacts. See Table 7-27 for additional discount rate estimates of SC-CH_4 benefits. Air quality benefits associated with the NSPS are not reflected in these estimates. See Chapter 4 for more discussion of these benefits. The estimates in this table do not account for the secondary CO_2 impacts.
[3] Compliance costs represent estimates of the annual operation and maintenance expenses plus the annualized portion of capital costs associated with installation and operation of GCCS to meet the NSPS for 2019 through 2040. Costs are presented net of revenues generated from energy produced from the capture of landfill gas. See Table 7-26 for more details. Compliance cost shown do not include testing and monitoring.
Totals may not sum due to rounding.

ES.4 Summary of Emission Guidelines and NSPS Impacts Changes from the Proposal RIA

This section summarizes major changes in the final Emission Guidelines and NSPS from the proposal version of the RIA. These changes were a result of revised model assumptions and methods, as well as changes in the EG and NSPS themselves from proposal. With respect to changes in the rule's provisions from proposal, we focus on changes that have an effect on estimates of emissions reductions, costs, and benefits.

The changes since proposal resulting from revisions to the EG and NSPS that affect emissions, benefits and costs include:

- **Effective date for an existing landfill to be considered closed:** The final Emission Guidelines include an extension of the deadline for closed landfills from August 17, 2015 at proposal to thirteen months after the publication of the final rule[8]. The EPA is providing this extension, because closed landfills do not produce as much LFG as an active landfill. Landfills in the closed subcategory will continue to be subject to an NMOC emission threshold of 50 Mg/yr for determining when controls must be installed or can be removed, consistent with the NMOC thresholds in subparts Cc and WWW of 40 CFR part 60. These closed landfills are also exempt from initial reporting requirements (i.e., initial design capacity, initial NMOC emission rate, GCCS design plan, initial annual report, closure report, equipment removal report, and initial performance test report), provided that the landfill already met these requirements under subparts Cc or WWW of 40 CFR part 60.

- **Testing, monitoring and recordkeeping:** The final guidelines include new rental assumptions for surface monitoring equipment (with enhanced features such as precise location data) and recordkeeping and reporting for leachate recirculation or liquids addition. The testing and monitoring cost estimates presented in this RIA have been adjusted to reflect these changes. EPA also changed some provisions of the Tier 4 approach for determining when a landfill must install GCCS. The EPA has not estimated the testing, recordkeeping and reporting costs for Tier 4 because it is provided as a voluntary means of assessing when GCCS should be installed. The Tier 4 methodology is a new provision; therefore we cannot provide an assumption of the universe of landfills that would actually use Tier 4. The EPA may provide an estimation of the impacts associated with Tier 4 in future reviews of the standards, if such data to conduct an assessment exist. Additionally, costs associated with the recordkeeping requirement to take and store digital photographs of the Tier 4 monitoring are not reflected in the final RIA.

[8] Extending the closed landfill effective date would result in five fewer landfills controlling emissions in 2025 compared to the final EG. This results in fewer emission reductions in 2025 for the final EG as follows: 125 Mg less NMOC and 0.02 million Mg less CH_4 (0.5 million CO2-equivalents Mg). Control costs are reduced approximately $2.2 million (2012$) in 2025 as a result of this change in effective date. Benefits associated with methane reductions in 2025 would also decrease. The amount of the 2025 benefits reduction ranges from $14 million to $80 million, depending on the estimate of the SC-CH_4; using the central SC-CH_4 estimate, benefits are reduced by $30 million.

The changes in the methods and model assumptions that affect emissions, cost, and benefit estimates include:

- **EPA Greenhouse Gas Inventory updates:** The EPA updated the landfill-level cost and emissions analyses where possible to reflect recent updates to the Greenhouse Gas Inventory. In particular, recent data from the Greenhouse Gas Reporting Program[9] (GHGRP) was used to update the landfill inventory used to estimate emission reductions and costs of the final EG and NSPS. About 97% of the landfills expected to control under the EG and 91% of landfills controlling in 2025 currently report to the GHGRP.

- **Collection Efficiency:** The impacts analysis at proposal did not apply a collection efficiency assumption. In consideration of public comments on the August 2015 proposal, a peer review of the LFGCost model, EPA assumptions in subpart HH of the GHGRP, and analyses performed for marginal abatement cost curves, in the final rule the EPA has included an 85 percent average gas collection efficiency factor to reflect a more realistic indicator of GCCS performance in the final EG and NSPS

- **Price forecasts for revenue estimates from the sale of electricity generated with captured landfill gas:** For the final EG and NSPS, the EPA adjusted electricity purchase price and anticipated revenue estimates using forecasted commercial retail electricity rate data and forecasted electricity generation price data for different Energy Information Administration (EIA) Electricity Market Module regions based on EIA's 2015 Annual Energy Outlook (AEO). At proposal, EPA used historical state wholesale estimates of prices as the electricity purchase price to estimate anticipated revenue from the sale of electricity generated with captured landfill gas. Forecasted electricity generation price data more closely reflect prices MSW landfill owner and operators will likely face when making decisions in the future regarding the capture of landfill gas to generate electricity. This approach is also consistent with

[9] Available at: https://www.epa.gov/ghgreporting

recommendations on technical inputs to the LFGcost model used in this analysis from the public as well as the LFGcost model peer review.

- **Emission rate forecasts for estimates of secondary emission impacts:** For the final EG and NSPS, the EPA used forecasted regional emission rates from the EIA 2015 AEO to estimates changes in secondary CO_2 emissions. At proposal, EPA assumed national emission rates for this estimation.

ES.5 Organization of this Report

The remainder of this report details the methodology and the results of the RIA. Chapter 1 provides an introduction. Chapter 2 presents the industry profile for the municipal solid waste landfill industry. Chapter 3 describes emissions, emissions control options, and engineering costs of the Emission Guidelines for existing landfills. Chapter 4 presents estimates of the benefits of emissions reductions from the Emission Guidelines for existing landfills. Chapter 5 present the economic impacts, employment impacts, and small entity screening analysis for the Emission Guidelines for existing landfills. Chapter 6 presents the comparison of the benefits and costs of the Emission Guidelines for existing landfills, Chapter 7 presents an analysis of the final New Source Performance Standards for new or modified MSW landfills, and Chapter 8 concludes with the statutory and executive order reviews.

1 INTRODUCTION

1.1 Background

The EPA is revising the Emission Guidelines (EG) for existing Municipal Solid Waste Landfills (MSW Landfills). The EPA is not statutorily obligated to conduct a review of the Emission Guidelines, but has the discretionary authority to do so when circumstances indicate that this is appropriate. Based on changes in the landfills industry and changes in size, ownership, and age of landfills since the Emission Guidelines were promulgated in 1996, the EPA has concluded that it is appropriate to review the landfills Emission Guidelines at this time. Based on our review, we are lowering the annual non-methane organic compound (NMOC) emissions threshold from 50 Mg/year to 34 Mg/year.

In addition, the EPA is finalizing New Source Performance Standards (NSPS) for new or modified Municipal Solid Waste Landfills. On July 17, 2014, the EPA proposed a new NSPS subpart that retained the same design capacity size threshold of 2.5 million m^3 or 2.5 million Mg, but presented several options for revising the NMOC emission rate at which a MSW landfill must install controls. Since presenting these options, the EPA has updated its model that estimates the emission reduction and cost impacts based on public comments and new data. As a result of these data and model improvements, EPA proposed to lower the annual NMOC emissions threshold from 50 Mg/year to 34 Mg/year in August 27, 2015. The EPA is now finalizing new performance standards for MSW landfills.

In accordance with Executive Order 12866, Executive Order 13563, OMB Circular A-4, and the EPA's "Guidelines for Preparing Economic Analyses," the EPA prepared this RIA for these "significant regulatory actions." These actions are economically significant regulatory actions because they may have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or state, local, or tribal governments or communities.[10] In this RIA, the EPA presents a profile of the municipal solid waste industry in the United States and an analysis of the costs and emission reductions associated with a range of regulatory options, including the option chosen for the final guidelines. The EPA drew upon a comprehensive database of existing landfills for this analysis. However, this dataset was missing some landfill data for recent years (2010-2014) and included incomplete data for many landfills. Thus, model landfills were created to represent the recent landfill data that were not included in the dataset. The model landfills were developed by evaluating the most recently opened existing landfills and assuming that the sizes and locations of landfills opening during 2010-2014 would be similar to the sizes and locations of landfills that opened in the most recent complete 5 years of data (2005-2010). The impacts of the Emission Guidelines for existing MSW landfills shown in this RIA are expressed as the incremental difference between facilities complying with the current Emission Guidelines for existing MSW landfills (40 CFR part 60, subpart Cc) and facilities that would be required to comply with subpart Cf. Likewise, the impacts of the NSPS for new or modified MSW landfills shown in this RIA are expressed as the incremental difference between facilities complying with the current NSPS for new or modified MSW landfills (40 CFR part 60, subpart WWW) and facilities that would be required to comply with subpart XXX. All impacts are shown for the year 2025. In addition, benefit and cost estimates are presented for the years 2020, 2030 and 2040 for the final rule and the regulatory alternatives. The net present value of the stream of benefits and costs for 2019 through 2040 for the final EG and NSPS are also presented. The EPA is assessing impacts in year 2025 as a representative year for the both the landfills Emission Guidelines and the NSPS. The number of existing landfills required to install controls under the final EG of 2.5/34 in year 2025 is the same as the number required to install emission controls in the estimated first year of implementation. Further, year 2025 represents a year in which several of the landfills subject to control requirements have had to expand their GCCS according the expansion lag times set forth in subpart Cf. While the primary analysis focuses on impacts in 2025, benefit and costs results for alternative years for the

[10] The analysis in this draft RIA constitutes the economic assessment required by CAA section 317. In the EPA's judgment, the assessment is as extensive as practicable taking into account the EPA's time, resources, and other duties and authorities.

final EG and NSPS as well as regulatory alternatives are also presented in this document and reflect comparable results.

The EPA certifies that the Emission Guidelines for existing landfills will not have a Significant Impact on a Substantial Number of Small Entities (SISNOSE), because the final guidelines will not impose any requirements on small entities. Specifically, Emission Guidelines established under CAA section 111(d) do not impose any requirements on regulated entities and, thus, will not have a significant economic impact upon a substantial number of small entities. After Emission Guidelines are promulgated, states establish standards on existing sources and it is those state requirements that could potentially impact small entities. The EPA also certifies that the final NSPS for new or modified MSW landfills also will not have a significant impact on a substantial number of small entities (SISNOSE). The revision to the NSPS does not impact a substantial number of small entities, and the impact to these entities are not significant. Impacts to small entities are discussed in greater detail in Section 7.4.

1.2 Statement of Need for Policy Action

1.2.1 Protection of Human Health and the Environment

The EPA has concluded, after reviewing data on MSW landfills, that a review of the Emission Guidelines for existing MSW landfills is appropriate at this time. In addition, the EPA is finalizing New Source Performance Standards for new or modified MSW landfills. To ensure that public health, safety, and the environment are protected, the EPA must ensure that emissions of methane, Volatile Organic Compounds (VOC), and hazardous air pollutants (HAP) from MSW landfills are limited. The pollutant regulated under rules affecting landfills is “MSW landfill emissions”. Municipal solid waste landfill emissions, also commonly referred to as landfill gas (LFG), are a collection of air pollutants, including methane and NMOC, some of which are toxic.[11] The 1996 NSPS/EG regulated NMOC as a surrogate for MSW landfill emissions but also considered significant methane reductions that could be achieved. In this EG and NSPS, we are lowering the annual NMOC emissions threshold from 50 Mg/year to 34 Mg/year. The NMOC portion of LFG can contain a variety of air pollutants, including VOC and various organic HAP. VOC emissions are precursors to both fine particulate matter ($PM_{2.5}$) and ozone formation, while methane is a greenhouse gas and a precursor to global ozone formation. As described in Chapter 4, these pollutants are associated with substantial health effects, climate effects, and other welfare effects. Thus, the final guidelines and NSPS are expected to reduce human morbidity and premature mortality due to exposure to $PM_{2.5}$, in addition to providing human health and ecosystem benefits due to reduced emissions of methane and HAP, and improved visibility due to reduced PM levels.

1.2.2 Need for Regulatory Intervention Because of Market Failure

The U.S. Office of Management and Budget (OMB) directs regulatory agencies to demonstrate the need for a major rule. If the rule is intended to correct a market failure, the regulatory impact analysis must show that a market failure exists and that it cannot be resolved by measures other than Federal regulation. Market failures are categorized by OMB as externalities, market power, or inadequate or asymmetric information. The only of these three categories that applies to MSW landfills is air pollution as an externality, discussed in the following section.

1.2.2.1 Air Pollution as an Externality

Air pollution is an example of a negative externality. This means that, in the absence of government regulation, the decisions of generators of air pollution do not fully reflect the costs associated with that pollution in the price of their product or service. For a MSW landfill

[11] LFG is composed of approximately 50 percent methane, 50 percent CO_2, and less than 1 percent NMOC. (Source: EPA. *Compilation of Air Pollution Emission Factors, Publication AP-42*, Draft Section 2.4 Municipal Solid Waste Landfills. October 2008. Available at http://www.epa.gov/ttn/chief/ap42/ch02/draft/d02s04.pdf.) While this composition is typical of LFG generated from established waste (waste that has typically been in place for at least a year), the quantity and composition of LFG does vary over the lifetime of the landfill. See Section 2.5 for more discussion.

operator, pollution from landfill gas is a by-product that can be ignored or disposed of cheaply by venting it to the atmosphere. Left to their own devices, many MSW landfill operators may choose to treat air as a free good and not internalize the damage cause by emissions. NMOC and Greenhouse Gas (GHG) emissions impose costs on society, such as negative health and welfare impacts that are not reflected in the market price of the MSW landfill services being provided. This damage is borne by society, and the people who are adversely affected by the pollution are not able to collect compensation to offset their costs. They cannot collect compensation because the adverse effects, like odor and increased risks of morbidity and mortality, are by and large non-market goods. That is, they are goods that are not explicitly and routinely traded in organized free markets. The final EG and NSPS will result in reductions in methane, a global pollutant that contributes to climate change. Climate change represents a classic public goods problem because each country's reductions benefit everyone else and no country can be excluded from enjoying the benefits of other countries' reductions, even if it provides no reductions itself. For further discussion of the public good nature of climate change, see section 4.2.1 below. These Emission Guidelines and NSPS are promulgated to correct market failures associated with pollution generated at MSW landfills that lead to a suboptimal allocation of resources within the free market.

1.3 Organization of this Report

The remainder of this report details the methodology and the results of the RIA. Chapter 2 presents the industry profile for the municipal solid waste landfill industry. Chapter 3 describes emissions, emissions control options, and engineering costs of the Emission Guidelines for existing landfills. Chapter 4 presents estimates of the benefits of emissions reductions from the Emission Guidelines for existing landfills. Chapter 5 present the economic impacts, employment impacts, and small entity screening analysis for the Emission Guidelines for existing landfills. Chapter 6 presents the comparison of the benefits and costs of the Emission Guidelines for existing landfills, Chapter 7 presents an analysis of the New Source Performance Standards (NSPS) for new and modified MSW landfills including emission reductions, costs and benefits, and Chapter 8 concludes with the statutory and executive order reviews for the Emission Guidelines and the NSPS.

1.4 References

U.S. Environmental Protection Agency (EPA). 2008. *Compilation of Air Pollution Emission Factors, Publication AP-42*, Draft Section 2.4 Municipal Solid Waste Landfills. October 2008. Available at http://www.epa.gov/ttn/chief/ap42/ch02/draft/d02s04.pdf.

2 INDUSTRY PROFILE

2.1 Introduction

Municipal solid waste (MSW) is the stream of garbage collected by sanitation services from homes, businesses, and institutions. MSW typically consists of metals, glass, plastics, paper, wood, organics, mixed categories, and composite products. The majority of collected MSW that is not recycled is typically sent to landfills—engineered areas of land where waste is deposited, compacted, and covered. The New Source Performance Standards (NSPS) and the state and federal plans implementing the Emission Guidelines (EG) for MSW landfills regulate air emissions from landfills that receive household waste as defined in 40 CFR 60.751. These MSW landfills can also receive other types of waste, such as construction and demolition debris, industrial wastes, or nonhazardous sludge. MSW landfills are designed to protect the environment from contaminants which may be present in the solid waste stream and as such are required to comply with federal Resource Conservation and Recovery Act (RCRA) regulations or equivalent state regulations, which include standards related to location restrictions, composite liners requirements, leachate collection and removal systems, operating practices, groundwater monitoring requirements, closure and post-closure care requirements, corrective action provisions, and financial assurance (EPA, 2016a).

EPA estimates the total amount of MSW generated in the United States in 2013 was approximately 254 million tons, a 22 percent increase from 1990. Despite increased waste generation, the amount of MSW deposited in landfills decreased from about 145 million tons in 1990 to 134 million tons in 2013. This decline is due to a significant increase in the amount of waste recovered for recycling and composting as well as that combusted for energy recovery (EPA, 2015a). The number of active MSW landfills in the United States has decreased from approximately 7,900 in 1988 to approximately 1,800 in 2015 (EPA, 2010; WBJ, 2015).

Landfills are different than many other traditionally regulated emissions source categories. Typically, entities regulated for air emissions are involved in manufacturing or production and their emissions are directly related to processes involved in creating products (e.g., vehicles, bricks) or commodities (e.g., natural gas, oil). When manufacturing or production facilities cease to operate, their emissions typically cease. Landfills are a service industry—a repository for waste that needs to be properly disposed—and their emissions are a by-product of the deposition of that waste. Landfills continue to emit air pollution for many years after the last waste is deposited.

Landfill gas (LFG) is a by-product of the decomposition of organic material in MSW in anaerobic conditions in landfills. LFG contains roughly 50 percent methane and 50 percent carbon dioxide, with less than 1 percent non-methane organic compounds (NMOC) and trace amounts of inorganic compounds. The amount of LFG created primarily depends on the quantity of waste and its composition and moisture content as well as the design and management practices at the site. LFG can be collected and combusted in flares or energy recovery devices to reduce emissions. MSW landfills receive approximately 63 percent of the total waste generated in the United States and produce 95 percent of landfill emissions. The remainder of the emissions is generated by industrial waste landfills (EPA, 2016b).

Entities potentially regulated under Standards of Performance for Municipal Solid Waste Landfills include owners of MSW landfills and owners of combustion devices that burn untreated LFG. Firms engaged in the collection and disposal of refuse in a landfill operation are classified under the North American Industry Classification System (NAICS) codes Solid Waste Landfill (562212) and Administration of Air and Water Resource and Solid Waste Management Programs (924110).

Landfills are owned by private companies, government (local, state, or federal), or individuals. In 2016, 57 percent of active MSW landfills were owned by public entities while 43 percent were privately owned (EPA, 2016c). Affected entities comprise establishments primarily engaged in operating landfills for the disposal of non-hazardous solid waste; or the combined activity of collecting and/or hauling non-hazardous waste materials within a local area and operating landfills for the disposal of non-hazardous solid waste. This industry also includes government establishments primarily engaged in the administration and regulation of solid waste management programs.

Private companies that own landfills range in size from very small businesses to large businesses with billions of dollars in annual revenue. Public landfill owners include cities, counties/parishes, regional authorities, state governments, and the federal government (including military branches, Bureau of Land Management, Department of Agriculture, Forest Service, and Department of the Interior - National Park Service).

2.2 Waste Stream Background

2.2.1 Municipal Waste

2.2.1.1 Generation of MSW

MSW is generally defined as nonhazardous waste from household, commercial, and institutional sources. These three broad categories of primary MSW generators are described as:

- Household – solid waste from single-and multiple-family homes, hotels and motels, bunkhouses, ranger stations, crew quarters, campgrounds, picnic grounds, and day-use recreation areas.
- Commercial – solid waste from stores, offices, restaurants, warehouses, and other nonmanufacturing activities.
- Institutional – solid waste from public works (such as street sweepings and tree and brush trimmings), schools and colleges, hospitals, prisons, and similar public or quasi-public buildings. Infectious and hazardous waste from these generators are managed separately from MSW.

Households are the primary source of MSW, accounting for 55 to 65 percent of total MSW generated, followed by the commercial sector (EPA, 2011). Waste from commercial and institutional locations amounts to 35 to 45 percent of total MSW (EPA, 2011). The industrial sector manages most of its own solid residuals by recycling, reuse, or self-disposal in industrial waste landfills. For this reason industry directly contributes a very small share of the MSW flow, although some industrial waste does end up in MSW landfills.

Various underlying factors influence the trends in the quantity of MSW generated over time. These factors include changes in population, individual purchasing power and disposal patterns, trends in product packaging, and technological changes that affect disposal habits and the nature of materials disposed. Generators of MSW provide most of the demand for services that collect, treat, or dispose of MSW. Fluctuations in the quantity of MSW generated and changes in the cost and pricing structure of disposal services result in varying demand for landfill services.

Most MSW generators are charged a flat fee for disposal services, which can be paid through taxes for household garbage collection. This structure may provide little economic incentive to lower waste disposal or to divert waste through recycling because generators are charged the same price regardless of the quantity of waste disposed. Less common are unit price programs, such as "pay-as-you-throw" (PAYT). In PAYT programs, each unit of waste disposed has an explicit price, such that the total fee paid for MSW services increases with the quantity of waste discarded. Hence, the unit price can act as a disincentive to dispose of excess waste and also encourages recycling (Callan, 2006; Shin, 2014).

2.2.1.2 Landfills Covered Under the Emissions Guidelines

The Landfills EG applies only to landfills that accept "household waste" as defined in 40 CFR 60.751, which states "household waste means any solid waste (including garbage, trash, and sanitary waste in septic tanks) derived from households (including, but not limited to, single and multiple residences, hotels and motels, bunkhouses, ranger stations, crew quarters, campgrounds, picnic grounds, and day-use recreation areas)." Some of the MSW landfills subject to the Landfills EG may also receive other types of wastes, such as commercial, industrial, and institutional solid waste, nonhazardous sludge, and construction and demolition debris.

2.2.1.3 Trends in Per Capita Waste Sent to Landfills

In 2013, Americans generated about 254 million tons of trash. More than 64.7 million tons of this material was recycled and more than 22 million tons was composted, equivalent to a 34.3 percent recycling rate (EPA, 2015a). In addition, about 32.7 million tons of waste was combusted for energy recovery (~13 percent) (EPA, 2015a). After recycling, composting, and combustion with energy recovery, the net per capita discard rate to landfills was 2.32 pounds per person per day in 2013 (EPA, 2015a). This is a 7.5 percent decrease from the 2.51 per capita discard rate in 1960, when minimal recycling occurred in the United States (see Table 2-1).

Since 1990, the total amount of MSW going to landfills has dropped by about 10 million tons, from 145 million to 134 million tons in 2013 (EPA, 2015a). While the number of U.S. MSW landfills has steadily declined over the years, the average landfill size has increased. At the national level, landfill capacity appears to be sufficient, although it is limited in some areas (EPA, 2015a).

Table 2-1 Generation and Discards of MSW, 1960 to 2013 (in pounds per person per day) [12]

Activity	1960	1970	1980	1990	2000	2005	2009	2011	2012	2013
Generation	2.68	3.25	3.66	4.57	4.74	4.69	4.37	4.41	4.38	4.40
Discards to landfill [a]	2.51	3.02	3.24	3.19	2.73	2.63	2.38	2.32	2.31	2.32
Discards to landfill (% of total generation)	94%	93%	89%	70%	58%	56%	54%	53%	53%	53%

[a] Discards after recovery minus combustion with energy recovery. Discards include combustion without energy recovery.

2.2.1.4 Composition of MSW Sent to Landfills

In 2013, organic materials continued to be the largest component of discarded MSW. Yard trimmings and food scraps account for 29.2 percent and paper and paperboard account for another 15.1 percent. Plastics comprise 17.7 percent while metals and wood make up 9.1 percent and 8.0 percent, respectively. Rubber, leather, and textiles combined account for 11.6 percent and glass accounts for 5.0 percent. Other miscellaneous materials account for the remaining 4.4 percent of the MSW discarded in 2013 (EPA, 2015a). Figure 2-1 displays material composition percentages of the MSW discard stream in 2013, and Table 2-2 shows the amounts of different materials discarded in the MSW stream from 1960 to 2013.

[12] Table adapted from U.S. Environmental Protection Agency. June 2015. “Advancing Sustainable Materials Management: Facts and Figures 2013.” Table ES-1. EPA-530-R-15-002. Washington, DC: U.S. EPA. <https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_rpt.pdf>. Accessed May 20, 2016.

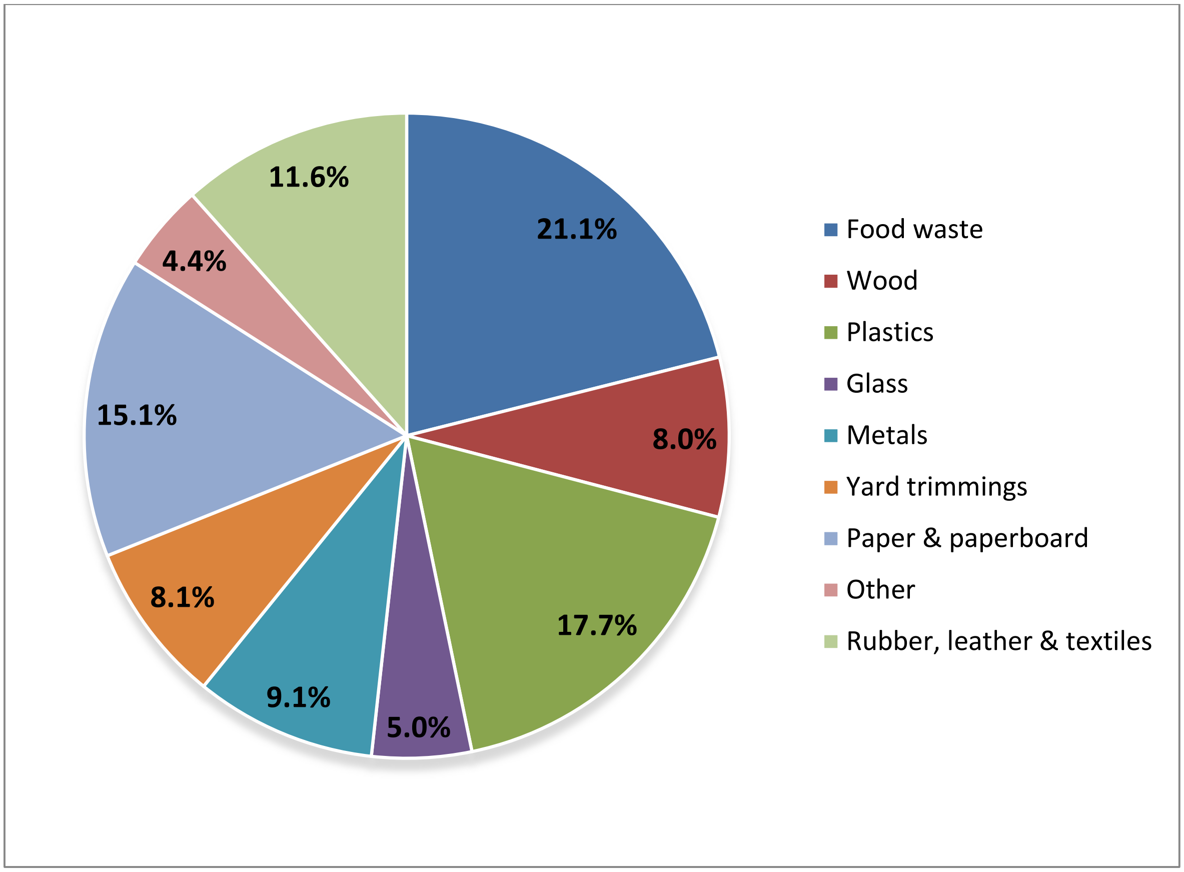


Figure 2-1 Material Composition of the MSW Discard Stream, 2013[13]

[13] Figure adapted from U.S. Environmental Protection Agency. June 2015. "Advancing Sustainable Materials Management: Facts and Figures 2013." Figure ES-5. EPA-530-R-15-002. Washington, DC: U.S. EPA. <https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_rpt.pdf>. Accessed May 20, 2016.

Table 2-2 Materials Discarded[a] In the MSW Stream, 1960 to 2013 (in thousands of tons)[14]

Wastes	1960	1970	1980	1990	2000	2005	2012	2013
Paper and Paperboard	24,910	37,540	43,420	52,500	50,180	42,880	24,260	25,200
Glass	6,620	12,580	14,380	10,470	9,890	9,950	8,380	8,390
Metals	10,770	13,350	14,290	12,580	12,340	13,410	14,660	15,190
Plastics	390	2,900	6,810	16,760	24,070	27,600	29,140	29,520
Rubber and Leather	1,510	2,720	4,070	5,420	5,850	6,240	6,300	6,480
Textiles	1,710	1,980	2,370	5,150	8,160	9,680	12,110	12,830
Wood	3,030	3,720	7,010	12,080	12,200	12,960	13,410	13,300
Other Materials[b]	70	470	2,020	2,510	3,020	3,080	3,250	3,270
Food Waste	12,200	12,800	13,000	23,860	30,020	32,240	34,690	35,220
Yard Trimmings	20,000	23,200	27,500	30,800	14,760	12,210	14,370	13,600
Miscellaneous Inorganic Wastes	1,300	1,780	2,250	2,900	3,500	3,690	3,900	3,930
Total MSW Discarded	82,510	113,040	137,120	175,030	173,990	173,940	164,470	166,930

[a] Discards after materials and compost recovery. In this table, discards include combustion with energy recovery. Does not include construction and demolition debris, industrial process wastes, or certain other wastes.

[b] Includes electrolytes in batteries and fluff pulp, feces, and urine in disposable diapers. Details may not add to totals due to rounding.

2.2.2 Consolidation of Waste Streams

Collection and transportation are necessary components of all MSW management systems regardless of the specific disposal options. Collections of MSW vary by service arrangements between local governments and collectors and by level of service provided to households. Depending on the arrangement type and other considerations for particular jurisdictions, MSW being sent to landfills may be deposited in a local landfill or routed to a regional landfill through a transfer process. Local landfills are generally located in the

[14] Table adapted from U.S. Environmental Protection Agency. June 2015. "Advancing Sustainable Materials Management: Facts and Figures 2013." Table 3. EPA-530-R-15-002. Washington, DC: U.S. EPA. <https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_rpt.pdf>. Accessed May 20, 2016.

communities in which they serve whereas regional landfills are often located outside of the communities they serve and receive waste from several cities and towns.

Solid waste transfer is the process in which collection vehicles unload their waste at centrally located transfer stations. Transfer stations can minimize hauling costs by decreasing the number of drivers and vehicles hauling waste to disposal sites and reducing the turn-around time of vehicles because they do not have to haul waste to distant regional landfills. Smaller loads are consolidated into larger vehicles, usually tractor-trailer trucks, trains, or barges, which are better suited for the long-distance hauls often required to reach the final disposal site, often a regional landfill. As public opposition to local MSW disposal facilities increases and the cost of disposal at locations near generators rise, long-distance hauls to regional landfills are becoming more common.

2.3 Disposal Facility Background

2.3.1 Technical Background on Landfills as a Source Category

An MSW landfill refers to an area of land or an excavation where MSW is placed for permanent disposal. MSW landfills do not include land application units, surface impoundments, injection wells, or waste piles. Modern MSW landfills are well-engineered disposal facilities that are sited, designed, operated, and monitored to protect human health and the environment from pollutants that may be present in the solid waste stream (EPA, 2016a).

2.3.1.1 Landfill Siting and Permitting

MSW landfills are required to comply with federal regulations contained in Subtitle D of RCRA [40 CFR part 258], or equivalent state regulations. RCRA requirements include location restrictions that ensure landfills are constructed away from environmentally-sensitive areas, including fault zones, wetlands, flood plains, or other restricted areas (EPA, 2016a). Site selection for landfills is an integral part of the design process.

Construction and operating permit applications for new landfills must be submitted to and approved by state and local regulatory agencies as part of the siting and design process. Often, states require a registered professional engineer to design the landfill (Guyer, 2009). Additional permits must be issued for each expansion of the landfill from its originally permitted waste design capacity and footprint area. New or modified landfills may also require air permits under the New Source Review (NSR) permitting program, which includes Prevention of Significant Deterioration (PSD) requirements for landfills sited in attainment areas, or areas where the air quality meets the National Ambient Air Quality Standards (NAAQS), and more stringent NSR requirements for landfills located in non-attainment areas.

Developing a new landfill or expanding an existing landfill has become increasingly difficult, especially in metropolitan areas, due to the urbanization of suitable sites, permitting barriers, elevated land costs, and other factors. If a new landfill is proposed or when expansion plans for existing landfills are announced, adjacent communities may mount opposition that can hinder issuance of required permits and thus development of the landfill (Alva, 2010).

2.3.1.2 Landfill Operations

The two most common methods for active disposal of waste into landfills are the area fill method and the trench method. The area fill method involves waste placement in a large open section of a lined landfill and then spreading and compacting waste in uniform layers using heavy equipment. The trench method of filling waste in a modern landfill involves placing and compacting waste into a trench and then using soil and other materials from the trench excavation as daily cover. Local conditions often determine the most appropriate method for a particular landfill, and a combination of the two methods can be utilized. The trench method is generally less desirable than the area fill method, mostly due to the expense of lining side slopes to protect groundwater from leachate leakage and restrict gas migration (Guyer, 2009).

As required by Subtitle D of RCRA, cover material is applied on top of the waste mass at the end of each day to prevent odors and fires and reduce litter, insects, and rodents. Materials used as daily cover include soil, compost, incinerator ash, foam, and tarps (NW&RA, 2008). Similarly, intermediate cover is used when an area of the landfill is not expected to receive waste or a cap for an extended period of time. Intermediate covers have traditionally consisted of layers of soil, geotextiles, or other materials. The reasons for using intermediate cover are similar to those for using daily cover and may also include erosion control.

It is important to maintain anaerobic conditions within the landfill waste mass to avoid excess air infiltration that can cause fires. Landfill fires can be avoided by closely monitoring landfill conditions and maintaining the landfill as a controlled facility. If an active LFG collection system is installed, then gas wells are monitored to ensure oxygen is not being pulled into the landfill due to excessive vacuum levels.

2.3.1.3 Landfill Closure

Once an area of the landfill, or cell, has reached its permitted height, that cell is closed and a low permeability cap made of compacted clay or synthetic material is installed to prevent infiltration of precipitation. To divert water off of the top of the landfill, a granular drainage layer is placed on top of the low-permeability barrier layer. A protective cover is placed on top of the filter blanket and topsoil is placed as the final layer to support vegetation. The final cap and cover inhibit soil erosion and provide odor and LFG control (NW&RA, 2008). If a LFG collection system is in place, then expansion of the collection system into filled cells or areas of the landfill may require additional gas wells to be installed soon after these cells are closed and capped. Gas collection system design is discussed further in Section 2.6.

RCRA Subtitle D regulations contain closure and post-closure care requirements, including written closure and post-closure care plans and maintaining the final cover, leachate collection system, and groundwater and LFG monitoring systems. The required post-closure care period is 30 years from site closure, but this can be shortened or extended if approved by state regulatory agencies (EPA, 2012d).

2.3.1.4 Management of Liquids

Leachate is the liquid that passes through the landfilled waste and strips contaminants from the waste as it percolates. Precipitation is the primary source of this liquid. To prevent water pollution and protect soil beneath, RCRA Subtitle D requires liners for landfills as well as leachate collection and removal and groundwater monitoring systems. Composite liner systems are used along the bottom and sides of landfills as impermeable barriers and are typically constructed with layers of natural materials with low permeability (e.g., compacted clay) and/or synthetic materials (e.g., high-density polyethylene) (NW&RA, 2008). Landfill liner systems also help prevent offsite migration of LFG.

Leachate collection systems remove leachate from the landfill as it collects on the liner using a perforated collection pipe placed in a drainage layer (e.g., gravel). Waste is placed directly above the leachate collection system in layers. Collected leachate can be treated on site or transported off site to treatment facilities. For landfills with LFG collection systems, LFG condensate can be combined with leachate prior to treatment.

Although traditional landfills tend to minimize the infiltration of liquids into a landfill using liners, covers, and caps (sometimes referred to as “dry tombs”), some landfills recirculate all or a portion of leachate collected to increase the amount of moisture within the waste mass. This practice of leachate recirculation results in a faster anaerobic biodegradation process and increased rate of LFG generation. Similarly, landfills may introduce liquids other than leachate, such as sludge and industrial wastewater. Conventional landfills typically have in-situ moisture contents of approximately 20 percent, whereas landfills recirculating leachate or other liquids may maintain moisture contents ranging from 35 to 65 percent (EPA, 2016e). Often, landfills injecting or recirculating liquids are termed bioreactors, but bioreactor landfills are defined differently amongst industry and regulatory agencies. In addition, bioreactor landfills may have air injected in a controlled manner to further accelerate biodegradation of the waste, which occurs for aerobic and hybrid bioreactor configurations.

2.3.2 Ownership and Characteristics of Landfills

Since the 1980s, the number of active MSW landfills in the United States has decreased by approximately 75 percent (from ~7,900 in 1988 to ~1,800 in 2015) and the share of sites that are publicly owned has also decreased—from 83 percent in 1984 to 57 percent in 2016 (EPA, 2010; WBJ, 2015; O’Brien, 2006; EPA, 2016c). However, the overall volume of disposal capacity has remained fairly constant, indicating a trend of growing individual landfill capacity (SWANA, 2007). Based on landfills reporting to the EPA Greenhouse Gas Reporting Program (GHGRP) that they were actively accepting waste in 2014, privately owned sites represented 71 percent of the overall permitted MSW landfill capacity and 71 percent of the MSW landfilled in that year, an indication that private landfills are likely to be significantly larger than public ones (GHGRP, 2015). Among these reporting sites, the average annual amount of MSW disposed at public sites was about 185,000 short tons, whereas the average private site landfilled about 445,000 short tons of MSW per year—further evidence that publicly owned landfills are generally much smaller than their private counterparts (GHGRP, 2015).

EPA recognized as early as 2002 that a nationwide trend in solid waste disposal is toward the construction of larger, more remote, regional landfills. Economic considerations, influenced by regulatory and social forces, are compelling factors that likely led to the closure of many existing sites and to the idea of regional landfills (EPA, 2002b). The passage of federal environmental regulations that affected landfills (e.g., RCRA in 1976, Subtitle D of RCRA in 1991), established requirements which made it more expensive to properly construct, operate, maintain, and close landfills (O'Brien, 2006; EPA 2016f; EPA, 2002b). Large, private companies are better able to accommodate the increased costs of owning a landfill, since owning multiple sites, many of which have large capacities, provides an economy of scale for cost expenditures (O'Brien, 2006). To offset the high cost of constructing and maintaining a modern landfill, facility owners construct large facilities that attract high volumes of waste from a large geographic area, often using shipments from rail or truck (BioCycle, 2014a). By maintaining a high volume of incoming waste, landfill owners can keep tipping fees relatively low, which subsequently attracts more business (EPA, 2002b).

As older, public landfills near their capacities, communities must decide whether to construct new landfills or seek other options. Many find the cost of upgrading existing facilities or constructing new landfills to be prohibitively high, and opt to close existing facilities. Also, public opposition often makes siting new landfills near population centers difficult and adequate land may not be available near densely populated or urban areas. Many communities are finding that the most economically viable solution to their waste disposal needs is shipping their waste to regional landfills. In these circumstances, a transfer station serves as the critical link in making the shipment of waste to distant facilities cost-effective (EPA, 2002b).

Waste transfer stations are facilities where MSW is unloaded from collection vehicles and reloaded into long-distance transport vehicles for delivery to landfills or other treatment/disposal facilities. By combining the loads of several waste collection trucks into a single shipment, communities and waste management companies can save money on the labor and operating costs of transporting waste to a distant disposal site. They can also reduce the total number of vehicular miles traveled to and from the disposal site(s) (EPA, 2016a). Given the dramatic decrease in the number of active landfills in the past 25 years, transfer stations play an important part in facilitating the movement of solid waste from the areas in which it originates to its end location, often a large, centrally located landfill. The role of transfer stations in waste management has become even more prominent with the increase in the number of “regional” landfills—sites with very large capacities, often located in remote areas, and usually privately owned. As more and more publicly owned landfills reach capacity and close, the waste must go somewhere, and often that is to a regional landfill by way of a transfer station.

There are approximately 100 private companies that own and/or operate currently active MSW landfills, ranging from large companies with numerous landfills throughout the country to local businesses that own a single landfill (EPA, 2016c). The handling of MSW in the United States generated $55 billion of revenue in 2011, of which landfilling contributed $13 billion (WBJ, 2012a) , while a more recent estimate is that the U.S. non-hazardous solid waste services industry generates about $60 billion in annual revenue (SEC, 2016RSG). In terms of their overall 2015 revenue, the top two companies that own and/or operate MSW landfills in the United States are Waste Management ($12.96 billion) and Republic Services ($9.12billion), which together accounted for approximately 37 percent of the solid waste management revenue share in 2015 when using the $60 billion estimate (SEC, 2016WM; SEC, 2016RSG). The next tier of companies involved in landfill management includes Clean Harbors ($3.28 billion), Waste Connections ($2.12 billion), and Progressive Waste Solutions ($1.93 billion) (SEC, 2016CLH; SEC, 2016WCN; SEC, 2016BIN). Table 2-3 contains a summary of the 2015 revenue for these top five companies, as well as information about their MSW landfills and transfer stations.

Table 2-3 Top 5 Waste Management Companies That Owned or Operated MSW Landfills in the United States in 2015[a]

Company	2013 Revenue (billion $)	No. of MSW Landfills Owned and/or Operated	MSW Received at Landfills (million tons)	No. of Transfer Stations Owned and/or Operated
Waste Management (SEC, 2016WM)	12.96	244	96.8	297
Republic Services (SEC, 2016RSG)	9.12	193 active/ 126 closed	N/A	201
Clean Harbors (SEC, 2016CLH)	3.28	2	N/A	N/A
Waste Connections (SEC, 2016WCN)	2.12	44	21.8	64
Progressive Waste Solutions (SEC, 2016BIN)	1.93	23	N/A	41

[a] Ranking of top five companies adapted from "The 2015 Waste Age 100". <http://waste360.com/waste-100/2015-waste-100-0>. Accessed May 19, 2016.
N/A = Not available.

The industry that deposits MSW in landfills encompasses a wide range of job types, including garbage collectors, truck drivers, heavy equipment operators, engineers of various disciplines, specialized technicians, executives, MSW department directors, administrative staff, weigh scale operators, salespersons, and landfill operations managers. In 2012, 1,275 private establishments had 16,209 employees in the continental United States under NAICS 562212 (Solid Waste Landfill) (Census, 2012). In 2014, solid waste management departments of local governments reported 96,021 full-time employees and 14,873 part-time employees (Census, 2014); however, statistics are not readily available solely for landfill-related aspects of these departments. As the population continues to grow in the United States the amount of waste generated will continue to increase, but the amount of waste landfilled may remain the same or decrease (EPA, 2016b). Employment within the waste management industry overall will likely remain strong, perhaps with an increased shift of employees from the public sector to the private sector.

