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Regulatory Impact Analysis of the Waste Emissions Charge

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Regulatory Impact Analysis of the Waste Emissions Charge

U.S. Environmental Protection Agency
Office of Atmospheric Protection
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1 EXECUTIVE SUMMARY

This executive summary presents the results of the U.S. Environmental Protection Agency's (EPA) regulatory impact analysis (RIA) of the final rule implementing the methane waste emissions charge (WEC) required under the Inflation Reduction Act (IRA). The RIA is intended to provide the public with information on the relevant benefits and costs of this final rulemaking and to comply with executive orders, as well as other potential impacts of the rulemaking. This rulemaking details how EPA would implement the WEC according to the specifications in the IRA. Specifically, the rule determines how the WEC will be calculated and how the exemption and netting provisions will function.

The WEC does not directly require emissions reductions from applicable facilities or emissions sources. However, by imposing a charge on methane emissions that exceed waste emissions thresholds, oil and natural gas facilities subject to the WEC are expected to perform methane mitigation actions and make operational changes where the costs of those changes are less than the WEC payments that would be avoided by reducing methane emissions. In addition, because volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions are emitted along with methane from oil and natural gas industry activities and are simultaneously reduced by methane mitigation actions, reductions in methane emissions as a result of the WEC also result in co-reductions of VOC and HAP emissions.

This RIA analyzes potential emissions changes and economic impacts of the WEC that arise through two pathways: 1) through the application of cost-effective methane mitigation technologies, and 2) through changes in oil and natural gas production resulting from the WEC and associated mitigation responses. The analysis of methane mitigation is based on bottom-up engineering cost and mitigation potential information for a range of methane mitigation technologies. Application of methane mitigation technologies reduce WEC payments for WEC obligated parties by reducing methane emissions compared to a baseline without additional methane mitigation actions. The analysis assumes that methane mitigation is implemented where the engineering control costs are less than the avoided WEC payments for a particular mitigation technology.

Additionally, oil and natural gas firms may change their production and operational decisions in response to the WEC. This potential impact is modeled using a partial equilibrium

(PE) model of the crude oil and natural gas markets. The total cost of methane mitigation and WEC payments is added as an increase to production costs, resulting in changes in equilibrium production of oil and natural gas and associated emissions. Projected WEC payments are estimated after methane emissions reductions from both methane mitigation and economic impacts are accounted for.

The number of facilities that will owe WEC obligations, and the amount of those WEC obligations, will ultimately depend on decisions that are within the control of owners and operators, among other factors. However, the EPA estimates that only a relatively small proportion of owner-operators of oil and gas facilities will owe WEC obligations. Using emissions reported to subpart W for Reporting Year (RY) 2022 as an illustrative example, approximately 250 companies would owe WEC obligations related to less than 400 facilities, less than one-fifth of facilities that reported to subpart W. Based on RY2022, Table 1-1 shows that the WEC would be imposed on less than 15 percent of national methane emissions from petroleum and natural gas systems. Total methane emissions reported to the Greenhouse Gas Reporting Program (GHGRP) subpart W are significantly less than national methane emissions from the U.S. Greenhouse Gas Inventory for petroleum and natural gas systems. WEC-applicable facilities are the subset of GHGRP facilities that report at least 25 thousand metric tons CO_2e to subpart W segments subject to the WEC.

It is also important to note that the WEC would only apply to methane emissions that are above the emissions threshold, not for all emissions from WEC-applicable facilities. The WEC has exemptions related to regulatory compliance, emissions from plugged wells, and unreasonable delay in environmental permitting, although these provisions do not impact the illustrative results in Table 1-1. Finally, emissions subject to WEC accounts for netting of emissions between facilities and entities under common ownership and control. Under the final WEC, facilties with emissions below their emissions threshold may reduce emissions subject to the WEC at other facilities with emissions above the threshold where those facilities are under common ownership or control.

Table 1-1 Emissions Subject to the WEC

	CH_4 emissions, 2022	
	(thousand metric tons)	**($MMTCO_2e$ with GWP=28)**
Petroleum and Natural Gas Systems National Total (GHGI)	7,900	220
GHGRP Subpart W	2,600	72
From WEC-applicable facilities (>25,000 $mtCO_2e$ to W)	1,900	54
Facility emissions exceeding emissions threshold	970	27
Emissions subject to WEC, after netting	730	20

The benefit-cost analysis contained in this RIA for the WEC considers the potential benefits and costs of the WEC arising from cost-effective mitigation actions under the WEC as well as the potential transfers from affected operators to the government in payments. Costs include engineering costs for methane mitigation actions and costs resulting from production changes in oil and natural gas markets under the rule. While EPA expects a range of health and environmental benefits from reductions in methane, VOC, and HAP emissions under the WEC, the monetized benefits of the rule are limited to the estimated climate benefits from projected methane emissions reductions. These benefit estimates are based on the social cost of methane (SC-CH_4). A screening-level analysis of ozone-related benefits from projected VOC reductions can be found in Appendix A of the RIA. However, these estimates are treated as illustrative and are not included in the quantified benefit-cost comparisons in the RIA.

The EPA estimates that this action will result in cumulative emissions reductions of 1.2 million metric tons of methane over the 2024 to 2035 period. These reductions represent about 40 percent of methane emissions that would be subject to the WEC before accounting for the adoption of cost-effective emission reduction technologies. Virtually all the reduced emissions result from mitigation activities undertaken by industry to reduce WEC payments. Less than one percent of the estimated reductions is associated with decreased production activity in the oil and natural gas sector resulting from the final rule. In addition to methane emissions reductions, the WEC is estimated to result in reductions of 170 thousand metric tons of VOC and 6 thousand metric tons of HAP over the 2024 to 2035 period.

Table 1-2 Projected Emissions Reductions from the Final Waste Emissions Charge, 2024-2035

	Emission Changes			
	Methane (thousand metric tons)	**VOC (thousand metric tons)**	**HAP (thousand metric tons)**	**Methane (million metric tons CO_2 Eq. using GWP=28)**
Total	1,200	170	6	34

The WEC has important interactions and is designed to work hand-in-hand with the New Source Performance Standards OOOOb and Emissions Guidelines OOOOc for the Oil and Natural Gas Sector (NSPS/EG) by accelerating the adoption of cost-effective methane mitigation technologies, including those that would eventually be required under the NSPS OOOOb or EG OOOOc. The annual projected emissions reductions, costs, and WEC obligations are significantly affected by these interactions.

The EPA finalized updates to the Oil and Gas NSPS/EG in March 2024. In addition to requirements already in place, these rules include standards for many of the major sources of methane emissions in the oil and natural gas industry. To avoid double counting of benefits and costs, the baseline for this analysis includes reductions resulting from the 2024 Final NSPS/EG based on information from the Final RIA for that rule (available in Docket No. EPA-HQ-OAR-2021-0317). Specifically, that analysis showed gradually increasing reductions in methane emissions resulting from the NSPS and deep reductions in methane emissions reductions beginning to take effect in 2028 as a result of the EG OOOOc. As facilities implement emission controls required by the NSPS/EG, emissions subject to the WEC decline.

The second interaction between the WEC and the Oil and Gas NSPS/EG is the regulatory compliance exemption provision of the WEC. Under this provision, when certain conditions are met with respect to the implementation of the Oil and Natural Gas NSPS/EG, applicable facilities in compliance with the NSPS/EG are exempted from the WEC. The analysis in this RIA assumes that the regulatory compliance exemption takes effect in 2029, such that, in 2029 and later, facilities in the industry segments subject to requirements under the NSPS/EG do not owe WEC payments. This assumption is based on an assumed timeline under which the conditions of the regulatory compliance exemption could be met. The timing of the regulatory compliance exemption availability will vary by state. As timing for any individual state is unknown, this RIA analysis assumes that the regulatory compliance exemption becomes available for all relevant facilities in 2029.

Projected methane emissions subject to WEC after accounting for methane mitigation and energy market impacts are estimated to be about 600 thousand metric tons in 2024, and then drop significantly as reductions from the EG OOOOc are implemented in 2028 and the regulatory compliance exemption takes effect in 2029. Table 1-3 provides projected WEC-applicable emissions in the baseline and policy scenario.

Table 1-3 Projected Net WEC Emissions and WEC Obligations in the Policy Scenario

Year	Methane Emissions Subject to WEC in Baseline (thousand metric tons)	Reductions from Methane Mitigation (thousand metric tons)	Reductions from Energy Market Impacts (thousand metric tons)	Methane Emissions Subject to WEC in Policy Scenario (thousand metric tons)
2024	710	110	0.1	600
2025	680	220	0.1	460
2026	650	310	1.7	340
2027	630	310	1.6	320
2028	77	42	0.0	35
2029	34	30	0.0	3.2
2030	33	31	0.0	2.9
2031	33	31	0.0	2.7
2032	33	31	0.0	2.4
2033	33	31	0.0	2.0
2034	32	31	0.0	1.7
2035	32	31	0.0	1.4
Total 2024-2035	3,000	1,200	3.7	1,800

Climate benefits associated with this final rule are monetized using estimates of the social cost of methane (SC-CH_4) which calculates the avoided climate related damages from reducing methane emissions. Methane is the principal component of natural gas. As a potent GHG, methane absorbs terrestrial infrared radiation once emitted into the atmosphere, which in turn contributes to increased global warming and continuing climate change. Methane reacts in the atmosphere to form ozone, which also impacts global temperatures. In addition to other GHG emissions, methane 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 sheets, increasingly severe weather events, such as hurricanes of greater intensity, and sea level rise, among other impacts.

This final rulemaking is projected to reduce VOC emissions, which are a precursor to ozone. Ozone is not generally emitted directly into the atmosphere but is created when its two primary precursors, VOC and oxides of nitrogen (NO_X), react in the atmosphere in the presence of sunlight. Emissions reductions under the WEC may decrease ozone formation, human exposure to ozone, and the incidence of ozone-related health effects. VOC emissions are also a precursor to fine particulate matter ($PM_{2.5}$), so VOC reductions may also decrease human exposure to $PM_{2.5}$ and the incidence of $PM_{2.5}$- related health effects.

Available emissions data show that several different HAP are emitted from oil and natural gas operations. Emissions of eight HAP make up a large percentage of the total HAP emissions by mass from the oil and natural gas sector: toluene, hexane, benzene, xylenes (mixed), ethylene glycol, methanol, ethyl benzene, and 2,2,4- trimethylpentane (U.S. EPA, 2011b). Reductions of HAP emissions under the WEC may reduce exposure to these and other HAP.

In Section 9.3 of the RIA, EPA identifies existing potential environmental justice issues for the communities in counties that have emissions sources that are expected to owe the WEC charge and thus may be positively affected by emissions changes under the rule. Compared to the national average, these communities include a higher percentage of individuals who identify as racial and ethnic minorities, have lower average incomes, and have slightly elevated health risks associated with various air emissions. Reductions in VOC and HAP emissions as a result of the WEC are expected to benefit communities in these counties. Because the WEC does not directly require emissions reductions, EPA has not projected specific locations that emissions reductions might occur. In addition, detailed proximity analysis is infeasible because the emissions affected by the WEC occur at hundreds of thousands of locations.

The total cost of the final rule includes the engineering costs for methane mitigation actions implemented by the oil and natural gas industry to reduce WEC obligations. Costs for methane mitigation are calculated on an annualized basis, with total costs spread over the expected lifetime. This includes the initial capital costs required to implement and install the specific mitigation technology. In addition, for mitigation technologies with expected lifetimes greater than one-year, annual recurring operations and maintenance (O&M) costs which include labor, energy and materials are also incorporated. Finally, the total mitigation costs also include the avoided cost of natural gas losses.

The social cost of energy market impacts is the loss in consumer and producer surplus value from changes in natural gas market production and prices. The economic impacts analysis uses a partial equilibrium model and estimates that the impact of the gas market is minimal, with the largest impact occurring in the first few years with a price increase of less than 0.1% and a quantity reduction of less than 0.1%.

Table 1-4 presents results of the benefit-cost analysis for the final WEC. The table presents the present value (PV) and equivalent annual value (EAV), estimated using discount rates of 2, 3, and 7 percent, of the changes in quantified benefits, costs, and net benefits relative to the baseline.[1] These values reflect an analytical time horizon of 2024 to 2035, are discounted to 2023, and are presented in 2019 constant dollars. The table includes consideration of the non-monetized benefits associated with the emissions reductions projected under this rule.[2]

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[1] Monetized climate effects are presented under a 2 percent near-term Ramsey discount rate, consistent with EPA's updated estimates of the SC-GHG. The 2003 version of OMB's Circular A-4 had generally recommended 3 percent and 7 percent as default discount rates for costs and benefits, though as part of the Interagency Working Group on the Social Cost of Greenhouse Gases, OMB had also long recognized that climate effects should be discounted only at appropriate consumption-based discount rates. While this RIA was being drafted, OMB finalized an update to Circular A-4, in which it recommended the general application of a 2.0 percent discount rate to costs and benefits (subject to regular updates), as well as the consideration of the shadow price of capital when costs or benefits are likely to accrue to capital (OMB 2023). Because the SC-GHG estimates reflect net climate change damages in terms of reduced consumption (or monetary consumption equivalents), the use of the discount rate estimated using the average return on capital (7 percent in OMB Circular A-4 (2003)) to discount damages estimated in terms of reduced consumption would inappropriately underestimate the impacts of climate change for the purposes of estimating the SC-GHG. See Section 6.1 for more discussion.

[2] As discussed in Section 6 of this RIA, the monetized benefits estimates provide an incomplete overview of the beneficial impacts of the rule. In particular, the monetized climate benefits are incomplete and an underestimate as explained in Section 6.1. In addition, important health and welfare benefits anticipated under these rules are not quantified or monetized. EPA anticipates that taking non-monetized effects into account would show the rule to have greater benefit than the tables in this section reflect. Simultaneously, the estimates of costs used in the net benefits analysis may provide an incomplete characterization of the true costs of the rule. The balance of unquantified benefits and costs is ambiguous but we believe is unlikely to change the result that the benefits of the rule exceed the costs.

Table 1-4 Projected Benefits and Costs from the Final Waste Emissions Charge (million 2019$)

		2 Percent Near-Term Ramsey Discount Rate				
	PV	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Monetized Climate Benefits[a]	$2,400	$230	$2,400	$230	$2,400	$230
	2 Percent Discount Rate		**3 Percent Discount Rate**		**7 Percent Discount Rate**	
	PV	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Total Social Costs	$460	$43	$440	$44	$380	$48
Cost of Methane Mitigation	$420	$40	$400	$41	$350	$44
Cost of Energy Market Impacts	$39	$4	$38	$4	$33	$4
Net Benefits[b]	$1,900	$190	$2,000	$190	$2,000	$180
Non-Monetized Benefits	Ozone benefits from reducing 1.2 million metric tons of methane from 2024 to 2035 PM2.5 and ozone health benefits from reducing 170 thousand metric tons of VOC from 2024 to 2035 HAP benefits from reducing 6 metric tons of HAP from 2024 to 2035 Visibility benefits Reduced vegetation effects					

[a] Monetized climate benefits are based on reductions in methane emissions and are calculated using three different estimates of the social cost of methane (SC-CH_4) (under 1.5 percent, 2.0 percent, and 2.5 percent near-term Ramsey discount rates). For the presentational purposes of this table, we show the climate benefits associated with the SC-CH_4 at the 2 percent near-term Ramsey discount rate. Please see Table 6-5 for the full range of monetized climate benefit estimates.

[b] Several categories of climate, human health, and welfare benefits from methane, VOC, and HAP emissions reductions remain unmonetized and are thus not directly reflected in the quantified benefit estimates in the table. See Section 6.1 for a discussion of climate effects that are not yet reflected in the SC-CH_4 and thus remain unmonetized and Section 6.2 for a discussion of other non-monetized benefits. A screening-level analysis of ozone benefits from VOC reductions can be found in Appendix A of the RIA.

WEC payments are transfers and do not affect total net benefits to society as a whole because payments by oil and natural gas operators are offset by receipts by the government. Therefore, from a net-benefit accounting perspective, transfers are considered separately from costs and benefits (and are therefore not included in Table 1-4). As explained further in Section 2.7, the approach taken here is in line with OMB guidance and the approach taken for RIAs for other rules impacting payments to the government, such as the Bureau of Land Management (BLM)'s waste prevention rule.

One of the reasons that transfers are not considered costs is because they represent payments to the U.S. Treasury that do not affect total resources available to society. Payments to the U.S. Treasury can then be used to fund other programs, and the pairing of revenue collection (e.g., the WEC payments) with commensurate expenditures (e.g., financial assistance programs) by the federal government can be designed to be revenue neutral. The Methane Emission Reduction Program created under CAA section 136 includes both collection and expenditure components. In addition to establishing the WEC, another key purpose of CAA section 136 is to encourage the transition to available and innovative methane emissions reduction technologies. See 168 Cong. Rec. E869 (August 23, 2022) (statement of Rep. Frank Pallone). CAA section 136(a) and (b) provides financial and technical assistance to reduce methane emissions from the oil and gas sector. To implement this program, EPA is partnering with the U.S. Department of Energy (DOE) to provide up to $1.36 billion in financial and technical assistance. As designed by Congress, these resources and incentives were intended to complement the regulatory programs and to help facilitate the transition to a more efficient petroleum and natural gas industry. These incentives for methane mitigation and monitoring complement the WEC.

The WEC has the effect of better aligning the economic incentives of oil and natural gas companies with the costs and benefits faced by society from oil and gas activities. In the baseline scenario the environmental damages resulting from methane emissions from the oil and gas sector are a negative externality spread across society as a whole. Under the WEC, this negative externality is internalized, oil and gas companies are required to make WEC payments in proportion to the climate damages of methane emissions subject to the WEC.[3] Alternatively, firms can avoid making WEC payments by mitigating their emissions generating climate benefits associated with the amount of mitigation.

Table 1-5 provides details of the calculation steps used to estimate projected WEC obligations and climate damages based on projected emission subject to WEC. In order to compare projected WEC payments to climate damages from emissions subject to the WEC, WEC payments are converted from nominal dollars to 2019 constant dollars using a chain-weighted GDP price index from the 2023 Annual Energy Outlook (EIA, 2023a).

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[3] Note that Congress specified that the WEC would rise to $1,500 per metric ton of methane in 2026 and beyond. This value is consistent with estimates of climate damages associated with emissions of a metric ton of methane that were available at the time the IRA was passed. The February 2021, 'Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990,' estimated that the social cost of CH4 under a 3% discount rate for emissions occuring in the year 2020 was $1,500.

Table 1-5 Details of Projected WEC Obligations and Climate Damages from Emissions Subject to WEC (million 2019$)

Year	Methane Emissions Subject to WEC in Policy Scenario[b] (thousand metric tons)	Charge Specified by Congress (nominal $ per metric ton)	WEC Payments in Policy Scenario (million nominal $)	WEC Payments in Policy Scenario (million 2019$)	SC-CH_4 Values under 2% Near-Term Discount Rate (2019$ per metric ton)	Climate Damages from Emissions Subject to WEC (million 2019$)[a]
2024	600	$900	$540	$450	$1,900	$1,200
2025	460	$1,200	$560	$450	$2,000	$930
2026	340	$1,500	$510	$400	$2,100	$700
2027	320	$1,500	$480	$380	$2,200	$690
2028	35	$1,500	$52	$40	$2,200	$77
2029	3	$1,500	$5	$4	$2,300	$7
2030	3	$1,500	$4	$3	$2,400	$7
2031	3	$1,500	$4	$3	$2,500	$7
2032	2	$1,500	$4	$3	$2,500	$6
2033	2	$1,500	$3	$3	$2,600	$5
2034	2	$1,500	$3	$2	$2,700	$5
2035	1	$1,500	$2	$1	$2,800	$4
Total 2024-2035	1,800	-	$2,200	$1,700	-	$3,600

[a] Climate damages are based on remaining methane emissions subject to WEC after accounting for emissions reductions and are calculated using three different estimates of the social cost of methane (SC-CH_4) (under 1.5 percent, 2.0 percent, and 2.5 percent near-term Ramsey discount rates). For the presentational purposes of this table, we show the climate benefits associated with the SC-CH_4 at the 2 percent near-term Ramsey discount rate.

[b] The decrease in methane emission subject to WEC in the policy scenario over time is due to combination of reductions in the baseline including those resulting from the 2024 Final NSPS/EG as well as responses to the WEC. In particular, the baseline assumes deep reductions in methane emissions beginning to take effect in 2028 as a result of the EG OOOOc.

Compared to the analysis presented in the RIA for the January 2024 WEC proposal, this analysis reflects some updates to methodologies used to project impacts reflecting changes in the final regulations relative to the proposal and updated available data. This analysis incorporates broader allowance for netting among owner-operators that share a common parent company, updates to requirements of the regulatory compliance exemption, and updated base year data from GHGRP for 2022.

2 BACKGROUND AND OVERVIEW

2.1 Introduction

This document presents the regulatory impact analysis (RIA) for the notice of final rulemaking titled “Waste Emissions Charge for Petroleum and Natural Gas Systems.” The final rulemaking implements a waste emissions charge (WEC) for methane (CH_4) emissions that are reported by applicable facilities to EPA under Greenhouse Gas Reporting Program (GHGRP) subpart W and exceed emissions intensity thresholds. The rulemaking responds to requirements from the Inflation Reduction Act.

2.2 Statutory Requirements

This section describes the legal basis for the final WEC. The Inflation Reduction Act (IRA), signed into law on August 16, 2022, introduced new requirements for methane emissions from petroleum and natural gas systems, including a Waste Emission Charge (WEC). EPA proposed regulations implementing the WEC in January 2024. Section 60113 of the Inflation Reduction Act added section 136 to the CAA, entitled “Methane Emissions and Waste Reduction Incentive Program for Petroleum and Natural Gas Systems.” Section 136(c) of the CAA, “Waste Emissions Charge, states, “The Administrator shall impose and collect a charge on methane emissions that exceed an applicable waste emissions threshold under subsection (f) from an owner or operator of an applicable facility that reports more than 25,000 metric tons of carbon dioxide equivalent of greenhouse gases emitted per year pursuant to subpart W of part 98 of title 40, Code of Federal Regulations, regardless of the reporting threshold under that subpart.” Other key sections of the CAA that define the requirements of the methane emissions and waste reduction incentive program include the following:

- Section 136(d) of the CAA, “Applicable Facility,” defines the term applicable facility for the purposes of section 136.
- CAA section 136(e), “Charge Amount,” specifies that the waste emissions charge is determined by multiplying methane emissions reported to subpart W by specified charge rates for calendar year 2024, calendar year 2025, and calendar year 2026 and each year thereafter.
- CAA section 136(f), “Waste Emissions Threshold,” establishes the thresholds by industry segment above which the EPA must impose and collect the CH_4 emissions charge. The subsection also provides that the EPA shall allow for the netting of

emissions for certain facilities under common ownership or control and provides for several exemptions from charges.
- CAA section 136(g) mandates that the waste emissions charge shall be imposed and collected beginning with respect to emissions reported for calendar year 2024 and for each year thereafter.

The charge per metric ton of methane emitted in excess of the facility waste emissions threshold increases according to the following schedule, as specified in the IRA: $900 in calendar year 2024, $1,200 in 2025, and $1,500 in 2026 and beyond. Thresholds are set based on industry segments and activities conducted at the facility. The waste emissions threshold is a facility-specific amount of metric tons of methane emissions calculated using the relevant intensity thresholds specified by Congress and a facility's natural gas throughput (or oil throughput in certain circumstances); facilities that have methane emissions below the threshold would not be required to pay the charge. It is also important to note that the WEC only applies to the subset of methane emissions that are above the emission threshold, not for a facility's total methane emissions. The emission thresholds for each industry are segment-specific and are specified in CAA section 136(f), which are shown in Table 2-1 .

Table 2-1 Waste Emissions Thresholds by Industry Segment in CAA Section 136(f)

Industry Segments	Applicable Waste Emissions Threshold, Calculated as the Metric Tons of Methane Emissions Equal to:
Onshore petroleum and natural gas production Offshore petroleum and natural gas production	0.20 percent of the natural gas sent to sale from the facility; OR 10 metric tons of methane per million barrels of oil sent to sale from such facility, if the facility sent no natural gas to sale
Onshore petroleum and natural gas gathering and boosting Onshore natural gas processing Liquefied natural gas storage Liquefied natural gas import and export equipment	0.05 percent of the natural gas sent to sale from or through the facility
Onshore natural gas transmission compression Underground natural gas storage Onshore natural gas transmission pipeline	0.11 percent of the natural gas sent to sale from or through the facility

The EPA is establishing provisions for the WEC at 40 CFR part 99 consistent with the authority and directives set forth in CAA section 136(c) through (g). This final rulemaking is hereafter referred to as the "WEC final rule."

For petroleum and natural gas systems, the Greenhouse Gas Reporting Program currently requires that owners or operators of facilities that emit 25,000 metric tons (mt) or more of greenhouse gases (GHGs) per year in combined emissions from all applicable source categories (expressed as carbon dioxide equivalents (CO_2e)) must report GHG data to the GHGRP according to the requirements of subpart W. Subpart W applies to each of the following ten industry segments:

- **Onshore Petroleum and Natural Gas Production**: Production of petroleum and natural gas associated with onshore production wells and related equipment.
- **Offshore Petroleum and Natural Gas Production**: Production of petroleum and natural gas from offshore production platforms.
- **Onshore Petroleum and Natural Gas Gathering and Boosting**: Gathering pipelines and other equipment used to collect petroleum/natural gas from onshore production gas or oil wells and used to compress, dehydrate, sweeten, or transport the petroleum/natural gas.
- **Onshore Natural Gas Processing**: Processing of field-quality gas to produce pipeline-quality natural gas, processing plants that fractionate gas liquids, and processing plants that do not fractionate gas liquids but have an annual average throughput of 25 million standard cubic feet per day (MMscf/day) or greater.
- **Onshore Natural Gas Transmission Compression**: Compressor stations used to transfer natural gas through transmission pipelines.
- **Onshore Natural Gas Transmission Pipeline**: All natural gas transmission pipelines as defined in §98.238 (a rate-regulated interstate or intrastate pipeline, or a pipeline that falls under the "Hinshaw Exemption" of the Natural Gas Act).
- **Underground Natural Gas Storage**: Facilities that store natural gas in underground formations.
- **Liquefied Natural Gas (LNG) Storage**: LNG storage equipment.
- **LNG Import/Export**: LNG import and export terminals.
- **Natural Gas Distribution**: Distribution systems that deliver natural gas to customers.[4]

Consistent with Section 136(d) of the CAA, we are defining a “WEC applicable facility” as a facility within nine of the ten industry segments subject to subpart W, as currently defined in 40 CFR 98.230 and listed above (i.e., all subpart W industry segments except natural gas distribution) for which the owner or operator of the subpart W reporting facility reports subpart W emissions of more than 25,000 metric tons CO_2e. The WEC would be imposed for each WEC

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[4] The Natural Gas Distribution segment is not included in CAA section 136 and is therefore not discussed further in this document.

obligated party, which is defined in the final rule as the owners or operators of one or more WEC applicable facilities.

2.3 Relationship to Other Requirements Impacting Methane Emissions

In addition to the Waste Emissions Charge, the EPA is currently undertaking several other actions that impact methane emissions from the oil and natural gas industry, and therefore influence the results presented in this RIA. In particular, the WEC has important interactions with revisions to GHGRP subpart W and the Oil and Gas New Source Performance Standards OOOOb and Emissions Guidelines OOOOc (NSPS/EG) for the Oil and Natural Gas Sector.

The Inflation Reduction Act mandates that the WEC calculations be based on methane emissions reported to GHGRP subpart W. Section 136(h) of the CAA requires that the EPA revise the requirements of subpart W within two years after the date of enactment of section 60113 of the IRA to ensure that WEC calculations "are based on empirical data, … accurately reflect the total methane emissions and waste emissions from the applicable facilities, and allow owners and operators of applicable facilities to submit empirical emissions data, in manner to prescribed by the Administrator..." On May 14, 2024, the EPA finalized revisions to the requirements of subpart W consistent with those directives (88 FR 50282). Those revisions will be used to report emissions to GHGRP and impact the resulting WEC calculations. However, reporters will implement the majority of the changes beginning with reports prepared for Reporting Year (RY) 2025, which are due March 31, 2026. Because CAA section 136(c) requires the Administrator to impose and collect the WEC beginning with emissions as reported for calendar year 2024, the first year that the WEC will be collected will be based on the provisions of subpart W applicable to 2024.[5] The analysis in this RIA is based on historical reported emissions for RY2022 and previous methods and factors rather than the recent revisions.

The GHGRP subpart W revisions make changes that may significantly affect reported emissions, but the specific changes are difficult to estimate, particularly at the specificity needed

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[5] Where the GHGRP revisions include changes in reporting requirements, those requirements generally begin with RY2025. However, some new calculation methods may optionally be used by reporters for the 2024 reporting year, so reported methane for 2024 may include a mix of reported emissions using previously existing and updated calculation methods.

to estimate WEC payments. For example, the revisions add a new emissions source, "other large release events." Other large release events are believed to occur sporadically at a minority of facilities, but with potentially significant emissions when they occur.[6] The EPA also has finalized revisions to add new calculation methods incorporating additional empirical data and measurements. Calculation methods based on facility- or company-specific measurements may lead to significantly different emissions reported depending on the particular conditions at each facility. In order to estimate WEC payments, reported emissions for each facility and WEC obligated party must be compared against waste emissions thresholds. In lieu of highly uncertain estimates of how revised GHGRP methods may impact reported emissions, the calculations in this RIA are mainly based on current reported emissions. Section 8.1 includes a qualitative discussion of potential sensitivity of this analysis to changes in reported emissions from GHGRP subpart W revisions.

The WEC also has important interactions and is designed to work hand-in-hand with the Oil and Gas NSPS/EG. The EPA proposed updates to the Oil and Gas NSPS/EG in 2021, published a supplemental proposal in 2022, and finalized in March 2024. In addition to requirements already in place, these rules include standards for many of the major sources of methane emissions in the oil and natural gas industry. The 2024 Final NSPS/EG includes new requirements for new and modified facilities and requirements for existing sources, which are to be implemented by the states via state regulations and state plans. The first way that the WEC interacts with the NSPS/EG is the significant overlap in the emissions impacted by the two policies. Some oil and gas operations are subject to emissions reporting under GHGRP subpart W and are also subject to the requirements of the NSPS/EG. As WEC obligated parties implement the emissions controls required by the NSPS/EG, the resulting reduced emissions would also mean reduced WEC payments. This RIA accounts for this interaction by including the emissions reduction impacts of the 2024 Final Oil and Gas NSPS/EG in the baseline scenario.

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[6] EPA does not have an estimate of the quantity of emissions which may be reported under the source category. Discussion of available information in included in section 8.1. EPA described available information regarding some event types, such as well blowouts, in section 3 of the technical support document for the GHGRP subpart W revisions, available here: https://www.regulations.gov/document/EPA-HQ-OAR-2023-0234-0163

The second interaction between the WEC and NSPS/EG is the regulatory compliance exemption provision of the WEC. Under this provision, when certain conditions are met with respect to the implementation of the Oil and Gas NSPS/EG, applicable facilities in compliance with the NSPS OOOOb and EG OOOOc requirements that would otherwise be subject to charge are exempted from the WEC. The analysis in this RIA assumes that the regulatory compliance exemption provision takes effect in 2029, such that in 2029 and later, facilities in the industry segments subject to requirements under the NSPS/EG do not owe WEC payments.[7] The 2024 Final Oil and Natural Gas NSPS/EG lays out the timing for state plan submission. Under the EG OOOOc, states have 24 months to submit their state plans, and EPA must approve or deny state plans within 12 months. Requirements under state plans generally phase-in over several years. For the purpose of this analysis, the EPA has assumed that the regulatory compliance exemption would be available starting in 2029, reflecting that plans could be effective as early as January 2027, and assuming that requirements phase in over 2027 to 2029. As finalized, the regulatory compliance exemption applies on a state-by-state basis and the availability of the regulatory compliance exemption will vary according to plan approval and implementation schedules. As described in Section 2.8, the timing for individual states is unknown, therefore the RIA assumes that the regulatory compliance exemption becomes available for all relevant facilities in 2029.

2.4 Economic Basis for the Rulemaking

This section describes the economic rationale for the final WEC. Market failures occur when free market interactions lead to a suboptimal allocation of resources. The core market failure addressed by section 136 (c) of the Inflation Reduction Act is the externality of climate damage from methane emissions. As described in more detail in the Regulatory Impact Analysis of the Supplemental Proposal for the Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review, producers contribute to climate change when extracting, processing, and transporting petroleum and natural gas products. The producers spread the costs of these actions

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[7] The analysis in this RIA assumes that all facilities in the industry segments subject to NSPS/EG requirements are eligible for the regulatory compliance exemption in 2029 and thereafter. We recognize that not all facilities will be eligible because of compliance issues. However, EPA does not have the capability to predict how many facilities this situation will affect. Furthermore, the existence of the regulatory compliance provision may have a beneficial effect on regulatory compliance. The assumption of full compliance is a simplifying assumption for analysis purposes.

to society as a whole by lowering the availability of public goods, such as better air quality or less severe effects of climate change, while reaping the financial benefits themselves.

The WEC attempts to address the market failure by imposing a charge on petroleum and natural gas producers that emit above a certain threshold of methane. In the absence of the WEC, the discrepancy in public and private costs means the socially optimal level of methane emissions is misaligned with the optimal level of methane emissions for petroleum and natural gas facilities operated by private companies. The final WEC attempts to bring the level of methane emissions that is optimal for producers in the oil and gas sector closer to the socially optimal level of methane emissions. Through this policy, oil and natural gas companies subject to the WEC internalize costs associated with environmental damages of remaining methane emissions. The WEC properly aligns private incentives: to the extent that companies subject to the WEC are able to mitigate their emissions, they can both reduce WEC payments and the environmental damages that result from emissions. In the absence of environmental policies, oil and natural gas producers may have some economic incentives to mitigate some fugitive methane emissions because those emissions represent loss of a saleable product, natural gas. Where mitigation actions cost less than expected revenue from recovered natural gas, a substantial portion of those actions are likely to be taken up voluntarily. However, this product revenue incentive does not account for external environmental damages. Where the mitigation costs exceed expected product revenue, energy market incentives alone would not likely be sufficient to induce socially optimal mitigation actions. Estimation of breakeven costs for methane mitigation actions is further discussed in section 5. Furthermore, as described in section 7, total projected WEC payments are less than the total projected damages associated with emissions subject to the WEC.

2.5 Analysis Overview

As described in section 2.2, CAA section 136(c) states that a WEC will be levied on methane emissions that exceed statutorily specified waste emissions thresholds from an owner or operator of an applicable facility. The waste emissions threshold is a methane intensity metric, therefore facilities that have methane emissions per unit of throughput below the threshold would not be required to pay the charge. The WEC only applies to the subset of a facility’s emissions that are above the waste emissions threshold. As explained in section 2.4, the economic effect of the WEC is to better align private incentives to reduce emissions that cause external environmental damages.

For this analysis it is assumed that the applicable facilities facing the WEC on emissions that exceed the waste emissions threshold will make an economic choice to invest in mitigation measures that reduce their emissions, thereby reducing the WEC obligation. While many facilities will likely find it less expensive to reduce their emissions via mitigation technology, there will be facilities where the cost of reducing emissions is higher than the WEC charges. In the latter case, it is assumed that the facility will elect to pay the WEC rather than invest in more costly mitigation technology.

Additionally, oil and natural gas firms may change their production and operational decisions in response to the WEC. This potential impact is modeled using a partial equilibrium (PE) model of the crude oil and natural gas markets. The total cost of methane mitigation and WEC payments is added as an increase to production costs, resulting in changes in equilibrium production of oil and natural gas and associated emissions. This change in production produces a loss in consumer and producer surplus in the oil and gas market, referred to as ‘costs of energy market impacts’ in this RIA.

Projected WEC payments are estimated after methane emissions reductions from both methane mitigation by applicable facilities and economic impacts in the oil and gas markets are accounted for. WEC payments are not social costs. They are transfers that do not affect net benefits because the payments by oil and natural gas operators are received as benefits by the government. Total social costs are the sum of two components, the mitigation costs, and the costs of energy market impacts (loss in consumer and producer surplus). Mitigation costs reflect cost-effective methane reduction from applicable facilities when the cost per ton of the mitigation technology is less than the WEC. The energy market impacts reflect the reduction in oil and gas production from the WEC.

The regulatory impacts of the final WEC are evaluated relative to a baseline that represents the oil and gas industry in the absence of this finalized action. To avoid double counting of costs, the baseline for this rule includes reductions resulting from the NSPS/EG for Oil and Gas, as detailed in the RIA for the 2024 Final NSPS/EG (U.S. EPA, 2023a). Only a subset of the baseline emissions is subject to the WEC, as seen in section 4.2.

The impact analysis relies in part on the marginal abatement cost curve (MACC) for the oil and gas industry, which is further discussed in section 7. The MACC model is a mitigation cost model that EPA developed to model methane mitigation potential from U.S. oil and natural gas systems as part of larger analyses of non-CO_2 GHG emissions projection and mitigation potential for over 20 years[8]. The MACC is used to estimate what methane mitigation could be expected as a result of facilities facing the WEC charges deciding to adopt mitigation measures earlier than they would have under the NSPS/EG rule. The flat charge per metric ton of methane suggests that some facilities may find it cheaper to adopt methane emission controls in early years to reduce or avoid WEC obligations while other facilities will find it cheaper to pay the WEC. The analysis used EPA's national oil and gas system MACC model to evaluate the potential emissions reductions likely to occur each year from facilities where mitigation technology would be cheaper than paying the WEC charges.

For this analysis, EPA updated the mitigation options technologies characterized in the model to reflect the most recently published best system of emission reduction (BSER) estimates of emissions reduction performance and costs. Additional information on the mitigation technologies updated for this analysis is available in Appendix C.

Owners and operators of oil and gas facilities subject to the requirements of the final Waste Emissions Charge must submit a WEC filing to the EPA. Fulfilling this requirement will involve calculation, reporting, and recordkeeping activities. The EPA estimated the total cost of these information collection activities as approximately $1.7 million per year over the 3 years covered by the Information Collection Request (ICR).[9] These reporting and recordkeeping costs are part of the costs borne by regulated entities as part of the final rulemaking. These costs are detailed in the ICR and supporting statement and are not included in the analysis in this RIA. Because these costs are relatively small in comparison to the benefits, costs, and transfers estimated in the RIA, including them in totals would not meaningfully change overall results.

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[8] For additional information on the MACC model and its modeling framework see Global Non-CO2 Greenhouse Gas Emissions Projections & Marginal Abatement Cost Analysis: Methodology Documentation. EPA-430-R-19-012.

[9] EPA ICR number 2787.02 (OMB Control No. 2060-0752. A copy of the ICR is available in the docket for this rulemaking and is briefly summarized in preamble section VI.B. Paperwork Reduction Act.

2.6 Economic Significance

The final Waste Emissions Charge constitutes a “significant regulatory action” as defined under section 3(f)(1) of Executive Order 12866, as amended by Executive Order 14094. Executive Order 12866 requires agencies to conduct regulatory analysis for actions that are significant under Section 3(f)(1) (as amended). Actions that are significant under Section 3(f)(1) include actions likely to result in annual costs, benefits, or transfers of at least $200 million per year. As discussion in Section 6, the emissions reductions projected under the rule are likely to produce substantial climate benefits, peaking at $530 million to $890 million in 2027, as well as non-monetized benefits from reductions in VOC and HAP emissions. At the same time, the final WEC is projected to result in substantial transfer payments by the oil and gas industry to comply with the rule, reaching a maximum of $560 million in 2025.

2.7 Transfers

From the perspective of calculating costs and benefits that accrue to society as a whole, WEC payments are transfers payments. Transfer payments are a shift in money from one party to another. On net, transfers do not affect total net benefits because payments by one group are offset by receipts by another group. In the case of the WEC, payments made by oil and gas operators are offset by receipts by the government in the societal cost benefit analysis. From OMB Circular A-4 (2003) and OMB Circular A-4 (2023), transfer payments potentially include fees to government agencies for goods and services, tax payments from individuals or businesses to the government (monetary transfers to the government) and tax refunds from the government (monetary transfers from the government to taxpayers). (OMB, 2003, 2023)

The approach taken here is in line with the approach taken for regulatory impact analyses for other rules impacting payments to the government. For example, in the BLM’s waste prevention rule, royalty payments were treated as transfers because they are income for the Federal or Tribal government and costs to the operator or lessee. (BLM, 2022) In an EPA rule modifying fees related to administration of the Toxic Substance Control Act, the total social cost did not include the fees incurred by firms and collected by EPA, as those fees represent a transfer from affected manufacturers and processors to taxpayers. (U.S. EPA, 2018)

There are two accounting approaches that can be used to quantify transfers in regulatory impact analyses. (OMB, 2023) First, transfers can be accounted for separately from costs and benefits. A second approach is to include one side of a transfer as a benefit and the other side of a transfer as a cost, such that the transfer is treated symmetrically in the estimate of net benefits. In the comparison of costs and benefits in this RIA, we use the first approach and do not include the transfer amount in either the benefits or costs.

Although WEC payments are transfers from the perspective of societal costs and benefits, for the purpose of analyses focused on impacts on oil and gas companies subject to the WEC, payments are included. In the energy markets analysis, both costs of methane mitigation and WEC payments impact production and operation costs and result in changes in equilibrium prices and production. In the small business analysis, WEC payments are the focus of the analysis of costs for small entities under this program.

2.8 Changes Between the Proposal and Final RIA

Compared to the analysis presented in the RIA for the January 2024 WEC proposal, this analysis reflects some updates to methodologies used to project impacts reflecting changes in the final regulations relative to the proposal and updated available data.

This analysis reflects changes to the regulatory requirements for netting for facilities under common ownership or control and implementation of the regulatory compliance exemption. Relative to the proposal, the final regulations allow broader netting at the parent company level, which allows more flexibility for netting, and results in lower anticipated WEC obligations in the baseline scenario.

The final regulations changed several aspects of the regulatory compliance exemption, only some of which are captured by the analysis in this RIA. Based on the proposed WEC regulations, the regulatory compliance exemption would have become available upon determination that state and other OOOOc-implementing plans met stringency requirements and were *approved and in effect* in all states. The final WEC regulations further require that mitigation requirements are fully implemented before the regulatory compliance exemption is available. As a result, while the proposal RIA assumed that the regulatory compliance exemption would be available starting in 2027, this analysis assumes the regulatory compliance exemption is available starting in 2029, based on the assumption that plan requirements would phase-in over several years.

The final WEC regulations include additional changes in requirements for the regulatory compliance exemption which cannot be captured in this analysis. The WEC proposal anticipated a national determination that would have made the regulatory compliance exemption available in all states after state plans were approved and in effect in all states. The final WEC has changed this approach to state-by-state evaluation. This means that in practice the regulatory compliance exemption will be available at different times in different states based on a variety of factors including OOOOc-implementing plan approval and implementation schedules. As timing for any individual state is unknown, this RIA analysis assumes that the regulatory compliance exemption becomes available for all relevant facilities in 2029. The final rule also made changes in how the regulatory compliance exemption is calculated in the case compliance issues. As described in preamble section II.D.2.f, the EPA is finalizing a definition of compliance which focuses on a narrower set of compliance activities that directly affect methane emissions. However, these changes are not reflected in the RIA results because the RIA projections assume all facilities in segments subject to NSPS/EG requirements are eligible for the regulatory compliance exemption starting in 2029.

Updated data from the GHGRP has also been incorporated. The baseline analysis has been updated to reflect reported data for 2022, which was not available at the time that the proposal RIA analysis was developed. Because reported emissions for RY2022 were approximately 15 percent lower than emissions reported for RY2021, many impacts reported in this document are somewhat lower due to this update, relative to the proposal RIA estimates.[10]

EPA notes that for the final rule the RIA assumes that all facilities in the industry segments subject to NSPS/EG requirements are eligible for the regulatory compliance exemption in 2029 and thereafter. EPA did not consider a scenario with the regulatory compliance exemption

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[10] The largest decrease in emissions by source was for pneumatic devices (a decrease of 3.3 $MMTCO_2e$). Emissions changes were driven by onshore production, which make up 85% of devices and 81% of CO2e emissions. The number of onshore intermittent-bleed devices decreased 10.5% from RY 2021) to 528,944. Additionally, there was an 8.7% increase in the number of low-bleed pneumatic devices reported in onshore production, indicating an overall shift from the use of high- and intermittent-bleeds to low-bleeds. Further information on historical emissions reported to GHGRP subpart W can be found in: https://www.epa.gov/system/files/documents/2023-10/subpart_w_2022_sector_profile.pdf

becoming available in different states at different times over several years. However, EPA recognizes that not all facilities will be eligible because of compliance issues including delays in implementation of plan approval and mitigation measures. EPA does not have the capability or data to predict how many facilities this situation will affect. Furthermore, the existence of the regulatory compliance provision may have a beneficial effect on regulatory compliance. The assumption of full compliance is a simplifying assumption for analysis purposes here and throughout the rest of the RIA.

2.9 Organization of RIA

The remainder of the RIA is organized as follows:

- **Section 3, Baseline**, describes the baseline projection of CH_4 emissions reported to subpart W for segments subject to the Waste Emissions Charge.
- **Section 4, WEC Scenario** describes the policy scenario analyzed, WEC applicable facilities, and the calculation steps for emissions subject to the WEC**.**
- **Section 5, Costs and Emissions Impacts** describes the costs and emissions impacts of the two major responses to the WEC: 1) application of methane mitigation technologies, and 2) energy market changes in oil and gas production and prices. This section includes descriptions of the marginal abatement cost analysis, and the partial equilibrium model used for market modeling.
- **Section 6, Benefits**, describes the methods used to estimate the climate benefits from reductions of CH_4 emissions. This analysis uses estimates of the social cost of greenhouse gases to monetize the estimated changes in CH_4 emissions expected to occur over 2024 through 2035 for the final rule. Qualitative benefits of VOC and HAP reductions are also discussed.
- **Section 7**, **Comparison of Benefits and Costs**: presents estimates of the net benefits of the rule.
- **Section 8, Uncertainty Analyses**: discusses sensitivity of results related to GHGRP calculation methods and potential interaction with NSPS/EG.
- **Section 9, Distributional and Economic Analyses:** presents the small business, employment, environmental justice, and distributional climate impacts analyses.

3 BASELINE

3.1 Baseline Projection Approach

This section describes the baseline projection of CH_4 emissions and throughput reported to GHGRP subpart W for segments subject to the Waste Emissions Charge, from the base year 2022 through 2035. The baseline is used to estimate facilities and emissions potentially subject to the Waste Emissions Charge and as an input to the mitigation analysis. The baseline begins from emissions and activity reported to subpart W in RY 2022, the most recent available reporting data at the time of this analysis. The base year data has been updated since the proposal RIA, which used emissions reported for 2021. Emissions trends are projected by segment, source, control status, and site types. The EPA acknowledges that the regulatory impact analysis baseline is based on emissions historically reported to Subpart W, and therefore does not reflect the recently finalized revisions of subpart W. For many sources, EPA has recently finalized revisions to reporting that may meaningfully change methane reported to subpart W starting in 2025. Section 8 of the RIAs contains a discussion of uncertainty related to this factor. Estimating WEC obligations requires estimates of reported emissions for particular facilities, which will be impacted by factors such as reporter choice of calculation method and site-specific measurements.

The baseline projection includes anticipated impacts from the Oil and Gas NSPS/EG. This approach is taken to avoid double-counting of costs and emissions reductions across the analyses for the NSPS/EG and WEC. This analysis reflects the RIA for the 2024 Final NSPS/EG. The impacts of the WEC are also likely affected by interactions with other policies affecting emissions and activities of the oil and gas sector, such as the Bureau of Land Management's waste prevention rule and state policies. These other policies are not explicitly modeled in the baseline.

