Regulatory Impact Analysis for the Proposed National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units Review of the Residual Risk and Technology Review

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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EXECUTIVE SUMMARY

ES.1 Introduction

On January 20, 2021, President Biden signed E.O. 13990, "Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis" (86 FR 7037; January 25, 2021). The executive order instructs EPA, inter alia, to review the 2020 final action titled, "National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units–Reconsideration of Supplemental Finding and Residual Risk and Technology Review" (85 FR 31286; May 22, 2020) (2020 Final Action) and to consider publishing a notice of proposed rulemaking suspending, revising, or rescinding that action. The 2020 Final Action included a finding that it is not appropriate and necessary to regulate coal and oil-fired electric utility steam generating units (EGUs) under Clean Air Act (CAA) section 112 as well as the RTR for the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Coal- and Oil-Fired EGUs, commonly referred to, including within this document, as the Mercury and Air Toxics Standards (MATS). The results of EPA's review of the appropriate and necessary finding were proposed on February 9, 2022 (87 FR 7624) and finalized on March 6, 2023 (88 FR 13956). This RIA presents the expected economic consequences of EPA's proposed MATS Risk and Technology Review.

In accordance with E.O. 12866 and 13563, the guidelines of OMB Circular A-4 and EPA's *Guidelines for Preparing Economic Analyses* (U.S. EPA, 2014), the RIA analyzes the benefits and costs associated with the projected emissions reductions under the proposed requirements, a less stringent set of requirements, and a more stringent set of requirements to inform the EPA and the public about these projected impacts. The benefits and costs of the proposed rule and regulatory alternatives are presented for the 2028 to 2037 time period.

This proposed rule is projected to reduce emissions of mercury and non-mercury metal HAP at a national level. Mercury emitted from U.S. EGUs can deposit to watersheds and associated waterbodies where it can accumulate as methylmercury in fish. Methylmercury is known to adversely impact neurological function and development and to exert some genotoxic activity and EPA has classified methylmercury as a "possible" human carcinogen. Reductions in methylmercury fish burden and human exposure reduces the potential for these adverse effects.

In addition, U.S. EGUs are a major source of non-mercury metallic HAP emissions The proposed controls are expected to reduce human exposure to non-mercury metallic HAP.

ES.2 Regulatory Requirements

For coal-fired EGUs, the MATS rule established standards to limit emissions of mercury, acid gas HAP, non-mercury HAP metals (e.g., nickel, lead, chromium), and organic HAP (e.g., formaldehyde, dioxin/furan). 77 FR 9310. Standards for hydrochloric acid (HCl) serve as a surrogate for the acid gas HAP, with an alternate standard for sulfur dioxide (SO_2) that may be used as a surrogate for acid gas HAP for those coal-fired EGUs with flue gas desulfurization (FGD) systems and SO_2 continuous emission monitoring systems (CEMS) installed and operational. Standards for filterable particulate matter serve as a surrogate for the non-mercury HAP metals, with standards for total non-mercury HAP metals and individual non-mercury HAP metals provided as alternative equivalent standards. Work practice standards limit formation and emission of the organic HAP.

For oil-fired EGUs, the rule established standards to limit emissions of HCl and hydrogen fluoride (HF), total HAP metals (e.g., mercury, nickel, lead), and organic HAP (e.g., formaldehyde, dioxin/furan). Standards for PM serve as a surrogate for total HAP metals, with standards for total HAP metals and individual HAP metals provided as alternative equivalent standards. Work practice standards limit formation and emission of the organic HAP.

While more detail can be found in the preamble of the proposed rule and in Section 1.3.1 of this document, this RIA focuses on evaluating the benefits, costs, and other impacts of four proposed amendments to the MATS rule, as follows:

- **Tightening the Standard for Non-Mercury Metal HAP Emissions for Existing Coal-fired EGUs:** Existing coal-fired EGUs are subject to numeric emission limits for filterable PM, a surrogate for the total non-mercury HAP metals.[1] MATS currently requires existing coal-fired EGUs to meet a filterable particulate matter emission standard

[1] As described in section III of the preamble to this proposed rule, EGUs in six subcategories are subject to numeric emission limits for specific HAP or fPM, a surrogate for the total non-mercury HAP metals. The fPM was chosen as a surrogate in the original rulemaking because the non-mercury HAP metals are predominantly a component of PM, and control of PM will also result in co-reduction of non-mercury HAP metals. Additionally, not all fuels emit the same type and amount of metallic HAP, but most generally emit PM that include some amount and combination of all the metallic HAP. Lastly, the use of fPM as a surrogate eliminates the cost of performance testing to comply with numerous standards for individual non-mercury metal HAP (Docket ID No. EPA-HQ-OAR-2009-0234). For these reasons, the EPA focused its review on the fPM emissions of coal-fired EGUs as a surrogate for the non-mercury metal HAP.

of 0.030 pounds per million British thermal units (lb/MMBtu) of heat input. After reviewing updated information on the current emission levels of filterable PM from existing coal-fired EGUs and the costs of meeting a standard more stringent than 0.030 lb/MMBtu, EPA is proposing to revise the filterable PM emission standard for existing coal-fired EGUs to 0.010 lb/MMBtu. EPA also solicits comment on requiring existing coal-fired EGUs to meet a filterable PM standard of 0.006 lb/MMBtu.

- **Mercury Emission Standard for Lignite-fired EGUs:** EPA is also proposing to revise the mercury emission standard for existing lignite-fired EGUs. Currently, lignite-fired EGUs must meet a mercury emission standard of 4.0 pounds per trillion British thermal units (lb/TBtu) or 4.0E-2 pounds per gigawatt hour (lb/GWh). EPA is proposing that lignite-fired EGUs meet the same standard as existing EGUs firing other types of coal, 1.2 lb/TBtu or 1.3E-2 lb/GWh.
- **Continuous Emissions Monitoring Systems:** After considering updated information on the costs for performance testing compared to the cost of PM CEMS and capabilities of PM CEMS measurement abilities, as well as the benefits of using PM CEMS, which include increased transparency and accelerated identification of anomalous emissions, EPA is proposing to require that all coal-fired EGUs demonstrate compliance with the PM emission standard by using PM CEMS. Currently EGUs have a choice of demonstrating compliance with the non-mercury HAP metals by monitoring filterable PM with quarterly sampling or PM CEMS.
- **Startup Definitions:** EPA is proposing to remove one of the two options for defining the startup period for EGUs. The first option defines startup as either the first-ever firing of fuel in a boiler for the purpose of producing electricity, or the firing of fuel in a boiler after a shutdown event for any purpose. In the second option, startup is defined as the period in which operation of an EGU is initiated for any purpose. EPA is proposing to remove the second option, which is currently being used by fewer than 10 EGUs.