2.4 Costs and Revenue Streams for Landfills

2.4.1 Major Cost Components for Landfills

EPA promulgated Criteria for Municipal Solid Waste Landfills (40 CFR part 258) under the RCRA on October 9, 1991. The law requires that non-hazardous MSW be disposed of in specially designed sanitary landfills. The criteria include location restrictions, design and operating standards, groundwater monitoring requirements, corrective actions, financial assurance requirements, LFG migration controls, closure requirements, and post-closure requirements (EPA, 2016a). It can cost more than $1 million per acre to construct, operate, and close a landfill in compliance with these regulations (Fitzwater, 2012).

Landfill costs are site specific and vary based on factors such as terrain, soil type, climate, site restrictions, regulatory issues, type and amount of waste disposed, preprocessing, and potential for groundwater contamination. Landfill costs fall into the following categories: site development, construction, equipment purchases, operation, closure, and post-closure.

Site development includes site surveys, engineering and design studies, and permit package fees. Surveys are necessary to determine if a potential site is feasible. Permits are required from local, state, and federal governments. As an example, engineering design and a permit application for an MSW landfill in Kentucky can cost approximately $750,000 to $1.2 million (KY SWB, 2012).

Construction costs encompass building the landfill cells as well as development of permanent onsite structures needed to operate the landfill. Cortland County, New York estimated that the cost for site development and cell construction (not including onsite building construction) for a 224.5-acre site would be approximately $500,000 per acre (EnSol, 2010). In 2005, a series of studies was written that estimated costs for a hypothetical landfill based on known market conditions and cost data. The theoretical landfill had a design capacity of 4 million cubic yards and a footprint of 33 acres. The study determined that the cost of constructing a landfill of this size would be between $300,000 and $800,000 per acre. Table 2-4 summarizes typical construction costs per acre by individual task for this example site (Duffy, 2005a).

Table 2-4 Typical Costs Per Acre for Components of Landfill Construction (Duffy, 2005a)

Task	Low End	High End
Clear and Grub	$1,000	$3,000
Site Survey	$5,000	$8,000
Excavation	$100,000	$330,000
Perimeter Berm	$10,000	$16,000
Clay Liner	$32,000	$162,000
Geomembrane	$24,000	$35,000
Geocomposite	$33,000	$44,000
Granular Soil	$48,000	$64,000
Leachate System	$8,000	$12,000
QA/QC	$75,000	$100,000
TOTAL	**$336,000**	**$774,000**

Excavation of the landfill site comprises a notable portion of the construction costs. Installation of a landfill liner can vary greatly in cost depending on the site's geology. Most states require only a single liner and leachate collection system for MSW, but requirements vary for the minimum thickness of clay liners. Landfill sites may have good quality clay located on site that would significantly lower the cost of a clay liner. The QA/QC task in Table 2-4 refers to management and quality oversight which is usually performed by independent third-party consultants.

For the hypothetical landfill in the study, total building and additional structure costs could total between $1.165 million and $1.77 million. Operation of the landfill requires a truck scale, scale house, wheel wash facility, and buildings to accommodate an office and provide space for maintenance. The cost of each building structure varies depending on its functions and could range from $10 to $100 per square foot. Office buildings cost more while maintenance buildings and tool sheds cost less. In addition, fencing around the facility and roadways are required and add to the costs (Duffy, 2005a).

Operating costs of the example landfill include staffing, equipment (payments and maintenance), leachate treatment, and facilities and general maintenance. Landfill operations and maintenance activities are performed using a variety of heavy construction equipment with operating costs dependent on fuel, repairs, and maintenance. Operating costs are relatively small when compared to the capital costs; estimated annual operating costs from this study are (Duffy, 2005a):

- Operations (equipment, staff, facilities and general maintenance): $500,000.

- Leachate collection and treatment (assumes sewer connection and discharge cost of $0.02/gallon): $10,000.
- Environmental sampling and monitoring (groundwater, surface water, air gas, leachate): $30,000.
- Engineering services (consulting firms and in-house staff): $60,000.

Once a landfill no longer accepts waste, the closure process includes the installation of a final cover and cap. Capital costs for installation of a cap can run between $80,000 and $500,000 per acre. For example, at a Maryland sanitary landfill costs were $150,000 per acre (MDE, 2012). The capping costs for a 249.4-acre site in Cortland County, New York were estimated to be approximately $134,000 per acre. Factors influencing these costs include the materials used for the cap, site topography, and the availability of clay or soil suitable for use as the cover. Similar to the costs of the clay liner during the construction of the landfill, availability of nearby clay would significantly reduce this cost (EnSol, 2010).

The closure process can include the installation of an LFG collection system which is necessary to collect and destroy or beneficially use the methane gas that is generated. (However, many landfills install gas collection and control systems as the landfill is being filled, or as areas within the landfill reach final grade, rather than waiting until closure to begin gas collection system installation.) The costs associated with an LFG collection and flare system are minimal as compared to the capital costs for landfill construction, annual landfill operating costs, and other closure costs. Section 2.6 discusses average installation costs for gas collection systems and flares.

Post-closure care requires maintenance to ensure the integrity and effectiveness of the final cover system, leachate collection system, groundwater monitoring system, and methane gas monitoring system. These activities prevent water and air pollution from escaping into the surrounding environment. The required post-closure care period is 30 years from site closure, and can be shortened or extended by the director of an approved state program as necessary to ensure protection of human health and the environment. Over a 30-year period, post-closure care and maintenance can cost from $64,000 to $88,000 per acre (Duffy, 2005b).

Figure 2-2 shows that landfill costs peak prior to the landfill opening and again following the landfill closing (EPA, 1997).

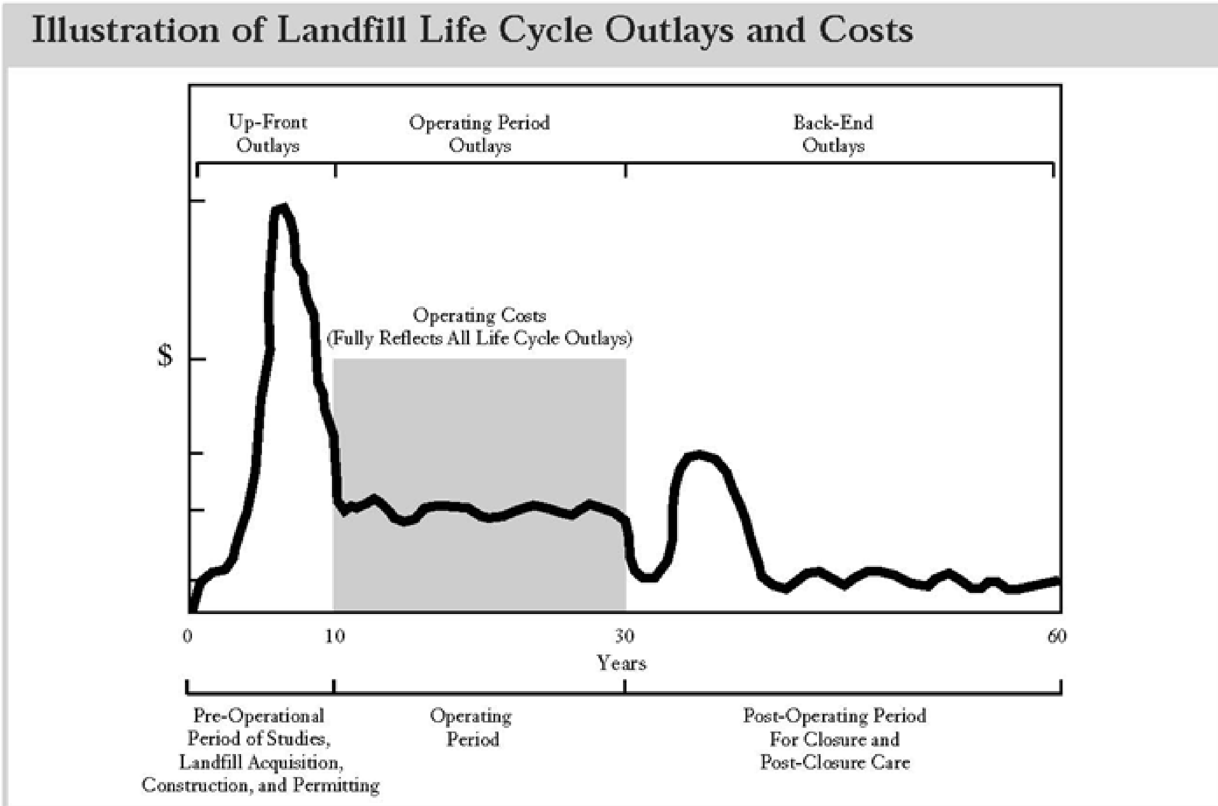


Figure 2-2 Landfill Cost Life Cycle

2.4.2 Landfill Revenue Sources

The cost to dispose of MSW at a landfill is commonly known as a "tip fee" or "gate fee". Typically, reported tip fees represent the "spot market" price for MSW disposal, i.e., the drive-up cost to dispose of a ton of waste (NW&RA, 2011). Other tip fees exist at MSW facilities (e.g., waste accepted under a long-term contract, volume discounts, and special wastes); these fees may be higher or lower than the spot market price (Repa, 2005). A 2016 analysis of collected tip fee data from ~120 U.S. landfills revealed an average national fee of $48.27 per ton (Waste360, 2016). In 2012, the average national spot market price to dispose of one ton of waste in a U.S. landfill was approximately $46.89 (in $2016[15]), up 3.5 percent over 2011 (WBJ, 2012b), while the national average for only the largest public and private landfills was about $51 per ton (in

[15] Normalized to constant $2016 using the consumer price index (CPI) from the Bureau of Labor Statistics to allow meaningful comparisons.

$2016[15]) (KleanIndustries, 2012). This compares to average national tip fees of approximately $47 (in $2016[15]) in 1998 (Repa, 2005) and $17.79 (in $2016[15]) in 1985 (NW&RA, 2011).

Average tip fees also vary by region of the country, as shown in Table 2-5. Tip fees in northeastern states have historically been and continue to be higher than those in other regions. with the exception of the West/Pacific average which presents higher in 2016 than the Northeast although this can be explained by the 2016 data source combining the historical Northeast and Mid-Atlantic state lists which lowered that average. Tip fees tend to be higher near large population centers (Wright, 2012); this is likely influenced by the fact that metropolitan areas have less land area for waste disposal and therefore, fewer landfills. There is variation in tip fees within states as well, depending on landfill ownership (public or private) and proximity of other landfills.

Table 2-5 Average Regional and National Per-Ton Tip Fees (Rounded): 1995-2016

U.S. Region	1995[a]	1998[a]	2000[a]	2002[a]	2004[a]	2008[b]	2010[c]	2011[d]	2016[e]
Northeast	$73	$67	$70	$69	$71	$67	NA	$78	$58
Mid-Atlantic	$46	$44	$46	$45	$46	$56	NA	$65	
South	$29	$31	$31	$30	$31	$32	NA	$39	$44
Midwest	$31	$31	$33	$34	$35	$39	NA	$43	$40
South Central	$20	$21	$22	$23	$24	$34	NA	$33	$36
West Central	$23	$23	$22	$23	$24	$39	NA	$35	$43
West	$38	$36	$35	$39	$38	$44	NA	$55	$61
National	$32	$32	$32	$34	$34	$42	$44	$50	$48

Northeast: CT, ME, MA, NH, NY, RI, VT
Mid-Atlantic: DE, MD, NJ, PA, VA, WV
South/Southeast: AL, FL, GA, KY, MS, NC, SC, TN
Midwest: IL, IN, IA, MI, MN, MO, OH, WI [plus KS and NE for 2016]
South Central: AZ, AR, LA, NM, OK, TX
West Central/Mountain Plains: CO, KS, MT, NE, ND, SD, UT, WY [minus KS and NE for 2016]
West/Pacific: AK, CA, HI, ID, NV, OR, WA [plus AZ for 2016]

[a] Source: Repa, 2005.
[b] Source: Data from BioCycle, 2010. Data were not available for all states. For nine states, 2006 or 2009 data were substituted for missing year 2008 data.
[c] Source: WBJ, 2010.
[d] Source: Shin, 2014 (data reported from Waste & Recycling News).
[e] Source: Waste360, 2016 (data from Environmental Research and Education Foundation).

Publicly owned landfills set tip fees based on the need to cover landfill and other waste management-related costs, while privately owned landfills' tip fees are set based on competition or the lack thereof (Wright, 2012). For municipalities that depend on landfill tip fees to fund programs and services, more waste disposed in the local community-owned landfill means more money generated to fund their solid waste systems, including non-disposal services like recycling. Conversely, if more waste starts going to private landfills instead, less revenue is generated for community programs. An increasing presence of private facilities that can set competitive tip fees has caused some communities to reduce their own tip fees in an effort to attract enough disposal volume to keep revenues at a sufficient level (Burgiel, 2003).

Historically, the construction and operating costs of public MSW landfills have been funded by tip fees, tax revenues (e.g., county/city property tax revenue that goes into a general fund), or a combination of these. Factors influencing tip fee values have included population and economic growth, recycling rates, operating and transportation costs, land values, and legislation. Traditionally, 30 percent of landfills receive all revenue from tip fees, 35 percent receive all revenue from taxes, and 35 percent cover the costs of waste disposal through a combination of tip fees and taxes. The use of taxes as a revenue source rather than tip fees has implications on waste disposal services. When disposal costs are included in taxes, most people are not aware of the actual costs involved and there is little incentive to reduce waste generation rates. Also, tax-supported facilities are typically underfunded relative to actual disposal costs, resulting in poorer operation than fully funded landfills supported by tip fees. Factors that influence the choice of revenue sources include landfill size and ownership. Landfills receiving small quantities of waste are likely to rely heavily on taxes for their revenue while larger landfills rely on both taxes and tip fees (EPA, 2002a).

Private owners of landfills rely heavily on tip fees relative to other landfill owners. It remains unclear whether private landfills rely on tip fees because they are larger, or larger landfills rely heavily on tip fees because they are private (EPA, 2002a).

As shown in Table 2-5, average tip fees by region remained fairly steady between 1995 and 2004, with minor declines in some years but with a gradual upward trend. The greatest increases in average tip fees occurred between 1985 and 1995, with the national average tip fee increasing by $24 (300 percent) or an average of $2.40 per year. From 1985 to 2008, tipping fees for private landfills increased an average of $1.25 per year but these private fees increased by about $1.95 per year between 2004 and 2008 (KleanIndustries, 2012). Tip fees are expected to continue to increase gradually, based on recent data and given rising fuel costs, insurance costs, and other operating costs (Wright, 2012).

A landfill can also generate revenue by entering an agreement to sell carbon credits for voluntary destruction of methane, entering a gas sales agreement to sell LFG for beneficial use, or entering a power purchase agreement to sell electricity generated from LFG and/or renewable energy credits from the generation of that electricity. These types of revenue are small relative to tip fees and total landfill revenues, but can help offset some landfill expenses, for example, the cost of installing a gas collection system or energy recovery equipment. More information about these potential revenue sources is available in Section 2.6.

2.5 Air Pollutant Emissions from Landfills

MSW landfills are a source of NMOC which include volatile organic compounds (VOC), methane, a potent greenhouse gas (GHG), and hazardous air pollutants. LFG is formed during the decomposition of landfilled waste and, if not controlled, can emit numerous pollutants into the air. Several factors affect the amount of LFG generated and its components, including the age and composition of the waste, the amount of organic compounds in the waste, and the moisture content and temperature of the waste (EPA, 2012). LFG generated from established waste (waste that has been in place for at least a year) is typically composed of roughly 50 percent methane and 50 percent carbon dioxide by volume, with trace amounts of NMOC and inorganic compounds (e.g., hydrogen sulfide) (EPA, 2015b; EPA, 2012).

2.5.1 NMOC in LFG

The NMOC portion of LFG, while a small amount of LFG by volume, can contain a variety of significant air pollutants. NMOC include various organic hazardous air pollutants (HAPs) and VOC. If left uncontrolled, VOC can contribute to the formation of ground-level ozone, a common pollutant with adverse health impacts. Nearly 30 organic hazardous air pollutants have been identified in uncontrolled LFG, including benzene, toluene, ethyl benzene, and vinyl chloride (EPA, 2012).

NMOC in LFG results mainly from the volatilization of organic compounds contained in the landfilled waste, while some NMOC may be formed by biological processes and chemical reactions within the waste (EPA, 1998). Waste materials that contribute to the formation of NMOC include items such as household cleaning products and materials coated with or containing paints and adhesives; during decomposition, NMOC can be stripped from these materials by other gases (e.g., methane or carbon dioxide) and become part of the LFG (EPA, 2012).

The concentration of NMOC in uncontrolled LFG depends on several factors, including waste types in the landfill and the local climate. EPA's Compilation of Air Pollutant Emission Factors (AP-42) provides a default NMOC concentration of 595 parts per million by volume (ppmv), of which 110 ppmv are considered HAP compounds. The total uncontrolled organic HAPs volume in LFG from MSW landfills is typically less than 0.02 percent of the total LFG (EPA, 2012).

2.5.2 Methane in LFG

Methane is 28-36 times more effective at retaining heat in the earth's atmosphere than carbon dioxide, over a 100 year time horizon, and therefore is considered a potent GHG (IPCC, 2007).[16] In 2014, landfills were the third-largest anthropogenic source of methane emissions in the United States, with MSW landfills accounting for approximately 18.2 percent of the total methane emissions from all sources (EPA, 2016b).

When waste is first placed in a landfill, it enters an aerobic decomposition stage. The availability of oxygen at this stage means that carbon released from the decomposition of organic waste materials is in the form of carbon dioxide, and little methane is produced. However, within a year or less, the waste environment becomes anaerobic, methane generation increases, and the amount of carbon dioxide produced begins to level out (EPA, 2015b). Figure 2-3 presents a sample LFG generation curve over time for a typical MSW landfill. Significant methane generation can continue for 10 to 60 years after initial waste placement (EPA, 2012).

[16] Note that this final rule uses a GWP value for methane of 25 for CO_2 equivalency calculations, consistent with the GHG emissions inventories and the IPCC Fourth Assessment Report.

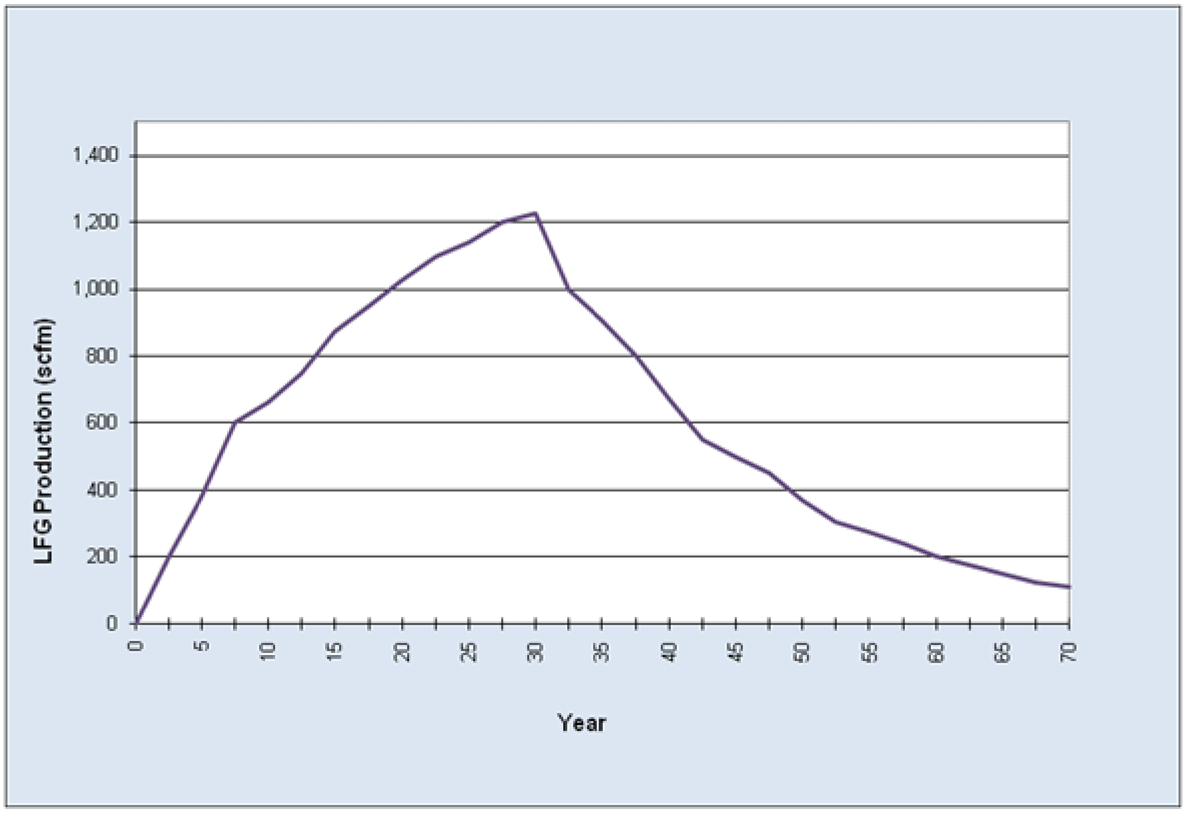


Figure 2-3   Typical LFG Generation Curve

As methane oxidizes in the atmosphere, the carbon in methane is converted to carbon dioxide. Both the carbon dioxide generated directly from aerobic decomposition in MSW landfills and created as a result of methane oxidation in the atmosphere would have been generated anyway as a result of natural decomposition of the organic waste materials if they had not been deposited in the landfill (EPA, 2015b). In other words, the increase in atmospheric carbon dioxide concentration associated with the decomposition of organic waste materials would have occurred in the baseline and is not affected by the final guidelines and NSPS.

2.5.3   Criteria Pollutants from Combustion of LFG

While collection and combustion of LFG in a flare or energy project equipment (e.g., reciprocating engine, boiler, turbine) greatly reduces emissions of methane and NMOC (including VOC and organic HAP), the combustion process generates criteria pollutants including carbon monoxide (CO), nitrogen oxides (NO_X), sulfur dioxide (SO_2), and particulate matter (PM) (EPA, 1998). NO_X formation is strongly tied to the combustion temperature in the equipment, while CO and PM emissions are primarily the result of incomplete combustion of the gas. SO_2 production depends upon the amount of sulfur in the LFG (EPA, 2000). More information about LFG combustion devices is available in Section 2.6.

2.6 Techniques for Controlling Emissions from Landfills

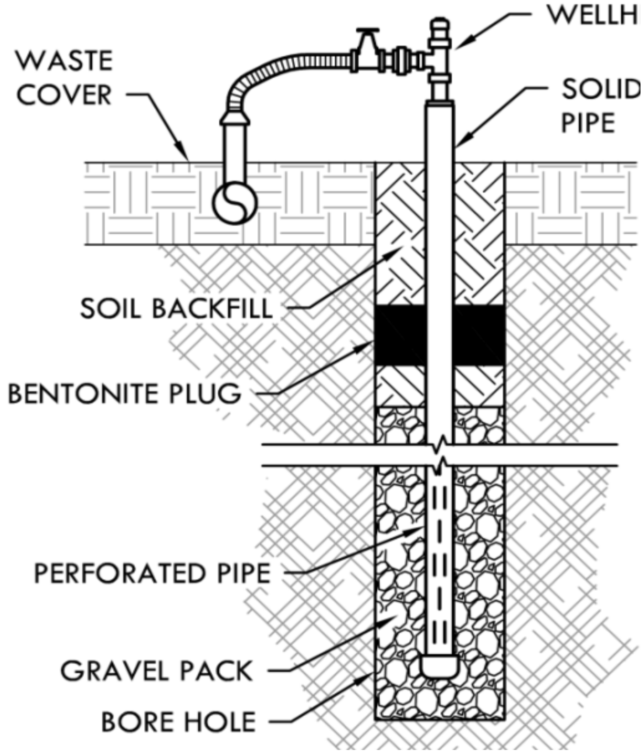
2.6.1 Introduction

Emissions from landfills can be controlled by installing gas collection systems and either flaring the LFG or utilizing it as an energy source. Large landfills with emissions exceeding 34 megagrams per year (Mg/yr) of NMOC are required by the MSW landfills EG to control and/or treat LFG to significantly reduce the amount of toxic air pollutants released. However, many landfills voluntarily choose to control emissions, in part because of the economic benefits of LFG energy projects.

This section describes the equipment and costs associated with LFG emission controls. The control technologies are divided into three categories: gas collection systems, destruction, and utilization. Much of the information in this section was obtained from the U.S. EPA's Landfill Methane Outreach Program (LMOP) *LFG Energy Project Development Handbook* (EPA, 2015b).

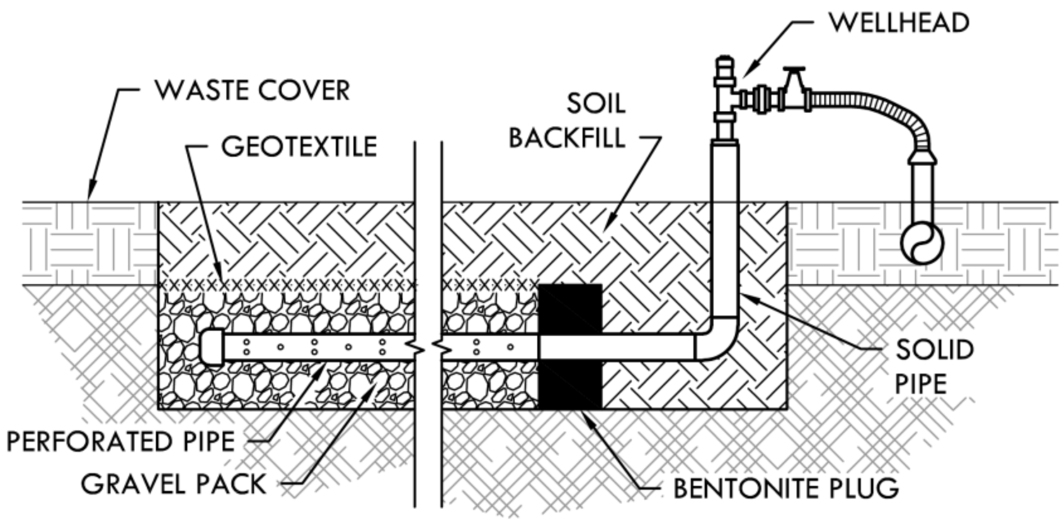
2.6.2 Gas Collection Systems

LFG collection typically begins after a portion of the landfill (known as a "cell") is closed to additional waste placement. Gas vents are installed to collect LFG from the closed cell. The gas vents may be configured as vertical or horizontal wells, and some collection systems involve a combination of the two. Vertical wells (Figure 2-4) are the most common method of LFG collection and involve drilling wells vertically in the waste to collect gas. Horizontal wells (Figure 2-5) use piping laid horizontally in trenches in the waste; these systems are useful in deeper landfills and in areas of active filling. Both types of collection systems connect the wellheads to lateral piping that transports the gas to a collection header.



Source: EPA, 2015b

Figure 2-4 Vertical Well LFG Collection



Source: EPA, 2015b

Figure 2-5 Horizontal Well LFG Collection

Collection from the gas vents may be either passive or active. Passive systems rely on the natural pressure gradient between the waste mass and the atmosphere to move gas to collection systems. Most passive systems intercept LFG migration and the collected gas is vented to the atmosphere. Active systems use mechanical blowers or compressors to create a vacuum that optimizes LFG collection (EPA, 1998).

Total collection system costs vary widely, based on a number of site-specific factors. For example, if the landfill is deep, collection costs tend to be higher because well depths will need to be increased. Collection costs also increase with the number of wells installed. Based on data from LMOP's Landfill Gas Energy Cost Model (LFGcost-Web), the estimated capital cost (in 2012 $'s) required for a 40-acre collection system is $897,000, assuming one well is installed per acre. Typical annual operation and maintenance (O&M) costs (in 2012 $'s) for collection systems are approximately $2,500 per well, or $100,000 for a 40-acre system (EPA, 2014a). If an LFG energy project generates electricity, a landfill will often use a portion of the electricity generated to operate the system and sell the rest to the grid in order to offset these operational costs.

2.6.3 Destruction

Collected LFG is typically combusted in flares or combustion devices that recover energy, such as boilers, internal combustion engines, and gas turbines. Properly designed and operated combustion equipment generally reduces NMOC by 98 percent or to a 20 ppmv outlet concentration, as specified in the current MSW landfills EG (40 CFR 60.752). Combustion also destroys over 98 percent of the methane.

Flares are the most common control device used at landfills. Flares are also a component of each energy recovery option because they may be needed to control LFG emissions during energy recovery system startup and downtime and to control any gas that exceeds the capacity of the energy conversion equipment. In addition, a flare is a cost-effective way to gradually increase the size of the energy recovery system at an active landfill. As more waste is placed in the landfill and the gas collection system is expanded, the flare is used to control excess gas between energy conversion system upgrades (e.g., before addition of another engine).

Flare designs include open (or candlestick) flares and enclosed flares. Open flares employ simple technology where the collected gas is combusted in an elevated open burner. A continuous or intermittent pilot light is generally used to maintain the combustion. Open flares used at landfills meeting the criteria in 40 CFR 60.18(b) have been demonstrated to have destruction efficiencies similar to enclosed flares. Enclosed flares typically employ multiple burners within fire-resistant walls, which allow them to maintain a relatively constant and limited peak temperature by regulating the supply of combustion air (ATSDR, 2001). Enclosed flares are more expensive but may be preferable (or required by state regulations) because they provide greater control of combustion conditions and allow for stack testing. They can also reduce noise and light nuisances.

Flare costs vary based on the gas flow of the system. LFGcost-Web estimates for flares include condensate collection and blowers. Condensate collection (also called knockout devices) is necessary because condensate forms when warm gas from the landfill cools as it travels through the collection system. If condensate is not removed, it can block the collection system. Blowers are needed to ensure a steady flow of gas to the flare. The size, type, and number of blowers needed depend on the gas flow rate and distance to downstream processes.

Based on data from LFGcost-Web (in 2012$), a flare for a system designed for 600 cubic feet per minute (cfm) of LFG will cost $223,000 (including condensate collection and blowers). Typical annual O&M costs (in 2012$) are approximately $5,000 per flare. Electricity costs to operate the blower for a 600-cfm active gas collection system would be $53,000 per year, assuming an electricity price of $0.085 per kilowatt-hour (kWh) (EPA, 2014a).

2.6.4 Utilization

After collection, LFG may be used in an energy recovery system to combust the methane and other trace contaminants. LMOP’s Landfill and LFG Energy Project Database, which tracks the development of U.S. LFG energy projects and landfills with project development potential, indicates that approximately 650 LFG energy projects are currently operating in 48 states and Puerto Rico. Roughly three-fourths of these projects generate electricity, while one-fourth are direct-use or upgraded LFG projects in which LFG is used for its thermal capacity (EPA, 2016g).

This section summarizes LFG utilization technologies in four general categories: power production, cogeneration, direct use, and alternative fuel. This section also provides a discussion of the economic benefits of LFG utilization projects.

2.6.4.1 Technologies

It is important to note that all of the technologies discussed below typically require treatment of LFG prior to entering the control device to remove moisture, particulates, and other impurities. (While "treatment" has a specific meaning within the MSW landfills EG, the term is used more generally in common usage and as discussed here.) The level of treatment can vary depending on the type of control and the types and amounts of contaminants in the gas. LFG is typically dehumidified, filtered, and compressed before being sent to energy recovery devices. For most boilers and internal combustion engines, no additional treatment is used. Some internal combustion engines and many gas turbine and microturbine projects apply siloxane removal using adsorption beds after the dehumidification step.

2.6.4.1.1 Power Production

Producing electricity from LFG continues to be the most common beneficial-use application, accounting for about three-fourths of all U.S. LFG energy projects (EPA, 2016g). Electricity can be produced by burning LFG in an internal combustion engine, a gas turbine, or a microturbine.

The majority (nearly 80 percent) of LFG energy projects that generate electricity do so by combusting LFG in internal combustion engines (EPA, 2016g). Advantages of this technology include: low capital cost, high efficiency, and adaptability to variations in the gas output of landfills. Internal combustion engines are well-suited for 800-kilowatt (kW) to 3-megawatt (MW) projects, but multiple units can be used together for projects larger than 3 MW. Internal combustion engines are relatively efficient at converting LFG into electricity, achieving efficiencies in the range of 25 to 35 percent.

Gas turbines are more likely to be used for large projects, where LFG volumes are sufficient to generate a minimum of 3 MW and typically more than 5 MW. Unlike most internal combustion engine systems, gas turbine systems have significant economies of scale. The cost per kW of generating capacity drops as gas turbine size increases, and the electric generation efficiency generally improves as well.

Microturbines, as their name suggests, are much smaller than turbines, with a single unit having between 30 and 250 kW in capacity, and thus are generally used for projects smaller than

1 MW. Small internal combustion engines are also available for projects in this size range and are generally less costly. Microturbines may be selected for certain projects (rather than internal combustion engines) because they can operate with as little as 35 percent methane and less than 300 cfm, and also produce low nitrogen oxide emissions.

An LFG energy project may use multiple units to accommodate a landfill's specific gas flow over time. For example, a project might have three internal combustion engines, two gas turbines, or an array of 10 microturbines, depending on gas flow and energy needs.

The costs of energy generation using LFG vary greatly; they depend on many factors including the type and size of electricity generation equipment, the necessary compression and treatment system, and the interconnect equipment. Table 2-6 presents examples of typical costs for several technologies, including costs for a basic gas treatment system typically used with each technology as well as interconnection costs.

Table 2-6 Average LFG Power Production Technology Costs

Technology	Typical Size Used to Estimate Costs	Typical Capital Costs ($/kW)[a]	Typical Annual O&M Costs ($/kW)[a]
Internal combustion engine	3,000 kW	$1,700	$200
Small internal combustion engine	500 kW	$2,500	$220
Gas turbine	10,000 kW	$1,400	$130
Microturbine	200 kW	$2,900	$220

Source: EPA, 2014a
[a] 2012$

2.6.4.1.2 Cogeneration

LFG energy cogeneration applications, also known as combined heat and power (CHP) projects, provide greater overall energy efficiency and are growing in number. In addition to producing electricity, these projects recover and beneficially use the heat from the unit combusting LFG. LFG cogeneration projects can use internal combustion engine, gas turbine, or microturbine technologies.

Less common LFG electricity generation technologies include a few boiler/steam turbine applications in which LFG is combusted in a large boiler to generate steam which is then used by a steam turbine to create electricity. A few combined cycle applications have also been implemented. These combine a gas turbine that combusts LFG with a steam turbine that uses steam generated from the gas turbine's exhaust to create electricity. Boiler/steam turbine and combined cycle applications tend to be larger in scale than the majority of LFG electricity projects that use internal combustion engines.

2.6.4.1.3 Direct Use

The simplest and often most cost-effective use of LFG is direct use as a fuel for boilers and other direct thermal applications to produce useful heat or steam. However, this is only an option if there is an end user located near the landfill who is willing and able to use the LFG. An end user's energy requirements are an important consideration when evaluating the sale of LFG for direct use. Because no economical way to store LFG exists, all gas that is recovered must be used as available; gas that cannot be immediately used in energy recovery equipment is flared and the associated revenue opportunities are lost. The ideal gas customer, therefore, will have a steady annual gas demand compatible with the landfill's gas flow. When a landfill does not have adequate gas flow to support the entire needs of a facility, LFG can still be used to supply a portion of the needs. The number and diversity of direct-use LFG applications is continuing to grow.

Boilers are the most common type of direct use, and LFG is used in boilers at a wide variety of industrial manufacturing facilities as well as commercial and institutional buildings. Boilers can often be easily converted to use LFG alone or in combination with fossil fuels. Equipment modifications or adjustments may be necessary to accommodate the lower Btu value of LFG, and the costs of modifications will vary. If retuning the boiler burner is the only modification required, costs will be minimal. However, retrofitting an existing natural gas boiler to include LFG may cost between $100,000 and $400,000, depending on the extent of the retrofit (EPA, 2014a).

Direct thermal applications include kilns (e.g., cement, pottery, and brick), tunnel furnaces, process heaters, and blacksmithing forges. In addition, infrared heaters can use LFG to fulfill space heating needs. Greenhouses can combust LFG in boilers to provide heat for the greenhouse and to heat water used in hydroponic plant culture. LFG can be used to heat the boilers in plants that produce biofuels including biodiesel and ethanol.

Table 2-7 presents typical cost ranges for the components of a direct-use project. The costs shown below for the gas compression and treatment system include compression, moisture removal, and filtration equipment typically required to prepare the gas for transport through the pipeline and for use in a boiler or process heater. If more extensive treatment is required to remove other impurities, costs will be higher. The gas pipeline costs also assume typical construction conditions and pipeline design. Pipelines can range from less than a mile to more than 30 miles long, although most are shorter than 10 miles because length has a major effect on costs. In addition, the costs of direct-use pipelines are often affected by obstacles along the route, such as highway, railroad, or water crossings. End users will likely need to modify their equipment to make it suitable for combusting LFG, but these costs are usually borne by the end user and are site-specific to their combustion device.

Table 2-7   Average LFG Direct-use Project Components Costs

Component	Typical Capital Costs[a]	Typical Annual O&M Costs[a,b]
Gas compression and treatment	$1,200/cfm	$130/cfm
Gas pipeline and condensate management system	$449,000/mile	Negligible

Source: EPA, 2014a

[a] 2012$, based on a 1,000-cfm system with a 5-mile pipeline
cfm: cubic feet per minute
[b] Assuming an electricity price of $0.085 per kWh

2.6.4.1.4   Alternative Fuel

Production of alternative fuels from LFG, by upgrading the gas using high-Btu conversion technologies, is becoming more prevalent. LFG can be used to produce the equivalent of pipeline-quality gas (natural gas), compressed natural gas (CNG), or liquefied natural gas (LNG). Pipeline-quality gas can be injected into a natural gas pipeline and used by residential, commercial, or industrial end users along the pipeline. CNG and LNG can be used to fuel vehicles at the landfill (e.g., water trucks, earthmoving equipment, light trucks, autos), fuel refuse-hauling tucks (long-haul refuse transfer trailers and route collection trucks), and supply the general commercial market. Although only a handful of these projects are currently operational, several more are in the construction or planning stages.

LFG can be converted into a high-Btu gas by increasing its methane content and, conversely, reducing its carbon dioxide, nitrogen, and oxygen content. In the United States, three methods have been commercially employed (i.e., beyond pilot testing) to remove carbon dioxide from LFG, including membrane separation, molecular sieve (also known as pressure swing adsorption or PSA), and amine scrubbing.

Capital costs of high-Btu processing equipment (in 2012$) range from $2,500 per cfm LFG for a 10,000-cfm processing system to $5,900 per cfm LFG for a 1,000-cfm processing system. The annual cost to provide electricity to, operate, and maintain these systems (in 2012$) is approximately $500 per cfm LFG (EPA, 2014a). Costs will depend on the purity of the high-Btu gas required by the receiving pipeline or energy end user as well as the size of the project, since some economies of scale can be achieved when producing larger quantities of high-Btu gas.

For alternative fuel projects, the capital costs of converting LFG into CNG also vary, depending primarily on the quantity of fuel being converted and the type of fueling station equipment. Similar to high-Btu processing equipment, some economies of scale are realized for larger volumes of gas. The capital costs for onsite CNG production with a fueling station (in 2012$) ranges from $7,200 per cfm LFG for a 600-cfm project to $14,800 per cfm LFG for a 100-cfm project. The annual cost to operate and maintain a CNG project (in 2012$), including media and equipment replacement, is approximately $1 per gallon of gasoline equivalent produced by the system, or $0.003 per cfm LFG assuming a conversion efficiency of 65 percent and a fuel use rate of 111,200 Btu per gallon of gasoline equivalent (EPA, 2014a).

2.6.4.2 Revenues and Incentives

Landfill owners can receive revenue from the sale of carbon credits, the sale of electricity generated from LFG to the local power grid, or from the sale of LFG to a direct end user or pipeline. However, the revenue received represents only a small percentage of the operating costs of a landfill.

2.6.4.2.1 Emission Reduction Credits

Voluntary GHG trading programs purchase credits from landfills that capture LFG to destroy or convert methane contained in the gas and obtain credit for the reduction of GHG in terms of carbon equivalents. In order to qualify for these programs, the emission reductions must be in addition to regulated actions and have recent project installation.

Bilateral trading and GHG credit sales are other voluntary sources of revenue. Bilateral trades are project-specific and are negotiated directly between a buyer and seller of GHG credits. In these cases, corporate entities or public institutions, such as universities, may wish to reduce their "carbon footprint" or meet internal sustainability goals, but do not have direct access to developing their own project. Therefore, a buyer may help finance a specific project in exchange for the credit of offsetting GHG emissions from their organization.

Certain LFG energy projects may qualify for participation in nitrogen oxides cap-and-trade programs, such as the nitrogen oxides State Implementation Plan (SIP). The revenues for these incentives vary by state and will depend on factors such as the allowances allocated to each project, the price of allowances on the market, and if the project is a CHP project (typically CHP projects receive more revenue due to credit for avoided boiler fuel use).

2.6.4.2.2 Electricity Project Revenue

The primary revenue component of the typical electricity project is the sale of electricity to the local utility. This revenue stream is affected by the electricity buy-back rates (i.e., the rate at which the local utility purchases electricity generated by the LFG energy project). Electricity buy-back rates for new projects depend on several factors specific to the local electric utility and the type of contract available to the project, but typically range between 2.5 and 11 cents per kWh (EPA, 2014a).

When assessing the economics of an electricity project, it is also important to consider the avoided cost of the electricity used on site. Electricity generated by the project that is used in other operations at the landfill is, in effect, electricity that the landfill does not have to purchase from a utility. This electricity is not valued at the buy-back rate, but at the rate the landfill is charged to purchase electricity (i.e., retail rate). The retail rate is often significantly higher than the buy-back rate.

LFG energy projects can potentially use a variety of additional environmental revenue streams, which typically take advantage of the fact that LFG is recognized as a renewable, or "green," energy resource. These additional revenues can come from premium pricing, tax credits, GHG credit trading, or incentive payments. They can be reflected in an economic analysis in various ways, but typically, converting to a cents/kWh format is most useful. LFGcost-Web accommodates four common types of electricity project credits: a direct cash grant, an electricity generation tax credit expressed in dollars per kWh, a direct GHG (carbon) reduction credit expressed in dollars per metric ton of carbon dioxide equivalent (discussed in Section 2.6.4.2.1), and a direct renewable electricity credit expressed in dollars per kWh. This section includes discussion of the available environmental revenue streams that an LFG electricity project could possibly use.

Premium pricing is often available for renewable electricity (including LFG) that is included in a green power program, through a Renewable Portfolio Standard (RPS), a Renewable Portfolio Goal (RPG), or a voluntary utility green pricing program. These programs could provide additional revenue above the standard buy-back rate because LFG electricity is generated from a renewable resource.