3.1.1 Base Year Emissions by Segment and Source

The baseline analysis begins from detailed GHGRP subpart W reported data by facility, segment, source, and unit type. The baseline scope is CH_4 emissions reported under segments subject to the WEC.[11] Detailed reporting data on throughput and emissions is necessary to estimate potential WEC amounts and emissions reductions resulting from the WEC, because the WEC is assessed by facility and owner or operator ("WEC obligated party"). As shown in Table 2-1, emissions reported to subpart W are broken out by source and unit type in order to assess mitigation potential for each emissions source and equipment type independently. Further detail on subpart W emissions reported by segment, source, and trends over time can be found in the GHGRP sector profile for petroleum and natural gas systems.[12]

Table 3-1 Methane Emissions Reported to Subpart W Segments Subject to the WEC, By Source and Unit Type (RY 2022)

Source	Unit Type	CH_4 tons
Pneumatic Devices	Intermittent Bleed Pneumatic Devices	822,000
Misc Equipment Leaks	Equipment Leak Population Counts	336,000
Blowdown Vent Stacks		199,000
Pneumatic Pumps		79,000
Combustion Equipment		75,000
Reciprocating Compressors	Reciprocating Compressors - Rod Packing	69,000
Liquids Unloading		60,000
Dehydrators		54,000
Other Flare Stacks		53,000
Offshore Sources		52,000
Pneumatic Devices	High-Bleed Pneumatic Devices	50,000
Pneumatic Devices	Low-Bleed Pneumatic Devices	44,000
Centrifugal Compressors	Wet Seal Centrifugal Compressors - Seals	44,000
Associated Gas Venting and Flaring		43,000
Misc Equipment Leaks	Equipment Leak Surveys	39,000
Atmospheric Storage Tanks		39,000
Reciprocating Compressors	Reciprocating Compressors - Leaks	33,000
Centrifugal Compressors	Wet Seal Centrifugal Compressors - Leaks	15,000
Centrifugal Compressors	Dry Seal Centrifugal Compressors - Leaks	9,100
Transmission Tanks		8,200
Well Compl. and Work. with HF		7,400
Gas Well Compl. and Work. without HF		1200
Well Testing		38

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[11] GHGRP subpart W segments subject to the WEC are onshore production, offshore production, gathering and boosting, gas processing, transmission compression, transmission pipelines, natural gas storage, LNG import/export, and LNG storage. The NG distribution segment is not subject to the WEC.

[12] 2011-2022 Greenhouse Gas Reporting Program Industrial Profile: Petroleum and Natural Gas Systems, reflecting the same data snapshot used in this analysis, available here: https://www.epa.gov/system/files/documents/2023-10/subpart_w_2022_sector_profile.pdf

Reporting requirements vary by segment and other facility characteristics. The base year emissions information is based on data reported for reporting year 2022 (RY 2022). For many sources, EPA has recently finalized revisions to reporting that may significantly change methane reported to subpart W starting in 2025. Because the most recent data available is from RY 2022, this baseline uses emissions methods and factors in place in 2022. The emissions calculation methods in subpart W can be grouped into categories: (1) direct emissions measurement; (2) combination of measurement and engineering calculations; (3) engineering calculations; (4) leak detection and use of a leaker emission factor; and (5) population count and population emission factors. subpart W emission factors (both population and leaker emission factors) include both those developed from published empirical data and those developed from site-specific data collected by the reporting facility. Currently, the majority of emissions reported are quantified based upon population emission factors or engineering calculations, which typically include specified measurements of process operating parameters (*e.g.*, temperature or pressure). The recently finalized revisions to subpart W include new measurement-based calculation methodologies for several sources, including pneumatic devices and pumps, equipment leaks, and compressors.

Calculating WEC obligations requires information on the throughput of each facility in addition to emissions information. All subpart W facilities report information on natural gas and/or liquids throughput. However, RY2022 throughput for facilities in the natural gas processing and transmission compression segments is classified as confidential business information (CBI). For this reason, the RIA analysis uses proxy estimates to substitute for reported throughput information for facilities in these segments. The proxy throughput estimates for RY2022 were constructed by allocating total throughput for all subpart W facilities in processing and transmission compression among the reporting facilities in proportion to carbon dioxide emissions from combustion reported by these facilities to subpart A.

3.1.2 Baseline Projection Trends

Emissions by segment and source trends are projected by segment and source including anticipated impacts of the Oil and Gas NSPS/EG. Projections by segment, source (e.g., fugitives, pneumatic controllers, compressors), and unit type (e.g., centrifugal compressors) were extracted from the projections from the RIA for the 2024 Final NSPS/EG[13]. For emissions sources reported to GHGRP subpart W, but not within the scope of the NSPS/EG RIA projections, simplified assumptions based on projected natural gas production activity were used to project future reported emissions from those sources. The 2023 Annual Energy Outlook projects crude oil and lease condensate production to grow by 13 percent from 2022 to 2030 (24.6 to 27.7 quads) and for dry natural gas production to increase 2 percent from 2022 to 2030 (37.8 to 38.4 quads). In addition to emissions trends for affected sources and equipment types, the NSPS/EG RIA projections are used to break out the baseline emissions by control status, vintage, and site. These categorizations are useful for characterizing mitigation potential and control costs. Projected throughput was also estimated using the 2023 Annual Energy Outlook projection of natural gas production, applied to the base year facility throughput (which is either as reported, or a proxy estimate depending on the segment).

Application of the emissions trends and characteristics from the Final NSPS/EG RIA projections implicitly assumes that the emissions trends among the subset of oil and gas operations reporting to the GHGRP subpart W and potentially subject to the WEC are comparable to the trends for the overall oil and gas industry, which is subject to the NSPS/EG.[14] Reporters to the GHGRP represent companies with larger operations than non-reporters. However, given the various uncertainties involved in constructing the emissions projections, and the significant coverage of GHGRP of the oil and gas industry, it is reasonable to assume that the overall projections from the NSPS/EG are relatively representative of the trends that could be expected from GHGRP reporters potentially subject to the WEC.

3.1.3 Summary of Projections Methodology from NSPS/EG RIA

Because the emissions baseline incorporates trends from the RIA for the 2024 Final NSPS/EG, a summary of the projection methodology used in that analysis is included here. The Final NSPS/EG RIA includes further details on the projections methodology (U.S. EPA, 2023a).

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[13] https://www.epa.gov/system/files/documents/2023-12/eo12866_oil-and-gas-nsps-eg-climate-review-2060-av16-ria-20231130.pdf

[14] For more information on historical petroleum and natural gas systems emission trends see: https://www.epa.gov/system/files/documents/2023-10/subpart_w_2022_sector_profile.pdf

The Final NSPS/EG RIA includes projections of activity data and emissions for the following sources: fugitive emissions/equipment leaks, pneumatic pumps, pneumatic controllers, reciprocating compressors, centrifugal compressors, liquids unloading, and storage vessels. Depending upon the source, the NSPS/EG includes requirements for equipment located at well sites and centralized production facilities, gathering and boosting stations, natural gas processing plants, and transmission and storage compressor stations. Tables 2-1 and 2-2 in the RIA for the 2024 Final NSPS/EG summarize the requirements of those rules. The Final NSPS/EG RIA did not quantify regulatory impacts of the super-emitter response program.

The NSPS/EG RIA activity data projections rely on historical data from the GHGI, industry data collected by EPA through an information collection request, information on wells and oil and gas production from the firm Enverus, and projections from the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO)[15,16,17]. The projections construct projected counts of oil and natural gas sites, such as well sites, compressor stations, and processing plants, that contain or are themselves affected facilities. The Final RIA contains descriptions of how projections for each site and equipment type are constructed. The projections used assumed retirement rates and annual new site construction[18] to track new and modified facilities (which would be subject to NSPS OOOOb requirements) and existing facilities (which would be subject to state requirements based on the emissions guidelines).

3.1.4 Baseline Emissions Results

Methane emissions reported to GHGRP subpart W in the baseline are expected to decline significantly, in particular with respect to sources subject to requirements under the NSPS/EG. Emissions decline gradually over time as a result of NSPS OOOOb, while emissions decline dramatically in 2028 as a result of the EG OOOOc.[19] Over the analysis period of 2024 to 2035, the EIA Annual Energy Outlook reference scenario includes a gradual increase in natural gas

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[15] Annual Energy Outlook 2023, https://www.eia.gov/outlooks/aeo/.

[16] U.S. Greenhouse Gas Emissions and Sinks, https://www.epa.gov/system/files/documents/2023-04/US-GHG-Inventory-2023-Main-Text.pdf

[17] Enverus Energy Analytics, http://www.enverus.com.

[18] See table 2-3 of the RIA for the 2024 Final NSPS/EG

[19] The RIA analysis for the 2024 Final NSPS/EG explained that emissions reductions as a result of the EG are expected to phase in from 2027 to 2029, but that for analytical purposes, all existing source reductions were assumed to take effect in 2028.

production, which results in slightly higher baseline emissions in 2035 relative to 2030. Table 3-2 lists results for the projected methane emissions baseline. This baseline does not include the effects of the Waste Emissions Charge; the policy scenario will be compared against this baseline scenario.

Table 3-2 Projected CH_4 Emissions Baseline of Emissions Reported to Subpart W

Year	CH_4 tons projected for subpart W (excl. NG dist)[a]
2024	2,100,000
2025	2,100,000
2026	2,000,000
2027	2,000,000
2028	730,000
2029	730,000
2030	730,000
2031	730,000
2032	740,000
2033	740,000
2034	740,000
2035	740,000

[a] The baseline projection begins from reported emissions to GHGRP subpart W for RY2022 and incorporates activity and emissions trends from the EIA AEO 2023 reference case and the RIA for the 2024 Final NSPS/EG. The baseline here includes all industry segments that report to subpart W except the natural gas distribution segment because facilities reporting for that segment are not subject to the WEC.

4 WEC SCENARIO

4.1 Identification of Regulated Sources

As described in section 2.2, CAA section 136(c) states that a WEC will be levied on applicable waste emissions above the threshold under subsection (f) from an owner or operator of an applicable facility that reports more than 25,000 metric tons of carbon dioxide equivalent (tCO_2e) of greenhouse gases emitted per year pursuant to subpart W of part 98 of title 40.

4.1.1 Description of Applicability Standards

Owners and operators would first determine whether their facility is a WEC applicable facility and then would determine whether the facility's methane emissions exceed the applicable waste emissions threshold. To calculate the amount by which a WEC applicable facility is below or exceeding the waste emissions threshold and thus determine the amount of waste emissions charge owed, the facility waste emissions threshold is subtracted from facility total methane emissions, as described in the final regulatory text. This results in a value of metric tons of methane, referred to as the total facility applicable emissions, that is negative for facilities below the waste emissions threshold and positive for facilities exceeding the waste emissions threshold.

A facility may report total GHG emissions to subpart W which exceed 25,000 tCO_2e (and thus is a WEC applicable facility) and also have negative facility applicable emissions. This can happen for facilities with relatively low methane emissions and relatively high natural gas throughput. For example, consider a WEC applicable facility in the onshore production segment which reports 2,000 tons of methane emissions and 78 million Mscf of natural gas throughput under subpart W. Accounting for the global warming potential (GWP) of methane, this facility reports more than 25,000 tCO_2e of GHG to subpart W. However, applying the segment-specific methane intensity threshold of 0.2%, this facility would have a facility waste emissions threshold of approximately 3,000 tons. Because it reported lower methane emissions than this number, its facility applicable emissions would be approximately negative 1,000 tons.

For a facility that would be subject to charge (*i.e.,* that has a positive value of total facility applicable emissions), there are three exemptions that may lower the facility's WEC or exempt the facility entirely from the charge. The first exemption, found in CAA section 136(f)(5), exempts from the charge emissions occurring at facilities in the onshore or offshore production segments that are caused by eligible delays in environmental permitting of gathering or transmission infrastructure. The second exemption, found in CAA section 136(f)(6), exempts from the charge facilities subject to and in compliance with the NSPS OOOOb and EG OOOOc if certain conditions are met. The third exemption, found in CAA section 136(f)(7), exempts from the charge reporting-year emission from wells that are permanently shut in and plugged. Based upon the applicability of these exemptions, the total facility applicable emissions are adjusted. The resulting value, also in units of metric tons of methane, is referred to as the WEC applicable emissions.

When determining the total WEC applicable emissions for a WEC obligated party, CAA section 136(f)(4) allows for the netting of emissions at facilities under common ownership or control within and across all applicable segments identified in 136(d). Thus, for the WEC regulations, the WEC applicable emissions (positive or negative) from all of a WEC obligated party's WEC applicable facilities are summed to calculate net WEC emissions for that WEC obligated party. WEC obligated parties with the same parent company can then transfer negative net WEC emissions to one another. To determine the WEC obligated party's total annual waste emissions charge, or WEC obligation, its net metric tons of methane exceeding the waste emissions thresholds after any transfers is multiplied by the annual $/metric ton charge. Any WEC obligated party with net WEC emissions greater than zero would therefore have a WEC obligation and be required to pay a waste emissions charge.

4.1.2 Identification of Applicable Facilities

As an illustration of the application of these terms and concepts, Table 4-1 shows the number of total facilities reporting under subpart W in RY 2022, the number of WEC applicable facilities based on RY 2022 reported data, and the number of facilities with WEC applicable emissions greater than zero based on RY 2022 emissions and throughputs, by subpart W industry segment. For this analysis, we used GHGRP data frozen as of August 18, 2023 (available through EPA's Envirofacts website[20]). To estimate the number of WEC applicable facilities within the GHGRP, we reviewed RY 2022 GHG emissions to determine which facilities reported more than 25,000 mt CO_2e to subpart W. For each WEC applicable facility, we calculated the

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[20] https://enviro.epa.gov/

waste emissions threshold using the RY 2022 facility-level throughputs and the provisions of CAA section 136(f) appropriate for that industry segment, and then we subtracted the waste emissions threshold from the RY 2022 reported CH_4 emissions to determine whether the WEC applicable emissions for each facility were greater than zero (*i.e.*, positive). The final WEC regulations allow broader netting among owners or operators that share a common parent company. To account for netting at the parent company level, for netting facilities with both positive and negative WEC applicable emissions, negative WEC applicable emissions were proportionally applied to facilities with positive WEC applicable emissions to calculate emissions subject to WEC after netting. In practice, this approach changes the count of facilities with emissions subject to WEC in cases where transfers of negative WEC emissions allow facilities to reduce net WEC emissions to zero.

Table 4-1 Numbers of Subpart W Reporting Facilities, WEC Appliable Facilities, and Facilities with WEC Applicable Emissions Greater than Zero By Industry Segment (Based on RY 2022)

Industry Segment	Total Number of Facilities Reporting	Number of WEC Applicable Facilities	Number of Facilities with WEC Applicable Emissions >0[a]	Number of Facilities with Emissions Subject to WEC, After Netting
Onshore petroleum and natural gas production	459	393	226	202
Offshore petroleum and natural gas production	116	23	17	16
Onshore petroleum and natural gas gathering and boosting	350	310	201	125
Onshore natural gas processing	444	180	~ 53	~ 16
Onshore natural gas transmission compression	659	22	~ 5	~ 0
Onshore natural gas transmission pipeline	44	20	4	4
Underground natural gas storage	51	1	1	1
Liquefied natural gas storage	5	0	0	0
Liquefied natural gas import and export equipment	11	7	0	0
Total	2,112[b]	954[b]	~ 507	~ 364

[a] Note that the count of facilities with positive WEC applicable emissions is not shown as an exact value for the Natural Gas Processing and Onshore Natural Gas Transmission Compression industry segments due to the sensitivity of throughputs in that industry segment and the relatively low number of WEC applicable facilities. For facilities in these segments, WEC calculations used proxy estimates of throughput to avoid using sensitive data.

[b] Also note that for industry segments that use the definition of "facility" as defined in 40 CFR 98.6, a subpart W reporting facility may include operations from multiple co-located industry segments. The counts presented reflect each industry segment reported, while the total count includes only unique facilities, and as a result may not match the sum of industry segment reporting.

4.1.3 Methodology for Projecting WEC-Applicable Emissions

To estimate potential impacts of the final rule, the EPA projected WEC applicable facilities and WEC applicable emissions before accounting for potential emissions reductions from methane mitigation actions.

- **Identify WEC applicable facilities**. WEC applicable facilities are GHGRP facilities that report more than 25,000 metric tons CO_2e to GHGRP subpart W and report emissions under any of the nine oil and natural gas industry segments subject to the WEC (all segments except the natural gas distribution segment). Facilities projected to report less than 25,000 metric tons CO_2e to subpart W in a given year would not be considered subject to the WEC and are not included in projections of WEC-applicable emissions. Emissions of CO_2 and N_2O reported to subpart W were assumed to be fixed for each facility at the same level as reported in RY 2022. Methane emissions were projected by segment and source as described in the baseline section.
- **Calculate facility waste emissions threshold from segment-specific methane intensity thresholds**. To calculate a facility's projected waste emissions threshold, the facility's projected natural gas throughput was first multiplied by the relevant intensity threshold specified by Congress to calculate the volume of gas equivalent to the segment-specific methane intensity threshold. These values were converted to metric tons by multiplying by the density of methane (0.0192 mt / Mscf) to calculate the waste emissions threshold in metric tons of methane The methane intensity thresholds for each segment are listed in Table 2-1 .
- **Calculate facility tons above or below waste emissions threshold, or total facility applicable emissions.** The facility's projected waste emissions threshold was subtracted from the facility's projected methane emissions to determine the total facility applicable emissions. A negative value represented the metric tons of methane emissions a facility was below the waste emissions threshold while a positive value represented the metric tons of methane emissions at the facility that exceeded the segment-specific methane intensity threshold. Facilities with projected subpart W emissions below 25,000 metric tons CO_2e were not considered eligible for the purpose of netting and positive or negative tons from these facilities were excluded.
- **Apply regulatory compliance exemption**. For this analysis, EPA assumed that the regulatory compliance exemption would apply starting in 2029 for all facilities reporting to segments containing facilities subject to the NSPS/EG and that had positive total facility applicable emissions. These segments are onshore production, natural gas gathering and boosting, natural gas processing, natural gas transmission compression, and underground natural gas storage segments. For this analysis, all facilities in these segments were assumed to have zero violations or deviations related to NSPS/EG requirements, and thus receive a regulatory compliance exemption. The assumption that the regulatory compliance exemption would apply starting in 2029 is based on prompt implementation of the schedule for state plans outlined in 2024 Final Oil and Gas EG OOOOc. Under the EG OOOOc, states have 24 months to submit their state plans, and EPA must approve or deny state plans within 12 months, which means that plans may be in effect as early as 2027, assuming no Federal Plan is needed. In general plan requirements are assumed to phase in over three years from 2027

to 2029, meaning that the regulatory compliance exemption would be available starting in 2029.

- **Emissions associated with plugged well and unreasonable delay exemptions.** To calculate WEC applicable emissions, emissions associated with wells plugged in the previous year and unreasonable delay in environmental permitting are subtracted from total facility applicable methane emissions for the purpose of WEC. This analysis does not include any estimate of projected facilities or emissions that would receive these exemptions.
- **Calculate WEC applicable emissions**. For facilities with a regulatory compliance exemption, the facility's WEC applicable emission are zero. For all others, the facility's WEC applicable emissions are equal to the previously calculated total facility applicable emissions.
- **Calculate net WEC emissions by WEC Obligated Party**. For WEC Obligated Parties with common ownership or control of multiple facilities, facility tons above or below the waste emissions thresholds were summed across all facilities to calculate net tons. In addition, owner-operators under a common parent company may transfer negative WEC emissions to lower their WEC obligations. Net WEC emissions after transfers for each owner-operator are estimated assuming netting among WEC obligated parties with a common parent company.
- **Calculate potential WEC obligations**. WEC Obligated Parties with net tons methane of zero or below would not be subject to the WEC and have zero WEC obligations. For WEC Obligated Parties with net tons methane greater than zero, net tons were multiplied by the WEC. In 2024 the WEC is $900/ton, in 2025 it is $1200/ton, and in 2026 and later years, it is $1500/ton of methane.

It is important to note that the reporting threshold of 25,000 mt CO_2e per facility for the GHGRP is not necessarily the same as the WEC applicable facility threshold in CAA section 136(c). Three of the industry segments included in CAA section 136(c), Onshore Petroleum and Natural Gas Production, Onshore Petroleum and Natural Gas Gathering and Boosting, and Onshore Natural Gas Transmission Pipeline, have unique definitions of facility in 40 CFR 98.238, and facilities in those segments only report emissions under subpart W, so the emissions compared to each of those thresholds would be the same for each facility. However, facilities in the other six segments use the standard GHGRP facility definition and report emissions under other GHGRP subparts as well if they are co-located (e.g., 40 CFR part 98, subpart C, General Stationary Fuel Combustion Sources or subpart Y, Petroleum Refineries). While emissions reported under these other subparts are included when an owner or operator is considering whether their facility is required to report to the GHGRP, the emissions from subparts other than subpart W would not be included when an owner or operator is determining whether their facility is a "WEC applicable facility."

Table 4-2 shows how only a portion of the emissions that report under subpart W are subject to the WEC. It is important to distinguish how each of these subcategories relates to the overall baseline. As shown in Table 4-1, many facilities have emissions that are below the waste emission threshold, as defined in the CAA. For those facilities whose emissions per unit of throughput are below their waste emission threshold, they do not have "WEC applicable emissions >0" (column b in Table 4-2).

Additionally, total emissions from facilities with WEC-applicable emissions greater than zero are distinct from methane tons subject to the WEC. The methane tons subject to the WEC at the facility level (column c in Table 4-2), is a subset of total emissions reported under subpart W. Lastly, the tons of methane subject to the WEC after accounting for netting among owner-operators that share a common parent company (column d in Table 4-2) is a subset of WEC-applicable emissions at the facility level.[21] Based on EPA's analysis of the 2022 data, a significant percentage of facilities are relatively efficient, that is, they have emission rates below the Congressionally mandated thresholds. Therefore, it is reasonable to expect netting to have a notable impact on WEC-subject emissions when facilities under common ownership and control are allowed to net their emissions. Both net WEC emissions and emissions from facilities with WEC-applicable emissions greater than zero are important inputs to further analyses in this RIA.

Table 4-2 Projected CH_4 Subject to Waste Emissions Charge in Baseline Before Accounting for Mitigation and Market Responses (tons)

Year	CH_4 tons projected for subpart W (excl. NG dist) (a)	CH_4 tons from facilities with WEC applicable emissions >0[a,b] (b)	CH_4 tons exceeding facility waste emissions thresholds[a,b] (c)	Net emissions (tons) subject to the WEC (d)
2024	2,100,000	1,400,000	960,000	710,000
2025	2,100,000	1,300,000	930,000	680,000
2026	2,000,000	1,300,000	900,000	650,000
2027	2,000,000	1,300,000	870,000	630,000
2028	730,000	240,000	140,000	77,000
2029	730,000	55,000	36,000	34,000
2030	730,000	55,000	36,000	33,000
2031	730,000	55,000	36,000	33,000
2032	740,000	55,000	36,000	33,000
2033	740,000	55,000	35,000	33,000
2034	740,000	55,000	35,000	32,000
2035	740,000	55,000	35,000	32,000

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[21] Calculations of netting are based on facility characteristics in the RY 2022 base year, combined with projected changes as described in Section 3, and the WEC and netting calculations described in this section. The netting calculations assume that patterns of WEC facility emissions and ownership are reflective of those in the 2022 GHGRP data but do not attempt to project future changes in the oil and natural gas industry.

Notes:

[a] Estimates of emissions subject to the WEC in this table are based on emissions in the baseline scenario. They do not include CH_4 reductions from application of mitigation technologies or energy market responses.

[b] Emissions from WEC-applicable facilities are greater than facility emissions exceeding waste emissions thresholds because a portion of the emissions reported by a WEC-applicable facility are below the waste emissions threshold. Total emissions from WEC-applicable facilities are included because these reflect emissions potentially targeted for methane mitigation.

Projected estimates of CH4 tons subject to the WEC in the baseline reflect projections starting from emissions reported to GHGRP subpart W for RY 2022, and thus assume this distribution of facilities and emissions.

The projections assume that starting in 2029, facilities in onshore production, gathering and boosting, transmission compression, and natural gas storage are exempted from the WEC as a result of the regulatory compliance exemption.

Table 4-3, Table 4-4, and Table 4-5 present snapshots of projected methane emissions subject to the WEC in the baseline by segment in 2024, 2026, and 2030. These results do not include mitigation or energy market responses to the WEC.

Table 4-3 Projected CH_4 Subject to Waste Emissions Charge in Baseline Before Accounting for Mitigation and Market Responses, by Segment, 2024, thousand tons

Industry Segment	CH_4 projected for subpart W (excl. NG dist)	CH_4 from facilities with WEC applicable emissions >0	Facility CH_4 exceeding waste emissions threshold	Net CH_4 subject to WEC
Onshore Production	1,100	850	610	530
Offshore Production	52	27	23	21
Gathering and Boosting	540	420	280	140
Natural Gas Processing	97	43	27	9
Natural Gas Transmission Compression	160	17	7	3
Natural Gas Transmission Pipeline	84	29	14	14
Underground Natural Gas Storage	11	1	0	0
LNG Import/Export	4	0	0	0
LNG Storage	0	0	0	0
Total	2,100	1,400	960	710

Table 4-4 Projected CH_4 Subject to Waste Emissions Charge in Baseline Before Accounting for Mitigation and Market Responses, by Segment, 2026, thousand tons

Industry Segment	CH4 projected for subpart W (excl. NG dist)	CH4 from facilities with WEC applicable emissions >0	Facility CH4 exceeding waste emissions threshold	Net CH4 subject to WEC
Onshore Production	1,100	780	550	470
Offshore Production	52	27	23	21
Gathering and Boosting	540	420	280	140
Natural Gas Processing	96	43	26	8
Natural Gas Transmission Compression	160	17	7	3
Natural Gas Transmission Pipeline	84	29	13	13
Underground Natural Gas Storage	10	1	0	0
LNG Import/Export	4	0	0	0
LNG Storage	0	0	0	0
Total	2,000	1,300	900	650

Table 4-5 Projected CH_4 Subject to Waste Emissions Charge in Baseline Before Accounting for Mitigation and Market Responses, by Segment, 2030, thousand tons

Industry Segment	CH_4 projected for subpart W (excl. NG dist)	CH_4 from facilities with WEC applicable emissions >0	Facility CH_4 exceeding waste emissions threshold	Net CH_4 subject to WEC
Onshore Production	200	0	0	0
Offshore Production	52	27	23	20
Gathering and Boosting	240	0	0	0
Natural Gas Processing	61	0	0	0
Natural Gas Transmission Compression	88	0	0	0
Natural Gas Transmission Pipeline	84	29	13	13
Underground Natural Gas Storage	2	0	0	0
LNG Import/Export	4	0	0	0
LNG Storage	0	0	0	0
Total	730	55	36	33

5 COST AND EMISSIONS IMPACTS

This section describes cost and emissions impacts of the WEC that arise through two pathways: 1) through the application of cost-effective methane mitigation technologies, and 2) through changes in oil and natural gas production and prices resulting from the WEC and associated mitigation responses. Total social costs include the sum of costs related to each of these two pathways. Section 5.1 describes the methods for estimating the expected cost of methane mitigation. The social cost of methane mitigation is estimated total engineering cost. Section 5.2 evaluates the equilibrium impact of increased production costs borne by oil and natural gas firms on market prices and quantities. The social cost of these energy market effects is estimated as the loss in consumer and producer surplus from changes in production resulting from the WEC. Section 5.3 summarizes the expected total methane abatement and co-abatement of VOC and HAP. Lastly, WEC obligations are estimated after accounting for methane mitigation and energy market responses.

5.1 Costs of Methane Mitigation

Mitigation options were used to estimate marginal abatement cost curves (MACCs) in a reduced form marginal abatement cost (MAC) model for the WEC applicable subsegments of the Oil and Gas Industry in a manner similar to that presented in the EPA's Global Non-CO_2 Greenhouse Gas Emission Projections & Mitigation, 2015–2050 report (U.S. EPA, 2019).[22] This analysis builds from the 2019 report and includes updated baseline projections, mitigation option performance characteristics, and implementation cost assumptions. Section 3 provides more detail on the baseline projections developed for this analysis. See Appendix C, for additional details on mitigation options and costs used in this analysis. The marginal abatement cost curve (MACC) shows the cumulative mitigation potential at incrementally higher costs, where mitigation is expressed in thousand metric tons of methane, and the costs are expressed in dollars per metric ton of methane reduced. The MACC represents the aggregation of information on a wide range of mitigation technologies applied to different types of oil and natural gas operations.

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[22] MAC curves are constructed by estimating the "break-even" price at which the present-value benefits and costs for each mitigation option are equal. We then draw a cumulative supply curve of emission reductions by summing over the reductions at each break-even price in ascending order. The methodology produces a curve where each step reflects the reduction potential supplied assuming systematic implementation of the mitigation technology were applied to similar model facilities across the sector.

When evaluated against the WEC implementation schedule, we can calculate the cost of abatement resulting from facilities implementing mitigation technologies where the cost of mitigation is economic relative to the alterative WEC payment.

Each step of the MACC represents a calculation for a particular mitigation option applied to a specific type of activity, facility, or type of equipment annual methane emissions representing the baseline projection of emissions from facilities with WEC-applicable emissions greater than zero. Each breakeven calculation results in a cost per ton of emissions reduction (the vertical dimension of the curve) and methane mitigation potential (the horizontal dimension). The asymptotic limit of the MACC curve represents the mitigation quantity that is technically achievable[23] using mitigation technologies included in the MACC model at facilities with emissions above the facility-specific waste emissions threshold.

Mitigation technologies used in this analysis were updated based on information gathered as part of technology assessment for the recent Oil and Gas NSPS/EG analysis (U.S. EPA, 2021b, 2022b). Available mitigation data for the offshore segment is limited and therefore cost estimates in those segments is more uncertain than in other segments. We requested comment on the application of cost-effective technologies for the offshore segment (and other segments not eligible for the regulatory compliance exemption), but did not receive extensive comments. The mitigation technologies are characterized based on the expected lifetime of equipment, the emissions reduction efficiency, and the costs of implementation. Costs include the initial capital costs of implementation, the annual operation and maintenance costs as well as any sources of expected cost savings for labor, energy or materials associated with the methane emission reductions.

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[23] The suite of mitigation measures considered for this analysis reflect the current achievable or demonstrated technologies considered in NSPS/EG analysis of the Oil and Gas Industry. The MACC model was updated for this analysis to include currently available information on mitigation measures and costs. However, the MACC model does not yet include newer emerging technologies such as remote monitoring of fugitive emissions. See Appendix C for more information on included mitigation measures.

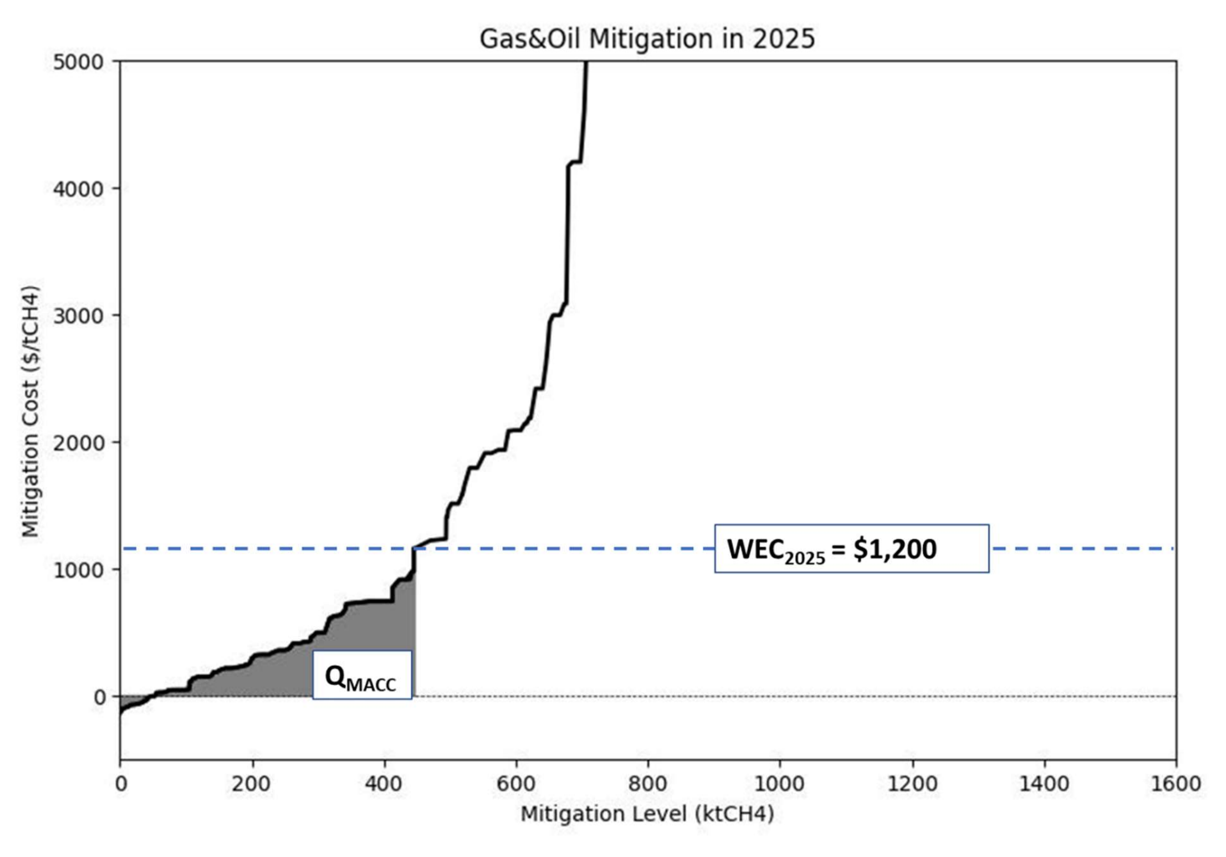

Figure 5-1 Oil and Natural Gas MACC with WEC Payment Cost in 2025

In Figure 5-1, the intersection point of the MACC and the horizontal blue line (representing the WEC payment cost of $1,200 per ton of methane for 2025) is the maximum mitigation which can be implemented at a lower cost per ton of methane abatement than the WEC. These cost-effective mitigation technologies (where cost-effective is taken to be those technologies with cost less than or equal to the WEC), shown as the total area under the MACC curve shaded in grey, is the total bottom-up engineering costs of implementing these mitigation technologies. Additional mitigation is technically feasible at higher prices ($/tCH$_4$) but would not be cost effective relative to the WEC price in 2025. As a result, facilities facing more expensive mitigation costs would elect to pay the WEC costs rather than implement these more expensive mitigation measures.

In order to account for practical limitations in the speed of deploying cost-effective mitigation to oil and gas operations, the analysis assumed a three-year phase-in period for reductions over 2024 to 2026. The phase-in parameter constrains the mitigation potential in 2024 and 2025 to 33% and 67% of total mitigation potential to simulate the assumption that it will take facilities several years to fully implement mitigation measures. Depending upon a variety of factors, potential technology deployment speed may be faster or slower than this assumption. Oil and natural gas companies have been aware of the WEC since the passage of the IRA in 2022. In addition, the NSPS/EG rulemaking was first proposed in 2021 and there is significant overlap in the mitigation technologies which would be used to satisfy NSPS/EG requirements and those which may be adopted to avoid WEC payments. However, widespread deployment of mitigation technologies may be affected by supply chain, labor, or other constraints that could prevent full utilization in the short term. Such constraints could include short term availability of skilled personnel or time needed to increase manufacturing production of necessary equipment.

Table 5-1 presents the total cost of methane mitigation for each year, as calculated by applying the MACC representing methane mitigation options to the baseline projection in each year (2024 to 2035). The total mitigation costs over the analysis timeline are then presented in 2023 present values. The year-by-year variation in mitigation costs reflects several factors. Between 2024 and subsequent years, costs associated with mitigation rise as technology deployment increases. In addition, as the WEC rises in 2025 and 2026, additional mitigation becomes cost-effective. Then, as emissions decline in the baseline as a result of NSPS/EG implementation, costs associated with mitigation resulting from the WEC decline. Costs associated with NSPS/EG implementation are considered in the RIA for that action and are not included in this RIA to avoid double-counting. When the regulatory compliance exemption takes effect, costs (and emissions reductions) resulting from the WEC decline further.

Table 5-1 Mitigation Costs

	Year	Mitigation costs (million 2019$)[a]
	2024	$40
	2025	$85
	2026	$120
	2027	$120
	2028	$17
	2029	$10
	2030	$10
	2031	$10
	2032	$10
	2033	$10
	2034	$10
	2035	$10
NPV	2%	$420
	3%	$400
	7%	$350
EAV	2%	$43
	3%	$44
	7%	$47

[a] Mitigation costs represent a stream of annualized costs based on engineering costs of methane mitigation technologies including capital costs, recurring costs, and revenue from avoided losses of natural gas. Mitigation expenditures in a given year serve to reduce WEC obligations in the corresponding year.

Total costs associated with methane mitigation activities include capital costs, recurring costs, and revenue from avoided losses of natural gas. Table 5-2 presents details of the composition of mitigation costs among these components including total costs with and without including revenue from avoided natural gas losses.

Table 5-2 Mitigation Cost Details (million 2019$)

Year	Mitigation costs with revenue	Mitigation costs without revenue	Capital costs	Recurring costs	Revenue from avoided natural gas losses
2024	$39.8	$53.6	$48.8	$4.0	$13.1
2025	$85.1	$114.4	$97.4	$14.6	$27.0
2026	$120.8	$163.1	$137.7	$22.2	$39.1
2027	$119.3	$161.0	$133.4	$24.4	$38.5
2028	$17.0	$18.4	$0.5	$17.9	$1.4
2029	$10.0	$11.1	$0.0	$11.1	$1.1
2030	$10.0	$11.1	$0.0	$11.1	$1.2
2031	$10.0	$11.1	$0.0	$11.1	$1.1

2032	$9.9	$11.1	$0.0	$11.1	$1.2
2033	$9.93	$11.1	$0.0	$11.1	$1.2
2034	$9.92	$11.1	$0.0	$11.1	$1.2
2035	$9.903	$11.1	$0.0	$11.1	$1.2

5.2 Market Modeling

This section describes estimates of energy market impacts of the WEC. EPA used a partial equilibrium model to estimate the energy market impacts of costs borne by oil and natural gas firms because of the WEC. This section presents estimates of the costs of these market impacts for inclusion in the benefit-cost analysis.

5.2.1 Model Description

The partial equilibrium model represents a single US oil and natural gas extraction sector, foreign supply and demand for crude oil and natural gas, and domestic demand for a combination of foreign and domestic sourced products, one for oil and one for gas. The model is calibrated to reference quantities and prices from the Energy Information Administration and parameterized with elasticities identified from a search of peer-reviewed literature.

US oil and gas producers supplied $281.0 billion of gas (36.4 TCF) and $412.6 billion of crude oil (4.3 billion barrels) in 2022. Table 5-3 shows the calculation for the total domestic oil and gas markets. By subtracting exports and adding imports to domestic production, we arrive at domestic supply totaling $251.0 billion in gas (32.5 TCF) and $577.2 billion in crude (6.1 billion barrels) supplies. Prices in 2022 were $7.73 per MCF of natural gas and $77.58 per barrel of crude.[24] The total undiscounted abatement and WEC payments of $2.4 billion over the period 2024 through 2035 are 0.3% of 2022 domestic oil and gas domestic supply values.

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[24] Gas: https://www.eia.gov/dnav/ng/hist/n3035us3M.htm
Oil: https://www.eia.gov/dnav/pet/pet_pri_spt_s1_a.htm

Table 5-3 Oil and Gas Markets Value and Quantity (2022)

Market / Product	Gas		Crude	
	$ Billion	**BCF**	**$ Billion**	**Million Barrels**
Output (Y)[25]	$ 281.0	36,353	$ 412.6	4,347
Imports (M)[26]	23.4	36,353	288.5	3,040
Exports (X)[27]	- 53.4	- 6,904	- 123.9	- 1,305
Domestic Supply	$ 251.09	32,473	$ 577.2	6,082

Production in the model includes elastic supply and demand combined with constant elasticity of substitution specifications for production of oil versus gas and demand for domestic versus foreign sources. The following eleven equations define the model, which we solve as a constrained non-linear system using the Conopt solver in GAMS:

Production: Total
$$Y = \bar{Y}\left(\frac{p_y}{(1+c_y)\bar{p}_y}\right)^{\sigma_y} \tag{1}$$

Production: Fuel
$$Y_f = \alpha_f Y\left(\frac{p_f}{(1+c_f)\,p_y}\right)^{\sigma_{FUEL}} \tag{2}$$

Supply: Imports
$$M_f = \bar{M}\left(\frac{p_f^M}{\bar{p}_f^M}\right)^{\sigma_f^M} \tag{3}$$

Demand: Total
$$D_f = \bar{D}_f\left(\frac{p_f^C}{\bar{p}_f^C}\right)^{\sigma_f^C} \tag{4}$$

Demand: Exports
$$X_f = \bar{X}_f\left(\frac{p_f}{\bar{p}_f}\right)^{\sigma_f^X} \tag{5}$$

Demand: Domestic
$$D_f^D = \beta_f\,\bar{D}_f\left(\frac{p_f^C}{p_f}\right)^{\sigma_f^A} \tag{6}$$

Demand: Imports
$$D_f^M = (1-\beta_f)\,\bar{D}_f\left(\frac{p_f^C}{p_f^M}\right)^{\sigma_f^A} \tag{7}$$

Market clearance: Domestic supply
$$Y_f - X_f - D_f^D = 0 \tag{8}$$

Market clearance: Imports
$$M_f - D_f^M = 0 \tag{9}$$

Zero profit: consumption
$$p_f^C = \left(\beta_f p_f^{1-\sigma_f^A} + (1-\beta_f)(p_f^M)^{1-\sigma_f^A}\right)^{\frac{1}{1-\sigma_f^A}} \tag{10}$$

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[25] Gas: https://www.eia.gov/international/data/world/natural-gas/dry-natural-gas-production
Oil: https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm

[26] Gas: https://www.eia.gov/international/data/world/natural-gas/dry-natural-gas-imports
Oil: https://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_a.htm

[27] Gas: https://www.eia.gov/international/data/world/natural-gas/dry-natural-gas-exports
Oil: https://www.eia.gov/dnav/pet/pet_move_exp_dc_NUS-Z00_mbbl_a.htm

Zero profit: supply

$$p_y = \left(\alpha_{CRU} p_{CRU}^{1-\sigma_{FUEL}} + \alpha_{GAS} p_{GAS}^{1-\sigma_{FUEL}}\right)^{\frac{1}{1-\sigma_{FUEL}}} \quad (11)$$

<u>Variable Definitions</u>

$\bar{\cdot}$: Benchmark value of variable under bar
Y: Joint production of oil and gas
p_y: Unit price of joint output
σ_y: Elasticity of supply for joint oil-gas production
Y_f: Output of fuel f
c_Y: Compliance costs for oil and gas segments
p_f: Unit price of fuel f
α_f: Cost share of fuel f in total production
c_f: Compliance cost applicable to segment f only (gas only)
σ_{FUEL}: Elasticity of substitution across gas and oil output
M_f: Imports of fuel f
σ_f^M: Elasticity of import supply for fuel f
p_f^M: Import price of fuel f
D_f: Total demand for fuel f
σ_f^c: Demand elasticity for fuel f
X_f: Exports of fuel f
σ_f^X: Elasticity of demand for exports of fuel f
D_f^D: Demand for domestically produced fuel f
β_f: Cost share of domestic demand in total demand
p_f^C: Armington aggregation consumption price of fuel f
D_f^M: Demand for imports of fuel f
p_f^M: Import price of fuel f
σ_f^A: Armington elasticity of substitution among domestic and foreign sources of fuel f

Several elasticity values parameterize the partial equilibrium model. Model elasticities dictate oil and gas quantities change in response to changes in market prices. In other words, an elasticity indicates by what percent quantities will change for every percent change in prices. Elasticities are estimated in the literature by applying statistical techniques to historical price and quantity data. The PE model includes 10 elasticities each with a short-medium-term and long-term estimate: 1 for combined oil and gas production activity, 1 for the ability to substitute the mix of oil and gas production, 2 for the supply of imports (one oil, one gas), 4 for domestic and foreign (export) demand (one oil, one gas each), and 2 for the substitution of foreign and domestic sources (one oil, one gas).

We identified long and short-term elasticities from our review of the elasticity literature for oil and gas markets. The literature includes estimates of both long- and short-term elasticities, though these terms are not always explicit or well defined in the literature. The model represents a year's worth of production activity, which is generally consistent with the definitions of short- to medium-run used in the elasticity literature. For later periods in the analysis period, we use higher elasticity values closer to the long-run estimates, where the literature generally defines long-run as time periods on the order of multiple years to decades.

Table 5-4 lists the elasticates identified across supply and demand categories. Production supply elasticities in the literature were disaggregated by fuel source. Substitution elasticities for fuel competition between the supply of oil and gas were assumed zero (i.e., fixed proportions). The domestic supply and demand elasticities are for the United States and selected to be representative of aggregate demand. For example, estimates that cover elasticities from residential natural gas demand or only several states are excluded. These elasticities are a simple average of five short-term supply elasticities and three long-term supply elasticities as no supply elasticities for joint-production were identified in the literature. Import elasticities are taken from global mean supply elasticities and export demand elasticities from global mean demand elasticities. Foreign-domestic substitution elasticities were reported in the literature for oil and gas separately and had either an undefined term-length or were reported as long-term. The PE model takes the average of these values to parameterize short-term and long-term substitution. The PE model's own-price elasticity of domestic demand (consumption) is an average of five literature sources for long-term natural gas elasticities, four sources for long-term oil, seven for short-term gas, and nine for short-term oil elasticity. The literature sources are cited in the source in Table 5-4 and in the Reference section. Short-run supply and demand elasticities are small as it takes time for consumers and producers to adjust their equipment and processes in response to price changes. Longer-term elasticity estimates are generally higher as they capture the increased ability of market participants to change production decisions, install new equipment, revise contract terms, and make other capital and operations adjustments in response to price changes over time. In this analysis, short-term elasticities were applied to the PE model for periods 2024-2025 while long-term elasticities were used for periods 2026-2038.

Table 5-4 PE Model Elasticity Values

	Short-Medium Term		Long Term	
	Gas	**Oil**	**Gas**	**Oil**
Supply				
Production: σ_y	0.02		0.44	
Substitution (oil-gas): σ_{FUEL}	0.0		0.0	
Imports (Foreign): σ_f^M	0.01	0.06	0.19	0.25
Demand				
Exports (Foreign): σ_f^X	-0.01	-0.01	-0.01	-0.26
Substitution (Dom.-For.): σ_f^A	2.80	7.30	2.80	7.30
Consumption: σ_f^C	-0.30	-0.15	-0.68	-0.47

Source: Elasticities are from: Rubaszek, Szafranek, and Uddin (2021); Newell and Prest (2019); Baumeister and Hamilton (2019); Marten and Garbaccio (2018); Labandeira et al. (2017); Ponce and Neumann (2014); Krichene (2005).

As reflected in the elasticity values summarized in Table 5-4, oil and gas markets are relatively inelastic compared to some other markets, particularly in the short-run. With regard to consumption, oil and gas are often consumed for basic needs including heating, transportation, and manufacturing processes. With regard to production, the oil and gas production cycle is relatively long, requiring a number of years to complete lease acquisition, exploration, development, and production. For this reason oil and gas production responds relatively slowly to change in long-term price expectations. These factors may point towards the relatively inelastic nature of oil and gas markets.

5.2.2 Market Impacts

EPA relied on a partial equilibrium simulation model of domestic oil and gas markets with foreign trade to estimate the market impacts of the WEC. The analysis of methane mitigation approach (Section 5.1) produced a national estimate of abatement costs, WEC payments, and emissions reductions over the analysis period. The market analysis conducted here indicates the scale and direction of estimated price and output changes in oil and gas markets resulting from the WEC, which support EPA's assessment of EO 13211 "Actions Concerning Regulations that Significantly Affect Energy Supply, Distribution, or Use."

Together, costs of methane mitigation and WEC payments add to the production costs borne by oil and natural gas operators for the purpose of energy markets modeling. Over the analysis period, methane mitigation costs resulting from the WEC and WEC obligations fall as emissions reductions are required in the baseline by the NSPS/EG. This analysis assumes that cost-effective mitigation options are phased in over three years. Assuming faster adoption of methane mitigation actions would increase costs of methane mitigation and decrease the WEC obligations borne by oil and natural gas firms in the initial years of the analysis.

EPA's approach is to model the market implications of the production costs borne by oil and natural gas firms in aggregate as opposed to trying to capture the individual decisions of each company. However, production cost changes will affect entities in different segments of the oil and gas market leading to differential impacts on oil and gas prices. For example, oil and gas producers will face a portion of the costs that impact both crude and gas production costs while costs faced by natural gas processing facilities, which handle gas but no liquids, will directly impact only natural gas costs.

Cumulative costs borne by upstream segments are applied via the c_y term in Equation (1) as a fraction of total output. Cumulative costs borne by downstream (gas-only) segments are applied via the c_f term in Equation (2). The key outcomes of interest for this analysis are the changes in prices and quantities. These model results will be used to calculate the energy market welfare cost of reduced natural gas production and the change in emissions and WEC payments resulting from changes in output.