Table ES-1 summarizes how we have structured the regulatory options to be analyzed in this RIA. The proposed regulatory option includes the proposed amendments just discussed in this section: the proposed revision to the filterable PM standard to 0.010 lb/MMBtu, in which PM is a surrogate for non-mercury metal HAP, the proposed revision to the mercury standard for lignite-fired EGUs to 1.2 lb/TBtu, the proposal to require PM CEMS to demonstrate compliance, and the removal of the startup definition number two. The more stringent regulatory option examined in this RIA tightens the proposed revision to the filterable PM standard to 0.006 lb/MMBtu. Note EPA is soliciting comment on this more stringent filterable PM standard. The other three proposed amendments are not changed in the more stringent regulatory option examined in this RIA. Finally, the less stringent regulatory option examined in this RIA assumed the filterable PM and mercury limits remain unchanged and examines just the proposed PM CEMS requirement and removal of startup definition number two.

Table ES-1 Summary of Proposed Regulatory Options Examined in this RIA

	Regulatory Options Examined in this RIA		
Provision	**Less Stringent**	**Proposed**	**More Stringent**
Filterable PM Standard (Surrogate Standard for Non-Hg metal HAP)	Retain existing filterable PM standard of 0.030 lb/MMBtu	Revised filterable PM standard of 0.010 lb/MMBtu	Revised filterable PM standard of 0.006 lb/MMBtu
Mercury Standard	Retain mercury standard for lignite-fired EGUs of 4.0 lb/TBtu	Revised mercury standard for lignite-fired EGUs of 1.2 lb/TBtu	Revised mercury standard for lignite-fired EGUs of 1.2 lb/TBtu
Continuous Emissions Monitoring Systems (PM CEMS)	Require installation of PM CEMS to demonstrate compliance	Require installation of PM CEMS to demonstrate compliance	Require installation of PM CEMS to demonstrate compliance
Startup definition	Remove startup definition #2	Remove startup definition #2	Remove startup definition #2

ES.3 Baseline and Analysis Years

The impacts of proposed regulatory actions are evaluated relative to a modeled baseline that represents expected behavior in the electricity sector under market and regulatory conditions in the absence of a regulatory action. EPA frequently updates the power sector modeling baseline to reflect the latest available electricity demand forecasts from the U.S. Energy Information Administration (EIA) as well as expected costs and availability of new and existing generating resources, fuels, emission control technologies, and regulatory requirements. The baseline includes the proposed Good Neighbor Plan (GNP), the Revised Cross-State Air Pollution Rule (CSAPR) Update, CSAPR Update, and CSAPR, as well as the Mercury and Air Toxics Standards. The power sector baseline also includes the 2015 Effluent Limitation Guidelines (ELG) and the 2015 Coal Combustion Residuals (CCR), and the recently finalized 2020 ELG and CCR rules. This version of the model ("EPA's Post-IRA 2022 Reference Case") also includes recent updates to state and federal legislation affecting the power sector, including Public Law 117-169, 136 Stat. 1818 (August 16, 2022), commonly known as the Inflation Reduction Act of 2022 (IRA). The modeling documentation includes a summary of all legislation reflected in this version of the model as well as a description of how that legislation is implemented in the model.[2] Also, see Section 3.3 for additional detail about the power sector baseline for this RIA.

All analysis begins in the year 2028, the compliance year for the proposed standards. In addition, the regulatory impacts are evaluated for the specific analysis years of 2030 and 2035. These results are used to estimate the present value (PV) and equivalent annualized value (EAV) of the 2028 through 2037 period, discounted to 2023.

ES.4 Emissions Impacts

The emissions reductions presented in this RIA are from years 2028, 2030, and 2035 and are based on IPM projections. Table ES-2 presents the estimated impact on power sector emissions resulting from compliance with the evaluated regulatory control alternatives in the contiguous U.S. As the incremental cost of requiring PM CEMS is negative and small relative to other aspects of this proposed rulemaking, the less stringent regulatory alternative was not modeled using IPM. The projections indicate that both the proposed rule and the more stringent alternative result in emissions reductions in all run years, and those emission reductions follow an expected pattern: the proposed rule, which revises the filterable PM standard to 0.010 lb/MMBtu, produces smaller emissions reductions than the more stringent alternative, which evaluates a lower filterable PM standard to limit of 0.006 lb/MMBtu. The additional reductions of mercury emissions in the more stringent alternative are largely attributable to the additional projected coal steam retirements in this scenario.

[2] See document titled "Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model Post-IRA 2022 Reference Case", which is available in the docket for this action.

Table ES-2 Projected EGU Emissions and Emissions Changes for the Baseline and the Regulatory Control Alternatives for 2028, 2030, and 2035 [a]

		Total Emissions			Change from Baseline	
	Year	**Baseline Run**	**Proposed Rule**	**More-Stringent Alternative**	**Proposed Rule**	**More-Stringent Alternative**
Mercury (lbs.)	2028	5,019	4,957	4,811	-62	-208
	2030	4,206	4,139	4,037	-67	-169
	2035	3,219	3,137	3,052	-82	-168
$PM_{2.5}$ (thousand tons)	2028	74.6	74.2	72	-0.4	-2.6
	2030	65.5	65.1	64	-0.4	-1.5
	2035	46.6	45.8	45.3	-0.8	-1.3
SO_2 (thousand tons)	2028	394	393	382	-0.9	-11.6
	2030	282	282	282	-0.5	-0.3
	2035	130	128	121	-1.5	-8.8
Ozone-season NO_X (thousand tons)	2028	195	195	188	-0.2	-7.2
	2030	163	163	158	-0.4	-5.1
	2035	104	101	99	-3.2	-5.6
Annual NO_X (thousand tons)	2028	457	456	439	-0.4	-18.1
	2030	368	367	358	-0.8	-9.5
	2035	214	211	205	-3.4	-8.7
HCl (thousand tons)	2028	2.6	2.6	2.5	0.0	-0.2
	2030	1.8	1.8	1.7	0.0	-0.1
	2035	0.9	0.9	0.8	0.0	-0.1
CO_2 (million metric tons)	2028	1222	1222	1200	-0.2	-21.9
	2030	972	971	963	-0.8	-8.7
	2035	608	604	605	-4.6	-2.9

[a] This analysis is limited to the geographically contiguous lower 48 states.