Renewable energy certificates (RECs) are sold through voluntary markets to consumers seeking to reduce their environmental footprint. They are typically offered in 1 megawatt-hour (MWh) units, and are sold by LFG electricity generators to industries, commercial businesses, institutions, and even private citizens who wish to achieve a corporate renewable energy portfolio goal or to encourage renewable energy. If the electricity produced by an LFG energy project is not being sold as part of a utility green power program or green pricing program, the project owner may be able to sell RECs through voluntary markets to generate additional revenue.

Tax credits, tax exemptions, and other tax incentives, as well as federal and state grants, low-cost bonds, and loan programs are available to potentially provide funding for an LFG energy project. For example, Section 45 of the Internal Revenue Code provides a per-kWh federal tax credit, commonly referred to as the renewable electricity Production Tax Credit (PTC), for power generated at privately owned LFG electricity projects. To qualify for the credit, which was 1.2 cents per kWh for the 2015 and 2016 calendar years, all electricity produced must be sold to an unrelated person during the taxable year. Under legislation passed in December 2015, the under-construction date deadline for LFG energy projects to be eligible was extended to December 31, 2016 (DSIRE, 2016).

2.6.4.2.3 Direct-use Project Revenues

The primary source of revenue for direct-use projects is the sale of LFG to the end user; the price of LFG, therefore, dictates a project’s revenue. Often LFG sales prices are indexed to the price of natural gas, but prices will vary depending on site-specific negotiations, the type of contract, and other factors. In December 2013, the U.S. Energy Information Administration (EIA) *Annual Energy Outlook 2014 Early Release* forecasted a 2014-2015 Henry Hub natural gas price of $3.74 per million British thermal units (MMBtu). Using a default methane content of 50 percent, the estimated value of LFG was estimated to be $1.75 per MMBtu. In recent years, the natural gas price has been depressed as a result of abundant domestic supply and efficient methods of production (EPA, 2014a). The actual average natural gas spot price for year 2014 was $4.39 per MMBtu and for year 2015 was $2.63 per MMBtu (EIA, 2016). In general, the price paid by the end user must provide an energy cost savings that outweighs the cost of required modifications to boilers, process heaters, kilns, and furnaces in order to burn LFG.

Federal and state tax incentives, loans, and grants are available that may provide additional revenue for direct-use projects. Specific to vehicle fuel, EPA's Renewable Fuel Standard (RFS) program allows registered renewable fuel producers, including biofuels produced from LFG, to generate Renewable Identification Number (RIN) credits for the renewable fuel produced which are purchased by parties required to meet specified volumes of renewable fuel (EPA, 2014b). In 2014, RIN credits for advanced biofuels (such as LFG-based biogas) were between $0.74 and $1.00 per RIN, equivalent to a range of $9 to $13 per million Btu (ABC, 2014). GHG emissions trading programs are also potential revenue streams for direct-use projects.

2.7 Integrated Waste Management Strategies

2.7.1 Introduction

Landfills are one method of waste disposal, but alternative strategies are available for the treatment of MSW, and multiple strategies are often used in combination. EPA has developed a non-hazardous waste management hierarchy that ranks the most environmentally sound strategies for MSW. Source reduction and reuse (waste prevention) is the most preferred method, followed by recycling and composting, energy recovery, and, lastly, treatment and disposal (EPA, 2016h).

Source reduction, also known as waste prevention is the practice of designing products to reduce the amount of waste that will later need to be thrown away, which may result in less toxic waste (EPA, 2016h). Recycling involves the recovery of useful materials, such as paper, glass, plastic, and metals from trash and using these materials to make new products. Recycling saves resources, including energy, raw materials, and landfill space.

The diversion of organic materials, such as food scraps and yard waste (e.g., lawn trimmings, fallen leaves and branches), from landfills allows these materials to be used to create compost or generate energy. The management of organic materials is discussed in Section 2.7.2.

Alternatively, MSW can be directly combusted in waste-to-energy facilities to generate electricity. At the power plant, MSW is unloaded from collection trucks and shredded or processed to ease handling. Recyclable materials are separated out, and the remaining waste is fed into a combustion chamber to be burned. The heat released from burning the MSW is used to produce steam, which turns a steam turbine to generate electricity (EPA, 2016i).

Landfilling is often used as part of an integrated waste management strategy (e.g., where the same community has recycling programs, yard waste composting, and landfilling) and LFG can often be used for energy recovery as described in Section 2.6.4. LFG energy projects aim to recover and beneficially utilize methane generated from waste that has not been successfully diverted from landfills. The promotion of LFG energy is not in conflict with the promotion of organic waste diversion, nor does it compete with waste prevention or recycling, but allows LFG energy projects to utilize methane generated from millions of tons of organic waste already disposed in landfills while supporting future diversion of organic waste from landfills to reduce the amount of uncontrolled methane generated. (EPA, 2015c).

2.7.2 Organics Management

As detailed in Section 2.2.1.4, food waste, yard debris, and other organic materials continue to be the largest component of MSW discarded, with food waste comprising the largest portion (EPA, 2015a). Decreasing the amount of organics disposed in landfills would reduce the amount of LFG generated. If diverted from disposal in landfills, organic wastes can be composted or anaerobically digested.

Composting is the controlled biological decomposition of organic material in the presence of air to form a humus-like material. Controlled methods of composting include mechanical mixing and aerating, ventilating the materials by dropping them through a vertical series of aerated chambers, or placing the compost in piles out in the open air and mixing the piles periodically (EPA, 2016j). Diverted organic materials can also be used in an anaerobic digester, although digesters generally handle relatively small quantities of easily digestible waste. BioCycle identified nearly 5,000 composting facilities in the United States, with about 70 percent composting only yard trimmings and 7 percent composting food scraps (BioCycle, 2014a).

Anaerobic digestion involves the conversion of organic matter to energy by microbiological organisms in the absence of oxygen. The biogas produced in the digestion process is a mixture of methane and carbon dioxide and can be used as a fuel source for heating or electricity production. Organic waste can either be digested at facilities specifically designed for the organic portion of MSW, or co-digested at wastewater treatment plants and manure digesters. The number of anaerobic digesters in the United States that process MSW-based wastes is on the rise with 20 stand-alone anaerobic digestion plants processing an estimated one million tons per year of food waste, and another 30 plants in permitting or under construction; additional sites co-digest food waste with wastewater, manure or other organics (Arsova, 2015; RWI, 2013a; RWI, 2013b).

2.7.2.1 Trends

States and municipalities in the United States are increasingly moving toward the diversion of organic wastes from landfills. State initiatives to recycle organic wastes have contributed to the growth of curbside organics collection as well as commercial and institutional collection and treatment. Table 2-8 lists the 21 states that have mandated organics diversion and/or banned disposal of organics from landfills. In particular, five states (California, Connecticut, Massachusetts, Rhode Island, and Vermont) have enacted legislation for organics disposal specific to food waste (BioCycle, 2014b; MSW Management, 2015). At a local level, BioCycle’s Fall 2014 survey identified 198 communities in 19 states with curbside collection of food scraps, as shown in Table 2-8. Between 2009 and 2014, the number of municipalities with source separated food waste collection more than doubled (from 90 to 198) and the number of households grew by nearly 50 percent (BioCycle, 2015a). The assortment of organics management initiatives and programs at state and local levels varies across the country by:

- Type of organic wastes targeted (e.g., food waste, yard waste);
- Source of organic waste generation (e.g., commercial, residential, institutional);
- Phase of implementation (from pilot projects to mandatory requirements with fines for violations); and
- Pricing formats (e.g., “pay-as-you-throw,” property tax, fixed fee) (BioCycle, 2015a).

Table 2-8 Waste Management of Organics in the United States

State	State-wide Organics Diversion Mandate and/or Disposal Ban[1,2,3]	Local Residential Food Waste Collection Program[4]
Arkansas	✔	
California	✔ (FW)	✔
Colorado		✔
Connecticut	✔ (FW)	✔
Delaware	✔	
Illinois		✔
Indiana	✔	
Iowa	✔	✔
Kentucky		✔
Maryland	✔	✔
Massachusetts	✔ (FW)	✔
Michigan		✔
Minnesota	✔	✔
Nebraska	✔	
New Hampshire	✔	
New Jersey	✔	✔
New York		✔
North Carolina	✔	
Ohio	✔	✔
Oregon		✔
Rhode Island[2]	✔ (FW)	
Pennsylvania	✔	✔
South Carolina	✔	
South Dakota	✔	
Tennessee	✔	
Texas		✔
Vermont	✔ (FW)	✔
Washington		✔
Wisconsin	✔	✔
Number of States	21	19

FW = Food waste diversion mandate and/or disposal ban

[1] Source: BioCycle, 2014a. Survey results from 39 states that responded.

[2] Source: BioCycle, 2014b. Rhode Island legislation goes into effect January 2016.

[3] Source: MSW Management, 2015.

[4] Source: BioCycle, 2015a. Denotes states that have one or more communities with a residential source separated food waste collection program. Programs are not state-wide initiatives.

2.7.2.2 Benefits

The benefits of diverting organic wastes from landfills include:

- Reduction of methane, NMOC, and other air pollutants generated by the organic fraction of waste disposed in landfills;
- Production of soil-improving compost material from composting (ILSR, 2014);
- Generation of biogas from anaerobic digestion used to generate electricity and/or heat; and
- Recovery and recycling of food waste to support food banks for humans or animals (MSW Management, 2015).

2.7.2.3 Barriers

Some barriers exist that can deter mandating the diversion of organics from landfills, especially in the format of a federal mandate, such as:

- *Lack of or variation in regulatory policies, incentives, and drivers to encourage organics diversion and make it more affordable* (ILSR, 2014). For example, Kentucky's composting permit fees for private entities led to a decline in applicants when the fee went from $0 to $3,000 in 2011, with an annual renewal fee of $500 (BioCycle, 2014b). While New York does not have legislation in place, the state does review local materials management plans to provide suggestions on improving organics management and offers waste reduction and recycling grants to municipalities for education or capital expenditures (BioCycle, 2014b). Lessening permit restrictions and fees for organic waste facilities and offering state-level assistance to municipalities may spur movement to establish and expand organics management programs.
- *Limited capacity for organic material receiving, processing, and treatment facilities (e.g., composters, anaerobic digesters) and associated infrastructure (e.g., hauling services, transfer stations)* (ILSR, 2014). While the United States has no shortage of landfill capacity overall, the average amount of organics diverted to composting in 27 states is 5,155 tons per facility per year, which is far too low to adequately achieve higher composting rates (BioCycle, 2014a). Composting of organics can occur at several tiers, from home-based and small-scale farm and community sites to onsite

institutional systems (primarily schools) to large-scale centralized facilities, thus encouraging backyard and locally-based composting and developing adequate infrastructure for commercial composting (beyond yard waste) would lead to an increased capacity for organic wastes in urban, suburban, and rural areas (BioCycle, 2014a). There are approximately 20 stand-alone anaerobic digester plants in the U.S. with an estimated annual capacity of approximately 1 million tons (Biocycle, 2015b).

- *Low cost to dispose waste in landfills relative to other waste treatment technologies* (ILSR, 2014). Traditionally, waste disposal in the United States has been based on landfill tipping fees, or the fee a waste collector or hauler pays to discard waste in a landfill. Tipping fees at landfills vary across the United States, ranging from $5 to $142 per ton in 2011, with a national average just below $50 per ton (Shin, 2014). When recycling and organics diversion are introduced, the pricing structure shifts from a disposal cost to transportation and processing or treatment costs. Anaerobic digesters require significant capital investment and rely on tipping fees to recover costs to construct and operate the facility. In addition, due to opposition for siting these facilities, it is difficult to obtain permits to build digesters in densely populated areas, which results in increased costs to transport feedstock to the digester (Waste360, 2014). More recently, local solid waste agencies have offered reduced fees for source separated loads of organics at composting facilities. For example, Charleston County, South Carolina has a $25 per ton fee to drop off food and organic waste for composting, compared to $66 per ton for traditional waste sent to the landfill (ILSR, 2014). In addition, variable rate fees, or "pay-as-you-throw" pricing, incentivize separate collection of organics and recyclables as trash collection is typically priced at a higher fee than source separated organics and recyclables (ILSR, 2014).
- *Multifaceted and regional nature of the solid waste management industry.* Waste generators include households, institutions, and commercial entities, and these parties vary regionally in both density and demographics. Historically, state and local government has controlled all aspects of collection, transportation, disposal, and treatment of solid waste including the permitting of facilities and infrastructure and assessment of fees through taxes and operation of landfills. Private companies also

play a significant role that ranges from collecting and hauling waste to owning and operating landfills. While the industry is moving towards more integrated solid waste management approaches at a local or regional level, there is not a shift towards a national solid waste management system. As a result, the policies, programs, and infrastructure to accommodate organics diversion must be tailored to the unique situations of each region, state, or municipality to best implement change among interlinked entities of generators, collectors, and treatment and disposal facilities.

- *Lack of information and understanding of the environmental and energy benefits of separating, recovering, and utilizing organics.* Ultimately, effective organics diversion from landfills begins at the point of generation. Changing waste disposal habits can be challenging for individuals, businesses, and industries in the United States, but education and awareness about the benefits of composting and anaerobic digestion in a manner that relates directly to individuals and organizations may encourage and increase diversion of organics.

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3 REGULATORY PROGRAM COSTS AND EMISSIONS REDUCTIONS FOR THE EMISSION GUIDELINES

3.1 Introduction

Currently, the Emission Guidelines for existing MSW landfills requires landfills of at least 2.5 million megagrams (Mg) capacity and 2.5 million cubic meters in size with estimated non-methane organic compound (NMOC) emissions of at least 50 Mg per year to collect and control or treat landfill gas (LFG). Landfills which meet the design size requirements but do not emit at least 50 Mg NMOC per year are required to test and monitor. As part of this review, the EPA evaluated the emission reductions and costs associated with a series of regulatory options. This chapter of the RIA includes three sets of discussions related to the new Emission Guidelines:

- Emissions Analysis
- Engineering and Administrative Cost Analysis
- Regulatory Option Analysis

This discussion of the emissions and cost analyses is meant to assist the reader of the RIA to better understand the regulatory impact analysis. However, we provide references to technical memoranda for readers interested in a greater level of detail.

3.2 General Assumptions and Procedures

The final Emission Guidelines will affect existing MSW landfills. Any changes to the MSW Landfills EG that might result from this review will ultimately apply to landfills that accepted waste on or after November 8, 1987[17], and that commenced construction, reconstruction, or modification prior to July 17, 2014 (the date of publication of proposed revisions to the landfills NSPS, 40 CFR part 60, subpart XXX). However, the EPA recognizes

[17] This date in 1987 is the date on which permit programs were established under the Hazardous and Solid Waste Amendments of RCRA. This date was also selected as the regulatory cutoff in the EG for landfills no longer receiving wastes because EPA judged States would be able to identify active facilities as of this date.

that many landfills subject to the proposed Subpart Cf are closed or contain inactive areas that do not produce as much landfill gas. Therefore, the EPA is finalizing a separate subcategory for landfills that closed after 1987 but on or before 13 months following the publication date of the final Emission Guidelines in the Federal Register. These landfills would be subject to a 50 Mg/yr NMOC emission rate threshold, consistent with the NMOC thresholds in Subparts Cc and WWW of Part 60. These landfills will also be exempt from initial reporting requirements, provided that the landfill already met these requirements under Subparts Cc or WWW of Part 60.

To assess the impacts of the final guidelines, the EPA drew upon a comprehensive database of existing landfills, derived from a landfill and LFG energy project database maintained by the EPA's Landfill Methane Outreach Program (LMOP) and data from the Greenhouse Gas Reporting Program (GHGRP). Unfortunately, this dataset was missing some landfill data for recent years (2013-2014) and included incomplete data for many landfills. To better represent landfills from recent years, model landfills were created. These model future landfills were developed by evaluating the most recently opened existing landfills and assuming that the sizes and locations of landfills opening in 2013-2018 would be similar to the sizes and locations of landfills that opened from 2005-2012. Based on this assessment, the EPA created a total of five model landfills to represent landfills opening during 2013-2014. In addition, 11 model landfills were created that would be subject to the NSPS discussed in Chapter 7. The creation of the landfill dataset is detailed in the docketed memorandum, "Summary of Updated Landfill Dataset Used in the Cost and Emission Reduction Analysis of Landfill Regulations. 2016."

To estimate the cost and emission impacts of each regulatory option, EPA determined those landfills that met the design capacity and emission rate thresholds for each regulatory option, and then calculated the emission reductions and costs for each landfill under each regulatory option in 2025 using the methods described below. The EPA is assessing impacts in year 2025 as a representative year for the MSW Landfills EG. While the year 2025 differs somewhat from the expected first year of implementation for the EG, the number of existing landfills required to install controls under the final 2.5/34 option in year 2025 is the same number of landfills required to control in the estimated first year of implementation. Further, year 2025 represents a year in which several of the landfills subject to control requirements have had to expand their GCCS according the expansion lag times set forth in final subpart Cf. While the analysis focuses on impacts in 2025, results for alternative years are also presented in Section 3.6. The resulting costs and emission reductions incurred by each landfill were used to assess the overall impacts of the current EG in the baseline and the incremental impacts of the regulatory options considered. The emission reduction and cost and revenue equations and assumptions are detailed in the docketed memorandum from ERG to EPA, "Updated Methodology for Estimating Cost and Emission Impacts of Final MSW Landfill Regulations. 2016"

The emissions and cost modeling was based upon the following basic assumptions:

- The baseline represents the emission reductions and costs associated with the requirements of Subpart Cc. Each regulatory option was compared to this baseline.
- Each landfill would install gas collection and control systems (GCCS) when the landfill exceeds the emission rate and design capacity threshold. [18]
- Each landfill would remove GCCS when the actual emissions are below the emissions threshold, the landfill is closed, and the controls have been in place for at least 15 years.

[18] EPA expanded the tiering system used by landfills to determine when the final rule emission rate threshold is exceeded (34 Mg/yr of NMOC) and a GCCS must be installed to include an additional voluntary approach, Tier 4. The new Tier 4 provides for surface emission monitoring at the landfill to be used in the determination of the necessity and timing of installation of GCCS. (See the preambles for the EG and NSPS for more details on the Tier 4 approach.) The analysis of benefits and costs in this RIA is generally not dependent upon the tiering method used by a landfill to determine exceedance of the threshold. The LandGEM model estimates when landfills will exceed the final EG and NSPS NMOC emission threshold based upon a variety of relevant factors such as expected waste disposal at a particular landfill and the decomposition rates of the waste, among other factors. In estimating the emission control costs, the results of the model are not dependent upon the tier a particular landfill uses to determine eligibility. EPA assumes the use of Tier 1 and 2 in developing estimates of the monitoring, testing and reporting requirement costs. The EPA has not estimated monitoring, reporting and recordkeeping costs for Tier 4, because it is provided as a voluntary means of assessing when GCCS should be installed. The Tier 4 methodology is new; therefore we cannot provide an assumption of the universe of landfills that would actually use Tier 4. The EPA may provide an estimation of the impacts associated with Tier 4 in future reviews of the standards, if such data to conduct an assessment exist. The testing and monitoring cost estimates presented in this RIA have been adjusted to reflect these changes. In addition, costs associated with the recordkeeping requirement to take and store digital photographs of the Tier 4 monitoring is not reflected in the final RIA

Costs were annualized using a 7% interest rate, which is consistent with OMB Circular A-4 and EPA guidance for cost evaluations. Costs are also presented using a 3% interest rate, in accordance with OMB guidance.

Alternative regulatory options varied the emission rate thresholds and design capacity thresholds.

3.3 Emissions Analysis

To estimate emission reductions, the amount of LFG and NMOC emitted at each landfill was estimated using a model programmed in Microsoft® Access. The model assumes that the collection equipment is installed and operational at the landfill 30 months after the emissions exceed the NMOC emission threshold in each option[19]. As the landfill is filled over time, the model assumes the landfill expands the GCCS into new areas of waste placement in accordance with the expansion lag time of the standard. Once the landfill has reached maximum gas production, gas generation will begin to decline once waste is no longer accepted. At this point, the analysis assumes that the GCCS no longer needs to be expanded and the GCCS will continue to collect all the gas being produced until the gas production falls back below the emission threshold of the standard and the GCCS has been installed for at least 15 years.

The emission reductions were calculated by multiplying the amount of collected gas by a destruction efficiency of 98 percent. The amount of gas collected is governed by a gas collection efficiency assumption of 85 percent.

The impacts analysis at proposal did not apply such a collection efficiency assumption. However, the EPA received public comments from the August 2015 proposal and peer review comments[20] of the LFGCost model that resulted in a reassessment of the collection efficiency assumption for the final rule impacts analysis. A number of sources of information were

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[19] Note that even though the guidelines allow a 30-month initial lag time, the model actually assumes the collection equipment is installed and operational at 36 months. We modeled assuming a 36 month (3-year) lag time since the first-order decay equation used to model emissions is on an annual, instead of monthly, basis. Further, because the current rule requires annual NMOC emission reports to be submitted by 6 months into the following calendar year, the landfill would have 30 months after the submittal of its first NMOC emission report showing an exceedance to install the GCCS, which is approximately 36 months after the excess emissions occurred.

[20] Peer review of the LFGCost model is included in the docket.

evaluated in reaching this determination. Specifically, in the EPA report, *Global Mitigation of Non-CO_2 Greenhouse Gases: 2010*-2030 (EPA Report # EPA-430-R-13-011), the marginal abatement cost (MAC) model used for the report analysis assumed an 85% collection efficiency for engineered landfills (those designed with leachate and gas collection systems) and 75% for basic landfills, with a distribution in the U.S. of 20% basic landfills and 80% engineered landfills (resulting in a collection efficiency of 83% averaged across the U.S). The assumptions used in the MAC model are based on peer reviewed articles cited in the report and expert solicitation, and was peer reviewed prior to publication of the report in September 2013. Additionally**,** AP-42, *Compilation of Air Pollutant Emission Factors*[21], serves as the primary compilation of EPA's emission factor information. It contains emission factors and process information for more than 200 air pollution source categories. A source category is a specific industry sector or group of similar emitting sources. The emission factors were developed and compiled from source test data, material balance studies, and engineering estimates. In the AP-42 chapter for landfills, reported collection efficiencies typically range from 60 to 85 percent, with an average of 75 percent most commonly assumed. Higher collection efficiencies may be achieved at some sites (i.e., those engineered to control gas emissions). If site-specific collection efficiencies are available (i.e., through a comprehensive surface sampling program), AP-42 recommends that they be used instead of the 75 percent average. Additionally, through the public comment process, the EPA also became aware of a study by Barlaz, et al.[22] which described changes in collection efficiency over time. The study asserted that typical collection efficiencies were 0 percent in years 1 and 2 of waste disposal; 50 percent in year 3; 75 percent in year 4; 75 percent in years 5-10; and 95 percent from year 11 on. Finally, the EPA is also aware of public commenters from the waste-to-energy industry who asserted that gas collection efficiency was overestimated at proposal due to the inefficiencies at landfills capturing methane emissions.

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[21] AP-42, *Compilation of Air Pollutant Emission Factors* available at: https://www3.epa.gov/ttn/chief/ap42/index.html

[22] Barlaz et al., "*Controls on Landfill Gas Collection Efficiency: Instantaneous and Lifetime Performance*," Journal of the Air and Waste Management Association, December, 2009, Volume 59, p.1402, Table 3, Case 3.

After considering the various sources of information discussed above including public comments on the August 2015 proposal, the peer review of the LFGCost model, EPA assumptions in subpart HH of the GHGRP[23], and analyses performed for marginal abatement cost curves, in the final rule the EPA has included an 85 percent average gas collection efficiency factor to reflect a more realistic indicator of GCCS performance. The EPA recognizes that there is uncertainty in the collection efficiency assumption that results in uncertainty in the associated emission reductions, benefits and costs reported. As discussed above, collection efficiency estimates often average around 75 percent, and are typically higher for those engineered to control gas emissions (depending on a variety of factors including how well the GCCS is operated and maintained, cover material, and liner), increasing to 95 percent in the later years. If one assumes 75 percent control efficiency, EPA estimates emission reductions would be 10% lower than currently projected, whereas emission reductions may be 10% higher with a collection efficiency assumption of 100 percent. Costs are also likely to change depending upon the collection efficiency, but these changes would not be directly proportional to the emissions reductions achieved because costs are highly dependent upon a number of factors including costs associated with sizing of equipment.

In addition to direct emission reductions, the EG are expected to have secondary air impacts due to the additional energy demand required to operate the control system and the by-product emissions from the combustion of LFG. However, these are offset by avoided emissions from the national electrical grid as landfills generate electricity from the LFG and demand less electricity. The methodology used to estimate net secondary impacts of the Emission Guidelines are detailed in the docketed memorandum from ERG to EPA, "Revised Estimates of Secondary Impacts of the Landfills Emissions Guidelines Review. 2016". See Table 4-4 of this RIA for the estimated net CO_2 emission reductions associated with secondary impacts for the final EG and regulatory alternatives. For the final EG, the EPA estimates secondary CO_2 reductions of about 280,000 metric tons in 2025.

In addition to CO_2 emissions changes, secondary SO_2 and NOx and trace amounts of LFG constituent pollutants may be impacted. Increases in these pollutants may occur due to

[23] USEPA. Global Mitigation of Non-CO_2 Greenhouse Gases: 2010-2030. EPA-430-R-13-011.

increased energy demand required to operate control equipment and as a by-product of combustion of LFG. However, reductions in these pollutants may also occur due to reduced demand for electricity from the national electrical grid. The net of these changes in SO2, NOx, and trace amounts of LFG constituent pollutants are expected to be relatively small and are not estimated.

3.4 Engineering and Administrative Cost Analysis

The evaluation will assume that landfills will install and remove LFG controls as required by the rule. Landfills are required to install controls when the landfill exceeds the emission rate and design capacity thresholds. Landfills are allowed to remove controls when the actual emissions are below the emissions threshold, the landfill is closed, and the controls have been in place for at least 15 years.

The EPA derived the cost equations used in the evaluation from the EPA's Landfill Gas Energy Cost Model (LFGcost-Web), version 3.0, which was developed by the EPA's Landfill Methane Outreach Program (LMOP). LFGcost-Web estimates gas collection, flare, and energy recovery system costs and was developed based on cost data obtained from equipment vendors and consulting firms that have installed and operated numerous gas collection and control systems. LFGcost-Web encompasses the types of costs included in the EPA Air Pollution Control Cost Manual including capital costs, annual costs, and revenue from LFG electricity sales. Total capital costs include purchased equipment costs, installation costs, engineering and design costs, costs for site preparation and buildings, costs of permits and fees, and working capital. Total annual compliance costs include direct costs, indirect costs, and are offset by revenue from LFG electricity sales. Direct annual costs are those that are proportional to a facility-specific metric such as the facility's productive output or size. Indirect annual costs are independent of facility-specific metrics and may include categories such as administrative charges, taxes, or insurance.

The EPA conducted an external peer review of the LFGcost model, and peer reviewer responses were received in January 2016.[24] Three reviewers considered 14 charge questions that covered various aspects of the model including: model methods, model functionality, model documentation, and applicability of the model for regulatory analysis. With regards to use of the model for regulatory analysis, reviewers agreed that use of the LFGcost-Web cost equations to calculate annualized capital, operations and maintenance and where profitable annual revenue from electricity sales and the application of these equations to the landfills in the proposed landfill regulations was appropriate. In response to a question about the availability of other more appropriate data sources or models, the reviewers stated that they were not aware of alternative data sources or models that would be more appropriate than the LFGcost model for estimating the costs of emission controls.

The EPA received helpful suggestions on technical inputs to the LFGcost model from the public as well as the peer review that are relevant to the cost analysis for this rule – e.g. collection efficiency (discussed above) and the relevant electricity prices for consideration in the revenue calculations. We have adjusted electricity prices used in the analysis in response to these recommendations. Specifically, the EPA adjusted electricity purchase price and anticipated revenue estimates using forecasted commercial retail electricity rate data and forecasted electricity generation price data for different Energy Information Administration (EIA) "Electric Power Projections by Electricity Market Module Region" table in the Annual Energy Outlook

[24] For a copy of the peer review see the docket for this rulemaking.

2015.[25,26] There are two types of electricity prices relevant for the analysis. First, is the rate the landfill is charged to purchase electricity (i.e., retail rate) that will be used in operating compliance equipment. Second, is the electricity buy-back rate relevant to calculating the expected revenue from new energy projects that will supply electricity to the power grid. In both cases, the electricity prices used in the analyses are based on forecasts from EIA's 2015 Annual Energy Outlook reference case.[27, 28]

To calculate the expected cost of electricity for operating compliance equipment, such as blowers for active gas collection systems, commercial retail rates for EIA Electricity Market Module region in which the landfill is located are used. Similarly, the commercial retail rates are also used in assessing the avoided cost of electricity when it is forecast that the site will find it

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[25] Energy Information Agency. Annual Energy Outlook for 2015. Electric Power Projections by Electricity Market Module Region", http://www.eia.gov/forecasts/aeo/data/browser/#/?id=62-AEO2015&cases=ref2015&sourcekey=0. AEO2015 was the most recent version of the Annual Energy Outlook available at the time the analysis was conducted. The AEO2015 projections are based generally on federal, state, and local laws and regulations in effect as of the end of October 2014. The potential impacts of pending or proposed legislation, regulations, and standards (and sections of existing legislation that require implementing regulations or funds that have not been appropriated) are not reflected in the projections. In certain situations, however, where it is clear that a law or a regulation will take effect shortly after AEO2015 is completed, it may be considered in the projection. See http://www.eia.gov/forecasts/aeo/assumptions/pdf/appendix_a.pdf for more details.

[26] To map existing landfill sites to EIA's Electricity Market Module (EMM) regions, the sites' geospatial coordinates were overlaid on a map of the EMM regions. The AEO Electricity Market Module regions are commensurate with the eGRID2012 primary regions for which a shapefile is available at https://www.epa.gov/energy/download-egrid2012-shapefiles. For expected new landfills within a state the specific location is unknown, therefore the landfill is located at the state's centroid for purposes of mapping the site to an EMM region.

[27] To map existing landfill sites to EIA's Electricity Market Module regions, the sites' geospatial coordinates were overlaid on a map of the EMM regions. The AEO Electricity Market Module regions are commensurate with the eGRID2012 primary regions for which a shapefile is available at https://www.epa.gov/energy/download-egrid2012-shapefiles. For expected new landfills within a state the specific location is unknown, therefore the landfill is located at the state's centroid for purposes of mapping the site to an EMM region.

[28] AEO 2015 forecasts extend to the year 2040, while EPA's analysis extends beyond this time frame to capture the investment horizon that may be considered by landfill operators. The AEO price forecasts are extended to the end of the modeling horizon by assuming that they remain constant after 2040. Since EIA's AEO forecasts for electricity prices only cover the lower 48 contiguous U.S. states, these forecasts need to be extrapolated to Alaska, Hawaii, and the affected U.S. territories. This extrapolation is based on scaling the average U.S. commercial and generation price forecasts by factors consistent with EIA statements/data on how electricity prices in these areas compare to the U.S. average in recent years. See the document Regional Average Electricity Generation Prices in the docket for a complete list of the electricity prices assigned to each landfill.

profitable to operate an energy project that will generate electricity, which will be used to offset on site electricity requirements.

The electricity buy-back rates relevant to calculating the revenue from new energy projects will depend on several factors specific to the local electric utility and the type of contract available to the project. These electricity buy-back rates are contractually agreed upon and not typically publicly available. However, in general the rate at which local utilities are willing to purchase electricity generated at landfills will be related to the costs of producing electricity from other sources located on the power grid. Therefore, the buy-back rates are based on the AEO generation portion of the electricity price for the EIA Electricity Market Module region in which the site is located.[29]

The marginal cost of generation for electric utilities in the region of the power market where the landfill is located will represent the resources that could be saved by the utilities when they purchase a unit of electricity from the landfill instead of producing it from the most expensive facility they are currently operating. In deregulated electricity markets, this marginal cost will equal the wholesale electricity price, or in other words the generation portion of the electricity price. In regulated electricity markets, where the generation portion of the electricity price is set based on the average cost of generation, as such it will not be equivalent to the marginal cost of generation for the region. As a result the buy-back rate used for landfills located in regulated electricity markets based on this approximation may be slightly biased for sites located in regulated electricity markets. However, generation prices in all regions are still based on the underlying factors that would determine the price electric utilities would be willing to pay for electricity generated from LFG. Empirical evidence on buy-back rates is limited, but available evidence suggests rates typically range between 2.5 and 11 cents per kWh in recent years (EPA, 2014b). Regional generation prices in AEO reported for 2012, a year comparable with the time frame of the aforementioned rates, ranges similarly from 2.1 to 12.3 cents per kWh.

[29] Specifically, the energy project investment decision is based on the average generation price forecasted for the power region in which the landfill is located over 2020-2034, i.e., the time period the typical project is expected to generate electricity (about 15 years). See the document Regional Average Electricity Generation Prices in the docket for a complete list of the average generation price assigned to each landfill.

The generation portion of the forecast electricity price in the AEO is expected to track general electricity market trends in these regions and thus provides a reasonable basis for estimating the revenues associated with new energy projects in the analysis time frame.

For this evaluation, the EPA assessed costs in 2012$. The costs included in LFGcost-Web are in 2013$ and were adjusted for inflation to 2012$ using a factor of 0.97 for capital costs, based on the ratio of the 2013 Chemical Engineering Plant Cost Index (CEPCI) to the 2012 CEPCI (567.3/584.6). For O&M costs, a factor of 1.5 percent was used based on the 2013 Consumer Price Index Change relative to 2012. For the primary estimate of costs, the EPA used an interest rate of 7% to annualize the capital costs in this evaluation to estimate the annual capital cost of flares, wells, wellheads (including piping to collect gas), and engines over the lifetime of the equipment. Costs were also estimated using an interest rate of 3%. The EPA assumes that the equipment will be replaced when its lifetime is over, so the annualized capital costs are incurred as long as the landfill still has controls in place. In order to calculate the annualization factors, the EPA assumes that flares, wells, well heads, and engines have a 15-year lifetime. In addition, there is a mobilization/installation charge to bring well drilling equipment on site each time the gas collection system is expanded. Because the landfill will be drilling wells to expand the control system during the expansion lag year, EPA assumes that this capital installation cost has a lifetime equal to the expansion lag time (4 years average on average).

A number of the capital costs equations are dependent upon the number of wells at each landfill. In order to estimate the number of wells at each landfill, EPA estimated the number of acres that have been filled with waste for each landfill for each year. We assumed that the percentage of design area filled (acres) would track the ratio of waste in place/design capacity (e.g., is a landfill has a waste-in-place amount equivalent to 40% of design capacity, then 40% of the planned acreage is filled). EPA assumed that each landfill would install one well per acre and that the number of wells would increase periodically based on expansion lag time.

Engines are assumed to be installed only at landfills that produce enough LFG to power the engine and only when the electricity buyback rates allow the operation of the engine to be profitable. Standard engines used at landfills have approximately 1 MW capacity, which equates to 195 million ft^3 per year of collected LFG (at 50 percent methane). Therefore, engines are assumed to be installed at landfills that have at least 195 million ft^3 per year of collected LFG for at least 15 years.

EPA calculated and summed the engine capital and operation and maintenance (O&M) equations to determine at what electricity buyback rate an engine is profitable. The profitable electricity buyback rates are rates that are greater than $0.0593 per kWh at 7% and greater than $0.0511 per kWh at 3% interest. Engines were only assumed to be installed in EIA's Electricity Market Module regions (EMM regions) with buyback rates exceeding those values.

Multiple engines may be present at a landfill when there is sufficient gas flow to support additional engines. As noted above, one engine requires 195 million ft^3 per year of collected LFG, so in order to have two engines on-site, the landfill must have double that amount of LFG (390 million ft^3 per year) for at least 15 years.

The capital costs for engines are based on the capital costs for standard reciprocating engine-generator sets in LFGcost-Web. These costs include gas compression and treatment to remove particulates and moisture (e.g., a chiller), reciprocating engine and generator, electrical interconnect equipment, and site work including housings, utilities, and total facility engineering, design, and permitting.

Several of the compliance requirements require labor to complete the activities in addition to capital expenses for purchasing the monitoring and control equipment. This analysis assumes that a Civil Engineer or Civil Engineer Technician completes compliance requirements of the amendments, depending on the complexity of the task. Some landfill owners or operators do all or a portion of this work directly while others contract out control installation or monitoring requirements.

3.5 Regulatory Baseline and Options

As mentioned before, the alternative regulatory options differ from the baseline by varying in the design capacity thresholds and emission rate thresholds:

- **Baseline:** design capacity retained at 2.5 Mg, emission threshold retained at 50 Mg NMOC/year

- **Alternative Option 2.5/40:** design capacity retained at 2.5 Mg, emission threshold reduced to 40 NMOC Mg/yr
- **Final Option 2.5/34:** design capacity retained at 2.5 Mg, emission threshold reduced to 34 NMOC Mg/yr
- **Alternative Option 2.0/34:** design capacity reduced to 2.0 Mg, emission threshold reduced to 34 Mg NMOC/year

The baseline reflects the parameters of the current EG. In the baseline, the EG affect 1014 landfills, with 638 landfills controlling emissions, 177 landfills reporting but not controlling emissions, and 228 landfills in the closed subcategory in 2025.

Table 3-1 Number of Affected Landfills in 2025 under the Baseline, Final Guidelines and Alternative Options

	Affected Landfills	Landfills Controlling Emissions	Open Landfills Reporting, but Not Controlling Emissions
Baseline	1,014	638	177
	Incremental Values From Current Emission Guidelines		
Alternative option 2.5/40	0	58	-58
Final option 2.5/34	0	93	-100
Alternative option 2.0/34	103	113	-65

Note: Affected landfills include landfills subject to rule based on size and open as of 2017 (13 months after the final rule is promulgated) for the final option or as of 2015 (the date of proposal) for alternative option 2.5/40 or 2.0/34 as well as landfills in the closed subcategory. Affected open landfills are comprised of open landfills controlling emissions and open landfills reporting but not controlling emissions. Some closed landfills are still controlling emissions in 2025. The number of landfills affected remains the same as the baseline except for the most stringent option. This means the number of landfills reporting NMOC (but not controlling) decreases under each option, because more landfills will control emissions under the final rule. Of the 1,014 landfills affected in the baseline, 930 report to the GHGRP.

Based on the characteristics of the landfills, the final guidelines presented in Table 3-1 would require 93 additional open landfills to install controls by 2025. The less stringent alternative option would require 58 additional landfills to install controls by 2025, while the more stringent alternative option would require 113 additional landfills to install controls by 2025. Some landfills will be required only to report, while others will be required to install controls by 2025. Under the most stringent option, the design capacity threshold is reduced to 2.0 million Mg and this alternative would result in 103 additional affected landfills.

Under the final guidelines option 2.5/34, the emission reductions would be an additional 1,810 Mg NMOC and 0.29 million Mg methane (7.1 million Mg CO_2-Equivalents) compared to the baseline in 2025. The less stringent alternative option 2.5/40 would yield emissions reductions of 1,180 Mg of NMOC per year and 0.19 million Mg methane (4.6 million Mg CO_2-Equivalents) compared to the baseline, while the more stringent alternative option 2.0/34 would result in emissions reductions of 2,190 Mg NMOC and 0.34 million Mg methane (8.6 million Mg CO_2-Equivalents) compared to the baseline. The wide range in magnitude of emission reductions among pollutants is due to the composition of landfill gas. Specifically, NMOC emissions represent less than 1 percent of landfill gas, while methane represents approximately 50 percent. The emission reductions are summarized in Table 3-2.

Table 3-2 Estimated Annual Average Emissions Reductions in 2025 for the Baseline, Final Guidelines and Alternative Options

	Annual Average Reduction (Mg)		
	NMOC	Methane Million Mg	Methane (in CO_2-equivalents) Million Mg*
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC			
Baseline	58,800	9.3	231
Incremental values versus the current EG			
Alternative option 2.5/40	1,180	0.19	4.6
Final option 2.5/34	1,810	0.29	7.1
Alternative option 2.0/34	2,190	0.34	8.6

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are not included in this table. See Table 4-4 for estimates of secondary CO_2 emission reductions. Note that 1 Mg is equivalent to 1 metric ton.

Under the final guidelines option of 2.5/34, when using a 7% discount rate the additional cost of control over the baseline in 2025 is estimated to be $93 million, about $39 million of which is estimated to be offset by increased revenue from capture landfill gas beneficial-use projects, so the net cost is estimated to be $54 million as shown on Table 3-3 below. This estimate includes testing and monitoring costs of $0.76 annually in 2025 (2012$). The methods used to estimate the testing and monitoring costs are outlined in the technical support document included in the docket entitled Updated Methodology for Estimating Testing and Monitoring Costs for the MSW Landfills Regulations. The additional cost of control for the less stringent alternative option 2.5/40 is estimated to be $63 million, $32 million of which is estimated to be offset by increased revenue from captured landfill gas beneficial-use projects, so the net cost is estimated to be $32 million (includes 0.47 million annually in testing and monitoring costs). The cost of control for the more stringent alternative option 2.0/34 is estimated to be $110 million, $50 million of which is estimated to be offset by increased revenue from beneficial-use projects, so the net cost is estimated to be $62 million annually (includes $0.97 million in testing and monitoring costs (2012$)). The costs associated with these options represent approximately between 5 to 10 percent in additional net costs beyond the baseline, with the final option 2.5/34 resulting in about an 8 percent increase in net emission control costs beyond the baseline emission control costs for the industry as a whole.

Table 3-3 Estimated Engineering Compliance Costs in 2025 for Baseline and Alternative Options (7% Discount Rate)

	Estimated Annualized Net Cost (Millions 2012$)			
	Testing and Monitoring Costs	Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	11	2,550	1,920	640
Incremental values versus the current EG				
Alternative option 2.5/40	0.47	63	32	32
Final option 2.5/34	0.76	93	39	54
Alternative option 2.0/34	0.97	110	50	62

Note: All total are independently rounded and may not sum.

When using a 3% discount rate, the model predicts a different timing in the investment behavior by the landfills, which affects both the costs and revenue that are predicted in 2025. Under the final guidelines option of 2.5/34, the additional cost of control over the baseline in 2025 is estimated to be $84 million per year, $42 million of which is estimated to be offset in increased revenue from capture of landfill gas beneficial-use projects, so the net cost is estimated to be $43 million (includes $0.75 million in testing and monitoring costs annually (2012$). The costs of the final guidelines and alternatives are shown in Table 3-4 below.

The cost of control for the less stringent alternative option 2.5/40 is estimated to be $57 million, $33 million of which is estimated to be offset by increased revenue from beneficial use projects, so the net cost is estimated to be $24 million (includes 0.46 million in monitoring and testing costs and assumes a 3% discount rate and 2012$). The cost of control for the more stringent alternative option 2.0/34 is estimated to be $100 million, of which $53 million is estimated to be offset by increased revenue from beneficial-use projects, so the net cost is estimated to be $48 million annually in 2025 (2012$). These options represent approximately between 8 to 15 percent in additional net costs of emission controls beyond the baseline, with the final option 2.5/34 resulting in a 13 percent increase in net costs of emission control beyond the baseline for the industry as a whole. However, it is important to note that the baseline value of emission control when using a 3% discount rate is less than 50 percent of the value when using a 7% discount rate, because the increased costs of earlier installation of GCCS and engines are offset by increased revenue from energy generation.