Table 5-5 shows the market model results with WEC and abatement costs having a negligible impact on natural gas and crude oil prices with 0.006%~0.007% in the first two years of the analysis period each year of the analysis period. Natural gas and crude oil quantity percentage impacts (not presented) are an also negligible (-0.002%). Baseline projections for prices and quantities for production, imports, and exports are based on the Annual Energy Outlook 2023 reference case. The impact of WEC and abatement cost on natural gas production and prices is significantly smaller than their share relative to production value. For example, in 2024 the 0.07% production cost shock for the gas segment results in a 0.006% price increase. Relatively inelastic supply will lead to lower price changes, all else equal. Much of the cost falls on industry in the short run where elasticities are relatively low and consumer and producer gas quantities are relatively unresponsive to price changes. Natural gas trade is also a relatively small component of the domestic market and inelastic in the short term, meaning it displaces relatively little domestic gas production in response. Gas price and production change by 0.044% and -0.026% respectively while crude oil changes by 0.030% for price and -0.026% for production in

2026 (not presented here). Given WEC and abatement costs are close in 2024-2026, the relatively larger impact in 2026-2027 than in 2024-2005 is due to the shift from short-term to long-term elasticity. With the larger long-term elasticity, oil/gas industry foresees the regulatory cos and have more flexibility to increase price and reduce production. Between 2027-2035, WEC and abatement costs becomes smaller, thus has negligible impact on natural gas and crude prices and quantities, at a level of no more than 0.001% and -0.001%.

Table 5-5 PE Model Outcomes

Year	Price: $/MCF			Quantity: BCF		
	Benchmark	**WEC**	**% Change**	**Benchmark**	**WEC**	**% Change**
2024	5.5055	5.5059	0.006%	35,038	35,038	-0.002%
2025	5.5276	5.5280	0.007%	35,214	35,213	-0.002%
2026	5.5497	5.5521	0.044%	35,390	35,381	-0.026%
2027	5.5719	5.5741	0.041%	35,567	35,558	-0.024%
2028	5.5942	5.5942	0.001%	35,744	35,744	-0.001%
2029	5.6165	5.6166	0.001%	35,923	35,923	0.000%
2030	5.6390	5.6390	0.001%	36,103	36,103	0.000%
2031	5.6616	5.6616	0.001%	36,283	36,283	0.000%
2032	5.6842	5.6842	0.001%	36,465	36,465	0.000%
2033	5.7069	5.7070	0.001%	36,647	36,647	0.000%
2034	5.7298	5.7298	0.001%	36,830	36,830	0.000%
2035	5.7527	5.7527	0.001%	37,014	37,014	0.000%

Output reductions reduce natural gas emissions beyond the methane mitigation actions taken by producers. This analysis applies a sector-wide emissions factor to output changes from the emissions model to estimate this market-induced abatement and the value of WEC payments avoided as a result. These quantities modify the total abatement and WEC payments estimated in Section 5.1. Last, we estimate the cost of energy market impacts (the loss in consumer and producer surplus) associated with the WEC charge as the change in price times the change in quantity.[28] Table 5-6 summarizes the costs of energy market impacts from implementing the WEC in the oil and gas markets, which totals $0.2 to 0.3 million in 2024-2025, $22.00 million in

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[28] This calculation provides an approximate value for the loss of consumer and producer surplus that differs depending on the relative value of the supply and demand elasticities.

2026, $19.08 million in 2027, and less than $0.02 in the later years of the analysis period. The NPV of costs of energy market impacts are $37.6 million at 3% to $33.0 million at 7%.

Table 5-6 Cost of Energy Market Impacts

	Year	Cost of Energy Market Impacts $ Million [a]
	2024	$0.21
	2025	$0.25
	2026	$22.00
	2027	$19.08
	2028	$0.02
	2029	$0.01
	2030	$0.01
	2031	$0.01
	2032	$0.01
	2033	$0.01
	2034	$0.01
	2035	$0.01
NPV	2%	$38.9
	3%	$37.6
	7%	$33.0
EAV	2%	$4.0
	3%	$4.1
	7%	$4.4

[a] Cost of energy market impacts refers to loss in consumer and producer surplus resulting from oil and gas production changes as estimated in the partial equilibrium energy market modeling.

5.3 Emission Impacts

Estimating total methane mitigation and WEC transfer payments includes accounting for baseline emissions (Section 3), voluntary mitigation (Section 5.1), and market-induced mitigation (Section 5.2). The market-induced mitigation estimates in this analysis apply a sector-wide emissions coefficient of 186 metric tons of methane per billion cubic feet of natural gas times the change in market output. This calculation implicitly assumes that reductions in natural gas production occurs at facilities with an average emissions rate equal to the sector average.

The final WEC rule implements a charge for methane emissions that exceed certain thresholds. In practice, emissions from the oil and natural gas industry do not occur as pure methane, but as 'whole gas' or natural gas. Natural gas is composed of methane and certain other chemicals in quantities that vary depending on the natural gas and petroleum industry segment. Natural gas in the production and gathering and boosting segments include a higher proportion of compounds other than methane than gas in the transmission and storage segment. Volatile organic compounds (VOC) and hazardous air pollutants (HAP) emissions are released alongside methane. VOC and HAP emissions present adverse health consequences discussed in Section 6.2. This analysis relies on a prior study of the composition of natural gas in different segments to estimate VOC and HAP abatement likely to occur alongside methane abatement. The prior study of several emissions sources across the natural gas industry estimated that for every metric ton of methane emissions, 0.277 metric tons of VOCs and 0.01 tons of HAPs are emitted in the production sector and 0.028 tons of VOCs and 0.8kg of HAPs are emitted in transmission (Brown, 2011). Table 5-7 summarizes natural gas composition by weight and segment.

Table 5-7 Chemical Composition of Natural Gas by Weight by Segment

	Production	Transmission
Methane	0.695	0.908
VOC	0.193	0.0251
HAP	0.00728	0.00074

Source: Brown, 2011.

Table 5-8 summarizes the annual emissions reductions from abatement activities by pollutant associated with the final WEC rule between 2024 and 2035. The impacts of these pollutants accrue at different spatial scales. HAP emissions increase exposure to carcinogens and other toxic pollutants primarily near the emission source. VOC emissions are precursors to secondary formation of $PM_{2.5}$ and ozone on a broader region. Methane reductions are largest in years 2024 through 2026 as cost-effective mitigation options are phased in prior to EG OOOOc requirements taking effect. After the regulatory compliance exemption takes effect in 2029, emissions reductions resulting from the WEC decline significantly.[29] The remaining reductions

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[29] EPA expects that the WEC would incentivize adoption of mitigation technologies required under the NSPS/EG. The cost analysis uses an annualized cost approach, such that breakeven price calculations involve both operating costs and capital costs spread over the mitigation technology lifetime. The abatement and costs characterized in this RIA only relate to the time period before those technologies would have been adopted in the baseline.

associated with the WEC after 2029 relate to facilities in the offshore production segment, which is not subject to requirements under the NSPS/EG. For context, total reductions average about 33% of WEC-applicable emissions in the baseline before accounting for responses to the WEC. The market-induced component is a small fraction (about one one-hundredth to one one-thousandth) of total abatement.

Table 5-8 Projected Annual Reductions of Methane, VOC, HAP Emissions from Economic Impacts (kt)

	Methane			**VOCs**			**HAPs**		
Year	**Mitigated**	**Market-Induced**	**Total**	**Mitigated**	**Market-Induced**	**Total**	**Mitigated**	**Market-Induced**	**Total**
2024	110	0.1	110	17	0.0	17	0.6	0.0	0.6
2025	220	0.1	220	34	0.0	34	1.2	0.0	1.2
2026	310	1.7	320	47	0.3	48	1.8	0.01	1.8
2027	310	1.6	310	46	0.2	46	1.7	0.01	1.7
2028	42	0.0	42	4.2	0.0	4.2	0.15	0.0	0.15
2029	30	0.0	30	3.0	0.0	3.0	0.11	0.0	0.11
2030	30	0.0	31	3.0	0.0	3.0	0.11	0.0	0.11
2031	31	0.0	31	3.0	0.0	3.0	0.11	0.0	0.11
2032	31	0.0	31	3.0	0.0	3.0	0.11	0.0	0.11
2033	31	0.0	31	3.0	0.0	3.0	0.11	0.0	0.11
2034	31	0.0	31	3.0	0.0	3.0	0.11	0.0	0.11
2035	31	0.0	31	3.0	0.0	3.0	0.11	0.0	0.11
2024	1,200	3.7	1,200	170	0.6	170	6.2	0.0	6.2

Table 5-9 presents details related to the calculation of methane reductions from mitigation using the MACC, further discussed in Appendix C. Total technical abatement potential represents all technology options represented in the model regardless of costs. Cost-effective abatement potential is limited to technology options with breakeven costs less than the WEC. Finally, a phase-in factor is used to account for practical limits in deployment of cost-effective mitigation in the short term. For additional details on the MACC calculations, see section 5.1.

Table 5-9 Methane Mitigation Potential Details

Year	Total Technical Abatement Potential (kt)	Cost-Effective Abatement Below WEC (kt)	Phase-In Factor	Abatement Incl. Phase-In (kt)
2024	632	322	0.33	107
2025	613	330	0.67	220
2026	581	314	1	314
2027	567	309	1	309
2028	42	42	1	42
2029	30	30	1	30
2030	30	30	1	30
2031	31	31	1	31
2032	31	31	1	31
2033	31	31	1	31
2034	31	31	1	31
2035	31	31	1	31

Note: See section 5.1 for details on mitigation modeling and assumptions

5.4 WEC Transfer Payments

This analysis estimates WEC-applicable methane emissions in the policy scenario as baseline WEC-applicable emissions less total methane mitigation. The mitigation comes from a combination of application of methane mitigation options and energy market changes (although the reductions from energy market impacts are quite small relative to methane mitigation). Table 5-10 presents projections of WEC-applicable emissions in the policy scenario as constructed from these components, and projected WEC payments calculated by applying the appropriate WEC amount, depending on the year. Because the WEC amounts ($900 in 2024, $1200 in 2025, and $1500 in 2026 and beyond) are nominal dollar amounts, the WEC obligations in Table 5-10 are expressed in undiscounted nominal dollars.

Table 5-10 Projected WEC Payments in the Policy Scenario, 2024-2035

Year	Net Methane Emissions Subject to WEC in Baseline (thousand metric tons)	Reductions from Methane Mitigation (thousand metric tons)	Reductions from Energy Market Impacts (thousand metric tons)	Net Methane Emissions Subject to WEC in Policy Scenario (thousand metric tons)	Charge Specified by Congress (nominal $ per metric ton)	WEC Payments in Policy Scenario (million undiscounted nominal $)
2024	710	110	0.1	600	$900	$540
2025	680	220	0.1	460	$1,200	$560
2026	650	310	1.7	340	$1,500	$510
2027	630	310	1.6	320	$1,500	$490
2028	77	42	0.05	35	$1,500	$52
2029	34	30	0.03	3	$1,500	$5
2030	33	30	0.03	3	$1,500	$4
2031	33	31	0.03	3	$1,500	$4
2032	33	31	0.03	2	$1,500	$4
2033	33	31	0.03	2	$1,500	$3
2034	32	31	0.03	2	$1,500	$3
2035	32	31	0.03	1	$1,500	$2
Total 2024-2035	3,000	1,200	3.7	1,800		

6 BENEFITS

The final rule is expected to reduce emissions of methane, VOC, and HAP emissions. This section reports the estimated monetized climate benefits associated with the estimated emission reductions. In addition to presenting monetized estimates of impacts from methane reductions, we also provide a qualitative discussion of potential climate, human health, and welfare impacts of emissions reductions we are unable to quantify and monetize.

The section describes the methods used to estimate the climate benefits from reductions of CH_4 emissions. This analysis uses estimates of the social cost of methane (SC-CH_4) to monetize the estimated changes in CH_4 emissions expected to occur over 2024 through 2035 for the final rule. In principle, SC-CH_4 includes the value of all climate change impacts (both negative and positive), including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-CH_4 therefore, reflects the societal value of reducing emissions of SC-CH_4 by one metric ton and is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect CH_4 emissions.

6.1 Climate Benefits Resulting from CH_4 Emission Reductions

We estimate the climate benefits of CH_4 emissions reductions expected from the final rule using estimates of the social cost of methane (SC-CH_4) that reflect recent advances in the scientific literature on climate change and its economic impacts and incorporate recommendations made by the National Academies of Science, Engineering, and Medicine (National Academies, 2017). The EPA published and used these estimates in the RIA for the 2024 Final NSPS/EG (U.S. EPA, 2023a). The EPA solicited public comment on the methodology and use of these estimates in the RIA for the agency's December 2022 NSPS/EG Supplemental Proposal[30] and has conducted an external peer review of these estimates, as described further below.

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[30] See https://www.epa.gov/environmental-economics/scghg for a copy of the final report and other related materials.

The SC-CH_4 is the monetary value of the net harm to society from emitting a metric ton of CH_4 into the atmosphere in a given year, or the benefit of avoiding that increase. In principle, SC-CH_4 is a comprehensive metric that includes the value of all future climate change impacts (both negative and positive), including changes in net agricultural productivity, human health effects, property damage from increased flood risk, changes in the frequency and severity of natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-CH_4, therefore, reflects the societal value of reducing CH_4 emissions by one metric ton and is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect CH_4 emissions. In practice, data and modeling limitations restrain the ability of SC-CH_4 estimates to include all physical, ecological, and economic impacts of climate change, implicitly assigning a value of zero to the omitted climate damages. The estimates are, therefore, a partial accounting of climate change impacts and likely underestimate the marginal benefits of abatement.

Since 2008, the EPA has used estimates of the social cost of various greenhouse gases (i.e., social cost of carbon (SC-CO_2), social cost of methane (SC-CH_4), and social cost of nitrous oxide (SC-N_2O)), collectively referred to as the “social cost of greenhouse gases” (SC-GHG), in analyses of actions that affect GHG emissions. The values used by the EPA from 2009 to 2016, and since 2021 have been consistent with those developed and recommended by the Interagency Working Group on the SC-GHG (IWG); and the values used from 2017 to 2020 were consistent with those required by E.O. 13783, which disbanded the IWG. During 2015–2017, the National Academies conducted a comprehensive review of the SC-CO_2 and issued a final report in 2017 recommending specific criteria for future updates to the SC-CO_2 estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process (National Academies, 2017). The IWG was reconstituted in 2021 and E.O. 13990 directed it to develop a comprehensive update of its SC-GHG estimates, recommendations regarding areas of decision-making to which SC-GHG should be applied, and a standardized review and updating process to ensure that the recommended estimates continue to be based on the best available economics and science going forward.

The EPA is a member of the IWG and is participating in the IWG’s work under E.O. 13990. While that process continues, as noted in previous EPA RIAs, the EPA is continuously reviewing developments in the scientific literature on the SC-GHG, including more robust methodologies for estimating damages from emissions, and looking for opportunities to further improve SC-GHG estimation going forward.[31] In the December 2022 Oil and Gas Supplemental Proposal NSPS RIA, the Agency included a sensitivity analysis of the climate benefits of the Supplemental Proposal using a new set of SC-GHG estimates that incorporates recent research addressing recommendations of the National Academies (2017) in addition to using the interim SC-GHG estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (2021) that the IWG recommended for use until updated estimates that address the National Academies' recommendations are available

The EPA solicited public comment on the sensitivity analysis and the accompanying draft technical report, *EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*, which explains the methodology underlying the new set of estimates, in the December 2022 Supplemental Oil and Gas Proposal.[32] The response to comments document can be found in the docket for that action.

To ensure that the methodological updates adopted in the technical report are consistent with economic theory and reflect the latest science, the EPA also initiated an external peer review panel to conduct a high-quality review of the technical report, completed in May 2023. See 88 FR at 26075/2 noting this peer review process. The peer reviewers commended the agency on its development of the draft update, calling it a much-needed improvement in estimating the SC-GHG and a significant step towards addressing the National Academies' recommendations with defensible modeling choices based on current science. The peer reviewers provided numerous recommendations for refining the presentation and for future modeling improvements, especially with respect to climate change impacts and associated damages that are not currently included in the analysis. Additional discussion of omitted impacts and other updates have been incorporated in the technical report to address peer reviewer recommendations. Complete information about the external peer review, including the peer

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[31] EPA strives to base its analyses on the best available science and economics, consistent with its responsibilities, for example, under the Information Quality Act.

[32] See https://www.epa.gov/environmental-economics/scghg for a copy of the final report and other related materials.

reviewer selection process, the final report with individual recommendations from peer reviewers, and the EPA's response to each recommendation is available on EPA's website.[33]

The remainder of this section provides an overview of the methodological updates incorporated into the SC-GHG estimates used in this RIA. A more detailed explanation of each input and the modeling process is provided in the technical report, *Supplementary Material for the RIA: EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances* (U.S. EPA, 2023b).

The steps necessary to estimate the SC-GHG with a climate change integrated assessment model (IAM) can generally be grouped into four modules: socioeconomics and emissions, climate, damages, and discounting. The emissions trajectories from the socioeconomic module are used to project future temperatures in the climate module. The damage module then translates the temperature and other climate endpoints (along with the projections of socioeconomic variables) into physical impacts and associated monetized economic damages, where the damages are calculated as the amount of money the individuals experiencing the climate change impacts would be willing to pay to avoid them. To calculate the marginal effect of emissions, i.e., the SC-GHG in year t, the entire model is run twice – first as a baseline and second with an additional pulse of emissions in year t. After recalculating the temperature effects and damages expected in all years beyond t resulting from the adjusted path of emissions, the losses are discounted to a present value in the discounting module. Many sources of uncertainty in the estimation process are incorporated using Monte Carlo techniques by taking draws from probability distributions that reflect the uncertainty in parameters.

The SC-GHG estimates used by the EPA and many other federal agencies since 2009 have relied on an ensemble of three widely used IAMs: Dynamic Integrated Climate and Economy (DICE) (Nordhaus, 2010); Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) (Anthoff & Tol, 2013a, 2013b); and Policy Analysis of the Greenhouse Gas Effect (PAGE) (Hope, 2013). In 2010, the IWG harmonized key inputs across the IAMs, but all other model features were left unchanged, relying on the model developers' best estimates

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[33] https://www.epa.gov/environmental-economics/scghg-tsd-peer-review

and judgments. That is, the representation of climate dynamics and damage functions included in the default version of each IAM as used in the published literature was retained.

The SC-GHG estimates in this RIA no longer rely on the three IAMs (i.e., DICE, FUND, and PAGE) used in previous SC-GHG estimates. Instead, EPA uses a modular approach to estimating the SC-GHG, consistent with the National Academies' 2017 near-term recommendations. That is, the methodology underlying each component, or module, of the SC-GHG estimation process is developed by drawing on the latest research and expertise from the scientific disciplines relevant to that component. Under this approach, each step in the SC-GHG estimation improves consistency with the current state of scientific knowledge, enhances transparency, and allows for more explicit representation of uncertainty.

The socioeconomic and emissions module relies on a new set of probabilistic projections for population, income, and GHG emissions developed under the Resources for the Future (RFF) Social Cost of Carbon Initiative (Rennert, Prest, et al., 2022). These socioeconomic projections (hereafter collectively referred to as the RFF-SPs) are an internally consistent set of probabilistic projections of population, GDP, and GHG emissions (CO_2, CH_4, and N_2O) to 2300. Based on a review of available sources of long-run projections necessary for damage calculations, the RFF-SPs stand out as being most consistent with the National Academies' recommendations. Consistent with the National Academies' recommendation, the RFF-SPs were developed using a mix of statistical and expert elicitation techniques to capture uncertainty in a single probabilistic approach, taking into account the likelihood of future emissions mitigation policies and technological developments, and provide the level of disaggregation necessary for damage calculations. Unlike other sources of projections, they provide inputs for estimation out to 2300 without further extrapolation assumptions. Conditional on the modeling conducted for the SC-GHG estimates, this time horizon is far enough in the future to capture the majority of discounted climate damages. Including damages beyond 2300 would increase the estimates of the SC-GHG. As discussed in (U.S. EPA, 2023b), the use of the RFF-SPs allows for capturing economic growth uncertainty within the discounting module.

The climate module relies on the Finite Amplitude Impulse Response (FaIR) model (IPCC, 2021b; Millar et al., 2017; Smith et al., 2018), a widely used Earth system model which captures the relationships between GHG emissions, atmospheric GHG concentrations, and global mean surface temperature. The FaIR model was originally developed by Richard Millar, Zeb Nicholls, and Myles Allen at Oxford University, as a modification of the approach used in IPCC AR5 to assess the GWP and GTP (Global Temperature Potential) of different gases. It is open source, widely used (e.g., IPCC (2018, 2021a)), and was highlighted by the (National Academies, 2017) as a model that satisfies their recommendations for a near-term update of the climate module in SC-GHG estimation. Specifically, it translates GHG emissions into mean surface temperature response and represents the current understanding of the climate and GHG cycle systems and associated uncertainties within a probabilistic framework. The SC-GHG estimates used in this RIA rely on FaIR version 1.6.2 as used by the IPCC (2021a). It provides, with high confidence, an accurate representation of the latest scientific consensus on the relationship between global emissions and global mean surface temperature, offers a code base that is fully transparent and available online, and the uncertainty capabilities in FaIR 1.6.2 have been calibrated to the most recent assessment of the IPCC (which importantly narrowed the range of likely climate sensitivities relative to prior assessments). See U.S. EPA (2023a) for more details.

The socioeconomic projections and outputs of the climate module are inputs into the damage module to estimate monetized future damages from climate change.[34] The National Academies' recommendations for the damage module, scientific literature on climate damages, updates to models that have been developed since 2010, as well as the public comments received on individual EPA rulemakings and the IWG's February 2021 TSD, have all helped to identify available sources of improved damage functions. The IWG (e.g., IWG 2010, 2016a, 2021), the National Academies (2017), comprehensive studies (e.g., Rose et al. (2014)), and public comments have all recognized that the damages functions underlying the IWG SC-GHG estimates used since 2013 (taken from DICE 2010 (Nordhaus, 2010); FUND 3.8 (Anthoff & Tol, 2013a, 2013b); and PAGE 2009 (Hope, 2013)) do not include all the important physical, ecological, and economic impacts of climate change. The climate change literature and the

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[34] In addition to temperature change, two of the three damage modules used in the SC-GHG estimation require global mean sea level (GMSL) projections as an input to estimate coastal damages. Those two damage modules use different models for generating estimates of GMSL. Both are based off reduced complexity models that can use the FaIR temperature outputs as inputs to the model and generate projections of GMSL accounting for the contributions of thermal expansion and glacial and ice sheet melting based on recent scientific research. Absent clear evidence on a preferred model, the SC-GHG estimates presented in this RIA retain both methods used by the damage module developers. See U.S. EPA (2023a).for more detail.

science underlying the economic damage functions have evolved, and DICE 2010, FUND 3.8, and PAGE 2009 now lag behind the most recent research.

The challenges involved with updating damage functions have been widely recognized. Functional forms and calibrations are constrained by the available literature and need to extrapolate beyond warming levels or locations studied in that literature. Research focused on understanding how these physical changes translate into economic impacts is still developing, and has received less public resources, relative to the research focused on modeling and improving our understanding of climate system dynamics and the physical impacts from climate change (Auffhammer, 2018). Even so, there has been a large increase in research on climate impacts and damages in the time since DICE 2010, FUND 3.8, and PAGE 2009 were published. Along with this growth, there continues to be variation in methodologies and scope of studies, such that care is required when synthesizing the current understanding of impacts or damages. Based on a review of available studies and approaches to damage function estimation, the EPA uses three separate damage functions to form the damage module. They are:

A subnational-scale, sectoral damage function (based on the Data-driven Spatial Climate Impact Model (DSCIM) developed by the Climate Impact Lab (Carleton et al., 2022; Climate Impact Lab (CIL), 2023; Rode et al., 2021), a country-scale, sectoral damage function (based on the Greenhouse Gas Impact Value Estimator (GIVE) model developed under RFF's Social Cost of Carbon Initiative (Rennert, Errickson, et al., 2022), and a meta-analysis-based damage function (based on Howard and Sterner (2017)). The damage functions in DSCIM and GIVE represent substantial improvements relative to the damage functions underlying the SC-GHG estimates used by the EPA to date and reflect the forefront of scientific understanding about how temperature change and SLR lead to monetized net (market and nonmarket) damages for several categories of climate impacts. The models' spatially explicit and impact-specific modeling of relevant processes allows for improved understanding and transparency about mechanisms through which climate impacts are occurring and how each damage component contributes to the overall results, consistent with the National Academies' recommendations. DSCIM addresses common criticisms related to the damage functions underlying current SC-GHG estimates (e.g., Pindyck (2017)) by developing multi-sector, empirically grounded damage functions. The damage functions in the GIVE model offer a direct implementation of the National Academies' near-term recommendation to develop updated sectoral damage functions that are based on recently published work and reflective of the current state of knowledge about damages in each sector. Specifically, the National Academies noted that "[t]he literature on agriculture, mortality, coastal damages, and energy demand provide immediate opportunities to update the [models]" (National Academies 2017, p. 199), which are the four damage categories currently in GIVE. A limitation of both models is that the sectoral coverage is still limited, and even the categories that are represented are incomplete. Neither DSCIM nor GIVE yet accommodate estimation of several categories of temperature driven climate impacts (e.g., morbidity, conflict, migration, biodiversity loss) and only represent a limited subset of damages from changes in precipitation. For example, while precipitation is considered in the agriculture sectors in both DSCIM and GIVE, neither model takes into account impacts of flooding, changes in rainfall from tropical storms, and other precipitation related impacts. As another example, the coastal damage estimates in both models do not fully reflect the consequences of SLR-driven salt-water intrusion and erosion, or SLR damages to coastal tourism and recreation. Other missing elements are damages that result from other physical impacts (e.g., ocean acidification, non-temperature-related mortality such as diarrheal disease and malaria) and the many feedbacks and interactions across sectors and regions that can lead to additional damages.[35] See U.S. EPA (2023a) for more discussion of omitted damage categories and other modeling limitations. DSCIM and GIVE do account for the most commonly cited benefits associated with CO_2 emissions and climate change — CO_2 crop fertilization and declines in cold related mortality. As such, while the GIVE- and DSCIM-based results provide state-of-the-science assessments of key climate change impacts, they remain partial estimates of future climate damages resulting from incremental changes in CO_2, CH_4, and N_2O.[36]

Finally, given the still relatively narrow sectoral scope of the recently developed DSCIM and GIVE models, the damage module includes a third damage function that reflects a synthesis of the state of knowledge in other published climate damages literature. Studies that employ meta-analytic techniques offer a tractable and straightforward way to combine the results of multiple studies into a single damage function that represents the body of evidence on climate

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[35] The one exception is that the agricultural damage function in DSCIM and GIVE reflects the ways that trade can help mitigate damages arising from crop yield impacts.

[36] One advantage of the modular approach used by these models is that future research on new or alternative damage functions can be incorporated in a relatively straightforward way. DSCIM and GIVE developers have work underway on other impact categories that may be ready for consideration in future updates (e.g., morbidity and biodiversity loss).

damages that pre-date CIL and RFF's research initiatives.[37] The first use of meta-analysis to combine multiple climate damage studies was done by Tol (2009) and included 14 studies. The studies in Tol (2009) served as the basis for the global damage function in DICE starting in version 2013R (Nordhaus, 2014). The damage function in the most recent published version of DICE, DICE 2016, is from an updated meta-analysis based on a rereview of existing damage studies and included 26 studies published over 1994-2013 (Nordhaus & Moffat, 2017). Howard and Sterner (2017) provide a more recent published peer-reviewed meta-analysis of existing damage studies (published through 2016) and account for additional features of the underlying studies. They address differences in measurement across studies by adjusting estimates such that the data are relative to the same base period. They also eliminate double counting by removing duplicative estimates. Howard and Sterner's final sample is drawn from 20 studies that were published through 2015. Howard and Sterner (2017) present results under several specifications, and their analysis shows that the estimates are somewhat sensitive to defensible alternative modeling choices. As discussed in detail in U.S. EPA (2023a), the damage module underlying the SC-GHG estimates in this RIA includes the damage function specification (that excludes duplicate studies) from Howard and Sterner (2017) that leads to the lowest SC-GHG estimates, all else equal.

The discounting module discounts the stream of future net climate damages to its present value in the year when the additional unit of emissions was released. Given the long-time horizon over which the damages are expected to occur, the discount rate has a large influence on the present value of future damages. Consistent with the findings of National Academies (2017), the economic literature, OMB Circular A-4's guidance for regulatory analysis, and IWG recommendations to date (IWG, 2010, 2013, 2016a, 2016b, 2021), the EPA continues to conclude that the consumption rate of interest is the theoretically appropriate discount rate to discount the future benefits of reducing GHG emissions and that discount rate uncertainty should be accounted for in selecting future discount rates in this intergenerational context. OMB's Circular A-4 (2003) points out that "the analytically preferred method of handling temporal differences between benefits and costs is to adjust all the benefits and costs to reflect their value

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[37] Meta-analysis is a statistical method of pooling data and/or results from a set of comparable studies of a problem. Pooling in this way provides a larger sample size for evaluation and allows for a stronger conclusion than can be provided by any single study. Meta-analysis yields a quantitative summary of the combined results and current state of the literature.

in equivalent units of consumption and to discount them at the rate consumers and savers would normally use in discounting future consumption benefits" (OMB, 2003).[38] The damage module described above calculates future net damages in terms of reduced consumption (or monetary consumption equivalents), and so an application of this guidance is to use the consumption discount rate to calculate the SC-GHG. Thus, EPA concludes that the use of the discount rate estimated using the average return on capital (7 percent in OMB Circular A-4 (2003)), which does not reflect the consumption rate, to discount damages estimated in terms of reduced consumption would inappropriately underestimate the impacts of climate change for the purposes of estimating the SC-GHG.[39]

For the SC-GHG estimates used in this RIA, EPA relies on a dynamic discounting approach that more fully captures the role of uncertainty in the discount rate in a manner consistent with the other modules. Based on a review of the literature and data on consumption discount rates, the public comments received on individual EPA rulemakings, and the February 2021 TSD (IWG, 2021), and the National Academies (2017) recommendations for updating the discounting module, the SC-GHG estimates rely on discount rates that reflect more recent data on the consumption interest rate and uncertainty in future rates. Specifically, rather than using a constant discount rate, the evolution of the discount rate over time is defined following the latest empirical evidence on interest rate uncertainty and using a framework originally developed by Ramsey (1928) that connects economic growth and interest rates. The Ramsey approach explicitly reflects (1) preferences for utility in one period relative to utility in a later period and (2) the value of additional consumption as income changes. The dynamic discount rates used to develop the SC-GHG estimates applied in this RIA have been calibrated following the Newell et al. (2022) approach, as applied in Rennert, Errickson, et al. (2022); Rennert, Prest, et al. (2022). This approach uses the Ramsey (1928) discounting formula in which the parameters are calibrated such that (1) the decline in the certainty-equivalent discount rate matches the latest empirical evidence on interest rate uncertainty estimated by Bauer and Rudebusch (2020, 2023) and (2) the average of the certainty-equivalent discount rate over the first decade matches a near-

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[38] Similarly, OMB's Circular A-4 (2023) points out that "The analytically preferred method of handling temporal differences between benefits and costs is to adjust all the benefits and costs to reflect their value in equivalent units of consumption before discounting them" (OMB 2023).

[39] See also the discussion of the inappropriateness of discounting consumption-equivalent measures of benefits and costs using a rate of return on capital in Circular A-4 (OMB 2023).

term consumption rate of interest. Uncertainty in the starting rate is addressed by using three near-term target rates (1.5, 2.0, and 2.5 percent) based on multiple lines of evidence on observed market interest rates.

The resulting dynamic discount rate provides a notable improvement over the constant discount rate framework used for SC-GHG estimation in previous EPA RIAs. Specifically, it provides internal consistency within the modeling and a more complete accounting of uncertainty consistent with economic theory (Arrow et al., 2013; Cropper et al., 2014) and the National Academies' (2017) recommendation to employ a more structural, Ramsey-like approach to discounting that explicitly recognizes the relationship between economic growth and discounting uncertainty. This approach is also consistent with the National Academies (2017) recommendation to use three sets of Ramsey parameters that reflect a range of near-term certainty-equivalent discount rates and are consistent with theory and empirical evidence on consumption rate uncertainty. Finally, the value of aversion to risk associated with net damages from GHG emissions is explicitly incorporated into the modeling framework following the economic literature. See U.S. EPA (2023a) for a more detailed discussion of the entire discounting module and methodology used to value risk aversion in the SC-GHG estimates.

Taken together, the methodologies adopted in this SC-GHG estimation process allow for a more holistic treatment of uncertainty than in past estimates by the EPA. The updates incorporate a quantitative consideration of uncertainty into all modules and use a Monte Carlo approach that captures the compounding of uncertainties across modules. The estimation process generates nine separate distributions of discounted marginal damages per metric ton – the product of using three damage modules and three near-term target discount rates – for each gas in each emissions year. These distributions have long right tails reflecting the extensive evidence in the scientific and economic literature that shows the potential for lower-probability but higher-impact outcomes from climate change, which would be particularly harmful to society. The uncertainty grows over the modeled time horizon. Therefore, under cases with a lower near-term target discount rate – that give relatively more weight to impacts in the future – the distribution of results is wider. To produce a range of estimates that reflects the uncertainty in the estimation exercise while also providing a manageable number of estimates for policy analysis, the EPA combines the multiple lines of evidence on damage modules by averaging the results across the three damage module specifications. The full results generated from the updated methodology for methane and other greenhouse gases (SC-CO_2, SC-CH_4, and SC-N_2O) for emissions years 2020 through 2080 are provided in U.S. EPA (2023a).

Table 6-1 summarizes the resulting averaged certainty-equivalent SC-CH_4 estimates under each near-term discount rate that are used to estimate the climate benefits of the CH_4 emission reductions expected from the final rule. These estimates are reported in 2019 dollars but are otherwise identical to those presented in U.S. EPA (2023a). The SC-CH_4 increases over time within the models — i.e., the societal harm from one metric ton emitted in 2030 is higher than the harm caused by one metric ton emitted in 2024 — because future emissions produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change, and because GDP is growing over time and many damage categories are modeled as proportional to GDP.

Table 6-1 Estimates of the Social Cost of CH_4, 2024-2035 (in 2019$ per metric ton CH_4)

	Near-Term Ramsey Discount Rate		
Year	**1.5%**	**2.0%**	**2.5%**
2024	$2,600	$1,900	$1,500
2025	$2,700	$2,000	$1,600
2026	$2,800	$2,100	$1,600
2027	$2,900	$2,200	$1,700
2028	$3,000	$2,200	$1,800
2029	$3,000	$2,300	$1,800
2030	$3,100	$2,400	$1,900
2031	$3,200	$2,500	$2,000
2032	$3,300	$2,500	$2,100
2033	$3,400	$2,600	$2,100
2034	$3,500	$2,700	$2,200
2035	$3,600	$2,800	$2,300

Source: U.S. EPA (2023a).

Note: These SC-CH_4 values are identical to those reported in the technical report U.S. EPA (2023a) adjusted for inflation to 2019 dollars using the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9. The values are stated in $/metric ton CH_4 and vary depending on the year of CH_4 emissions. This table displays the values rounded to two significant figures. The annual unrounded values used in the calculations in this RIA are available in Appendix A.5 of U.S. EPA (2023a) and at: www.epa.gov/environmental-economics/scghg.

The methodological updates described above represent a major step forward in bringing SC-GHG estimation closer to the frontier of climate science and economics and address many of the National Academies' (2017) near-term recommendations. Nevertheless, the resulting SC-

GHG estimates, including the SC-CH_4 estimates presented in Table 6-1, still have several limitations, as would be expected for any modeling exercise that covers such a broad scope of scientific and economic issues across a complex global landscape. There are still many categories of climate impacts and associated damages that are only partially or not reflected yet in these estimates and sources of uncertainty that have not been fully characterized due to data and modeling limitations. For example, the modeling omits most of the consequences of changes in precipitation, damages from extreme weather events, the potential for nongradual damages from passing critical thresholds (e.g., tipping elements) in natural or socioeconomic systems, and non-climate mediated effects of GHG emissions. The SC-CH_4 estimates do not account for the direct health and welfare impacts associated with tropospheric ozone produced by methane. As discussed further in U.S. EPA (2023a), recent studies have found the global ozone-related respiratory mortality benefits of CH_4 emissions reductions, which are not included in the SC-CH_4 values presented in Table 6-1, to be, in 2019 dollars, approximately $2,400 per metric ton of methane emissions in 2030 (McDuffie et al., 2023). In addition, the SC-CH_4 estimates do not reflect that methane emissions lead to a reduction in atmospheric oxidants, like hydroxyl radicals, nor do they account for impacts associated with CO_2 produced from methane oxidizing in the atmosphere. Importantly, the updated SC-GHG methodology does not yet reflect interactions and feedback effects within, and across, Earth and human systems. For example, it does not explicitly reflect potential interactions among damage categories, such as those stemming from the interdependencies of energy, water, and land use. These, and other, interactions and feedbacks were highlighted by the National Academies as an important area of future research for longer-term enhancements in the SC-GHG estimation framework.

Tables 6-2 through 6-4 present the annual, monetized climate benefits under the final WEC. Projected methane emissions reductions each year are multiplied by the SC-CH_4 estimate for that year from Table 6-1. Table 6-5 shows the annual climate benefits discounted back to 2023 and the PV and the EAV for the 2024–2035 period under each discount rate. In this analysis, to calculate the present and annualized values of climate benefits, EPA uses the same discount rate as the near-term target Ramsey rate used to discount the climate benefits from future CH_4 reductions. That is, future climate benefits estimated with the SC-CH_4 at the near-term 2 percent Ramsey rate are discounted to the base year of the analysis using the same 2 percent rate.[40]

Table 6-2 Undiscounted Monetized Climate Benefits from Methane Mitigation under the WEC, 2024–2035 (millions, 2019$)

	Near-Term Ramsey Discount Rate (Annual Undiscounted)		
Year	**1.5%**	**2%**	**2.5%**
2024	$280	$210	$160
2025	$590	$440	$350
2026	$880	$650	$510
2027	$890	$670	$530
2028	$120	$94	$75
2029	$93	$70	$56
2030	$96	$72	$58
2031	$99	$75	$60
2032	$100	$78	$63
2033	$110	$81	$65
2034	$110	$84	$68
2035	$110	$86	$70

Note: Estimates may not sum due to independent rounding.

[a] Climate benefits are based on changes (reductions) in CH_4 emissions and are calculated using updated estimates of the SC-CH_4 from U.S. EPA (2023a).

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[40] As discussed in U.S. EPA. (2023a) the error associated with using a constant discount rate rather than the certainty-equivalent rate path to calculate the present value of a future stream of monetized climate benefits is small for analyses with moderate time frames (e.g., 30 years or less). EPA (2023a) also provides an illustration of the amount that climate benefits from reductions in future emissions will be underestimated by using a constant discount rate relative to the more complicated certainty-equivalent rate path.

Table 6-3 Undiscounted Monetized Climate Benefits from Partial Equilibrium Model under the WEC, 2024–2035 (millions, 2019$)

	Near-Term Ramsey Discount Rate (Annual Undiscounted) [a]		
Year	**1.5%**	**2%**	**2.5%**
2024	$0.3	$0.2	$0.2
2025	$0.3	$0.2	$0.2
2026	$4.7	$3.5	$2.8
2027	$4.6	$3.4	$2.7
2028	$0.1	$0.1	$0.1
2029	$0.1	$0.1	$0.1
2030	$0.1	$0.1	$0.1
2031	$0.1	$0.1	$0.1
2032	$0.1	$0.1	$0.1
2033	$0.1	$0.1	$0.1
2034	$0.1	$0.1	$0.1
2035	$0.1	$0.1	$0.1

Note: Estimates may not sum due to independent rounding.

[a] Climate benefits are based on changes (reductions) in CH_4 emissions and are calculated using updated estimates of the SC-CH_4 from U.S. EPA (2023a).

Table 6-4 Undiscounted Total Monetized Climate Benefits under the WEC, 2024–2035 (millions, 2019$)

	Near-Term Ramsey Discount Rate (Annual Undiscounted)[a]		
Year	**1.5%**	**2%**	**2.5%**
2024	$280	$210	$160
2025	$590	$440	$350
2026	$880	$660	$520
2027	$890	$670	$530
2028	$130	$94	$75
2029	$93	$70	$56
2030	$96	$72	$58
2031	$99	$75	$61
2032	$100	$78	$63
2033	$110	$81	$65
2034	$110	$84	$68
2035	$110	$86	$70

Note: Estimates may not sum due to independent rounding.

[a] Climate benefits are based on changes (reductions) in CH_4 emissions and are calculated using updated estimates of the SC-CH_4 from U.S. EPA (2023a).

Table 6-5 Discounted Monetized Climate Benefits under the WEC, 2024–2035 (millions, 2019$)

	Discounted back to 2023[a]		
Year	**1.5%**	**2%**	**2.5%**
2024	$280	$200	$160
2025	$580	$420	$330
2026	$840	$620	$480
2027	$840	$620	$480
2028	$120	$85	$66
2029	$85	$62	$48
2030	$86	$63	$49
2031	$88	$64	$50
2032	$89	$65	$50
2033	$91	$66	$51
2034	$92	$67	$52
2035	$93	$68	$52
PV	$3,300	$2,400	$1,900
EAV	$300	$230	$180

Note: Estimates may not sum due to independent rounding.

[a] Climate benefits are based on changes (reductions) in CH_4 emissions and are calculated using updated estimates of the SC-CH_4 from U.S. EPA (2023a).

Unlike many environmental problems where the causes and impacts are distributed more locally, GHG emissions are a global externality making climate change a true global challenge. GHG emissions contribute to damages around the world regardless of where they are emitted. Because of the distinctive global nature of climate change, in the RIA for this final rule the EPA centers attention on a global measure of climate benefits from CH_4 reductions. Consistent with all IWG recommended SC-GHG estimates to date, the SC-CH_4 values presented in Table 6-1 provide a global measure of monetized damages from CH_4 emissions, and Tables 6-2 through 6-5 present the monetized global climate benefits of the CH_4 emission reductions expected from the final rule. This approach is the same as that taken in EPA regulatory analyses from 2009 through 2016 and since 2021. It is also consistent with guidance in OMB Circular A-4 (2003, 2023) that recommends reporting of important international effects.[41] EPA also notes that EPA's

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[41] The 2003 version of OMB Circular A-4 states when a regulation is likely to have international effects, "these effects should be reported"; while OMB Circular A-4 recommends that international effects we reported separately, the guidance also explains that "[d]ifferent regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues." (OMB, 2003).

The 2023 update to Circular A-4 states that "In certain contexts, it may be particularly appropriate to include effects experienced by noncitizens residing abroad in your primary analysis. Such contexts include, for example, when:

cost estimates in RIAs, including the cost estimates contained in this RIA, regularly do not differentiate between the share of compliance costs expected to accrue to U.S. firms versus foreign interests, such as to foreign investors in regulated entities.[42] A global perspective on climate effects is therefore consistent with the approach EPA takes on costs. There are many reasons, as summarized in this section — and as articulated by OMB and in IWG assessments (IWG 2010, 2013, 2016a, 2016b, 2021), the 2015 Response to Comments (IWG 2015), and in detail in EPA (2023a) and in Appendix A of the Response to Comments document for the 2024 Final Oil and Gas NSPS/EG — why the EPA focuses on the global value of climate change impacts when analyzing policies that affect GHG emissions.

International cooperation and reciprocity are essential to successfully addressing climate change, as the global nature of greenhouse gases means that a ton of GHGs emitted in any other country harms those in the U.S. just as much as a ton emitted within the territorial U.S. Assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. This is 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. The only way to achieve an efficient allocation of resources for

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- assessing effects on noncitizens residing abroad provides a useful proxy for effects on U.S. citizens and residents that are difficult to otherwise estimate;
- assessing effects on noncitizens residing abroad provides a useful proxy for effects on U.S. national interests that are not otherwise fully captured by effects experienced by particular U.S. citizens and residents (e.g., national security interests, diplomatic interests, etc.);
- regulating an externality on the basis of its global effects supports a cooperative international approach to the regulation of the externality by potentially inducing other countries to follow suit or maintain existing efforts; or
- international or domestic legal obligations require or support a global calculation of regulatory effects" (OMB 2023). Due to the global nature of the climate change problem, the OMB recommendations of appropriate contexts for considering international effects are relevant to the CO_2 emission reductions expected from the final rule. For example, as discussed in this RIA, a global focus in evaluating the climate impacts of changes in CO_2 emissions supports a cooperative international approach to GHG mitigation by potentially inducing other countries to follow suit or maintain existing efforts, and the global SC-CO_2 estimates better capture effects on U.S. citizens and residents and U.S. national interests that are difficult to estimate and not otherwise fully captured.

[42] For example, in the RIA for the 2018 Proposed Reconsideration of the Oil and Natural Gas Sector Emission Standards for New, Reconstructed, and Modified Sources, the EPA acknowledged that some portion of regulatory costs will likely "accru[e] to entities outside U.S. borders" through foreign ownership, employment, or consumption (EPA 2018, p. 3-13). In general, a significant share of U.S. corporate debt and equities are foreign-owned, including in the oil and gas industry.

emissions reduction on a global basis — and so benefit the U.S. and its citizens and residents — is for *all* countries to base their policies on global estimates of damages. A wide range of scientific and economic experts have emphasized the issue of international cooperation and reciprocity as support for assessing global damages of GHG emission in domestic policy analysis. Using a global estimate of damages in U.S. analyses of regulatory actions allows the U.S. to continue to actively encourage other nations, including emerging major economies, to also assess global climate damages of their policies and to take steps to reduce emissions. For example, many countries and international institutions have already explicitly adapted the global SC-GHG estimates used by EPA in their domestic analyses (e.g., Canada, Israel) or developed their own estimates of global damages (e.g., Germany), and recently, there has been renewed interest by other countries to update their estimates since the draft release of the updated SC-GHG estimates presented in the December 2022 Oil and Gas NSPS/EG Supplemental Proposal RIA.[43] Several recent studies have empirically examined the evidence on international GHG mitigation reciprocity, through both policy diffusion and technology diffusion effects. See U.S. EPA (2023a) for more discussion.

For all of these reasons, the EPA believes that a global metric is appropriate for assessing the climate benefits of avoided methane emissions in this final RIA. In addition, as emphasized in the National Academies (2017) recommendations, “[i]t is important to consider what constitutes a domestic impact in the case of a global pollutant that could have international implications that impact the United States.” The global nature of GHG pollution and its impacts means that U.S. interests are affected by climate change impacts through a multitude of pathways and these need to be considered when evaluating the benefits of GHG mitigation to U.S. citizens and residents. The increasing interconnectedness of global economy and populations means that impacts occurring outside of U.S. borders can have significant impacts on U.S. interests. Examples of affected interests include direct effects on U.S. citizens and assets located abroad, international trade, and tourism, and spillover pathways such as economic and political destabilization and global migration that can lead to adverse impacts on U.S. national security,

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[43] In April 2023, the government of Canada announced the publication of an interim update to their SC-GHG guidance, recommending SC-GHG estimates identical to the EPA’s updated estimates presented in the December 2022 Supplemental Proposal RIA. The Canadian interim guidance will be used across all federal departments and agencies, with the values expected to be finalized by the end of the year. https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-cost-ghg.html.

public health, and humanitarian concerns. Those impacts point to the global nature of the climate change problem and are better captured within global measures of the social cost of greenhouse gases.

In the case of this global pollutant, for the reasons articulated in this section, the assessment of global net damages of GHG emissions allows EPA to fully disclose and contextualize the net climate benefits of the CH_4 emission reductions expected from this final rule. The EPA disagrees with commenters on the December 2022 Oil and Gas NSPS/EG Supplemental Proposal that suggested that the EPA can or should use a metric focused on benefits resulting solely from changes in climate impacts occurring within U.S. borders. The global models used in the SC-GHG modeling described above do not lend themselves to be disaggregated in a way that could provide comprehensive information about the distribution of the rule's climate benefits to citizens and residents of particular countries, or population groups across the globe and within the U.S. Two of the models used to inform the damage module, the GIVE and DSCIM models, have spatial resolution that allows for some geographic disaggregation of a subset of climate impacts across the world. This permits the calculation of a partial GIVE and DSCIM-based SC-GHG measuring the damages from four or five climate impact categories (respectively) projected to physically occur within the U.S., subject to caveats. As discussed at length in U.S. EPA (2023a) these damage modules are only a partial accounting and do not capture many significant pathways through which climate change affects public health and welfare. For example, this modeling omits most of the consequences of changes in precipitation, damages from extreme weather events (e.g., wildfires), the potential for nongradual damages from passing critical thresholds (e.g., tipping elements) in natural or socioeconomic systems, and non-climate mediated effects of GHG emissions other than CO_2 fertilization (e.g., tropospheric ozone formation due to CH_4 emissions). Thus, this modeling only cover a subset of potential climate change impacts. Furthermore, the damage modules do not capture spillover or indirect effects whereby climate impacts in one country or region can affect the welfare of residents in other countries or regions — such as how economic and health conditions across countries will impact U.S. business, investments, and travel abroad.