ES.5 Compliance Costs

The baseline includes approximately 7 GW of operational EGU capacity designed to burn low rank virgin coal (i.e. lignite) in 2028. All of this capacity is currently equipped with Activated Carbon Injection (ACI) technology, which is designed to reduce mercury emissions, and operation of this technology for compliance with existing mercury emissions limits (e.g., MATS and other enforceable state regulations) is reflected in the baseline. In the proposed and more stringent modeling scenarios, each of these EGUs projected to consume lignite is assigned an additional variable operating cost that is consistent with improvements in sorbent that EPA assumes is necessary to achieve the lower proposed limit. In the proposed option, this additional cost does not result in incremental retirements for these units, nor does it result in a significant change to the projected generation level for these units.

In 2028, the baseline projection also includes 4.8 GW of operational coal capacity that, based on the analysis documented in the EPA memorandum titled: “2023 Technology Review for the Coal- and Oil-Fired EGU Source Category” EPA assumes would either need to improve existing PM controls or install new PM controls to comply with the proposed option. The vast majority of that 4.8 GW is currently operating existing electrostatic precipitators (ESPs) and/or fabric filters, and nearly all of that capacity is projected to install control upgrades and remain operational in 2028. About 500 MW of that coal steam capacity is projected to retire in response to the proposed rule. Under the more stringent alternative, EPA assumes that 22.7 GW of capacity that is projected to be operational in the baseline in 2028 would need to take some compliance action in order to meet the proposed standards. About half of that capacity (11.3 GW) is projected to remain operational with the installation of PM control upgrades in 2028.

Table ES-3 below summarizes the PV and EAV of the total national compliance cost estimates for EGUs for the proposed rule and the less and more stringent alternatives. We present the PV of the costs over the 10-year period of 2028 to 2037. We also present the EAV, which represents a flow of constant annual values that, had they occurred annually, would yield a sum equivalent to the PV. The EAV represents the value of a typical cost for each year of the analysis. These compliance cost estimates are used as a proxy for the social cost of the rule. Section 4 reports how annual power costs are projected to change over the time period of analysis.

Table ES-3 Total National Compliance Cost Estimates for the Proposed Rule and the Less and More Stringent Alternatives (millions of 2019 dollars, discounted to 2023)

	3% Discount Rate		7% Discount Rate	
Regulatory Option	**PV**	**EAV**	**PV**	**EAV**
Proposed	330	38	230	33
Less Stringent	-45	-5.2	-31	-4.5
More Stringent	4,600	540	3,400	490

Note: Values have been rounded to two significant figures.

ES.6 Benefits

ES.6.1Health Benefits

ES.6.1.1 Hazardous Air Pollutants

This proposed rule is projected to reduce emissions of mercury and non-mercury metal HAP at a national level. Mercury emitted from U.S. EGUs can deposit to watersheds and associated waterbodies where it can accumulate as methylmercury in fish. Methylmercury is formed by microbial action in the top layers of sediment and soils, after mercury has precipitated from the air and deposited into waterbodies or land. Once formed, methylmercury is taken up by aquatic organisms and bioaccumulates up the aquatic food web. Methylmercury in fish, originating from U.S. EGUs, is consumed both as self-caught fish by subsistence fishers and as commercial fish by the general population. Exposure to methylmercury is known to have adverse impacts on neurodevelopment and the cardiovascular system. Methylmercury is known to exert some genotoxic activity and EPA has classified methylmercury as a "possible" human carcinogen. While the screening analysis that EPA completed suggests that exposures associated with mercury emitted from EGUs, including lignite-fired EGUs, are below levels of concern from a public health standpoint, further reductions in these emissions should further decrease fish burden and exposure through fish consumption including exposures to subsistence fishers.

In addition, U.S. EGUs are a major source of metallic HAP emissions including selenium (Se), arsenic (As), chromium (Cr), nickel (Ni), and cobalt (Co), cadmium (Cd), beryllium (Be), lead (Pb), and manganese (Mn). Some metal HAP emitted by U.S. EGUs are known to be persistent and bioaccumulative and others have the potential to cause cancer. Exposure to these metal HAP, depending on exposure duration and levels of exposures, is associated with a variety of adverse health effects. The proposed controls are expected to reduce human exposure to non-mercury metallic HAP, including carcinogens.

The projected reductions in mercury under this proposed rule are expected to reduce the bioconcentration of methylmercury in fish. In 2020, EPA examined risk to subsistence fishers from methylmercury exposure at a lake near three U.S. EGU lignite-fired facilities. The results of this site-specific analysis suggest that exposure to methylmercury from lignite-fired facilities falls below the current health benchmark for adverse effects (U.S. EPA, 2020). However, while exposure to methylmercury from lignite-fired facilities may be below the health benchmark, these emissions reductions will result in further reductions in the exposure of subsistence fishers to methylmercury. Further, the projected reductions in non-mercury metal HAP from the use of PM controls should help EPA reduce exposure of individuals residing near these facilities to carcinogenic HAP.

ES.6.1.2 Criteria Pollutants

This rule is expected to reduce emissions of direct $PM_{2.5}$, NO_X and SO_2 throughout the year. Because NO_X and SO_2 are also precursors to secondary formation of ambient $PM_{2.5}$, reducing these emissions would reduce human exposure to ambient $PM_{2.5}$ throughout the year and would reduce the incidence of $PM_{2.5}$-attributable health effects.

This proposed rule is expected to reduce ozone season NO_X emissions. In the presence of sunlight, NO_X and volatile organic compounds (VOCs) can undergo a chemical reaction in the atmosphere to form ozone. Reducing NO_X emissions generally reduces human exposure to ozone and the incidence of ozone-related health effects, though the degree to which ozone is reduced will depend in part on local concentration levels of VOCs.

In this RIA, EPA reports estimates of the health benefits of changes in $PM_{2.5}$ and ozone concentrations. The health effect endpoints, effect estimates, benefit unit-values, and how they were selected, are described in the Technical Support Document (TSD) titled *Estimating $PM_{2.5}$- and Ozone-Attributable Health Benefits* (U.S. EPA, 2023). This document, hereafter referred to as the "Health Benefits TSD," can be found in the docket for this rulemaking. Our approach for updating the endpoints and to identify suitable epidemiologic studies, baseline incidence rates, population demographics, and valuation estimates is summarized in Section 4.3.