Table 3-4 Estimated Engineering Compliance Costs in 2025 for Baseline, Final Guidelines and Alternative Options (3% Discount Rate)

	Estimated Annualized Net Cost (Millions 2012$)			
	Testing and Monitoring Costs	Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	11	2,290	1,990	320
Incremental values versus the current EG				
Alternative option 2.5/40	0.46	57	33	24
Final option 2.5/34	0.75	84	42	43
Alternative option 2.0/34	0.95	100	53	48

Note: All total are independently rounded and may not sum.

In terms of cost effectiveness, when considering the estimated net cost of the options at a 7% discount rate, the overall average cost effectiveness for NMOC reductions is $10,900 per Mg NMOC under the baseline and roughly $29,900 per Mg NMOC under the final guidelines option

2.5/34, 28,200 under alternative option 2.0/34, and roughly $26,800 per Mg NMOC under the alternative option 2.5/40 (Table 3-5). The average cost-effectiveness of controlling methane is significantly lower than for NMOC because methane constitutes approximately 50 percent of landfill gas, while NMOC represents less than 1 percent of landfill gas. The overall average cost effectiveness for methane reductions is roughly $69 per Mg methane under the baseline and approximately $170 - $190 per Mg methane under the final guidelines option 2.5/34 and the alternative options 2.5/40 and 2.0/34.

When estimating cost effectiveness excluding the estimated revenue from beneficial-use projects, the overall average cost effectiveness for NMOC reductions is $43,600 per Mg NMOC under the baseline and roughly $51,600 per Mg NMOC under the final option 2.5/34, 51,200 under alternative option 2.0/34, and roughly $53,600 per Mg NMOC under the alternative option 2.5/40 (Table 3-5). The average cost-effectiveness of controlling methane is significantly lower than for NMOC because methane constitutes approximately 50 percent of landfill gas, while NMOC represents less than 1 percent of landfill gas. The overall average cost effectiveness for methane reductions is $280 per Mg methane under the baseline and approximately $330 - $340 per Mg methane under the final option 2.5/34 and the alternative options 2.5/40 and 2.0/34. Cost effectiveness estimates assuming a 3% discount rate are shown in Table 3-6 below.

Table 3-5 Estimated Cost-effectiveness in 2025 for the Baseline, Final Guidelines and Alternative Options (7% Discount Rate)

	Cost-effectiveness (2012$ per Mg)					
	NMOC		Methane		Methane (in CO_2-equivalents)*	
	Net Cost[b]	Total Cost	Net Cost[b]	Total Cost	Net Cost[b]	Total Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC						
Baseline	10,900	43,600	69	280	2.8	11.1
Incremental values versus the current EG						
Alternative option 2.5/40	26,800	53,600	170	340	6.8	13.6
Final option 2.5/34	29,900	51,600	190	330	7.6	13.1
Alternative option 2.0/34	28,200	51,200	180	330	7.2	13.0

Note: The cost-effectiveness of NMOC and methane are estimated as if all of the control cost were attributed to each pollutant separately. One megagram is equivalent to one metric ton and these terms may be used interchangeably.
[a] A global warming potential of 25 is used to convert methane to CO_2-equivalents. The secondary CO_2 emission reductions are not reflected in these estimates.
[b] Total and net costs include the cost of testing and monitoring. Net Cost is the total control costs of GCCS installation and operation plus testing and monitoring cost minus any project revenue. The control costs for landfills with energy projects includes costs to install and operate a reciprocating engine (and associated electrical equipment), which is more expensive than a standard flare. Reciprocating engines are not required by the regulation but are expected to be installed to offset compliance costs when it is cost-effective to recovery the LFG energy.

Table 3-6 Estimated Cost-effectiveness in 2025 for the Baseline, Final Guidelines and Alternative Options (3% Discount Rate)

	Cost-effectiveness (2012$ per Mg)					
	NMOC		Methane		Methane (in CO_2-equivalents)*	
	Net Cost[b]	Total Cost	Net Cost[b]	Total Cost	Net Cost[b]	Total Cost
Baseline	5,400	39,200	34	250	1.4	9.9
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC						
Incremental values versus the current EG						
Alternative option 2.5/40	20,300	48,300	130	310	5.2	12
Final option 2.5/34	23,600	46,900	150	300	6.0	12
Alternative option 2.0/34	22,000	46,400	140	300	5.6	12

Note: The cost-effectiveness of NMOC and methane are estimated as if all of the control cost were attributed to each pollutant separately. One megagram is equivalent to one metric ton and these terms may be used interchangeably.
[a] A global warming potential of 25 is used to convert methane to CO_2-equivalents. The secondary CO_2 emission reductions are not reflected in these estimates.
[b] Total and net costs include the cost of testing and monitoring. Net Cost is the total control costs of GCCS installation and operation plus testing and monitoring cost minus any project revenue. The control costs for landfills with energy projects includes costs to install and operate a reciprocating engine (and associated electrical equipment), which is more expensive than a standard flare. Reciprocating engines are not required by the regulation but are expected to be installed to offset compliance costs when it is cost-effective to recovery the LFG energy.

3.6 Alternative Years of Analysis

While the EPA is assessing impacts in year 2025 as a representative year for the landfills Emission Guidelines for existing MSW landfills, the expansion of landfills, installation of control equipment, and the quantity and composition of landfill gas do change over the lifetime of a landfill, as discussed in Chapter 2. For this reason, the EPA is presenting the emission reductions, costs and potential revenues generated from the capture of landfill gas for additional years including 2020, 2030, and 2040 for the final option of 2.5/34 as well as the more stringent and less stringent regulatory alternatives. The emission reductions and costs resulting from the EG are incremental to the baseline of the current standard (2.5 million Mg design capacity and an annual NMOC emission threshold of 50 Mg/yr). The patterns of emission reductions and costs over time are reflective of the timing and magnitude of emission control equipment installed to meet the standards. Lowering the annual threshold requires controls to be installed earlier than in the baseline, and would result in the controls remaining installed for a longer period than the baseline for some landfills.

The comparison of the emission reductions and costs of the final EG and regulatory alternatives for 2020, 2025, 2030 and 2040 as well as the NPV of the final EG for the period 2019 through 2040 present a more complete picture of the emission reductions and costs of the final Emission Guidelines and regulatory alternatives over time. Throughout the 2020, 2030 and 2040 snapshot year analyses, costs are presented only at a 7% interest rate[30], and do not include testing and monitoring costs. However, testing and monitoring costs are typically a very small percentage of the overall costs. Tables 3-7 and 3-8 present the emissions reductions and compliance costs, respectively, of the alternatives in the 2020 snapshot year.

Table 3-7 Estimated Annual Average Emissions Reductions in 2020 for the Baseline, Final Emission Guidelines and Alternative Options

	Annual Average Reduction (Mg)		
	NMOC	Million Methane	Million Methane (in CO_2-equivalents)*
Current EG = 2.5 million Mg and m[3] design capacity and 50 Mg/yr NMOC			
Baseline	52,960	8.3	210
Incremental values versus the current EG			
Alternative option 2.5/40	1,290	0.20	5.1
Final option 2.5/34	1,990	0.31	7.9
Alternative option 2.0/34	2,270	0.36	8.9

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are not included in this table.

[30] Emission control cost estimates presented in Tables 3-8, 3-10 and 3-12 assume a 7% discount rate. Cost estimates assuming a 3% discount rate would be lower than the estimates shown.

Table 3-8 Estimated Engineering Compliance Costs in 2020 for Baseline, Final Emission Guidelines and Alternative Options (7% Discount Rate)

	Landfills Controlling Emissions	Estimated Annualized Net Cost (Millions 2012$)		
		Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	634	2,360	1,880	480
Incremental values versus the current EG				
Alternative option 2.5/40	56	78	50	28
Final option 2.5/34	95	110	64	46
Alternative option 2.0/34	110	130	74	52

Note: All total are independently rounded and may not sum.

Tables 3-9 and 3-10 present the emissions reductions and compliance costs, respectively, in the 2030 snapshot year.

Table 3-9 Estimated Annual Average Emissions Reductions in 2030 for the Baseline, Final Emission Guidelines and Alternative Options

	Annual Average Reduction (Mg)		
	NMOC	Million Methane	Million Methane (in CO_2-equivalents)*
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC			
Baseline	59,450	9.4	230
Incremental values versus the current EG			
Alternative option 2.5/40	1,330	0.21	5.2
Final option 2.5/34	1,900	0.30	7.5
Alternative option 2.0/34	2,270	0.36	8.9

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are not included in this table.

Table 3-10 Estimated Engineering Compliance Costs in 2030 for Baseline and Alternative Options (7% Discount Rate)

	Landfills Controlling Emissions	Estimated Annualized Net Cost (Millions 2012$) Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	635	2,610	1,890	720
Incremental values versus the current EG				
Alternative option 2.5/40	54	55	25	31
Final option 2.5/34	83	84	37	47
Alternative option 2.0/34	104	100	47	56

Note: All total are independently rounded and may not sum.

Tables 3-11 and 3-12 present the emissions reductions and compliance costs, respectively, in the 2040 snapshot year.

Table 3-11 Estimated Annual Average Emissions Reductions in 2040 for the Baseline, Final Guidelines and Alternative Options

	Annual Average Reduction (Mg) NMOC	Million Methane	Million Methane (in CO_2-equivalents)*
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC			
Baseline	54,470	8.6	210
Incremental values versus the current EG			
Alternative option 2.5/40	1,540	0.24	6.1
Final option 2.5/34	2,250	0.35	8.9
Alternative option 2.0/34	2,340	0.37	9.2

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are not included in this table.

Table 3-12 Estimated Engineering Compliance Costs in 2040 for Baseline, Final Guidelines and Alternative Options (7% Discount Rate)

	Landfills Controlling Emissions	Estimated Annualized Net Cost (Millions 2012$) Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	540	2,430	1,605	820
Incremental values versus the current EG				
Alternative option 2.5/40	49	87	36	51
Final option 2.5/34	75	120	53	70
Alternative option 2.0/34	81	130	54	73

Note: All total are independently rounded and may not sum.

3.7 Net Present Value of Control Costs of the Final Emission Guidelines

The EPA presents the emission reductions and emission control costs for the period 2019 through 2040 for the final EG standard of 2.5/34. For the period 2019 through 2040 cumulative emission reductions amount to about 43,300 Mg of NMOC and 6.8 million Mg of methane (about 170 million Mg of CO_2-equivalents). EPA also estimates the net present values (NPV) of the emission control costs for this period as well as the equivalent annualized values. The equivalent annualized values are the constant annual values that, when discounted over the period of 2019 through 2040, result in the NPV in 2019. All NPV values presented for the period 2019 through 2040 are discounted to the year 2019. This year represents the first year in which EPA anticipates affected landfills will comply with the NSPS by installing and operating GCCS. This also represents the time period when emission reductions are expected to begin as a result of the final NSPS.

Estimates of the potentially affected landfills and annual emission reductions of NMOC and methane for the final EG are presented in Table 3-13 for the period. The costs of installing and operating emission controls are shown in Table 3-14. Costs shown represent estimates of the annual operation and maintenance expenses plus the annualized portion of capital costs associated with installation and operation of GCCS to meet the EG for 2019 through 2040. Revenues associated with generating electricity resulting from the capture of landfill gas are also reflected. Total emission control costs are offset by revenues to estimate the net emission control costs of the final EG.

The NPV of the annualized costs for the period 2019 through 2040 is estimated to be about $1.5 billion assuming a 3% discount rate and $1.2 billion assuming a 7% discount rate. The NPV of revenues relating to energy generated with captured landfill gas amounts to about $790 million and $550 million for 3% and 7% discount rates, respective. When these incremental control costs are offset by the revenues associated with producing energy from captured landfill gas, the NPV of net emission control costs become $680 million and $620 million for the 3% and 7% discount rate, respectively. Equivalent annualized costs estimated using the NPV of the control costs without consideration of revenues generated from the capture of landfill gas, are $90 and $98 million (3% and 7% discount rate, respectively). Net equivalent annualized control costs for the period (after consideration of revenues generated from the energy produced by captured landfill gas) are approximately $41 million and $52 million assuming 3% and 7% discount rates, respectively. All estimates are shown in 2012$.

Table 3-13 Estimated Annual Average Emissions Reductions for the Final Emission Guidelines for 2019 through 2040

		Incremental Emission Reductions		
Year	Number of Affected Landfills	NMOC (Mg)	CH_4 (million Mg)	CO_2-equivalents (million mt)
2019	92	2,080	0.33	8.2
2020	95	1,990	0.31	7.9
2021	99	1,950	0.31	7.7
2022	103	1,940	0.31	7.6
2023	92	2,070	0.33	8.2
2024	94	1,940	0.31	7.6
2025	93	1,810	0.29	7.1
2026	89	1,680	0.26	6.6
2027	86	1,920	0.30	7.6
2028	84	1,840	0.29	7.3
2029	86	1,810	0.28	7.1
2030	83	1,900	0.30	7.5
2031	86	2,020	0.32	7.9
2032	88	2,080	0.33	8.2
2033	89	2,140	0.34	8.4
2034	93	1,820	0.29	7.2
2035	73	2,070	0.33	8.2
2036	74	1,910	0.30	7.5
2037	70	1,830	0.29	7.2
2038	66	2,010	0.32	7.9
2039	72	2,250	0.35	8.9
2040	75	2,250	0.35	8.9

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are not included in this table.

Table 3-14 Estimated Incremental Engineering Compliance Costs, Revenues and Net Costs Reductions for 2019 through 2040 for the Final Guidelines (millions of 2012$)

	Incremental Costs					
	3% Discount Rate			7% Discount Rate		
Year	**Total Control Cost**	**Revenue**	**Net Costs**	**Total Control Cost**	**Revenue**	**Net Costs**
2019	$110	$74	$34	$120	$69	$49
2020	$100	$69	$33	$110	$64	$46
2021	$97	$66	$31	$110	$61	$45
2022	$95	$60	$35	$100	$56	$48
2023	$90	$49	$41	$100	$46	$53
2024	$84	$45	$39	$92	$42	$50
2025	$84	$42	$42	$93	$39	$53
2026	$78	$40	$39	$86	$37	$49
2027	$81	$37	$44	$90	$35	$55
2028	$77	$34	$44	$86	$32	$54
2029	$77	$33	$44	$85	$31	$54
2030	$77	$39	$37	$84	$37	$47
2031	$85	$40	$45	$93	$37	$56
2032	$87	$41	$46	$95	$38	$57
2033	$90	$44	$45	$97	$39	$57
2034	$85	$37	$48	$93	$34	$60
2035	$87	$43	$44	$94	$39	$56
2036	$87	$42	$45	$94	$36	$57
2037	$87	$43	$44	$93	$37	$56
2038	$91	$52	$40	$98	$46	$52
2039	$100	$56	$49	$110	$50	$63
2040	$110	$58	$55	$120	$53	$70
Net Present Value	$1,500	$790	$680	$1,200	$550	$620
Equivalent Annualized Value	$90	$48	$41	$98	$46	$52

Notes: Costs represent estimates of the annual operation and maintenance expenses plus the annualized portion of capital costs associated with installation and operation of GCCS to meet the NSPS for 2019 through 2040. Costs do not include testing and monitoring.
Revenues relate to energy produced from captured landfill gas.
Totals may not sum due to rounding.

4 BENEFITS OF EMISSIONS REDUCTIONS FOR THE EMISSION GUIDELINES

4.1 Introduction

The final EG are expected to result in significant emissions reductions of landfill gas (LFG) from existing MSW landfills. By lowering the NMOC emissions threshold to 34 Mg/yr, the final action is anticipated to achieve reductions of 1,810 Mg/yr NMOC and 0.29 million Mg/yr methane in 2025. The NMOC portion of LFG can contain a variety of air pollutants, including VOC and various organic HAP. VOC emissions are precursors to both fine particulate matter ($PM_{2.5}$) and ozone formation, while methane is a GHG and a precursor to global ozone formation. As described in the subsequent sections, these pollutants are associated with substantial health effects, climate effects, and other welfare effects. The only categories of benefits monetized in this RIA are methane-related climate effects and secondary CO_2 impacts associated with reduced electricity demand due to increased generation of electricity by landfills through the burning of LFG in engines. The methane-related climate benefits are estimated to range from $200 million (2012$) to approximately $1.1 billion (2012$); these benefits are estimated to reach a mean of $430 million (2012$) in 2025 using a 3% discount rate.[31] The secondary CO_2 benefits are estimated to range from $4.2 million (2012$) to $41 million (2012$) in 2025; estimated CO_2 benefits are $14 million (2012$) in 2025 using a 3% discount rate.

While we expect that these avoided emissions will also result in improvements in air quality and reduce health and welfare effects associated with exposure to HAP, ozone, and fine particulate matter ($PM_{2.5}$), we have determined that quantification of those health benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available. With the data available, we are not able to provide a credible health $PM_{2.5}$ benefits estimates for this rule, due

[31] Table 4-3 presents the methane-related climate effects based on SC-CH_4 at discount rates of 2.5, 3, and 5 percent.

to the differences in the locations of MSW landfill emission points relative to the available air quality modeling scenarios that have predicted changes in fine particle levels attributable to this sector, and the highly localized nature of air quality responses associated with HAP and VOC reductions.[32] In addition, not knowing the composition of the LFG is another reason why credible health $PM_{2.5}$ benefits cannot be quantified or monetized. .Nearly 30 organic HAPs have been identified in uncontrolled LFG, including benzene, ethylbenzene, toluene, and vinyl chloride, and they will be reduced by this rule. In this chapter, we provide a qualitative assessment of the health benefits associated with reducing exposure to these pollutants, as well as visibility impairment and ecosystem benefits. Table 4-1 summarizes the quantified and unquantified benefits in this analysis.

Table 4-1 Climate and Human Health Effects of Emission Reductions in this Rule

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Improved Environment				
Reduced climate effects	Global climate impacts from methane (CH_4) and carbon dioxide (CO_2)	—[1]	✓	Marten et al. (2014), SC-CO_2 TSDs
	Other climate impacts (e.g., ozone, black carbon, aerosols, other impacts)	—	—	IPCC, Ozone ISA, PM ISA[2]
Improved Human Health				
Reduced incidence of premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimates and expert elicitation estimates (age >25 or age >30)	—	—	PM ISA[3]
	Infant mortality (age <1)	—	—	PM ISA[3]
Reduced incidence of morbidity from exposure to $PM_{2.5}$	Non-fatal heart attacks (age > 18)	—	—	PM ISA[3]
	Hospital admissions—respiratory (all ages)	—	—	PM ISA[3]
	Hospital admissions—cardiovascular (age >20)	—	—	PM ISA[3]
	Emergency room visits for asthma (all ages)	—	—	PM ISA[3]
	Acute bronchitis (age 8-12)	—	—	PM ISA[3]
	Lower respiratory symptoms (age 7-14)	—	—	PM ISA[3]

[32] Previous studies have estimated the monetized benefits-per-ton of reducing VOC emissions associated with the effect that those emissions have on ambient $PM_{2.5}$ levels and the health effects associated with $PM_{2.5}$ exposure (Fann, Fulcher, and Hubbell, 2009). While these ranges of benefit-per-ton estimates provide useful context, the geographic distribution of VOC emissions from the MSW landfill sector are not consistent with emissions modeled in Fann, Fulcher, and Hubbell (2009). In addition, the benefit-per-ton estimates for VOC emission reductions in that study are derived from total VOC emissions across all sectors. Coupled with the larger uncertainties about the relationship between VOC emissions and $PM_{2.5}$ and the highly localized nature of air quality responses associated with VOC reductions, these factors lead us to conclude that the available VOC benefit-per-ton estimates are not appropriate to calculate monetized benefits of these rules, even as a bounding exercise.

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
	Upper respiratory symptoms (asthmatics age 9-11)	—	—	PM ISA[3]
	Asthma exacerbation (asthmatics age 6-18)	—	—	PM ISA[3]
	Lost work days (age 18-65)	—	—	PM ISA[3]
	Minor restricted-activity days (age 18-65)	—	—	PM ISA[3]
	Chronic Bronchitis (age >26)	—	—	PM ISA[3]
	Emergency room visits for cardiovascular effects (all ages)	—	—	PM ISA[3]
	Strokes and cerebrovascular disease (age 50-79)	—	—	PM ISA[3]
	Other cardiovascular effects (e.g., other ages)	—	—	PM ISA[2]
	Other respiratory effects (e.g., pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA[2]
	Reproductive and developmental effects (e.g., low birth weight, pre-term births, etc)	—	—	PM ISA[2,4]
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA[2,4]
Reduced incidence of mortality from exposure to ozone	Premature mortality based on short-term study estimates (all ages)	—	—	Ozone ISA[3]
	Premature mortality based on long-term study estimates (age 30–99)	—	—	Ozone ISA[3]
Reduced incidence of morbidity from exposure to ozone	Hospital admissions—respiratory causes (age > 65)	—	—	Ozone ISA[3]
	Hospital admissions—respiratory causes (age <2)	—	—	Ozone ISA[3]
	Emergency department visits for asthma (all ages)	—	—	Ozone ISA[3]
	Minor restricted-activity days (age 18–65)	—	—	Ozone ISA[3]
	School absence days (age 5–17)	—	—	Ozone ISA[3]
	Decreased outdoor worker productivity (age 18–65)	—	—	Ozone ISA[3]
	Other respiratory effects (e.g., premature aging of lungs)	—	—	Ozone ISA[2]
	Cardiovascular and nervous system effects	—	—	Ozone ISA[2]
	Reproductive and developmental effects	—	—	Ozone ISA[2,4]
Reduced incidence of morbidity from exposure to HAP	Effects associated with exposure to hazardous air pollutants such as benzene	—	—	ATSDR, IRIS[2,3]
Improved Environment				
Reduced visibility impairment	Visibility in Class 1 areas	—	—	PM ISA[3]
	Visibility in residential areas	—	—	PM ISA[3]
Reduced effects from PM deposition (organics)	Effects on Individual organisms and ecosystems	—	—	PM ISA[2]

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Reduced vegetation and ecosystem effects from exposure to ozone	Visible foliar injury on vegetation	—	—	Ozone ISA[3]
	Reduced vegetation growth and reproduction	—	—	Ozone ISA[3]
	Yield and quality of commercial forest products and crops	—	—	Ozone ISA[3]
	Damage to urban ornamental plants	—	—	Ozone ISA[2]
	Carbon sequestration in terrestrial ecosystems	—	—	Ozone ISA[3]
	Recreational demand associated with forest aesthetics	—	—	Ozone ISA[2]
	Other non-use effects			Ozone ISA[2]
	Ecosystem functions (e.g., water cycling, biogeochemical cycles, net primary productivity, leaf-gas exchange, community composition)	—	—	Ozone ISA[2]

[1] The global climate and related impacts of CO_2 and CH_4 emissions changes, such as sea level rise, are estimated within each integrated assessment model as part of the calculation of the SC-CO_2 and SC-CH_4. The resulting monetized damages, which are relevant for conducting the benefit-cost analysis, are used in this RIA to estimate the welfare effects of quantified changes in CO_2 emissions.

[2] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.

[3] We assess these benefits qualitatively due to data limitations for this analysis, but we have quantified them in other analyses.

[4] We assess these benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

4.2 Methane (CH_4)

4.2.1 Methane climate effects and valuation

Methane is the one of the principal components of landfill gas. Methane is also a potent greenhouse gas (GHG) that once emitted into the atmosphere absorbs terrestrial infrared radiation, which in turn contributes to increased global warming and continuing climate change. Methane reacts in the atmosphere to form ozone and ozone also impacts global temperatures. Methane, in addition to other GHG emissions, contributes to warming of the atmosphere, which over time leads to increased air and ocean temperatures, changes in precipitation patterns, melting and thawing of global glaciers and ice, increasingly severe weather events, such as hurricanes of greater intensity, and sea level rise, among other impacts.

According to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5, 2015), changes in methane concentrations since 1750 contributed 0.48 W/m^2 of forcing, which is about 17% of all global forcing due to increases in anthropogenic GHG concentrations, and which makes methane the second leading long-lived climate forcer after

CO_2. However, after accounting for changes in other greenhouse substances such as ozone and stratospheric water vapor due to chemical reactions of methane in the atmosphere, historical methane emissions were estimated to have contributed to 0.97 W/m^2 of forcing today, which is about 30% of the contemporaneous forcing due to historical greenhouse gas emissions.

MSW landfills emit significant amounts of methane. The Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014 (published April 2016) estimates 2014 methane emissions from MSW landfills to be 148 MMt CO_2-Equivalents In 2014, total methane emissions from MSW landfills represented approximately 20.2 percent of the total methane emissions from all sources and account for about 2.7 percent of all CO_2-Equivalents emissions in the U.S., with landfills being the third largest contributor to U.S. anthropogenic methane emissions (EPA, 2016).

This rulemaking finalizes emission control technologies and regulatory alternatives that are expected to significantly decrease methane emissions from existing MSW landfills. By lowering the NMOC emissions threshold to 34 Mg/yr, the guidelines would achieve reductions of approximately 1,810 Mg/yr NMOC and 0.29 million Mg/yr methane in 2025.

We calculated the global social benefits of methane emissions reductions expected from the NSPS using estimates of the social cost of methane (SC-CH_4), a metric that estimates the monetary value of impacts associated with marginal changes in methane emissions in a given year. It includes a wide range of anticipated climate impacts, such as net changes in agricultural productivity and human health, property damage from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning. The SC-CH_4 estimates applied in this analysis were developed by Marten et al. (2014) and are discussed in greater detail below.

A similar metric, the social cost of CO_2 (SC-CO_2), provides important context for understanding the Marten et al. SC-CH_4 estimates. Estimates of the SC-CO_2 have been used by the EPA and other federal agencies to value the impacts of CO_2 emissions changes in benefit cost analysis for GHG-related rulemakings since 2008. The SC-CO_2 is a metric that estimates the monetary value of impacts associated with marginal changes in CO_2 emissions in a given year.

Similar to the SC-CH_4, it includes a wide range of anticipated climate impacts, such as net changes in agricultural productivity, property damage from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning. It is used to quantify the benefits of reducing CO_2 emissions, or the disbenefit from increasing emissions, in regulatory impact analyses.

The SC-CO_2 estimates were developed over many years, using the best science available, and with input from the public. Specifically, an interagency working group (IWG) that included the EPA and other executive branch agencies and offices used three integrated assessment models (IAMs) to develop the SC-CO_2 estimates and recommended four global values for use in regulatory analyses. The SC-CO_2 estimates were first released in February 2010 and updated in 2013 using new versions of each IAM. The 2013 update did not revisit the 2010 modeling decisions with regards to the discount rate, reference case socioeconomic and emission scenarios, and equilibrium climate sensitivity distribution. Rather, improvements in the way damages are modeled are confined to those that have been incorporated into the latest versions of the models by the developers themselves and published in the peer-reviewed literature. The 2010 SC-CO_2 Technical Support Document (2010 SC-CO_2 TSD) provides a complete discussion of the methods used to develop these estimates and the current SC-CO_2 TSD presents and discusses the 2013 update (including recent minor technical corrections to the estimates).[33]

One key methodological aspect discussed in the SC-CO_2 TSDs is the global scope of the estimates. The SC-CO_2 estimates represent global measures because of the distinctive nature of the climate change, which is highly unusual in at least three respects. First, emissions of most GHGs contribute to damages around the world independent of the country in which they are emitted. The SC-CO_2 must therefore incorporate the full (global) damages caused by GHG emissions to address the global nature of the problem. Second, the U.S. operates in a global and highly interconnected economy, such that impacts on the other side of the world can affect our economy. This means that the true costs of climate change to the U.S. are larger than the direct impacts that simply occur within the U.S. Third, climate change represents a classic public goods

[33] Both the 2010 SC-CO_2 TSD and the current SC-CO_2 TSD are available at: https://www.whitehouse.gov/omb/oira/social-cost-of-carbon

problem because each country's reductions benefit everyone else and no country can be excluded from enjoying the benefits of other countries' reductions, even if it provides no reductions itself. In this situation, the only way to achieve an economically efficient level of emissions reductions is for countries to cooperate in providing mutually beneficial reductions beyond the level that would be justified only by their own domestic benefits. In reference to the public good nature of mitigation and its role in foreign relations, thirteen prominent academics noted that these "are compelling reasons to focus on a global SCC" (Pizer et al., 2014). In addition, the IWG recently noted that there is no bright line between domestic and global damages. Adverse impacts on other countries can have spillover effects on the United States, particularly in the areas of national security, international trade, public health and humanitarian concerns.[34]

The 2010 SC-CO_2 TSD also noted a number of limitations to the SC-CO_2 analysis, including the incomplete way in which the IAMs capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. Currently IAMs do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature due to a lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research.[35] The limited amount of research linking climate impacts to economic damages makes the modeling exercise even more difficult. These individual limitations do not all work in the same direction in terms of their influence on the SC-CO_2 estimates, though taken together they suggest that the SC-CO_2 estimates are likely conservative. In particular, the IPCC Fourth Assessment Report (2007), which was the most

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[34] See Response to Comments: Social Cost of Carbon For Regulatory Impact Analysis Under Executive Order 12866, July 2015, page 31, at https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-response-to-comments-final-july-2015.pdf

[35] Climate change impacts and social cost of greenhouse gases modeling is an area of active research. For example, see: (1) Howard, Peter, "Omitted Damages: What's Missing from the Social Cost of Carbon." March 13, 2014, http://costofcarbon.org/files/Omitted_Damages_Whats_Missing_From_the_Social_Cost_of_Carbon.pdf; and (2) Electric Power Research Institute, "Understanding the Social Cost of carbon: A Technical Assessment," October 2014, www.epri.com.

current IPCC assessment available at the time of the IWG's 2009-2010 review, concluded that "It is very likely that [SC-CO_2 estimates] underestimate the damage costs because they cannot include many non-quantifiable impacts." Since then, the peer-reviewed literature has continued to support this conclusion. For example, the IPCC Fifth Assessment report (2014) observed that SC-CO_2 estimates continue to omit various impacts, such as "the effects of the loss of biodiversity among pollinators and wild crops on agriculture."[36] Nonetheless, these estimates and the discussion of their limitations represent the best available information about the social benefits of CO_2 reductions to inform benefit-cost analysis. The new versions of the models offer some improvements in these areas, although further work is warranted.

Accordingly, the EPA and other agencies continue to engage in research on modeling and valuation of climate impacts with the goal to improve these estimates. The EPA and other agencies also continue to consider feedback on the SC-CO_2 estimates from stakeholders through a range of channels, including public comments on Agency rulemakings that use the SC-CO_2 in supporting analyses and through regular interactions with stakeholders and research analysts implementing the SC-CO_2 methodology used by the IWG. In addition, OMB sought public comment on the approach used to develop the SC-CO_2 estimates through a separate comment period and published a response to those comments in 2015.[37]

After careful evaluation of the full range of comments submitted to OMB, the IWG continues to recommend the use of the SC-CO_2 estimates in regulatory impact analysis. With the release of the response to comments, the IWG announced plans in July 2015 to obtain expert independent advice from the National Academies of Sciences, Engineering and Medicine to

[36] Oppenheimer, M., M. Campos, R.Warren, J. Birkmann, G. Luber, B. O'Neill, and K. Takahashi, 2014: Emergent risks and key vulnerabilities. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1039-1099.

[37] See https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-response-to-comments-final-july-2015.pdf.

ensure that the $SC\text{-}CO_2$ estimates continue to reflect the best available scientific and economic information on climate change.[38] The Academies then convened a committee, "Assessing Approaches to Updating the Social Cost of Carbon," (Committee) that is reviewing the state of the science on estimating the $SC\text{-}CO_2$, and will provide expert, independent advice on the merits of different technical approaches for modeling and highlight research priorities going forward. While the Committee's review focuses on the $SC\text{-}CO_2$ methodology, recommendations on how to update many of the underlying modeling assumptions will also likely pertain to the $SC\text{-}CH_4$ estimates. EPA will evaluate its approach based upon any feedback received from the Academies' panel.

To date, the Committee has released an interim report, which recommended against doing a near term update of the $SC\text{-}CO_2$ estimates. For future revisions, the Committee recommended the IWG move efforts towards a broader update of the climate system module consistent with the most recent, best available science, and also offered recommendations for how to enhance the discussion and presentation of uncertainty in the $SC\text{-}CO_2$ estimates. Specifically, the Committee recommended that "the IWG provide guidance in their technical support documents about how [$SC\text{-}CO_2$] uncertainty should be represented and discussed in individual regulatory impact analyses that use the [$SC\text{-}CO_2$]" and that the technical support document for each update of the estimates present a section discussing the uncertainty in the overall approach, in the models used, and uncertainty that may not be included in the estimates.[39] At the time of this writing, the IWG is reviewing the interim report and considering the recommendations. EPA looks forward to working with the IWG to respond to the recommendations and will continue to follow IWG guidance on $SC\text{-}CO_2$.

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[38] The Academies' review will be informed by public comments and focus on the technical merits and challenges of potential approaches to improving the $SC\text{-}CO_2$ estimates in future updates. See https://www.whitehouse.gov/blog/2015/07/02/estimating-benefits-carbon-dioxide-emissions-reductions.

[39] National Academies of Sciences, Engineering, and Medicine. (2016). *Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update*. Committee on Assessing Approaches to Updating the Social Cost of Carbon, Board on Environmental Change and Society. Washington, DC: The National Academies Press. doi: 10.17226/21898. See Executive Summary, page 1, for quoted text.

The four SC-CO_2 estimates are: $13, $45, $67, and $130 per metric ton of CO_2 emissions in the year 2020 (2012 dollars).[40] The first three values are based on the average SC-CO_2 from the three IAMs, at discount rates of 5, 3, and 2.5 percent, respectively. Estimates of the SC-CO_2 for several discount rates are included because the literature shows that the SC-CO_2 is sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context (where costs and benefits are incurred by different generations). The fourth value is the 95th percentile of the SC-CO_2 across all three models at a 3 percent discount rate. It is included to represent lower probability but higher impact outcomes from climate change, which are captured further out in the tail of the SC-CO_2 distribution, and while less likely than those reflected by the average SC-CO_2 estimates, would be much more harmful to society and therefore, are relevant to policy makers. The SC-CO_2 increases over time because future emissions are expected to produce larger incremental damages as economies grow and physical and economic systems become more stressed in response to greater climate change.

A challenge particularly relevant to this analysis is that the IWG did not estimate the social costs of non-CO_2 GHG emissions at the time the SC-CO_2 estimates were developed. One alternative approach to value methane impacts is to use the global warming potential (GWP) to convert the emissions to CO_2 equivalents which are then valued using the SC-CO_2 estimates.

The GWP measures the cumulative radiative forcing from a perturbation of a non-CO_2 GHG relative to a perturbation of CO_2 over a fixed time horizon, often 100 years. The GWP mainly reflects differences in the radiative efficiency of gases and differences in their atmospheric lifetimes. While the GWP is a simple, transparent, and well-established metric for assessing the relative impacts of non-CO_2 emissions compared to CO_2 on a purely physical basis, there are several well-documented limitations in using it to value non-CO_2 GHG benefits, as discussed in the 2010 SC-CO_2 TSD and previous rulemakings (e.g., U.S. EPA 2012b, 2012d).[41]

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[40] The current version of the SC-CO_2 TSD is available at: < https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf>. The TSDs present SC-CO_2 in $2007. The estimates were adjusted to 2012$ using the GDP Implicit Price Deflator (1.0804). Also available at: http://www.bea.gov/iTable/index_nipa.cfm. The SC-CO_2 values have been rounded to two significant digits. Unrounded numbers from the 2013 SCC TSD were adjusted to 2012$ and used to calculate the CO_2 benefits.

[41] See also Reilly and Richards, 1993; Schmalensee, 1993; Fankhauser, 1994; Marten and Newbold, 2012.

In particular, several recent studies found that GWP-weighted benefit estimates for methane are likely to be lower than the estimates derived using directly modeled social cost estimates for these gases (Marten and Newbold, 2012; Marten et al. 2014; and Waldhoff et al. 2014). Gas comparison metrics, such as the GWP, are designed to measure the impact of non-CO_2 GHG emissions relative to CO_2 at a specific point along the pathway from emissions to monetized damages (depicted in Figure 4-1), and this point may differ across measures.

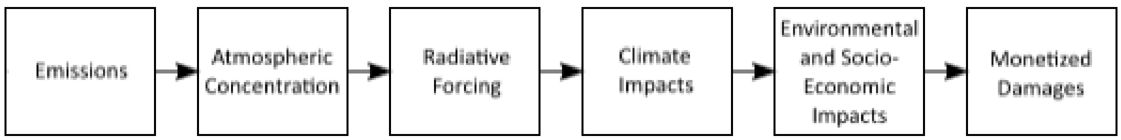

Figure 4-1 Path from GHG Emissions to Monetized Damages (Source: Marten et al., 2014)

The GWP is not ideally suited for use in benefit-cost analyses to approximate the social cost of non-CO_2 GHGs because it ignores important nonlinear relationships beyond radiative forcing in the chain between emissions and damages. These can become relevant because gases have different lifetimes and the SC-CO_2 takes into account the fact that marginal damages from an increase in temperature are a function of existing temperature levels. Another limitation of gas comparison metrics for this purpose is that some environmental and socioeconomic impacts are not linked to all of the gases under consideration, or radiative forcing for that matter, and will therefore be incorrectly allocated. For example, the economic impacts associated with increased agricultural productivity due to higher atmospheric CO_2 concentrations included in the SC-CO_2 would be incorrectly allocated to methane emissions with the GWP-based valuation approach.

Also of concern is the fact that the assumptions made in estimating the GWP are not consistent with the assumptions underlying SC-CO_2 estimates in general, and the SC-CO_2 estimates developed by the IWG more specifically. For example, the 100-year time horizon usually used in estimating the GWP is less than the approximately 300-year horizon the IWG used in developing the SC-CO_2 estimates. The GWP approach also treats all impacts within the time horizon equally, independent of the time at which they occur. This is inconsistent with the role of discounting in economic analysis, which accounts for a basic preference for earlier over later gains in utility and expectations regarding future levels of economic growth. In the case of methane, which has a relatively short lifetime compared to CO_2, the temporal independence of the GWP could lead the GWP approach to underestimate the SC-CH_4 with a larger downward bias under higher discount rates (Marten and Newbold, 2012).[42]

The EPA sought public comments on the valuation of non-CO_2 GHG impacts in previous rulemakings (e.g., U.S. EPA 2012b, 2012d). In general, the commenters strongly encouraged the EPA to incorporate the monetized value of non-CO_2 GHG impacts into the benefit cost analysis, however they noted the challenges associated with the GWP-approach, as discussed above, and encouraged the use of directly-modeled estimates of the SC-CH_4 to overcome those challenges.

The EPA had cited several researchers that had directly estimated the social cost of non-CO_2 emissions using IAMs but noted that the number of such estimates was small compared to the large number of SC-CO_2 estimates available in the literature. The EPA found considerable variation among these published estimates in terms of the models and input assumptions they employ (U.S. EPA, 2012d)[43]. These studies differed in the emissions perturbation year, employed a wide range of constant and variable discount rate specifications, and considered a range of baseline socioeconomic and emissions scenarios that have been developed over the last 20 years. Furthermore, at the time, none of the other published estimates of the social cost of non-CO_2 GHG were consistent with the SC-CO_2 estimates developed by the IWG, and most were likely underestimates due to changes in the underlying science since their publication.

Therefore, the EPA concluded in those rulemaking analyses that the GWP approach would serve as an interim method of analysis until directly modeled social cost estimates for non-CO_2 GHGs, consistent with the SC-CO_2 estimates developed by the IWG, were developed.

[42] We note that the truncation of the time period in the GWP calculation could lead to an overestimate of SC-CH_4 for near term perturbation years when the SC-CO_2 is based on a sufficiently low or steeply declining discount rate.

[43] The researchers cited U.S. EPA 2012d include: Fankhauser (1994); Kandlikar (1995); Hammitt et al. (1996); Tol et al. (2003); Tol (2004); and Hope and Newberry (2006).

The EPA presented GWP-weighted estimates in sensitivity analyses rather than the main benefit-cost analyses.[44]

Since then, a paper by Marten et al. (2014) provided the first set of published SC-CH_4 estimates in the peer-reviewed literature that are consistent with the modeling assumptions underlying the SC-CO_2 estimates.[45] Specifically, the estimation approach Marten et al. incorporated the same set of three IAMs, five socioeconomic and emissions scenarios, equilibrium climate sensitivity distribution, three constant discount rates, and aggregation approach used by the IWG to develop the SC-CO_2 estimates. The aggregation method involved distilling the 45 distributions of the SC-CH_4 produced for each emissions year into four estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3 percent discount rate. Marten et al. also used the same rationale as the IWG to develop global estimates of the SC-CH_4, given that methane is a global pollutant.

In addition, the atmospheric lifetime and radiative efficacy of methane used by Marten et al. is based on the estimates reported by the IPCC in their Fourth Assessment Report (AR4, 2007), including an adjustment in the radiative efficacy of methane to account for its role as a precursor for tropospheric ozone and stratospheric water. These values represent the same ones used by the IPCC in AR4 for calculating GWPs. At the time Marten et al. developed their estimates of the SC-CH_4, AR4 was the latest assessment report by the IPCC. The IPCC updates GWP estimates with each new assessment, and in the most recent assessment, AR5, the latest estimate of the methane GWP ranged from 28-36, compared to a GWP of 25 in AR4. The

[44] For example, the 2012 New Source Performance Standards and Amendments to the National Emissions Standards for Hazardous Air Pollutants for the Oil and Natural Gas Industry are expected to reduce methane emissions by 900,000 metric tons annually, see http://www.gpo.gov/fdsys/pkg/FR-2012-08-16/pdf/2012-16806.pdf. Additionally, the 2017-2025 Light-duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, promulgated jointly with the National Highway Traffic Safety Administration, is expected to reduce methane emissions by over 100,000 metric tons in 2025 increasing to nearly 500,000 metric tons in 2050, see http://www.gpo.gov/fdsys/pkg/FR-2012-10-15/pdf/2012-21972.pdf

[45] Marten et al. (2014) also provided the first set of SC-N_2O estimates that are consistent with the assumptions underlying the SC-CO_2 estimates.

updated values reflect a number of changes: changes in the lifetime and radiative efficiency estimates for CO_2, changes in the lifetime estimate for methane, and changes in the correction factor applied to methane's GWP to reflect the effect of methane emissions on other climatically important substances such as tropospheric ozone and stratospheric water vapor. In addition, the range presented in the latest IPCC report reflects different choices regarding whether to account for climate feedbacks on the carbon cycle for both methane and CO_2 (rather than just for CO_2 as was done in AR4).[46,47]

Marten *et al.* (2014) discuss these estimates, (SC-CH_4 estimates presented below in Table 4-2), and compare them with other recent estimates in the literature.[48] The authors noted that a direct comparison of their estimates with all of the other published estimates is difficult, given the differences in the models and socioeconomic and emissions scenarios, but results from three relatively recent studies offer a better basis for comparison (see Hope (2006), Marten and Newbold (2012), Waldhoff *et al.* (2014)). Marten *et al.* found that, in general, the SC-CH_4 estimates from their 2014 paper are higher than previous estimates. The higher SC-CH_4 estimates are partially driven by the higher effective radiative forcing due to the inclusion of indirect effects from methane emissions in their modeling. Marten *et al.*, similar to other recent studies, also find that their directly modeled SC-CH_4 estimates are higher than the GWP-weighted estimates. More detailed discussion of the SC-CH_4 estimation methodology, results and a comparison to other published estimates can be found in Marten *et al.*

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[46] *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[47] Note that this analysis uses a GWP value for methane of 25 for CO_2 equivalency calculations, consistent with the GHG emissions inventories and the IPCC Fourth Assessment Report (AR4).