Additional modeling efforts can and have shed further light on some omitted damage categories. For example, the Framework for Evaluating Damages and Impacts (FrEDI) is an open-source modeling framework developed by the EPA to facilitate the characterization of net annual climate change impacts in numerous impact categories within the contiguous U.S. and monetize the associated distribution of modeled damages (Sarofim et al., 2021; U.S. EPA, 2021a).[44] The additional impact categories included in FrEDI reflect the availability of U.S.-specific data and research on climate change effects. As discussed in U.S. EPA (2023a), results from FrEDI show that annual damages resulting from climate change impacts within the contiguous U.S. (CONUS) (i.e., excluding Hawaii, Alaska, and U.S. territories) and for impact categories not represented in GIVE and DSCIM are expected to be substantial. For example, FrEDI estimates a partial SC-CH_4 of \$590/mtCH_4 for damages physically occurring within CONUS for 2030 emissions (under a 2 percent near-term Ramsey discount rate) (Hartin et al., 2023), compared to a GIVE and DSCIM-based U.S.-specific SC-CH_4 of \$280/mtCH_4 and \$75/mtCH_4, respectively, for 2030 emissions. While the FrEDI results help to illustrate how monetized damages physically occurring within CONUS increase as more impacts are reflected in the modeling framework, they are still subject to many of the same limitations associated with the DSCIM and GIVE damage modules, including the omission or partial modeling of important damage categories.[45] Finally, none of these modeling efforts — GIVE, DSCIM, and FrEDI — reflect non-climate mediated effects of GHG emissions experienced by U.S. populations (other than CO_2 fertilization effects on agriculture). As one example of new research on non-climate mediated effects of methane emissions, McDuffie et al. (2023) estimate the monetized increase in respiratory-related human mortality risk from the ozone produced from a marginal pulse of methane emissions. Using the socioeconomics from the RFF-SPs and the 2 percent near-term

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[44] The FrEDI framework and Technical Documentation have been subject to a public review comment period and an independent external peer review, following guidance in the EPA Peer-Review Handbook for Influential Scientific Information (ISI). Information on the FrEDI peer-review is available at the EPA Science Inventory EPA Science Inventory. (2021). *Technical Documentation on The Framework for Evaluating Damages and Impacts (FrEDI)*. Retrieved February 16, 2023 from https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=351316&Lab=OAP&simplesearch=0&showcriteria=2&sortby=pubDate&searchall=fredi&timstype=&datebeginpublishedpresented=02/14/2021.

[45] Another method that has produced estimates of the effect of climate change on U.S.-specific outcomes uses a top-down approach to estimate aggregate damage functions. Published research using this approach include total-economy empirical studies that econometrically estimate the relationship between GDP and a climate variable, usually temperature. As discussed in U.S. EPA. (2023a). , the modeling framework used in the existing published studies using this approach differ in important ways from the inputs underlying the SC-GHG estimates described above (e.g., discounting, risk aversion, and scenario uncertainty) and focus solely on CO_2. Hence, we do not consider this line of evidence in the analysis for this RIA. Updating the framework of total-economy empirical damage functions to be consistent with the methods described in this RIA and ibid. would require new analysis. Finally, because total-economy empirical studies estimate market impacts, they do not include non-market impacts of climate change (e.g., mortality impacts) and therefore are also only a partial estimate. The EPA will continue to review developments in the literature and explore ways to better inform the public of the full range of GHG impacts.

Ramsey discounting approach, this additional risk to U.S. populations is on the order of approximately \$320/mtCH_4 for 2030 emissions (U.S. EPA 2023a).

Applying the U.S.-specific partial SC-CH_4 estimates derived from the evidence described above to the CH_4 emissions reduction expected under the WEC final rule would yield substantial benefits. For example, the present value of the climate benefits of the final rule as measured by FrEDI using additional U.S.-specific data and research on climate change impacts in CONUS are estimated to be \$620 million (under a 2 percent near-term Ramsey discount rate).[46] However, even with these additional impact categories, the numerous explicitly omitted damage categories and other modeling limitations discussed above and throughout U.S. EPA (2023a) make it likely that these estimates underestimate the benefits to U.S. citizens and residents of the CH_4 reductions from the final rule; the limitations in developing a U.S.-specific estimate that accurately captures direct and spillover effects on U.S. citizens and residents further demonstrates that it is more appropriate to use a global measure of climate benefits from CH_4 reductions. The EPA will continue to review developments in the literature, including more robust methodologies for estimating the magnitude of the various damages to U.S. populations from climate impacts and reciprocal international mitigation activities, and explore ways to better inform the public of the full range of GHG impacts.

6.2 Health Effects Associated with Exposure to Non-GHG Pollutants

6.2.1 Ozone-Related Impacts Due to VOC Emissions

This final rulemaking is projected to reduce VOC emissions, which are a precursor to ozone. Ozone is not generally emitted directly into the atmosphere but is created when its two primary precursors, VOC and oxides of nitrogen (NO_X), react in the atmosphere in the presence of sunlight. In urban areas, compounds representing all classes of VOC can be important for ozone formation, but biogenic VOC emitted from vegetation tend to be more important compounds in non-urban vegetated areas (U.S. EPA 2020a). Recent observational and modeling

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[46] DCIM and GIVE use global damage functions. Damage functions based on only U.S.-data and research, but not for other parts of the world, were not included in those models. FrEDI does make use of some of this U.S.-specific data and research and as a result has a broader coverage of climate impact categories.

studies have found that VOC emissions can impact ozone levels (U.S. EPA 2020a). Emissions reductions may decrease ozone formation, human exposure to ozone, and the incidence of ozone-related health effects.

Calculating ozone impacts from changes in VOC emissions requires information about the spatial patterns in those emissions changes. In addition, the ozone health effects from the final rule will depend on the relative proximity of expected VOC and ozone changes to population. In this analysis, we have not characterized VOC emissions changes at a finer spatial resolution than the national total due to data and resource constraints. In light of these limitations, we present an illustrative screening analysis of ozone-related health benefits in Appendix A based on modeled oil and natural gas VOC contributions to ozone concentrations as they occurred in 2017 and do not include the results of this screening analysis in the estimate of benefits (and net benefits) projected from this final rule. To more definitively analyze the impacts of VOC reductions from this final rule on ozone health benefits, we would need credible projections of spatial patterns of expected VOC emissions reductions. Similarly, due to the high degree of variability in the responsiveness of ozone formation to VOC emissions reductions, we are unable to determine how this rule might affect air quality in downwind ozone nonattainment areas without modeling air quality changes.

6.2.1.1 Ozone Health Effects

Human exposure to ambient ozone concentrations is associated with adverse health effects, including premature respiratory mortality and cases of respiratory morbidity (U.S. EPA, 2020a). Researchers have associated ozone exposure with adverse health effects in numerous toxicological, clinical, and epidemiological studies (U.S. EPA, 2020a). When adequate data and resources are available, the EPA has generally quantified several health effects associated with exposure to ozone (U.S. EPA, 2010, 2011a, U.S. EPA, 2021c, 2021e, 2024d). EPA quantifies and monetizes effects the Integrated Science Assessment (ISA) identifies as having either a causal or likely-to-be-causal relationship with the pollutant. Relative to the 2015 ISA, the 2020 ISA for Ozone reclassified the casual relationship between short-term ozone exposure and total mortality, changing it from “likely to be causal” to “suggestive of, but not sufficient to infer, a causal relationship.” The 2020 Ozone ISA separately classified short-term ozone exposure and respiratory outcomes as being “causal” and long-term exposure as being “likely to be causal.”

When determining whether there existed a causal relationship between short- or long-term ozone exposure and respiratory effects, EPA evaluated the evidence for both morbidity and mortality effects. The ISA identified evidence in the epidemiologic literature of an association between ozone exposure and respiratory mortality, finding that the evidence was not entirely consistent and there remained uncertainties in the evidence base. EPA continues to quantify premature respiratory mortality attributable to both short- and long-term exposure to ozone because doing so is consistent with: (1) the evaluation of causality noted above; and (2) EPA's approach for selecting and quantifying endpoints described in the TSD "Estimating PM2.5- and Ozone Attributable Health Benefits," which was recently reviewed by the U.S. EPA Science Advisory Board (U.S. EPA, 2023p; U.S. EPA Science Advisory Board, 2024)

6.2.1.2 Ozone Vegetation Effects

Exposure to ozone has been found to be associated with a wide array of vegetation and ecosystem effects in the published literature (U.S. EPA, 2020a). 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 cause damage to, or impairment of, the intended use of the plant or ecosystem. Such effects are considered adverse to public welfare and can include reduced growth and/or biomass production in sensitive trees, reduced yield and quality of crops, visible foliar injury, changed to species composition, and changes in ecosystems and associated ecosystem services.

6.2.1.3 Ozone Climate Effects

Ozone is a well-known short-lived climate forcing GHG (U.S. EPA, 2013). 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 (U.S. EPA, 2009b). The IPCC AR5 estimated that the contribution to current warming levels of increased tropospheric ozone concentrations resulting from human methane, NO_X, 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.

6.2.2 Ozone-Related Impacts Due to Methane

The tropospheric ozone produced by the reaction of methane in the atmosphere has harmful effects for human health and plant growth in addition to its climate effects (Nolte et al., 2018). In remote areas, methane is a dominant precursor to tropospheric ozone formation. Approximately 50 percent of the global annual mean ozone increase since preindustrial times is believed to be due to anthropogenic methane (Myhre et al., 2013). Projections of future emissions also indicate that methane is likely to be a key contributor to ozone concentrations in the future (Myhre et al., 2013). Unlike NO_X and VOC, which affect ozone concentrations regionally and at hourly time scales, methane emissions affect ozone concentrations globally and on decadal time scales given methane's long atmospheric lifetime when compared to these other ozone precursors (Myhre et al., 2013). Reducing methane emissions, therefore, will contribute to efforts to reduce global background ozone concentrations that contribute to the incidence of ozone-related health effects (Sarofim et al., 2015; USGCRP, 2018). The benefits of such reductions are global and occur in both urban and rural areas. As discussed in Section 6.1, these effects are not included in estimates of the social cost of methane. However, a recent analysis by McDuffie et al. (2023) used a combination of global model simulations from the United Nations Environment Programme & Climate and Clean Air Coalition (UNEP/CCAC), in combination with BenMAP, to evaluate the additional risk in respiratory-related human mortality from ozone produced per ton of methane emissions. This approach is similar to the social cost of methane and finds that, globally, the monetized increase in respiratory-related human mortality risk from ozone produced from methane emissions in 2030 is $2,400 per ton of methane per mt CH_4 in 2019 US dollars). As discussed in U.S. EPA (2023f), this monetized result is similar to an earlier study by Sarofim et al. (2017) but smaller than in a 2021 study conducted by the UNEP/CCAC, which included additional cardiovascular mortality risk due to elevated ozone concentrations (United Nations Environment Programme and Climate and Clean Air Coalition, 2021). Collectively, these and other prior studies suggest that there are additional risks to human health from the methane-ozone mechanism that are not currently accounted for in the social cost of methane. Applying the ozone-related health benefit per ton estimates from McDuffie et al.

(2023) would yield a present value of the ozone-related health benefits from the 2024–2035 CH_4 emission reductions of the final rule on the order of \$2.4 billion (2019 dollars), of which approximately \$340 million are accruing to populations within U.S. borders.[47] Because these benefits are the result of methane, which is a global pollutant, EPA believes it is most appropriate to focus attention on the global benefits to human health from the methane-ozone mechanism for the same reasons discuss above with respect to climate benefits. EPA will continue to look for opportunities to incorporate the ozone related impacts of CH_4 emissions in future updates to the SC-CH_4.

6.2.3 $PM_{2.5}$-Related Impacts Due to VOC Emissions

This final rulemaking is expected to result in emissions reductions of VOC, which are a precursor to $PM_{2.5}$, thus decreasing human exposure to $PM_{2.5}$ and the incidence of $PM_{2.5}$-related health effects, although the magnitude of this effect has not been quantified at this time. Most VOC emitted are oxidized to CO_2 rather than to PM, but a portion of VOC emissions contributes to ambient $PM_{2.5}$ levels as organic carbon aerosols (U.S. EPA, 2020a). 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 lower than the biogenic (natural) contribution (U.S. EPA, 2019a). The potential for an organic compound to partition into the particle phase is highly dependent on its volatility such that compounds with lower volatility are more prone to partition into the particle phase and form secondary organic aerosols (SOA) (Cappa & Wilson, 2012; Donahue, Kroll, Pandis, & Robinson, 2012; Jimenez et al., 2009). Hydrocarbon emissions from oil and natural gas operations tend to be dominated by high volatility, low-carbon number compounds that are less likely to form SOA (Helmig et al., 2014; Koss et al., 2017; Pétron et al., 2012). Given that only a fraction of secondarily formed organic carbon aerosols is from anthropogenic VOC emissions,

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[47] This estimate relies on benefit per ton numbers that use the socioeconomics from the RFF-SPs and the 2 percent near-term Ramsey discounting approach. See McDuffie, E. E., Sarofim, M. C., Raich, W., Jackson, M., Roman, H., Seltzer, K., . . . Fann, N. (2023). The Social Cost of Ozone-Related Mortality Impacts From Methane Emissions. *Earth's Future*, *11*(9), e2023EF003853. https://doi.org/https://doi.org/10.1029/2023EF003853 for more details.

and the relatively volatile nature of VOCs emitted from this sector, it is unlikely that the VOC emissions reductions projected to occur under this proposal would have a large contribution to ambient secondary organic carbon aerosols. Therefore, we have not quantified the $PM_{2.5}$-related benefits in this analysis. Moreover, without modeling air quality changes, we are unable to determine how this rule might affect air quality in downwind $PM_{2.5}$ nonattainment areas.

6.2.3.1 $PM_{2.5}$ Health Effects

Decreasing exposure to $PM_{2.5}$ is associated with significant human health benefits, including reductions in respiratory mortality and respiratory morbidity. Researchers have associated $PM_{2.5}$ exposure with adverse health effects in numerous toxicological, clinical, and epidemiological studies (U.S. EPA, 2020a). These health effects include asthma development and aggravation, decreased lung function, and increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing (U.S. EPA, 2019a). These health effects result in hospital and ER visits, lost workdays, and restricted activity days. When adequate data and resources are available, the EPA has quantified the health effects associated with exposure to $PM_{2.5}$ (U.S. EPA, 2021d, 2024d).

When the 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 (U.S. EPA, 2019a). Based on our review of the current body of scientific literature, the EPA estimates PM-related premature 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. These data are summarized in the Final Report of the Supplement to the 2019 Integrated Science Assessment for Particulate Matter. (U.S. EPA, 2022d).

6.2.3.2 PM Welfare Effects

Suspended particles and gases degrade visibility by scattering and absorbing light. Decreasing secondary formation of $PM_{2.5}$ from VOC emissions could improve visibility throughout the U.S. Visibility impairment has a direct impact on 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 (U.S. EPA, 2006, 2011b, 2011c, 2012) show that visibility benefits are a significant welfare benefit category. However, without air quality modeling of $PM_{2.5}$ impacts, we are unable to estimate visibility related benefits.

Separately, persistent and bioaccumulative HAP reported as emissions from oil and natural gas operations, including polycyclic organic matter, could lead to PM welfare effects. Several significant ecological effects are associated with the deposition of organic particles, including persistent organic pollutants and polycyclic aromatic hydrocarbons (PAHs) (U.S. EPA, 2009a). PAHs can accumulate to high enough concentrations in some coastal environments to pose an environmental health threat that includes cancer in fish populations, toxicity to organisms living in the sediment and risks to those (e.g., migratory birds) that consume these organisms. Atmospheric deposition of particles is thought to be the major source of PAHs to the sediments of coastal areas of the U.S. (U.S. EPA, 2012).

6.2.4 Hazardous Air Pollutants (HAP) Impacts

Available emissions data show that several different HAP are emitted from oil and natural gas operations. The HAP emissions from the oil and natural gas sector in the 2020 National Emissions Inventory (NEI) emissions data are summarized in Table 6-6. The table includes either oil and natural gas nonpoint or oil and natural gas point emissions of at least 10 tons per year, in descending order of annual nonpoint emissions. Emissions of eight HAP make up a large percentage of the total HAP emissions by mass from the oil and natural gas sector: toluene, hexane, benzene, xylenes (mixed), ethylene glycol, methanol, ethyl benzene, and 2,2,4-trimethylpentane (U.S. EPA, 2011d).

Table 6-6 Top Annual HAP Emissions as Reported in 2020 NEI for Oil and Natural Gas Sources

Pollutant	Nonpoint Emissions (tons/year)	Point Emissions (tons/year)
Benzene	31,117	1,496
Xylenes (Mixed Isomers)	31,439	1,068
Formaldehyde	39,768	326
Toluene	19,306	2,674
Acetaldehyde	4,191	45
Hexane	2,411	1,878
Ethyl Benzene	2,163	305
Acrolein	2,642	29
Methanol	2,841	401
1,3-Butadiene	600	1
2,2,4-Trimethylpentane	189	142
Naphthalene	106	2
Propionaldehyde	90	0
PAH/POM - Unspecified	124	0
1,1,2-Trichloroethane	32	0
Methylene Chloride	34	1
1,1,2,2-Tetrachloroethane	25	0
Ethylene Dibromide	21	0
Methyl Tert-Butyl Ether	0	21

In the subsequent sections, we describe the health effects associated with the main HAP of concern from the oil and natural gas sector: benzene (Section 6.2.4.1), formaldehyde (Section 6.2.4.2), toluene (Section 6.2.4.3), carbonyl sulfide (Section 6.2.4.4), ethylbenzene (Section 6.2.4.5), mixed xylenes (Section 6.2.4.6), and n-hexane (Section 6.2.4.7), and other air toxics (Section 6.2.4.8). This proposal is projected to reduce 4,000 tons of HAP emissions over the 2023 through 2035 period. With the data available, it was not possible to estimate the change in emissions of each individual HAP.

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 are providing a qualitative discussion of the health effects associated with HAP emitted from sources subject to control under the final WEC. The EPA remains committed to improving methods for estimating HAP benefits by continuing to explore additional aspects of HAP-related risk from the oil and natural gas sector, including the distribution of that risk. This is discussed further in the context of environment justice in Section 9.3.

6.2.4.1 Benzene

The EPA's Integrated Risk Information System (IRIS) database lists benzene as a known human carcinogen (causing leukemia) by all routes of exposure and concludes that exposure is associated with additional health effects, including genetic changes in both humans and animals and increased proliferation of bone marrow cells in mice (IARC, 1982; Irons, Stillman, Colagiovanni, & Henry, 1992; U.S. EPA, 2003a). The EPA states 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 International Agency for Research on Carcinogens (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 (IARC, 1987; NTP, 2004). Several adverse noncancer health effects have been associated with chronic inhalation of benzene in humans including arrested development of blood cells, anemia, leukopenia, thrombocytopenia, and aplastic anemia. Respiratory effects have been reported in humans following acute exposure to benzene vapors, such as nasal irritation, mucous membrane irritation, dyspnea, and sore throat (ATSDR, 2007a).

6.2.4.2 Formaldehyde

The IARC (2006, 2012) classified formaldehyde as a human carcinogen based upon sufficient human evidence of nasopharyngeal cancer and strong evidence for leukemia. Similarly, in 2016, the National Toxicology Program (NTP) classified formaldehyde as known to be a human carcinogen based on sufficient evidence of cancer from studies in humans supporting data on mechanisms of carcinogenesis (NTP, 2016). In 2024, EPA updated its classification of formaldehyde from a probable human carcinogen to carcinogenic to humans via the inhalation route of exposure based upon evidence that formaldehyde inhalation causes nasopharyngeal cancer, sinonasal cancer, and myeloid leukemia in humans. (U.S. EPA, 2024e). Formaldehyde inhalation exposure causes a range of noncancer health effects including irritation of the nose, eyes, and throat in humans and animals. Repeated exposures cause respiratory tract irritation, chronic bronchitis and nasal epithelial lesions such as metaplasia and loss of cilia in humans. Airway inflammation, including eosinophil infiltration, has been observed in animals exposed to formaldehyde. In children, there is evidence that formaldehyde may increase the risk of asthma and chronic bronchitis (ATSDR, 1999; WHO, 2002). Evidence also indicates that inhalation of formaldehyde may cause reproductive toxicity and decreased pulmonary function in humans (U.S. EPA, 2024).

6.2.4.3 Toluene[48]

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, toluene was not carcinogenic in adequate inhalation cancer bioassays of rats and mice exposed for life, and increased incidences of mammary cancer and leukemia were reported in a lifetime rat oral bioassay.

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,

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[48] All health effects language for this section came from: U.S. EPA (2005b).

decreased performance in neurobehavioral analysis, changes in motor and sensory nerve conduction velocity, headache, and dizziness) as the most sensitive endpoint.

6.2.4.4 Carbonyl Sulfide

Limited information is available on the health effects of carbonyl sulfide. Acute (short-term) inhalation of high concentrations of carbonyl sulfide may cause narcotic effects and irritate the eyes and skin in humans (U.S. National Library of Medicine, 2020). No information is available on the chronic (long-term), reproductive, developmental, or carcinogenic effects of carbonyl sulfide in humans. Carbonyl sulfide has not undergone a complete evaluation and determination under the EPA's IRIS program for evidence of human carcinogenic potential (U.S. EPA, 1991a).

6.2.4.5 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 and nasal 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. No association has been found between the occurrence of cancer in humans and ethylbenzene exposure (ATSDR, 2010). 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 (Maltoni et al., 1997; Maltoni, Conti, Cotti, & Belpoggi, 1985). 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, 1999). 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 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.

6.2.4.6 Mixed Xylenes

Short-term inhalation of mixed xylenes (a mixture of three closely related compounds) in humans may cause irritation of the nose and throat, nausea, vomiting, gastric irritation, mild transient eye irritation, and neurological effects (U.S. EPA, 2003b). Other reported effects include labored breathing, heart palpitation, impaired function of the lungs, and possible effects in the liver and kidneys (ATSDR, 2007b). Long-term inhalation exposure to xylenes in humans has been associated with a number of effects in the nervous system including headaches, dizziness, fatigue, tremors, and impaired motor coordination (ATSDR, 2007b). The EPA has classified mixed xylenes in Category D, not classifiable with respect to human carcinogenicity.

6.2.4.7 n-Hexane

The studies available in both humans and animals indicate that the nervous system is the primary target of toxicity upon exposure of n-hexane via inhalation. There are no data in humans and very limited information in animals about the potential effects of n-hexane via the oral route. Acute (short-term) inhalation exposure of humans to high levels of hexane causes mild central nervous system effects, including dizziness, giddiness, slight nausea, and headache. Chronic (long-term) exposure to hexane in air causes numbness in the extremities, muscular weakness, blurred vision, headache, and fatigue. Inhalation studies in rodents have reported behavioral effects, neurophysiological changes, and neuropathological effects upon inhalation exposure to n-hexane. Under the Guidelines for Carcinogen Risk Assessment (U.S. EPA, 2005a), the database for n-hexane is considered inadequate to assess human carcinogenic potential, therefore the EPA has classified hexane in Group D, not classifiable as to human carcinogenicity.

6.2.4.8 Other Air Toxics

In addition to the compounds described above, other toxic compounds might be affected by this rule, including hydrogen sulfide (H_2S). Information regarding the health effects of those compounds can be found in the EPA's IRIS database.[49]

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[49] The U.S. EPA Integrated Risk Information System (IRIS) database is available at https://www.epa.gov/iris. Accessed April 26, 2020.

7 COMPARISON OF BENEFITS AND COSTS

7.1 Comparison of Benefits and Costs

This section presents a comparison of quantified benefits and costs. Additionally, projections of WEC payments are presented separately from costs and benefits as transfers. All estimates are in 2019 dollars. All costs, emissions changes, and benefits are estimated for the years 2024 to 2035 relative to a baseline without the final Waste Emissions Charge. The monetized benefits presented are climate benefits calculated using the social cost of methane. The costs are the engineering costs of methane mitigation technologies from the marginal abatement cost (MAC) model, and energy market costs related to the outcomes of the partial equilibrium modeling.

Table 7-1 summarizes the emissions reductions estimated to result from the WEC over the 2024 to 2035 period. Table 7-2 presents the present value (PV) and equivalent annual value (EAV), estimated using discount rates of 2, 3, and 7 percent, of the changes in quantified benefits, costs, and net benefits [50]. These values are discounted to 2023. Note that while the PV of the costs and net benefits are calculated with discount rates of 2 percent, 3 percent, and 7 percent, the monetized climate benefits are only discounted at 2 percent. Table 7-2 includes consideration of non-monetized benefits associated with the emissions reductions resulting from the final rule.

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[50] Monetized climate effects are presented under a 2 percent near-term Ramsey discount rate, consistent with EPA's updated estimates of the SC-GHG. The 2003 version of OMB's Circular A-4 had generally recommended 3 percent and 7 percent as default discount rates for costs and benefits, though as part of the Interagency Working Group on the Social Cost of Greenhouse Gases, OMB had also long recognized that climate effects should be discounted only at appropriate consumption-based discount rates. OMB finalized an update to Circular A-4 in 2023, in which it recommended the general application of a 2.0 percent discount rate to costs and benefits (subject to regular updates), as well as the consideration of the shadow price of capital when costs or benefits are likely to accrue to capital (OMB 2023). Because the SC-GHG estimates reflect net climate change damages in terms of reduced consumption (or monetary consumption equivalents), the use of the social rate of return on capital (7 percent under OMB Circular A-4 (2003)) to discount damages estimated in terms of reduced consumption would inappropriately underestimate the impacts of climate change for the purposes of estimating the SC-GHG. See Section 6.1 for more discussion.

Table 7-1 Projected Emissions Reductions from the Final Waste Emissions Charge, 2024-2035

	Emission Changes			
	Methane (thousand metric tons)	**VOC (thousand metric tons)**	**HAP (thousand metric tons)**	**Methane (million metric tons CO2 Eq. using GWP=28)**
Total	1,200	170	6	34

Table 7-2 Projected Benefits and Costs from the Final Waste Emissions Charge (million 2019$)

	2 Percent Near-Term Ramsey Discount Rate					
	PV	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Monetized Climate Benefits[a]	$2,400	$230	$2,400	$230	$2,400	$230
	2 Percent Discount Rate		**3 Percent Discount Rate**		**7 Percent Discount Rate**	
	PV	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Total Social Costs	$460	$43	$440	$44	$380	$48
Cost of Methane Mitigation	$420	$40	$400	$41	$350	$44
Cost of Energy Market Impacts	$39	$4	$38	$4	$33	$4
Net Benefits	$1,900	$190	$2,000	$190	$2,000	$180
Non-Monetized Benefits	Ozone benefits from reducing 1.2 million metric tons of methane from 2024 to 2035 PM2.5 and ozone health benefits from reducing 170 thousand metric tons of VOC from 2024 to 2035 HAP benefits from reducing 6 metric tons of HAP from 2024 to 2035 Visibility benefits Reduced vegetation effects					

[a] Monetized climate benefits are based on reductions in methane emissions and are calculated using three different estimates of the social cost of methane (SC-CH_4) (under 1.5 percent, 2.0 percent, and 2.5 percent near-term Ramsey discount rates). For the presentational purposes of this table, we show the climate benefits associated with the SC-CH_4 at the 2 percent near-term Ramsey discount rate. Please see Table 6-5 for the full range of monetized climate benefit estimates.

[b] A screening-level analysis of ozone benefits from VOC reductions can be found in Appendix A of the RIA.

7.2 Annual Benefits and Costs

Table 7-3 presents annual emissions reductions of methane, VOC, and HAP emissions from mitigation actions and energy market impacts.

Table 7-4 provides year-by-year estimates of climate benefits, social costs, and net benefits, which underlie the summary benefit and cost information presented in Table 7-2. The present value (PV) and equivalent annualized value (EAV) presented in Table 7-2 and 7-4 summarize the estimates over the 2024 to 2035 analysis period discounted to the year 2023 using discount rates of 2, 3, and 7 percent.

Table 7-3 Projected Annual Emissions Reductions from the Final Waste Emissions Charge (thousand metric tons)

	Methane			**VOC**			**HAP**		
Year	**Mitigated**	**Market-Induced**	**Total**	**Mitigated**	**Market-Induced**	**Total**	**Mitigated**	**Market-Induced**	**Total**
2024	110	0.1	110	17	0.0	17	0.6	0.00	0.6
2025	220	0.1	220	34	0.0	34	1.2	0.00	1.2
2026	310	1.7	320	47	0.3	48	1.8	0.01	1.8
2027	310	1.6	310	46	0.2	46	1.7	0.01	1.7
2028	42	0.0	42	4.2	0.0	4.2	0.15	0.00	0.15
2029	30	0.0	30	3.0	0.0	3.0	0.11	0.00	0.11
2030	30	0.0	31	3.0	0.0	3.0	0.11	0.00	0.11
2031	31	0.0	31	3.0	0.0	3.0	0.11	0.00	0.11
2032	31	0.0	31	3.0	0.0	3.0	0.11	0.00	0.11
2033	31	0.0	31	3.0	0.0	3.0	0.11	0.00	0.11
2034	31	0.0	31	3.0	0.0	3.0	0.11	0.00	0.11
2035	31	0.0	31	3.0	0.0	3.0	0.11	0.00	0.11
Total	1,200	3.7	1,200	170	0.6	170	6.2	0.0	6.2

Table 7-4 Summary of Annual Undiscounted Values, Present Values, and Equivalent Annualized Values for the 2024–2035 Timeframe for Estimated Incremental Abatement Costs, Benefits, and Net Benefits for Final Rule (millions of 2019$, discounted to 2023)

Year	*Climate Benefits*[a] *(2% DR)*	*Total Social Costs ($MM)*			*Net Benefits (2% Benefits)*		
2024	$210	$40			$170		
2025	$440	$85			$350		
2026	$660	$140			$510		
2027	$670	$140			$530		
2028	$94	$17			$77		
2029	$70	$10			$60		
2030	$72	$10			$62		
2031	$75	$10			$65		
2032	$78	$10			$68		
2033	$81	$10			$71		
2034	$84	$10			$74		
2035	$86	$10			$77		
Discount Rate	2%	2%	3%	7%	2%[b]	3%[b]	7%[b]
PV	$2,400	$460	$440	$380	$1,900	$2,000	$2,000
EAV	$230	$43	$44	$48	$190	$190	$180

[a] Monetized climate benefits are based on reductions in methane emissions and are calculated using three different estimates of the social cost of methane (SC-CH_4) (under 1.5 percent, 2.0 percent, and 2.5 percent near-term Ramsey discount rates). For the presentational purposes of this table, we show the climate benefits associated with the SC-CH_4 at the 2 percent near-term Ramsey discount rate. Please see Tables 6.2-6.5 for the full range of monetized climate benefit estimates.

[b] Headings denote what percent discount rates are used in calculating different versions of net benefits. In this case, EPA is using 2% near-term Ramsey discount rate for climate benefits and 2%, 3%, and 7% discount rates for costs respectively.

7.3 Transfer Payments

WEC payments are transfers and do not affect total net benefits to society as a whole because payments by oil and natural gas operators are offset by receipts by the government. Therefore, from a net-benefit accounting perspective, transfers are considered separately from costs and benefits (and are therefore not included in Table 7-2). As explained in Section 2.7, the approach taken here is in line with OMB guidance and the approach taken for RIAs for other rules impacting payments to the government, such as the Bureau of Land Management (BLM)'s waste prevention rule.

One of the reasons that transfers are not considered costs is because they represent payments to the U.S. Treasury that do not affect total resources available to society. Payments to the U.S. Treasury can then be used to fund other programs, and the pairing of revenue collection (e.g., the WEC payments) with commensurate expenditures (e.g., financial assistance programs) by the federal government can be designed to be revenue neutral. The Methane Emission Reduction Program created under CAA section 136 includes both collection and expenditure components. In addition to establishing the WEC, another key purpose of CAA section 136 is to encourage the transition to available and innovative methane emissions reduction technologies. See 168 Cong. Rec. E869 (August 23, 2022) (statement of Rep. Frank Pallone). CAA section 136(a) and (b) provides financial and technical assistance to reduce methane emissions from the oil and gas sector. To implement this program, EPA is partnering with the U.S. Department of Energy (DOE) to provide up to $1.36 billion in financial and technical assistance. As designed by Congress, these resources and incentives were intended to complement the regulatory programs and to help facilitate the transition to a more efficient petroleum and natural gas industry. These incentives for methane mitigation and monitoring complement the WEC.

The WEC has the effect of better aligning the economic incentives of oil and natural gas companies with the costs and benefits faced by society from oil and gas activities. In the baseline scenario the environmental damages resulting from methane emissions from the oil and gas sector are a negative externality spread across society as a whole. Under the WEC, this negative externality is internalized, oil and gas companies are required to make WEC payments in proportion to the climate damages of methane emissions subject to the WEC.[51] Alternatively, firms can avoid making WEC payments by mitigating their emissions generating climate benefits associated with the amount of mitigation.

Table 7-5 provides details of the calculation steps used to estimate projected WEC obligations and climate damages based on projected emission subject to WEC. In order to

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[51] Note that Congress specified that the WEC would rise to $1,500 per metric ton of methane in 2026 and beyond. This value is consistent with estimates of climate damages associated with emissions of a metric ton of methane that were available at the time the IRA was passed. The February 2021, 'Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990,' estimated that the social cost of CH4 under a 3% discount rate for emissions occuring in the year 2020 was $1,500.

compare projected WEC payments to climate damages from emissions subject to the WEC, WEC payments are converted from nominal dollars to 2019 constant dollars using a chain-weighted GDP price index from the 2023 Annual Energy Outlook.

Table 7-5 Details of Projected WEC Obligations and Climate Damages from Emissions Subject to WEC (million 2019$)

Year	Methane Emissions Subject to WEC in Policy Scenario (thousand metric tons)	Charge Specified by Congress (nominal $ per metric ton)	WEC Payments in Policy Scenario (million nominal $)	WEC Payments in Policy Scenario (million 2019$)	SC-CH_4 Values at 2% Near-Term Discount Rate (2019$ per metric ton)	Climate Damages from Emissions Subject to WEC (million 2019$)[a]
2024	600	$900	$540	$450	$1,900	$1,200
2025	460	$1,200	$560	$450	$2,000	$930
2026	340	$1,500	$510	$400	$2,100	$700
2027	320	$1,500	$480	$380	$2,200	$690
2028	35	$1,500	$52	$40	$2,200	$77
2029	3	$1,500	$5	$4	$2,300	$7
2030	3	$1,500	$4	$3	$2,400	$7
2031	3	$1,500	$4	$3	$2,500	$7
2032	2	$1,500	$4	$3	$2,500	$6
2033	2	$1,500	$3	$2	$2,600	$5
2034	2	$1,500	$3	$2	$2,700	$5
2035	1	$1,500	$2	$1	$2,800	$4
Total 2024-2035	1,800	-	-	$1,700	-	$3,600

[a] Climate damages are based on remaining methane emissions subject to WEC after accounting for emissions reductions and are calculated using three different estimates of the social cost of methane (SC-CH4) (under 1.5 percent, 2.0 percent, and 2.5 percent near-term Ramsey discount rates). For the presentational purposes of this table, we show the climate benefits associated with the SC-CH4 at the 2 percent near-term Ramsey discount rate.

7.4 Uncertainties and Limitations

Throughout the RIA we considered several sources of uncertainty regarding the emissions reductions, benefits, costs, and transfer payments estimated for the final rule. We summarize some of the key elements of our discussions of uncertainty below.

Interactions with other policies impacting methane from the oil and natural gas industry: In addition to the WEC, the EPA has implemented several other actions that impact methane emissions from the oil and natural gas industry. In particular, the WEC has important interactions with recently finalized revisions to GHGRP subpart W and the now finalized NSPS/EG for the Oil and Natural Gas Sector. Considerations in the interactions of these policies are discussed in Section 2.3 and in further detail in Section 8. The impacts of the WEC are also likely affected by interactions with other policies affecting emissions and activities of the oil and gas sector, such as the Bureau of Land Management's waste prevention rule and state policies. These other policies are not explicitly modeled in this analysis.

Projection methods and assumptions: because the WEC is assessed by facility and WEC obligated party, detailed reporting data and projections are needed to estimate potential WEC obligations and impacts of the rule. However, facility-specific trends may diverge significantly from overall trends that are used to generate the baseline emissions and throughput projections. In addition, because the projections begin from RY 2022 subpart W reported data, the projections reflect details in that data which are likely to shift over time. For example, oil and natural gas assets are frequently bought and sold by different companies, which could potentially impact the effects of netting as part of WEC calculations, but it isn't possible to project how ownership changes may impact WEC obligations. The change to netting does not improve EPA's ability to project or predict this.

Methane mitigation potential analysis: estimates of methane emissions reductions resulting from the WEC depend in part on the characterization of mitigation technologies in the MACC analysis. Section 5.1 discusses important assumptions included in that analysis. Mitigation technology costs faced by different oil and natural gas companies may vary from the assumptions used in the MAC model. Mitigation costs vary by segment and may also vary based on site-specific or operator-specific factors. Where possible, EPA has utilized information specific to the different segments of the oil and natural gas industry, and reflecting several model site types. However, various factors that affect cost and emissions reductions are uncertain and the range of variation cannot be fully captured by the marginal abatement cost analysis. Actual mitigation activities induced by the WEC may be higher or lower than are estimated here. For some mitigation technologies, the MAC model has estimated revenue from avoided natural gas losses. This revenue may be available, for example, in cases where the cost of reducing emissions exceeds the potential revenue from avoided natural gas losses. The magnitude of avoided losses may be higher or lower than estimated and may be impacted by factors not accounted for in the analysis, such as availability of pipeline capacity. The mitigation analysis may not fully capture various other factors such as unplanned downtime, deferred maintenance, unplanned capital upgrades, uncertainty about sectoral contracting jobs, or other factors. Additional information on the mitigation technologies characterized in the analysis is available in Appendix C to this RIA.

Oil and natural gas market impact analysis: the oil and natural gas market impact analysis presented in this RIA is subject to several caveats and limitations. The market impact analysis depends on uncertain input parameters and assumptions regarding market structure. A more detailed discussion of the caveats and limitations of the oil and natural gas market analysis can be found in Section 5.2.

Monetized methane-related climate benefits: the EPA considered the uncertainty associated with the social cost of methane (SC-CH_4) estimates, which were used to calculate the monetized climate benefits of the decrease in methane emissions projected because of this action. Section 6.1 provides a detailed discussion of the limitations and uncertainties associated with the SC-CH_4 estimates used in this analysis and describes ways in which the modeling addresses quantified sources of uncertainty.

Monetized VOC-related ozone benefits: the illustrative screening analysis described in Appendix A includes many data sources as inputs that are each subject to uncertainty. Input parameters include projected emissions inventories, projected mitigation actions, air quality data from models (with their associated parameters and inputs), population data, population estimates, health effect estimates from epidemiology studies, economic data, and assumptions regarding the future state of the world (i.e., regulations, technology, and human behavior). When compounded, even small uncertainties can greatly influence the size of the total quantified benefits.

8 UNCERTAINTY ANALYSES

8.1 Sensitivity on GHGRP Calculation Methods

On May 14, 2024, the EPA finalized revisions to the requirements of subpart W consistent with directives in the Inflation Reduction Act (referred to in this section as the 2024 subpart W revisions). The 2024 subpart W revisions rule and 2024 GHGRP revisions rule[52] include a number of changes that could meaningfully change reported methane emissions and the resulting potential WEC obligations. The changes can be categorized as:

- new reported emissions sources, such as "other large release events" and crankcase venting, and existing sources required for more segments;
- changes to emissions factors used in some existing calculation methods, such as changes in the fugitive emissions factors used in the population method for fugitive emissions in onshore production and gathering and boosting;
- new calculation methods, especially those involving site- or reporter-specific measurements or data, such as new measurement methods for equipment leaks and new leaker factor methods for pneumatic controllers; and
- changes that may result in additional reporters to GHGRP subpart W which have not reported in past years.

EPA does not currently have a precise quantitative estimate of expected emissions reporting inclusive of all of these revisions because a broad range of potential outcomes are plausible. This section first discusses qualitative factors in how the revisions will influence reported emissions, and then describes one quantitative scenario in how reported emissions may change below.

8.1.1 Qualitative Factors in Sensitivity on GHGRP Calculation Methods

New emissions sources. The 2024 GHGRP subpart W revisions added new reported emissions sources such as "other large release events" and crankcase venting. Considered alone, the addition of new reporting emissions sources will increase overall methane reported to subpart W and subject to the requirements of the WEC. However, in particular with respect to other large release events it is difficult to estimate the magnitude of emissions that will be reported and

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[52] Under the GHGRP, the EPA finalized a separate rule (89 FR 31802, April 25, 2024), which included updates to the General Provisions of the GHGRP to reflect revised global warming potentials, reporting of GHG data from additional sectors (i.e., non-subpart W sectors), and revisions to source categories other than subpart W.

which facilities will report those emissions. During the development of the 2024 GHGRP subpart W revisions, the EPA reviewed published studies and data reported to state agencies related to emission release events in order to understand the frequency and magnitude of other large release events.[53] Additionally, the EPA has reviewed emissions observation data from the Carbon Mapper data portal.[54] During a review of the available data, we identified an average of approximately 800 events that exceed the 100 kg/hr threshold per year from 2016-2023 that have been attributed to oil and gas. However, there is not sufficient data to estimate event duration or attribute to particular sources to understand whether these emissions may already be captured under reporting for other sources. We note that although subpart W provides a default duration of 91 days under the other large release events source category, we do not think it would be appropriate for purposes of this sensitivity analysis to assign this default to all of these events identified in the Carbon Mapper data set, as we expect facilities will in many cases be able to use surveys or monitored data to bound events and some of these events may be appropriately captured under other sources in subpart W (e.g., if any these events were blowdowns). We note that the default duration is only required under subpart W when survey data or other monitored data is not available.

Changes to emissions factors. Changes to emissions factors have several potential effects. For example, the 2024 Subpart W revisions increase the emissions factors used for the population method for equipment leaks in onshore production and gathering and boosting. In RY 2022, most facilities' equipment leak emissions were calculated using the population method.[55] If we assume that these reporters continue to use the population method, then their reported emissions would increase. However, the population method is not the only available method for reporting equipment leak emissions, and higher fugitive emissions factors that more accurately reflect potential emissions in the absence of fugitive monitoring also increase the economic incentive to perform equipment leak monitoring and repair and to report using other calculation methods for fugitives that are able to reflect emissions reductions from monitoring and repair

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[53] The details of this review are included in the "Greenhouse Gas Reporting Rule: Technical Support for Revisions and Confidentiality Determinations for Data Elements Under the Greenhouse Gas Reporting Rule; Final Rule – Petroleum and Natural Gas Systems" (see Docket Item No EPA-HQ-OAR-2023-0234-0453).

[54] Carbon Mapper data [2016-2023]. Retrieved from https://data.carbonmapper.org [April 2024]

[55] The population method consists of multiplying default population emission factors by counts of all applicable major equipment or equipment component types that exist at the facility, and by the equipment or component type total annual operating time.

programs. In addition, as more oil and natural gas operations become subject to fugitive monitoring requirements under the NSPS/EG, those facilities will be required to switch to other calculation methods for equipment leaks.[56] Because of the possibility that reporters will switch reporting methods, an increase in emissions factors may not lead to a proportionate increase in reported emissions. For other emissions source types, switching between methods may be optional and therefore potentially less likely. For example, switching between methods is optional in the case of liquids unloading emissions.

New reporting methods. It is particularly uncertain what emissions will be reported using new required or optional calculation methods in subpart W that utilize site- or reporter-specific measurements.[57] Measurements or reporter-specific data might lead to higher or lower reported emissions than would have been calculated under other methods. When choosing whether to report using an optional reporter-specific measurement or using a default emissions factor, reporters are expected to choose calculation approaches that they expect will minimize WEC obligations and measurement and reporting costs. Thus, holding other calculation methods constant, the addition of optional measurement methods is likely to reduce reported emissions and WEC obligations. However, in most cases GHGRP reporters are required to report based on measurements or surveys that they have conducted. For example, where reporters have performed fugitive emissions surveys pursuant to NSPS requirements or have elected to complete a voluntary survey consistent with subpart W requirements, they are required to report leaks found through those surveys. To estimate WEC obligations, EPA would further need to make assumptions about how incorporation of measurement data would affect the distribution of reported emissions by individual facilities. Results of measurements may vary significantly between different oil and natural gas operators, and EPA does not yet have sufficient data to

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[56] These other methods consist of conducting leak surveys to identify leaking components and multiplying default leaker emission factors by the number of components found to be leaking during the surveys and an estimated leak duration. Starting with reporting year 2024, facilities may also optionally elect to measure emissions from components found to be leaking during surveys and use the measured emission rates as an alternative to applying default leaker emission factors. Furthermore, once a minimum number of leak measurements are conducted as prescribed under 40 CFR 98 Subpart W, facilities may develop facility-specific leaker factors to apply to leaking components instead of the default leaker factors provided in the rule.

[57] The subpart W revisions introduced several new measurement-based methods to estimate emissions from different source types (e.g., equipment leaks, pneumatic devices, associated gas venting and flaring). In many cases, these new measurement-based methods are optional and, therefore, it is unknow to what extent they will be adopted by reporters in lieu of existing methods.

quantitatively estimate whether facilities will choose to adopt these new optional measurement methods and the corresponding impact of these methods on potential WEC obligations.

New reporters. Several changes in the 2024 Subpart W revisions and the 2024 GHGRP revisions to general provisions may result in additional reporters who have not been required to report to GHGRP in the past. For example, the revised GHGRP general provisions includes an increase in GWP of methane from 25 to 28, which may lead more oil and natural gas facilities to exceed the 25,000 CO_2e reporting threshold beginning with the 2025 reporting year. EPA estimated that approximately 200 additional facilities would report to subpart W as a result of this change to GWP starting with reporting year 2025.[58] However, not all oil and gas facilities newly subject to the GHGRP and reporting under subpart W would likely be subject to the WEC, as some of these facilities may have emissions below 25,000 metric tons CO_2e reported to subpart W (i.e. they may report emissions under other subparts that in total put them over the reporting threshold to the GHGRP even if their emissions to subpart W remain below metric tons CO_2e). Similarly, the addition of new reporting source categories may bring facilities that were previously below the reporting threshold above 25,000 metric tons CO_2e starting with reporting year 2025. New reporting facilities would increase the overall baseline used in this RIA, but information on the emissions intensity of these new reporters is unavailable. Even if new reporters cause the total reported methane to subpart W to increase, total WEC-applicable emissions may not be increased significantly. For example, emissions reported by new reporters may fall above or below the relevant methane intensity thresholds specified by Congress.

8.1.2 Quantitative Scenario of Sensitivity on GHGRP Calculation Methods

Quantitative estimation of future emissions reported under subpart W is complicated by multiple layers of uncertainty. These layers include uncertainty in what calculation methods will be used where options are available, uncertainty in the outcome of new measurements, and uncertainty in the occurrence of certain conditions such as other large release events. Some aspects of the revisions will lead to increases in emissions, while other aspects could lead to either increases or decreases in reported emissions. Despite the relatively broad range of plausible outcomes described above, some indication of potential outcomes can be discerned

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[58] https://www.regulations.gov/document/EPA-HQ-OAR-2023-0234-0166

through estimation of changes which are amenable to calculation, such as changes in emissions factors.

Table 8-1 provides the results of a sensitivity analysis on potential emissions reported to GHGRP subpart W and subject to WEC under an assumption of fixed calculation methods accounting for changes in GHGRP emissions factors that are effective starting with reporting year 2025. It also includes estimates for reporting of select new emissions sources by existing reporters: crankcase venting, equipment leaks for stations and farm taps, and blowdowns from underground natural gas storage facilities. This assessment starts from emissions reporting for RY2022 to subpart W. It assumes that facilities which used default emissions factors to calculate emissions for an emissions source continue to use the same calculation methods (*i.e.*, fixed calculation methods), but re-estimates emissions as if the revised factors had been used. Sources for which changes were estimated include pneumatic devices, equipment leaks, flare stacks, combustion slip, and dehydrators. This particular approach is used not because it is necessarily the most likely, but because it is the only alternative for which we have sufficient data available at this time. In addition, this scenario represents the least-cost approach for GHGRP reporters with respect to emissions measurement and reporting burden. Performing additional measurements or implementing alternative calculation methods might entail additional reporting burden but lower WEC obligations.