ES.6.2 Climate Benefits

Elevated concentrations of GHGs in the atmosphere have been warming the planet, leading to changes in the Earth's climate including changes in the frequency and intensity of heat waves, precipitation, and extreme weather events, rising seas, and retreating snow and ice. The well-documented atmospheric changes due to anthropogenic GHG emissions are changing the climate at a pace and in a way that threatens human health, society, and the natural environment. Climate change touches nearly every aspect of public welfare in the U.S. with resulting economic costs, including: changes in water supply and quality due to changes in drought and extreme rainfall events; increased risk of storm surge and flooding in coastal areas and land loss due to inundation; increases in peak electricity demand and risks to electricity infrastructure; and the potential for significant agricultural disruptions and crop failures (though offset to some extent by carbon fertilization).

There will be important climate benefits associated with the CO_2 emissions reductions expected from this proposed rule. Climate benefits from reducing emissions of CO_2 can be monetized using estimates of the social cost of carbon (SC-CO_2). See Section 4.4 for more discussion of the approach to monetization of the climate benefits associated with this rule.

ES.6.3 Additional Unquantified Benefits

Data, time, and resource limitations prevented EPA from quantifying the estimated health impacts or monetizing estimated benefits associated with direct exposure to NO_2 and SO_2 (independent of the role NO_2 and SO_2 play as precursors to $PM_{2.5}$ and ozone), as well as ecosystem effects, and visibility impairment due to the absence of air quality modeling data for these pollutants in this analysis. Regarding HAP, data, time, and resource limitations prevent us from quantifying potential benefits associated with ecosystem services. While all health benefits and welfare benefits were not able to be quantified, it does not imply that there are not additional benefits associated with reductions in exposures to HAP, ozone, $PM_{2.5}$, NO_2 or SO_2. For a qualitative description of these and potential water quality benefits, please see Section 4.

ES.6.4 Total Health and Climate Benefits

Table ES-4 presents the total monetized health and climate benefits for the proposed rule and the more and less stringent alternatives. Note the less stringent regulatory alternative has no quantified emissions reductions associated with the proposed requirements for PM CEMS and the removal of startup definition number two. As a result, there are no quantified benefits associated with this regulatory option.

Table ES-4 Monetized Health Benefits and Climate Benefits for the Proposed Rule from 2028 through 2037 (millions of 2019 dollars, discounted to 2023)[a]

	All Benefits Calculated using 3% Discount Rate					
	$PM_{2.5}$ and O_3-related Health Benefits [b]		Climate Benefits [c]		Total Benefits [d,e]	
Regulatory Option	**PV**	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Proposed	1,900	220	1,400	170	3,300	390
Less Stringent	0.0	0.0	0.0	0.0	0.0	0.0
More Stringent	11,000	1,300	3,200	380	14,000	1,700

	Health Benefits Calculated using 7% Discount Rate, Climate Benefits Calculated using 3% Discount Rate					
Regulatory Option	$PM_{2.5}$ and O_3-related Health Benefits [b]		Climate Benefits [c]		Total Benefits [d,e]	
Proposed	1,200	170	1,400	170	2,600	330
Less Stringent	0.0	0.0	0.0	0.0	0.0	0.0
More Stringent	7,100	1,000	3,200	380	10,000	1,400

[a] Values have been rounded to two significant figures. Rows may not appear to add correctly due to rounding.
[b] For simplicity of presentation, the estimated value of the health benefits reported here are the larger of the two benefits estimates presented in Table 7-1, Table 7-2, and Table 7-3. Monetized benefits include those related to public health associated with reductions in $PM_{2.5}$ and ozone concentrations. The health benefits are associated with several point estimates.
[c] Climate benefits in this table are based on estimates of the SC-CO_2 at a 3 percent discount rate.
[d] Several categories of benefits remain unmonetized and are thus not reflected in the table. Nonmonetized benefits include important benefits from reductions in mercury and non-mercury metal HAP.
[e] For discussions of the uncertainty associated with these health benefits estimates, see Section 4.3.8. See Section 4.3.10 for a discussion of the uncertainties associated with the climate benefit estimates.

ES.7 Environmental Justice Impacts

Executive Order 12898 directs the EPA to identify the populations of concern who are most likely to experience unequal burdens from environmental harms; specifically, minority populations, low-income populations, and Indigenous peoples.[3] Additionally, Executive Order 13985 is intended to advance racial equity and support underserved communities through federal government actions.[4] The EPA defines environmental justice (EJ) 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. The EPA further defines the term fair treatment to mean that "no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental, and

[3] 59 FR 7629, February 16, 1994.
[4] 86 FR 7009, January 20, 2021.

commercial operations or programs and policies."[5] In recognizing that minority and low-income populations often bear an unequal burden of environmental harms and risks, the EPA continues to consider ways of protecting them from adverse public health and environmental effects of air pollution.

Environmental justice (EJ) concerns for each rulemaking are unique and should be considered on a case-by-case basis, and EPA's EJ Technical Guidance (2015) states that "[t]he analysis of potential EJ concerns for regulatory actions should address three questions:

1. Are there potential EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern in the baseline?
2. Are there potential EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern for the regulatory option(s) under consideration?
3. For the regulatory option(s) under consideration, are potential EJ concerns created or mitigated compared to the baseline?"

To address these questions, EPA developed an analytical approach that considers the purpose and specifics of the rulemaking, as well as the nature of known and potential disproportionate and adverse exposures and impacts. For the rule, we quantitatively evaluate 1) the proximity of affected facilities to potentially vulnerable and/or overburdened populations for consideration of local pollutants impacted by this rule but not modeled here (Section 6.3) and 2) the distribution of ozone and $PM_{2.5}$ concentrations in the baseline and changes due to the proposed rulemaking across different demographic groups on the basis of race, ethnicity, poverty status, employment status, health insurance status, age, sex, educational attainment, and degree of linguistic isolation (Section 6.5). We also qualitatively discuss potential EJ HAP and climate impacts (Sections 6.3 and 6.6). Each of these analyses depends on mutually exclusive assumptions, was performed to answer separate questions, and is associated with unique limitations and uncertainties.