[48] Marten et al. (2014) estimates are presented in 2007 dollars. These estimates were adjusted for inflation using National Income and Product Accounts Tables, Table 1.1.9, Implicit Price Deflators for Gross Domestic Product (US Department of Commerce, Bureau of Economic Analysis), http://www.bea.gov/iTable/index_nipa.cfm (1.0804) Accessed 3/3/15.

Table 4-2 Social Cost of CH_4, 2012 – 2050[a] [in 2012$ per metric ton] (Source: Marten et al., 2014[b])

Year	SC-CH_4			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2012	$430	$1,000	$1,400	$2,800
2015	$490	$1,100	$1,500	$3,000
2020	$580	$1,300	$1,700	$3,500
2025	$700	$1,500	$1,900	$4,000
2030	$820	$1,700	$2,200	$4,500
2035	$970	$1,900	$2,500	$5,300
2040	$1,100	$2,200	$2,800	$5,900
2045	$1,300	$2,500	$3,000	$6,600
2050	$1,400	$2,700	$3,300	$7,200

[a] The values are emissions-year specific and are defined in real terms, i.e., adjusted for inflation using the GDP implicit price deflator.
[b] The estimates in this table have been adjusted to reflect the minor technical corrections to the SC-CO_2 estimates described above. See Marten et al. (2015) for more details.

The application of directly modeled estimates from Marten *et al.* (2014) to benefit-cost analysis of a regulatory action is analogous to the use of the SC-CO_2 estimates. Specifically, the SC-CH_4 estimates in Table 4-2 are used to monetize the benefits of reductions in methane emissions expected as a result of the rulemaking. Forecasted changes in methane emissions in a given year, expected as a result of the regulatory action, are multiplied by the SC-CH_4 estimate for that year. To obtain a present value estimate, the monetized stream of future non-CO_2 benefits are discounted back to the analysis year using the same discount rate used to estimate the social cost of the non-CO_2 GHG emission changes. In addition, the limitations for the SC-CO_2 estimates discussed above likewise apply to the SC-CH_4 estimates, given the consistency in the methodology.

In early 2015, the EPA conducted a peer review of the application of the Marten *et al.* (2014) non-CO_2 social cost estimates in regulatory analysis and received responses that supported this application.[49] Three reviewers considered seven charge questions that covered issues such as the EPA's interpretation of the Marten *et al.* estimates, the consistency of the estimates with the SC-CO_2 estimates, the EPA's characterization of the limits of the GWP-approach to value non-CO_2 GHG impacts, and the appropriateness of using the Marten *et al.* estimates in regulatory impact analyses. The reviewers agreed with the EPA's interpretation of Marten *et al.*'s estimates, generally found the estimates to be consistent with the SC-CO_2 estimates, and concurred with the limitations of the GWP approach, finding directly modeled estimates to be more appropriate. While outside of the scope of the review, the reviewers briefly considered the limitations in the SC-CO_2 methodology (e.g., those discussed earlier in this section) and noted that because the SC-CO_2 and SC-CH_4 methodologies are similar, the limitations also apply to the resulting SC-CH_4 estimates. Two of the reviewers concluded that use of the SC-CH_4 estimates developed by Marten *et al.* and published in the peer-reviewed literature is appropriate in RIAs, provided that the Agency discuss the limitations, similar to the discussion provided for SC-CO_2 and other economic analyses. All three reviewers encouraged continued improvements in the SC-CO_2 estimates and suggested that as those improvements are realized they should also be reflected in the SC-CH_4 estimates, with one reviewer suggesting the SC-CH_4 estimates lag this process. The EPA supports continued improvement in the SC-CO_2 estimates developed by the U.S. government and agrees that improvements in the SC-CO_2 estimates should also be reflected in the SC-CH_4 estimates. The fact that the reviewers agree that the SC-CH_4 estimates are generally consistent with the SC-CO_2 estimates that are recommended by OMB's guidance on valuing CO_2 emissions reductions, leads the EPA to conclude that use of the SC-CH_4 estimates is an analytical improvement over excluding methane emissions from the monetized portion of the benefit cost analysis.

The EPA also carefully considered the full range of public comments and associated technical issues on the Marten et al. SC-CH_4 estimates received through this rulemaking and determined that it would continue to use the estimates in the final rulemaking analysis. Based on the evaluation of the public comments on this rulemaking, the favorable peer review of the

[49] For a copy of the peer review and responses, see https://cfpub.epa.gov/si/si_public_pra_view.cfm?dirEntryID=291976 (see "SCCH4 EPA PEER REVIEW FILES.PDF").

Marten et al. application, and past comments urging EPA to value non-CO_2 GHG impacts in its rulemakings, EPA concluded that the estimates represent the best scientific information on the impacts of climate change available in a form appropriate for incorporating the damages from incremental methane emissions changes into regulatory analysis. The Agency has valued the methane benefits expected from this rulemaking using the Marten *et al.* (2014) SC-CH_4 estimates and has included those benefits in the main benefits analysis. Please see the Response to Comments document for EPA's detailed responses to the comments on methane valuation.

The estimated methane benefits are presented in Table 4-3 below for year 2025 across regulatory options. Applying this approach to the methane reductions estimated for the final EG option, the 2025 methane benefits vary by discount rate and range from about $200 million to approximately $1.1 billion; the mean SC-CH_4 at the 3 percent discount rate results in an estimate of about $430 million in 2025. See Section 4.6 for benefit estimates in alternative years as well as the net present value calculation.

Table 4-3 Estimated Global Benefits of CH_4 Reductions in 2025* (in millions, 2012$)

	Million metric tons of CH_4 reduced**	**Million metric tons of CO_2-equivalent reduced**	**Discount rate and statistic**			
			5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	0.19	4.6	$130	$280	$360	$740
Final Option 2.5/34	0.29	7.1	$200	$430	$550	$1,100
Alternative Option 2.0/34	0.34	8.6	$240	$520	$670	$1,400

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts.
**One metric tons equals one megagram.

While the vast majority of the final guidelines' climate-related benefits are associated with methane reductions, additional climate-related benefits are expected from the guidelines' secondary air impacts, specifically, a net reduction in CO_2 emissions due to reduced demand for electricity from the grid as landfills generate electricity from landfill gas.[50] These benefits are presented in Table 4-4 below. Monetizing the net CO_2 reductions with the SC-CO_2 estimates described in this section yields benefits that vary by discount rate and range from about $4.2 million to approximately $41 million in 2025. For the proposed option, the mean SC-CO_2 at the 3% discount rate results in an estimate of about $14 million in 2025. Changes in net secondary NO_x, SO_2 and LFG constituent pollutants may also occur, but are expected to be minimal and are not estimated.

Table 4-4 Estimated Global Benefits of Net CO_2 Reductions in 2025* (in millions, 2012$)

	Metric tons of net CO_2 reduced**	Discount rate and statistic			
		5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	220,000	$3.4	$11	$16	$33
Final Option 2.5/34	280,000	$4.2	$14	$20	$41
Alternative Option 2.0/34	330,000	$5.1	$17	$25	$50

*The SC-CO_2 values are dollar-year and emissions-year specific. Four SC-CO_2 values for year 2025 were used to estimate the CO_2 benefits and the marginal values are: $15, $50, $73, and $150 (2012$ per metric ton). The first three are the average SC-CO_2 at a 5, 3, and 2.5 percent discount rate, respectively, and the fourth is the 95th percentile estimate at a 3 percent discount rate. SC-CO_2 values represent only a partial accounting of climate impacts. Changes in net secondary NO_x, SO_2 and LFG constituent pollutants may also occur, but are expected to be minimal and are not estimated.
** One metric ton equals one megagram.

Finally, in addition to the CO_2 impacts discussed above, there is a small increase in CO_2 emissions resulting from flaring of methane in response to this rule. However, as discussed in section 2.5.2, both the CO_2 generated directly from aerobic decomposition in MSW landfills and that created as a result of methane oxidation in the atmosphere would have been generated anyway as a result of natural decomposition of the organic waste materials if they had not been deposited in the landfill (EPA, 2015a). In other words, the increase in atmospheric CO_2 concentration associated with the decomposition of organic waste materials would have occurred in the baseline and is not affected by the final rule. Therefore, we are not estimating the monetized disbenefits of these secondary emissions of CO_2. Note that the CO_2 produced from the methane oxidizing in the atmosphere is not included in the calculation of the SC-CH_4.

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[50] The reduced demand for electricity from the grid more than offsets the additional energy demand required to operate the control system and the by-product emissions from the combustion of LFG.

However, from the perspective of this regulatory impact analysis, there is a shift in the timing of the contribution of atmospheric CO_2 concentration under the policy case (i.e., the final regulatory option in which case some landfill gas emissions are flared). In the case of VOCs, the oxidization time in the atmosphere is relatively short, on the order of hours to months, so from a climate perspective the difference between emitting the carbon immediately as CO_2 during combustion or as VOCs is expected to be negligible. In the case of methane, the oxidization time is on the order of a decade, so the timing of the contribution to atmospheric CO_2 concertation will differ between the baseline and policy case. Because the growth rate of the SC-CO_2 estimates are lower than their associated discount rates, the estimated impact of CO_2 produced in the future via oxidized methane from these emissions may be less than the estimated impact of CO_2 released immediately from combusting emissions, which would imply a small disbenefit associated with the earlier release of CO_2 during combustion of the CH_4 emissions.

In the proposal RIA, the EPA solicited comment on the appropriateness of monetizing the impact of the earlier release of CO_2 due to combusting methane and VOC emissions from landfills and a new potential approach for approximating this value using the SC-CO_2. This illustrative analysis provides a method for evaluating the estimated emissions outcomes associated with destroying one metric ton of methane by combusting emissions at landfills (flaring) and releasing the CO_2 emissions immediately versus releasing them in the future via the methane oxidation process. This illustrative analysis as provided in the proposal demonstrated that the potential disbenefits of flaring—i.e., an earlier contribution of CO_2 emissions to atmospheric concentrations –are minor compared to the benefits of flaring—i.e., avoiding the release of and associated climate impacts from CH_4 emissions. EPA did not receive any comments regarding the appropriate methodology for conducting such an analysis, but did receive one comment letter that voiced general support for monetizing other secondary impacts, namely methane's indirect effects on surface ozone levels.

In consideration of this broad comment and while recognizing the challenges and uncertainties related to estimation of these secondary emissions impacts for this rulemaking, EPA has continued to examine this issue in the context of this regulatory analysis—i.e., the combusting of CH_4 at landfills—and explored ways to improve this illustrative analysis. Specifically, EPA has modified the illustrative analysis by updating the oxidization process of

CH_4 to be dynamic and consistent with the modeling that underlies the SC-CH_4 estimates. Also for this illustrative analysis, EPA assumed an average methane oxidation period of 12 years, consistent with the perturbation lifetime-folding time used in IPCC AR4. The estimated disbenefits associated with destroying one metric ton of methane through combustion of emissions at landfills and releasing the CO_2 emissions in 2020 instead of being released in the future via the methane oxidation process are found to be small relative to the benefits of flaring. Specifically, the disbenefit is estimated to be about $15 per metric ton CH_4 (based on average SC-CO_2 at 3 percent) or roughly one percent of the SC-CH_4 estimate per metric ton for 2020. The analogous estimate for 2025 is $18 per metric ton CH_4 or about one percent of the SC-CH_4 estimates per metric ton for 2025.[51,52]

The EPA will continue to study this issue and assess the complexities involved in estimating the net emissions effects associated with secondary emissions, including differences in the timing of contributions to atmospheric CO_2 concentrations. Given the uncertainties related to estimating net secondary emissions effects and that the EPA has not yet received appropriate input and review on some aspects of these calculations, the EPA is not including monetized estimates of the impacts of small changes in the timing of atmospheric CO_2 concentration

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[51] To calculate the CO_2 related impacts associated the complete destruction of a ton of CH_4 emissions through flaring for this illustrative application, EPA took the difference between the SC-CO_2 at the time of the flaring and the discounted value of the CO2 impacts assuming a geometric decay of CH_4 via the oxidation process with a 12 year e-folding time using the same discount rate as used to estimate the SC-CO_2. This value was then scaled by 44/16 to account for the relative mass of carbon contained in a ton of CH_4 versus a ton of CO_2. More specifically, the impacts of shifting the CO_2 impacts are calculated as

$$(44/16)\left[\text{SC-CO2}_{\tau} - \sum_{t=\tau}^{T} e^{-1/12(t-\tau)}\left(1-e^{-1/12}\right)\left(\frac{1}{1+r}\right)^{t-\tau}\text{SC-CO2}_{t}\right],$$

where *t* is the year the CH_4 is destroyed, r is the discount rate, and T is the time horizon of the analysis. Ideally the time horizon, T, would be sufficiently long to capture the period in which nearly all of the CH4 is expected to have been oxidized. In this analysis we use the 2100 as the time horizon, making the assumption that the SC-CO_2 remains constant after 2050, the last year for which the IWG provides estimates. This methodology improves upon the one presented at proposal by updating the oxidization process of CH_4 to be dynamic and consistent with the modeling that underlies the SC-CH_4 estimates.

[52] The EPA also calculated these estimates using additional SC-CO_2 values, specifically the average SC-CO_2 at discount rates of 5 and 2.5 percent and the 95^{th} percentile at 3 percent. Applying these values, the estimates of the disbenefit of releasing CO_2 emissions in 2020 instead of in the future via methane oxidation ranges from $7 to $40 per metric ton CH_4. The corresponding estimates for 2025 range from $9 to $51 per metric ton CH_4.

increases in the final benefits estimates in this RIA. The EPA will continue to follow the scientific literature on this topic and update its methodologies as warranted.

4.2.2 Methane as an ozone precursor

This rulemaking would reduce emissions of methane, a GHG and also a precursor to ozone. In remote areas, methane is an important precursor to tropospheric ozone formation (EPA, 2013). NOX and VOC are well known to influence ozone concentrations regionally and at hourly time scales. On the other hand, methane emissions affect ozone concentrations globally and on decadal time scales given methane's relatively long atmospheric lifetime. Anthropogenic methane emissions account for slightly less than half of the increase in background ozone concentrations since the preindustrial era, and the relative contribution of methane is expected to grow in the future (EPA, 2013). Reducing methane emissions, therefore, has the potential to reduce global background ozone concentrations, human exposure to ozone, and thus the incidence of ozone-related health effects (West et al., 2006, Anenberg et al., 2009, Sarofim et al., 2015). These benefits are global and occur in both urban and rural areas. Reductions in background ozone concentrations can also have benefits for agriculture and ecosystems (UNEP/WMO, 2011). Studies show that controlling methane emissions can reduce global ozone concentrations and climate change simultaneously, but controlling other shorter-lived ozone precursors such as NO_X, carbon monoxide, or non-methane VOC has larger local health benefits from greater reductions in local ozone concentrations (West and Fiore, 2005; West et al., 2006; Fiore et al. 2008; Dentener et al., 2005; Shindell et al., 2005, 2012; UNEP/WMO, 2011). The health, welfare, and climate effects associated with ozone are described in the preceding sections.

Recently, a paper was published in the peer-reviewed scientific literature that presented a range of estimates of the monetized ozone-related mortality benefits of reducing methane emissions (Sarofim et al. 2015). For example, under their base case assumptions using a 3% discount rate, Sarofim et al. find global ozone-related mortality benefits of methane emissions reductions to be $790 per tonne of methane in 2020, with 10.6%, or $80, of this amount resulting from mortality reductions in the United States. The methodology used in this study is consistent in some (but not all) aspects with the modeling underlying the SC-CO_2 and SC-CH_4 estimates discussed above, and required a number of additional assumptions such as baseline mortality rates and mortality response to ozone concentrations. The benefit per ton estimated in this study is consistent in magnitude with other studies that have estimated the global monetized benefit of ozone reduction (Anenberg et al., 2012; Shindell et al. 2012). The proposal requested comment on the application of the Sarofim et al. (2015) study for this benefits analysis as an approach to estimating the ozone related mortality benefits resulting from the methane reductions expected from this proposed rulemaking. A few commenters objected to the inclusion of these benefits because they argue that methane is not a VOC, whereas one commenter agreed that there is a connection between methane emissions, higher ozone levels, and therefore human mortality. While the EPA does consider the methane impacts on ozone to be of interest, there remain unresolved questions regarding several methodological choices involved in applying the Sarofim et al. (2015) approach in the context of an EPA benefits analysis, and therefore the EPA is not including a quantitative analysis of this effect in this rule at this time.

4.2.3 Combined climate and ozone effects of methane

A recent United Nations Environment Programme (UNEP) assessment provided a comprehensive analysis of the health, climate, and agricultural benefits of measures to reduce methane, as well as black carbon, a component of fine particulate matter that absorbs radiation (UNEP/WMO, 2011; Shindell et al., 2012). The UNEP assessment found that while reducing longer-lived GHGs such as CO_2 is necessary to protect against long-term climate change, reducing global methane and black carbon emissions would have global health benefits by reducing exposure to ozone and $PM_{2.5}$ as well as potentially slowing the rate of climate change within the first half of this century. Relative to a business as usual reference scenario, implementing methane mitigation measures that achieve approximately 40% reductions in global methane emissions were estimated to avoid approximately 0.3°C globally averaged warming in 2050 (including the impacts of both methane itself and subsequently formed ozone) and 47,000 ozone-related premature deaths and 27 million metric tons of ozone-related crop yield losses globally in 2030 (Shindell et al., 2012). These benefits, including global climate impacts of methane and resulting ozone changes, and global ozone-related health and agricultural impacts, were valued at \$700 to \$5,000 per metric ton.[53] While monetized per-ton benefits of the climate, health, and agriculture impacts of methane mitigation have been estimated, there has not yet been a similar monetization of the parallel impacts on broader ecosystems.

4.3 VOC as a $PM_{2.5}$ precursor

This rulemaking would reduce emissions of VOC, which are a precursor to $PM_{2.5}$. Most VOC emitted are oxidized to carbon dioxide (CO_2) rather than to PM, but a portion of VOC emission contributes to ambient $PM_{2.5}$ levels as organic carbon aerosols (EPA, 2009a). Therefore, reducing these emissions would reduce $PM_{2.5}$ formation, human exposure to $PM_{2.5}$, and the incidence of $PM_{2.5}$-related health effects. However, we have not quantified the $PM_{2.5}$-related benefits in this analysis. Analysis of organic carbon measurements suggest only a fraction of secondarily formed organic carbon aerosols are of anthropogenic origin. The current state of the science of secondary organic carbon aerosol formation indicates that anthropogenic VOC contribution to secondary organic carbon aerosol is often less than the natural contribution. Given that a fraction of secondarily formed organic carbon aerosols is from anthropogenic VOC emissions and the extremely small amount of VOC emissions from this sector relative to the entire VOC inventory it is unlikely this sector has a large contribution to ambient secondary organic carbon aerosols. Photochemical models typically estimate secondary organic carbon from anthropogenic VOC emissions to be less than 0.1 $\mu g/m^3$.

Data resources and methodological limitations prevented EPA from monetizing the benefits of reducing VOCs. We were unable to perform air quality modeling for this rule to quantify the $PM_{2.5}$ benefits associated with reducing VOC emissions. Due to the high degree of variability in the responsiveness of $PM_{2.5}$ formation to VOC emission reductions, we are unable to estimate the effect that reducing VOC will have on ambient $PM_{2.5}$ levels without air quality

[53] Benefit per ton values derived from Shindell et al. (2012) cannot be directly compared to, nor are they additive with, the ozone health benefit-per-ton estimates for the U.S. reported in Section 4.4.1, since they include climate and agricultural impacts, are calculated for global rather than U.S. impacts, and use different assumptions for the value of a statistical life. Similarly, these values cannot be compared to, nor are they additive with, the methane climate valuation estimates in Section 4.2.1 since they include health and agricultural benefits and use different assumptions for the Social Cost of Carbon.

modeling. However, we provide the discussion below for context regarding findings from previous modeling.

4.3.1 $PM_{2.5}$ health effects and valuation

Reducing VOC emissions would reduce $PM_{2.5}$ formation, human exposure, and the incidence of $PM_{2.5}$-related health effects. Reducing exposure to $PM_{2.5}$ is associated with significant human health benefits, including avoiding mortality and respiratory morbidity. Researchers have associated $PM_{2.5}$ exposure with adverse health effects in numerous toxicological, clinical and epidemiological studies (EPA, 2009a). When adequate data and resources are available, EPA generally quantifies several health effects associated with exposure to $PM_{2.5}$ (e.g., EPA, 2011d). These health effects include premature mortality for adults and infants, cardiovascular morbidity such as heart attacks, hospital admissions, and respiratory morbidity such as asthma attacks, acute and chronic bronchitis, hospital and ER visits, work loss days, restricted activity days, and respiratory symptoms. Although EPA has not quantified these effects in previous benefits analyses, the scientific literature suggests that exposure to $PM_{2.5}$ is also associated with adverse effects on birth weight, pre-term births, pulmonary function, other cardiovascular effects, and other respiratory effects (EPA, 2009a).

When EPA quantifies $PM_{2.5}$-related benefits, the Agency assumes that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type (EPA, 2009a). Based on our review of the current body of scientific literature, EPA estimates PM-related mortality without applying an assumed concentration threshold. This decision is supported by the data, which are quite consistent in showing effects down to the lowest measured levels of $PM_{2.5}$ in the underlying epidemiology studies.

Fann, Fulcher, and Hubbell (2009) examined how the monetized benefit-per-ton estimates of reducing ambient $PM_{2.5}$ varies by the location of the emission reduction, the type of source emitting the precursor, and the specific precursor controlled. This study employed a reduced form air quality model to estimate changes in ambient $PM_{2.5}$ from reducing 12 different combinations of precursor emissions and emission sources, including reducing directly emitted carbonaceous particles, nitrogen oxides, sulfur oxides, ammonia, and VOCs for nine urban areas and nationwide. For each precursor/source combination in each location, the study authors then estimated the total monetized health benefits associated with the $PM_{2.5}$ change and divided these benefits by the corresponding emissions changes to generate benefit-per-ton estimates. The estimates from this study can provide general context for the unquantified VOC benefits in this rulemaking. Specifically, Fann, Fulcher, and Hubbell (2009) found that the monetized benefit-per-ton of reducing VOC emissions ranged from $560 in Seattle, WA to $5,700 in San Joaquin, CA, with a national average of $2,400. These estimates assume a 50 percent reduction in VOC, from the Laden *et al.* (2006) mortality function (based on the Harvard Six Cities study, a large cohort epidemiology study in the Eastern U.S., an analysis year of 2015, a 3 percent discount rate, and 2006$). Additional benefit-per-ton estimates are available from this dataset using alternate assumptions regarding the relationship between $PM_{2.5}$ exposure and premature mortality from empirical studies and those supplied by experts (e.g., Pope *et al.*, 2002; Laden *et al.*, 2006; Roman *et al.*, 2008). The EPA generally presents a range of benefits estimates derived from the American Cancer Society cohort (e.g., Pope *et al.*, 2002; Krewski *et al.*, 2009) to the Harvard Six Cities cohort (e.g., Laden *et al.*, 2006; Lepuele *et al.*, 2012) because the studies are both well-designed and extensively peer reviewed. The EPA provides the benefit estimates derived from expert opinions in Roman *et al.* (2008) as a characterization of uncertainty. As shown in Table 4-5, the range of VOC benefits that reflect the range of epidemiology studies and the range of the urban areas is $300 to $7,500 per ton of VOC reduced (2012$).[54] Since these estimates were presented in the 2012 Oil and Gas NSPS RIA (U.S. EPA, 2012b), we updated our methods to apply more recent epidemiological studies for these cohorts (i.e., Krewski *et al.*, 2009; Lepuele *et al.*, 2012) as well as additional updates to the morbidity studies and population data.[55] Because

[54] We also converted the estimates from Fann, Fulcher, and Hubbell (2009) to 2012$ and applied EPA's current value of a statistical life (VSL) estimate. For more information regarding EPA's current VSL estimate, please see Section 5.6.5.1 of the RIA for the PM NAAQS RIA (U.S. EPA, 2012c). EPA continues to work to update its guidance on valuing mortality risk reductions.

[55] For more information regarding these updates, please see Section 5.3 of the RIA for the final PM NAAQS (U.S. EPA, 2012c).

these updates would not lead to significant changes in the benefit-per-ton estimates for VOC, we have not updated them here.

While these ranges of benefit-per-ton estimates provide general context, the geographic distribution of VOC emissions from the MSW landfill sector are not consistent with emissions modeled in Fann, Fulcher, and Hubbell (2009). In addition, the benefit-per-ton estimates for VOC emission reductions in that study are derived from total VOC emissions across all sectors, and there is uncertainty regarding the composition of VOC in the landfills sector. Coupled with the larger uncertainties about the relationship between VOC emissions and $PM_{2.5}$, these factors lead the EPA to conclude that the available VOC benefit per ton estimates are not appropriate to calculate monetized benefits of this rule, even as a bounding exercise.

Table 4-5 Monetized Benefits-per-Ton Estimates for VOC in 9 Urban Areas and Nationwide based on Fann, Fulcher, and Hubbell (2009) in (2012$)

Area	Pope et al. (2002)	Laden et al. (2006)	Expert A	Expert B	Expert C	Expert D	Expert E	Expert F	Expert G	Expert H	Expert I	Expert J	Expert K	Expert L
Atlanta	$660	$1,600	$1,700	$1,300	$1,300	$920	$2,100	$1,200	$780	$980	$1,300	$1,000	$260	$1,000
Chicago	$1,600	$4,000	$4,200	$3,300	$3,200	$2,300	$5,300	$3,000	$1,900	$2,400	$3,200	$2,600	$640	$2,500
Dallas	$320	$790	$830	$650	$630	$450	$1,000	$580	$380	$480	$630	$510	$130	$490
Denver	$770	$1,900	$2,000	$1,500	$1,500	$1,100	$2,400	$1,400	$910	$1,100	$1,500	$1,200	$300	$910
NYC/ Philadelphia	$2,300	$5,600	$5,900	$4,600	$4,500	$3,200	$7,300	$4,100	$2,700	$3,400	$4,500	$3,600	$890	$3,300
Phoenix	$1,100	$2,700	$2,800	$2,200	$2,100	$1,500	$3,500	$2,000	$1,300	$1,600	$2,100	$1,700	$420	$1,600
Salt Lake	$1,400	$3,300	$3,500	$2,700	$2,700	$1,900	$4,400	$2,500	$1,600	$2,000	$2,700	$2,200	$570	$2,100
San Joaquin	$3,100	$7,500	$7,900	$6,100	$6,000	$4,300	$9,700	$5,500	$3,600	$4,500	$6,000	$4,900	$1,400	$4,600
Seattle	$300	$730	$770	$570	$590	$420	$950	$540	$350	$440	$580	$470	$120	$350
National average	**$1,300**	**$3,200**	**$3,400**	**$2,600**	**$2,600**	**$1,800**	**$4,200**	**$2,300**	**$1,500**	**$1,900**	**$2,500**	**$2,100**	**$520**	**$1,900**

* The estimates in this table provide general context regarding the potential magnitude of monetized benefits from reducing VOC emissions, but these urban areas were not chosen based on the locations of VOC emissions from the Landfills sector. Coupled with other uncertainties, these VOC benefit-per-ton estimates are not appropriate to calculate monetized benefits of this rule. These estimates assumed a 50 percent reduction in VOC emissions, an analysis year of 2015, and a 3 percent discount rate. All estimates are rounded to two significant digits. These estimates have been adjusted from Fann, Fulcher, and Hubbell (2009) to reflect a more recent currency year and the EPA's current VSL estimate. However, these estimates have not been updated to reflect recent epidemiological studies for mortality studies, morbidity studies, or population data. Using a discount rate of 7 percent, the benefit-per-ton estimates would be approximately 9 percent lower. Assuming a 75 percent reduction in VOC emissions would increase the VOC benefit-per-ton estimates by approximately 13 percent. Assuming a 25 percent reduction in VOC emissions would decrease the VOC benefit-per-ton estimates by 13 percent. The EPA generally presents a range of benefits estimates derived from the expert functions from Roman *et al.* (2008) as a characterization of uncertainty.

4.3.2 Visibility Effects

Reducing secondary formation of $PM_{2.5}$ from VOC emissions would improve visibility throughout the U.S. Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil (Sisler, 1996). Suspended particles and gases degrade visibility by scattering and absorbing light. Higher visibility impairment levels in the East are due to generally higher concentrations of fine particles, particularly sulfates, and higher average relative humidity levels. Visibility has direct significance to people's enjoyment of daily activities and their overall sense of wellbeing. Good visibility increases the quality of life where individuals live and work, and where they engage in recreational activities. Previous analyses (EPA, 2006b; EPA, 2011d; EPA, 2011a; EPA, 2012c) show that visibility benefits are a significant welfare benefit category. Without air quality modeling, we are unable to estimate visibility related benefits, nor are we able to determine whether VOC emission reductions would be likely to have a significant impact on visibility in urban areas or Class I areas.

4.4 VOC as an Ozone Precursor

This rulemaking would reduce emissions of VOC, which are also precursors to secondary formation of ozone. Ozone is not emitted directly into the air, but is created when its two primary components, volatile organic compounds (VOC) and oxides of nitrogen (NO_X), react in the presence of sunlight. In urban areas, compounds representing all classes of VOC and CO are important compounds for ozone formation, but VOC emitted from vegetation tend to be more important compounds in non-urban vegetated areas (EPA, 2013). Therefore, reducing these emissions would reduce ozone formation, human exposure to ozone, and the incidence of ozone-related health effects. However, we have not quantified the ozone-related benefits in this analysis for several reasons. First, previous rules have shown that the monetized benefits associated with reducing ozone exposure are generally smaller than PM-related benefits, even when ozone is the pollutant targeted for control (EPA, 2010a; EPA, 2014a). Second, the complex non-linear chemistry of ozone formation introduces uncertainty to the development and application of a benefit-per-ton estimate, particularly for sectors with substantial new growth. Third, the impact of reducing VOC emissions is spatially heterogeneous depending on local air chemistry. Urban areas with a high population concentration are often VOC-limited, which means that ozone is most effectively reduced by lowering VOC. Rural areas and downwind suburban areas are often NO_X-limited, which means that ozone concentrations are most effectively reduced by lowering NO_X emissions, rather than lowering emissions of VOC. Between these areas, ozone is relatively insensitive to marginal changes in both NO_X and VOC.

Due to data limitations, we did not perform air quality modeling for this rule needed to quantify the ozone benefits associated with reducing VOC emissions. Due to the high degree of variability in the responsiveness of ozone formation to VOC emission reductions and data limitations regarding the location of the emissions reductions, we are unable to estimate the effect that reducing VOC will have on ambient ozone concentrations without air quality modeling.

4.4.1 Ozone health effects and valuation

Reducing ambient ozone concentrations is associated with significant human health benefits, including mortality and respiratory morbidity (EPA, 2010a). Researchers have associated ozone exposure with adverse health effects in numerous toxicological, clinical and epidemiological studies (EPA, 2013). When adequate data and resources are available, EPA generally quantifies several health effects associated with exposure to ozone (e.g., EPA, 2010a; EPA, 2011a). These health effects include respiratory morbidity such as asthma attacks, hospital and emergency department visits, school loss days, as well as premature mortality. The scientific literature is also suggestive that exposure to ozone is also associated with chronic respiratory damage and premature aging of the lungs.

In a recent EPA analysis, EPA estimated that reducing 15,000 tons of VOC from industrial boilers resulted in \$3.6 to \$15 million (2008\$) of monetized benefits from reduced ozone exposure (EPA, 2011b).[56] After updating the currency year to 2012\$, this implies a benefit-per-ton for ozone of \$260 to \$1,000 per ton of VOC reduced. Since EPA conducted the

[56] While EPA has estimated the ozone benefits for many scenarios, most of these scenarios also reduce NO_X emissions, which make it difficult to isolate the benefits attributable to VOC reductions.

analysis of industrial boilers, EPA published the *Integrated Science Assessment for Ozone* (EPA, 2013), the *Health Risk and Exposure Assessment for Ozone* (EPA, 2014a), and the RIA for the proposed Ozone NAAQS (EPA, 2014b). Therefore, the ozone mortality studies applied in the boiler analysis, while current at that time, do not reflect the most updated literature available. The selection of ozone mortality studies used to estimate benefits in RIAs was revisited in the RIA for the proposed Ozone NAAQS. Applying the more recent studies would lead to benefit-per-ton estimates for ozone within the range shown here. While these ranges of benefit-per-ton estimates provide useful context, the geographic distribution of VOC emissions from the MSW landfill sector are not consistent with emissions modeled in the boiler analysis. Therefore, we do not believe that those estimates to provide useful estimates of the monetized benefits of this rule, even as a bounding exercise.

4.4.2 Ozone vegetation effects

Exposure to ozone has been associated with a wide array of vegetation and ecosystem effects in the published literature (EPA, 2013a). Sensitivity to ozone is highly variable across species, with over 66 vegetation species identified as "ozone-sensitive", many of which occur in state and national parks and forests. These effects include those that damage or impair the intended use of the plant or ecosystem. Such effects are considered adverse to the public welfare and can include reduced growth and/or biomass production in sensitive trees, reduced yield and quality of crops, visible foliar injury, species composition shift, and changes in ecosystems and associated ecosystem services.

4.4.3 Ozone climate effects

Ozone is a well-known short-lived climate forcing (SLCF) greenhouse gas (GHG) (EPA, 2006a). Stratospheric ozone (the upper ozone layer) is beneficial because it protects life on Earth from the sun's harmful ultraviolet (UV) radiation. In contrast, tropospheric ozone (ozone in the lower atmosphere) is a harmful air pollutant that adversely affects human health and the environment and contributes significantly to regional and global climate change. Due to its short atmospheric lifetime, tropospheric ozone concentrations exhibit large spatial and temporal variability (EPA, 2009b). The IPCC AR5 estimated that the contribution to current warming levels of increased tropospheric ozone concentrations resulting from human methane, NOx, and VOC emissions was 0.5 W/m^2, or about 30 percent as large a warming influence as elevated CO_2 concentrations. This quantifiable influence of ground level ozone on climate leads to increases in global surface temperature and changes in hydrological cycles.

4.5 Hazardous Air Pollutant (HAP) Benefits

Even though emissions of air toxics from all sources in the U.S. declined by approximately 62 percent since 1990, the 2011 National-Scale Air Toxics Assessment (NATA) predicts that most Americans are exposed to ambient concentrations of air toxics at levels that have the potential to cause adverse health effects (EPA, 2015).[57] The levels of air toxics to which people are exposed vary depending on where they live and work and the kinds of activities in which they engage. In order to identify and prioritize air toxics, emission source types and locations that are of greatest potential concern, the U.S. EPA conducts the NATA.[58] The most recent NATA was conducted for calendar year 2011 and was released in December 2015. NATA includes four steps:

1) Compiling a national emissions inventory of air toxics emissions from outdoor sources

2) Estimating ambient concentrations of air toxics across the United States utilizing dispersion models

3) Estimating population exposures across the United States utilizing exposure models

[57] The 2011 NATA is available on the Internet at http://www.epa.gov/national-air-toxics-assessment/2011-national-air-toxics-assessment.

[58] The NATA modeling framework has a number of limitations that prevent its use as the sole basis for setting regulatory standards. These limitations and uncertainties are discussed on the 2011NATA website. Even so, this modeling framework is very useful in identifying air toxic pollutants and sources of greatest concern, setting regulatory priorities, and informing the decision making process. U.S. EPA. (2015) 2011 National-Scale Air Toxics Assessment.< http://www.epa.gov/national-air-toxics-assessment/2011-national-air-toxics-assessment>.

4) Characterizing potential public health risk due to inhalation of air toxics including both cancer and noncancer effects

Based on the 2011 NATA, EPA estimates that less than one percent of census tracts nationwide have increased cancer risks greater than 100 in a million. The average national cancer risk is about 40 in a million. Nationwide, the key pollutants that contribute most to the overall cancer risks are formaldehyde and benzene.[59,60] Secondary formation (e.g., formaldehyde forming from other emitted pollutants) was the largest contributor to cancer risks, while stationary, mobile, biogenics, and background sources contribute lesser amounts to the remaining cancer risk.

Noncancer health effects can result from chronic,[61] subchronic,[62] or acute[63] inhalation exposures to air toxics, and include neurological, cardiovascular, liver, kidney, and respiratory effects as well as effects on the immune and reproductive systems. According to the 2011 NATA, about 80 percent of the U.S. population was exposed to an average chronic concentration of air toxics that has the potential for adverse noncancer respiratory health effects. Results from the 2011 NATA indicate that acrolein is the primary driver for noncancer respiratory risk.

Figure 4-2 and Figure 4-3 depict the 2011 NATA estimated census tract-level carcinogenic risk and noncancer respiratory hazard from the assessment. It is important to note that large reductions in HAP emissions may not necessarily translate into significant reductions in health risk because toxicity varies by pollutant, and exposures may or may not exceed levels of concern. For example, acetaldehyde mass emissions were more than seventeen times acrolein

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[59] Details on EPA's approach to characterization of cancer risks and uncertainties associated with the 2011 NATA risk estimates can be found at <http://www.epa.gov/national-air-toxics-assessment/nata-limitations>.

[60] Details about the overall confidence of certainty ranking of the individual pieces of NATA assessments including both quantitative (e.g., model-to-monitor ratios) and qualitative (e.g., quality of data, review of emission inventories) judgments can be found at <http://www.epa.gov/ttn/atw/nata/roy/page16.html>.

[61] Chronic exposure is defined in the glossary of the Integrated Risk Information System (IRIS) database (<http://www.epa.gov/iris>) as repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species).

[62] Defined in the IRIS database as repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10% of the life span in humans (more than 30 days up to approximately 90 days in typically used laboratory animal species).

[63] Defined in the IRIS database as exposure by the oral, dermal, or inhalation route for 24 hours or less.

emissions on a national basis in the EPA's 2011 National Emissions Inventory (NEI). However, the Integrated Risk Information System (IRIS) reference concentration (RfC) for acrolein is considerably lower than that for acetaldehyde, this results in 2011 NATA estimates of nationwide chronic respiratory noncancer risks from acrolein being over three times that of acetaldehyde.[64] Thus, it is important to account for the toxicity and exposure, as well as the mass of the targeted emissions.

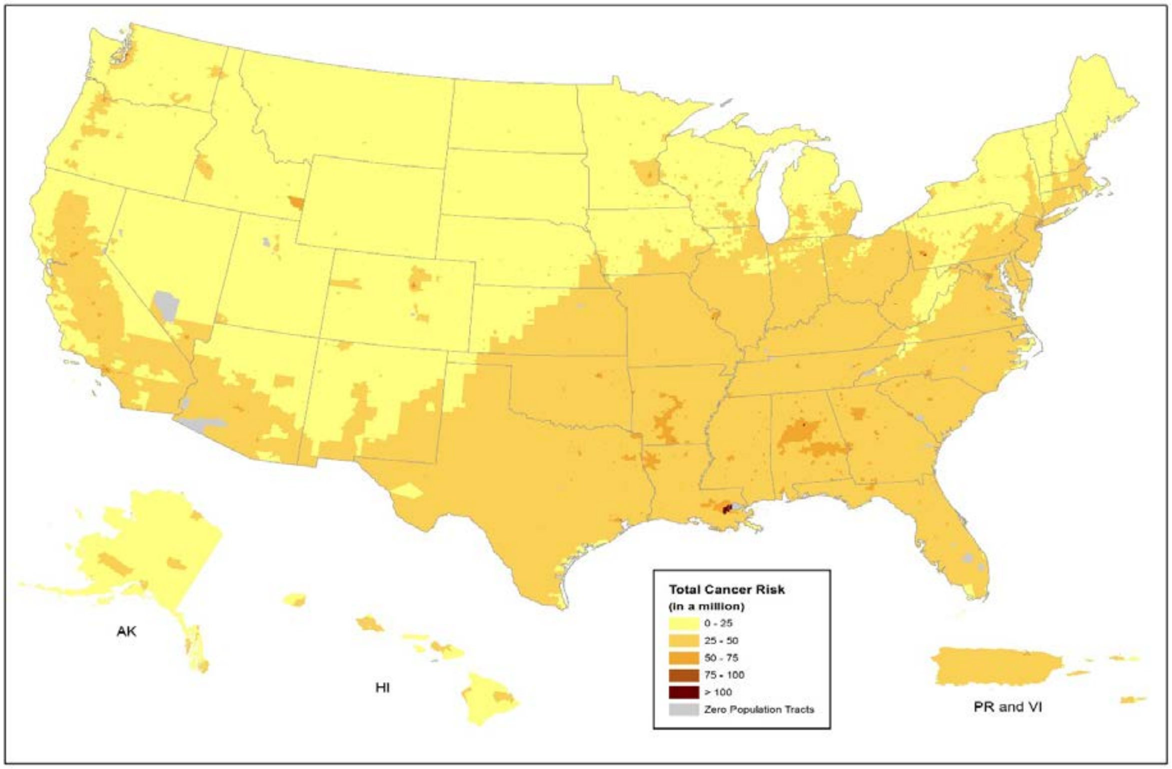

Figure 4-2 2011 NATA Model Estimated Census Tract Carcinogenic Risk from HAP Exposure from All Outdoor Sources based on the 2011 National Emissions Inventory

[64] Details on the derivation of IRIS values and available supporting documentation for individual chemicals (as well as chemical values comparisons) can be found at < http://www.epa.gov/iris>.