Table 8-1 Sensitivity of Emissions Exceeding Facility Waste Emissions Thresholds from GHGRP Revisions Assuming Fixed Calculation Methods and Select New Sources (tons methane)

Industry Segment	Facility CH_4 exceeding waste emissions threshold (tons) Current Subpart W Reporting (RY2022)	Final Revision (Estimated)[a]	Percent Change (Estimated)[a]
Onshore Production	640,000	1,200,000	+90%
Offshore Production	21,000	23,000	+9%
Gathering and Boosting	270,000	690,000	+160%
Natural Gas Processing	*n/a*[b]	*n/a*[b]	*n/a*[b]
Natural Gas Transmission Compression	*n/a*[b]	*n/a*[b]	*n/a*[b]
Natural Gas Transmission Pipeline	13,000	19,000	+42%
Underground Natural Gas Storage	150	990	+550%
LNG Import/Export	0	0	0%
LNG Storage	0	0	0%
Total	940,000	1,950,000	+107%

[a] Estimated changes resulting from GHGRP subpart W revisions only account for select aspects of the revisions for which data are available to estimate. The estimated change assumes that reporters continue to use the same calculation methods as in RY2022. The estimates account for reporting of several new emissions sources by existing reporters: crankcase venting, equipment leaks for stations and farm taps, and blowdowns from underground natural gas storage facilities. The estimates related to the revisions do not account for the addition of other large release events, the addition of new calculation methods, new reporting facilities, netting, or switching between calculation methods.

b The estimates of emissions changes related to GHGRP subpart W revisions exclude Natural Gas Processing and Natural Gas Transmission Compression. due to CBI data considerations.

The result of the fixed calculation method and select new sources scenario is approximately a 80 percent increase in reported methane emissions to subpart W resulting in approximately 110 percent increase in emissions which exceed facility waste emissions thresholds. Please note that this analysis does not account for a variety of factors including use of site-specific measurements, other new reporting sources such as other large release events, emissions reported by new reporting facilities or other factors described qualitatively above. It represents one potential scenario in how emissions may change within a relatively broad range of plausible outcomes. Again, EPA does not expect that the results presented here are the most likely scenario. There are both reasons that future reporting under the revised GHGRP subpart W may be higher than estimated here (such as because this estimate does not include new sources like other large release events) or lower than estimated here (such as if incorporated measurement data result in lower reported emissions, or due to reductions in emissions from

NSPS/EG compliance, as discussed below, or other mitigation activities). The estimate for this scenario is broadly consistent with at least one estimate from an outside group. Enverus Intelligence Research (EIR) conducted an analysis using a similar approach based upon the 2023 proposed GHGRP subpart W revisions and RY2021 reported data. In addition to emissions factor changes, the EIR analysis included an estimate for other large release events. That analysis found a 130% increase in methane reported by the upstream and gathering sectors.[59]

8.2 Sensitivity on Interaction with NSPS/EG

The WEC has important interactions and is designed to complement the Oil and Gas NSPS/EG. Because of these interactions, the requirements and implementation of the NSPS/EG influence the reductions and impacts of the WEC. To the extent that oil and natural gas companies implement strong emissions controls because of requirements in the NSPS/EG, emissions reductions resulting from the WEC and WEC obligations would be lower than if less stringent emissions controls were required under the NSPS /EG. To the extent that NSPS/EG implementation is delayed relative to the planned schedule, the WEC may serve as a partial backstop to ensure that cost-effective mitigation actions are implemented promptly.

The EPA proposed updates to the Oil and Gas NSPS/EG in 2021, published a supplemental proposal in 2022, and finalized rules in March 2024. In addition to requirements already in place, these proposals include standards for many of the major sources of methane emissions in the oil and natural gas industry. The revised NSPS includes new requirements for new and modified facilities, while the EG OOOOc includes requirements for existing sources, which are to be implemented by the states via state regulations and state plans.

There is significant overlap in both the oil and natural gas operations subject to the WEC and the NSPS/EG and the emissions reduction measures that could be taken to avoid WEC obligations and those potentially required under the NSPS/EG. On the one hand, the scope of operations impacted by the WEC is a subset of those affected by the NSPS OOOOb and EG OOOOc because the WEC must be collected from owners or operators of applicable facilities that report more than 25,000 metric tons of carbon dioxide equivalent of greenhouse gases per year pursuant to the petroleum and natural gas systems source category requirements of the

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[59] https://www.enverus.com/newsroom/epas-emission-revision-more-rules-double-the-methane-triple-the-tax/

Greenhouse Gas Reporting Rule, and that exceed methane emissions intensity thresholds set forth in CAA section 136 for different types of applicable facilities. On the other hand, the scope of equipment and emissions sources affected by the 2024 Final NSPS/EG is a subset of the reported emissions sources and equipment for which GHGRP facilities report methane emissions.

With respect to overlap in oil and natural gas operations, the scope or coverage of GHGRP subpart W reporting coverage varies by segment. For example, in RY 2022 emissions were reported to GHGRP related to approximately 500,000 oil and natural gas onshore production wells, out of over 900,000 producing wells in 2022 (EIA, 2023b). Because GHGRP reporters skew towards higher-production wells, the proportion of total oil and natural gas production covered by GHGRP subpart W reports is significantly higher than the proportion of producing wells. By contrast, because the ownership structure and operations of natural gas gathering and boosting tends to be more concentrated than onshore production, more than 95% of gathering and boosting facilities are estimated to report to GHGRP. Regardless, in both the onshore production and gathering and boosting segments of the oil and natural gas industry, many operators are subject to both the requirements of the WEC and the NSPS/EG.

With respect to overlap in emissions sources and mitigation actions relevant to both the WEC and the NSPS/EG, emissions sources with requirements under the NSPS/EG make up a majority of methane emission reported to subpart W. Many of the most cost-effective methane mitigation options estimated in the MACC correspond to sources and requirements under the NSPS/EG. The Final NSPS/EG RIA estimated methane emissions reductions associated with fugitive emission, natural gas driven pneumatic controllers, pneumatic pumps, reciprocating compressors, centrifugal compressors, liquids unloading, storage vessels, and associated gas. These sources make up about 80% of methane emissions currently reported to subpart W.

Because the WEC and Oil and Gas NSPS/EG apply to overlapping facilities and emissions sources, the emissions reduction and mitigation costs of the two policies can be thought of as complementary. To the extent that more emissions reductions (and costs) result from the NSPS/EG, the expected emissions reductions (and costs) resulting from the WEC would be expected to be lower.

8.3 Sensitivity on Netting Scenarios

One important feature of the statutory provisions of the waste emissions charge program is the allowance for netting of WEC obligations among facilities under common ownership or control; this section evaluates the sensitivity of RIA results to the alternative interpretations of the netting provision, or netting scenarios.

EPA's final interpretation of the netting provisions differs from the proposed interpretation. The EPA proposed that the WEC obligated party and the scope of netting facilities would be among facilities owned or operated by the same owner-operator organization. EPA is finalizing a broader interpretation of netting that allows transfers of negative WEC emissions among owner-operators that share a common parent company. The final interpretation of the netting provisions was informed by public comments received and statutory interpretation reflecting Congress' support for broad application of netting. Below we evaluate the implications for RIA results of these differing approaches to netting. The EPA did not base its interpretation of the netting provisions on these scenario results.

The broader allowance for netting in the common parent netting scenario results in lower WEC obligations before accounting for methane mitigation and market responses because broader netting allows broader opportunities for WEC obligated parties to net negative WEC emissions to reduce their WEC obligations. This lower initial exposure to potential WEC obligations leads to lower impacts generally, across WEC obligations, emissions reductions, costs, and benefits. This RIA has a limited capability to capture the extent to which differences in the netting scenarios may drive different incentives for facilities to pursue mitigation because the MACC analysis (which drives the emissions reduction estimates) cannot capture the full heterogeneity of oil and gas facilities and thus their differing opportunities for mitigation activities.

Table 8-2 compares emissions subject to WEC under the proposal owner-operator netting scenario to the emissions subject to WEC under the final rule, which allows netting among owner-operators with a common parent company. The illustrative analysis based on reporting for RY2022 indicates that the broader netting scenario results in approximately 15 percent less emissions subject to WEC before mitigation actions or market responses are incorporated. Please note that these results are based on emissions reported in RY2022, not the sensitivity results discussed in Section 8.1.

Table 8-2 Comparison of Estimated Emissions Subject to WEC across Netting Scenarios Before Accounting for Mitigation or Market Responses

	CH4 emissions, 2022			
	(thousand metric tons)		(MMTCO2e with GWP=28)	
	Proposal Owner-Operator Netting	Final Netting of O/O with Common Parent	Proposal Owner-Operator Netting	Final Netting of O/O with Common Parent
Petroleum and Natural Gas Systems Total (GHGI)	7,900		220	
GHGRP subpart W	2,600		72	
From WEC-applicable facilities	1,900		54	
Facility emissions exceeding emissions threshold	970		27	
Emissions subject to WEC, after netting	840	730	24	20

Note: calculation steps for estimating emissions subject to WEC are described in section 4.1.3.

While Table 8-2 focuses on overall emissions subject to WEC across netting scenarios, Table 8-3 compares facilities potentially subject to WEC by segment, based on illustrative analysis of RY2022 emissions reporting. Broader opportunities for netting particularly affect the counts of facilities with WEC obligations in the gathering and boosting and processing segments of the industry. This indicates that corporate organization in these segments more often allows for opportunities to transfer negative net WEC emissions between owner-operators with a common parent than in other industry segments.

Table 8-3 Comparison of Illustrative Facilities Impacted across Netting Scenarios by Industry Segment (RY2022)

Industry Segment	Total Number of Facilities Reporting under subpart W	Number of WEC Applicable Facilities	Number of Facilities with WEC Applicable Emissions >0[a]	Proposal Owner-Operator Netting	Final Netting of O/O with Common Parent
				Number of Facilities with Emissions Subject to WEC, After Netting	
Onshore Production	459	393	226	213	202
Offshore Production	116	23	17	15	16

Gathering and Boosting	350	310	201	163	125
Natural Gas Processing	444	180	~ 53	~ 36	~ 16
Natural Gas Transmission Compression	659	22	~ 5	~ 3	~ 0
Natural Gas Transmission Pipeline	44	20	4	4	4
Underground Natural Gas Storage	51	1	1	1	1
LNG Storage	5	0	0	0	0
LNG Import/Export	11	7	0	0	0
Total	2,112	954	~ 507	~ 435	~ 364

Note: calculation steps for estimating emissions subject to WEC are described in section 4.1.3.

Lastly, Table 8-4 presents summary estimates of emissions reductions, costs, benefits, and net benefits for the owner-operator versus common parent netting scenarios. The broader netting allowed in the common parent netting scenario results in lower emissions reductions, costs, benefits and net benefits than the owner-operator scenario. However, this result is limited by the analysis's limited ability to capture the effect of broader netting incentivizing emissions reductions at a broader range of facilities.

Table 8-4 Comparison of Emissions Reductions, Costs, and Benefits across Netting Scenarios

	Proposal Owner-Operator Netting	**Final Netting of O/O with Common Parent**
	(thousand tons)	
Emissions Subject to WEC in Baseline	3400	3000
Emissions Reductions		
Methane	1,400	1,200
VOC	200	170
	2 Percent Near-Term Ramsey Discount Rate (million 2019$)	
Monetized Climate Benefits (PV)[a]	$2,900	$2,400
Total Social Costs	$540	$460
Cost of Methane Mitigation	$500	$420
Cost of Energy Market Impacts	$44	$39
Net Benefits	$2,400	$1,900

[a] Monetized climate benefits are based on reductions in methane emissions and are calculated using three different estimates of the social cost of methane (SC-CH_4) (under 1.5 percent, 2.0 percent, and 2.5 percent near-term Ramsey discount rates). For the presentational purposes of this table, we show the climate benefits associated with the SC-CH_4 at the 2 percent near-term Ramsey discount rate. Please see Tables 6.2-6.5 for the full range of monetized climate benefit estimates

9 DISTRIBUTIONAL AND ECONOMIC ANALYSES

9.1 Small Business Analysis

9.1.1 Background for Small Entity Impacts

The EPA evaluated the impacts of this action where it identified small entities could potentially be affected and considered whether additional measures to minimize impacts were needed. In evaluating the impacts of this action, the EPA assessed the costs and impacts to small entities from the WEC. Because the WEC is a charge on emissions exceeding specific methane intensity thresholds and does not impose emissions standards or require implementation of technologies or work practices, estimated costs for the purposes of the small entity impact analysis were based only on the WEC and do not include costs associated with reducing emissions below the specified methane intensity thresholds. An assessment of costs for individual facilities to achieve the methane intensity thresholds is also inappropriate for the small entity analysis due to the impact of netting across multiple facilities. For many WEC Obligated Parties (i.e., reported facility owners or operators), total WEC is based on the methane intensity performance of multiple facilities, and reduction of methane intensity at an individual facility may or may not impact total WEC. These costs were therefore evaluated at the owner or operator level and account for netting of emissions from facilities under common ownership or control. Estimated WEC obligations include netting among owner-operators that share a common parent company. Costs are based on the WEC impact in 2024, applying a charge of $900 per metric ton of methane.

9.1.2 Methodology for Calculating Small Entity Impacts

To evaluate whether this rule would have a significant economic impact on a substantial number of small entities, the EPA evaluated the costs of the rule on small entities identified in the RY 2022 subpart W dataset. The EPA used reported facility-to-parent company and facility-to-owner or operator data to link facilities to WEC obligated parties. While the EPA recognizes there have been mergers and acquisitions since the end of 2022 that impact facility ownership, there are no available data that track these changes at the subpart W facility level, nor is there any means to project any additional ownership changes that may occur through the end of 2024.

Reported 2022 ownership structures were therefore held constant for the small entity impact analysis. Revisions were made to the RY 2022 data to project RY 2024 methane intensity at the facility level. These include:

- Methane emissions data were projected forward from 2022 to 2024 using the 2017-2022 annual segment-specific rate of change in reported methane emissions for each segment of subpart W applicable to WEC
- Total facility CO_2e in 2024 was recalculated using the projected methane emissions data and application of AR5 GWPs for methane and N_2O (no changes to actual N_2O or CH_4 emissions were made). Projected CO_2e was used to determine if facilities would exceed the WEC applicability threshold of reported subpart W emissions equal to or greater than 25,000 metric tons CO_2e
- Throughput volumes were projected forward from 2022 to 2024 using the 2022-2030 annual rate of change for dry natural gas production in the Energy Information Administration's 2023 Annual Energy Outlook. The dry gas production rate of change was to project forward throughput for all subpart W segments; the rate of change for crude oil and lease condensate production was applied to onshore and offshore production facilities that report zero gas sales.

In order to analyze the impacts on the entities subject to the WEC, the EPA employed a survey-like approach. The survey approach consists of review of available or reported data from a sample of facilities that are representative of the total population of affected facilities, in order to estimate the likelihood of impacts on small entities in the total population. However, instead of drawing a small, representative sample, the EPA sampled every unit in the universe of parent entities in a current reporting facility. Business information was available for a large proportion of parent entities, and those with no available information were treated as non-responders.

The survey approach is based on a survey of the full population of current subpart W reporters and their parent entities. The survey estimates the business size distribution and the annual revenues for each parent company, which are compared to the estimated WEC costs of each parent company's associated facility owner or operator. For the survey approach, the EPA reviewed the available RY 2022 data for owners or operators of subpart W facilities to determine whether the reporters were part of a small entity and whether the annualized costs of the rule would have a significant impact on a substantial number of small entities. The survey approach included the following steps:

1. Soliciting business information from each parent entity for the survey, including a listing of all facilities that the parent entity has an ownership stake in.

2. Classifying parent entities with available employment and revenue data as small or "not small."
3. Mapping facility parent entities to facility owners or operators.
4. Classifying facility owners or operators as small or "not small" based on the classification of their parent entities.
5. Analyzing expected costs and assigning cost-to-revenue ratios for facility owners or operators.

Soliciting business information. To obtain the employment and revenue data for each of the RY 2022 subpart W parent entities, the EPA reviewed information from ZoomInfo, Experian, and D&B Hoovers business databases in a three-step process. Using an approximate string-matching algorithm, the list of operators was first merged with business information from ZoomInfo for approximately 86% of subpart W parent entities. The remaining unmatched operators were matched to the Experian business database when possible. Additionally, a small number of operators were matched with the D&B Hoovers database information that was collected as part of the Regulatory Impact Analysis (RIA) for the supplemental notice of proposed rulemaking titled "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review." This matching process added information on the ultimate parent entities, number of employees, and annual revenues of the operators. The matches were examined and, when necessary, manual adjustments were made to the matched list of ultimate parent entities to standardize company names, revenue, and employment information. Revenue and employment data were identified for 453 of 468 subpart W parent entities.

Classifying small businesses. Each subpart W parent company's NAICS codes that were reported to subpart A (40 CFR 98.3(c)(10)) for RY 2021 were used in conjunction with revenue and/or employment data to classify the company as either "small business" or "not small business." NAICS codes are reported at the facility level under subpart A. Therefore, the company's employment and revenue data were evaluated against the Small Business Association (SBA) size classification threshold associated with the relevant NAICS code(s) for the facilities owned by the company. If a company reported emissions to subpart W from facilities with different NAICS codes, then the NAICS code for each of their owned facilities was evaluated against the SBA size classification thresholds. For example, if a company reported one facility under onshore petroleum and natural gas production (NAICS code 211130) and another facility under onshore natural gas transmission compression (NAICS code 486210), then the company's employment and revenue data was compared to the small business thresholds for both NAICS codes (211130 and 486210). If either NAICS code threshold comparison indicated that the company was a small business, then the company was designated as a small business for the purposes of this analysis. This approach was taken to conservatively identify all potential small entities that may be subject to subpart W; therefore, it is likely that some entities identified as "Small" may not reflect true small entities. Additionally, the classification also reflects only U.S. reported revenues. The entities for which revenue and employee data were not identified were assumed to be small businesses.

Mapping parents to WEC Obligated Parties. Because the final rule uses facility owners or operators as the WEC Obligated Party, parent companies must be mapped to owners or operators. For facilities with a single parent company and a single owner or operator, the reported owner or operator was mapped to the reported parent company. The final rule also uses a Designated Company approach under which all tons of methane from a facility with multiple parent companies are allocated to a single WEC Obligated Party. For these facilities, the assigned WEC Obligated Party was the owner or operator that mapped to the parent company with the largest equity share in the facility. For facilities with parent companies that had equal equity share in the facility but a single owner or operator, the WEC Entity was mapped to the parent company associated with that owner or operator (e.g., an owner or operator whose name indicated it was a subsidiary of one of the parent companies). For facilities with parent companies that had equal equity share in the facility and an owner or operator associated with each parent company, the WEC Entity was mapped to the parent company with operational control of the facility (based on an internet search). For facilities with multiple parent companies but a single owner or operator that could not be linked to any of the parent companies, the owner or operator was mapped to the parent company with the largest equity share in the facility. For all facilities, the assigned WEC Entity (i.e., owner or operator) was classified as a small business or not small business based on the classification of its parent company.

Analyzing expected costs to WEC obligated parties and assigning cost-to-revenue ratios. To estimate expected costs to reported owners or operators, the EPA calculated the facility-level tons of methane emissions above or below the waste emissions thresholds, summed facility-level tons across facilities under common ownership or control of each WEC Obligated Party to calculate net tons of methane, and multiplied any positive value by $900 to calculate total cost.

There would be no costs for WEC Obligated Parties with netted tons of methane equal to or below zero. WEC costs for 2024 were estimated using the emissions and throughput projections described in section 9.1.1 and the WEC calculation steps described below.

- **Identify WEC applicable facilities**. WEC applicable facilities are GHGRP facilities that report more than 25,000 metric tons CO_2e to GHGRP subpart W and report emissions under any of the nine oil and natural gas industry segments subject to the WEC (all segments except the natural gas distribution segment). Facilities projected to report less than 25,000 metric tons CO_2e to subpart W in a given year would not be considered subject to the WEC and are not included in projections of WEC-applicable emissions. Emissions of CO_2 and N_2O reported to subpart W were assumed to be fixed for each facility at the same level as reported in RY 2021. Methane emissions were projected by segment and source as described section 9.1.1.
- **Calculate facility waste emissions threshold from segment-specific methane intensity thresholds**. To calculate a facility's projected waste emissions threshold, the facility's projected natural gas throughput was first multiplied by the relevant methane intensity threshold specified by Congress to calculate the volume of gas equivalent to the segment-specific methane intensity threshold. These values were converted to metric tons by multiplying by the density of methane (0.0192 mt / Mscf) to calculate the waste emissions threshold in metric tons of methane. The methane intensity thresholds for each segment are listed in Table 1-1.
- **Calculate facility tons above or below waste emissions threshold, or WEC applicable emissions**. A facility's projected waste emissions threshold was subtracted from the facility's projected methane emissions to determine the total facility applicable emissions. This analysis conservatively did not consider the impact of exemptions, so the total facility applicable emissions are equal to the WEC applicable emissions. A negative value represented the metric tons of methane emissions a facility was below the waste emissions threshold while a positive value represented the metric tons of methane emissions at the facility that exceeded the methane intensity threshold. Facilities with projected subpart W emissions below 25,000 metric tons CO_2e were not considered eligible for the purpose of netting and positive or negative tons from these facilities were excluded.
- **Calculate net WEC emissions by owner-operator**. For WEC Obligated Parties with common ownership or control of multiple facilities, facility tons above or below the waste emissions thresholds were summed across all facilities to calculate net tons.
- **Calculate potential WEC obligations**. WEC Obligated Parties with net tons methane of zero or below would not be subject to the WEC and have zero WEC obligations. For WEC Obligated Parties with net tons methane greater than zero, net tons were multiplied by the WEC, which for 2024 is $900/ton of methane.

To estimate small business impacts, the EPA conducted an analysis to estimate the cost-to-revenue ratio (CRR) based on the total 2024 WEC costs and the reported revenues. Because revenue data were available for the majority of parent companies but only a small number of owners or operators, parent company revenue was used to calculate CRR for each WEC Obligated Party. Estimated CRR were calculated for each WEC Obligated Parties by dividing total WEC costs by reported revenue data.

Revenue data were not found for seven WEC Obligated Parties with estimated WEC obligations. For these entities, a proxy for revenue was used by calculating the value equal to the first quartile of revenue for all small entities with revenue data.

9.1.3 Results and Conclusions of Small Entity Impacts Analysis

The number of small entities potentially affected by the final WEC regulation were estimated based on the information collected for 590 owners or operators associated with a facility within one or more of the industry segments identified in CAA section 136(d) reporting at least 25,000 metric tons CO2e under subpart W in RY2022. Of these, 371 were identified as small entities. Table 9-1 below shows the percent of small entities estimated to have a cost-to-revenue ratio that exceeds 1% or 3%. Since this analysis relied, in part, upon confidential business information (CBI) reported under subpart W to estimate these impacts, we present only aggregated data and will not provide economic impact estimates by firm.

Table 9-1 Small Entity Cost-to-Revenue-Ratio Threshold Analysis Results

WEC Obligated Parties	590
Small Entity WEC Obligated Parties	371
Number of Small Entities with a CRR >1%	101
Percent of Small Entities with a CRR >1%	27%
Number of Small Entities with a CRR >3%	70
Percent of Small Entities with a CRR >3%	19%

After considering the economic impact of the final rule on small entities, EPA has concluded that the final rule costs would not likely have a significant impact on a substantial number of small entities. EPA's evaluation of the impacts to small entities relied on several methodologies involving conservative assumptions. Therefore, this evaluation likely overestimates the potential impacts on small entities. First, the analysis calculates WEC obligations at the owner or operator level but does not take into account netting of emissions, which the final rule allows among owners or operators with the same parent company. For many owners or operators, netting will reduce the total charge owed. The analysis therefore projects the maximum amounts owed by owners or operators under the estimated 2024 emissions levels; actual charges will be lower if parent company netting is applied. This analysis does not apply netting at the parent company level because there is no meaningful way to estimate how tons will be transferred from an owner or operator with net negative tons to one or multiple owners or operators with positive net negative tons that shares the same parent company. Additionally, the identification and classification of subpart W parent entities reporting under more than one NAICS code resulted in a designation of "small" based on whether the business information available met the SBA size classification threshold for a single NAICS code. The classification also reflects only U.S. reported revenues. The Agency is aware that there some WEC obligated parties classified as "small" that are subsidiaries to international corporations, but we are unable to identify the total number of these entities and associated revenues. If such information was known, those WEC obligated parties would likely not be considered as affected small entities. The Agency is also aware that some WEC obligated parties classified as "small" are subsidiaries to private equity firms or banks that would not meet the SBA definition of a small business. Additionally, the individual costs imposed on a facility may be distributed across multiple WEC obligated parties. As a result, the CRRs estimated by WEC obligated party may be overstated.

In addition to the conservative assumptions listed above, there are further mitigating factors not included in this screening analysis that will likely significantly reduce compliance costs, and, as a result, cost-to-revenue-ratios. As discussed in Section 5.1, the compliance cost estimate using only the defined WEC obligations does not account for early adoption of mitigation measures that, when implemented, can lower an entity's emissions below the threshold and therefore result in no WEC. Some facilities may find that it is less expensive to invest in mitigation technologies than to pay the WEC. EPA notes it does not have sufficient information to estimate which individual facilities will undertake mitigation actions. As result, the total cost to a small entity could be greatly reduced. We estimate that the avoided WEC payments in 2024 resulting from methane mitigation is hundreds of millions of dollars cumulatively across all WEC entities. Over the analysis period, total compliance costs fall as economic abatement options are taken and residual emissions facing WEC payments fall. The cumulative result of this additional analysis that the CRRs estimated here are likely overstated.

Further mitigating factors not included in this screening analysis are evident from the market model analysis described in Section 5.2. Estimates of price elasticities of demand and supply are needed to assess cost pass through. The price elasticity of demand is a measure of the responsiveness of product demand to a change in price of a product. Likewise, the price elasticity of supply is a measure of the responsiveness of supply of a product to a change in its price. Elasticity estimates are used when they are available to provide an indication of how much of the control costs borne directly by firms in affected industries can be passed on to consumers. For example, WEC obligations shift supply curves upward. As evidenced by the price elasticities shown in Table 5-4, demand for product from affected producers is inelastic (i.e., the price elasticity of demand is less than 1), indicating there will be a price increase that allows cost pass through to consumers.

The cumulative effect of the above mitigating factors and conservative assumptions used in the screening analysis indicates that, overall, the final rule would not likely have a significant impact on a substantial number of small entities.

9.2 Employment Impacts

This section provides background information on employment in natural gas extraction, transmission, and distribution sectors as well as an estimate of the likely employment impacts of the WEC. For the latter, we consider employment impacts in other sectors that will provide installation and manufacturing services to support expected methane abatement activity.

9.2.1 Background

Table 9-2 shows employment in three sectors related to the oil and gas industry based on data provided by the Bureau of Labor Statistics (BLS): oil and gas extraction (NAICS 2111), pipeline transportation of natural gas (NAICS 486210), and natural gas distribution (NAICS 221210).[60] In total, about 263,000 people were employed by the three sectors in 2022, with oil and gas extraction employing the largest number and natural gas distribution only slightly fewer. Please note that the employment discussion and analysis in this section does not account for

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[60] Retrieved from FRED: IPUCN221210W200000000 (221210), IPUIN486210W200000000 (486210), IPUBN2111W200000000 (2111) on July 19,2024, not seasonally adjusted

employment in related sectors such as support activities for oil and gas extraction (NAICS 213112).[61]

Table 9-2 Employment in Oil and Gas Sectors (2022)

NAICS	Sector	Employment (thousands)
2111	Oil and gas extraction	118.9
486210	Pipeline transportation of natural gas	31.7
221210	Natural gas distribution	112.7
Total		**263.3**

Federal Reserve employment data report annual sectoral employment. Employment in oil and gas extraction has declined 39% since 2015, dropping from 195 thousand employees in 2015 to 119 thousand employees in 2022. Employment has remained steady in pipeline transportation and natural gas distribution, with consistent levels over the past decade. Collectively, employment across the three sectors has declined 22% from 338 thousand in 2015 to 263 thousand in 2022.

Table 9-3 shows total labor compensation in NAICS 2111 and 221210 based on data provided from the Bureau of Labor Statistics (BLS).[62] Labor compensation is defined as payroll plus supplemental payments, and includes salaries, wages, commissions, dismissal pay, bonuses, vacation and sick leave pay, and compensation in kind. In total, the two sectors provided $48.7 billion in labor compensation. Per worker, the oil and gas extraction sector provided $253.3 thousand, while natural gas distribution provided $163.4 thousand. The Economic Census provides wage data for additional 6-digit NAICs codes every five years, with 2012 and 2017 being the latest available.[63]

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[61] Over the past two decades, firms in the oil and gas industry have increasingly relied on contractors relative to hiring employees directly. These contractors are not counted as employees within the sectors, so labor productivity for oil and gas extraction for oil and gas extraction appears to be greater than it otherwise would be if these contract workers were included.

[62] Retrieved from FRED: IPUBN2111L020000000 (2111), IPUCN221210L020000000 (221210)

[63] https://data.census.gov/table?q=all+sectors:+summary+statistics&y=2012&n=N0600.00

Table 9-3 Labor Compensation in the Oil and Gas Sector (2022)[64]

NAICS	Sector	Total Labor Compensation (billions)	Total Compensation per Worker (thousands)
2111	Oil and gas extraction	$30.2	$253.3
221210	Natural gas distribution	$18.4	$163.4

While total labor compensation in the oil and gas extraction sector has declined in the last decade due to fewer employees, total compensation per employee has risen from $195.5 thousand in 2012 to $253.3 thousand in 2022. Total labor compensation in natural gas distribution has risen from $14.5 billion in 2012 to $18.4 billion in 2022, and compensation per worker has risen from $132.7 thousand in 2012 to $163.4 thousand in 2022.

The BLS Office of Productivity and Technology (OPT) also measures sectoral output per worker, a measure of labor productivity, for select sectors.[65] In oil and gas extraction (2111), output-per-worker has nearly tripled over the past decade. In natural gas distribution (221210), labor productivity has increased 23% from 2022 to 2023. Output has risen sharply in 2021 and 2022, from an average of approximately $100 billion per year for distribution over the period 2012-2020 to $175 billion in 2022. Similarly, oil and gas extraction, while varying more over 2012-2020 from $200-400 billion, was $650 billion in 2022.

9.2.2 Employment Impacts

This section presents an analysis of potential employment impacts of the final WEC. The analysis is focused on employment within the oil and natural gas industry and does not attempt to model economy-wide employment changes. Oil and natural gas industry employment is potentially affected through each of the cost and emissions impact pathways analyzed in this RIA. Increased expenditures on methane mitigation technologies lead to potential increases in

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[64] Data accessed in July 2024. The information has since been updated; however, these figures were used as inputs into other parts of this analysis. The updated numbers were not available in time to produce new results elsewhere in this analysis. As of July 2024, total labor compensation for oil and gas extraction was $30.2 billion in 2022, and $18.4 billion in 2022 for natural gas distribution. Total worker compensation per worker in 2022 was $253.3 thousand for oil and gas extraction, and $163.4 thousand for natural gas distribution.

[65] https://www.bls.gov/productivity/tables/ see labor productivity and costs measures, detailed industries.

employment because of the labor-intensive nature of some mitigation actions, such as performing fugitive leak detection and repair activities. The energy market impacts lead to reduced employment through reduced production of natural gas. However, based on the analyses in section 5, the costs of methane mitigation are dominant when compared to production changes.

Facilities expecting to pay the WEC will take on abatement activities that allow them to avoid paying the WEC where they can abate for less money. The cost of these activities is represented by the costs of methane mitigation, characterized in Section 5.1 as the height of the $MACC$. These costs represent expenditures on capital equipment and labor to install and maintain natural gas handling and emissions abatement. As these expenditures are already accounted for within the costs of methane mitigation, they are not additive to societal welfare that has already been characterized. However, given the importance of employment as an economic issue, we identify the value of certain employment supported by abatement expenditures.

This analysis estimates the employment induced by the WEC by disaggregating total abatement expenditures, equal to the area under the MACC curve up to total abatement, into capital and operations-and-maintenance. Total capital expenditures represent a mix of capital equipment, labor for construction and installation, and other materials. EPA considers the magnitude of wages paid to construct, operate, and maintain the control equipment (direct employment) and to manufacture control equipment (indirect employment). For oil and natural gas firms that pay the WEC this analysis assumes no associated increased employment, though there may be additional labor demand associated with WEC compliance, reporting, and payment processing for WEC-applicable facilities.

This analysis bases job and wage benefits associated with abatement expenditures on the ratio of employment and wages to total output within sectors that provide emissions abatement services. These ratios are calculated from economic survey data conducted under the Economic Census for a range of North American Industrial Classification System (NAICS) codes. This analysis associates expenditures with an appropriate NAICS codes for capital equipment, installation, and operations and maintenance with NAICS to assign an employment multiplier for each. Table 9-4 presents the multipliers, which range from 0.4 jobs per million dollars of expenditure in natural gas extraction (NAICS code 211130) to 4.3 jobs per million dollars expenditure on capital installation.

Table 9-4 Employment Multipliers for Abatement Expenditures

Expenditure	Type / Segment	NAICS	Employment / $MM Output	Segment Group	Average Employment / $MM
Capital	Equipment	333132	2.72		
	Installation	237120	4.25		
O&M	Oil Extraction	211120	0.60	Production	0.5
	Natural Gas Extraction	211130	0.44		
	Pipeline Transportation	486210	1.11	Gathering, Boosting, Transmission, & Storage (GBTS)	1.0
	Natural Gas Distribution	221210	0.91		
Production	Natural Gas (all segments)	Multiple	0.5		

Direct job impacts of the WEC come from a mix of compliance expenditures (positive) and changes in output (negative). The largest jobs impact comes from capital equipment manufacturing and installation, which support about 155 jobs in 2024 up to about 438 jobs in 2026. Capital and O&M expenditures from the MACC analysis and output changes estimated from the PE Model form the basis of the jobs impacts estimates. The split of capital expenditures between equipment and installation expenditures is assumed to be 70/30. Job losses from reduced output are 2 jobs in 2024 and 28 jobs in 2026 and with none in the remainder of the analysis period. Total jobs supported are about 162 in 2024, rising to about 443 in 2026, and dropping to zero in the later years of the analysis period.

Table 9-5 Employment Impacts of Compliance Expenditures and Output Changes

	Capital				O&M				Output		Total
	Equipment		Installation		Production		GBTS[a]				
Multiplier:		2.7		4.3		0.5		1.0		0.5	
Year	Exp.	Jobs	Exp.	Jobs	Exp.	Jobs	Exp.	Jobs	Rev.	Jobs	Jobs
2024	$34.2	93	$14.6	62	-$9.9	-5	$14.0	14	-$3.3	-2	162
2025	$68.2	186	$29.2	124	-$16.2	-8	$30.9	31	-$3.6	-2	331
2026	$96.4	262	$41.3	176	-$22.0	-11	$44.2	45	-$50.2	-28	443
2027	$93.4	254	$40.0	170	-$19.6	-10	$43.9	44.4	-$46.9	-26	433
2028	$0.3	1	$0.1	1	$15.5	8	$2.5	2	-$1.4	-1	11
2029	$0.0	0	$0.0	0	$11.1	6	$0.0	0	-$1.0	-1	5
2030	$0.0	0	$0.0	0	$11.1	6	$0.0	0	-$0.9	-1	5
2031	$0.0	0	$0.0	0	$11.1	6	$0.0	0	-$0.9	-1	5
2032	$0.0	0	$0.0	0	$11.1	6	$0.0	0	-$0.9	-1	5
2033	$0.0	0	$0.0	0	$11.1	6	$0.0	0	-$0.9	0	5
2034	$0.0	0	$0.0	0	$11.1	6	$0.0	0	-$0.9	0	5
2035	$0.0	0	$0.0	0	$11.1	6	$0.0	0	-$0.9	0	5

[a] GBTS stands for Gathering, Boosting, Transmission, & Storage.

9.3 Environmental Justice

9.3.1 Introduction and Background

Executive Order 14906, signed April 21, 2023, builds on the prior executive orders to further advance environmental justice (88 FR 25251), including Executive Order 12898 (59 FR 7629, February 16, 1994) and Executive Order 14008 (86 FR 7619, January 27, 2021) which establish federal executive policy on environmental justice. EPA defines[66] environmental justice as the "just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, Tribal affiliation, or disability, in agency decision-making and other Federal activities that affect human health and the environment so that people: (i) are fully protected from disproportionate and adverse human health and environmental effects (including risks) and hazards, including those related to climate change, the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic

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[66] EPA recognizes that Executive Order 14096 (88 FR 25251, April 21, 2023) provides a new terminology and a new definition for environmental justice. For additional information, see *https://www.federalregister.gov/documents/2023/04/26/2023-08955/revitalizing-our-nations-commitment-to-environmental-justice-for-all*.

barriers; and (ii) have equitable access to a healthy, sustainable, and resilient environment in which to live, play, work, learn, grow, worship, and engage in cultural and subsistence practices."[67]

Executive Order 12898 (59 FR 7629; February 16, 1994) establishes federal executive policy on environmental justice. Its main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on communities with environmental justice concerns in the United States. EPA defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. EPA's "Technical Guidance for Assessing Environmental Justice in Regulatory Analysis" (U.S. EPA, 2016) provides recommendations that encourage analysts to conduct the highest quality analysis feasible, recognizing that data limitations, time and resource constraints, and analytic challenges will vary by media and circumstance.

A reasonable starting point for assessing the need for a more detailed EJ analysis is to review the available evidence from the published literature and from community input on what factors may make population groups of concern more vulnerable to adverse effects (e.g., underlying risk factors that may contribute to higher exposures and/or impacts). It is also important to evaluate the data and methods available for conducting an EJ analysis. EJ analyses can be grouped into two types, both of which are informative, but not always feasible for a given rulemaking:

1. Baseline: Describes the current (pre-control) distribution of exposures and risk, identifying potential disparities.
2. Policy: Describes the distribution of exposures and risk after the regulatory option(s) have been applied (post-control), identifying how potential disparities change in response to the rulemaking.

EPA's 2016 Technical Guidance does not prescribe or recommend a specific approach or methodology for conducting EJ analyses, though a key consideration is consistency with the

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[67] See, *e.g.*, Environmental Protection Agency. "*Environmental Justice*." Available at: *https://www.epa.gov/environmentaljustice.*

assumptions underlying other parts of the regulatory analysis when evaluating the baseline and regulatory options.

9.3.2 Scope and Limitations

The EJ analysis described in this section evaluates only a "baseline" set of environmental justice indicators of 559 counties determined to have methane emissions expected to be affected by the WEC, using the most recent available data. This analysis uses historical data, which enables us to characterize communities that in these counties prior to implementation of the final rule, and identify potential environmental justice concerns – on aggregate – across the populations of the 559 counties. We lack key information that would be needed to assess post-control risks (the "policy" scenario as described above) under the WEC or the regulatory alternatives analyzed in this RIA. Therefore, the extent to which this rule will affect potential EJ outcomes is not quantitatively evaluated.

This action chronologically follows the Oil and Gas NSPS/EG RIA which presents a detailed environmental justice analysis of health risks and economic activity associated with the oil and gas industry. Because the sources potentially affected by the WEC are a subset of those affected by the 2024 Final NSPS/EG rule and the populations overlap, EPA expects the WEC implications for environmental justice to be directionally similar to those of the NSPS/EG rule. Because the magnitude of emissions reductions is larger for the NSPS/EG rule than for the WEC, the magnitude of environmental justice implications is also smaller for the WEC.

In updating the analysis for this final rule, EPA has used the most recent data for county level emissions that are expected to be affected by the rule. Time and resource constraints prevent the replication of the full series of analyses conducted for the NSPS/EG RIA.

9.3.3 Summary of Environmental Justice Findings of the NSPS/EG RIA

The RIA for the 2024 Final NSPS/EG conducted detailed analyses of impacts the rule across several areas of concern for environmental justice.

The NSPS/EG RIA presented an evaluation of the EJ implications of ozone from VOC emissions from the oil and natural gas sector. The RIA for the 2024 Final NSPS/EG concluded that because of expected reductions in methane emissions, the NSPS/EG would also contribute to the slight reductions in formation of ground level ozone, with attendant benefits for human health. Similarly, the Air Toxics exposure analysis showed that there are many sources of air toxics from a number of sectors, but populations currently over-represented in exposure to emissions from the oil and gas sector include environmental justice communities, and that emissions reductions from the Rule will benefit those communities.

The RIA for the 2024 Final NSPS/EG also considered the economic impacts of regulation on employment among overburdened or marginalized communities. The RIA notes that a reduction in employment in the oil and natural gas sector may be associated with loss of income for workers in the oil and gas industry, and for oil and gas communities. With respect to energy expenditures, the RIA notes that low income, and, to some extent, racial and ethnic minorities are more likely to be negatively impacted by energy price increases. However, the RIA notes that the NSPS/EG rule is unlikely to have a significant impact on oil and gas employment or on energy prices among overburdened and marginalized communities, and, therefore, that it is unlikely to exacerbate existing inequality. Please note that Section 9.2 of this RIA estimates employment impacts of the WEC, and finds net increase in employment in oil and gas industries.

As mentioned above, EPA expects that the findings of the environmental justice analysis included in the RIA for the 2024 Final NSPS/EG are generally relevant for the WEC as well because of the overlap in affected sources and populations.

9.3.4 Environmental Justice Analysis of the Final WEC Rule

EPA constructed an analysis of reported methane emissions - by county - in the United States for the facilities in the Onshore Petroleum and Natural Gas Production and Onshore Petroleum and Natural Gas Gathering and Boosting industry segments with methane emissions that exceed their waste emissions threshold (i.e., their WEC applicable emissions are greater than zero) based on reported RY 2022 emissions and throughputs. We allocated the reported methane emissions for facilities in the Onshore Petroleum and Natural Gas Production industry segment to counties proportional to the number of producing wells the facility reported for each county (which is part of the reported sub-basin identifier). We determined the counties in which each facility in the Onshore Petroleum and Natural Gas Gathering and Boosting industry segment operated based on the reported location of acid gas removal units, dehydrators, flare stacks, and atmospheric storage tanks. We then allocated the reported methane emissions evenly across the counties identified.

We used this analysis to identify 559 counties where Onshore Petroleum and Natural Gas Production and/or Onshore Petroleum and Natural Gas Gathering and Boosting facilities with reported emissions for 2022 that would exceed facility waste emissions thresholds (see Section 4). See Figure 9-1.

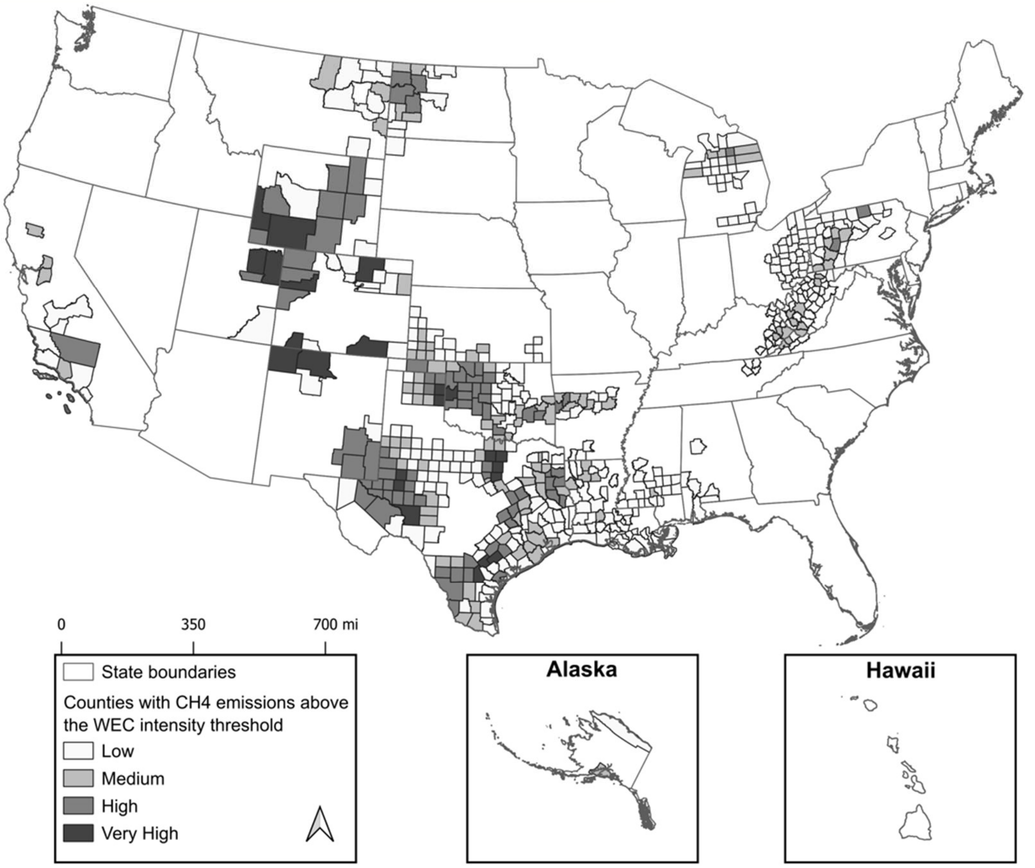

Figure 9-1 Map of the counties identified as having emissions from facilities potentially subject to the Waste Emissions Charge (2022)

As noted above, the analysis in this section is focused on baseline conditions using historical data. Again, we are not able to assess how the rule may affect emissions from specific counties – emissions changes will depend on decisions taken by regulated entities in response to specific local conditions. Consequently, we do not quantify any environmental justice impact of the WEC following its implementation. Importantly, we note that this final rule may not impact all locations with oil and natural gas emissions equally, in part due to differences in existing state regulations in locations like Colorado and California, which have more stringent requirements.

For the 559 counties described above, we can identify certain demographic characteristics of the communities, the incidence of some chronic disease conditions among the populations, and Total Cancer Risk and Total Respiratory Risk for the people in these counties. We compare the data on these characteristics for counties likely to be affected by the WEC to data on the characteristics to national averages. Note that this comparison does not isolate the correlation between environmental justice concerns and oil and gas production –counties may have oil and gas activity and associated emissions but may not be subject to the WEC and there are other sources of emissions that contribute to health risks. Additionally, emissions from the oil and gas sector may affect populations downwind of the source county, but for this analysis we are not conducting air transport modeling and limiting analysis to the populations living in the source counties.

Demographic data, including income, race and ethnicity are taken from the most recent (2018-2022) American Communities Survey (ACS) published by the Census Bureau (2023a). This data was gathered from 2018-2022. We use the 2022 "PLACES Dataset," published by the Centers for Disease Control, to gather county-level incidence of asthma and heart disease (specifically "Chronic Asthma Prevalence Among Adults ≥ 18 years," and "Chronic Heart Disease Prevalence Among Adults ≥ 18 years"). We provide county level cancer risk and respiratory risk at the county level by analyzing the EPA dataset on risks from atmospheric pollution called AirToxScreen (U.S. EPA, 2024b). "Total Cancer Risk" is presented as cancers per one million people from a lifetime exposure to a certain level of air pollution, over and above other cancer risks. "Total Respiratory Risk" is a non-cancer hazard quotient, which is exposure to a substance divided by the level of exposure at which no adverse effects are expected – both risk measures are the sum of all individual risk values for the chemicals evaluated in the AirToxScreen database (U.S. EPA, 2024c).

Emissions from the 559 counties described above range from under one metric ton per year of methane, to more than 50,000 tons per year. We've divided the counties into groups based on their respective annual emissions and compare the average demographic and risk indicators for each category with the averages for the entire group, and with the averages for all U.S. counties. The categories are “low, medium, high, and very high.” (see Table 9-6)

Table 9-6 Categorizing Category Emissions by Intensity

Category Label	County emissions (mt/year)	Percentile	Total Counties	Percent of Total Emissions
Low	<1-585	<60th	334	6%
Medium	585 – 1,292	60th – 80th	113	12%
High	1,292 – 6,818	80th-95th	82	32%
Very High	6,818– 50,543	>95th	30	50%

These results show that the emissions vary widely, and that the highest emitting counties account for a disproportionate fraction of the total. The top 30 counties, less than 5% of the of the group, contribute over 50% of the methane emissions. Emissions from the 334 low emissions counties contributes 6 percent of the total. Figure 9-2 shows emissions from all 559 counties ranked from lowest total annual emissions to highest.

The categorization gives an opportunity to investigate any relationship between county emissions quantity and health risk for communities in these counties. Clearly, there are many potential reasons that emissions identified here may not be directly correlated with risks, even though these emissions are associated with emissions of hazardous air pollution and are precursors to ground level ozone. First, counties are large areas, and populations in counties may not be near oil and gas emissions sources. Second, there are other sources of emissions risks in these counties. Moreover, many of these counties include emissions from the oil and gas sector that are not affected by the proposal, and therefore not quantified in these results. Additionally, many communities in these counties face risks from atmospheric emissions from outside of their county boundaries.