Baseline demographic proximity analyses provide information as to whether there may be potential EJ concerns associated with environmental stressors, such as noise, traffic, or SO_2 emitted from sources affected by the regulatory action for certain population groups of concern (Section 6.4). The baseline demographic proximity analyses examined the demographics of

[5] https://www.epa.gov/environmentaljustice.

populations living within 10 km of the following sources: lignite plants with units potentially subject to the proposed mercury standard revision, coal plants with units potentially subject to the proposed filterable PM standard revision, and coal plants with units potentially subject to the alternate filterable PM standard revision. The baseline analysis indicates that on average the percentage of the population living within 10 km of coal plants potentially subject to the proposed or alternate filterable PM standards have a higher percentage of people living below two times the poverty level than the national average. In addition, on average the percentage of the Native American population living within 10 km of lignite plants potentially subject to proposed mercury standard is higher than the national average. Relating these results to question 1, above, we conclude that there may be potential EJ concerns associated with directly emitted pollutants that are affected by the regulatory action (e.g., SO_2) for certain population groups of concern in the baseline. However, as proximity to affected facilities does not capture variation in baseline exposure across communities, nor does it indicate that any exposures or impacts will occur, these results should not be interpreted as a direct measure of exposure or impact.

As HAP exposure results generated as part of the 2020 Residual Risk analysis were below both the presumptive acceptable cancer risk threshold and the RfD, and this proposed regulation should further reduce exposure to HAP, there are no 'disproportionate and adverse effects' of potential EJ concern. Therefore, we did not perform a quantitative EJ assessment of HAP risk.

In contrast, ozone and $PM_{2.5}$ emission changes are also expected from this action and exposure analyses that evaluate demographic variables are better able to evaluate any potentially disproportionate pollution impacts of this rulemaking. The baseline ozone and $PM_{2.5}$ exposure analyses respond to question 1 from EPA's EJ Technical Guidance document more directly than the proximity analyses, as they evaluate a form of the environmental stressor primarily affected by the regulatory action (see Section 6.5). Baseline ozone and $PM_{2.5}$ exposure analyses show that certain populations, such as Hispanics, Asians, those linguistically isolated, those less educated, and children may experience disproportionately higher ozone and $PM_{2.5}$ exposures as compared to the national average. American Indians may also experience disproportionately higher ozone concentrations than the reference group. Therefore, there likely are potential EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern in the baseline.

Finally, we evaluate how post-policy regulatory alternatives of this proposed rulemaking are expected to differentially impact demographic populations, informing questions 2 and 3 from EPA's EJ Technical Guidance with regard to ozone and $PM_{2.5}$ exposure changes. Due to the small magnitude of the exposure changes across population demographics associated with the rulemaking relative to the magnitude of the baseline disparities, we infer that disparities in the ozone and $PM_{2.5}$ concentration burdens are likely to remain after implementation of the regulatory action or alternatives under consideration. This is due to the small magnitude of the concentration changes associated with this rulemaking across population demographic groups, relative to the magnitude of the baseline disparities (question 2). Also due to the very small differences observed in the distributional analyses of post-policy ozone and $PM_{2.5}$ exposure impacts across population groups, we do not find evidence that potential EJ concerns related to ozone and $PM_{2.5}$ concentrations will be created or mitigated as compared to the baseline (question 3).

ES.8 Comparison of Benefits and Costs

All benefits analyses, and most cost analyses, begin in the year 2028, the compliance year for the proposed standards. In this RIA, the regulatory impacts are evaluated for the specific years of 2028, 2030, and 2035. Comparisons of benefits to costs for these snapshot years are presented in Section 7.3 of this RIA. Here we present the PV of costs, benefits, and net benefits, calculated for the years 2028 to 2037 from the perspective of 2023, using both a three percent and seven percent end-of-period discount rate as directed by OMB's Circular A-4. All dollars are in 2019 dollars. We also present the EAV, which represents a flow of constant annual values that, had they occurred in each year from 2028 to 2037, would yield a sum equivalent to the PV. The EAV represents the value of a typical cost or benefit for each year of the analysis, in contrast to the year-specific estimates reported in the costs and benefits sections of this RIA. The comparison of benefits and costs in PV and EAV terms for the proposed rule and less and more stringent regulatory options can be found in Table ES-5. Estimates in the tables are presented as rounded values. Note the less stringent regulatory alternative has no quantified emissions reductions associated with the proposed requirements for PM CEMS and the removal of startup definition number two. As a result, there are no quantified benefits associated with this regulatory option.

Table ES-5 Monetized Benefits, Costs, and Net Benefits of the Proposed Rule and Less and More Stringent Alternatives (millions of 2019 dollars, discounted to 2023) [a,b]

	Values Calculated using 3% Discount Rate							
	$PM_{2.5}$ and O_3-related Health Benefits [b]		Climate Benefits [c]		Compliance Costs		Net Benefits [d]	
Regulatory Option	**PV**	**EAV**	**PV**	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Proposed	1,900	220	1,400	170	330	38	3,000	350
Less Stringent	0.0	0.0	0.0	0.0	-45	-5.2	45	5.2
More Stringent	11,000	1,300	3,200	380	4,600	540	9,800	1,100
	Compliance Costs and Health Benefits Calculated using 7% Discount Rate, Climate Benefits Calculated using 3% Discount Rate							
	$PM_{2.5}$ and O_3-related Health Benefits [b]		Climate Benefits [c]		Compliance Costs		Net Benefits [d]	
Regulatory Option	**PV**	**EAV**	**PV**	**EAV**	**PV**	**EAV**	**PV**	**EAV**
Proposed	1,200	170	1,400	170	230	33	2,400	300
Less Stringent	0.0	0.0	0.0	0.0	-31	-4.5	31	4.5
More Stringent	7,100	1,000	3,200	380	3,400	490	6,900	900

[a] Values have been rounded to two significant figures. Rows may not appear to add correctly due to rounding.
[b] The health benefits estimates use the larger of the two benefits estimates presented in Table 7-1, Table 7-2, and Table 7-3. Monetized benefits include those related to public health associated with reductions in $PM_{2.5}$ and ozone concentrations. The health benefits are associated with several point estimates.
[c] Climate benefits are based on reductions in CO_2 emissions and are calculated using four different estimates of the social cost of carbon dioxide (SC-CO_2): model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate. The 95th percentile estimate is included to provide information on potentially higher-than-expected economic impacts from climate change, conditional on the 3 percent estimate of the discount rate. For the presentational purposes of this table, we show the climate benefits associated with the average SC-CO_2 at a 3 percent discount rate, but the Agency does not have a single central SC-CO_2 point estimate. Climate benefits in this table are discounted using a 3 percent discount rate to obtain the PV and EAV estimates in the table. We emphasize the importance and value of considering the benefits calculated using all four SC-CO_2 estimates. Section 4.4 of the RIA presents estimates of the projected climate benefits of this proposal using all four rates. We note that consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, is warranted when discounting intergenerational impacts.
[d] Several categories of benefits remain unmonetized and are thus not directly reflected in the quantified benefit estimates in the table. Non-monetized benefits include benefits from reductions in mercury and non-mercury metal HAP emissions and from the increased transparency and accelerated identification of anomalous emission anticipated from requiring CEMS.