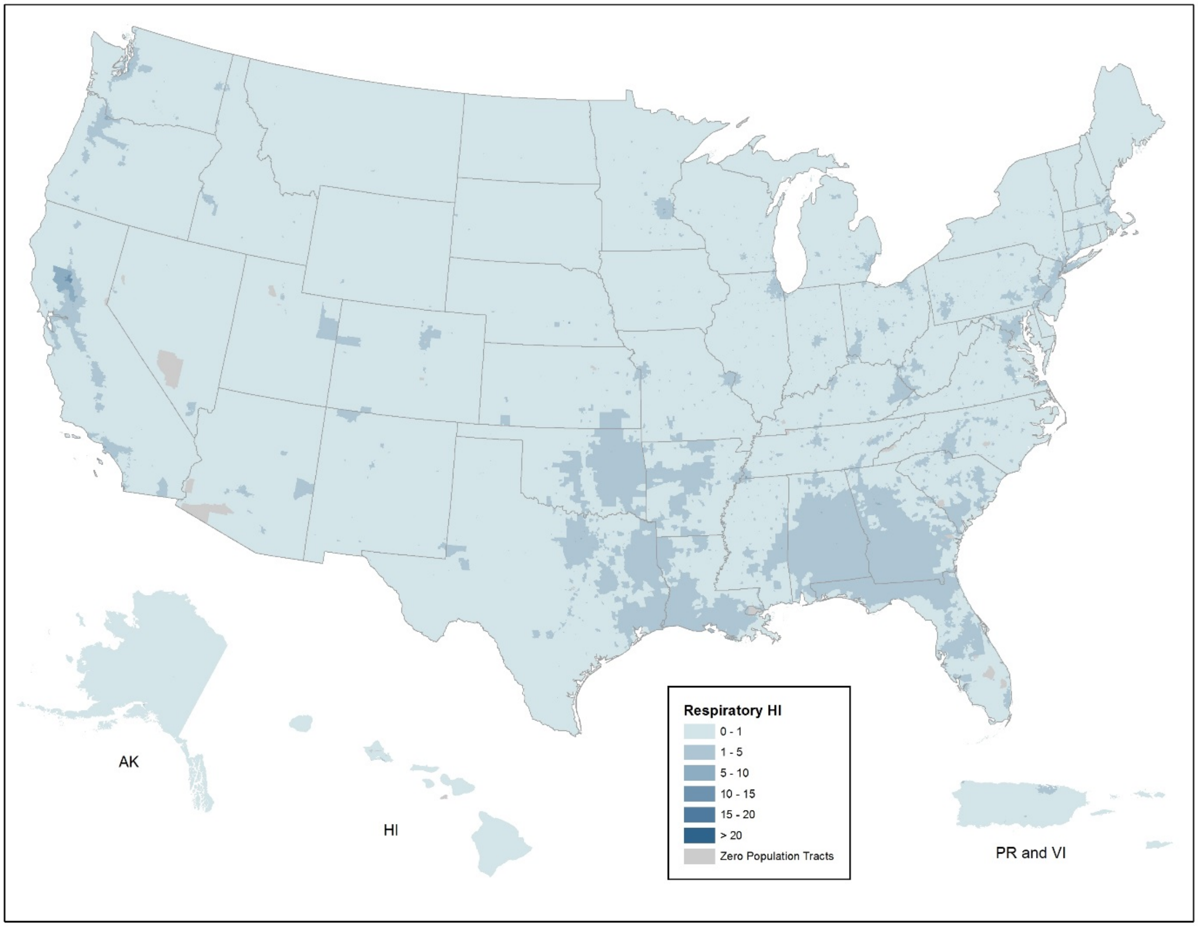

Figure 4-3 2011 NATA Model Estimated Census Tract Noncancer (Respiratory) Risk from HAP Exposure from All Outdoor Sources based on the 2011 National Emissions Inventory

Due to methodology and data limitations, we were unable to estimate the benefits associated with the hazardous air pollutants that would be reduced as a result of this rule. In a few previous analyses of the benefits of reductions in HAP, EPA has quantified the benefits of potential reductions in the incidences of cancer and noncancer risk (e.g., EPA, 1995). In those analyses, EPA relied on unit risk factors (URF) and reference concentrations (RfC) developed through risk assessment procedures. The URF is a quantitative estimate of the carcinogenic potency of a pollutant, often expressed as the probability of contracting cancer from a 70-year lifetime continuous exposure to a concentration of one µg/m3 of a pollutant. These URFs are designed to be conservative, and as such, are more likely to represent the high end of the distribution of risk rather than a best or most likely estimate of risk.

An RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer health effects during a lifetime. As part of the second prospective analysis of the benefits and costs of the Clean Air Act (EPA, 2011a), EPA conducted a case study analysis of the health effects associated with reducing exposure to benzene in Houston from implementation of the Clean Air Act (IEc, 2009). While reviewing the draft report, EPA's Advisory Council on Clean Air Compliance Analysis concluded that "the challenges for assessing progress in health improvement as a result of reductions in emissions of hazardous air pollutants (HAP) are daunting...due to a lack of exposure-response functions, uncertainties in emissions inventories and background levels, the difficulty of extrapolating risk estimates to low doses and the challenges of tracking health progress for diseases, such as cancer, that have long latency periods" (EPA-SAB, 2008).

In 2009, EPA convened a workshop to address the inherent complexities, limitations, and uncertainties in current methods to quantify the benefits of reducing HAP. Recommendations from this workshop included identifying research priorities, focusing on susceptible and vulnerable populations, and improving dose-response relationships (Gwinn et al., 2011).

In summary, monetization of the benefits of reductions in cancer incidences requires several important inputs, including central estimates of cancer risks, estimates of exposure to carcinogenic HAP, and estimates of the value of an avoided case of cancer (fatal and non-fatal). Due to methodology and data limitations, we did not attempt to monetize the health benefits of reductions in HAP in this analysis. Instead, we provide a qualitative analysis of the health effects associated with the HAP anticipated to be reduced by this rule. EPA remains committed to improving methods for estimating HAP benefits by continuing to explore additional concepts of benefits, including changes in the distribution of risk.

In the subsequent sections, we describe the health effects associated with the main HAP of concern from the MSW landfill sector: benzene, ethylbenzene, toluene, and vinyl chloride. This rule is anticipated to avoid or reduce 1,809 tons of NMOC per year. With the data available, it was not possible to estimate the tons of each individual HAP that would be reduced.

Therefore, in addition to the reasons identified above, we cannot estimate the monetized benefits associated with reducing HAP emissions for this rule.

4.5.1 Benzene

The EPA's IRIS database lists benzene as a known human carcinogen (causing leukemia) by all routes of exposure, and concludes that its exposure is associated with additional health effects, including genetic changes in both humans and animals, and increased proliferation of bone marrow cells in mice.[65,66,67] EPA states in its IRIS database that data indicate a causal relationship between benzene exposure and acute lymphocytic leukemia and suggest a relationship between benzene exposure and chronic non-lymphocytic leukemia and chronic lymphocytic leukemia. The IARC has determined that benzene is a human carcinogen and the U.S. Department of Health and Human Services has characterized benzene as a known human carcinogen.[68,69]

A number of adverse noncancer health effects including blood disorders, such as preleukemia and aplastic anemia, have also been associated with long-term exposure to benzene.[70,71]

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[65] U.S. Environmental Protection Agency (U.S. EPA). 2000. Integrated Risk Information System File for Benzene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at: http://www.epa.gov/iris/subst/0276.htm.

[66] International Agency for Research on Cancer, IARC monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 29, Some industrial chemicals and dyestuffs, International Agency for Research on Cancer, World Health Organization, Lyon, France, p. 345-389, 1982.

[67] Irons, R.D.; Stillman, W.S.; Colagiovanni, D.B.; Henry, V.A. (1992) Synergistic action of the benzene metabolite hydroquinone on myelopoietic stimulating activity of granulocyte/macrophage colony-stimulating factor in vitro, Proc. Natl. Acad. Sci. 89:3691-3695.

[68] International Agency for Research on Cancer (IARC). 1987. Monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 29, Supplement 7, Some industrial chemicals and dyestuffs, World Health Organization, Lyon, France.

[69] U.S. Department of Health and Human Services National Toxicology Program 11th Report on Carcinogens available at: http://ntp.niehs.nih.gov/go/16183 .

[70] Aksoy, M. (1989). Hematotoxicity and carcinogenicity of benzene. Environ. Health Perspect. 82: 193-197.

[71] Goldstein, B.D. (1988). Benzene toxicity. Occupational medicine. State of the Art Reviews. 3: 541-554.

4.5.2 Ethylbenzene

Ethylbenzene is a major industrial chemical produced by alkylation of benzene. The pure chemical is used almost exclusively for styrene production. It is also a constituent of crude petroleum and is found in gasoline and diesel fuels. Acute (short-term) exposure to ethylbenzene in humans results in respiratory effects such as throat irritation and chest constriction, and irritation of the eyes, and neurological effects such as dizziness. Chronic (long-term) exposure of humans to ethylbenzene may cause eye and lung irritation, with possible adverse effects on the blood. Animal studies have reported effects on the blood, liver, and kidneys and endocrine system from chronic inhalation exposure to ethylbenzene. No information is available on the developmental or reproductive effects of ethylbenzene in humans, but animal studies have reported developmental effects, including birth defects in animals exposed via inhalation. Studies in rodents reported increases in the percentage of animals with tumors of the nasal and oral cavities in male and female rats exposed to ethylbenzene via the oral route.[72,73] The reports of these studies lacked detailed information on the incidence of specific tumors, statistical analysis, survival data, and information on historical controls, thus the results of these studies were considered inconclusive by the International Agency for Research on Cancer (IARC, 2000) and the National Toxicology Program (NTP).[74,75] The NTP (1999) carried out a chronic inhalation bioassay in mice and rats and found clear evidence of carcinogenic activity in male rats and some evidence in female rats, based on increased incidences of renal tubule adenoma or carcinoma in male rats and renal tubule adenoma in females. NTP (1999) also noted increases in

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[72] Maltoni C, Conti B, Giuliano C and Belpoggi F, 1985. Experimental studies on benzene carcinogenicity at the Bologna Institute of Oncology: Current results and ongoing research. *Am J Ind Med* 7:415-446.

[73] Maltoni C, Ciliberti A, Pinto C, Soffritti M, Belpoggi F and Menarini L, 1997. Results of long-term experimental carcinogenicity studies of the effects of gasoline, correlated fuels, and major gasoline aromatics on rats. *Annals NY Acad Sci* 837:15-52.

[74]International Agency for Research on Cancer (IARC), 2000. Monographs on the Evaluation of Carcinogenic Risks to Humans. Some Industrial Chemicals. Vol. 77, p. 227-266. IARC, Lyon, France.

[75] National Toxicology Program (NTP), 1999. Toxicology and Carcinogenesis Studies of Ethylbenzene (CAS No. 100-41-4) in F344/N Rats and in B6C3F1 Mice (Inhalation Studies). Technical Report Series No. 466. NIH Publication No. 99-3956. U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. NTP, Research Triangle Park, NC.

the incidence of testicular adenoma in male rats. Increased incidences of lung alveolar/bronchiolar adenoma or carcinoma were observed in male mice and liver hepatocellular adenoma or carcinoma in female mice, which provided some evidence of carcinogenic activity in male and female mice (NTP, 1999). IARC (2000) classified ethylbenzene as Group 2B, possibly carcinogenic to humans, based on the NTP studies.

4.5.3 Toluene[76]

Under the 2005 Guidelines for Carcinogen Risk Assessment, there is inadequate information to assess the carcinogenic potential of toluene because studies of humans chronically exposed to toluene are inconclusive, and toluene was not carcinogenic in adequate inhalation cancer bioassays of rats and mice exposed for life.[77,78,79] Increased incidences of mammary cancer and leukemia were reported in a lifetime rat oral bioassay;[80] however, this evidence was considered equivocal since cancers were observed at the low dose tested (500mg/kg/day) but not at the higher dose tested (800 mg/kg/day). In support of EPA's cancer classification, IARC has classified toluene as Group 3 (*not classifiable as to its carcinogenicity in humans*) with a supporting statement that there is inadequate evidence in humans and evidence suggesting a lack of carcinogenicity of toluene in experimental animals.[81]

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[76] All health effects language for this section came from: U.S. EPA. 2005. "Full IRIS Summary for Toluene (CASRN 108-88-3)" Environmental Protection Agency, Integrated Risk Information System (IRIS), Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH. Available on the Internet at <http://www.epa.gov/iris/subst/0118.htm>.

[77] CIIT (Chemical Industry Institute of Toxicology). (1980) A twenty-four month inhalation toxicology study in Fischer-344 rats exposed to atmospheric toluene. Conducted by Industrial Bio-Test Laboratories, Inc., Decatur, IL, and Experimental Pathology Laboratories, Inc., Raleigh, NC, for CIIT, Research Triangle Park, NC..

[78] NTP (National Toxicology Program), 1990. Toxicology and carcinogenesis studies of toluene (CAS No. 108-88-3) in F344/N rats and B5C3F1 mice (inhalation studies). Public Health Service, U.S. Department of Health and Human Services; NTP TR 371. Available from: National Institute of Environmental Health Sciences, Research Triangle Park, NC.

[79] Huff, J., 2003. Absence of carcinogenic activity in Fischer rats and B6C3F1 mice following 103-week inhalation exposures to toluene. Int J Occup Environ Health 9:138-146.

[80] Maltoni, C; Ciliberti, A; Pinto, C; et al., 1997. Results of long-term experimental carcinogenicity studies of the effects of gasoline, correlated fuels, and major gasoline aromatics on rats. Ann NY Acad Sci 837:15-52.

[81] IARC. (International Agency for Research on Cancer), 1999. IARC monographs on the evaluation of carcinogenic risks of chemicals to humans. Vol. 71, Part 2. Re-evaluation of some organic chemicals, hydrazine and hydrogen peroxide. Lyon, France: International Agency for Research on Cancer, pp. 829-864.

The central nervous system (CNS) is the primary target for toluene toxicity in both humans and animals for acute and chronic exposures. CNS dysfunction (which is often reversible) and narcosis have been frequently observed in humans acutely exposed to low or moderate levels of toluene by inhalation: symptoms include fatigue, sleepiness, headaches, and nausea. Central nervous system depression has been reported to occur in chronic abusers exposed to high levels of toluene. Symptoms include ataxia, tremors, cerebral atrophy, nystagmus (involuntary eye movements), and impaired speech, hearing, and vision. Chronic inhalation exposure of humans to toluene also causes irritation of the upper respiratory tract, eye irritation, dizziness, headaches, and difficulty with sleep.

Human studies have also reported developmental effects, such as CNS dysfunction, attention deficits, and minor craniofacial and limb anomalies, in the children of women who abused toluene during pregnancy. A substantial database examining the effects of toluene in subchronic and chronic occupationally exposed humans exists. The weight of evidence from these studies indicates neurological effects (i.e., impaired color vision, impaired hearing, decreased performance in neurobehavioral analysis, changes in motor and sensory nerve conduction velocity, headache, and dizziness) as the most sensitive endpoint.

4.5.4 Vinyl Chloride[82]

Most vinyl chloride is used to make polyvinyl chloride (PVC) plastic and vinyl products. Acute (short-term) exposure to high levels of vinyl chloride in air has resulted in central nervous system effects (CNS), such as dizziness, drowsiness, and headaches in humans. Chronic (long-term) exposure to vinyl chloride through inhalation and oral exposure in humans has resulted in liver damage. Cancer is a major concern from exposure to vinyl chloride via inhalation, as vinyl chloride exposure has been shown to increase the risk of a rare form of liver cancer in humans.

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[82] U.S. Environmental Protection Agency. Integrated Risk Information System (IRIS) on Vinyl Chloride. 2000. Available online at <http://www.epa.gov/iris/subst/1001.htm>.

EPA has classified vinyl chloride as a Group A, “*human carcinogen*”. IARC has classified vinyl chloride as *carcinogenic to humans* (Group 1).[83]

4.5.5 Other Air Toxics

In addition to the compounds described above, other air toxic compounds might be affected by this rule. Information regarding the health effects of those compounds can be found in EPA’s IRIS database.[84]

4.6 Alternative Years of Analysis

While the EPA is assessing impacts in year 2025 as a representative year for the EG for existing MSW landfills, the quantity and composition of landfill gas does change over the lifetime of a landfill, as discussed in Chapter 2. This section presents a more complete picture of the climate benefits of the EG alternatives over time by presenting results from the years 2020, 2030, and 2040. Tables 4-6 through 4-8 present the climate benefits of the options in those snapshot years, respectively.

Table 4-6 Estimated Global Benefits of CH_4 Reductions in 2020* (in millions, 2012$)

	Million metric tons of CH_4 reduced**	**Million metric tons of CO_2-equivalent reduced**	**Discount rate and statistic**			
			5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	0.20	5.1	$120	$260	$350	$700
Final Option 2.5/34	0.31	7.9	$180	$410	$540	$1,100
Alternative Option 2.0/34	0.34	8.6	$200	$450	$600	$1,200

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years.
**One metric ton equals one megagram.

[83] International Agency for Research on Cancer (IARC). 2008. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals for Humans. Vol. 97, pp311. Lyon, France: International Agency for Research on Cancer. Available online at <http://monographs.iarc.fr/ENG/Monographs/vol97/index.php>.
[84] U.S. EPA Integrated Risk Information System (IRIS) database is available at:< www.epa.gov/iris>.

Table 4-7 Estimated Global Benefits of CH_4 Reductions in 2030* (in millions, 2012$)

	Million metric tons of CH_4 reduced**	Million metric tons of CO_2-equivalent reduced	Discount rate and statistic			
			5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	0.21	5.2	$170	$360	$450	$950
Final Option 2.5/34	0.30	7.5	$250	$520	$650	$1,400
Alternative Option 2.0/34	0.36	8.9	$290	$620	$770	$1,600

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years.
**One metric ton equals one megagram.

Table 4-8 Estimated Global Benefits of CH_4 Reductions in 2040* (in millions, 2012$)

	Million metric tons of CH_4 reduced**	Million metric tons of CO_2-equivalent reduced	Discount rate and statistic			
			5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	0.24	6.1	$260	$530	$680	$1,400
Final Option 2.5/34	0.35	8.9	$380	$770	$1,000	$2,100
Alternative Option 2.0/34	0.37	9.2	$400	$800	$1,000	$2,200

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years.
**One metric ton equals one megagram.

4.7 Net Present Value of Climate-related Methane Benefits of the Final Emission Guidelines

EPA calculated the net present value of the climate-related benefits associated with the methane reductions from the final option in years 2019 through 2040. The net present value of these benefits ranges from $3.3 billion to $23 billion, depending on the SC-CH_4 value used, with net present value at $8.4 billion using the central SC-CH_4 estimate. The equivalent annualized value of the methane benefit net present value for the period 2019 through 2040 is $510 million using the central SC-CH_4 estimate. Table 4-9 shows these results.

Table 4-9 Estimated Global Benefits of CH_4 Reductions and Net Present Value* (in millions, 2012$)

Year	Million metric tons of CH_4 reduced	Discount rate and statistic			
		5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
2019	0.33	$180	$410	$550	$1,100
2020	0.31	$180	$410	$540	$1,100
2021	0.31	$190	$410	$550	$1,100
2022	0.31	$190	$420	$550	$1,100
2023	0.33	$210	$470	$610	$1,200
2024	0.31	$210	$450	$580	$1,200
2025	0.29	$200	$430	$550	$1,100
2026	0.26	$190	$410	$530	$1,100
2027	0.30	$230	$480	$610	$1,300
2028	0.29	$220	$480	$600	$1,300
2029	0.28	$230	$480	$600	$1,300
2030	0.30	$250	$520	$650	$1,400
2031	0.32	$270	$560	$710	$1,500
2032	0.33	$290	$600	$750	$1,600
2033	0.34	$310	$630	$790	$1,700
2034	0.29	$270	$550	$700	$1,500
2035	0.33	$320	$630	$810	$1,700
2036	0.30	$300	$600	$770	$1,600
2037	0.29	$290	$590	$750	$1,600
2038	0.32	$330	$660	$850	$1,800
2039	0.35	$380	$750	$970	$2,100
2040	0.35	$380	$770	$1,000	$2,100
Net present value		$3,300	$8,400	$11,000	$23,000
Equivalent Annualized value		$240	$510	$660	$1,400

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years.

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5 ECONOMIC IMPACT ANALYSIS AND DISTRIBUTIONAL ASSESSMENTS FOR THE EMISSION GUIDELINES

5.1 Introduction

This chapter of the RIA includes three sets of discussions related to the final Emission Guidelines for MSW landfills:

- Economic Impact Analysis
- Employment Analysis
- Small Business Analysis

These discussions are intended to assist the reader of the RIA to better understand the potential economic impacts of the action, though data and methodological limitations prevented a complete assessment of the economic impacts of the final EG.

5.2 Economic Impact Analysis

The impacts shown for the action reflect the incremental difference between facilities in the baseline and for an option that reduces the NMOC emission rate threshold to 34 Mg/yr from the current emissions guideline level of 50 Mg/yr (final option 2.5/34). The guidelines retain the design capacity threshold of 2.5 million Mg or 2.5 million cubic feet. Because the final option 2.5/34 tightens the criteria for installing and expanding the gas collection and control system, there are incremental costs associated with capturing and/or utilizing the additional LFG under this more stringent option. These costs were shown in Chapter 3 of this RIA to be about $54 million in 2025 for the final option (assuming a discount rate of 7% and 2012$).

Assessing the economic impacts of these costs is difficult due to the nature of the MSW industry. As previously discussed in Chapter 2, landfills are owned by private companies, governments (local, state, or federal), and/or individuals. In 2015, 57 percent of landfills were owned by public entities. Households served by public landfills may not respond to price increases in the same way as they would if served by private firms, since these households typically pay their collection fees through property taxes or other mandatory payments. In these cases, affected landfills may be more readily able to pass through increased costs to customers. Households served by private landfills may choose to alter their behavior in response to increased collection fees, but research into the price elasticity of demand for waste services has typically found the demand for waste services to be price inelastic (Bel and Gradus, 2014; Kinnaman, 2006). As was shown in Table 2-5, tipping fees have for the most part increased over time, and industry reports indicate that "firms have generally managed to hold the line on pricing and win 2-3 percent increases to maintain positive revenue amid slow volume growth" (WBJ, 2012a). This suggests that firms will, for the most part, be able to pass along increased costs to their consumers. While households faced with higher costs will have less income to spend on other goods and services, the large number of households served by any particular landfill suggests that any individual household will be only modestly impacted.

As previously discussed in Chapter 2, the handling of MSW in the United States generated $55 billion of revenue in 2011, of which landfilling contributed $13 billion (WBJ, 2012a). A more recent estimate is that the U.S. non-hazardous solid waste services industry generates about $60 billion in annual revenue (SEC, 2016RSG). Of the $54 million of costs in 2025 for the final option, around 15 percent are borne by the five largest firms in the industry, who together accounted for nearly $30 billion in revenue in 2013 (see Table 2-3). An additional 79 percent of the costs are expected to be incurred by entities that are large by SBA standards. Small public entities are predicted to incur approximately six percent of the costs, while small private entities are predicted to incur less than one percent of the total cost.

Because of the relatively low net cost of final option 2.5/34 compared to the overall size of the MSW industry, as well as the lack of appropriate economic parameters or model, the EPA is unable to estimate the impacts of the options on the supply and demand for MSW landfill services. However, because of the relatively low incremental costs of the final option 2.5/34, the EPA does not believe the final guidelines would lead to changes in supply and demand for landfill services or waste disposal costs, tipping fees, or the amount of waste disposed in landfills. Hence, the overall economic impact of the final guidelines should be minimal on the affected industries and their consumers.

5.3 Employment Impacts

In addition to addressing the costs and benefits of the final rule, EPA has analyzed the impacts of this rulemaking on employment, which are presented in this section. While a standalone analysis of employment impacts is not included in a standard cost-benefit analysis, such an analysis is of particular concern in the current economic climate given continued interest in the employment impact of regulations such as this final rule. Executive Order 13563, states, "Our regulatory system must protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation." [85] While disaggregated compliance costs are not available for the analyzed options, a brief discussion of the labor requirements associated with the installation, operation, and maintenance of control requirements, as well as reporting and recordkeeping requirements is included in Section 3.4, on engineering and administrative costs, of this RIA. However, due to data and methodology limitations, we have not quantified the rule's effects on employment. What follows is an overview of the various ways that environmental regulation can affect employment. Subsequent to proposal, the EPA continued to explore the relevant theoretical and empirical literature and to evaluate public comments in order to ensure that the way EPA characterizes the employment effects of its regulations is valid and informative.[86]

5.3.1 Background on the Regulated Industry

This regulation is expected to affect domestic employment in the regulated sector – municipal solid waste landfills. Municipal solid waste (MSW) is the stream of garbage collected by sanitation services from homes, businesses, and institutions. The majority of collected MSW that is not recycled is typically sent to landfills—engineered areas of land where waste is deposited, compacted, and covered. Landfill gas (LFG) is a by-product of the decomposition of organic material in MSW in anaerobic conditions in landfills. LFG contains roughly 50 percent methane and 50 percent carbon dioxide, with less than 1 percent non-methane organic compounds (NMOC) and trace amounts of inorganic compounds. The amount of LFG created primarily depends on the quantity of waste and its composition and moisture content as well as the design and management practices at the landfill. LFG can be collected and combusted in

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[85] Executive Order 13563 (January 21, 2011). *Improving Regulation and Regulatory Review. Section 1. General Principles of Regulation*, Federal Register, Vol. 76, Nr. 14, p. 3821.

[86] The employment analysis in this RIA is part of EPA's ongoing effort to "conduct continuing evaluations of potential loss or shifts of employment which may result from the administration or enforcement of [the Act]" pursuant to CAA section 321(a).

flares or energy recovery devices to reduce emissions. In this rulemaking EPA is finalizing lowering the annual NMOC emissions threshold from 50 Mg/year to 34 Mg/year. Because of the lack of appropriate economic parameters or model, EPA is unable to estimate the impacts of the rule options on the supply and demand for MSW landfill services. However, because of the relatively low incremental costs of the final option, the EPA does not believe the final guidelines would lead to changes in supply and demand for landfill services or waste disposal costs, tipping fees, or the amount of waste disposed in landfills. Hence, the overall economic impact of the guidelines should be minimal on the affected industries and their consumers.

As described in Chapter 2 of this RIA, EPA estimates the total amount of MSW generated in the United States in 2013 was approximately 254 million tons, a 22 percent increase from 1990. The number of active MSW landfills in the United States has decreased from approximately 7,900 in 1988 to approximately 1,800 in 2015 (EPA, 2010; WBJ, 2015). Firms engaged in the collection and disposal of refuse in a landfill operation are classified under the North American Industry Classification System (NAICS) codes Solid Waste Landfill (562212) and Administration of Air and Water Resource and Solid Waste Management Programs (924110). There are more than 100 private companies that own and/or operate active landfills, ranging from large companies with numerous landfills throughout the country to local businesses that own a single landfill (EPA, 2016c). In terms of 2013 revenue, the top two companies that own and/or operate MSW landfills in the United States were Waste Management ($12.96 billion) and Republic Services ($9.12 billion). See Chapter 2, Table 2-3, for a summary of the 2013 revenue for the top five companies, as well as information about their MSW landfills and transfer stations.

Landfills are owned by private companies, government (local, state, or federal), or individuals. In 2014, 58 percent of active MSW landfills were owned by public entities while 42 percent were privately owned (EPA, 2014). As older local public landfills approach their capacities, many communities are finding that the most economically viable solution to their waste disposal needs is shipping their waste to large regional landfills. In these circumstances, a transfer station serves as the critical link in making the shipment of waste to distant facilities cost-effective (EPA, 2002). Waste transfer stations are facilities where MSW is unloaded from collection vehicles and reloaded into long-distance transport vehicles for delivery to regional landfills or other treatment/disposal facilities. By combining the loads of several waste collection trucks into a single shipment, communities and waste management companies can reduce labor used and operating costs for transporting waste to a distant disposal site. They can also reduce the total number of vehicular miles traveled to and from the disposal site(s) (EPA, 2012b).

The industry that collects, transfers, deposits and manages MSW in landfills encompasses a wide range of job types, including garbage collectors, truck drivers, heavy equipment operators, engineers of various disciplines, specialized technicians, executives, MSW department directors, administrative staff, weigh scale operators, salespersons, and landfill operations managers. For employment estimates related to publicly-owned landfills, solid waste management departments of local governments reported, in 2013, 95,674 full-time employees and 14,638 part-time employees (U.S. Census Bureau, 2013); however, statistics from the U.S. Census Bureau are not readily available solely for landfill-related aspects of these departments. An additional government source of employment data by detailed industry is the Bureau of Labor Statistics (BLS). The BLS Quarterly Census of Employment and Wages, which gathers employment data from state unemployment insurance programs, reports employment data for publicly-owned solid waste landfills (NAICS 562212) owned by local governments: in March 2013, they report 22,586 employees (U.S. Bureau of Labor Statistics, 2013). For employment estimates related to private landfills, both the U.S. Census Bureau and the Bureau of Labor Statistics provide employment data. However, because these agencies use different methods to gather and classify employment data, their estimates indicate a range of employment within NAICS 562212, “solid waste landfills”.[87] For March 2012, the U.S. Census Bureau’s County Business Patterns, the Census estimate is 18,208 employees at privately-owned solid waste landfills (U.S. Census Bureau, 2012). However, for privately-owned solid waste landfills, the BLS estimate for March 2012 is 37,628 employees (U.S. Bureau of Labor Statistics, 2012). When data series differ, it can be instructive to look at more aggregated industry categories, and in this case, more aggregated employment estimates are very similar between Census and BLS at the 3-digit level NAICS, 562 Waste Management and Remediation Services. When compared to

[87] BLS QCEW methodology for “industrial classification”: http://www.bls.gov/opub/hom/homch5_b.htm. Census methodology for “industry classification of establishments”: https://www.census.gov/econ/cbp/methodology.htm.

NAICS 562, the range in estimates at the 6-digit NAICS 562212 appears to be driven by methodological differences in categorizing establishments by their “main economic activity”. For this detailed industry, the main economic activity is likely a combination of waste treatment, waste disposal, and waste remediation and recovery services, and therefore difficult to classify by a single economic activity.[88]

As the population continues to grow in the United States the amount of waste generated will continue to increase, but the amount of waste landfilled may remain the same or decrease due to recycling and other diversion activities (EPA, 2012c). Employment within the waste management industry overall will likely remain strong, perhaps with an increased shift of employees from the public sector to the private sector as the trend towards increased use of regional landfills and waste transfer stations continues. In addition, employment may be affected as landfills add technologies in response to the final regulation. Whether the technology added will capture and flare landfill gas, or capture and combust it for energy recovery, employment will be associated with these activities.

5.3.2 Employment Impacts of Environmental Regulation

From an economic perspective labor is an input into producing goods and services; if a regulation requires that more labor be used to produce a given amount of output, that additional labor is reflected in an increase in the cost of production. Moreover, when the economy is at full employment, we would not expect an environmental regulation to have an impact on overall employment because labor is being shifted from one sector to another. On the other hand, in periods of high unemployment, employment effects (both positive and negative) are possible.

For example, an increase in labor demand due to regulation may result in a short-term net increase in overall employment as workers are hired by the regulated sector to help meet new requirements (e.g., to install new equipment) or by the environmental protection sector to produce new abatement capital resulting in hiring previously unemployed workers . When

[88] 2-, 3-, 4-, 5-, and 6-digit NAICS listings for NAICS 56 “Administrative and Support and Waste Management and Remediation Services” < http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart_code=56&search=2012%20NAICS%20Search>.

significant numbers of workers are unemployed, the opportunity costs associated with displacing jobs in other sectors are likely to be smaller. And, in general, if a regulation imposes high costs and does not increase the demand for labor, it may lead to a decrease in employment. The responsiveness of industry labor demand depends on how these forces all interact. Economic theory indicates that the responsiveness of industry labor demand depends on a number of factors: price elasticity of demand for the product, substitutability of other factors of production, elasticity of supply of other factors of production, and labor's share of total production costs. Berman and Bui (2001) put this theory in the context of environmental regulation, and suggest that, for example, if all firms in the industry are faced with the same compliance costs of regulation and product demand is inelastic, then industry output may not change much at all.

Regulations set in motion new orders for pollution control equipment and services. New categories of employment have been created in the process of implementing environmental regulations. When a regulation is promulgated, one typical response of industry is to order pollution control equipment and services in order to comply with the regulation when it becomes effective. On the other hand, the closure of plants that choose not to comply – and any changes in production levels at plants choosing to comply and remain in operation - occur after the compliance date, or earlier in anticipation of the compliance obligation. Environmental regulation may increase revenue and employment in the environmental technology industry. While these increases represent gains for that industry, they translate into costs to the regulated industries required to install the equipment.

Environmental regulations support employment in many basic industries. Regulated firms either hire workers to design and build pollution controls directly or purchase pollution control devices from a third party for installation. Once the equipment is installed, regulated firms hire workers to operate and maintain the pollution control equipment—much like they hire workers to produce more output. In addition to the increase in employment in the environmental protection industry (via increased orders for pollution control equipment), environmental regulations also support employment in industries that provide intermediate goods to the environmental protection industry. The equipment manufacturers, in turn, order steel, tanks, vessels, blowers, pumps, and chemicals to manufacture and install the equipment. Currently in most cases there is no scientifically defensible way to generate sufficiently reliable estimates of the employment impacts in these intermediate goods sectors.

It is sometimes claimed that new or more stringent environmental regulations raise production costs thereby reducing production which in turn must lead to lower employment. However, the peer-reviewed literature indicates that determining the direction of net employment effects in a regulated industry is challenging due to competing effects. Environmental regulations are assumed to raise production costs and thereby the cost of output, so we expect the "output" effect of environmental regulation to be negative (higher prices lead to lower sales). On the other hand, complying with the new or more stringent regulation requires additional inputs, including labor, and may alter the relative proportions of labor and capital used by regulated firms in their production processes. Two sets of researchers discussed here, Berman and Bui (2001) and Morgenstern, Pizer, and Shih (2002),[89] demonstrate using standard neoclassical microeconomics that environmental regulations have an ambiguous effect on employment in the regulated sector. These theoretical results imply that the effect of environmental regulation on employment in the regulated sector is an empirical question and both sets of authors tested their models empirically using different methodologies. Both Berman and Bui and Morgenstern et al. examine the effect of environmental regulations on employment and both find that overall they had no significant net impact on employment in the sectors they examined.

Berman and Bui (2001) developed an innovative approach to examine how an increase in local air quality regulation that reduces nitrogen oxides (NO_X) emissions affects manufacturing employment in the South Coast Air Quality Management District (SCAQMD), which incorporates Los Angeles and its suburbs. During the time frame of their study, 1979 to 1992, the SCAQMD enacted some of the country's most stringent air quality regulations. Using

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[89] Berman, E. and L. T. M. Bui (2001). "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." *Journal of Public Economics* 79(2): 265-295. Morgenstern, R. D., W. A. Pizer, and J. S. Shih. 2002. Jobs versus the Environment: An Industry-Level Perspective. *Journal of Environmental Economics and Management* 43(3):412-436.

SCAQMD's local air quality regulations, Berman and Bui identify the effect of environmental regulations on net employment in the regulated industries.[90,91] The authors find that "while regulations do impose large costs, they have a limited effect on employment" (Berman and Bui, 2001, p. 269). Their conclusion is that local air quality regulation "probably increased labor demand slightly" but that "the employment effects of both compliance and increased stringency are fairly precisely estimated zeros, even when exit and dissuaded entry effects are included" (Berman and Bui, 2001, p. 269).[92]

Morgenstern et al. (2002) estimated the effects of pollution abatement expenditures from 1979 to 1991 at the plant level on net employment in four highly regulated sectors (pulp and paper, plastics, steel, and petroleum refining). Thus, in contrast to Berman and Bui (2001), this study identifies employment effects by examining differences in abatement expenditures rather than geographical differences in stringency. They conclude that increased abatement expenditures generally have not caused a significant change in net employment in those sectors. While the specific sectors Morgenstern et al. examined are different than the sectors considered here, the methodology that Morgenstern et al. developed is still an informative way to qualitatively, if not quantitatively, assess the effects of this rulemaking on employment at MSW landfills. For example, as firms add new technologies to capture landfill gases for flaring or for conversion to energy, there will be a demand for labor to install, monitor, and operate these new approaches to waste management and energy production.

While there is an extensive empirical, peer-reviewed literature analyzing the effect of environmental regulations on various economic outcomes including productivity, investment, competitiveness as well as environmental performance, there are only a few papers that examine the impact of environmental regulation on employment, but this area of the literature has been growing. As stated previously in this RIA section, empirical results from Berman and Bui (2001) and Morgenstern et al (2002) suggest that new or more stringent environmental regulations do

[90] Note, like Morgenstern, Pizer, and Shih (2002), this study does not estimate the number of jobs created in the environmental protection sector.
[91] Berman and Bui include over 40 4-digit SIC industries in their sample.
[92] Including the employment effect of exiting plants and plants dissuaded from opening will increase the estimated impact of regulation on employment.

not have a substantial impact on net employment (either negative or positive) in the regulated sector. Similarly, Ferris, Shadbegian, and Wolverton (2014) also find that regulation-induced net employment impacts are close to zero in the regulated sector. Furthermore, Gray et al. (2014) find that pulp mills that had to comply with both the air and water regulations in EPA's 1998 "Cluster Rule" experienced relatively small and not always statistically significant, decreases in employment. Nevertheless, other empirical research suggests that more highly regulated counties may generate fewer jobs than less regulated ones (Greenstone 2002, Walker 2011). However, the methodology used in these two studies cannot estimate whether aggregate employment is lower or higher due to more stringent environmental regulation, it can only imply that relative employment growth in some sectors differs between more and less regulated areas. List et al. (2003) find some evidence that this type of geographic relocation, from more regulated areas to less regulated areas may be occurring. Overall, the peer-reviewed literature does not contain evidence that environmental regulation has a large impact on net employment (either negative or positive) in the long run across the whole economy.

While the theoretical framework laid out by Berman and Bui (2001) and Morgenstern et al. (2002) still holds for the industries affected under these emission guidelines, important differences in the markets and regulatory settings analyzed in their study and the setting presented here lead us to conclude that it is inappropriate to utilize their quantitative estimates to estimate the employment impacts from this regulation. In particular, the industries used in these two studies as well as the timeframe (late 1970's to early 1990's) are quite different than those in the final EG. Furthermore, the control strategies analyzed for this RIA include gas collection systems, destruction, and utilization, which are very different than the control strategies examined by Berman and Bui and Morgenstern et al.[93] For these reasons we conclude there are too many uncertainties as to the transferability of the quantitative estimates in these two studies to apply their estimates to quantify the employment impacts within the regulated sectors for this regulation, though these studies have usefulness for qualitative assessment of employment impacts.

[93] More detail on how emission reductions expected from compliance with this rule can be obtained can be found in Chapter 3 of this RIA.

The preceding sections have outlined the challenges associated with estimating net employment effects in the regulated sector and in the environmental protection sector. These challenges make it very difficult to accurately produce net employment estimates for the whole economy that would appropriately capture the way in which costs, compliance spending, and environmental benefits propagate through the macro-economy. Quantitative estimates are further complicated by the fact that macroeconomic models often have very little sectoral detail and usually assume that the economy is at full employment. EPA’s Science Advisory Board (SAB) is currently in the process of seeking input from an independent expert panel on modeling economy-wide impacts, including employment effects.

5.3.3 Conclusion

Economic theory predicts that the total effect of an environmental regulation on labor demand in regulated sectors is not necessarily positive or negative. Peer-reviewed econometric studies that use a structural approach, applicable to in the regulated sectors, converge on the finding that such effects, whether positive or negative, have been small.

Because of the lack of appropriate economic parameters or model, the EPA is unable to estimate the impacts of the regulatory options on the supply and demand for MSW landfill services. However, because of the relatively low incremental costs of the final guideline option, the EPA does not believe the guidelines would lead to changes in supply and demand for landfill services or waste disposal costs, tipping fees, or the amount of waste disposed in landfills. Hence, the overall economic impact of the final guidelines should be minimal on the affected industries and their consumers.

MSW landfill activities encompasses a wide range of job types, including garbage collectors, truck drivers, heavy equipment operators, engineers of various disciplines, specialized technicians, executives, MSW department directors, administrative staff, weigh scale operators, salespersons, and landfill operations managers. As the population continues to grow in the United States the amount of waste generated will continue to increase, but the amount of waste landfilled may remain the same or decrease due to recycling or other waste diversion (EPA, 2012c). Employment within the waste management industry overall will likely remain strong, perhaps with an increased shift of employees from the public sector to the private sector.

Employment to design, construct and operate new technologies for managing landfill gases either through flaring or conversion to energy may also increase.

5.4 Small Business Impacts Analysis

The Regulatory Flexibility Act as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute, unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small governmental jurisdictions, and small not-for-profit enterprises.

For the purposes of assessing the impact of the Emission Guidelines on small entities, a small entity is defined as: (1) A small business that is primarily engaged in the collections and disposal of refuse in a landfill operation as defined by NAICS code 562212 with annual receipts less than $38.5 million; (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or school district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise that is independently owned and operated and is not dominant in its field.

After considering the economic impact of the Emission Guidelines on small entities, the EPA certifies that the regulation will not have a Significant Impact on a Substantial Number of Small Entities (SISNOSE).

The final rule will not impose any requirements on small entities. Specifically, Emission Guidelines established under CAA section 111(d) do not impose any requirements on regulated entities and, thus, will not have a significant economic impact upon a substantial number of small entities. After Emission Guidelines are promulgated, states establish standards on existing sources and it is those state requirements that could potentially impact small entities. Our analysis here is consistent with the analysis of the analogous situation arising when the EPA establishes NAAQS, which do not impose any requirements on regulated entities. As here, any impact of a NAAQS on small entities would only arise when states take subsequent action to maintain and/or achieve the NAAQS through their state implementation plans. See American

Trucking Associations v. EPA, 175 F.3d 1029, 1043-45 (D.C. Cir. 1999) (NAAQS do not have significant impacts upon small entities because NAAQS themselves impose no regulations upon small entities).

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6 COMPARISON OF BENEFITS AND COST FOR THE EMISSION GUIDELINES

6.1 Introduction

The EPA compared the monetized methane-related climate benefits and secondary CO_2 benefits of the final Emission Guidelines for existing landfills against the estimated annualized compliance costs and found that the benefits of the rule outweigh the costs. The net benefits are likely larger since the EPA was not able to monetize the benefits from reducing exposure to 1,810 Mg/yr of NMOC. The NMOC portion of LFG can contain a variety of air pollutants, including VOC and various organic HAP, and these pollutants are associated with health and welfare effects described in Chapter 4.

6.2 Net Benefits of the Final Standards

For the final 2.5/34 option, the monetized methane-related climate benefits are estimated to range from $200 million to $1.1 billion (2012$)[94] in 2025; these benefits are estimated to be $430 million (2012$) in 2025 using a 3% discount rate. The secondary CO_2 benefits are estimated to range from $4.2 million to $41 million (2012$)[95] in 2025; estimated CO_2 benefits are $14 million (2012$) in 2025 using a 3% discount rate. Under the final option 2.5/34, when using a 7% discount rate the additional cost in 2025 would be $54 million. Using a 3% discount rate, the additional cost over the baseline in 2025 would be $43 million. Thus, the net benefits, using a 7% discount rate, are expected to be $150 million to $1.1 billion, with a central estimate of $390 million. These results are summarized in Table 6-1.