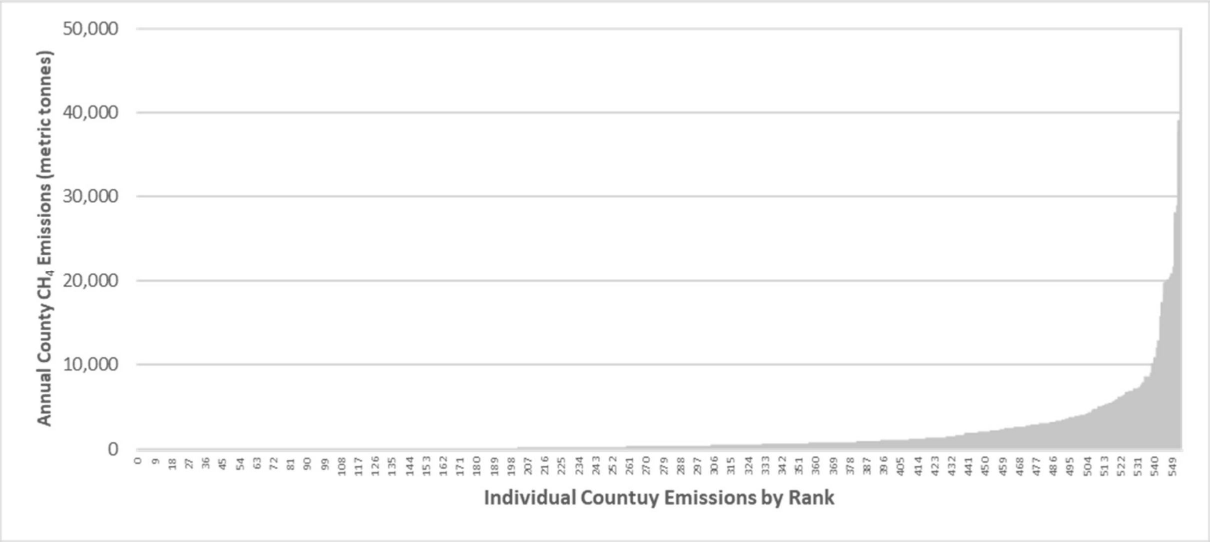

Figure 9-2 Individual County Emissions Ranked from Lowest to Highest

It is important to note, however, that these results are averages, and circumstances for communities and households in individual counties can be very different from the average risks we can show with this data.

9.3.5 Aggregate Average Conditions for Potentially Affected Counties

The data shown in Table 9-7 are taken for each county from the most recent government datasets. The demographic data is from the 2018-2022 American Communities Survey (US Census, 2023). The Total Cancer Risk and Total Respiratory Risk data are from the EPA AirToxScreen 2020 database (EPA, 2024b). Chronic Asthma Prevalence among Adults Age ≥ 18 years and Chronic Heart Disease Prevalence among Adults Age ≥ 18 years are from the Center for Disease Control "2022 PLACES" Dataset (CDC, 2023). For each indicator, the national average for the indicator is in the first column (note that national average of 3,143 counties includes the counties in this dataset). The second column includes the averages for all 559 counties identified as having emissions potentially subject to the WEC. The Low Emissions column averages are for the 334 counties with annual methane emissions less than 585 metric tons. The Medium Emissions column shows the indicator averages for the 118 counties with emissions between 585 and 1,292 metric tons. The82 counties represented in the High Emissions column have emissions between 1,292 and 6,818 metric tons, and the Very High Emission column represents the 30 counties with reported emissions above 6,818 tons (the county with the highest emissions potentially subject to the WEC has reported emissions of 50,544 metric tons of methane).

Looking at all of the potential WEC counties, this analysis shows results that are generally consistent with the main results from the NSPS/EG RIA analysis. The communities in these counties are generally more diverse than the national average. These counties are home to higher percentages of individuals who identify as being Native American, or who identify as members of race “other” than White, Black or African American, or Native American. There are generally more people who identify as having Hispanic or Latino ethnicity – who are substantially over-represented in the High and Very High Emissions counties. There are generally fewer individuals who identify as Black or African Americans in these counties, with progressively fewer moving from Low to Medium to High emissions counties, but a high percentage (10.4) again in the 30 “Very High Emissions” counties. Native Americans populations are disproportionately represented in these counties with High Emissions and Very High Emissions. While the median household income for these counties is generally lower than the national average, it is higher than the national average in the 30 counties with the highest emissions. Similarly, the households with low incomes (below the Poverty line) and very low incomes (below 50% of the poverty line) are over-represented compared to the national average, but in the counties with the highest emissions there are fewer households with low and very low incomes.

Table 9-7 Overall Demographic and Health Indicators for All Counties, by Category

	National Average	**All Potential WEC Counties**	**Low Emissions *(<60th percentile)***	**Medium Emissions *(60th - 80th percentile)***	**High Emissions *(80th-95th percentile)***	**Very High Emissions *(>95th percentile)***
% White (race)	65.9	61.7	62.4	57.5	66.5	62.9
% Black or African American (Race)	12.5	10.7	11.2	10.7	4.7	10.4
% Native American (Race)	0.84	1.0	1.0	0.8	1.6	1.8
% Other (Race)	21.7	27.7	26.4	31.8	21.5	27.8
% Hispanic (Ethnicity)	18.7	27.6	23.2	36.3	31.0	32.4
Median Household Income (1k 2019$)	78.6	74.5	75.7	71..5	62.5	83.8
% Below Poverty Line	6.5	7.5	7.3	7.8	9.9	5.7
% Below Half the Poverty Line	5.7	6.4	6.4	6.8	6.4	5.4
Total Cancer Risk (per million)	25.4	27.6	26.9	30.8	23.3	28.5
Total Respiratory Risk (hazard quotient)	0.31	0.32	0.31	0.35	0.25	0.30
Chronic Asthma Prevalence (≥ 18 yrs)	9.7	9.8	9.9	9.5	9.9	9.6
Chronic Heart Disease Prevalence (≥ 18 yrs)	5.6	5.9	5.9	6.0	6.4	5.7

With regard to the health indicators from the AirToxScreen and PLACES datasets, there appears to be a general elevation across all health categories for the 559 counties compared to the national averages[68]. However, there does not appear to be a significant trend in health risks for counties with higher emissions potentially subject to the WEC.

These health indicators are consistent with the findings from the NSPS/EG RIA: that while ozone and hazardous pollutants from the oil and gas industry are known to present health risks, data at the county level is too aggregated and across too large an area to show the impacts of the emissions on entire county populations.

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[68] The statistical significance of the cancer risk factors from the AirToxScreen Data cannot be quantitatively characterized since the dose-response function is modeled. The general observation from the analysis is not that affected sources are uniquely responsible for elevated risk to communities, as there are other sources of risk.

It is possible, however, that some households in these 559 counties are located in close proximity to sources of emissions and may face higher than average health risks. This analysis indicates that these risks appear to be higher for communities with environmental justice concerns. With currently available data, the quantitative assessments of existing environmental justice indicators are subject to various types of uncertainty, but these results suggest additional and continuing analysis of environmental justice concerns for these communities is warranted.

Due to lack of resources, time, and data, it is not possible to conduct a more thorough investigation of the very localized conditions of communities that may be subject to disproportionate risk, which include environmental justice communities of concern, and that may be affected by the rule.

Because the impacts of the rule will depend on decisions about emissions sources that will be made in response to local economic and regulatory conditions, it is not possible to project the impact of the rule on specific communities. EPA believes, however, that in aggregate the final action will result in reduction of methane, hazardous air pollutants, and volatile organic compounds, and, generally, this result will improve environmental justice outcomes.

9.4 The Distribution of Long-Term Climate Impacts

9.4.1 Environmental Justice Implications of Climate Change

Methane emissions represent a significant share of total GHG emissions and hence are a major contributor to climate change. In 2009, under the Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act (“Endangerment Finding”), the Administrator considered how climate change threatens the health and welfare of the U.S. population. As part of that consideration, the EPA Administrator also considered risks to communities with environmental justice concerns, finding that certain parts of the U.S. population may be especially vulnerable based on their characteristics or circumstances. These groups include economically and socially vulnerable communities; individuals at vulnerable life stages, such as the elderly, the very young, and pregnant or nursing women; those already in poor health or with comorbidities; the disabled; those experiencing homelessness, mental illness, or substance abuse; and/or Indigenous or people of color dependent on one or limited resources for subsistence due to factors including but not limited to geography, access, and mobility.

Scientific assessment reports produced over the past decade by the U.S. Global Change Research Program (USGCRP), the IPCC, and the National Academies of Science, Engineering, and Medicine add more evidence that the impacts of climate change raise potential EJ concerns (IPCC, 2018; Oppenheimer et al., 2014; Porter et al., 2014; Smith et al., 2014; USGCRP, 2016, 2018).

These reports conclude that poorer or predominantly non-White communities can be especially vulnerable to climate change impacts because they tend to have limited adaptive capacities and are more dependent on climate-sensitive resources such as local water and food supplies or have less access to social and information resources. Some communities of color, specifically populations defined jointly by ethnic/racial characteristics and geographic location, may be uniquely vulnerable to climate change health impacts in the U.S. In particular, the 2016 scientific assessment on the Impacts of Climate Change on Human Health found with high confidence that vulnerabilities are place- and time-specific, life stages and ages are linked to immediate and future health impacts, and social determinants of health are linked to greater extent and severity of climate change-related health impacts. The GHG emission reductions associated with this proposal would contribute to efforts to reduce the probability of severe impacts related to climate change. Individuals living in socially and economically disadvantaged communities, such as those living at or below the poverty line or who are experiencing homelessness or social isolation, are at greater risk of health effects from climate change. This is also true with respect to people at vulnerable life stages, specifically women who are pre- and perinatal, or are nursing; in utero fetuses; children at all stages of development; and the elderly. Per the Fifth National Climate Assessment (NCA5), “Health risks from a changing climate include higher rates of heat-related morbidity and mortality; increases in the geographic range of some infectious diseases; greater exposure to poor air quality; increases in some adverse pregnancy outcomes; higher rates of pulmonary, neurological, and cardiovascular diseases; and worsening mental health.” Many of these exacerbated health conditions occur at higher rates within vulnerable communities. Importantly, negative public health outcomes include those that are physical in nature, as well as mental, emotional, social, and economic.

The scientific assessment literature demonstrates that there are myriad ways these populations may be affected at the individual and community levels. Individuals face differential exposure to criteria pollutants, in part due to the proximities of highways, trains, factories, and other major sources of pollutant-emitting sources to less-affluent residential areas. Outdoor workers, such as construction or utility crews and agricultural laborers, who frequently are comprised of already at-risk groups, are exposed to poor air quality and extreme temperatures without relief. Furthermore, individuals within EJ populations of concern face greater housing, clean water, and food insecurity and bear disproportionate economic impacts and health burdens associated with climate change effects. They have less or limited access to healthcare and affordable, adequate health or homeowner insurance. Resiliency and adaptation are more difficult for economically disadvantaged communities: They have less liquidity, individually and collectively, to move or to make the types of infrastructure or policy changes to limit or reduce the hazards they face. They frequently are less able to self-advocate for resources that would otherwise aid in building resilience and hazard reduction and mitigation.

In a 2021 report, *Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts,* EPA considered the degree to which four socially vulnerable populations—defined based on income, educational attainment, race and ethnicity, and age— may be more exposed to the highest impacts of climate change (U.S. EPA, 2021c). The report found that Blacks and African American populations are approximately 40 percent more likely to currently live in these areas of the U.S. projected to experience the highest increases in mortality rates due to changes in temperature. Additionally, Hispanic and Latino individuals in weather exposed industries were found to be 43 percent more likely to currently live in areas with the highest projected labor hour losses due to temperature changes. American Indian and Alaska Native individuals are projected to be 48 percent more likely to currently live in areas where the highest percentage of land may be inundated by sea level rise. Overall, the report confirmed findings of broader climate science assessments that Americans identifying as people of color, those with low-income, and those without a high school diploma face higher differential risks of experiencing the most damaging impacts of climate change.

The assessment literature cited in EPA's 2009 and 2016 Endangerment and Cause or Contribute Findings, as well as Impacts of Climate Change on Human Health (2016) and the NCA4 (2018), also concluded that certain populations and life stages, including children, are especially sensitive to climate-related health effects. In a more recent 2023 report, *Climate Change Impacts on Children's Health and Well-Being in the U.S.,* EPA considered the degree to which children's health and well-being may be impacted by five climate-related environmental hazards – extreme heat, poor air quality, changes in seasonality, flooding, and different types of infectious diseases (U.S. EPA, 2023c). The report found that children's academic achievement is projected to be reduced by 4-7% per child, as a result of moderate and higher levels of warming, impacting future income levels. The report also projects increases to the numbers of annual emergency department visits associated with asthma and a four to eleven percent increase in new asthma diagnoses due to climate-driven increases in air pollution. In addition, more than 1 million children in coastal regions are projected to be temporarily displaced from their homes annually due to climate-driven flooding, and infectious disease rates are similarly anticipated to rise, with the number of new Lyme disease cases in children living in 22 states in the eastern and midwestern U.S. increasing by approximately 3,000-23,000 per year compared to current levels. Overall, the report confirmed findings of broader climate science assessments that children are uniquely vulnerable to climate-related impacts and that in many situations, children in the U.S. who identify as Black, Indigenous, and People of Color, are limited English-speaking, do not have health insurance, or live in low-income communities may be disproportionately exposed to the most severe impacts of climate change.

Native American Tribal communities possess unique vulnerabilities to climate change, particularly those impacted by degradation of natural and cultural resources within established reservation boundaries and threats to traditional subsistence lifestyles. Tribal communities whose health, economic well-being, and cultural traditions depend upon the natural environment will likely be affected by the degradation of ecosystem goods and services associated with climate change. The IPCC indicates that losses of customs and historical knowledge may cause communities to be less resilient or adaptable. The NCA4 noted that while Indigenous peoples are diverse and will be impacted by the climate changes universal to all Americans, there are several ways in which climate change uniquely threatens Indigenous peoples' livelihoods and economies. In addition, there can institutional barriers to their management of water, land, and other natural resources that could impede adaptive measures.

For example, Indigenous agriculture in the Southwest is already being adversely affected by changing patterns of flooding, drought, dust storms, and rising temperatures leading to increased soil erosion, irrigation water demand, and decreased crop quality and herd sizes. The Confederated Tribes of the Umatilla Indian Reservation in the Northwest have identified climate risks to salmon, elk, deer, roots, and huckleberry habitat. Housing and sanitary water supply infrastructure are vulnerable to disruption from extreme precipitation events.

NCA4 noted that Indigenous peoples often have disproportionately higher rates of asthma, cardiovascular disease, Alzheimer's, diabetes, and obesity, which can all contribute to increased vulnerability to climate-driven extreme heat and air pollution events. These factors also may be exacerbated by stressful situations, such as extreme weather events, wildfires, and other circumstances.

NCA4 and IPCC Fifth Assessment Report also highlighted several impacts specific to Alaskan Indigenous Peoples. Coastal erosion and permafrost thaw will lead to more coastal erosion, exacerbated risks of winter travel, and damage to buildings, roads, and other infrastructure – these impacts on archaeological sites, structures, and objects that will lead to a loss of cultural heritage for Alaska's Indigenous people. In terms of food security, the NCA4 discussed reductions in suitable ice conditions for hunting, warmer temperatures impairing the use of traditional ice cellars for food storage, and declining shellfish populations due to warming and acidification. While the NCA also noted that climate change provided more opportunity to hunt from boats later in the fall season or earlier in the spring, the assessment found that the net impact was an overall decrease in food security.

In addition, the U.S. Pacific Islands and the indigenous communities that live there are also uniquely vulnerable to the effects of climate change due to their remote location and geographic isolation. They rely on the land, ocean, and natural resources for their livelihoods, but face challenges in obtaining energy and food supplies that need to be shipped in at high costs. As a result, they face higher energy costs than the rest of the nation and depend on imported fossil fuels for electricity generation and diesel. These challenges exacerbate the climate impacts that the Pacific Islands are experiencing. NCA4 notes that Indigenous peoples of the Pacific are threatened by rising sea levels, diminishing freshwater availability, and negative effects to ecosystem services that threaten these individuals' health and well-being.

9.4.2 Avoided U.S. Climate Impacts of the Final Rule

As discussed in the previous section, large-scale impacts resulting from GHG-driven long-term climate change may be experienced differently across populations and regions. This section presents an analysis of the distribution of avoided long-term climate impacts associated with the CH_4 emission reductions from the final rule to better understand how the WEC rule may mitigate climate change impacts, and how these changes may be experienced differently by residents across the U.S. This analysis uses the Framework for Evaluating Damages and Impacts (FrEDI)[69] (U.S. EPA, 2024a) to illustrate how climate-driven impacts at the end of the century (2100) may be distributed across different sectors, regions, and populations within contiguous U.S. borders. While the impact categories included in this analysis cover a large range across the U.S. economy, FrEDI does not include a comprehensive list of all climate-driven impacts and only explores those effects that directly occur within contiguous U.S. borders. Therefore, FrEDI only provides a subset of the impacts expected to accrue to U.S. citizens and their interests. See Appendix B for additional information on the FrEDI analysis.

Summary of Changes Across Sectors, Regions, and Populations

Annual net[70] climate-driven impacts across all modeled sectors of the U.S. are projected to decrease as a result of methane emission reductions from the rule. These avoided damages are associated with reductions in climate-driven impacts on human health, such as changes in temperature-related mortality, climate-driven air quality (ozone and ambient fine particulate matter ($PM_{2.5}$)) related mortality[71], suicide, violent crime, and exposure to wildfire smoke, ambient dust in the Southwest, Vibriosis, and Valley fever; infrastructure-related impacts such as effects on transportation from high-tide flooding, property damage from hurricane winds, and damages to roads and rail; and labor hours lost when temperatures are too hot for workers to work outdoors or in unconditioned workplaces.

Of these analyzed sectors, reductions in climate-driven impacts associated with the final rule will not be distributed evenly across different geographic U.S. regions. However, all states

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[69] This analysis uses v4.1 of the Framework for Evaluating Damages and Impacts (U.S. EPA, 2024a). The FrEDI Technical Documentation and associated R package have been subject to both a public review comment period and an independent expert peer review, following EPA peer-review guidelines. The original FrEDI Technical Documentation was published in October 2021 (U.S. EPA, 2021a). www.epa.gov/cira/fredi

[70] FrEDI evaluates both negative and positive effects of climate change across its sectors, which can geographically vary in sign and magnitude (e.g., warming can lead to decreases in health effects in the Midwest from climate-driven changes in $PM_{2.5}$). At the national level, the net impacts are reduced in all sectors in response to changes in methane emissions from the final rule.

[71] The air quality benefits described here are a result of changes in concentrations of ozone and fine particulate matter ($PM_{2.5}$) that are the result of climate-driven changes in meteorology, atmospheric chemistry, and other biogeochemical factors and not from direct changes in $PM_{2.5}$ and ozone precursor emissions.

are projected to benefit. Regional and sectoral differences are driven in part by geographic variations in where climate change damages are projected to occur, the sector being considered, and the current demographic patterns of where populations currently live. Figure 9-3 shows the distribution of the climate impacts per capita that are projected to be avoided under the final rule in the year 2100, across 48 U.S. states plus the District of Columbia. Virginia is projected to have the largest avoided impacts per capita, with Massachusetts, and North Carolina projected to experience the second and third largest avoided per capita impacts. When further considering the detailed sector-specific impacts avoided under the final WEC, there are also important differences in the distribution of the relative avoided impacts across each U.S. state. For example, while temperature-related mortality is projected to be the largest sector (e.g., the sector experiencing the largest per capita avoided damages) in each state in 2100, avoided damages from climate-driven changes in air quality are projected to be the second largest in 27 states, avoided damages to transportation infrastructure (e.g., rail and roads) are projected to be the second largest in seven states throughout the Midwest and Northern Plains (Kansas, Minnesota, Montana, North Dakota, Nebraska, South Dakota, Wyoming), avoided damages to agriculture are projected to be the second largest in Iowa and Illinois, and avoided damages from wildfire are projected to be either the second or third largest in eight states within the Northwest, Northern Plains, and Southwest regions (Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming). In addition, avoided impacts from some sectors are only expected to be experienced in select regions. For example, avoided damages from climate-driven changes in dust and Valley Fever will primarily be experienced by populations living in states in the Southwest region (second or third largest sectors in Arizona, Colorado, New Mexico, and Utah), while reductions in tropical wind damage and transportation impacts from high-tide flooding will largely occur along coastlines of states in the Southeast, Southern Plains, and Northeast regions (second or third largest sectors in 18 states, including DC, Louisiana, New Hampshire, Massachusetts, New Jersey, and Texas).

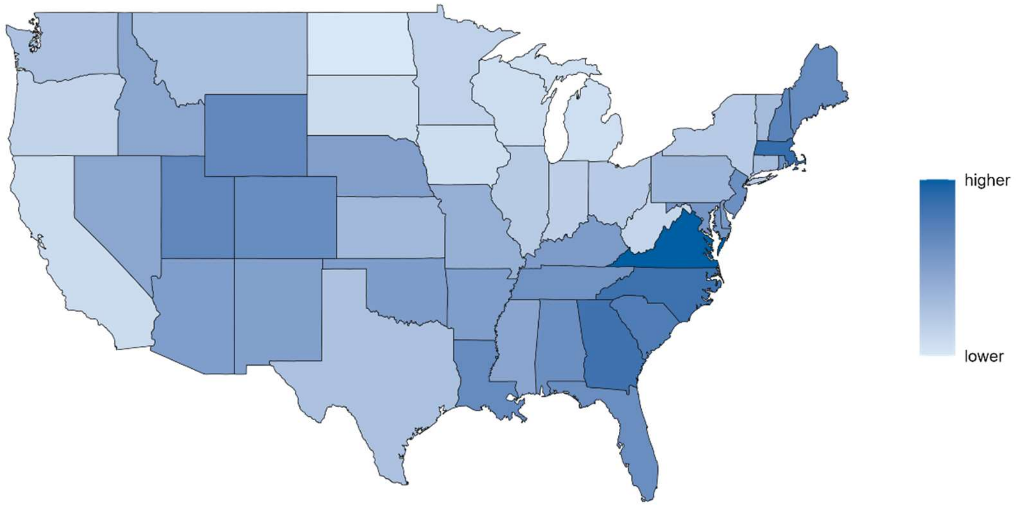

Figure 9-3 Annual Avoided Climate Driven Damages Per Capita, by State in the Year 2100[72]

Lastly, while all populations are also projected to experience a reduction in net climate-driven impacts from the rule, these avoided impacts will not be evenly distributed across populations. Understanding the comparative risks to different populations is critical for developing effective and equitable strategies for responding to climate change. Of the four dimensions of social vulnerability considered in this analysis (age, income, education level, and race and ethnicity[73]), BIPOC (Black, Indigenous, and People of Color) individuals aged 65 and older are more likely to live in regions that are projected to see the largest reductions in climate-driven air quality mortality, while those with low-incomes[74] are more likely to see larger reductions in avoided lost labor hours due to extreme temperatures. When further considering differences across different races and ethnicities included in this analysis, Black or African Americans over the age of 65 are more likely to see greater reductions in climate-driven changes in air quality mortality and transportation impacts from high tide flooding, largely driven by the regional differences in where different populations currently live and where avoided climate driven changes are projected to occur due to emission reductions in the final rule.

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[72] Figure 9-3 includes avoided damages from all sectors modeled within FrEDI v4.1, which is not a comprehensive accounting of all the ways in which climate will impact American interests.

[73] Based on the data and methodology presented in a recent EPA report on Climate Change and Social Vulnerability in the United States (U.S. Environmental Protection Agency: Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts, Washington, DC, EPA/430/R-21/003, 2021.).

[74] Individuals living in households with income that is 200% of the poverty level or lower

This analysis advances the detailed understanding of the distribution of climate change impacts within U.S. borders (excluding Alaska, Hawaii, and the U.S. territories), and is intended to provide a snapshot of the different ways U.S. residents are projected to experience fewer climate-driven damages as a result of the methane reductions from the WEC. See Appendix B for detailed discussion of avoided damages across all 22 impact sectors, 7 regions, 48 states (plus the District of Columbia), and 4 dimensions of social vulnerability included within FrEDI. This assessment is the most detailed and complete to date but is not comprehensive and should therefore be considered a preliminary accounting of climate impacts relevant to U.S. interests.

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ANNEXES

APPENDIX A
ILLUSTRATIVE SCREENING ANALYSIS OF MONETIZED VOC-RELATED OZONE HEALTH BENEFITS

In this appendix, we present a supplementary screening analysis to estimate potential health benefits from the changes in ozone concentrations resulting from VOC emissions reductions under the final rule. As described in detail below, the distribution of the projected change in VOC emissions are subject to significant uncertainties; for this reason, the estimated benefits reported below should not be interpreted as a central estimate and thus are not reflected in the calculated net benefits above. For this analysis, we apply a national benefit-per-ton approach based on photochemical modeling with source apportionment paired with the Environmental Benefits Mapping and Analysis Program (BenMAP) for years between 2024 and 2035 using an April–September average of 8-hr daily maximum (MDA8) ozone metric.

A.1 Air Quality Modeling Simulations

The photochemical model simulations are described in detail in U.S. EPA (2021a) and are summarized briefly in this section. The air quality modeling used in this analysis included annual model simulations for the year 2017. The photochemical modeling results for 2017, in conjunction with modeling to characterize the air quality impacts from groups of emissions sources (i.e., source apportionment modeling) and expected emissions changes due to this rule, were used to estimate ozone benefits expected from this rule in the years 2024–2035.

The air quality model simulations (i.e., model runs) were performed using the Comprehensive Air Quality Model with Extensions (CAMx version 7.00) (Ramboll Environ, 2016). The CAMx nationwide modeling domain (i.e., the geographic area included in the modeling) covers all lower 48 states plus adjacent portions of Canada and Mexico using a horizontal grid resolution of 12×12 km shown in Figure A-1.

Figure A-1 Air Quality Modeling Domain

A.2 Ozone Model Performance

While U.S. EPA (2021a) provides an overview of model performance, we provide a more detailed assessment here specifically focusing on ozone model performance relevant to the metrics used in this analysis. In this section, we report CAMx model performance for the MDA8 ozone across all days in April-September. While regulatory analyses often focus on model performance on high ozone days relevant to the NAAQS (U.S. EPA, 2018a), here we focus on all days in April-September since the relevant ozone metrics used as inputs into BenMAP use summertime seasonal averages. Model performance information is provided for each of the nine National Oceanic and Atmospheric Administration (NOAA) climate regions in the contiguous US, as shown in Figure A-2 and first described by Karl and Koss (1984).

Table A-1 provides a summary of model performance statistics by region. Normalized Mean Bias was within ±10 percent in every region and within ±5 percent in the Northeast, Ohio Valley, South, Southwest, and West regions. Across all monitoring sites, normalized mean bias was -0.2 percent. Normalized mean error for modeled MDA8 ozone was less than ±20 percent in every region except the Northwest where it was 21 percent. Correlation between the modeled and observed MDA8 ozone values was 0.7 or greater in five of the nine regions (Northeast, Upper Midwest, Southeast, South, and West). In the remaining four regions correlation was 0.69 in the Ohio Valley, 0.64 in the Northern Rockies and Plains, 0.46 in the Southwest, and 0.69 in the Northwest. Across the contiguous U.S. as a whole, the correlation between modeled and measured MDA8 ozone was 0.72.

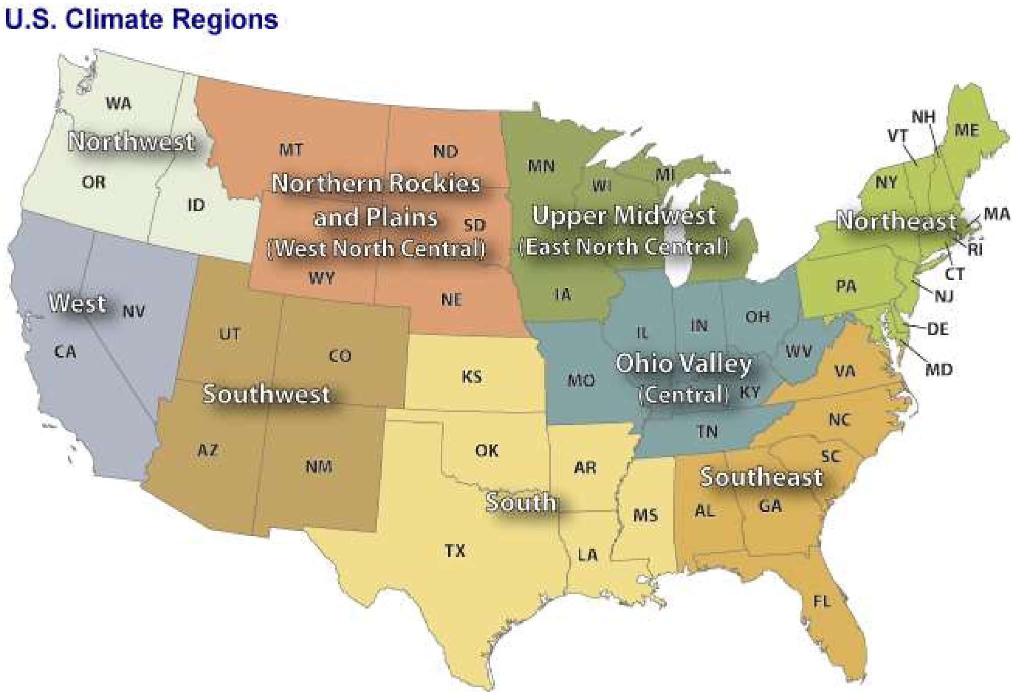

Figure A-2 Climate Regions Used to Summarize 2017 CAMx Model Performance for Ozone

Table A-1 Summary of 2017 CAMx MDA8 ozone model performance for all April–September days

Region	Number of Monitoring Sites	Mean observed MDA8 (ppb)	Mean modeled MDA8 (ppb)	Correlation	Mean bias (ppb)	RMSE (ppb)	Normalized mean bias (%)	Normalized mean error (%)
Northeast	189	42.4	42.5	0.71	0.1	9.1	0.3	17.2
Upper Midwest	107	42.5	39.1	0.70	-3.4	9.1	-8.0	17.2
Ohio Valley	236	45.4	45.8	0.69	0.4	8.3	0.8	14.7
Southeast	177	40.2	43.4	0.76	3.3	8.8	8.2	17.7
South	145	42.0	43.5	0.73	1.5	8.8	3.6	16.7
Northern Rockies and Plains	55	46.8	43.1	0.64	-3.7	9.3	-7.9	16.4
Southwest	117	54.3	52.5	0.46	-1.8	10.2	-3.4	15.5
Northwest	28	41.4	44.0	0.69	2.7	12.4	6.4	21.0
West	200	51.6	50.1	0.74	-1.5	10.3	-2.9	16.1
All	**1258**	**45.4**	**45.3**	**0.72**	**-0.1**	**9.3**	**-0.2**	**16.4**

Figure A-3 displays modeled MDA8 normalized mean bias at individual monitoring sites. This figure reveals that the model has slight overpredictions of mean April-September MDA8 ozone in the southeastern portion of the country and along the Pacific coast and slight underpredictions in the northern and western portions of the country. Time series plots of the modeled and observed MDA8 ozone and model performance statistics across the nine regions were developed. Overall, the model closely captures day to day fluctuations in ozone concentrations, although the model had a tendency to underpredict ozone in the earlier portion of the ozone season (April and May) and overpredict in the later portion of the ozone season (July-September) with mixed results in June. This model performance is within the range of other ozone model applications, as reported in scientific studies (Emery et al., 2017; Simon, Baker, & Phillips, 2012). Thus, the model performance results demonstrate the scientific credibility of our 2017 modeling platform. These results provide confidence in the ability of the modeling platform to provide a reasonable projection of expected future year ozone concentrations and contributions.

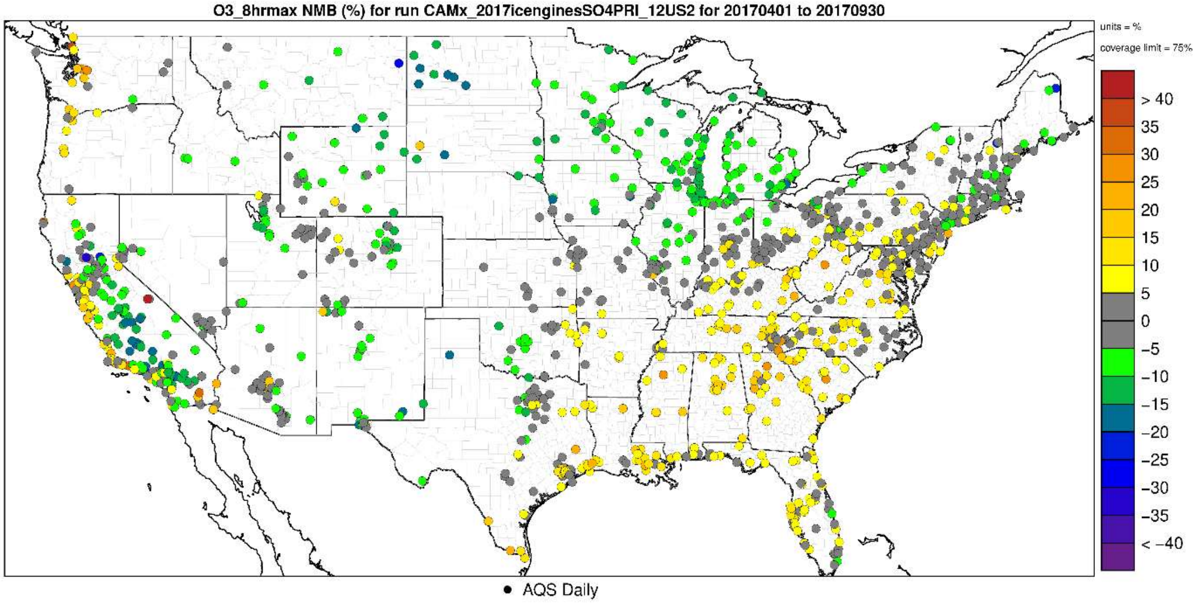

Figure A-3 Map of 2017 CAMx MDA8 Normalized Mean Bias (%) for April–September at all U.S. monitoring sites in the model domain

A.3 Source Apportionment Modeling

The contribution of specific emissions sources to ozone in the 2017 modeled case were tracked using a tool called "source apportionment." In general, source apportionment modeling quantifies the air quality concentrations formed from individual, user-defined groups of emissions sources or "tags." These source tags are tracked through the transport, dispersion, chemical transformation, and deposition processes within the model to obtain hourly gridded contributions from the emissions in each individual tag to hourly modeled concentrations of ozone.

For this analysis ozone contributions were modeled using the Ozone Source Apportionment Technique (OSAT) tool. In this modeling, VOC emissions from oil and natural gas operations were tagged separately for three regions of the U.S. regions. The model-produced gridded hourly ozone contributions from emissions from each of the source tags which we aggregated up to an ozone metric relevant to recent health studies (i.e., the April-September average of the MDA8 ozone concentration). The April-September average of the MDA8 ozone contributions from each regional oil and natural gas tag were summed to produce a spatial field representing national oil and natural gas VOC contributions to ozone across the United States (Figure A-4).

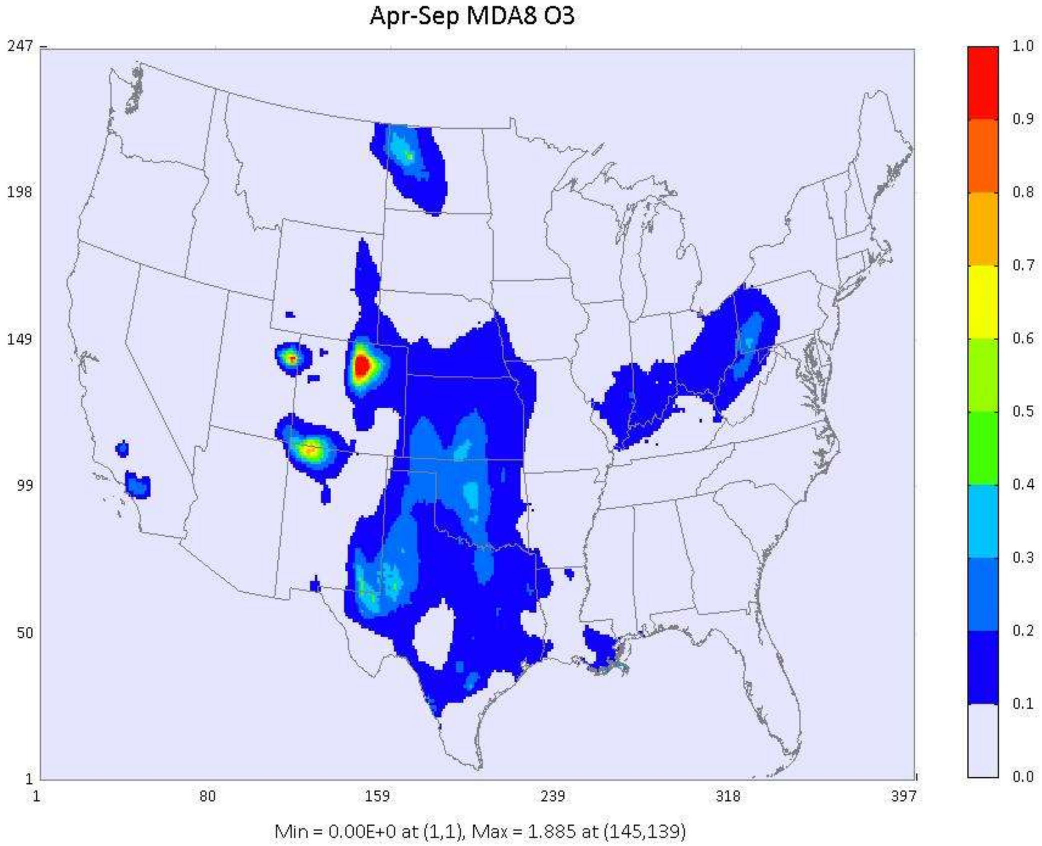

Figure A-4 **Contributions of 2017 Oil and Natural Gas VOC Emissions across the Contiguous U.S. to the April-September Average of MDA8 Ozone.**

A.4 Applying Modeling Outputs to Quantify a National VOC-Ozone Benefit Per-Ton Value

Following an approach detailed in the RIA and TSD for the Revised Cross-State Update, we estimated the number and value of ozone-attributable premature deaths and illnesses for the purposes of calculating a national ozone VOC benefit per-ton value for the policy scenario (U.S. EPA, 2021f, 2021g).

The EPA historically has used evidence reported in the Integrated Science Assessment (ISA) for the most recent NAAQS review to inform its approach for quantifying air pollution-attributable health, welfare, and environmental impacts associated with that pollutant. The ISA synthesizes the toxicological, clinical and epidemiological evidence to determine whether each pollutant is causally related to an array of adverse human health outcomes associated with either short-term (hours to less than one month) or long-term (one month to years) exposure; for each outcome, the ISA reports this relationship to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship, or not likely to be a causal. We estimate the incidence of air pollution-attributable premature deaths and illnesses using methods reflecting evidence reported in the 2020 Ozone ISA (U.S. EPA, 2020a) and accounting for recommendations from the Science Advisory Board. When updating each health endpoint the EPA considered: (1) the extent to which there exists a causal relationship between that pollutant and the adverse effect; (2) whether suitable epidemiologic studies exist to support quantifying health impacts; (3) and whether robust economic approaches are available for estimating the value of the impact of reducing human exposure to the pollutant. EPA calculated and monetized the incidence change of mortality, respiratory hospital admissions, respiratory ED visits, asthma symptoms / exacerbation, allergic rhinitis symptoms, minor restricted activity days, and school absence days. For a detailed description, see (U.S. EPA, 2021e, 2024d).

In brief, we used the environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE) to quantify estimated counts of premature deaths and illnesses attributable to summer season average ozone concentrations using the modeled surface described above (Section A.1.2). We calculate effects using a health impact function, which combines information regarding the: concentration-response relationship between air quality changes and the risk of a given adverse outcome; population exposed to the air quality change; baseline rate of death or disease in that population; and air pollution concentration to which the population is exposed. These quantified health impacts were then used to estimate the economic value of these ozone-attributable effects as described below. For this supplemental proposal, we quantified counts of premature deaths and illnesses by multiplying an incidence per ton against an updated estimate of emissions described in Section 2.3. Modeled air quality changes were not available.

We performed BenMAP-CE analyses for 2025, 2030, and 2035 using the single model surface described above, but accounting for the change in population size, baseline death rates and income growth in each future year. We next divided the sum of the monetized ozone benefits in each year the April-September VOC emissions associated with the oil and natural gas source apportionment tags in the 2017 CAMx modeling to determine a benefit per ton value for each year from 2024–2035.[75] Emissions totals for the oil and natural gas sector used in the contribution modeling are reported in U.S. EPA (2023). Finally, the benefit per ton values were multiplied by the expected national VOC emissions changes in each year, as reported in Section 5.3. Since values reported in Section 5 were annual totals, we assume the emissions changes are distributed evenly across months of the year and divide emissions changes by two to estimate the April-September VOC changes expected from this final rule. Dividing by two is used to calculate the emissions during the six month ozone season from April through September.

A.5 Uncertainties and Limitations of Air Quality Methodology

The approach applied in this screening analysis is consistent with how air quality impacts have been estimated in past regulatory actions (U.S. EPA, 2019b, 2021f). However, in this section we acknowledge and discuss several limitations.

First, the 2017 modeled ozone concentrations are subject to uncertainty. While all models have some level of inherent uncertainty in their formulation and inputs, evaluation of the model outputs against ambient measurements shows that ozone model performance is within the range of model performance reported from photochemical modeling studies in the literature (Emery et al., 2017; Simon et al., 2012) and is adequate for estimating ozone impacts of VOC emissions for the purpose of this rulemaking.

In any complex analysis using estimated parameters and inputs from a variety of models, there are likely to be many sources of uncertainty. This analysis is no exception. This analysis includes many data sources as inputs, including emissions inventories, air quality data from models (with their associated parameters and inputs), population data, population estimates, health effect estimates from epidemiology studies, economic data for monetizing benefits, and assumptions regarding the future state of the world (i.e., regulations, technology, and human behavior). Each of these inputs are uncertain and generate uncertainty in the benefits estimate. When the uncertainties from each stage of the analysis are compounded, even small uncertainties can have large effects on the total quantified benefits. Therefore, the estimates of annual benefits should be viewed as representative of the magnitude of benefits expected, rather than the actual benefits that would occur every year.

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[75] The monetized benefit-per-ton values are listed in Table A-2.

Because regulatory health impacts are distributed based on the degree to which housing and work locations overlap geographically with areas where atmospheric concentrations of pollutants change, it is difficult to fully know the distributional impacts of a rule. Air quality models provide some information on changes in air pollution concentrations induced by regulation, but it may be difficult to identify the characteristics of populations in those affected areas, as well as to perform high-resolution air quality modeling nationwide. Furthermore, the overall distribution of health benefits will depend on whether and how households engage in averting behaviors in response to changes in air quality, e.g., by moving or changing the amount of time spent outside (Sieg, Smith, Banzhaf, & Walsh, 2004).

Another limitation of the methodology is that it treats the response of ozone benefits to changes in emissions from the tagged sources as linear. For instance, the benefits associated with a 10 percent national change in oil and natural gas VOC emissions would be estimated to be twice as large as the benefits associated with a 5 percent change in nation oil and natural gas VOC emissions. The methodology therefore does not account for 1) any potential nonlinear responses of ozone atmospheric chemistry to emissions changes and 2) any departure from linearity that may occur in the estimated ozone-attributable health effects resulting from large changes in ozone exposures.

We note that the emissions changes are relatively small compared to 2017 emissions totals from all sources. Previous studies have shown that air pollutant concentrations generally respond linearly to small emissions changes of up to 30 percent (Cohan, Hakami, Hu, & Russell, 2005; Cohan & Napelenok, 2011; Dunker, Yarwood, Ortmann, & Wilson, 2002; Koo, Dunker, & Yarwood, 2007; Napelenok, Cohan, Hu, & Russell, 2006; Zavala, Lei, Molina, & Molina, 2009) and that linear scaling from source apportionment can do a reasonable job of representing impacts of 100 percent of emissions from individual sources (Baker & Kelly, 2014). Additionally, past studies have shown that ozone responds more linearly to changes in VOC emissions than changes in NO_X emissions (Hakami, Odman, & Russell, 2003; Hakami, Odman, & Russell, 2004). Therefore, it is reasonable to expect that the ozone benefits from expected VOC emissions changes from this rule can be adequately represented using this this linear assumption.

A final limitation is that the source apportionment ozone contributions reflect the spatial and temporal distribution of the emissions from each source tag in the 2017 modeled case. The representation of the spatial patterns of ozone contributions are important because benefits calculations depend on the spatial patterns of ozone changes in relationship to spatial distribution of population and health incidence values. While we accounted for changes the size of the population, baseline rates of death and income, we assume the spatial pattern of oil and natural gas VOC contributions to ozone remain constant at 2017 levels. Thus, the current methodology does not allow us to represent any expected changes in the spatial patterns of ozone that could result from changes in oil and natural gas emissions patterns in future years or from spatially heterogeneous emissions changes resulting from this final rule. For instance, the method does not account for the possibility that new sources would change the spatial distribution of oil and natural gas VOC emissions.

Table A-2 Benefit-per-ton Estimates of Ozone-Attributable Premature Mortality and Illnesses for the WEC in 2019 Dollars

	Benefit-per-ton of Reducing VOC Emissions from the Oil and Natural Gas Sector					
	Short-term mortality and morbidity (discounted at 2%)	**Short-term mortality and morbidity (discounted at 3%)**	**Short-term mortality and morbidity (discounted at 7%)**	**Long-term mortality and morbidity (discounted at 2%)**	**Long-term mortality and morbidity (discounted at 3%)**	**Long-term mortality and morbidity (discounted at 7%)**
2025	$244	$229	$204	$1,840	$1,780	$1,590
2030	$262	$247	$221	$2,050	$1,980	$1,780
2035	$278	$262	$236	$2,280	$2,200	$1,970

Table A-3 Estimated Discounted Economic Value of Ozone-Attributable Premature Mortality and Illnesses under the Final WEC, 2024–2035 (million 2019$)[a,d]

	Final WEC		
Year	**2% Discount Rate**	**3% Discount Rate**	**7% Discount Rate**
2024	$2.0[b] and $15[c]	$1.8[b] and $14[c]	$1.6[b] and $12[c]
2025	$3.9[b] and $30[c]	$3.6[b] and $28[c]	$3.0[b] and $23[c]
2026	$5.5[b] and $41[c]	$5.0[b] and $39[c]	$4.0[b] and $31[c]
2027	$5.2[b] and $39[c]	$4.7[b] and $37[c]	$3.6[b] and $28[c]
2028	$0.50[b] and $3.9[c]	$0.45[b] and $3.6[c]	$0.33[b] and $2.7[c]
2029	$0.35[b] and $2.8[c]	$0.31[b] and $2.5[c]	$0.22[b] and $1.8[c]
2030	$0.34[b] and $2.7[c]	$0.30[b] and $2.4[c]	$0.21[b] and $1.7[c]
2031	$0.34[b] and $2.6[c]	$0.29[b] and $2.3[c]	$0.19 and $1.6[c]
2032	$0.33[b] and $2.6[c]	$0.28[b] and $2.3[c]	$0.18[b] and $1.4[c]
2033	$0.34[b] and 2.8[c]	$0.29[b] and $2.4[c]	$0.18[b] and $1.5[c]
2034	$0.33[b] and $2.7[c]	$0.28[b] and $2.4[c]	$0.17[b] and $1.4[c]
2035	$0.32[b] and $2.7[c]	$0.27[b] and $2.3[c]	$0.16[b] and $1.3[c]

[a] Values rounded to two significant figures.

[b] Includes ozone mortality estimated using the pooled Katsouyanni et al. (2009) and Zanobetti and Schwartz (2008) short-term risk estimates.

[c] Includes ozone mortality estimated using the Turner et al. (2016) long-term risk estimate.

[d] The WEC regulates emissions of methane. Additional benefits to the regulation may result from associated reductions in VOC emissions.