The quantitative estimates of net benefits presented in this section are underestimated because important categories of benefits, including benefits from reducing mercury and non-mercury metal HAP emissions and the increased transparency and accelerated identification of anomalous emission anticipated from requiring PM CEMS, were not monetized and are therefore not directly reflected in the monetized benefit-cost comparisons. We nonetheless consider these potential impacts in our evaluation of the net benefits of the rule in that, if we were able to monetize these impacts, the proposal would have greater net benefits.

ES.9 References

U.S. EPA. (2014). *Guidelines for Preparing Economic Analyses*. (EPA 240-R-10-001). Washington DC: U.S. Environmental Protection Agency, Office of Policy, National Center for Environmental Economics. Available at: *https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analyses*

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U.S. EPA. (2023). *Estimating $PM_{2.5}$- and Ozone-Attributable Health Benefits*. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Health and Environmental Impact Division. Available at: *https://www.regulations.gov/docket/EPA-HQ-OAR-2018-0794*

1 INTRODUCTION AND BACKGROUND

1.1 Introduction

On January 20, 2021, President Biden signed E.O. 13990, "Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis" (86 FR 7037; January 25, 2021). The executive order instructs EPA, among other things, to review the 2020 final action titled, "National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units–Reconsideration of Supplemental Finding and Residual Risk and Technology Review" (85 FR 31286; May 22, 2020) (2020 Final Action) and to consider publishing a notice of proposed rulemaking suspending, revising, or rescinding that action. The 2020 Final Action included a finding that it is not appropriate and necessary to regulate coal and oil-fired EGUs under CAA section 112 as well as the RTR for the MATS rule. The results of EPA's review of the appropriate and necessary finding were proposed on February 9, 2022 (87 FR 7624) and finalized on March 6, 2023 (88 FR 13956). This action presents the proposed results of EPA's review of the MATS RTR, as directed by E.O. 13990.

Several statutes and executive orders apply to federal rulemakings. In accordance with E.O. 12866 and E.O. 13563 and the guidelines of OMB Circular A-4, the RIA analyzes the benefits and costs associated with the projected emissions reductions under the proposed rule. OMB Circular A-4 requires analysis of one potential regulatory option more stringent and one less stringent than the rule under examination, so this RIA evaluates the benefits, costs, and impacts of a more and a less stringent alternative to the selected alternative in this proposal. The benefits and costs of the proposed rule and regulatory alternatives are presented for the 2028 to 2037 time period. The estimated monetized benefits are those health benefits expected to arise from reduced $PM_{2.5}$ and ozone concentrations and the climate benefits from reductions in GHGs. Several categories of benefits remain unmonetized including important benefits from reductions in mercury and non-mercury metal HAP emissions. The estimated monetized costs for EGUs are the costs of installing and operating controls and the increased costs of producing electricity. Unquantified benefits and costs are described qualitatively. This section contains background information relevant to the rule and an outline of the sections of this RIA.

1.2 Legal and Economic Basis for Rulemaking

In this section, we summarize the statutory requirements in the CAA that serve as the legal basis for the proposed rule and the economic theory that supports environmental regulation as a mechanism to enhance social welfare. The CAA requires EPA to prescribe regulations for new and existing sources. In turn, those regulations attempt to address negative externalities created when private entities fail to internalize the social costs of air pollution.

1.2.1 Statutory Requirement

The statutory authority for this action is provided by sections 112 and 301 of the CAA, as amended (42 U.S.C. 7401 et seq.). Section 112 of the CAA establishes a two-stage regulatory process to develop standards for emissions of HAP from stationary sources. Generally, the first stage involves establishing technology-based standards and the second stage involves evaluating those standards that are based on maximum achievable control technology (MACT) to determine whether additional standards are needed to address any remaining risk associated with HAP emissions. This second stage is commonly referred to as the "residual risk review." In addition to the residual risk review, the CAA also requires EPA to review standards set under CAA section 112 no less than every eight years and revise the standards as necessary taking into account any "developments in practices, processes, or control technologies." This review is commonly referred to as the "technology review," and is the subject of this proposal.

1.2.2 Regulated Pollutants

For coal-fired EGUs, the 2012 MATS rule established standards to limit emissions of mercury, acid gas HAP, non-mercury HAP metals (e.g., nickel, lead, chromium), and organic HAP (e.g., formaldehyde, dioxin/furan). Standards for hydrochloric acid (HCl) serve as a surrogate for the acid gas HAP, with an alternate standard for sulfur dioxide (SO_2) that may be used as a surrogate for acid gas HAP for those coal-fired EGUs with flue gas desulfurization (FGD) systems and SO_2 CEMS installed and operational. Standards for filterable particulate matter serve as a surrogate for the non-mercury HAP metals, with standards for total non-mercury HAP metals and individual non-mercury HAP metals provided as alternative equivalent standards. Work practice standards limit formation and emission of the organic HAP.

For oil-fired EGUs, the 2012 MATS rule establishes standards to limit emissions of HCl and hydrogen fluoride (HF), total HAP metals (e.g., mercury, nickel, lead), and organic HAP (e.g., formaldehyde, dioxin/furan). Standards for filterable PM serve as a surrogate for total HAP metals, with standards for total HAP metals and individual HAP metals provided as alternative equivalent standards. Work practice standards limit formation and emission of the organic HAP.

1.2.2.1 Definition of Affected Source

The source category that is the subject of this proposal is Coal- and Oil-Fired EGUs regulated under 40 CFR 63, subpart UUUUU. The North American Industry Classification System (NAICS) codes for the Coal- and Oil-fired EGU industry are 221112, 221122, and 921150. This list of categories and NAICS codes is not intended to be exhaustive, but rather provides a guide for readers regarding the entities that this proposed action is likely to affect. The proposed standards, once promulgated, will be directly applicable to the affected sources. Federal, state, local, and tribal government entities that own and/or operate EGUs subject to 40 CFR part 63, subpart UUUUU would be affected by this proposed action. The Coal- and Oil-Fired EGU source category was added to the list of categories of major and area sources of HAP published under section 112(c) of the CAA on December 20, 2000 (65 FR 79825). CAA section 112(a)(8) defines an EGU as: any fossil fuel fired combustion unit of more than 25 megawatts that serves a generator that produces electricity for sale. A unit that cogenerates steam and electricity and supplies more than one-third of its potential electric output capacity and more than 25 megawatts electrical output to any utility power distribution system for sale is also considered an EGU.