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[94] The range of estimates reflects four SC-CH_4 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

[95] The range of estimates reflects four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

Table 6-1 Summary of the Monetized Benefits, Costs, and Net Benefits for the Final Emission Guidelines Option 2.5/34 in 2025 (millions of 2012$)[1]

	3% Discount Rate	7% Discount Rate
Monetized Methane-related Benefits[2]	**$200 - $1,100**	
Monetized Secondary CO_2 Benefits[2]	**$4.2 - $41**	
Total Costs[3]	**$43**	**$54**
Compliance expenditures	*$84*	*$93*
Revenues from electricity sales produced with captured LFG	*$42*	*$39*
Net Benefits	**$160 - $1,100**	**$150 - $1,100**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient PM2.5, ozone, and HAP concentrations resulting from reduction of 1,810 Mg of NMOC/yr	

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of 0.29 million Mg methane in 2025, valued using the social cost of methane, and the net reduction of 277,000 Mg of CO_2 in 2025, and valued using the social cost of carbon. The range of estimates reflects four SC-CH_4 and four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.
[3] The engineering compliance cost estimates are annualized capital costs plus annual operation and maintenance expenses and are offset by the estimated revenue from electricity sales generated using captured landfill gas. Compliance expenditures also include testing and monitoring costs. Engineering costs are considered a proxy for the social costs of the regulation.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

6.3 Net Benefits of the Alternate Standards

For the less stringent 2.5/40 option, the monetized methane-related climate benefits are estimated to range from $130 million to $740 million (2012$)[96] in 2025; these benefits are

[96] The range of estimates reflects four SC-CH_4 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

estimated to be $280 million (2012$) in 2025 using a 3% discount rate. The secondary CO_2 benefits are estimated to range from $3.4 million to $33 million (2012$)[97] in 2025; estimated CO_2 benefits are $11 million (2012$) in 2025 using a 3% discount rate. Under this option, when using a 7% discount rate the additional cost in 2025 would be $32 million. Using a 3% discount rate, the additional cost over the baseline in 2025 would be $24 million. Thus, the net benefits, when using a 7% discount rate, would be expected to be $100 million to $740 million, with a central estimate of $260 million. These results are summarized in Table 6-2.

[97] The range of estimates reflects four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

Table 6-2 Summary of the Monetized Benefits, Costs, and Net Benefits for the Alternative Emission Guidelines Option 2.5/40 in 2025 (millions of 2012$)[1]

	3% Discount Rate	7% Discount Rate
Monetized Methane-related Benefits[2]	**$130 - $740**	
Monetized Secondary CO_2 Benefits[2]	**$3.4 - $33**	
Total Compliance Costs[3]	**$24**	**$32**
Compliance expenditures	*$56*	$63
Revenues from electricity sales produced with captured LFG	*$33*	$32
Net Benefits	**$110 - $750**	**$100 - $740**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient PM2.5, ozone, and HAP concentrations resulting from reduction of 1,810 Mg of NMOC/yr	

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of 190,000 Mg methane in 2025, valued using the social cost of methane, and the net reduction of 220,000 Mg of CO_2 in 2025, and valued using the social cost of carbon. The range of estimates reflects four SC-CH_4 and four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.
[3] The engineering compliance costs are annualized and include estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. Costs shown include testing and monitoring.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

For the more stringent 2.0/34 option, the monetized methane-related climate benefits are estimated to range from $240 million to $1.4 billion (2012$)[98] in 2025; these benefits are estimated to be $520 million (2012$) in 2025 using a 3% discount rate. The secondary CO_2 benefits are estimated to range from $5.1 million to $50 million (2012$)[99] in 2025; estimated

[98] The range of estimates reflects four SC-CH_4 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.
[99] The range of estimates reflects four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

CO_2 benefits are $17 million (2012$) in 2025 using a 3% discount rate. Under this option, when using a 7% discount rate the additional cost in 2025 would be $62 million. Using a 3% discount rate, the additional cost over the baseline in 2025 would be $48 million. Thus, the net benefits, when using a 7% discount rate, would be expected to be $190 million to $1.4 billion, with a central estimate of $480 million. These results are summarized in Table 6-3.

Table 6-3 Summary of the Monetized Benefits, Costs, and Net Benefits for the Alternative Emission Guidelines Option 2.0/34 in 2025 (millions of 2012$)[1]

	3% Discount Rate	**7% Discount Rate**
Monetized Methane-related Benefits[2]	**$240 - $1,400**	
Monetized Secondary CO_2 Benefits[2]	**$5.1 - $50**	
Total Costs[3]	**$48**	**$62**
Compliance expenditures	*$100*	*$110*
Revenues from electricity sales produced with captured LFG	*$53*	*$50*
Net Benefits	**$190 - $1,400**	**$190 - $1,400**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient PM2.5, ozone, and HAP concentrations resulting from reduction of 2,188 Mg of NMOC/yr	

[1] Totals may not sum due to rounding**.**
[2] Monetized benefits include the climate-related benefits associated with the reduction of 340,000 Mg methane in 2025, valued using the social cost of methane, and the net reduction of 330,000 Mg of CO_2 in 2025, and valued using the social cost of carbon. The range of estimates reflects four SC-CH_4 and four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.
[3] The engineering compliance costs are annualized costs reduced by the estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. Costs shown include testing and monitoring.

[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

6.4 Net Benefits of Alternative Years of Analysis

Estimates of the net benefits of alternative years of analysis are presented below for 2020, 2030 and 2040, as well as the years 2025 are presented below. Table 6-4 shows the monetized benefits and costs for the final Emission Guideline 2.5/34. Tables 6-5 and 6-6 reflect the less stringent option of 2.5/40 and more stringent option of 2.0/34 for the alternative years, respectively. The estimates shown assume costs are estimates assuming a 7% discount rate.[100]

Table 6-4 Summary of the Monetized CH_4–Related Benefits, Costs, and Net Benefits for the Final Emission Guidelines Option 2.5/34 in 2020, 2025, 2030 and 2040 (7% Discount Rate, millions of 2012$)[1]

	2020	2025	2030	2040
Monetized Methane-related Benefits[2]	**$410**	**$430**	**$520**	**$770**
Total Costs[3]	**$46**	**$53**	**$47**	**$70**
Compliance expenditures	*$110*	*$92*	*$84*	*$120*
Revenues from electricity sales produced with captured LFG	*$64*	*$39*	*$37*	*$53*
Net Benefits	**$360**	**$380**	**$470**	**$700**
Non-Monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient PM2.5, ozone, and HAP concentrations resulting from reduction of NMOC each year[5]			

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of methane in 2020, 2025, 2030 and 2040, valued using the social cost of methane. The social costs of methane estimates are shown at the 3% discount rate. See Chapter 4 for a range of social costs of methane estimates for the four SC-CH_4: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion. Benefits associated with secondary CO_2 emission are not reflected in this table.
[3] The engineering compliance costs are annualized and are reduced by estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. Compliance costs do not include testing and monitoring.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.
[5] Annual NMOC reductions in Mg/yr are estimated to be approximately 1,990, 1,810, 1,900, and 2,250 for 2020, 2025, 2030 and 2040 respectively.

[100] Emission control costs presented in Tables 6-4 through 6-6 are estimates assuming a discount rate of 7%. Cost estimates assuming a 3% discount rate would be lower than the estimates shown, and the resulting net benefits would be greater than the amounts shown.

Table 6-5 Summary of the Monetized CH_4-Related Benefits, Costs, and Net Benefits for Less Stringent Emission Guidelines Option 2.5/40 in 2020, 2025, 2030 and 2040 (7% Discount Rate, millions of 2012$)[1]

	2020	2025	2030	2040
Monetized Methane-related Benefits[2]	**$260**	**$280**	**$360**	**$530**
Total Compliance Costs[3]	**$28**	**$32**	**$31**	**$51**
Compliance expenditures	*$78*	*$57*	*$55*	*$87*
Revenues from electricity sales produced with captured LFG	*$50*	*$33*	*$25*	*$36*
Net Benefits	***$230***	**$350**	**$330**	**$470**
Non-Monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient PM2.5, ozone, and HAP concentrations resulting from reduction of NMOC each year[5]			

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of methane in 2020, 2025, 2030 and 2040, valued using the social cost of methane. The social costs of methane estimates are shown at the 3% discount rate. See Chapter 4 for a range of social costs of methane estimates for the four SC-CH_4: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion. Benefits associated with secondary CO_2 emission are not reflected in this table.
[3] The engineering compliance costs are annualized costs and are reduced by the estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. Compliance costs shown do not include testing and monitoring.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.
[5] Annual NMOC reductions in Mg/yr are estimated to be 1,285, 1,179, 1,330, and 1,543 for 2020, 2025, 2030 and 2040 respectively.

Table 6-6 Summary of the Monetized CH_4-Related Benefits, Costs, and Net Benefits for More Stringent Emission Guidelines Option 2.0/34 in 2020, 2025, 2030 and 2040 (7% Discount Rate, millions of 2012$)[1]

	2020	2025	2030	2040
Monetized Methane-related Benefits[2]	**$450**	**$520**	**$620**	**$800**
Total Compliance Cost[3]	**$52**	**$62**	**$56**	**$73**
Compliance expenditures	*$130*	*$110*	*$100*	*$130*
Revenues from electricity sales produced with captured LFG	*$74*	*$50*	*$47*	*$54*
Net Benefits	**$400**	**$460**	**$570**	**$720**
Non-Monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient PM2.5, ozone, and HAP concentrations resulting from reduction of NMOC each year[5]			

[1] Totals may not sum due to rounding
[2] Monetized benefits include the climate-related benefits associated with the reduction of methane in 2020, 2025, 2030 and 2040, valued using the social cost of methane. The social costs of methane estimates are shown at the 3% discount rate. See Chapter 4 for a range of social costs of methane estimates for the four SC-CH_4: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion. Benefits associated with secondary CO_2 emission are not reflected in this table.
[3] The engineering compliance costs are annualized costs reduced by the estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. Costs shown do not include testing and monitoring.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.
[5] Annual NMOC reductions in Mg/yr are estimated to be 2,270, 2,188, 2,266, and 2,340 for 2020, 2025, 2030 and 2040 respectively.

A review of the benefits and costs of the alternative standards for 2020, 2025, 2030 and 2040 shows that the net benefits for the final standard of 2.5/34 exceed the net benefits for the less stringent standard of 2.5/40. In comparison, the net benefits of the most stringent alternative 2.0/34 exceeds those of the final standard in each of the years evaluated. EPA considered multiple factors in its determination of the final EG in addition to economic efficiency. While the most stringent standard achieves greater net benefits than the final standard, this standard would result in a larger number of existing landfills of a smaller size being potentially affected by the regulation. In moving from design capacity threshold of 2.5 million Mg to 2.0 million Mg, 103 additional existing landfills are potentially affected by this rule. Some of these landfills are small entities. During outreach meetings at proposal with small landfills and the Small Business Administration (discussed below in section 8.3), participants voiced concerns that lowering the design threshold would negatively impact small landfills. For example, landfills that are between 2.0 and 2.5 million Mg historically have not been subject to calculating and reporting their NMOC emissions. Additionally, these landfills have not been required to obtain a Title V permit. The additional burden for calculating and reporting NMOC emissions and obtaining a Title V permit was significant on these landfills and the delegated permitting authorities. Further a large number of landfills that would exceed the 2.0 million Mg design threshold are closed and would likely exceed the 34 Mg/yr NMOC emission rate, thus requiring the installation of GCCS despite the fact that these landfills have been closed for many years and are on the downside of their gas production curve. Based upon these factors, the EPA determined that retaining the current design capacity of 2.5 million Mg and lowering the NMOC emission threshold to 34 Mg/yr provided the most emission reductions when weighed against the additional burden to small and closed landfills.

6.5 Net Present Value of Net Benefits of the Final Guidelines

The EPA also presents a net present value analysis of the benefits and costs for the final EG for the period 2019 through 2040 on Table 6-7. As discussed in chapter 4, the net present value (NPV) of SC-CH_4 benefits central estimate assuming a 3% discount rate is $8.4 billion. Additional methane benefit estimates based upon alternative discount rates are discussed in chapter 4. This benefit estimate relates to monetized climate benefits associated with methane reductions and does not include secondary CO_2 emission reductions nor benefits associated with air quality improvements discussed in chapter 4.

As presented in chapter 3, the NPV of the net control costs for the final EG amount to approximately $680 million to $620 million (3% and 7% discount rates, respectively) for 2019 to 2040. These costs represent the NPV of annual operation and maintenance expenses plus the annualized portion of capital costs associated with installing and operating GCCS. These costs are offset by the estimated annual revenues associated with energy produced from captured landfill gas to derive the net emission control costs.

The NPV of net benefits is derived by comparing the NPV of benefits to the NPV of costs. The NPV of net benefits for the final EG is approximately $7.8 billion for both the 3% and 7% discount rate estimates. These estimates compare the discount values of benefits assessed using a 3% discount rate to net costs derived using 3% and 7% discount rates.

We also estimate the equivalent annualized portion of the NPV values. The equivalent annualized value represents a constant level of benefits and costs respectively that would generate the NPV values. For benefits the equivalent annualized value is approximately $510 million assuming the central 3% discount rate for the SC-CH_4. Equivalent annualized costs are approximately $41 million and $52 million assuming 3% and 7% discount rates, respectively. This results in equivalent annualized net benefits of $470 million assuming a 3% discount rate for costs and $460 million assuming a 7% discount rate for costs. All estimates are shown in 2012$.

Table 6-7 Summary of the NPV of Monetized CH_4-Related Benefits, Costs, and Net Benefits for the Final Guidelines

Year	Monetized Methane-Related Benefits 3% Discount Rate	Total Costs 3% Discount Rate	Total Costs 7% Discount Rate	Net Benefits 3% Discount Rate	Net Benefits 7% Discount Rate
2019	$410	$34	$49	$380	$360
2020	$410	$32	$46	$370	$360
2021	$410	$31	$45	$380	$370
2022	$420	$35	$48	$390	$370
2023	$470	$41	$53	$420	$410
2024	$450	$39	$50	$410	$400
2025	$430	$42	$53	$390	$380
2026	$410	$39	$49	$370	$360
2027	$480	$44	$55	$440	$430
2028	$480	$44	$54	$430	$420
2029	$480	$44	$54	$440	$430
2030	$520	$37	$47	$480	$470
2031	$560	$45	$56	$520	$510
2032	$600	$46	$57	$550	$540
2033	$630	$45	$57	$580	$570
2034	$550	$48	$60	$500	$490
2035	$630	$44	$56	$590	$580
2036	$600	$45	$57	$550	$540
2037	$590	$44	$56	$540	$530
2038	$660	$40	$52	$620	$610
2039	$750	$49	$63	$700	$690
2040	$770	$55	$70	$710	$700
Net Present Value	$8,400	$680	$620	$7,800	$7,800
Equivalent Annualized Value	$510	$41	$52	$470	$460

Notes: Monetized methane-related benefits refer to climate-related benefits from methane emission reductions, which are valued using the central SC-CH_4 estimate (average SC-CH_4 at 3 percent). SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years. These tables do also not reflect non-monetized air quality benefits associated with reductions in NMOC from the final EG.
Costs represent estimates of the annual operation and maintenance expenses plus the annualized portion of capital costs associated with installation and operation of GCCS to meet the NSPS for 2019 through 2040. They include revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. See Section 3.7 for more cost details. Costs do not include testing and monitoring.
Totals may not sum due to rounding.

7 FINAL NEW SOURCE PERFORMANCE STANDARDS

7.1 Introduction

On July 17, 2014, the EPA proposed a new NSPS subpart resulting from its ongoing review of the landfills NSPS (79 FR 41796). The proposed new subpart retained the same design capacity size threshold of 2.5 million m^3 or 2.5 million Mg, but presented several options for revising the NMOC emission rate at which a MSW landfill must install controls. Since presenting these options, the EPA has updated its model that estimates the emission reduction and cost impacts based on public comments and new data.

At the July 17, 2014 proposal, the EPA estimated the emission reductions and costs associated with 17 new “greenfield” landfills that the EPA projected to commence construction, reconstruction, or modification between 2014 and 2018 and have a design capacity of 2.5 million m3 and 2.5 million Mg. The basis of the projected number of new landfills and associated emission reductions is presented in the landfills NSPS docket EPA-HQ-OAR-2003-0215. Multiple commenters on the July 2014 landfills NSPS proposal stated that the EPA underestimated the cost impacts of the landfills NSPS because the EPA failed to consider the number of landfills that are expected to undergo a modification, and thus become subject to the proposed NSPS. In response to these comments, the EPA consulted with its Regional Offices, as well as state and local authorities, to identify landfills expected to undergo a modification within the next 5 years. Based on this information, the EPA estimated the number of existing landfills likely to modify after July 17, 2014 and become subject to subpart XXX. In addition, the EPA made several changes to its underlying dataset and methodology used to analyze the impacts of potential control options, as discussed in Chapter 3 of this RIA. Using the revised dataset, the EPA re-ran the model and control options similar to the options presented in the July 2014 proposed NSPS. As a result of these changes, the number and characteristics of the model new landfills and modified landfills that are expected to become subject to proposed subpart XXX have changed. On August 27, 2015, the EPA issued a supplemental proposal for the NSPS. Based upon the comments received in the supplemental proposal, the EPA revised the number of affected landfills, as well as revised estimates of the costs and benefits of the previously proposed and newly proposed option. Consistent with the Methane Strategy that was developed as part of the President's Climate Action Plan, when preparing the supplemental NSPS proposal and the final standards, the EPA considered more stringent control options that may achieve additional reductions of methane and NMOC for new landfills. As a result of the revised analysis, the EPA is finalizing no changes to the design capacity threshold for new sources, but is lowering the NMOC emission rate threshold to 34 Mg/yr for new and modified sources subject to subpart XXX. In addition to responding to feedback received during the NSPS proposal and supplemental proposal comment period, the EPA believes consistency between the thresholds in the emission guidelines and the NSPS is important, given that an existing landfill can modify and become subject to the proposed subpart XXX by commencing construction on an increase in design capacity. Commenters on the notices weighed in on consistency between the NSPS and emission guidelines. An environmental organization recommended adopting consistent applicability standards, such as design capacity and NMOC emission thresholds, between subpart XXX for new landfills and subpart Cf for existing landfills to maximize beneficial environmental impacts for existing landfills, which are more numerous than anticipated new landfills, and to prevent creating incentives for existing landfills subject to modification by allowing them to comply with less rigorous requirements. In addition, two regulatory agencies requested harmonizing requirements for existing and new landfills between the current regulations in subpart WWW and subpart XXX. The benefits and costs of the final standards and regulatory alternatives are discussed below. The methodologies used to estimate the emission reductions, costs and benefits for the NSPS are discussed in Chapters 3 and 4 of this document.

The EPA typically analyzes NSPS at a date in the future when the standards are expected to be fully implemented and often uses a 5 year period in the future to estimate impacts of these standards. The primary economic analysis for the NSPS is based upon impacts occurring in 2025. The year 2025 is representative, because the landfills regulations require controls at a given landfill only after the NMOC emission rate reaches the level of the regulatory threshold, and a new landfill may take a number of years to trigger the threshold. Further, once the NMOC emission rate is exceeded, the reporting and control timeframe allows 3 months to submit the first NMOC emission report and then 30 months after exceeding the NMOC emission threshold before the GCCS is required to be installed. Emission controls would not be required over the same time period for all landfills. By 2025, over 80 percent of the estimated new greenfield landfills and modified landfills affected by the NSPS are expected to have installed controls, and the EPA considered the impacts of the final rule relative to the baseline in 2025.

7.2 Regulatory Baseline and Options

The final New Source Performance Standards and regulatory options analyzed for this NSPS for new or modified MSW landfills match the options analyzed for the final revisions to the emissions guidelines for existing MSW landfills, and are:

- **Baseline:** design capacity retained at 2.5 Mg, emission threshold retained at 50 Mg NMOC/year
- **Alternative Option 2.5/40:** design capacity retained at 2.5 Mg, emission threshold reduced to 40 NMOC Mg/yr
- **Final Option 2.5/34:** design capacity retained at 2.5 Mg, emission threshold reduced to 34 NMOC Mg/yr
- **Alternative Option 2.0/34:** design capacity reduced to 2.0 Mg, emission threshold reduced to 34 Mg NMOC/year

The baseline and alternative option 2.5/40 correspond to options analyzed in the original NSPS proposal, and can be compared to the results in that economic impact analysis to better understand the effects of the change in the number of landfills predicted to be affected by the NSPS.[101] However, the 2014 proposal did not incorporate impacts on modified landfills as the 2015 supplemental and this 2016 final rule, so it is not directly comparable. The baseline reflects the parameters of the current NSPS. Specifically, all reported results are incremental to the current NSPS (2.5/50). In the baseline, the NSPS affects 128 landfills, with 25 landfills reporting but not controlling emissions and 103 landfills are controlling emissions in 2025. The EPA is assessing impacts in year 2025 as a representative year for the both the landfills Emission

[101] U.S. Environmental Protection Agency (EPA). 2014. “Economic Impact Analysis for the Proposed New Subpart to the New Source Performance Standards.” June 2014. Available at < http://www.epa.gov/ttn/ecas/regdata/EIAs/LandfillsNSPSProposalEIA.pdf>.

Guidelines and NSPS. While the analysis focuses on impacts in 2025, results for alternative years are also presented in Section 7.8.

Based on the characteristics of the projected landfills, the final option presented in Table 7-1 would require 12 additional landfills to install controls by 2025. The less stringent alternative option 2.5/40 (which corresponds to the proposed option in the July 2014 NSPS proposal) would require 9 additional landfills to install controls by 2025, while the more stringent alternative option 2.0/34 would result in 17 additional landfills controlling emissions. In that most stringent option, 9 fewer landfills than the baseline would be reporting and not controlling in 2025.

Table 7-1 Number of Affected Landfills in 2025 under the Baseline, Final NSPS and Alternative Options

	Affected Landfills*		
	Landfills Affected	Landfills Controlling Emissions	Landfills Reporting, but Not Controlling Emissions
Current NSPS = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC			
Baseline	128	103	25
Incremental values versus the current NSPS			
Alternative option 2.5/40	0	9	-16
Final option 2.5/34	0	12	-13
Alternative option 2.0/34	8	17	-9

*Of the 128 landfills potentially affected by the NSPS in 2025, 113 landfills currently report to the GHGRP.

Under the final option 2.5/34, the emission reductions would be an additional 280 Mg NMOC and 44,000 Mg methane (1.1 million Mg CO_2-Equivalents) compared to the baseline in 2025. The less stringent alternative option 2.5/40 would yield emissions reductions of 240 Mg NMOC and 38,000 Mg methane (950,000 Mg CO_2-Equivalents) compared to the baseline, while the more stringent alternative option 2.0/34 would result in emissions reductions of 360 Mg NMOC and 57,000 Mg methane (1.4 million Mg CO_2-Equivalents) compared to the baseline. The emission reductions are summarized in Table 7-2.

Table 7-2 Estimated Annual Average Emissions Reductions in 2025 for the Baseline, Final NSPS and Alternative Options

	Annual Average Reduction (Mg)		
	NMOC	Methane	Methane (in CO_2-equivalents) million Mg*
Current NSPS = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC			
Baseline	10,500	1,700,000	41
Incremental values versus the current NSPS			
Alternative option 2.5/40	240	38,000	0.95
Final option 2.5/34	280	44,000	1.1
Alternative option 2.0/34	360	57,000	1.4

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Minor secondary air impacts are not included in this table. See Section 7.3 for details. One megagram is equivalent to one metric ton and these terms may be used interchangeably.

Costs for the NSPS were estimated in the same manner as the costs for the emissions guidelines. This methodology is discussed in Chapter 3. Under the final option 2.5/34, when using a 7% discount rate the additional cost of control in 2025 is estimated to be $11 million, of which approximately $5.1 million is estimated to be offset by increased revenue from beneficial-use projects, so the net cost is estimated to be approximately $6.0 million (includes monitoring and testing costs of $0.08 million). See Table 7-3 below. The cost of control for the less stringent alternative option 2.5/40 is estimated to be $6.5 million, which is estimated to be supplemented by approximately $1.0 million in revenue from beneficial-use projects, so the net cost is estimated to be approximately $5.5 million (2012$). This estimate includes the annual cost of monitoring and testing of approximately $0.07 million. The cost of control for the more stringent alternative option 2.0/34 is estimated to be $15 million, of which approximately $6.7 million is estimated to be offset by increased revenue from beneficial-use projects, so the net cost is estimated to be approximately $8.5 million (includes monitoring and testing costs of $0.13 million annually). These options represent approximately between 6 to 9 percent in additional net emission control costs beyond the baseline, with the proposed option 2.5/34 resulting in a 7 percent increase in net costs beyond the baseline emission control costs for the industry as a whole.

Table 7-3 Estimated Engineering Compliance Costs in 2025 for Baseline, Final Guidelines and Alternative Options (7% Discount Rate)

	Estimated Annualized Net Cost (Millions $2012)			
	Testing and Monitoring Costs	Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current NSPS = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	1.5	383	294	90
Incremental values versus the current NSPS				
Alternative option 2.5/40	0.07	6.5	1.0	5.5
Final option 2.5/34	0.08	11	5.1	6.0
Alternative option 2.0/34	0.13	15	6.7	8.5

Note: All totals are independently rounded and may not sum.

When using a 3% discount rate, the model predicts a different timing in the investment behavior by the landfills, which affects both the costs and revenue that are predicted in 2025. Under the proposed option 2.5/34, the additional cost of control over the baseline in 2025 is estimated to be $9.3 million, of which $4.6 is estimated to be offset by increased revenue from beneficial-use projects, so the net cost is estimated to be $4.8 million 2012$ (includes testing and monitoring costs of $0.08 million). See Table 7-4 below. The cost of control for the less stringent alternative option 2.5/40 is estimated to be $5.4 million, of which $0.6 million is estimated to be offset by increased revenue from beneficial-use projects, so the net cost is estimated to be $4.9 million (includes testing and monitoring of $0.07 million per year). The cost of control for the more stringent alternative option 2.0/34 is estimated to be $13 million, of which $6.2 million is estimated to be offset by increased revenue from beneficial-use projects, so the net cost is estimated to be $6.8 million (includes testing and monitoring annual costs of $0.13 million). These options represent approximately between 12 to 17 percent in additional emission control net costs beyond the baseline, with the proposed option 2.5/34 resulting in a 12 percent increase in net emission control costs beyond the baseline for the industry as a whole. However, it is important to note that the baseline value when using a 3% discount rate is approximately 45 percent of the cost when using a 7% discount rate, because the increased costs of earlier installation of GCCS and engines are offset by increased revenue from energy generation.

Table 7-4 Estimated Engineering Compliance Costs in 2025 for Baseline and Alternative Options (3% Discount Rate)

	Estimated Annualized Net Cost (Millions $2012)			
	Testing and Monitoring Costs	Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current NSPS = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	1.5	351	312	41
Incremental values versus the current NSPS				
Alternative option 2.5/40	0.07	5.4	0.6	4.9
Final option 2.5/34	0.08	9.3	4.6	4.8
Alternative option 2.0/34	0.13	13	6.2	6.8

Note: All totals are independently rounded and may not sum.

In terms of cost effectiveness at a 7% discount rate, when considering the estimated net cost of the options, the overall average cost effectiveness for NMOC reductions is $8,600 per Mg NMOC under the baseline and roughly $21,500 per Mg NMOC under the final option 2.5/34. As shown in Table 7-5 the cost effectiveness for NMOC for the alternative options 2.5/40 and 2.0/34 is approximately $22,800 and $23,300 per Mg, respectively. The average cost-effectiveness of controlling methane is significantly lower than for NMOC because methane constitutes approximately 50 percent of landfill gas, while NMOC represents less than 1 percent of landfill gas. The overall average cost effectiveness for methane reductions is roughly $55 per Mg methane under the baseline and approximately $140 per Mg methane under the final option 2.5/34.

When estimating cost effectiveness excluding the estimated revenue from beneficial-use projects, the overall average cost effectiveness for NMOC reductions is $36,600 per Mg NMOC under the baseline and roughly $39,500 per Mg NMOC under the final option 2.5/34. As shown in Table 7-5 the cost-effectiveness varies from $27,100 to $41,700 per Mg for the least stringent and more stringent options. The average cost-effectiveness of controlling methane is significantly lower than for NMOC because methane constitutes approximately 50 percent of landfill gas, while NMOC represents less than 1 percent of landfill gas. The overall average cost effectiveness for methane reductions is $230 per Mg methane under the baseline and approximately $250 per Mg methane under the final option 2.5/34 and ranges from about $170 to $260 per Mg for the alternative options 2.5/40 and 2.0/34. Cost effectiveness estimates for the final NSPS assuming a 3% discount rate are shown on Table 7-6.

Table 7-5 Estimated Cost-effectiveness in 2025 for the Baseline, Final NSPS and Alternative Options (7% Discount Rate)

	Cost-effectiveness (2012$ Cost per Mg)					
	NMOC		Methane		Methane (in CO_2-equivalents)*	
	Net Cost[b]	Total Cost	Net Cost[b]	Total Cost	Net Cost[b]	Total Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC						
Baseline	8,600	36,600	55	230	2.2	9.3
Incremental values versus the current EG						
Alternative option 2.5/40	22,800	27,100	140	170	5.8	6.9
Final option 2.5/34	21,500	39,500	140	250	5.5	10
Alternative option 2.0/34	23,300	41,700	150	260	5.9	11

Note: The cost-effectiveness of NMOC and methane are estimated as if all of the control cost were attributed to each pollutant separately. One megagram is equivalent to one metric ton and these terms may be used interchangeably.
[a] A global warming potential of 25 is used to convert methane to CO_2-equivalents. The secondary CO_2 emission reductions are not reflected in these estimates.
[b] Net Cost is the total control and testing and monitoring cost minus any project revenue. The control costs for landfills with energy projects includes costs to install and operate a reciprocating engine (and associated electrical equipment), which is more expensive than a standard flare. Reciprocating engines are not required by the regulation, but are expected to be used as control devices when it is cost-effective to recovery the LFG energy.

Table 7-6 Estimated Cost-effectiveness in 2025 for the Baseline, Final NSPS and Alternative Options (3% Discount Rate)

	Cost-effectiveness (2012$ Cost per Mg)					
	NMOC		Methane		Methane (in CO_2-equivalents)*	
	Net Cost[b]	Total Cost	Net Cost[b]	Total Cost	Net Cost[b]	Total Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC						
Baseline	3,900	33,500	25	210	1.0	8.5
Incremental values versus the current EG						
Alternative option 2.5/40	20,200	22,600	130	140	5.1	5.7
Final option 2.5/34	17,200	33,600	110	210	4.4	8.5
Alternative option 2.0/34	18,700	35,800	120	230	4.8	9.1

Note: The cost-effectiveness of NMOC and methane are estimated as if all of the control cost were attributed to each pollutant separately. One megagram is equivalent to one metric ton and these terms may be used interchangeably.
[a] A global warming potential of 25 is used to convert methane to CO_2-equivalents. The secondary CO_2 emission reductions are not reflected in these estimates.
[b] Net Cost is the total control and testing and monitoring cost minus any project revenue. The control costs for landfills with energy projects includes costs to install and operate a reciprocating engine (and associated electrical equipment), which is more expensive than a standard flare. Reciprocating engines are not required by the regulation, but are expected to be used as control devices when it is cost-effective to recovery the LFG energy.

7.3 Benefits

The final NSPS is expected to result in significant emissions reductions of landfill gas (LFG) from new or modified MSW landfills. By lowering the current NMOC emissions threshold of 50 Mg/yr to 34 Mg/yr, the final NSPS is anticipated to achieve reductions of 280 Mg/yr NMOC and 44,000 Mg/yr methane in 2025. The NMOC portion of LFG can contain a variety of air pollutants, including VOC and various organic HAP. VOC emissions are precursors to both fine particulate matter ($PM_{2.5}$) and ozone formation, while methane is a GHG and a precursor to global ozone formation. As described in detail in Chapter 4, these pollutants are associated with substantial health effects, climate effects, and other welfare effects. As with the emissions guidelines, the only categories of benefits monetized for the final NSPS are methane-related and CO_2-related climate effects. The methane-related climate effects are positive as with the emissions guidelines, and there are small CO_2 benefits associated with increased generation of electricity by landfills through the capturing of landfill gas exceeding the landfill electricity demand due to the energy demands of the GCCS for the final NSPS (2.5/34) and the more stringent alternative of 2.0/34. For the least stringent regulatory alternative of 2.5/40, it is expected that the electricity demands due to energy demands of the GCCS will slightly exceed the generation of electricity by the landfills leading to minimal disbenefits.

While we expect that these avoided emissions will also result in improvements in air quality and reduce health and welfare effects associated with exposure to HAP, ozone, and fine particulate matter ($PM_{2.5}$), we have determined that quantification of those health benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

The methodology used to calculate methane climate benefits is discussed in detail in Section 4.2 of this RIA. Applying the approach discussed in that section to the CH_4 reductions estimated for final NSPS, the 2025 methane benefits vary by discount rate and range from about $31 million to approximately $180 million; for the final NSPS option, the mean SC-CH_4 at the 3% discount rate results in an estimate of about $67 million in 2025 (2012$). These benefits are presented below in Table 7-7 for the final NSPS and across regulatory options. The benefits for alternative years are shown in Section 7.8. In addition, EPA calculated the net present value of the climate-related benefits associated with the methane reductions from the final option in years 2019 through 2040. See Section 7.9 for a discussion of the net present value.

Table 7-7 Estimated Global Benefits of CH_4 Reductions in 2025* (in millions, 2012$)

	Million metric tons of CH_4 reduced**	Million metric tons of CO_2-equivalent reduced	Discount rate and statistic			
			5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	0.038	0.95	$27	$57	$74	$150
Final Option 2.5/34	0.044	1.1	$31	$67	$86	$180
Alternative Option 2.0/34	0.057	1.4	$40	$86	$110	$230

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts.
**One metric ton equals one megagram.

In addition, there are secondary air impacts expected from the final NSPS, similar to the final EG. The sources of these secondary air impacts are discussed in section 3.3 of this RIA. Changes in net secondary NOx, SO_2, and LFG constituent pollutants may occur but were not quantified because they are expected to be minimal. EPA estimated the secondary CO_2 emissions impacts of the final NSPS, specifically, a net decrease in CO_2 emissions under the final option. These benefits arise because more energy is produced by these landfills through the burning of LFG in engines than is required to operate the GCCS at some landfills.[102] These benefits are presented in Table 7-8 below. As previously discussed, there are slight CO_2 emission disbenefits for the least stringent alternative option 2.5/40. Monetizing the net CO_2 increases with the SC-CO_2 estimates also described in Section 4.2 yields benefits that vary by discount rate and range from about $0.39 million to approximately $3.9 million in 2025. For the final option, the mean SC-CO_2 at the 3% discount rate results in an estimate of about $1.3 million in 2025.

[102] As in the case of the Emissions Guidelines, there is an additional CO_2 impact, specifically a small increase in CO_2 emissions resulting from flaring of methane in response to this rule. We are not estimating the monetized disbenefits of these secondary emissions of CO_2 because much of the methane that would have been released in the absence of the flare would have eventually oxidized into CO_2 in the atmosphere. See Section 4.2.1 for more discussion.

Table 7-8 Estimated Global Impacts of Net CO_2 Changes in 2025[a] (in millions, 2012$)

	Metric tons of net CO_2 change[b]	Discount rate and statistic			
		5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	(1,700)	(0.026)	(0.084)	(0.12)	(0.25)
Final Option 2.5/34	26,000	$0.39	$1.3	$1.9	$3.9
Alternative Option 2.0/34	37,000	$0.57	$1.9	$2.7	$5.6

[a] The SC-CO_2 values are dollar-year and emissions-year specific. SC-CO_2 values represent only a partial accounting of climate impacts.
[b] Estimates in parentheses signify increases in emissions, i.e., disbenefits, whereas estimates without parentheses represent reductions in emissions, i.e., benefits. Changes in net secondary NO_x, SO_2 and LFG constituent pollutants may also occur, but are expected to be minimal and are not estimated. One metric ton equals one megagram.

7.4 Economic Impacts

7.4.1 Economic Impact Analysis

As was discussed in Section 5.2, assessing the economic impacts of the costs of the option is difficult due to the nature of the MSW industry. The cost of the final NSPS is estimated to be $6.0 million in 2025. Because of the relatively low net cost of final option 2.5/34 compared to the overall size of the MSW industry as was discussed in Chapter 2 and Section 5.2, as well as the lack of appropriate economic parameters or model, the EPA is unable to estimate the impacts of the options on the supply and demand for MSW landfill services. However, because of the relatively low incremental costs of the proposed option 2.5/34, the EPA does not believe the final NSPS would lead to changes in supply and demand for landfill services or waste disposal costs, tipping fees, or the amount of waste disposed in landfills. Hence, the overall economic impact of the NSPS should be minimal on the affected industries and their consumers.

7.4.2 Employment Impacts

As is the case with the final emissions guidelines, the EPA is unable to quantify the effect of the NSPS on employment. However, a discussion of the potential impacts on employment appears in Section 5.3, and is relevant for the final NSPS as well as the emissions guidelines.

7.4.3 Small Business Impacts Analysis

As discussed in Section 5.4, the Regulatory Flexibility Act as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute, unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small governmental jurisdictions, and small not-for-profit enterprises.

It was determined that the July 2014 proposed NSPS and the August 2015 supplemental proposed NSPS would not have a significant economic impact on a substantial number of small entities. Given the changes in the number of landfills anticipated to become subject to the new final NSPS, the potential impact on small entities has been reanalyzed.

For the purposes of assessing the impact of the final NSPS on small entities, a small entity is defined as: (1) A small business that is primarily engaged in the collections and disposal of refuse in a landfill operation as defined by NAICS code 562212 with annual receipts less than $38.5 million; (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or school district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise that is independently owned and operated and is not dominant in its field.

The EPA typically assessed how the regulatory program may potentially impact owners (ultimate parent companies, governmental jurisdictions, or not-for-profit enterprises) by comparing pollution control costs to total sales or revenue. This is referred to as a “sales” test or cost-to-sales ratio. To perform this test, the total annualized control cost for a small entity (*i*) is divided by its reported revenue:

$$Sales\ Test_i = \frac{Total\ Annualized\ Compliance\ Cost_i}{Total\ Revenue_i}$$

The "sales test" is the impact metric the EPA employs in analyzing small entity impacts as opposed to a "profits test," in which annualized compliance costs are calculated as a share of profits. The use of a "sales test" for estimating small business impacts for a rulemaking such as this one is consistent with guidance offered by the EPA on compliance with SBREFA[103] and is consistent with guidance published by the U.S. SBA's Office of Advocacy that suggests that cost as a percentage of total revenues is a metric for evaluating cost increases on small entities in relation to increases on large entities.[104] The results of the screening analysis appear below in Table 7-9.

Table 7-9 Small Business Impact Screening Assessment Results (Reporters and Controllers)

	2.5 million Mg; Reduce to 40 Mg/yr NMOC		**2.5 million Mg; Reduce to 34 Mg/yr NMOC**		**2.0 million Mg; Reduce to 34 Mg/yr NMOC**	
	Count from Screen Based on Total Cost	Count from Screen Based on Net Cost	Count from Screen Based on Total Cost	Count from Screen Based on Net Cost	Count from Screen Based on Total Cost	Count from Screen Based on Net Cost
No. Affected	7	7	7	7	7	7
No. Affected with Sales Data	6	6	6	6	6	6
No. Affected > 1% (n)	0	0	0	0	0	0
No. Affected > 3% (n)	0	0	0	0	0	0
No. Affected > 1% (%)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
No. Affected > 3% (%)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

After considering the economic impact of the final NSPS on small entities, the analysis indicates that this rule will not have a significant impact on a substantial number of small entities (SISNOSE). First, the final NSPS does not impact a substantial number of small entities, since only seven small entities are projected to be impacted by the final option. Additionally, the

[103] The SBREFA compliance guidance to EPA rule writers regarding the types of small business analysis that should be considered can be found at <http://www.epa.gov/sbrefa/documents/rfaguidance11-00-06.pdf>

[104] U.S. SBA, Office of Advocacy. A Guide for Government Agencies, How to Comply with the Regulatory Flexibility Act, Implementing the President's Small Business Agenda and Executive Order 13272, June 2010.

impact to these entities are not significant, because no entities have impacts greater than 1 percent of sales.

7.5 Comparison of Benefits and Costs

The EPA compared the monetized methane-related climate benefits and secondary CO_2 impacts of the final NSPS for new or modified MSW landfills against the estimated annualized costs and found that the benefits of the rule outweigh the costs. The net benefits are likely larger since the EPA was not able to monetize the benefits associated with reducing exposure to 280 Mg/yr of NMOC. The NMOC portion of LFG can contain a variety of air pollutants, including VOC and various organic HAP, and these pollutants are associated with health and welfare effects described in Chapter 4.

7.6 Net Benefits of the Final Standards

For the final 2.5/34 option, the monetized methane-related climate benefits are estimated to range from $31 million to $180 million (2012$)[105] in 2025; these benefits are estimated to be $67 million (2012$) in 2025 using a 3% discount rate. The secondary CO_2 benefits are estimated to range from $0.39 million to $3.9 million (2012$)[106] in 2025; estimated secondary CO_2 benefits are $1.3 million (2012$) in 2025 using a 3% discount rate. Under the final option 2.5/34, when using a 7% discount rate the additional cost in 2025 would be $6.0 million. Using a 3% discount rate, the additional cost over the baseline in 2025 would be $4.8 million. These cost estimates include monitoring and testing costs and are net of potential revenues associated with the capture of landfill gas. Thus, the net benefits in 2025, when using a 7% discount rate, are expected to be $25 million to $180 million, with a central estimate of $62 million. All estimates are reflected in 2012$. These results are summarized in Table 7-10.

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[105] The range of estimates reflects four SC-CH_4 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

[106] The range of estimates reflects four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

Table 7-10 Summary of the Monetized Benefits, Costs, and Net Benefits for the Final NSPS Option 2.5/34 in 2025 (millions of 2012$)[1]

	3% Discount Rate	7% Discount Rate
Monetized Methane-related Benefits[2]	**$31 - $180**	
Monetized Secondary CO_2 Benefits[2]	**$0.39 - $3.9**	
Total Costs[3]	**$4.8**	**$6.0**
Compliance expenditures	*$9.3*	*$11*
Revenues from electricity sales produced with captured LFG	*$4.6*	*$5.1*
Net Benefits	**$27 - $180**	**$25 - $180**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient $PM_{2.5}$, ozone, and HAP concentrations resulting from reduction of 280 Mg of NMOC	

[1] Totals may not add due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of 44,000 Mg methane in 2025, valued using the social cost of methane, and the net reduction of 26,000 Mg of CO_2 in 2025, valued using the social cost of carbon. The range of estimates reflects four SC-CH_4 and four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.
[3] The engineering compliance cost estimates are annualized capital costs plus annual operation and maintenance expenses and are offset by the estimated revenue from electricity sales generated using captured landfill gas. Compliance expenditures also include testing and monitoring costs. Engineering costs are considered a proxy for the social costs of the regulation.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

7.7 Net Benefits of the Alternate Standards

For the less stringent 2.5/40 option, the monetized methane-related climate benefits are estimated to range from $27 million to $150 million (2012$)[107] in 2025; these benefits are

[107] The range of estimates reflects four SC-CH_4 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

estimated to be $57 million (2012$) in 2025 using a 3% discount rate. The secondary CO_2 disbenefits are estimated to range from $0.026 million to $0.25 million (2012$)[108] in 2025; estimated secondary CO_2 disbenefits are $0.084 million (2012$) in 2025 using a 3% discount rate. Under this option, when using a 7% discount rate the additional cost in 2025 would be $5.5 million. Using a 3% discount rate, the additional cost over the baseline in 2025 would be $4.9 million. These cost estimates include monitoring and testing costs and are net of potential revenues associated with the capture of landfill gas. Thus, the net benefits, when using a 7% discount rate, would be expected to be $22 million to $150 million in 2025, with a primary estimate of $52 million. All estimates are in 2012$. These results are summarized in Table 7-11.