Table A-4 Stream of Human Health Benefits under the Final WEC, 2024–2035: Monetized Benefits Quantified as Sum of Avoided Morbidity Health Effects and Avoided Long-term Ozone Mortality (discounted at 2 percent to 2023; million 2019$)[a,b]

Year	Final WEC Option
2024	$15
2025	$30
2026	$41
2027	$39
2028	$3.9
2029	$2.8
2030	$2.7
2031	$2.6
2032	$2.6
2033	$2.8
2034	$2.7
2035	$2.7
Present Value (PV)	**$150**
Equivalent Annualized Value (EAV)	**$14**

[a] Benefits calculation includes ozone-related morbidity effects and avoided ozone-attributable deaths quantified using the Turner et al. (2016) long-term risk estimate.

[b] The WEC is expected to result in emissions reductions of methane. Additional benefits to the regulation may result from associated reductions in VOC emissions.

Table A-5 Stream of Human Health Benefits under the Final WEC, 2024–2035: Monetized Benefits Quantified as Sum of Avoided Morbidity Health Effects and Avoided Long-term Ozone Mortality (discounted at 3 percent to 2023; million 2019$)[a,b]

Year	Final WEC Option
2024	$14
2025	$28
2026	$39
2027	$37
2028	$3.6
2029	$2.5
2030	$2.4
2031	$2.3
2032	$2.3
2033	$2.4
2034	$2.4
2035	$2.3
Present Value (PV)	**$140**
Equivalent Annualized Value (EAV)	**$14**

[a] Benefits calculation includes ozone-related morbidity effects and avoided ozone-attributable deaths quantified using the Turner et al. (2016) long-term risk estimate.
[b] The WEC regulates emissions of methane. Additional benefits to the regulation may result from associated reductions in VOC emissions.

Table A-6 Stream of Human Health Benefits under theFinal WEC, 2024–2035: Monetized Benefits Quantified as Sum of Avoided Morbidity Health Effects and Avoided Long-term Ozone Mortality (discounted at 7 percent to 2023; million 2019$)[a,b]

Year	Final WEC Option
2024	$12
2025	$23
2026	$31
2027	$28
2028	$2.7
2029	$1.8
2030	$1.7
2031	$1.6
2032	$1.4
2033	$1.5

2034	$1.4
2035	$1.3
Present Value (PV)	**$110**
Equivalent Annualized Value (EAV)	**$14**

[a] Benefits calculated as value of avoided ozone-attributable deaths (quantified using a concentration-response relationship from the Turner et al. (2016) study and ozone-related morbidity effects).

[b] The WEC regulates emissions of methane. Additional benefits to the regulation may result from associated reductions in VOC emissions.

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APPENDIX B
APPLICATION OF THE FRAMEWORK FOR EVALUATING DAMAGES AND IMPACTS (FREDI) TO ASSESS THE DISTRIBUTION OF AVOIDED CLIMATE-DRIVEN DAMAGES

In this Appendix, we provide further detail on the distribution of climate-driven impacts avoided as a result of the methane (CH_4) emission reductions from the final WEC, using the Framework for Evaluating Damages and Impacts (FrEDI) (U.S. EPA, 2024).

B.1 What is the Framework for Evaluating Damages and Impacts (FrEDI)?

The EPA developed FrEDI to better understand and communicate the detailed impacts and risks from climate change in the United States. FrEDI is a reduced complexity model that quantifies annual physical and economic impacts within contiguous U.S. (CONUS) borders through the end of the 21st century resulting from future climate change under any user-defined temperature trajectory. FrEDI draws upon over 30 existing peer-reviewed studies and climate change impact models, including from the Climate Change Impacts and Risk Analysis (CIRA) project[76], to estimate the relationship between future degrees of warming and damages across more than 20 impact sectors. The temperature-impact relationships are then used to rapidly estimate climate change damages under any custom policy scenario. Recent FrEDI applications[77] have advanced the collective understanding of how future impacts from climate change are expected to be differentially experienced in different sectors across U.S. regions. The FrEDI framework and its Technical Documentations (U.S. EPA, 2024) have been subject to a public review and an independent external peer review[78], following guidance in the EPA Peer-Review

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[76] EPA Climate Change Impacts and Risk Analysis (CIRA). https://www.epa.gov/cira

[77] (1) Supplementary Material for the Regulatory Impact Analysis for the Supplemental Proposed Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review", Docket ID No. EPA-HQ-OAR-2021-0317 2022; (2) The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050. United States Department of State and the United States Executive Office of the President, Washington DC. 2021; (3) Climate Risk Exposure: An Assessment of the Federal Government's Financial Risks to Climate Change, White Paper, Office of Management and budget, April 2022; (4) Hartin et al., Advancing the estimation of future climate impacts within the United States. EGUsphere, https://doi.org/10.5194/egusphere-2023-114.

[78] Information on the peer-review is available at the EPA Science Inventory: https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=OAP&dirEntryId=360384

Handbook for Influential Scientific Information (ISI)[79]. FrEDI documentation and source code are available at: https://www.epa.gov/cira/fredi.

B.2 Why are Distributional Climate Impacts Important to Consider?

The impacts of climate change occurring in a particular area or to a particular community are determined by the physical climate stressors (e.g., heat, and precipitation) unique to that location, the sensitivity to adverse effects, and the ability or capacity to adapt. This means that understanding the risks of climate change to the U.S., and the damages avoided due to greenhouse gas (GHG) emission reductions, is improved with detailed information regarding where impacts may occur, to what sectors, and how populations may be differentially affected. By leveraging the unique capabilities of FrEDI, EPA thereby offers additional context for this specific rulemaking to help the public better understand the environmental impacts and potential benefits from policies that reduce national GHG emissions, such as methane. The inclusion of this analysis also directly aligns with general recommendations from EPA's Science Advisory Board on a recent Agency rule[80]: "Given that exposure and vulnerability to climate risks vary, the benefits of reducing emissions vary as well. The differential benefits of reduced greenhouse gas emissions are not captured by the average social cost of carbon value and therefore additional consideration of the distributional effects of reducing greenhouse gas emissions is warranted. […] The EPA should utilize … the EPA CIRA program for information on the disproportionate health impacts of climate change and consider greenhouse gas implications from the proposed rule." By following these recommendations, the distributional application of FrEDI presented in this RIA complements, but does not replace, existing global climate impact and benefit assessments that use the social cost of greenhouse gases (SC-GHG). While global impacts from the WEC are captured by the SC-GHG (in Chapter 6), FrEDI provides complementary illustrative information about how reductions in long-term climate-driven impacts may be differentially experienced within U.S. borders. Therefore, these results should not be compared to global SC-GHG estimates.

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[79] EPA Science and Technology Policy Council Peer Review Handbook. https://www.epa.gov/sites/default/files/2020-08/documents/epa_peer_review_handbook_4th_edition.pdf

[80] EPA Science Advisory Board Letter to Administrator Regan, Final Science Advisory Board Regulatory Review Report of Science Supporting EPA Decisions for the Proposed Rule: Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards (RIN 2060-AU41), EPA-SAB-23-001, December 2022.

B.3 How is FrEDI Applied in the Final WEC RIA?

For this RIA, FrEDI is applied within a broader modeling workflow shown in Figure B-1 to analyze the distribution of avoided climate-driven impacts associated with final WEC CH_4 emission changes. While this application of FrEDI may be considered the most detailed and complete analysis of its kind, these estimates do not account for all damage categories, do not include damages outside U.S. borders, and do not consider damages that occur due to interactions between different sectors. Therefore, these estimates should be considered a preliminary accounting of net avoided climate driven impacts relevant to U.S. interests.

B.3.1 Methodological Overview

Future global emission scenarios (Figure B-1, Input 1) are first passed to a climate emulator (model information provided in Section B.3.5) to develop projections of global mean temperature (Figure B-1, Output 1). These mean temperature changes (Figure B-1, Input 2) are then passed to FrEDI[81], which quantifies the climate-driven damages in 22 sectors within U.S. borders that are associated with these temperature changes (Figure B-1, Output 2). In this analysis, the two global emission scenarios include: 1) a global time series of emissions with no additional mitigation (used to quantify projected 'reference' climate-driven damages) and 2) the same global scenario, with each year starting in 2024 (first year of the WEC CH_4 reductions) adjusted for CH_4 emission changes resulting from the final WEC. Details and results are presented in the following sections.

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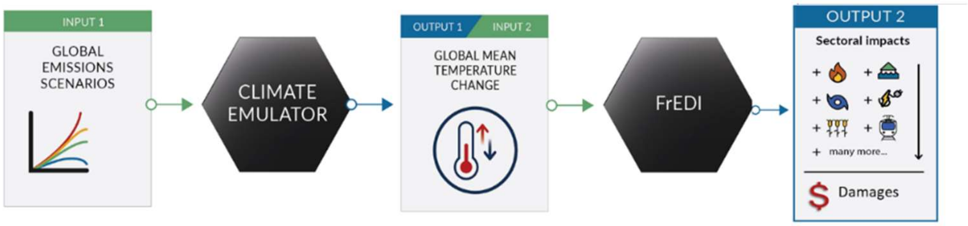
[81] https://github.com/USEPA/FrEDI/releases/tag/v4.1

Figure B-1 Schematic of Analysis Workflow from emissions to damages[82]



B.3.2 How are Avoided Climate Impacts Calculated?

This analysis presents the distribution of annual net avoided climate-driven impacts in the year 2100 that are associated with WEC CH_4 emission reductions. Reductions of CH_4 emissions are taken from RIA Table 5-8, which presents the total annual CH_4 emission reductions from abatement activities associated with the final WEC (hereafter called the WEC scenario). The avoided climate-driven impacts in 2100 are calculated by comparing the distribution of long-term climate-driven damages across multiple populations, regions, and sectors in the WEC scenario compared to the reference scenario. The metric of annual net impacts captures both positive and negative impacts from climate change and is consistent with the approach used in the climate impacts literature, including the U.S. National Climate Assessment (USGCRP, 2018) and United Nations' Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2022) assessments. Given the way that climate impacts accumulate over time, results here focus on the year 2100 to capture the impacts from avoided long-term climate-driven changes[83]. Recognizing that "climate change creates new risks and exacerbates existing vulnerabilities in communities across the United States" (USGCRP, 2018), we use this approach to examine how the final WEC may mitigate projected monetized climate impacts across different regions, sectors, and populations.

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[82] Global emission scenarios (through 2100) are passed to the Finite amplitude Impulse Response (FaIR v1.6.4) climate emulator to develop global temperature projections associated with global emission changes. Global temperature changes are then passed to FrEDI, which applies sector and state-specific damage functions to project the domestic annual climate-driven damages across sectors associated with the emissions-driven global mean temperature changes.

[83] FrEDI is capable to quantifying impacts for any year through 2100. The snapshot of avoided impacts here represents the projected impacts in the year 2100 that are projected as a result of annual changes in emissions, each year, from the first policy year through 2100. This is a different approach than a net present damage analysis, which aggregates all impacts that result from a single emissions change in a particular year, through the year 2300.

B.3.3 Global Emissions Scenario

Global ‘reference scenario’ emissions of greenhouse gases (GHGs) (CO_2, CH_4, N_2O, HFCs, PFCs), primary aerosol components (black carbon, organic carbon), pollutant precursors (CO, NO_x, SO_x, VOCs, NH_3), and other halogenated species (CFCs, CH_3Cl, CH_3Br, etc.) through the year 2100 are from the ‘current policy scenario’ developed by Ou et al., 2021. Projected temperature changes and climate-driven damages associated with these emissions represent projected damages in the absence of additional emissions mitigation policies.

B.3.4 Policy Emissions Scenario

To account for annual CH_4 emission reductions from abatement activities associated with the final WEC, the second ‘policy scenario’ is calculated by subtracting the expected rule-specific reductions from the global reference emissions scenario. In this analysis, reductions of CH_4 are held constant between the final WEC emission year and the year 2100. Results are minimally sensitive to this assumption. For all other compounds, emissions through the end of the century are from the global reference scenario.

B.3.5 Climate Emulator & Projected Temperature Change

To convert global emissions to global temperature projections, we use the Finite amplitude Impulse Response (FaIR v1.6.4) climate emulator (Smith et al., 2018a; Smith et al., 2018b), which captures the relationships between GHG emissions, atmospheric GHG concentrations, and global mean surface temperature. FaIR is a widely used reduced-complexity Earth system model recommended by the National Academies, calibrated to and extensively used within the Sixth Assessment Report (AR6) of the United Nations’ IPCC, and applied in the December 2023 Final Oil and Gas NSPS/EG Rulemaking, “Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review” (U.S. EPA, 2023). The mean results presented in this analysis are derived by running FaIR with an ensemble of 2237 sets of uncertain climate parameters[84] that have been previously calibrated to the IPCC AR6 Working Group 1 assessment (Smith, 2021).

B.4 Calculation of Avoided U.S. Climate-Driven Impacts

As described in the Technical Documentation (U.S. EPA, 2024), FrEDI uses projections of global temperature and socioeconomic conditions (U.S. Gross Domestic Product [U.S. GDP] and regional population[85]) with underlying damage functions[86] to project economic damage end points for 22 impact sectors, listed in Table B-1.

While these sectors represent a large range of impacts across the U.S. economy, FrEDI does not include a comprehensive list of all impacts and only explores a subset of those that directly occur within CONUS borders. Therefore, FrEDI only provides a partial estimate of avoided climate impacts expected to accrue to U.S. citizens and their interests. In addition, not all anticipated impacts are quantified within the represented sectors – for example the coastal property analysis addresses direct flood damage to structures but omits indirect impacts such as business interruptions that result from that damage. This approach also incorporates climate uncertainty from the FaIR model but does not fully account for uncertainty in the underlying temperature-impact relationships for each sector. For a more detailed accounting of uncertainties, please see the FrEDI Technical Documentation (U.S. EPA, 2024). Lastly, FrEDI also does not account for impacts of the final WEC resulting from factors outside of the direct impact of CH_4 emission reductions on climate change, such as direct air quality improvements from reductions in co-emissions of air pollutants.

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[84] Uncertainties in climate model parameters considered in FaIR, include but are not limited to the sensitivity of climate to increases in atmospheric CO_2 concentrations, forcing from aerosol components, forcing from black carbon on snow, and carbon cycle parameters.

[85] Population scenarios are based on UN Median Population projection (United Nations, Department of Economic and Social Affairs, Population Division, 2015. World Population Prospects: The 2015 Revision, Key Findings, and Advance Tables. No. Working Paper No. ESA/P/WP.241) and EPA's ICLUSv2 model (Bierwagen, et al., National housing and impervious surface scenarios for integrated climate impact assessments. Proc. Natl. Acad. Sci. 107, 2010; U.S. EPA, 2017), and GDP from the EPPA version 6 model (Chen, et al., Long-term economic modeling for climate change assessment. Economic Modelling, 52 (Part B): 867–883, 2015, http://www.sciencedirect.com/science/article/pii/S0264999315003193)).

[86] A temperature binning approach is used to develop relationships between climate-driven changes in CONUS surface temperature or sea level rise (calculated from temperature), socioeconomic conditions (e.g., U.S. Gross Domestic Product [GDP] and state population), and the resulting physical and economic damages across 22 sectors and 48 states and the District of Columbia. These temperature-impact relationships are synthesized from over 30 underlying peer-reviewed studies on climate change impact and form a key basis of FrEDI's calculations.

Table B-1 Current FrEDI sectors, including aggregate category group, default adaptation assumptions, and descriptions. Adapted from the FrEDI Technical Documentation

Sector	Aggregate Category	Default Adaptation or Variant Option	Impact Description
Agriculture	Agriculture	With CO_2 fertilization	Revenue lost from changes in wheat, cotton, soybean, and maize crop yields
Coastal Property	Infrastructure	Reactive Adaptation	Costs related to armoring, elevation, nourishment, structure repair, and abandonment (including storm surge impacts)
Electricity Demand and Supply	Electricity	No Additional Adaptation*	Changes in power sector costs for heating and cooling (demand) and required capacity expansion (supply)
Electricity Transmission and Distribution	Electricity	Reactive Adaptation	Repair of replacement of transmission & distribution infrastructure
Temperature-Related Mortality‡	Health	No Additional Adaptation*	Damages from the net of heat- and cold-related mortality
Transportation Impacts from High Tide Flooding	Infrastructure	Reasonably Anticipated Adaptation	Damages from coastal flooding related traffic delays, rerouting, infrastructure improvements, and other transport impacts.
Inland Flooding	Infrastructure	No Additional Adaptation*	Residential property damages from riverine flooding
Labor	Labor	No Additional Adaptation*	Damages from work hours lost and lost wages in high-risk industries due to temperature
Marine Fisheries	Ecosystems + Recreation	No Additional Adaptation*	Lost value of marine fisheries landings from changes in thermally available habitat for commercial fish species
Climate-Driven Changes in Air Quality	Health	2011 precursor Emissions	Damages from climate-driven changes in temperature and weather on ozone and fine particulate matter exposure and attributable mortality
Crime	Health	No Additional Adaptation*	Damages from the change in the number of Property and Violent crimes and crime valuation
Rail	Infrastructure	Reactive Adaptation	Infrastructure repair and delay costs associated with temperature-induced track buckling
Roads	Infrastructure	Reactive Adaptation	Cost of road repair, user costs (vehicle damage), and road delays due to changes in road surface quality
Southwest Dust	Health	No Additional Adaptation*	Damages from mortality and hospitalization costs from changes in fine and coarse dust particle exposure
Suicide‡	Health	No Additional Adaptation*	Damages from climate-driven changes in temperature and weather on suicide
Wind Damage from Tropical Storms	Infrastructure	No Additional Adaptation*	Cost of property damage from hurricane winds to coastal properties
Urban Drainage	Infrastructure	Proactive Adaptation	Costs of upgrading urban stormwater infrastructure
Water Quality	Ecosystems + Recreation	No Additional Adaptation*	Willingness to pay to avoid water quality changes for recreation

Wildfire	Health	No Additional Adaptation*	Damages from mortality and morbidity from wildfire-driven air pollution exposure and response cost for fire suppression
Winter Recreation	Ecosystems + Recreation	Adaptation	Revenue lost from suppliers of alpine, cross-country skiing, and snowmobiling
Valley Fever	Health	No Additional Adaptation*	Damages from mortality, morbidity, and lost wages
Vibriosis	Health	No Additional Adaptation*	Damages from hospitalization costs, lost wages, and mortality from Vibriosis

*'No additional adaptation' classification is sector specific and does not imply that there is no adaptation in the underlying study. Rather, adaptive measures and strategies are included to the extent that these actions were taken in recent history in response to climate hazards. However, no alternative adaptation options are modeled in FrEDI for these sectors. For more information, please see the FrEDI technical documentation (U.S. EPA, 2024). ‡ As described in the 2024 FrEDI Technical Documentation, default temperature-related mortality damages have been adjusted to account for the fraction of heat related deaths that are attributable to suicide, which are explicitly represented by the 'suicide' sector.

B.5 Results: Distributional Changes in Avoided U.S. Climate-Driven Impacts

Results in this section represent the expected reduction in annual climate-driven impacts in 2100, or the economic impacts avoided, when implementing the WEC CH_4 emission reductions (e.g., avoided impacts = reference scenario damages – policy scenario damages)[87]. Considering the 22 sectors included in FrEDI, net avoided climate-driven damages from the WEC at the national level are projected to occur across all sectors and regions within the CONUS. The majority of these improvements are projected to occur within sectors that impact human health, including reductions in mortality from avoided warming, mortality from climate-driven changes in air pollution (ozone and ambient fine particulate matter)[88], suicide incidence, exposure to wildfire smoke, Southwest dust, Vibriosis, and Valley fever, as well as reduced impacts to labor hours in high-risk industries and reductions in infrastructure-related damages such as avoided transportation impacts from high-tide flooding, reduced property damage from hurricane winds, and avoided damages to roads and rail.

At the regional level, Figure B-2 provides a more detailed breakdown, by sector, of how changes in avoided climate-driven sectoral impacts per capita are expected to vary across seven regions[89] within the CONUS by 2100. While all regions are expected to see reductions in net

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[87] This metric differs from the net present benefits that are presented in RIA Chapter 6, which account for the discounted sum of climate-driven damages from the each WEC reduction year through 2300. Changes in annual impacts from FrEDI focus on 2100 to capture long-term climate-driven changes.

[88] The air quality impacts described here are a result of changes in concentrations of ozone and fine particulate matter ($PM_{2.5}$) that are the result of climate-driven changes in meteorology, atmospheric chemistry, and other biogeochemical factors. This is in contrast and in addition to the direct air quality changes resulting from changes in pollutant emissions from smokestacks, as discussed in other sections of this RIA.

[89] Corresponding to regions of the 4th U.S. National Climate Assessment.

impacts under the final WEC scenario (column 1), which will increase overtime (column 2), the right panel of Figure B-2 also lists the five sectors (of the 22 analyzed) that will accrue the largest annual impact reductions per capita in each region. For example, while the largest improvements in all regions are projected to be from reduced mortality from avoided temperature changes, improvements related to climate-driven changes in air quality mortality (2nd largest sector at the national level) are expected to be most pronounced in the Southwest, Southeast, Northeast, and Northwest regions. In addition, avoided damages to transportation infrastructure (e.g., rail and roads) and agriculture are relatively more important in the Midwest and Northern Plains, while reduction in transportation impacts from high-tide flooding and avoided coastal property flood and wind damage are relatively more important in coastal regions.

Figure B-2 Relative avoided per capita climate driven impacts by sector and US region in 2100.[90]

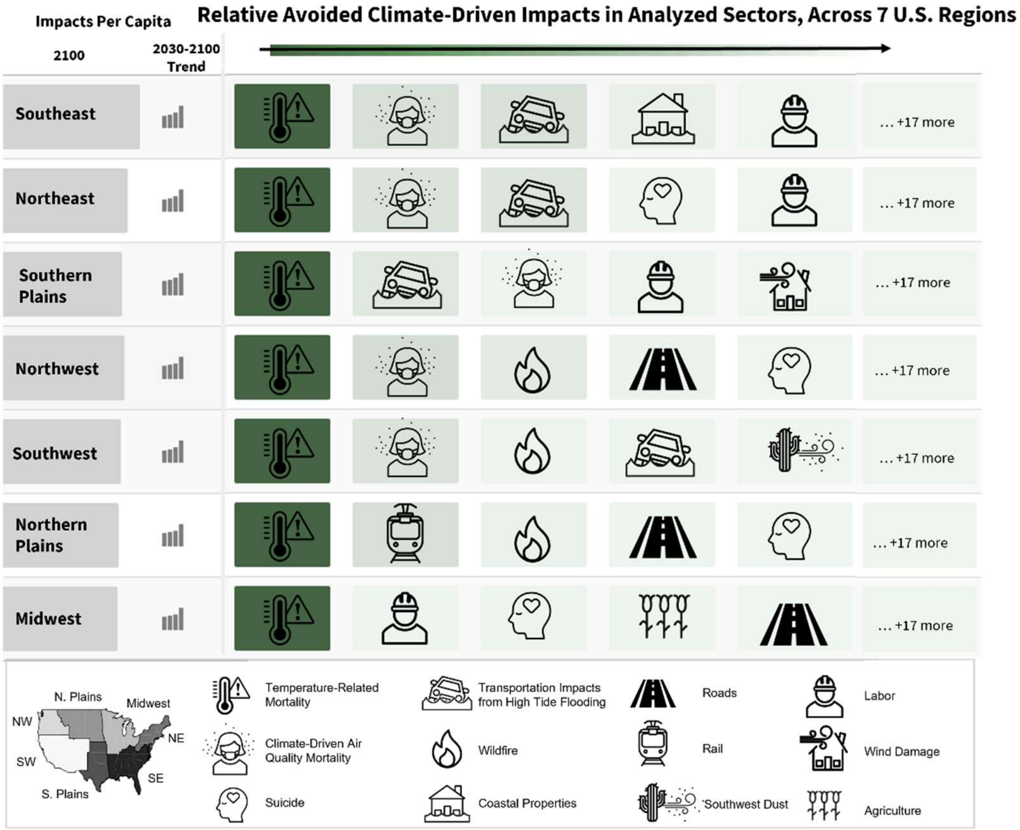

Figure B-3 provides a more detailed breakdown of the distribution of avoided climate-driven impacts per capita across each state under the final WEC. Overall, Virginia is projected to have the largest avoided impacts per capita, with Massachusetts, and North Carolina projected to experience the second and third largest avoided per capita impacts. For illustrative purposes, Figure B-3 includes a call-out to the state in each region that is projected to experience the largest avoided damages per capita, as well as the top five sectors in those states that are projected to have the largest avoided impacts. Combined, Figures B-2 and B-3 show that while the Southeast region is projected to experience the largest avoided damages, the distribution of these improvements varies across states within this region. These figures also highlight the regional differences in avoided impacts across sectors. For example, avoided impacts from

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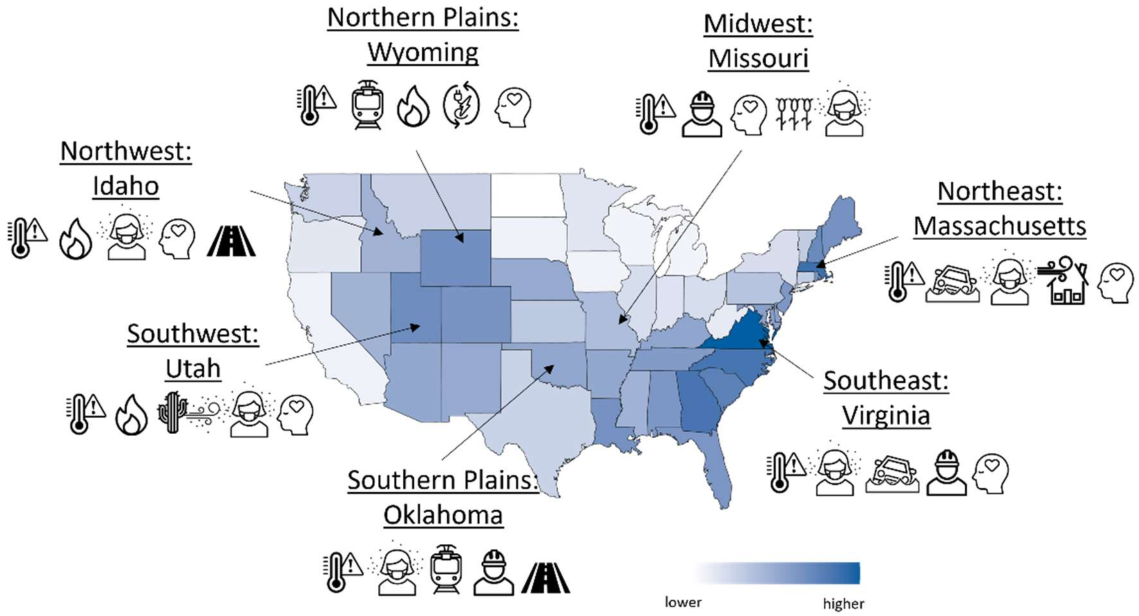
[90] Left bars) relative per capita improvements in each region in 2100 as well as the per capita improvements in the years 2030, 2050, 2070, 2090, and 2100. Right green tiles and icons) avoided climate–driven impacts experienced in the top 5 sectors within FrEDI in each region, in order of decreasing per capita impact changes (from left to right). Green shading illustrates the relative changes in each sector, normalized to the temperature-related mortality impacts in that region. Results are not a comprehensive accounting of all the ways climate-change is projected to impact the American public.

climate-driven changes in wildfire and dust will primarily impact populations living in the western U.S., and reductions in tropical wind damage and transportation impacts from high-tide flooding will largely occurring in states along the eastern U.S. coastline.

Figure B-3 State share of annual average avoided U.S. climate-driven impacts in 2100[91]



Lastly, understanding the comparative risks to different populations living in different areas is also critical for developing effective and equitable strategies for responding to climate change. Analysis from a recent independently peer-reviewed EPA report on Climate Change and Social Vulnerability in the United States (U.S. EPA, 2021) (hereafter referred to as the SV Report), provides a framework within FrEDI for better understanding the degree to which socially vulnerable populations are disproportionately exposed to the impacts from climate change in six impact categories.

As described in the SV Report, differential climate change risks are a function of exposure to where physical climate change impacts are projected to occur and vulnerability, in terms of an individual's capacity to prepare for, cope with, and recover from these impacts. This

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[91] Map insert shows the relative avoided climate-driven damages per capita in each CONUS state in the year 2100. For each NCA region, the state with the largest avoided damages per capita is called-out, with icons indicating the top five sectors in FrEDI that are projected to experience the largest avoided damages in those states. Icons are the same as in Figure B-2. Results are not a comprehensive accounting of all the ways climate-change is projected to impact the American public.

framework uses data on where populations live as an indicator of exposure and for vulnerability, considers four categories for which there is evidence of differential vulnerability (Table B-2), including low income (individuals living in households with income at or below 200% of the poverty level), ethnicity and race (individuals identifying as BIPOC[92]), educational attainment (individuals ages 25 and older with less than a high school diploma or equivalent), and age (individuals ages 65 and older). These categories are consistent with population groups of concern highlighted in EPA's Technical EJ Guidance (U.S. EPA, 2016).

Table B-2 Four socially vulnerable and reference groups considered here

Categories	Group Name	Description	Reference Group
Income	Low income	Individuals living in households with income that is 200% of the poverty level or lower	Individuals living in households with income greater than 200% of the poverty level.
Age	65 and Older	Ages 65 and older	Under age 65
Race and ethnicity	BIPOC	Individuals identifying as one or more of the following: Black or African American, American Indian or Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, and/or Hispanic or Latino	Individuals identifying as White and/or non-Hispanic
Education	No High School Diploma	individuals aged 25 and older with less than a high school diploma or equivalent	Individuals aged 25 or older with educational attainment of a high school diploma (or equivalent) or higher.

As described in the FrEDI Technical Documentation (Appendix E) (U.S. EPA, 2024), differential impacts in each group are calculated in FrEDI at the Census tract level as a function of current population demographic patterns (i.e., percent of each group living in each census tract), projections of CONUS population (from ICLUS, U.S. EPA, 2017), and projections of where climate-driven impacts are projected to occur (i.e., using FrEDI temperature-impact relationships) at the Census tract level. The relative percent of each socially vulnerable group in each Census tract are from the 2014-2018 U.S. Census American Community Survey dataset

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[92] This analysis uses the term BIPOC to refer to individuals identifying as Black or African American; American Indian or Alaska Native; Asian; Native Hawaiian or Other Pacific Islander; and/or Hispanic or Latino. It is acknowledged that there is no 'one size fits all' language when it comes to talking about race and ethnicity, and that no one term is going to be embraced by every member of a population or community. The use of BIPOC is intended to reinforce the fact that not all people of color have the same experience and cultural identity. This analysis therefore also includes results for individual racial and ethnic groups.

(U.S. Census) and are held constant overtime because robust and long-term projections of local changes in demographics are not readily available.

Figure B-4 shows how reductions in annual climate-driven impacts within the six impact categories[93], under the final WEC, are expected to be distributed across different populations, according to age, income, education level, and race and ethnicity. Those populations with greater than 100% differential improvements (right of the dashed lines) are projected to experience relatively larger reductions in long-term climate-driven impacts due to the WEC, compared to their reference populations (Table B-2). These are the same populations that are projected to experience relatively larger damages under the reference scenario. Those socially vulnerable groups with changes of less than 100% (left of the dashed lines) are still expected to see improvements but are projected to experience relatively smaller impact reductions than their reference populations. For example, Figure B-4 shows that BIPOC individuals age 65 and older are 13% more likely to see larger reductions in air quality attributable mortality relative to their white and/or non-Hispanic reference population. In addition, those in the low-income group are more likely (5%) to see larger reductions in lost labor hours than then those outside the low-income group. As most bars are to the right of the dashed lines, Figure B-4 shows that nearly all socially vulnerable groups are projected to experience larger reductions in climate change impacts, compared to their reference populations.

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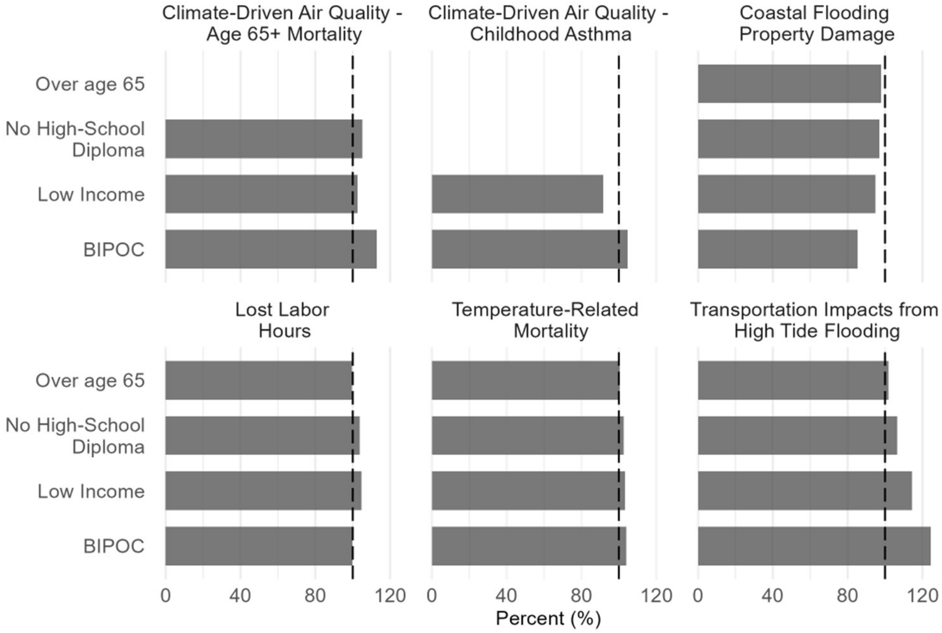
[93] The six impact categories include premature mortality (ages 65+) and new childhood (ages 0-17) asthma cases attributable climate-driven changes in air quality (ambient fine particulate matter), temperature mortality, labor hours lost due to high-temperature days, people impacted by coastal property inundation due to sea level rise, and transportation impacts from high tide flooding.

Figure B-4 Differential reductions in per capita climate-driven impacts in 2090 across socially vulnerable groups, normalized to the changes in their reference populations.[94]



Impacts to the BIPOC individuals in Figure B-4 can also be distributed across different races and ethnicities as shown in Figure B-5[95]. These are normalized to the per capita changes experienced by the national impacted population instead of a reference population. Therefore, bars to the right on the dashed lines in Figure B-5 indicate where specific groups of individuals will experience greater reductions in climate driven impacts compared to the national average and those to the left will experience smaller impact reductions than the national average.

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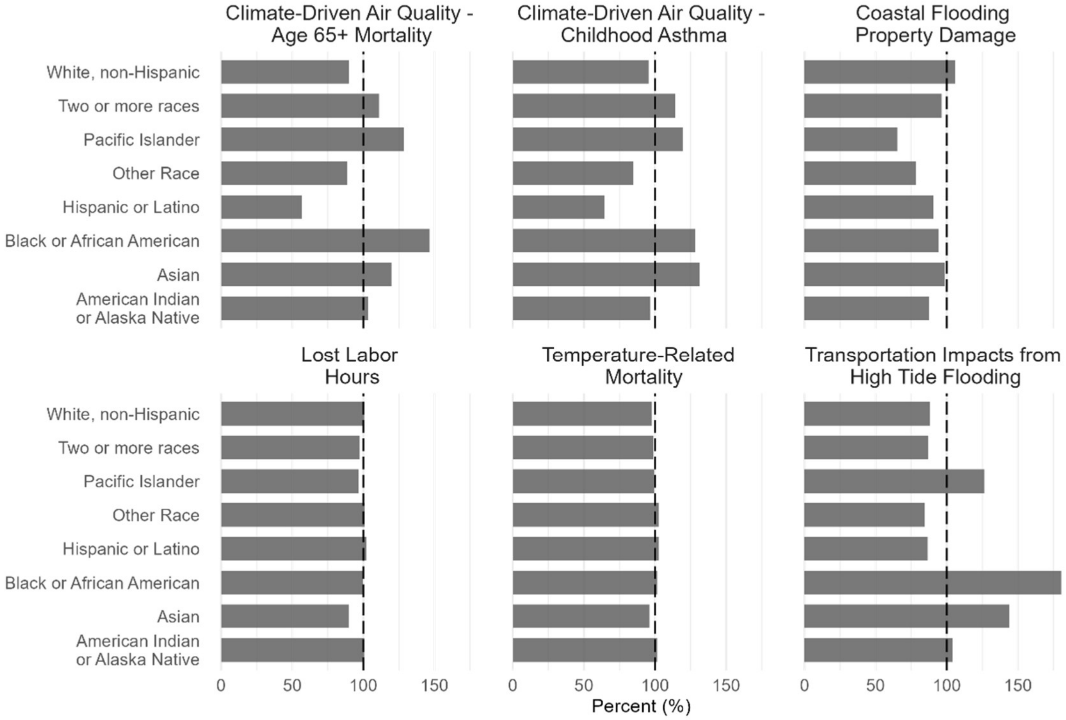
[94] Dashed gray lines represent 100% of the annual avoided impacts that are experienced by the reference population for that sector (Table B-2). Bars greater than 100% indicate that a group is projected to experience more impact reductions from WEC reductions than the reference population. Bars less than 100% indicate that a group is projected to experience fewer impact reductions than the reference population. No bars indicate there are no impacts considered in that group. This is not a complete accounting of all climate impacts to the U.S. Coastal property damage and transportation impacts from high tide flooding are included considering no additional adaptation.

[95] Impact results as a function of racial and ethnic group were also presented in EPA's SV Report.

Figure B-5 Per capita reductions in climate-driven impacts for six sectors in 2090, distributed by race and ethnicity.[96]



When considering the six impact categories analyzed here, Figure B-5 shows that all groups are projected to see fewer climate change impacts under the WEC (all bars are greater than zero), but that some specific populations may see more benefits than others. For example, by 2100, Black or African Americans over the age of 65 are 47% more likely to see more reductions in climate-driven changes in air quality mortality than the national average, which is largely because of regional differences in where these populations currently live and where future climate-driven air quality changes are projected to occur. As another example, Asian Americans are 44% more likely to see larger reductions in transportation impacts from high tide flooding than the national average. Typically, the populations projected to be impacted the most by climate change under the reference scenario are the same groups that are projected to experience the greatest impact reductions under the WEC.

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[96] Results for each sector are normalized to the average per capita impact avoided by the total impacted population in that sector. See Figure 4 caption for more details. This analysis does not consider effects on populations living in Hawai'i, Alaska, or U.S. territories but does use demographic data from the U.S. Census which includes individuals living in the CONUS who identify as "American Indian or Alaska Native" and "Native Hawaiian or Other Pacific Islander." This is not a complete accounting of all climate impacts to the U.S. Coastal property damage and transportation impacts from high tide flooding are included considering no additional adaptation.

There are many impacts of climate change and additional dimensions of vulnerability that are not incorporated into this analysis, and therefore these results only reveal a portion of the potential unequal risks to socially vulnerable populations. In addition, this analysis does not consider how changes in future demographic patterns in the U.S. could affect risks to these populations, nor how climate change may affect socially vulnerable populations living outside the CONUS.

Overall, the FrEDI analysis presented here is intended to produce estimates of annual net climate-driven impacts within U.S. borders using the best available data and methods. FrEDI was developed using a transparent process, peer-reviewed methodologies, and is designed as a flexible framework that is continually refined to reflect the current state of climate change impact science. While FrEDI does not provide a complete and comprehensive accounting of all potential climate change impacts relevant to U.S. interests and is subject to uncertainties (such as future levels of adaptation), this analysis provides the most detailed and complete illustration to date of the distribution of climate change impacts within U.S. borders.

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APPENDIX C
ADDITIONAL INFORMATION ON MARGINAL ABATEMENT COST (MAC) MODELING FOR ANALYSIS OF WASTE EMISSIONS CHARGE

C.1 MAC Model Overview

Marginal abatement cost (MAC) model is a bottom-up, engineering cost analysis using the most current information on mitigation options available to the United States oil and gas industry. The modeling approach and many of the key assumptions are consistent with the methodology described in the EPA's *Global Non-CO_2 Greenhouse Gas Emission Projections & Mitigation, 2015–2050 report*. The MAC curves were constructed for each region and sector by estimating the carbon price at which the present-value benefits and costs for each mitigation option equilibrate. The methodology produces a stepwise curve, where each point reflects the average price and reduction potential if a mitigation technology were applied across the sector. In conjunction with the projected GHG emissions for from facilities subject to the WEC, we express the resulting annual reductions in metric tons of methane (tCH_4).

C.2 MAC Model Description

The MAC model considers a suite of mitigation technologies applicable to facilities subject to the WEC. Each mitigation technology is characterized with respect to variables related to technical effectiveness in reducing emissions and cost for the purpose of calculating a breakeven price. The MACC is constructed by aggregating mitigation potential from all technologies as applied to the emissions baseline.

C.3 Mitigation Technology Emissions Reduction Characteristics

The mitigation potential associated with each mitigation is based on a number of factors that include technical applicability, market penetration, and reduction efficiency. The technical effectiveness of each mitigation option is calculated as shown in Table C-1. Technical effectiveness is the percent mitigation potential of a specific mitigation technology or control option that considers technical appropriateness of the option, the market penetration or uptake of the mitigation measure within the oil and gas industry combined with the emissions reduction efficiency of the mitigation technology when implemented/installed.

Table C-1 Calculation of Emission Reductions for a Mitigation Option

Technical Applicability (%)	**X**	**Market Share[a] (%)**	**X**	**Reduction Efficiency (%)**	**=**	**Technical Effectiveness (%)**				
						Technical Effectiveness (%)	X	Baseline Emissions (tCH_4)	=	Emissions Reductions (tCH_4)
Percentage of total baseline emissions from a particular emission source to which a given option can be potentially applied.		Percentage of technically applicable baseline emissions to which a given option is applied; avoids double counting among competing options.		Percentage of technically achievable emission mitigation for an option after it is applied to a given emission stream.		Percentage of baseline emissions that can be reduced at the national or regional level by a given option.		Emission stream to which the option is applied.		Unit emission reductions.

[a] Implied market shares for noncompeting mitigation options (i.e., only one option is applicable for an emission streams) sums to 100%.

where:

TA = technical applicability (%)
MS = market share (%)
RE = reduction efficiency (%)
TE = technical efficiency (%)
BE = baseline emissions (tCH_4)

Technical applicability accounts for the portion of emissions from a facility or region that a mitigation option could feasibly reduce based on its application. For example, if an option applies only to the underground portion of emissions from coal mining, then the technical applicability for the option would be the percentage of emissions from underground mining relative to total emissions from coal mining.

The implied market share of an option is a mathematical adjustment for other qualitative factors that may influence the effectiveness or adoption of a mitigation option. EPA does not imply that effectiveness and adoption are interchangeable. We used market shares for each mitigation option within every sector. The market shares, determined by various sector-specific methods, must sum to one for each sector and were assumed constant over time. This assumption avoids cumulative reductions of greater than 100% across options.

When nonoverlapping options are applied, they affect 100% of baseline emissions from the relevant source. Examples of two nonoverlapping options in the natural gas system are replacement of high-bleed pneumatic devices and leak detection and repair of compressors in the transmission segment. These options were applied independently to different parts of the sector and do not compete for the same emission stream.

The reduction efficiency of a mitigation option is the percentage reduction achieved with adoption. The reduction efficiency was applied to the relevant baseline emissions as defined by technical applicability and adoption effectiveness. Most abatement options, when adopted, reduce an emission stream less than 100%. If multiple options are available for the same component, the total reduction for that component is less than 100%.

Once the technical effectiveness of an option was calculated as described above, this percentage was multiplied by the baseline emissions for each sector and region to calculate the absolute amount of emissions reduced by employing the option. The absolute amount of baseline emissions reduced by an option in a given year is expressed in metric tons of methane.

If the options were assumed to be technically feasible in a given region, they were assumed to be implemented systematically for all applicable components in the industry. Furthermore, once options are adopted, they were assumed to remain in place for the duration of the analysis, and an option's parameters do not change over its lifetime.

C.4 Mitigation Technology Economic Characteristics

Each abatement option is characterized in terms of its costs and benefits per abated unit of gas (tons of emitted CH_4). The carbon price at which an option's benefits equal the costs is referred to as the option's break-even price expressed in $/$tCH_4$ reduced.

For each mitigation option, the carbon price (P) at which that option becomes economically viable was calculated using the equation below (i.e., where the present value of the benefits of the option equals the present value of the costs of implementing the option). A present value analysis of each option was used to determine break-even mitigation costs. Break-even calculations are independent of the year the mitigation option is implemented but are contingent on the life expectancy of the option. The net present value calculation solves for break-even price *P* by equating the present value of the benefits with the present value of the costs of the mitigation option. More specifically,

$$\begin{aligned}\sum_{t=1}^{T}\left[\frac{(1-TR)(P\cdot ER+R)+TB}{(1+DR)^{t}}\right] \\ &= CC+\sum_{t=1}^{T}\left[\frac{(1-TR)RC}{(1+DR)^{t}}\right]\sum_{t=1}^{T}\left[\frac{(1-TR)(P\cdot ER+R)+TB}{(1+DR)^{t}}\right] \\ &= CC+\sum_{t=1}^{T}\left[\frac{(1-TR)RC}{(1+DR)^{t}}\right]\end{aligned} \tag{D.1}$$

$$\underbrace{\hphantom{\sum_{t=1}^{T}\left[\frac{(1-TR)(P\cdot ER+R)+TB}{(1+DR)^{t}}\right]}}_{\textit{Net Present Benefits}} \qquad \underbrace{\hphantom{CC+\sum_{t=1}^{T}\left[\frac{(1-TR)RC}{(1+DR)^{t}}\right]}}_{\textit{Net Present Costs}}$$

where:

P = the break-even price of the option (\$/tCH4)
ER = the emission reduction achieved by the technology (tCH4)
R = the revenue generated from energy production (scaled based energy prices)
T = the option lifetime (years)
DR = the discount rate (5%)
CC = the one-time capital cost of the option (\$)
RC = the recurring (O&M) cost of the option (portions of which may be scaled based on regional labor and materials costs) (\$/year)
TR = the tax rate (0%)

Assuming that the emission reduction *ER*, the recurring costs *RC*, and the revenue *R* do not change on an annual basis, then we can rearrange this equation to solve for the break-even price P of the option for a given year:

$$P=\frac{CC}{(1-TR)\cdot ER\cdot \sum_{t=1}^{T}\frac{1}{(1+DR)^{t}}}+\frac{RC}{ER}-\frac{R}{ER}-\frac{CC}{ER\cdot T}\cdot\frac{TR}{(1-TR)} \tag{D.2}$$

Costs include capital or one-time costs and O&M or recurring costs. Most of the agricultural sector options, such as changes in management practices, do not have applicable capital costs, with the exception of anaerobic digesters for manure management.

Benefits or revenues from employing an abatement option can include (1) the intrinsic value of the recovered gas (e.g., the value of CH4 either as natural gas or as electricity/heat),

(2) non-GHG benefits of abatement options (e.g., non-energy savings for labor or equipment). In most cases, the abatement of CH_4 has two price signals: one price based on CH_4's value as energy (because natural gas is between 90% and 98% CH_4) and one price based on CH_4's value as a GHG. All cost and benefit values are expressed in constant-year 2019 dollars. The analysis applied a 5% discount rate and assumed a 0% tax rate. Table C-2 lists the basic financial assumptions used in the analysis.