1.2.3 The Need for Air Emissions Regulation

OMB Circular A-4 indicates that one of the reasons a regulation may be issued is to address a market failure. The major types of market failure include externalities, market power, and inadequate or asymmetric information. Correcting market failures is one reason for regulation; it is not the only reason. Other possible justifications include improving the function of government, correcting distributional unfairness, or securing privacy or personal freedom.

Environmental problems are classic examples of externalities – uncompensated benefits or costs imposed on another party as a result of one’s actions. For example, the smoke from a factory may adversely affect the health of local residents and soil the property in nearby neighborhoods. For the proposed regulatory action analyzed in this RIA, the good produced is electricity from coal- and oil-fired EGUs. If these electricity producers pollute the atmosphere when generating power, the social costs will not be borne exclusively by the polluting firm but rather by society as a whole. Thus, the producer is imposing a negative externality, or a social cost of emissions, on society. The equilibrium market price of electricity may fail to incorporate the full opportunity cost to society of these products. Consequently, absent a regulation on emissions, producers will not internalize the social cost of emissions and social costs will be higher as a result. The proposed regulation will work towards addressing this market failure by causing affected producers to begin internalizing the negative externality associated with HAP emissions from electricity generation by coal- and oil-fired EGUs.

1.3 Overview of Regulatory Impact Analysis

1.3.1 Regulatory Options

This RIA focuses on four proposed amendments to the MATS rule, which are described in more detail in this section. We vary these four proposed requirements in order to craft a set of three regulatory options to be analyzed in this RIA.

1.3.1.1 Filterable Particulate Matter Standards for Existing Coal-fired EGUs

Existing coal-fired EGUs are subject to numeric emission limits for filterable PM, a surrogate for the total non-mercury HAP metals.[6] MATS currently requires existing coal-fired EGUs to meet a filterable particulate matter emission standard of 0.030 pounds per million British thermal units (lb/MMBtu) of heat input. The standards for filterable PM serve as a surrogate for standards for non-mercury HAP metals. After reviewing updated information on the current emission levels of filterable PM from existing coal-fired EGUs and the costs of

[6] As described in section III of the preamble to this proposed rule, EGUs in six subcategories are subject to numeric emission limits for specific HAP or fPM, a surrogate for the total non-mercury HAP metals. The fPM was chosen as a surrogate in the original rulemaking because the non-mercury HAP metals are predominantly a component of PM, and control of PM will also result in co-reduction of non-mercury HAP metals. Additionally, not all fuels emit the same type and amount of metallic HAP, but most generally emit PM that include some amount and combination of all the metallic HAP. Lastly, the use of fPM as a surrogate eliminates the cost of performance testing to comply with numerous standards for individual non-mercury metal HAP (Docket ID No. EPA-HQ-OAR-2009-0234). For these reasons, the EPA focused its review on the fPM emissions of coal-fired EGUs as a surrogate for the non-mercury metal HAP.

meeting a standard more stringent than 0.030 lb/MMBtu, EPA is proposing to revise the filterable PM emission standard for existing coal-fired EGUs to 0.010 lb/MMBtu. EPA also solicits comment on requiring existing coal-fired EGUs to meet a filterable PM standard of 0.006 lb/MMBtu.

1.3.1.2 Mercury Emission Standard for Lignite-fired EGUs

EPA is also proposing to revise the mercury emission standard for lignite-fired EGUs. Currently, lignite-fired EGUs must meet a mercury emission standard of 4.0 pounds per trillion British thermal units (lb/TBtu) or 4.0E-2 pounds per gigawatt hour (lb/GWh). EPA recently collected information on current emission levels and mercury emission controls for lignite-fired EGUs using the authority provided under CAA section 114.[7] That information showed that many units are able to achieve a mercury emission rate that is much lower than the current standard, and there are cost-effective control technologies and methods of operation that are available to achieve a more stringent standard. EPA is proposing that lignite-fired EGUs meet the same standard as EGUs firing other types of coal, 1.2 lb/TBtu or 1.3E-2 lb/GWh.

1.3.1.3 Require that all coal-fired EGUs demonstrate compliance with the filterable PM emission standard by using PM CEMS.

In addition to revising the PM emission standard for existing coal-fired EGUs, EPA is proposing a revision to the requirements for demonstrating compliance with the PM emission standard for coal-fired EGUs. Currently, EGUs that are not part of the low emitting EGU (LEE) program can demonstrate compliance with the filterable PM standard either by conducting performance testing quarterly or through the use of PM CEMS. After considering updated information on the costs for performance testing compared to the cost of PM CEMS and capabilities of PM CEMS measurement abilities, as well as the benefits of using PM CEMS, which include increased transparency and accelerated identification of anomalous emissions, EPA is proposing to require that all coal-fired EGUs demonstrate compliance with the PM emission standard by using PM CEMS.

[7] For further information, see EPA memorandum titled: “2023 Technology Review for the Coal- and Oil-Fired EGU Source Category” which is available in the docket

1.3.1.4 Startup Definitions

Finally, EPA is proposing to remove one of the two options for defining the startup period for EGUs. The first option defines startup as either the first-ever firing of fuel in a boiler for the purpose of producing electricity, or the firing of fuel in a boiler after a shutdown event for any purpose. Startup ends when any of the steam from the boiler is used to generate electricity for sale over the grid or for any other purpose (including on-site use). In the second option, startup is defined as the period in which operation of an EGU is initiated for any purpose. Startup begins with either the firing of any fuel in an EGU for the purpose of producing electricity or useful thermal energy (such as heat or steam) for industrial, commercial, heating, or cooling purposes (other than the first-ever firing of fuel in a boiler following construction of the boiler) or for any other purpose after a shutdown event. Startup ends four hours after the EGU generates electricity that is sold or used for any other purpose (including on-site use), or four hours after the EGU makes useful thermal energy (such as heat or steam) for industrial, commercial, heating, or cooling purposes, whichever is earlier. EPA is proposing to remove the second option, which is currently being used by fewer than 10 EGUs.