Table 7-11 Summary of the Monetized Benefits, Costs, and Net Benefits for the Alternative NSPS Option 2.5/40 in 2025 (millions of 2012$)[1]

	3% Discount Rate	**7% Discount Rate**
Monetized Methane-related Benefits[2]	**$27 - $150**	
Monetized Secondary CO_2 Disbenefits[2]	**$0.03 - $0.25**	
Total Costs[3]	**$4.9**	**$5.5**
Compliance expenditures	*$5.4*	*$6.5*
Revenues from electricity sales produced with captured LFG	*$0.6*	*$1.0*
Net Benefits	**$22 - $150**	**$21 - $150**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient $PM_{2.5}$, ozone, and HAP concentrations resulting from reduction of 240 tons of NMOC	

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of 38,000 Mg methane in 2025, valued using the social cost of methane, and the net increase of 1,700 Mg of CO_2 in 2025, valued using the social cost of carbon. The range of estimates reflects four SC-CH_4 and four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.
[3] The engineering compliance costs are annualized and are net of estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. Compliance costs also include estimate of annual monitoring and testing costs. Engineering compliance costs are assumed to be a proxy for the social costs of the final NSPS.

[108] The range of estimates reflects four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

For the more stringent 2.0/34 option, the monetized methane-related climate benefits are estimated to range from $40 million to $230 million (2012$)[109] in 2025; these benefits are estimated to be $86 million (2012$) in 2025 using a 3% discount rate. The secondary CO_2 benefits are estimated to range from $0.57 million to $5.6 million (2012$)[110] in 2025; estimated secondary CO_2 benefits are $1.9 million (2012$) in 2025 using a 3% discount rate. Under this option, when using a 7% discount rate the additional cost in 2025 would be $8.5 million. Using a 3% discount rate, the additional cost over the baseline in 2025 would be $6.8 million. These cost estimates include monitoring and testing costs and are net of potential revenues associated with the capture of landfill gas. The net benefits, when using a 7% discount rate, would be expected to be $32 million to $230 million in 2025, with a primary estimate of $80 million. These results are summarized in Table 7-12.

[109] The range of estimates reflects four SC-CH_4 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

[110] The range of estimates reflects four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.

Table 7-12 Summary of the Monetized Benefits, Costs, and Net Benefits for the Alternative NSPS Option 2.0/34 in 2025 (millions of 2012$)[1]

	3% Discount Rate	7% Discount Rate
Monetized Methane-related Benefits[2]	**$40 - $230**	
Monetized Secondary CO_2 Benefits[2]	**$0.57 - $5.6**	
Total Compliance Costs[3]	**$6.8**	**$8.5**
Compliance expenditures	*$13*	*$15*
Revenues from electricity sales produced with captured LFG	*$6.2*	*$6.7*
Net Benefits	**$34 - $230**	**$32 - $230**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient $PM_{2.5}$, ozone, and HAP concentrations resulting from reduction of 360 Mg of NMOC	

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of 57,000 Mg methane in 2025, valued using the social cost of methane, and the net reduction of 37,000 Mg of CO_2 in 2025, valued using the social cost of carbon. The range of estimates reflects four SC-CH_4 and four SC-CO_2 estimates: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion.
[3] The engineering compliance costs are annualized costs and are reduced by the estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. Compliance costs also include estimate of annual monitoring and testing costs. Engineering compliance costs are assumed to be a proxy for the social costs of the final NSPS.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.

7.8 Alternative Years of Analysis

While the EPA is assessing impacts in year 2025 as a representative year for the landfills NSPS for new or modified MSW landfills, the quantity and composition of landfill gas does change over the lifetime of a landfill, as discussed in Chapter 2. This section presents a more complete picture of the emission reductions, costs, and benefits of the NSPS alternatives over time by presenting results from the years 2020, 2030, and 2040. Throughout this section, costs are presented only at a 7% interest rate[111], and do not include testing and monitoring costs. However, testing and monitoring costs are typically a very small percentage of the overall costs. Tables 7-13 and 7-14 present the emissions reductions and compliance costs, respectively, of the alternatives in the 2020 snapshot year.

Table 7-13 Estimated Annual Average Emissions Reductions in 2020 for the Baseline, Final NSPS and Alternative Options

	Annual Average Reduction (Mg)		
	NMOC	Million Methane	Million Methane (in CO_2-equivalents)*
Current NSPS = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC			
Baseline	8,100	1.3	32
Incremental values versus the current NSPS			
Alternative option 2.5/40	280	0.04	1.1
Final option 2.5/34	310	0.05	1.2
Alternative option 2.0/34	400	0.06	1.6

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are no considered in the estimates shown in this table.

[111] Estimates of emission control costs costs assuming a 3% discount rate would be lower than the estimate shown in tables 7-14, 7-16, and 7-18.

Table 7-14 Estimated Engineering Compliance Costs in 2020 for Baseline, Final NSPS and Alternative Options (7% Discount Rate)

		Non-monetized Benefits[3]		
	Landfills Controlling Emissions	Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current NSPS = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	97	342	283	59
Incremental values versus the current NSPS				
Alternative option 2.5/40	10	12	6.9	4.6
Final option 2.5/34	12	15	9.9	4.7
Alternative option 2.0/34	17	19	11	7.1

Note: All totals are independently rounded and may not sum. Costs do not include testing and monitoring costs.

Tables 7-15 and 7-16 present the emissions reductions and compliance costs, respectively, in the 2030 snapshot year.

Table 7-15 Estimated Annual Average Emissions Reductions in 2030 for the Baseline, Final NSPS and Alternative Options

	Annual Average Reduction (Mg)		
	NMOC	Million Methane	Million Methane (in CO_2-equivalents)*
Current NSPS = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC			
Baseline	11,400	1.8	45
Incremental values versus the current NSPS			
Alternative option 2.5/40	160	0.03	0.6
Final option 2.5/34	310	0.05	1.2
Alternative option 2.0/34	370	0.06	1.5

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are not considered in the estimates shown in this table.

Table 7-16 Estimated Engineering Compliance Costs in 2030 for Baseline, Final NSPS and Alternative Options (7% Discount Rate)

	Landfills Controlling Emissions	Estimated Annualized Net Cost (Millions 2012$)		
		Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	104	398	291	107
Incremental values versus the current EG				
Alternative option 2.5/40	8	4.8	1.7	3.1
Final option 2.5/34	14	13	7.0	5.8
Alternative option 2.0/34	19	17	8.6	8.1

Note: All totals are independently rounded and may not sum. Costs do not include testing and monitoring costs.

Tables 7-17 and 7-18 present the emissions reductions and compliance costs, respectively, in the 2040 snapshot year.

Table 7-17 Estimated Annual Average Emissions Reductions in 2040 for the Baseline, Final NSPS and Alternative Options

	Annual Average Reduction (Mg)		
	NMOC	Million Methane	Million Methane (in CO_2-equivalents)*
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC			
Baseline	11,390	1.8	45
Incremental values versus the current EG			
Alternative option 2.5/40	300	0.05	1.2
Final option 2.5/34	370	0.06	1.5
Alternative option 2.0/34	380	0.06	1.5

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are not considered in the estimates shown in this table.

Table 7-18 Estimated Engineering Compliance Costs in 2040 for Baseline, Final NSPS and Alternative Options (7% Discount Rate)

	Landfills Controlling Emissions	Estimated Annualized Net Cost (Millions 2012$) Control Costs	Revenue from Beneficial-use Projects	Net Cost
Current EG = 2.5 million Mg and m^3 design capacity and 50 Mg/yr NMOC				
Baseline	97	394	266	129
Incremental values versus the current EG				
Alternative option 2.5/40	9	12	5.1	6.5
Final option 2.5/34	15	16	4.5	11
Alternative option 2.0/34	16	16	4.5	12

Table 7-19, 7-20, and 7-21 present the climate benefits of the options in the snapshot years of 2020, 2030, and 2040, respectively.

Table 7-19 Estimated Global Benefits of CH_4 Reductions in 2020* (in millions, 2012$)

	Million metric tons of CH_4 reduced**	**Million metric tons of CO_2-equivalent reduced**	**Discount rate and statistic** 5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	0.044	1.1	$26	$57	$76	$150
Final Option 2.5/34	0.049	1.2	$29	$64	$85	$170
Alternative Option 2.0/34	0.063	1.6	$37	$82	$110	$220

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years.
**One metric ton equals one megagram.

Table 7-20 Estimated Global Benefits of CH_4 Reductions in 2030* (in millions, 2012$)

	Million metric tons of CH_4 reduced**	Million metric tons of CO_2-equivalent reduced	Discount rate and statistic			
			5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	0.025	0.63	$21	$43	$54	$110
Final Option 2.5/34	0.048	1.2	$40	$84	$100	$220
Alternative Option 2.0/34	0.059	1.5	$48	$100	$130	$270

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years.
**One metric ton equals one megagram.

Table 7-21 Estimated Global Benefits of CH_4 Reductions in 2040* (in millions, 2012$)

	Million metric tons of CH_4 reduced**	Million metric tons of CO_2-equivalent reduced	Discount rate and statistic			
			5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
Alternative Option 2.5/40	0.048	1.2	$52	$100	$130	$280
Final Option 2.5/34	0.059	1.5	$64	$130	$170	$350
Alternative Option 2.0/34	0.060	1.5	$65	$130	$170	$360

*The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. This table does not include secondary CO_2 impacts from the EG. Secondary CO_2 impacts were not estimated for alternative years.
**One metric ton equals one megagram.

7.9 Net Benefits of the NSPS for Alternative Years of Analysis

Estimates of the net benefits associated with the alternative years of analysis of 2020, 2030, 2040 as well as for 2025 are presented in Tables 7-22 through 7-24 below assuming a 7% discount rate[112].

[112] Emission control costs assuming a 3% discount rate would be lower than the estimates shown in Table 7-22, 7-23, and 7-24, and the corresponding net benefits would be greater than the estimates shown.

Table 7-22 Summary of the Monetized CH_4–Related Benefits, Costs, and Net Benefits for the Final NSPS 2.5/34 in 2020, 2025, 2030 and 2040 (7% Discount Rate, millions of 2012$)[1]

	2020	2025	2030	2040
Monetized Methane-related Benefits[2]	**$64**	**$67**	**$84**	**$130**
Total Compliance Costs[3]	**$4.7**	**$5.9**	**$5.8**	**$11**
Compliance expenditures	*$15*	*$11.0*	*$13*	*$16*
Revenues from electricity sales produced with captured LFG	*$9.9*	*$5.1*	*$7.0*	*$4.5*
Net Benefits	**$59**	**$61**	**$78**	**$120**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient $PM_{2.5}$, ozone, and HAP concentrations resulting from reduction of NMOC per year[5]			

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of methane in 2020, 2025, 2030 and 2040, valued using the social cost of methane. The social costs of methane estimates are shown at the 3% discount rate. See Chapter 7 for a range of social costs of methane estimates for the four SC-CH_4: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion. Benefits associated with secondary CO_2 emission reductions are not reflected in this table.
[3] The engineering compliance costs are annualized and include estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy. Cost estimates shown do not include testing and monitoring.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.
[5] Annual NMOC reductions in are estimated to be approximately 310, 280, 310, 370 Mg/year for 2020, 2025, 2030 and 2040, respectively.

Table 7-23 Summary of the Monetized CH_4–Related Benefits, Costs, and Net Benefits for the Less Stringent NSPS Option 2.5/40 in 2020, 2025, 2030 and 2040 (7% Discount Rate, millions of 2012$)[1]

	2020	2025	2030	2040
Monetized Methane-related Benefits[2]	**$57**	**$57**	**$43**	**$104**
Total Costs[3]	**$4.6**	**$5.5**	**$3.1**	**$6.5**
Compliance expenditures	*$12*	*$6.5*	*$4.8*	*$12*
Revenues from electricity sales produced with captured LFG	*$6.9*	*$1.0*	*$1.7*	*$5.1*
Net Benefits	**$52**	**$52**	**$40**	**$97**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient $PM_{2.5}$, ozone, and HAP concentrations resulting from reduction NMOC each year[5]			

[1] Totals may not sum due to rounding.
[2]Monetized benefits include the climate-related benefits associated with the reduction of methane in 2020, 2025, 2030 and 2040, valued using the social cost of methane. The social costs of methane estimates are shown at the 3% discount rate. See Chapter 7 for a range of social costs of methane estimates for the four SC-CH_4: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion. Benefits associated with secondary CO_2 emission reductions are not reflected in this table.
[3] The engineering compliance costs are annualized and include estimated revenue from electricity sales for landfills that are expected to gener3te revenue by using landfill gas for energy. Costs shown do not include testing and monitoring.
[4] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.
[5] Annual NMOC reductions in are estimated to be approximately 280, 240,160,300 Mg/year for 2020, 2025, 2030 and 2040, respectively.
Totals may not sum due to rounding.

Table 7-24 Summary of the Monetized CH_4–Related Benefits, Costs, and Net Benefits for the Most Stringent NSPS Option 2.0/34 in 2020, 2025, 2030 and 2040 (7% Discount Rate, millions of 2012$)[1]

	2020	2025	2030	2040
Monetized Methane-related Benefits[2]	**$82**	**$88**	**$102**	**$130**
Total Compliance Costs[3]	**$7.1**	**$8.5**	**$8.1**	**$12**
Compliance expenditures	*$19*	*$15*	*$17*	*$16*
Revenues from electricity sales produced with captured LFG	*$11*	*$6.7*	*$8.6*	*$4.1*
Net Benefits	**$75**	**$80**	**$94**	**$120**
Non-monetized Benefits[4]	Health, visibility, and vegetation effects from reducing ambient $PM_{2.5}$, ozone, and HAP concentrations resulting from reduction of NMOC per year[5]			

[1] Totals may not sum due to rounding.
[2] Monetized benefits include the climate-related benefits associated with the reduction of methane in 2020, 2025, 2030 and 2040, valued using the social cost of methane. The social costs of methane estimates are shown at the 3% discount rate. See Chapter 7 for a range of social costs of methane estimates for the four SC-CH_4: the mean across all models and scenarios using a 2.5 percent, 3 percent, and 5 percent discount rate, and the 95th percentile of the pooled estimates from all models and scenarios using a 3% discount rate. See Section 4.2 for a complete discussion. Benefits associated with secondary CO_2 emission reductions are not reflected in this table.
[2] The engineering compliance costs are annualized and include estimated revenue from electricity sales for landfills that are expected to generate revenue by using landfill gas for energy.
[3] While we expect that these avoided emissions will result in improvements in air quality and reductions in health effects associated with HAP, ozone, and particulate matter (PM), we have determined that quantification of those benefits cannot be accomplished for this rule in a defensible way. This is not to imply that these benefits do not exist; rather, it is a reflection of the difficulties in modeling the direct and indirect impacts of the reductions in emissions for this industrial sector with the data currently available.
[4] Annual NMOC reductions in are estimated to be approximately 400, 360, 380, and 380 Mg/year for 2020, 2025, 2030 and 2040, respectively.

7.10 Net Present Values of the Final NSPS

The EPA presents the emission reductions, benefits and costs for the period 2019 through 2040 for the final NSPS. The EPA also estimates the net present values (NPV) of benefits and costs for this period as well as equivalent annualized values. Equivalent annualized values are the constant annual values that, when discounted over the period, result in the NPV. All NPV values presented for the period 2019 through 2040 are discounted to the year 2019. This year represents the first year in which EPA anticipates affected landfills will comply with the NSPS by installing and operating GCCS. This also represents the time period when emission reductions are expected to begin as a result of the final NSPS.

Estimates of the potentially affected landfills each year and annual emission reductions of NMOC and methane for the final NSPS are presented on Table 7-25 for the period. For the period 2019 through 2040, cumulative emission reductions from the new sources evaluated amount to about 6,800 Mg of NMOC and 1.1 million Mg of CH_4 (about 27 million Mg of CO_2-equivalents). The costs of installing and operating emission controls are shown on Table 7-26. Costs shown represent estimates of the annual operation and maintenance expenses plus the annualized portion of capital costs associated with installation and operation of GCCS to meet the NSPS for 2019 through 2040. Revenues associated with generating electricity resulting from the capture of landfill gas are also reflected. Total emission control costs are offset by revenues to estimate the net costs of the final NSPS.

The NPV of the annualized costs for the period 2019 through 2040 is estimated to be about $180 million assuming a 3% discount rate and $140 million assuming a 7% discount rate. The NPV of revenues relating to energy generated with captured landfill gas amounts to about $97 and $71 million for 3% and 7% discount rates, respective. When these incremental control costs are offset by the revenues associated with producing energy from captured landfill gas, the NPV of net costs become $84 million and $73 million for the 3% and 7% discount rate, respectively. Equivalent annualized costs estimated using the NPV of the control costs without consideration of revenues generated from the capture of landfill gas, are $11 and $12 million (3% and 7% discount rate, respectively). Net annualized costs for the period (after consideration of revenues generated from the energy produced by captured landfill gas) are approximately $5.9 million and $6.0 million assuming 3% and 7% discount rates, respectively. All estimates are shown in 2012$.

We also present the methane-related climate benefits for the period 2019 through 2040 assuming the four discount rates previously discussed in Table 7-27. These benefit estimates do not include secondary CO_2 benefits (or possible disbenefits) nor benefits associated benefit categories such as air quality benefits that we are unable to monetize. For more information concerning the methods used to estimate these benefits, see chapter 4 and section 7.3 of this RIA. The net present value of these benefits ranges from $510 million to $3.5 billion, depending on the SC-CH_4 value used, with net present value at $1.3 billion using the central SC-CH_4 estimate.

A comparison of benefits and costs over the 2019 to 2040 time frame is presented in Table 7-28. As discussed, the net present value of SC-CH_4 benefits central estimate assuming a 3% discount rate is $1.3 billion. The net present value of the net costs of the final NSPS amount to approximately $84 million and $73 million (3% and 7% discount rates, respectively) in 2019 for the 2019 to 2040 period (after consideration of revenues generated from the energy produced by captured landfill gas). The net present value of the net benefits of the final NSPS is approximately $1.2 billion for both the 3% and 7% discount rate estimates.

We also estimate the equivalent annualized portion of the NPV values. The equivalent annualized value of the NPV for benefits is approximately $80 million assuming the central 3% discount rate for the SC-CH_4. Equivalent annualized net costs are approximately $5.1 million and $6.2 million assuming 3% and 7% discount rates, respectively. This results in equivalent annualized net benefits of $75 million assuming a 3% discount rate for costs and $74 million assuming a 7% discount rate for costs. All estimates are shown in 2012$.

Table 7-25 Landfills Controlled and Emission Reductions for the Final NSPS, 2.5/34 for 2019 through 2040

Year	Number of Affected Landfills	NMOC (Mg)	CH_4 (million Mg)	CO_2-equivalents (million mt)*
2019	11	303	0.048	1.2
2020	12	311	0.049	1.2
2021	10	174	0.027	0.7
2022	9	182	0.029	0.7
2023	9	265	0.042	1.0
2024	11	310	0.049	1.2
2025	12	281	0.044	1.1
2026	12	223	0.035	0.9
2027	13	275	0.043	1.1
2028	14	362	0.057	1.4
2029	13	304	0.048	1.2
2030	14	307	0.048	1.2
2031	15	304	0.048	1.2
2032	14	377	0.059	1.5
2033	16	344	0.054	1.4
2034	17	308	0.048	1.2
2035	16	339	0.053	1.3
2036	16	390	0.061	1.5
2037	16	376	0.059	1.5
2038	16	316	0.050	1.2
2039	14	358	0.056	1.4
2040	15	374	0.059	1.5

*A global warming potential of 25 is used to convert methane to CO_2-equivalents. Secondary CO_2 emission reductions are not included in this table.

Table 7-26 Total Control Costs, Revenues and Net Costs for the Final NSPS for 2019 through 2040 (millions of 2012$)

	Incremental Costs and Revenues					
	3% Discount Rate			7% Discount Rate		
Year	Total Control Cost	Revenue	Net Costs	Total Control Cost	Revenue	Net Costs
2019	$16	$13	$2.3	$18	$13	$4.6
2020	14	$11	$2.8	$15	$9.9	$4.7
2021	7.6	$4.6	$3.0	$9.2	$5.1	$4.0
2022	6.3	$3.4	$2.9	$7.7	$3.9	$3.7
2023	7.4	$2.4	$5.0	$8.8	$2.9	$6.0
2024	9.6	$5.0	$4.6	$11	$5.5	$5.9
2025	9.3	$4.6	$4.8	$11	$5.1	$5.9
2026	7.0	$2.4	$4.6	$8.4	$2.9	$5.4
2027	8.5	$3.1	$5.4	$10	$3.6	$6.5
2028	10	$3.7	$6.4	$12	$4.2	$7.7
2029	9.5	$4.5	$5.0	$11	$5.0	$6.2
2030	11	$6.5	$4.4	$13	$7.0	$5.8
2031	11	$4.5	$6.5	$13	$5.0	$7.9
2032	12	$4.8	$7.0	$12	$3.9	$8.4
2033	13	$5.3	$7.6	$13	$4.3	$9.2
2034	13	$5.8	$7.0	$13	$4.8	$8.7
2035	13	$7.4	$5.7	$14	$6.4	$7.3
2036	14	$6.9	$6.9	$15	$6.4	$8.6
2037	15	$8.8	$5.8	$16	$8.3	$7.7
2038	13	$7.8	$5.5	$14	$7.3	$7.2
2039	14	$8.7	$5.3	$15	$8.3	$7.1
2040	14	$5.0	$9.4	$16	$4.5	$11
Net Present Value	$180	$97	$84	$140	$71	$73
Equivalent Annualized Value	$11	$5.9	$5.1	$12	$6.0	$6.2

Notes: Costs represent estimates of the annual operation and maintenance expenses plus the annualized portion of capital costs associated with installation and operation of GCCS to meet the NSPS for 2019 through 2040. Costs do not include testing and monitoring.
Revenues relate to energy produced from captured landfill gas.
Totals may not sum due to rounding.

Table 7-27 Estimated Global Benefits of CH_4 Reductions for Final NSPS Option (2.5/34) and Net Present Value (in millions, 2012$)

Year	Million metric tons of CH_4 reduced	Discount rate and statistic			
		5% (average)	3% (average)	2.5% (average)	3% (95th percentile)
2019	0.05	$27	$60	$80	$160
2020	0.05	$29	$64	$85	$170
2021	0.03	$17	$37	$49	$98
2022	0.03	$18	$40	$52	$110
2023	0.04	$27	$60	$78	$160
2024	0.05	$33	$72	$93	$190
2025	0.04	$31	$67	$86	$180
2026	0.04	$26	$55	$70	$140
2027	0.04	$33	$69	$88	$180
2028	0.06	$44	$94	$120	$250
2029	0.05	$38	$81	$100	$210
2030	0.05	$40	$84	$100	$220
2031	0.05	$41	$85	$110	$220
2032	0.06	$52	$110	$140	$290
2033	0.05	$49	$100	$130	$270
2034	0.05	$46	$92	$120	$250
2035	0.05	$52	$100	$130	$280
2036	0.06	$61	$120	$160	$330
2037	0.06	$60	$120	$150	$330
2038	0.05	$52	$100	$130	$280
2039	0.06	$60	$120	$150	$330
2040	0.06	$64	$130	$170	$350
Net present value		$510	$1,300	$1,800	$3,500
Equivalent Annualized value		$37	$80	$100	$210

* The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values represent only a partial accounting of climate impacts. Air quality benefits associated with the NSPS are not reflected in these estimates. See Chapter 4 for more discussion of these benefits. The estimates in this table do not account for the secondary CO_2 impacts.

Table 7-28 Estimated Monetized CH_4-Related Benefits, Costs, and Net Benefits of the Final NSPS Option (2.5/34) and Net Present Value (in millions, 2012$)[1]

Year	Monetized CH_4–related Benefits 3% Discount Rate[2]	Total Costs 3% Discount Rate[3]	Total Costs 7% Discount Rate[3]	Net Benefits 3% Discount Rate	Net Benefits 7% Discount Rate
2019	$60	$2.3	$4.6	$57	$55
2020	$64	$2.8	$4.7	$61	$59
2021	$37	$3.0	$4.0	$34	$33
2022	$40	$2.9	$3.7	$37	$36
2023	$60	$5.0	$6.0	$55	$54
2024	$72	$4.6	$5.9	$67	$66
2025	$67	$4.8	$5.9	$62	$61
2026	$55	$4.6	$5.4	$50	$49
2027	$69	$5.4	$6.5	$64	$63
2028	$94	$6.4	$7.7	$87	$86
2029	$81	$5.0	$6.2	$76	$75
2030	$84	$4.4	$5.8	$79	$78
2031	$85	$6.5	$7.9	$78	$77
2032	$110	$7.0	$8.4	$100	$100
2033	$100	$7.6	$9.2	$92	$91
2034	$92	$7.0	$8.7	$85	$84
2035	$100	$5.7	$7.3	$98	$97
2036	$120	$6.9	$8.6	$110	$110
2037	$120	$5.8	$7.7	$110	$110
2038	$100	$5.5	$7.2	$95	$93
2039	$120	$5.3	$7.1	$110	$110
2040	$130	$9.4	$11.2	$120	$120
Net Present Value	$1,300	$84	$73	$1,200	$1,200
Equivalent Annualized Value	$80	$5.1	$6.2	$75	$74

[1] Totals may not sum due to rounding.

[2] Monetized methane-related benefits refer to climate-related benefits from methane emission reductions, which are valued using the central SC-CH_4 estimate (average SC-CH_4 at 3 percent). The SC-CH_4 values are dollar-year and emissions-year specific. SC-CH_4 values are shown for the 3% discount central estimate and represent only a partial accounting of climate impacts. See Table 7-27 for additional discount rate estimates of SC-CH_4 benefits. Air quality benefits associated with the NSPS are not reflected in these estimates. See Chapter 4 for more discussion of these benefits. The estimates in this table do not account for the secondary CO_2 impacts.

[3] Costs represent estimates of the annual operation and maintenance expenses plus the annualized portion of capital costs associated with installation and operation of GCCS to meet the NSPS for 2019 through 2040. Costs do not include testing and monitoring. Costs are presented net of revenues generated from energy produced from the capture of landfill gas. See Table 7-26 for more details.

8 STATUTORY REQUIREMENTS AND EXECUTIVE ORDERS

8.1 Executive Order 12866, Regulatory Planning and Review and Executive Order 13563, Improving Regulation and Regulatory Review

Under section 3(f)(1) of Executive Order (EO) 12866 (58 FR 51735, October 4, 1993), this action is an “economically significant regulatory action” because it is likely to have an annual effect on the economy of $100 million or more. Accordingly, the EPA submitted this action to the Office of Management and Budget (OMB) for review under EO 12866 and 13563 (76 FR 3821, January 21, 2011) and any changes made in response to OMB recommendations have been documented in the docket for this action. In addition, the EPA prepared this RIA of the potential costs and benefits associated with this action. For the final Emission Guidelines, the monetized methane-related climate benefits are estimated to range from $200 million to $1.1 billion (2012$); these benefits are estimated to be $430 million (2012$) in 2025 using a 3% discount rate. The secondary CO_2 benefits are estimated to range from $4.2 million to $41 million (2012$) in 2025; estimated secondary CO_2 benefits are $14 million (2012$) in 2025 using a 3% discount rate. Under the final option 2.5/34, when using a 3% discount rate, the additional emission control cost over the baseline in 2025 would be $43 million. When using a 7% discount rate, the additional cost in 2025 would be $54 million. Thus, the net benefits are expected to be $150 million to $1.1 billion, with a primary estimate of $400 million assuming a discount rate of 3% and $390 million assuming a 7% discount rate for costs (2012$). Table 6-1 shows the results of the cost and benefits analysis for the final EG in 2025.

The EPA also considered the impacts associated with the final NSPS and has concluded that the NSPS is also economically significant. For the rule, the monetized methane-related climate benefits are estimated to range from $31 million to $180 million (2012$) in 2025, depending on the discount rate; these benefits are estimated to be $67 million (2012$) in 2025 using a 3% discount rate. The secondary CO_2 benefits are estimated to range from $0.39 million to $3.9 million (2012$) in 2025, depending on the discount rate; estimated secondary CO_2 benefits are $1.3 million (2012$) in 2025 using a 3% discount rate. Under the final option 2.5/34, when using a 7% discount rate the additional emission control cost in 2025 would be $6.0 million. Using a 3% discount rate, the additional cost over the baseline in 2025 would be $4.8

million. Thus, the net benefits in 2025 assuming a 7% discount rate are expected to be $25 million to $180 million, with a central estimate of $63 million assuming a 3% discount rate for costs and $62 million assuming a 7% discount rate for costs (2012$). These results are summarized in Table 7-10.

8.2 Paperwork Reduction Act

The information collection requirements in the Emission Guidelines and NSPS have been submitted for approval to OMB under the Paperwork Reduction Act (PRA). OMB has approved the information collection activities contained in this rule under the PRA and has assigned OMB control number 2060-0697. The Information Collection Request (ICR) document that the EPA prepared for the final Emission Guidelines has been assigned EPA ICR number 2522.02. You can find a copy of the ICR in the docket for this rule, and it is briefly summarized here.

The information required to be collected is necessary to identify the regulated entities subject to the final rule and to ensure their compliance with the final Emission Guidelines. The recordkeeping and reporting requirements are mandatory and are being established under authority of CAA section 114 (42 U.S.C. 7414). All information other than emissions data submitted as part of a report to the agency for which a claim of confidentiality is made will be safeguarded according to CAA section 114(c) and the EPA's implementing regulations at 40 CFR part 2, subpart B.

Respondents/affected entities: MSW landfills that accepted waste after November 8, 1987, and commenced construction, reconstruction, or modification on or before July 17, 2014.

Respondent's obligation to respond: Mandatory (40 CFR part 60, subpart Cf).

Estimated number of respondents: 1,192 MSW landfills.

Frequency of response: Initially, occasionally, and annually.

Total estimated burden: 679,668 hours (per year) for the responding facilities and 17,829 hours (per year) for the agency. These are estimates for the average annual burden for the first 3 years after the rule is final. Burden is defined at 5 CFR 1320.3(b).

Total estimated cost: $45,225,362 (per year), which includes annualized capital or operation and maintenance costs, for the responding facilities and $1,161,840 (per year) for the agency. These are estimates for the average annual cost for the first 3 years after the rule is final.

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. The OMB control numbers for the EPA's regulations in 40 CFR are listed in 40 CFR part 9.

The Information Collection Request (ICR) document that the EPA prepared for the final NSPS has been assigned EPA ICR number 2498.03. You can find a copy of the ICR in the docket for the NSPS, and it is briefly summarized here.

The information required to be collected is necessary to identify the regulated entities subject to the final rule and to ensure their compliance with the final NSPS. The recordkeeping and reporting requirements are mandatory and are being established under authority of CAA section 114 (42 U.S.C. 7414). All information other than emissions data submitted as part of a report to the agency for which a claim of confidentiality is made will be safeguarded according to CAA section 111(c) and the EPA's implementing regulations at 40 CFR part 2, subpart B.

Respondents/affected entities: MSW landfills that commence construction, reconstruction, or modification after July 17, 2014.

Respondent's obligation to respond: Mandatory (40 CFR part 60, subpart XXX).

Estimated number of respondents: 133 MSW landfills (per year) that commence construction, reconstruction, or modification after July 17, 2014.

Frequency of response: Initially, occasionally, and annually.

Total estimated burden: 91,087 hours (per year) for the responding facilities and 2,634 hours (per year) for the agency. These are estimates for the average annual burden for the first 3 years after the rule is final. Burden is defined at 5 CCFR 1320.3(b).

Total estimated cost: $6,130,652 (per year), which includes annualized capital or operation and maintenance costs, for the responding facilities and $169,978 (per year) for the agency. These are estimates for the average annual cost for the first 3 years after the rule is final.

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. The OMB control numbers for the EPA's regulations in 40 CFR are listed in 40 CFR part 9.

8.3 Regulatory Flexibility Act

The Regulatory Flexibility Act (RFA) generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities (SISNOSE). Small entities include small businesses, small organizations, and small governmental jurisdictions.

For purposes of assessing the impacts of this rule on small entities, small entity is defined as: (1) a small business that is a small industrial entity as defined by the Small Business Administration's (SBA) regulations at 13 CFR 121.201; (2) a small governmental jurisdiction that is a government of a city, county, town, school district or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field.

After considering the economic impact of the final Emission Guidelines on small entities, the EPA certifies that the final regulation will not have a Significant Impact on a Substantial Number of Small Entities (SISNOSE). This action will not impose any requirements on small entities. Specifically, Emission Guidelines established under CAA section 111(d) do not impose any requirements on regulated entities and, thus, will not have a significant economic impact upon a substantial number of small entities. After Emission Guidelines are promulgated, states and U.S. territories establish standards on existing sources, and it is those state requirements that could potentially impact small entities.

Our analysis here is consistent with the analysis of the analogous situation arising when the EPA establishes National Ambient Air Quality Standards (NAAQS), which do not impose any requirements on regulated entities. As here, any impact of a NAAQS on small entities would only arise when states take subsequent action to maintain and/or achieve the NAAQS through their state implementation plans. See American Trucking Assoc. v. EPA, 175 F.3d 1029, 1043-45 (D.C. Cir. 1999) (NAAQS do not have significant impacts upon small entities because NAAQS themselves impose no regulations upon small entities).

Nevertheless, the EPA is aware that there is substantial interest in the rule among small entities. The EPA conducted stakeholder outreach as detailed in the preamble to the proposed Standards of Performance for MSW Landfills (79 FR 41828-41829; July 17, 2014) and in of the final EG preamble. The EPA convened a Small Business Advocacy Review (SBAR) Panel in 2013 for the landfills rulemaking. The EPA originally planned a review of the Emission Guidelines and NSPS in one action, but the actions were subsequently divided into separate rulemakings. The SBAR Panel evaluated the assembled materials and small-entity comments on issues related to the rule's potential effects and significant alternative regulatory approaches. A copy of the "Summary of Small Entity Outreach" is available in the rulemaking docket EPA-HQ-OAR-2014-0451. While formulating the provisions of the rule, the EPA considered the input provided over the course of the stakeholder outreach as well as the input provided in the many public comments, and we have incorporated many of the suggestions in this final rule.

The EPA certifies that the NSPS will not have a significant economic impact on a substantial number of small entities under the RFA. The small entities subject to the requirements of this final rule may include private small businesses and small governmental jurisdictions that own or operate landfills. Although it is unknown how many new landfills will be owned or operated by small entities, recent trends in the waste industry have been towards consolidated ownership among larger companies. The EPA has determined that approximately 10 percent of existing landfills subject to similar regulations (40 CFR part 60, subparts WWW and Cc or the corresponding state or federal plan) are small entities. It was determined that the July 2014 proposed NSPS and August 2015 supplemental to the proposed NSPS subpart would not have a significant economic impact on a substantial number of small entities. Given the changes in the number of landfills anticipated to become subject to the new NSPS, the potential impact on small entities has been reanalyzed. The EPA has determined that, with a size threshold of 2.5 million Mg and 2.5 million m^3 and an NMOC emission rate of 34 Mg/yr, no small entities are expected to experience an impact of greater than 1 percent of revenues in 2025. See section 7.4.3 for more information.

Although not required by the RFA to convene a Small Business Advocacy Review Panel because the EPA has now determined that the final NSPS would not have a significant economic impact on a substantial number of small entities, the EPA originally convened a panel to obtain advice and recommendations from small entity representatives potentially subject to this rule's requirements. A copy of the "Summary of Small Entity Outreach" is included in Docket ID No. EPA-HQ-OAR-2003-0215.

8.4 Unfunded Mandates Reform Act

The final Emission Guidelines do not contain any unfunded mandate of $100 million or more as described in UMRA, 2 U.S.C. 1531–1538. These Emission Guidelines apply to landfills that were constructed, modified, or reconstructed after November 8, 1987, and that commenced construction, reconstruction, or modification on or before July 17, 2014. Impacts resulting from the final Emission Guidelines are below the applicable threshold.

We note however, that the final Emission Guidelines may significantly or uniquely affect small governments because small governments operate landfills. The EPA consulted with small governments concerning the regulatory requirements that might significantly or uniquely affect them. In developing this rule, the EPA consulted with small governments pursuant to a plan established under section 203 of the UMRA to address impacts of regulatory requirements in the rule that might significantly or uniquely affect small governments. The EPA also held meetings as discussed under Federalism consultations in section 8.5 below.

The final NSPS does not contain any unfunded mandate of $100 million or more as described in UMRA, 2 U.S.C. 1531-1538. The NSPS applies to landfills that commence construction, reconstruction, or modification after July 17, 2014. Impacts resulting from the final NSPS are far below the applicable threshold. Thus, the final NSPS is not subject to the requirements of sections 202 or 205 of the UMRA. However, in developing the final NSPS, the EPA consulted with small governments pursuant to a plan established under section 203 of the UMRA to address impacts of regulatory requirements in the rule that might significantly or uniquely affect small governments. The EPA held meetings as discussed in section 8.5 below under Federalism consultations.

8.5 Executive Order 13132: Federalism

The EPA has concluded that the final Emission Guidelines have federalism implications, because the rule imposes substantial direct compliance costs on state or local governments, and the federal government will not provide the funds necessary to pay those costs.

The EPA provides the following federalism summary impact statement. The EPA consulted with state and local officials early in the process of developing the proposed action to permit them to have meaningful and timely input into its development. In developing the regulatory options described in this final action, the EPA consulted with 10 national organizations representing state and local elected officials to ensure meaningful and timely input by State/local governments, consisting of two consultation components.

In the spirit of Executive Order 13132, and consistent with EPA policy to promote communications between the EPA and state and local governments, the EPA specifically solicited comment on the proposed action from state and local officials. The EPA received comments from over 42 entities representing State and local governments. The EPA conducted a Federalism Consultation Outreach Meeting on September 10, 2013. Due to interest in that meeting, additional outreach meetings were held on November 7, 2013, and November 14, 2013. An additional Federalism outreach meeting was conducted on April 15, 2015. Participants included the National Governors' Association, the National Conference of State Legislatures, the Council of State Governments, the National League of Cities, the U.S. Conference of Mayors, the National Association of Counties, the International City/County Management Association, the National Association of Towns and Townships, the County Executives of America, the Environmental Council of States, National Association of Clean Air Agencies, Association of State and Territorial Solid Waste Management Officials, environmental agency representatives from 43 states, and approximately 60 representatives from city and county governments. The EPA also received 1 comment letter from an elected official and 14 comment letters from states and regulatory agencies during the public comment period. Concerns raised during the consultations and in the public comments include: implementation concerns associated with shortening of gas collection system installation and/or expansion timeframes, concerns regarding significant lowering of the design capacity or emission thresholds, the need for clarifications associated with wellhead operating parameters and the need for consistent, clear, and rigorous surface monitoring requirements. In response to public comments as well as the data currently available, the EPA has decided not to adjust the design capacity or significantly lower the emission threshold. The EPA has also decided not to adjust the time allotted for installation of the GCCS or expansion of the wellfield. In 80 FR 52121, the EPA highlighted specific concerns of commenters which included state agencies, landfill owners, and operators that raised concerns about the interaction between shortened lag times and design plan approvals, costs and safety concerns associated with reduced lag times, and the need for flexibility for lag time adjustments. Wellhead operating parameters have been adjusted to limit corrective action requirements to negative pressure and temperature. The EPA acknowledged concerns about wellhead operating parameters in 80 FR 52121 and reviewed public comments in favor and against retention of the parameters during the public comment period as described in the preamble.

As discussed in the preamble, the EPA is finalizing a surface emission modeling approach for determining GCCS installation. Commenters were generally supportive of this approach and recognized the additional flexibility provided as an alternative to the traditional approach for determining GCCS installation based on a series of models. The EPA is also finalizing a subcategory for closed landfills as outlined in the preamble. While federalism commenters primarily supported this approach, some representatives of local governments opposed it due to trends in ownership and size of landfills and the perception that landfills owned by these entities should not benefit from subcategorization.

A complete list of the comments from State and local governments has been provided to OMB and has been placed in the docket for this rulemaking. In addition, the detailed response to comments from these entities is contained in the EPA's response to comments document for this rulemaking.

As required by section 8(a) of Executive Order 13132, the EPA included a certification from its Federalism Official stating that the EPA had met the Executive Order's requirements in a meaningful and timely manner when it sent the draft of this final action to OMB for review pursuant to Executive Order 12866. A copy of this certification is included in the public version of the official record for this final action.

The EPA has concluded that the final NSPS does not have Federalism implications. The final NSPS does not have substantial direct effects on the states, on the relationship between the national government and the states, or on the distribution of power and responsibilities among the various levels of government, as specified in Executive Order 13132. The final rule does not have impacts of $25 million or more in any one year. Thus, Executive Order 13132 does not apply to the final NSPS.

Although section 6 of Executive Order 13132 does not apply to the final NSPS, the EPA consulted with state and local officials and representatives of state and local governments early in the process of developing the final rules for MSW landfills (both the NSPS and Emission Guidelines) as discussed above to permit them to have meaningful and timely input into its development.

Concerns raised relating to the NSPS during the consultations include: implementation concerns associated with shortening of gas collection system installation and/or expansion timeframes, concerns regarding significant lowering of the design capacity or emission thresholds, the need for clarifications associated with wellhead operating parameters, and the need for consistent, clear, and rigorous surface monitoring requirements. The EPA has addressed many of these concerns in the final NSPS.

8.6 Executive Order 13211: Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use

The EG is not a “significant energy action” because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. Further, we have concluded that the final Emission Guidelines are not likely to have any adverse energy effects because the energy demanded to operate these control systems will be offset by additional energy supply from landfill gas energy projects.

This NSPS is also not a “significant energy action” because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. Further, we have concluded that the NSPS is not likely to have any adverse energy effects because there are a small number of new or modified landfills expected to be subject to control requirements under 40 CFR part 60, subpart XXX in 2025. Further, the energy demanded to operate these control systems will be offset by additional energy supply from landfill gas energy projects.

Additional Executive Orders are discussed in the preambles for the EG and NSPS including Executive Order 13175 Consultation and Coordination with Indian Tribal Governments, Executive Order 13045 Protection of Children’s Health from Environmental Risks and Health Risks, Executive Order 12898 Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, the National Technology Transfer Act, and the Congressional Review Act.

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