Table C-2 Financial Assumptions in Break-Even Price Calculation for Mitigation Options

Economic Parameter	Assumption
Discount rate	5%
Tax rate	0%
Constant-year dollars	2019$

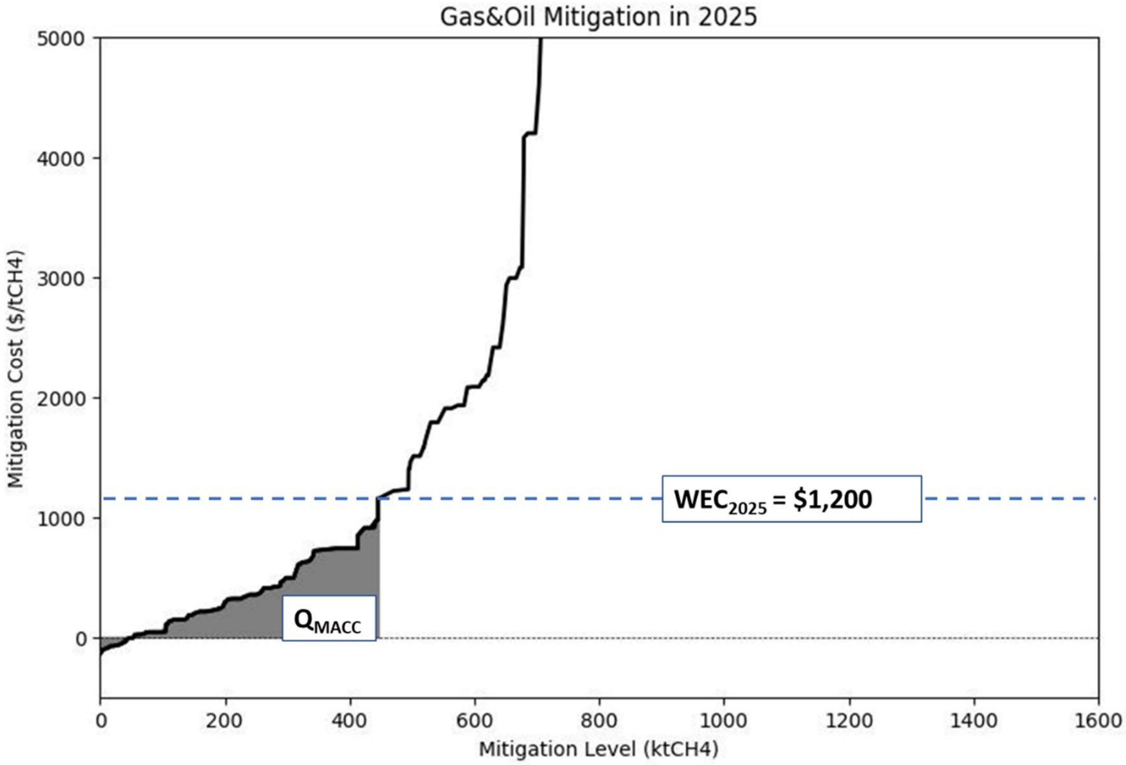
Finally, the MACC model also includes assumptions regarding the quantitative impacts of learning over time, with a learning rate of 15%. The learning rate defines the rate of decrease in the implementation costs overtime as industry gains more experience. The cost reduction curve initially drives costs down rapidly in the early years but decreases its year-on-year reductions in later years as potential cost reduction opportunities are exhausted. The results of learning overtime reduce the costs of implement the mitigation measures while also improving the reduction efficiency of mitigation measures over time. This element of the MACC model means costs of mitigation in future years will be lower compared to the present. As a result, some mitigation measures not cost-effective in 2024 ($\$/tCH_4 <= WEC\ \$/tCH_4$) may be costs-effective in later years.

C.5 WEC Facility MAC Curves Construction

The mitigation option analysis throughout this report was conducted using a common methodology and framework. MAC curves were constructed for each region and sector in the United States by estimating the "break-even" price at which the present-value benefits and costs for each mitigation option equilibrate. The methodology produces a curve where each point reflects the average price and reduction potential if a mitigation technology were systematically adopted by all similar facilities across the oil or gas segment. When combined with the projected baseline emissions for the specific facility type, results are expressed in absolute annual reductions (tCH4) at specific average mitigation costs or prices. For example, in the illustrative MAC shown in Figure C-1 below shows the quantity of mitigation technical achievable at prices below the WEC rate ($/tCH4). The quantity of mitigation (Q_macc) expected from WEC facilities in the 2025 is ~460 ktCH4, where the MAC curve crosses the WEC.

The Q_MACC represents the full technically available mitigation potential at mitigations costs below the WEC charge. In order to account for practical limitations in the speed of deploying cost-effective mitigation to oil and gas operations, the analysis assumed a three-year phase-in period for reductions over 2024 to 2026. The phase-in parameter constrains the mitigation potential in 2024 and 2025 to 33% and 67% of total mitigation potential to simulate the assumption that it will take facilities several years to fully implement mitigation measures. Depending upon a variety of factors, potential technology deployment speed may be faster or slower than this assumption. Because many of the mitigation technologies estimated in the MACC model correspond to mitigation technologies considered as part of the Oil and Gas NSPS/EG rulemaking process, oil and gas operators have been aware of potential requirements since 2021. However, widespread deployment of mitigation technologies may be affected by supply chain, labor, or other constraints that could prevent full utilization in the short term.

Figure C-1 Illustrative MAC Curve for Facilities with Emissions Subject to the WEC in the year 2025



C.6 Mitigation Options Modeled

This mitigation analysis utilized information on mitigation measures cost and performance gathered as part of technology analysis process from the Oil and Natural Gas NSPS/EG rulemaking process. Data on technologies was derived from both the analysis related to the 2021 proposal and the 2022 supplemental proposal. In particular, updated technology cost and performance data was drawn from spreadsheets published in the docket underlying the NSPS/EG Technical Support Documents (EPA, 2022 and 2021). Mitigation option information address methane emissions from the following emissions sources:

Table C-3 lists the mitigation technologies included in the MACC analysis for the WEC rule.

Table C-3 Mitigation Technologies Included in WEC Analysis by Source Category

Emissions Source	Mitigation Options
Pneumatic controllers	• Replace Continuous High-Bleed Controllers with Low-Bleed Controllers • Electric Powered Controllers (where a grid connection, on-site power exists) • Solar Powered Electronic Controllers
Fugitive emissions from well sites	• Fugitive Emissions Leak Detection and Repair at Well Sites
Fugitive emissions from natural gas processing plants	• Fugitive Emissions Leak Detection and Repair at NG Processing Plants
Fugitive emissions from compressor stations	• Fugitive Emissions Leak Detection and Repair at compressor stations
Fugitive emissions from offshore facilities	• Fugitive Emissions Leak Detection and Repair at offshore facilities
Pneumatic pumps	• Install a New Combustion Device or Process • Route Emissions to an Existing Combustion Device or Process • Replace a gas-driven pump with an electric pump – Processing
Liquids Unloading	• Non-Venting Liquids Unloading Techniques
Reciprocating compressors	• Replacement of rod packing every 3 years • Fugitive Emissions Leak Detection and Repair • Routing of Emission Through a Closed Vent System Under Negative Pressure to a Combustion Device
Centrifugal compressors	• Converting Wet Seals to Dry Seals System • Routing emissions to a New Control Device • Routing emissions to an Enclosed Combustion Device or Process.

The balance of this section briefly defines the sources and mitigation technologies considered for the WEC analysis. Much of the definitions are terms are borrowed directly from the EPA 2021 Background Technical Support Document for the NSPS/EG analysis of the Oil and Natural Gas Sectors (EPA,2021).

C.6.1 Pneumatic Controllers

Pneumatic controllers are devices used to regulate a variety of physical parameters, or process variables, using air or gas pressure to control the operation of mechanical devices, such as valves. The valve control process conditions such as levels, temperatures and pressures. When a pneumatic controller identifies the need to alter a process condition, it will open or close a control valve. In many situations across all segments of the oil and natural gas industry, pneumatic controllers make use of the available high-pressure natural gas to operate or control the valve. In these “gas-driven” pneumatic controllers, natural gas may be released with every valve movement and/or continuously from the valve control.

Pneumatic controllers can be categorized based on the emissions pattern of the controller. Some controllers are designed to have the supply-gas provide the required pressure to power the end-device, and the excess amount of gas is emitted. The emissions of this excess gas are referred to as “bleed,” and this bleed occurs continuously. Also referred to as “continuous bleed” pneumatic controllers, these controllers can be further categorized based on the bleed volume. Controllers with bleed rate less than or equal to 6 standard cubic feet per hour (scfh) are referred to as “low bleed,” and those with a higher bleed rate are referred to as “high bleed.” Another type of controller is designed to release gas only when the process parameter needs to be adjusted by opening or closing the valve, and there is no vent or bleed of gas to the atmosphere when the valve is stationary. These types of controllers are referred to as “intermittent vent” pneumatic controllers. EPA (2021) cites that while emissions from individual pneumatic controllers are small, there are an estimated 1.7 million controllers utilized across oil and gas production facilities and natural gas transmission and storage facilities. Combined emissions from all these pneumatic controllers represents approximately 50% of the baseline emissions from WEC applicable facilities.

Emissions from natural gas-powered pneumatic controllers occur as a function of their design. Continuous bleed controllers using natural gas as the power source emit a portion of that gas at a constant rate. Intermittent vent controllers using natural gas as the power source emit natural gas only when the controller sends a signal to open or close the valve.

The mitigation options for pneumatic controllers are summarized below these include: (1) replacing high-bleed controllers with low-bleed controllers; (2) electric powered controllers; and

(3) solar powered controller systems. Additionally, the analysis categorizes facilities based on the controller site type (new vs. existing) and facility size (large, medium, and small), these site configurations were assumed to change over from existing to new sites over a 15-year time frame.

Under the baseline projections developed for this analysis there are no emissions from the new facility in the baseline in 2021. All the CH_4 distribution are from existing facilities.

Zero Emissions Options in Production, Gathering and Boosting, Transmission Compression, and Underground Natural Gas Storage

Low-bleed controllers provide the same operational function as high-bleed controllers but have lower continuous bleed emissions. This analysis adopts the technology costs assumptions presented in EPA, 2022. The technical lifetime of equipment was assumed to be 15 years. The reduction efficiency is assumed to be 100% for all zero emissions mitigation options. Table C-4 below summarizes the reduction efficiency and costs by pneumatic controller type.

Table C-4 Technology and Cost Inputs by Model Facility Size and Type for Zero Emissions Options in Production; Gathering and Boosting; Transmission and Storage[97]

Facility Size	Site Type	Mitigation Option	Reduction Efficiency	Capital Costs ($2019)	O&M Costs ($2019)
Small	New	Electric controllers -grid	100%	$15,287	-$916
Small	New	Electric controllers - solar	100%	$16,831	-$726
Small	New	Compressed air - grid	100%	$47,512	$4,068
Small	New	Compressed air - generator	100%	$95,115	$2,161
Medium	New	Electric controllers -grid	100%	$25,426	-$1,832
Medium	New	Electric controllers - solar	100%	$28,515	-$1,452
Medium	New	Compressed air - grid	100%	$71,426	$2,816
Medium	New	Compressed air - generator	100%	$100,231	$909
Large	New	Electric controllers -grid	100%	$55,842	-$4,582
Large	New	Electric controllers - solar	100%	$63,049	-$3,665
Large	New	Compressed air - grid	100%	$113,277	$2,454
Large	New	Compressed air - generator	100%	$190,577	-$1,360
Small	Existing	Electric controllers -grid	100%	$20,593	-$916
Small	Existing	Electric controllers - solar	100%	$22,653	-$726
Small	Existing	Compressed air - grid	100%	$58,636	$4,068
Small	Existing	Compressed air - generator	100%	$120,000	$2,161
Medium	Existing	Electric controllers -grid	100%	$34,322	-$1,832
Medium	Existing	Electric controllers - solar	100%	$38,441	-$1,452
Medium	Existing	Compressed air - grid	100%	$76,481	$2,816
Medium	Existing	Compressed air - generator	100%	$120,000	$909
Large	Existing	Electric controllers -grid	100%	$75,508	-$4,582
Large	Existing	Electric controllers - solar	100%	$85,119	-$3,665
Large	Existing	Compressed air - grid	100%	$127,469	$2,454
Large	Existing	Compressed air - generator	100%	$220,000	-$1,360

Options If Zero-Emission Options are Technically Infeasible

As described in EPA, 2022, the primary costs associated with electronic controller systems are the initial capital expenditures for the equipment (i.e., controllers and control panel), the engineering and installation costs, and the operating costs for electrical energy. Electrical supply is assumed to be available at the facility irrespective of the electronic controllers at the

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[97] Capital and annual costs of controller systems are discussed in Chapter 3.2.3 of EPA, 2022.

site, the costs of the power supply were not included in the mitigation option costs for electronic controllers. Table C-5 presents the costs for electronic controllers across production, transmission and storage segments at facilities based on the number of controllers at each site. The technical lifetime of equipment was assumed to be 15 years.

Table C-5 Technology and Cost Inputs by Model Facility Size and Type Zero Emissions Options in Production; Gathering and Boosting; Transmission and Storage[98]

Facility Size	Site Type	Mitigation Option	Reduction Efficiency	Capital Costs ($2019)	O&M Costs ($2019)
Small	New	Route to existing combustion device	95.0%	$15,256	$497
Small	New	Route to new combustion device	95.0%	$53,725	$20,846
Small	New	Install low or intermittent controllers with inspection	27.3%	$0	$600
Medium	New	Route to existing combustion device	95.0%	$27,461	$1,329
Medium	New	Route to new combustion device	95.0%	$65,930	$21,244
Medium	New	Install low or intermittent controllers with inspection	38.4%	$0	$600
Large	New	Route to existing combustion device	95.0%	$64,075	$2,088
Large	New	Route to new combustion device	95.0%	$102,544	$22,437
Large	New	Install low or intermittent controllers with inspection	38.4%	$0	$600
Small	Existing	Route to existing combustion device	95.0%	$15,256	$497
Small	Existing	Route to new combustion device	95.0%	$53,725	$20,846
Small	Existing	Install low or intermittent controllers with inspection	27.3%	$0	$600
Medium	Existing	Route to existing combustion device	95.0%	$27,461	$1,329
Medium	Existing	Route to new combustion device	95.0%	$65,930	$21,244
Medium	Existing	Install low or intermittent controllers with inspection	38.4%	$0	$600

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[98] As discussed in EPA, 2022, electronic controller costs reflect information in the 2022 Carbon Limits report, as well as estimates of installation costs used in the November 2021 analyses and considered operation and maintenance costs for all types of pneumatic controller systems not driven by natural gas.

Large	Existing	Route to existing combustion device	95.0%	$64,075	$2,088
Large	Existing	Route to new combustion device	95.0%	$102,544	$22,437
Large	Existing	Install low or intermittent controllers with inspection*	38.4%	$0	$600

C.6.2 Fugitive Emissions from Well Sites, Gas Processing Plants, Compressor Stations and Offshore Facilities

There are several potential sources of fugitive emissions throughout the oil and natural gas industry. Fugitive emissions occur when connection points are not fitted properly or when seals and gaskets start to deteriorate. Changes in pressure and mechanical stresses can also cause components or equipment to emit fugitive emissions. Poor maintenance or operating practices, such as improperly reseated pressure relief valves (PRVs) or worn gaskets on thief hatches on controlled storage vessels are also potential causes of fugitive emissions. Additional sources of fugitive emissions include agitator seals, connectors, pump diaphragms, flanges, instruments, meters, open-ended lines (OELs), pressure relief devices such as PRVs, pump seals, valves or controlled liquid storage tanks. EPA 2022 analysis provided a breakdown of model facilities for the production well sites categorized by the types of equipment in operation at the site.

Table C-6 below presents the reduction efficiency and costs for the various mitigation options models to address fugitive emissions across the segments of the oil and natural gas industry. For production wellhead sites this analysis simplified the number of options to only include the options that assumed 0.5% leak rates. A discussion of how 0.5% leak rates are determined and used can be found in in EPA 2022. For offshore production facilities this analysis applies the directed inspection and maintenance option reported in EPA 2019, as there was no clear updated cost information for this type of facility in earlier cited NSPS/EG analysis.

Table C-6 Technology and Cost Inputs by Mitigation Option in Production; Gathering and Boosting; Transmission and Storage

Segment	Site Type	Mitigation Option	Reduction Efficiency	Capital Costs ($2019)	O&M Costs ($2019)
Production	Single Wellhead Only	Equipment Leak Monitoring at Well Site (0.5% leak rate, 30 day repair) [a]	48%	1,027	1,889
Production	Wellhead, tank, and other	Equipment Leak Monitoring at Well Site (0.5% leak rate, 30 day repair) [a]	47%	1,027	2,160
Production	Multi-Wellhead Only	Equipment Leak Monitoring at Well Site (0.5% leak rate, 30 day repair) [a]	44%	1,027	1,858
Production	Offshore	Direct Inspection & Maintenance [c]	95%	-	33,333
G&B	Compressor Station	Equipment Leak Monitoring Program at a Compressor Station (G&B) w/o Recovery Credits [b]	43%	1,027	10,134
Processing	Processing Plant	Equipment Leak Monitoring Program at Processing Plant [b]	40%	3,087	6,353
Transmission	Compressor Station	Equipment Leak Monitoring Program at a Compressor Station (Transmission) w/o Recovery Credits [b]	40%	23,883	12,903
Storage	Compressor Station	Equipment Leak Monitoring Program at a Compressor Station (Storage) w/o Recovery Credits [b]	40%	23,883	17,000

Source: a)EPA, 2022; b) EPA, 2021, and c) EPA, 2019.

C.6.3 Pneumatic Pumps

A pneumatic pump is a positive displacement reciprocating unit generally used by the Oil and Natural Gas Industry for one of four purposes: (1) hot oil circulation for heat tracing/freeze protection, (2) chemical injection, (3) moving bulk liquids, and (4) glycol circulation in dehydrators. There are two basic types of pneumatic pumps used in the Oil and Natural Gas Industry -- diaphragm pumps and piston pumps. Natural gas-driven pneumatic pumps emit methane and volatile organic compounds (VOC) as part of their normal operation. However, pneumatic pumps may also be powered by electricity or compressed air, and these types of controllers do not use or emit natural gas.

Two types of control options were evaluated in the revised technology analysis related to the 2022 Supplemental proposal (EPA, 2022). The first type utilizes pneumatic pumps that are not driven by natural gas, thus eliminating methane emissions. The other option is to reduce emissions when natural gas-driven pneumatic pumps are used. Table C-7 summarizes the base mitigation technology and cost assumptions for pneumatic pumps. These options are applied across to emissions from production and G&B, transmission, and storage segments.

Table C-7 Technology and Cost Inputs by Mitigation Option in Production; Gathering and Boosting; Transmission and Storage

Pump Type	Mitigation Option	Reduction Efficiency	Capital Costs ($2019)	O&M Costs ($2019)
Zero Emissions (Non NG-Driven)				
One Diaphragm	Electric Pump	100%	$5,219	$329
One Diaphragm	Solar Powered Electric Pump	100%	$2,246	$0
One Diaphragm	Compressed Air-Driven Pump	100%	$6,742	$10,335
One Piston	Electric Pump	100%	$2,043	$329
One Piston	Solar Powered Electric Pump	100%	$2,246	$0
One Piston	Compressed Air-Driven Pump	100%	$6,742	$0
Routing to Combustion if Zero Emissions is Technically Infeasible				
One Diaphragm	Route Emissions to an Existing Process	95%	$6,102	$0
One Piston	Route Emissions to an Existing Process	95%	$6,102	$0
One Diaphragm	Route Emissions to an Existing Combustion Device	95%	$6,102	$0
One Piston	Route Emissions to an Existing Combustion Device	95%	$6,102	$0
One Diaphragm	Route Emissions to a New Combustion Device	95%	$38,469	$19,095
One Piston	Route Emissions to a New Combustion Device	95%	$38,469	$19,095

Source: EPA, 2022.

C.6.4 Liquids Unloading

As described in EPA, 2021, the accumulation of liquids in new or mature wells[99] can impede and sometimes halt gas production. When the accumulation of liquid results in the slowing or cessation of gas production (i.e., liquids loading), removal of fluids (i.e., liquids unloading) is required in order to maintain production. Gas wells therefore often need to remove or "unload" accumulated liquids to maintain gas production.

This analysis models two liquid unloading techniques (i.e.; with and without the use of a plunger lift). For liquids unloading that do not employ plunger lift, emissions occur when there is

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[99] In new gas wells, there is generally sufficient reservoir pressure/gas velocity to facilitate the flow of water and hydrocarbon liquids through the well head and to the separator to the surface along with produced gas. In mature gas wells, the accumulation of liquids in the wellbore can occur when the bottom well pressure/ gas velocity approaches average pressure.

venting of a well, typically to an atmospheric tank. For example, a common unloading method manually diverts the well’s flow from a production separator to an atmospheric pressure tank. Under this scenario, venting to the atmospheric tank occurs because the separator operates at a higher pressure than the atmospheric tank and the well will temporarily flow to the atmospheric tank (which has a lower pressure than the pressurized separator). Natural gas is released through the tank vent to the atmosphere until liquids are unloaded.

For liquids unloading performed using a plunger lift, liquids may be removed manually or by automation. This method closes (shuts in) the well by lowering the plunger below the accumulated liquids in the well bore, which increases the reservoir pressure. Liquid is removed by the plunger when the well is reopened and the gas in the well pushes the plunger and the liquid back up the well bore (based on pressure differential). Emissions occur if the plunger does not return to the surface as expected, or when the plunger controller bypasses the separator and directs the flow to a lower pressure atmospheric pressure vent.

Table C-8 summarizes the mitigation technology and costs assumptions obtained from the Oil and Gas NSPS/EG technical analysis (EPA,2021). For costs, the analysis assumes 25 percent of the average duration of a liquids unloading event would be the additional time required to implement BMP (i.e., monitoring and following steps to minimize/eliminate venting of emissions). It is assumed that persons implementing BMPs are already onsite, and no travel costs would be required. An average duration of a liquids unloading venting event (1.9 hours) was obtained from the API/ANGA Report (API ANGA 2012). Thus, the time assumed to be needed to implement the BMP per unloading event was 0.475 hours per event. The reported cost per event assumes technical hour rate for plant and system operators, gas plant operators ($71.47/hr).

Table C-8 Technology and Cost Inputs by Mitigation Option in Production; Gathering and Boosting; Transmission and Storage

Segment	Mitigation Option	Reduction Efficiency	Capital Costs ($2019)	O&M Costs[a] ($2019)
Production	Liquids Unloading - Without Plunger Lift - 10% Control	10%	-	$65
Production	Liquids Unloading - Without Plunger Lift - 25% Control	25%	-	$65
Production	Liquids Unloading - Without Plunger Lift - 50% Control	50%	-	$65
Production	Liquids Unloading - With Plunger Lift - 10% Control	10%	-	$65

Production	Liquids Unloading - With Plunger Lift - 25% Control	25%	-	$65
Production	Liquids Unloading - With Plunger Lift - 50% Control	50%	-	$65

[a][1.9-hour event X 0.475 hour] X $71.74 hour = $64.75/event

Source: EPA, 2022.

C.6.5 Centrifugal Compressors

Table C-9 summarizes the technology costs and reduction efficiency assumptions obtained from the analysis update (EPA, 2022 and 2021). For wet seal centrifugal compressors, the technologies included: (1) routing emissions to a control device that achieves an emission reduction of 95.0 percent, (2) routing emissions to a process, and (3) implementing maintenance and repair activities to meet a numerical emission limit. For dry seal compressors, the mitigation technology was (1) direct inspection and maintenance/repair and routing to an enclosed combustor.

Table C-9 Technology and Cost Inputs by Mitigation Option in Production; Gathering and Boosting; Transmission and Storage

Segment	Site Type	Mitigation Option	Reduction Efficiency	Capital Costs ($2019)	O&M Costs ($2019)
Production	New	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Dry Seal Centrifugal Comp	37%	$0	$15,000
Production	Existing	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Dry Seal Centrifugal Comp	37%	$0	$15,000
Production	New	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Wet Seal Centrifugal Comp	89%	$0	$25,000
Production	Existing	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Wet Seal Centrifugal Comp	89%	$0	$25,000
Production	New	Emissions Routed to a New Combustion Device – Wet Seal Centrifugal Comp	95%	$80,926	$128,683

Production	Existing	Emissions Routed to a Existing Combustion Device – Wet Seal Centrifugal Comp	95%	$26,214	$3,732
G&B	New	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Dry Seal Centrifugal Comp	37%	$0	$15,000
G&B	Existing	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Dry Seal Centrifugal Comp	37%	$0	$15,000
G&B	New	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Wet Seal Centrifugal Comp	89%	$0	$25,000
G&B	Existing	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Wet Seal Centrifugal Comp	89%	$0	$25,000
G&B	New	Emissions Routed to a New Combustion Device – Wet Seal Centrifugal Comp	95%	$80,926	$128,683
G&B	Existing	Emissions Routed to a Existing Combustion Device – Wet Seal Centrifugal Comp	95%	$26,214	$3,732
T&S	New	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Dry Seal Centrifugal Comp	37%	$0	$15,000
T&S	Existing	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Dry Seal Centrifugal Comp	37%	$0	$15,000
T&S	New	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Wet Seal Centrifugal Comp	54%	$0	$25,000
T&S	Existing	Direct Inspection and Maintenance/Repair Option and Routing to An Enclosed Combustor Option – Wet Seal Centrifugal Comp	54%	$0	$25,000

T&S	New	Emissions Routed to a New Combustion Device – Wet Seal Centrifugal Comp	95%	$80,926	$128,683
T&S	Existing	Emissions Routed to a Existing Combustion Device – Wet Seal Centrifugal Comp	95%	$26,214	$3,732

C.6.6 Reciprocating Compressors

In a reciprocating compressor, natural gas enters the suction manifold, and then flows into a compression cylinder where it is compressed by a piston driven in a reciprocating motion by the crankshaft powered by an internal combustion engine. Emissions occur when natural gas leaks around the piston rod when pressurized natural gas is in the cylinder. The compressor rod packing system consists of a series of flexible rings that create a seal around the piston rod to prevent gas from escaping between the rod and the inboard cylinder head. However, over time, during operation of the compressor, the rings become worn, and the packaging system needs to be replaced to prevent excessive leaking from the compression cylinder.

For this analysis, the projected baseline emissions are estimates for two types of emission (1) emissions from rod packing system, and (2) fugitive leaks from reciprocating compressors. We applied the Rod Packing Change Out option to the first emissions stream. The annual monitoring option applied to the fugitive emissions.

Options to reduce emissions from reciprocating compressors include limiting leaks of natural gas past the piston rod packing unit. Two alternative approaches are analyzed in this analysis, these include: (1) specifying a frequency for the replacement of the compressor rod packing, (2) monitoring the emissions from the compressor and replacing the rod packing when the results exceed a specified threshold. Table C-10 summarizes the technologies used in the analysis by segment and compressor type.

Table C-10 Technology and Cost Inputs by Mitigation Option in Production; Gathering and Boosting; Transmission and Storage

Segment	Site Type	Mitigation Option	Reduction Efficiency	Capital Costs ($2019)	O&M Costs ($2019)
Production	New	Rod Packing Change Out	56%	$6,345	$1,963
Production	New	Annual Monitoring to Evaluate Need for Packing Replacement	92%	$6,345	$2,560
Production	Existing	Rod Packing Change Out	56%	$6,345	$1,963

Production	Existing	Annual Monitoring to Evaluate Need for Packing Replacement	92%	$6,345	$2,560
G&B	New	Rod Packing Change Out	56%	$6,345	$1,963
G&B	New	Annual Monitoring to Evaluate Need for Packing Replacement	92%	$6,345	$2,560
G&B	Existing	Rod Packing Change Out	56%	$6,345	$1,963
G&B	Existing	Annual Monitoring to Evaluate Need for Packing Replacement	92%	$6,345	$2,560
Processing	New	Rod Packing Change Out	80%	$4,807	$1,682
Processing	New	Annual Monitoring to Evaluate Need for Packing Replacement	92%	$4,807	$2,279
Processing	Existing	Rod Packing Change Out	80%	$4,807	$1,682
Processing	Existing	Annual Monitoring to Evaluate Need for Packing Replacement	92%	$4,807	$2,279
T&S	New	Rod Packing Change Out - Transmission	80%	$6,345	$1,963
T&S	New	Annual Monitoring to Evaluate Need for Packing Replacement - Transmission	92%	$6,345	$2,560
T&S	Existing	Rod Packing Change Out - Transmission	80%	$6,345	$1,963
T&S	Existing	Annual Monitoring to Evaluate Need for Packing Replacement - Transmission	92%	$6,345	$2,560
T&S	New	Rod Packing Change Out - Storage	77%	$8,653	$2,332
T&S	New	Annual Monitoring to Evaluate Need for Packing Replacement - Storage	92%	$8,653	$2,929
T&S	Existing	Rod Packing Change Out - Storage	77%	$8,653	$2,332
T&S	Existing	Annual Monitoring to Evaluate Need for Packing Replacement - Storage	92%	$8,653	$2,929

Source: EPA, 2022.

C.7 Emission Reductions and Mitigation Costs

The abatement potential achievable under the WEC analysis is summarized by segment and source in Table C-11. In 2024, our analysis estimates cost effective mitigation potential to be approximately 150 kilotonnes methane (ktCH$_4$). This potential increases in the following year to over 300 ktCH$_4$ and then drops to 47 ktCH$_4$ for years 2026 through 2035.

Table C-11 Abatement Potential by Industry Segment and Source Type (ktCH4)

Segment/Source[a]	2024	2025	2026	2027
Onshore Production	75.45	143.00	247.41	-
Offshore Production	1.59	3.17	4.76	4.76
Gathering and Boosting	63.33	134.79	196.99	-
Natural Gas Processing	6.43	12.80	18.83	-
Natural Gas Transmission Compression	1.69	3.39	5.06	-
Natural Gas Transmission Pipeline	-	-	-	-
Underground Natural Gas Storage	-	-	-	-
LNG Import/Export	-	-	-	-
LNG Storage	-	-	-	-
Total Abatement Potential	**148.48**	**297.15**	**473.06**	**4.76**

Author's Calculations. [a] NG pipeline transmission and storage, LNG import/export and storage are not included in the analysis because emissions from these sources did not exceed the WEC threshold criteria. As a result, no abatement is reported for these segments.

It is important to note several key assumptions and data limitations associated with these estimates.

First, the analysis presented in the RIA and the resulting mitigation potentials reflect the baseline projections of emissions developed specifically for this rule making effort. See section 3 of the RIA for additional description of the baseline projections and what assumptions and caveats are included in the final projection values. As shown in Table C-11 there are no applicable emissions subject to WEC in the transmission pipeline, gas storage and LNG segments.

Additionally, the mitigation potential reported is the quantity of abatement available at mitigation costs ($/tCH4) less than the WEC price ($/tCH4) in a given year. There is significant additional abatement available at prices above the WEC, but we assume that facilities where the cost of implementing mitigation technologies is more expensive that the WEC fee, these facilities would choose to pay the fee as it would be the more economical option.

Finally, the abatement potential reported in Table C-11 reflects an exogenous assumption of adoption "phase in", where only one third of the full abatement potential estimated is assumed to be achievable in 2024. This assumption increases to two thirds in 2025 and then increases to full mitigation potential by 2026. These "phase in" constraints are intended to reflect the fact that facilities need time to assess the mitigation options and costs before implementing them. As a result, the amount of mitigation observed in the first two years would be some fraction of the full economical (e.g. Mit Cost ≤ WEC) mitigation potential.

The MAC curve is a composite and the corresponding mitigation options available to the applicable segments of the Oil and Natural Gas Industry subject to the WEC rule. Figure C-2 below shows the aggregate MAC curve for the industry, which shows cost-effective mitigation potential of ~445 tCH_4 in 2024. Figure C-3 through Figure C-5 below, show the disaggregated MAC curves by segment (i.e. production, G&B, T&S) illustrating the differences in mitigation potential across the industry segments. The largest share of cost-effective mitigation potential is available in the production segment (Figure C-3), accounting for approximately 252 2 tCH_4 in 2024 or ~52% of the total abatement potential. Gathering and boosting and processing (Figure C-4) offers the next largest potential of cost-effective reductions, approximately 209 tCH_4 accounting for another ~47% of 2024 abatement potential. Finally, Transmission and Storage (Figure C-5) provides the remaining 5 tCH_4 of cost-effective abatement.

Figure C-2 Total MAC Curve for WEC Applicable Segments of the Oil and Gas Industry in 2024

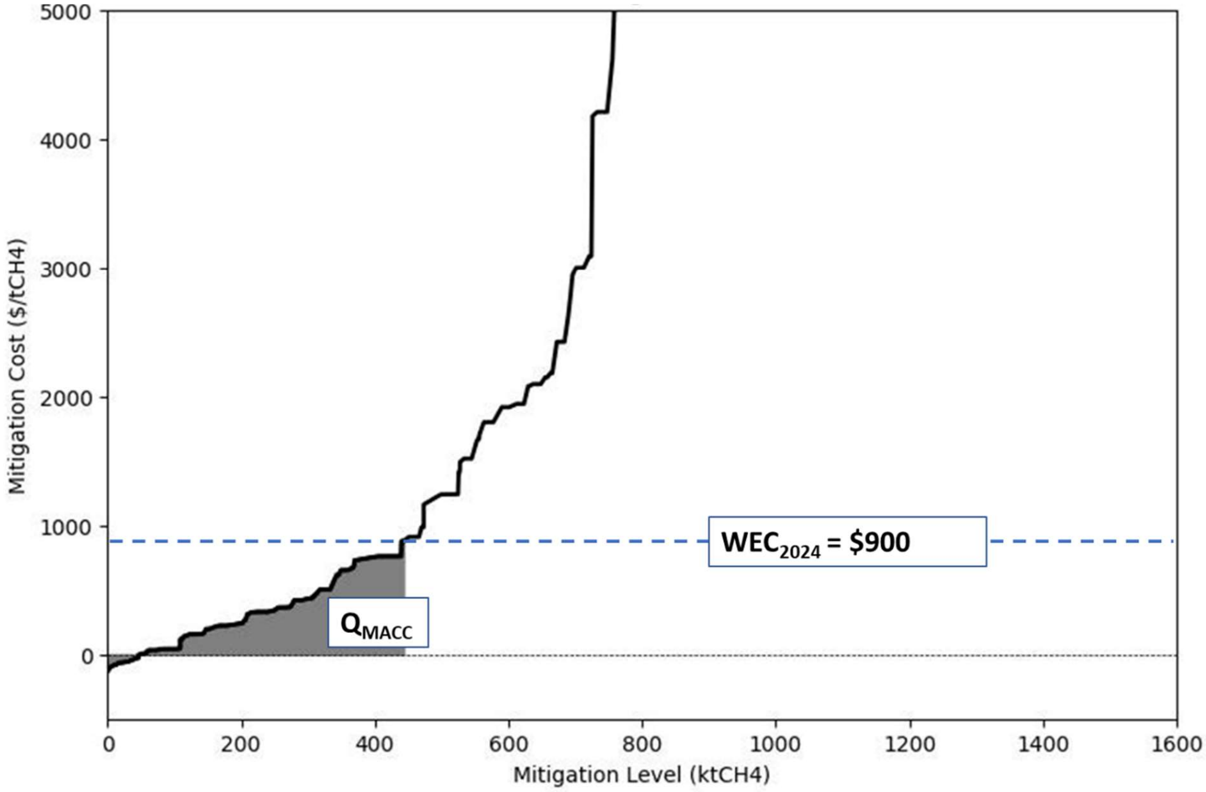

Figure C-3 Production Segment MAC Curve in 2024

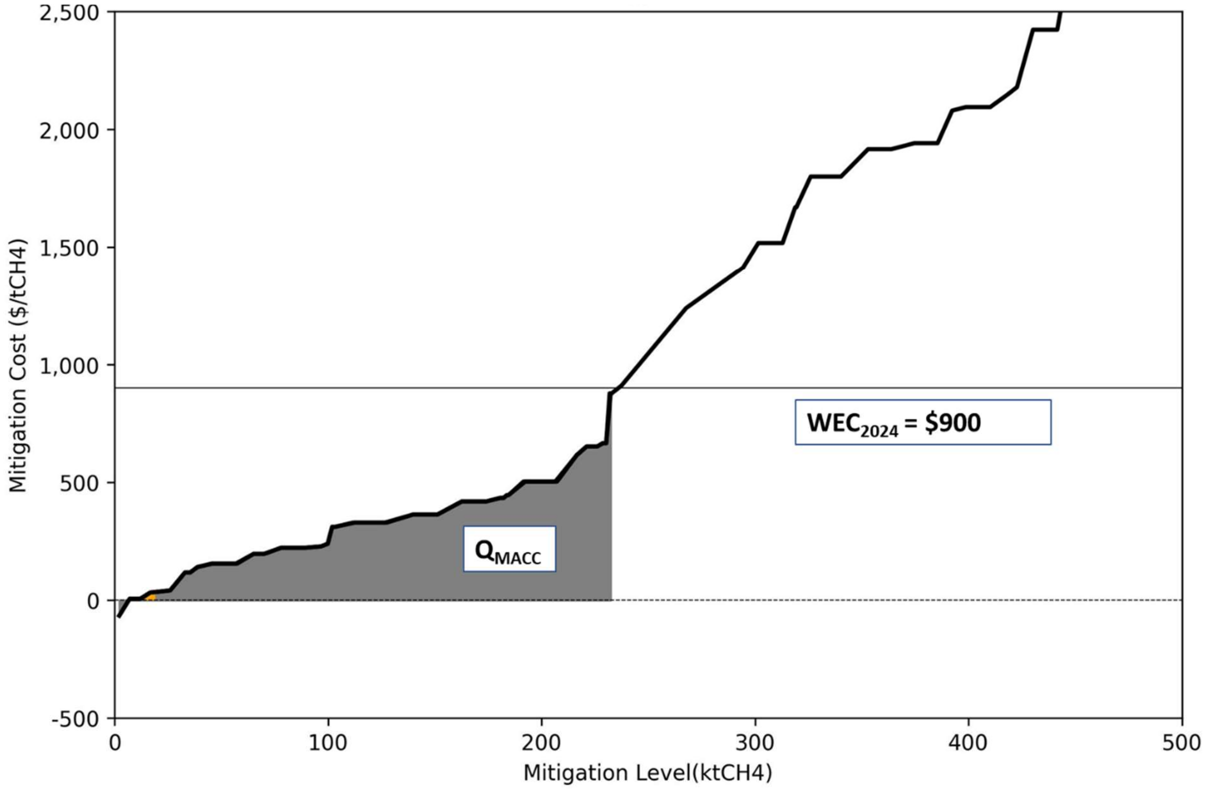

Figure C-4 G&B and Processing Segments MAC Curve in 2024

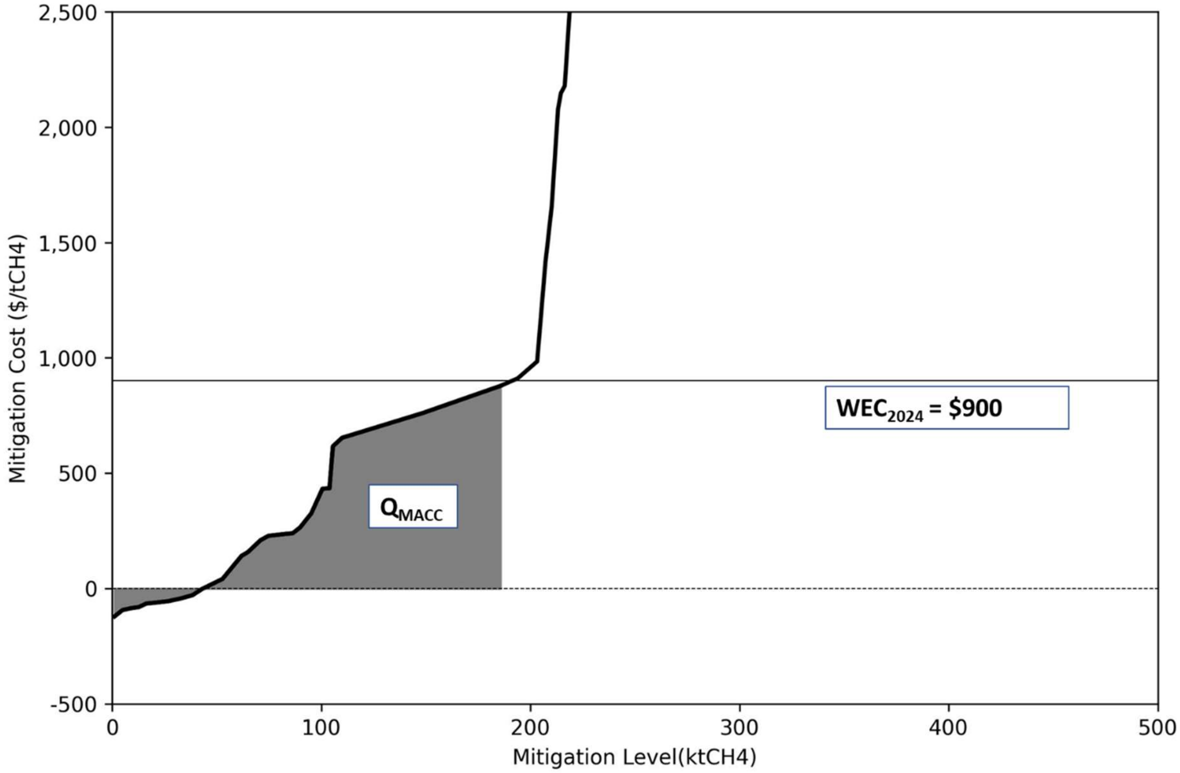

Figure C-5 Transmission and Storage Segment MAC Curve in 2024

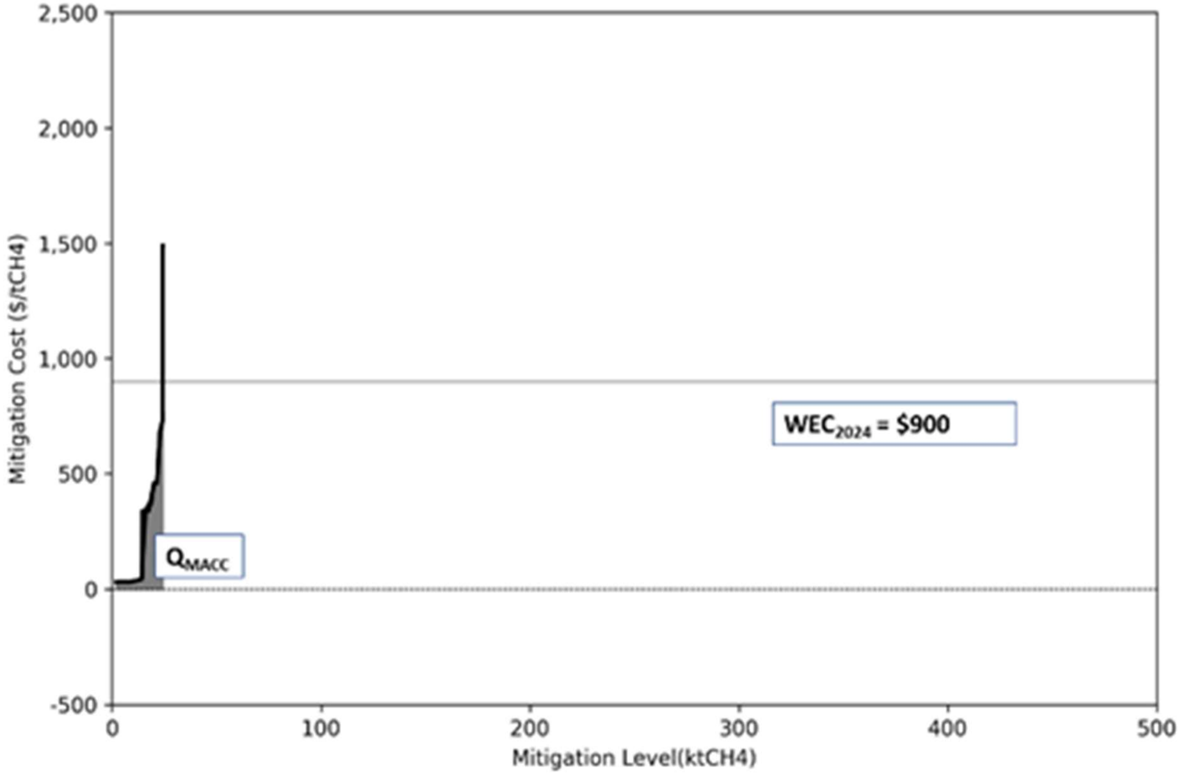

Table C-12 to Table C-14 provide snapshots of the mitigation results in years 2024, 2026 and 2030. In each table we report the full mitigation potential, the cost-effective abatement potential, potential after applying the “phase in” constraint. In addition, each table share the breakdown of cost to achieve the "phase in” abatement potential both with and without the inclusion of offsets of revenue from gas and non-gas savings.

Table C-12 Abatement Potential and Mitigation Costs by Segment and Source, 2024

Industry Segment / Source	Total MACC Technical Abatement Potential (kt)	Cost-Effective Abatement Below WEC (kt)	MACC Abatement Incl. Phase-In (kt)	Total Cost with Revenue (million $)	Total Cost without Revenue (million $)
Onshore Production	**480**	**187**	**62**	**$21.7**	**$30.9**
Pneumatic Controllers	462	175	58	$20.5	$29.2
Fugitive Emissions	0	0	0	$0.0	$0.0
Compressors	9	4	1	$0.2	$0.3
Pneumatic Pumps	0	0	0	$0.0	$0.0
Liquids Unloading	8	8	3	$1.0	$1.4
Offshore Production	**7**	**7**	**2**	**$0.1**	**$0.4**
Fugitive Emissions	0	0	0	$0.0	$0.0
Gathering and Boosting	**113**	**96**	**32**	**$13.6**	**$17.8**
Pneumatic Controllers	67	54	18	$3.7	$5.9
Fugitive Emissions	38	38	13	$9.7	$11.6
Compressors	8	4	1	$0.3	$0.4
Pneumatic Pumps	0	0	0	$0.0	$0.0
Natural Gas Processing	**4**	**4**	**1**	**$0.3**	**$0.4**
Fugitive Emissions	0	0	0	$0.0	$0.0
Compressors	4	4	1	$0.3	$0.4
Transmission and Storage	**28**	**28**	**9**	**$4.1**	**$4.1**
Pneumatic Controllers	0	0	0	$0.0	$0.0
Fugitive Emissions	23	23	8	$3.3	$3.3
Compressors	4	4	1	$0.8	$0.8
Total	**632**	**322**	**107**	**$39.8**	**$53.6**

Table C-13 Abatement Potential and Mitigation Costs by Segment and Source, 2026

Industry Segment / Source	Total MACC Technical Abatement Potential (kt)	Cost-Effective Abatement Below WEC (kt)	MACC Abatement Incl. Phase-In (kt)	Total Cost with Revenue (million $)	Total Cost without Revenue (million $)
Onshore Production	**436**	**176**	**176**	**$61.6**	**$88.9**
Pneumatic Controllers	419	159	159	$53.4	$79.3
Fugitive Emissions	0	0	0	$0.0	$0.0
Compressors	9	9	9	$5.5	$5.7
Pneumatic Pumps	0	0	0	$0.0	$0.0
Liquids Unloading	8	8	8	$2.7	$3.9
Offshore Production	**7**	**7**	**7**	**$0.1**	**$1.2**
Fugitive Emissions	0	0	0	$0.0	$0.0
Gathering and Boosting	**106**	**99**	**99**	**$46.0**	**$59.5**
Pneumatic Controllers	61	54	54	$14.4	$21.5
Fugitive Emissions	37	37	37	$26.8	$32.8
Compressors	8	8	8	$4.9	$5.2
Pneumatic Pumps	0	0	0	$0.0	$0.0
Natural Gas Processing	**4**	**4**	**4**	**$0.7**	**$1.1**
Fugitive Emissions	0	0	0	$0.0	$0.0
Compressors	4	4	4	$0.7	$1.1
Transmission and Storage	**28**	**28**	**28**	**$12.3**	**$12.4**
Pneumatic Controllers	0	0	0	$0.0	$0.0
Fugitive Emissions	24	24	24	$9.9	$9.9
Compressors	4	4	4	$2.4	$2.5
Total	**581**	**314**	**314**	**$120.8**	**$163.1**

Table C-14 Abatement Potential and Mitigation Costs by Segment and Source, 2030

Industry Segment / Source	Total MACC Technical Abatement Potential (kt)	Cost-Effective Abatement Below WEC (kt)	MACC Abatement Incl. Phase-In (kt)	Total Cost with Revenue (million $)	Total Cost without Revenue (million $)
Onshore Production	**0**	**0**	**0**	**$0.0**	**$0.0**
Pneumatic Controllers	0	0	0	$0.0	$0.0
Fugitive Emissions	0	0	0	$0.0	$0.0
Compressors	0	0	0	$0.0	$0.0
Pneumatic Pumps	0	0	0	$0.0	$0.0
Liquids Unloading	0	0	0	$0.0	$0.0
Offshore Production	**7**	**7**	**7**	**$0.1**	**$1.2**
Fugitive Emissions	0	0	0	$0.0	$0.0
Gathering and Boosting	**0**	**0**	**0**	**$0.0**	**$0.0**
Pneumatic Controllers	0	0	0	$0.0	$0.0
Fugitive Emissions	0	0	0	$0.0	$0.0
Compressors	0	0	0	$0.0	$0.0
Pneumatic Pumps	0	0	0	$0.0	$0.0
Natural Gas Processing	**0**	**0**	**0**	**$0.0**	**$0.0**
Fugitive Emissions	0	0	0	$0.0	$0.0
Compressors	0	0	0	$0.0	$0.0
Transmission and Storage	**24**	**24**	**24**	**$9.9**	**$9.9**
Pneumatic Controllers	0	0	0	$0.0	$0.0
Fugitive Emissions	24	24	24	$9.9	$9.9
Compressors	0	0	0	$0.0	$0.0
Total	**30**	**30**	**30**	**$10.0**	**$11.1**

C.8 References

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