1.3.1.5 Summary of Proposed Regulatory Options Examined in this RIA

Table 1- summarizes how we have structured the regulatory options to be analyzed in this RIA. The proposed regulatory option includes the proposed amendments just discussed in this section: the proposed revision to the filterable PM standard to 0.010 lb/MMBtu, in which filterable PM is a surrogate for non-mercury metal HAP, the proposed revision to the mercury standard for lignite-fired EGUs to 1.2 lb/TBtu, the proposal to require PM CEMS to demonstrate compliance, and the removal of the startup definition number two. The more stringent regulatory option examined in this RIA tightens the proposed revision to the filterable PM standard to 0.006 lb/MMBtu. Note EPA is soliciting comment on this more stringent filterable PM standard. The other three proposed amendments are not changed in the more stringent regulatory option examined in this RIA. Finally, the less stringent regulatory option examined in this RIA assumed the PM and mercury limits remain unchanged and examines just the proposed PM CEMS requirement and removal of startup definition number two.

Table 1-1 Summary of Proposed Regulatory Options Examined in this RIA

Provision	Regulatory Options Examined in this RIA		
	Less Stringent	**Proposed**	**More Stringent**
Filterable PM Standard (Surrogate Standard for Non-Hg metal HAP)	Retain existing filterable PM standard of 0.030 lb/MMBtu	Revised filterable PM standard of 0.010 lb/MMBtu	Revised filterable PM standard of 0.006 lb/MMBtu
Mercury Standard	Retain mercury standard for lignite-fired EGUs of 4.0 lb/TBtu	Revised mercury standard for lignite-fired EGUs of 1.2 lb/TBtu	Revised mercury standard for lignite-fired EGUs of 1.2 lb/TBtu
Continuous Emissions Monitoring Systems (PM CEMS)	Require installation of PM CEMS to demonstrate compliance	Require installation of PM CEMS to demonstrate compliance	Require installation of PM CEMS to demonstrate compliance
Startup definition	Remove startup definition #2	Remove startup definition #2	Remove startup definition #2

1.3.2 Baseline and Analysis Years

The impacts of proposed regulatory actions are evaluated relative to a baseline that represents the world without the proposed action. This version of the model ("EPA's Post-IRA 2022 Reference Case") used for the baseline in this RIA includes recent updates to state and federal legislation affecting the power sector, including Public Law 117-169, 136 Stat. 1818 (August 16, 2022), commonly known as the Inflation Reduction Act of 2022 (IRA). The modeling documentation includes a summary of all legislation reflected in this version of the model as well as a description of how that legislation is implemented in the model.[8] Also, see Section 3.3 for additional detail about the power sector baseline for this RIA.

All benefit analysis, and most cost analysis, begins in the year 2028, the compliance year for the proposed standards. In addition, the regulatory impacts are evaluated for the specific analysis years of 2030 and 2035. These results are used to estimate the PV and EAV of the 2028 through 2037 period.

1.4 Organization of the Regulatory Impact Analysis

This RIA is organized into the following remaining sections:

[8] See document titled "Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model Post-IRA 2022 Reference Case", which is available in the docket for this action.

- **Section 2: Power Sector Profile.** This section describes the electric power sector in detail.
- **Section 3: Cost, Emissions, and Energy Impacts.** The section summarizes the projected compliance costs and other energy impacts associated with the regulatory options.
- **Section 4: Benefits Analysis.** The section presents the projected health and environmental benefits of reductions in emissions of HAP, direct $PM_{2.5}$, and $PM_{2.5}$ and ozone precursors and the climate benefits of CO_2 emissions reductions across regulatory options. Potential benefits to drinking water quality and quantity are also discussed.
- **Section 5: Economic Impacts.** The section includes a discussion of potential small entity, economic, and labor impacts.
- **Section 6: Environmental Justice Impacts.** This section includes an assessment of potential impacts to potential EJ populations.
- **Section 7: Comparison of Benefits and Costs.** The section compares of the total projected benefits with total projected costs and summarizes the projected net benefits of the three regulatory options examined. The section also includes a discussion of potential benefits that EPA is unable to quantify and monetize.

2 INDUSTRY PROFILE

2.1 Background

In the past decade there have been significant structural changes in both the mix of generating capacity and in the share of electricity generation supplied by different types of generation. These changes are the result of multiple factors in the power sector, including normal replacements of older generating units with new units, changes in the electricity intensity of the U.S. economy, growth and regional changes in the U.S. population, technological improvements in electricity generation from both existing and new units, changes in the prices and availability of different fuels, and substantial growth in electricity generation by renewable and unconventional methods. Many of these trends will continue to contribute to the evolution of the power sector. The evolving economics of the power sector, specifically the increased natural gas supply and subsequent relatively low natural gas prices, have resulted in more natural gas being used as base load energy in addition to supplying electricity during peak load. Additionally, rapid growth in the penetration of renewables has led to their now constituting a significant share of generation. This section presents data on the evolution of the power sector from 2014 through 2020. Projections of future power sector behavior and the impact of this proposed rule are discussed in more detail in Section 3 of this RIA.

2.2 Power Sector Overview

The production and delivery of electricity to customers consists of three distinct segments: generation, transmission, and distribution.

2.2.1 Generation

Electricity generation is the first process in the delivery of electricity to consumers. There are two important aspects of electricity generation: capacity and net generation. *Generating Capacity* refers to the maximum amount of production an EGU is capable of producing in a typical hour, typically measured in megawatts (MW) for individual units, or gigawatts (1 GW = 1,000 MW) for multiple EGUs. *Electricity Generation* refers to the amount of electricity actually produced by an EGU over some period of time, measured in kilowatt-hours (kWh) or gigawatt-hours (1 GWh = 1 million kWh). Net Generation is the amount of electricity that is available to the grid from the EGU (i.e., excluding the amount of electricity generated but used within the generating station for operations). Electricity generation is most often reported as the total annual generation (or some other period, such as seasonal). In addition to producing electricity for sale to the grid, EGUs perform other services important to reliable electricity supply, such as providing backup generating capacity in the event of unexpected changes in demand or unexpected changes in the availability of other generators. Other important services provided by generators include facilitating the regulation of the voltage of supplied generation.

Individual EGUs are not used to generate electricity 100 percent of the time. Individual EGUs are periodically not needed to meet the regular daily and seasonal fluctuations of electricity demand. Furthermore, EGUs relying on renewable resources such as wind, sunlight, and surface water to generate electricity are routinely constrained by the availability of adequate wind, sunlight, or water at different times of the day and season. Units are also unavailable during routine and unanticipated outages for maintenance. These factors result in the mix of generating capacity types available (e.g., the share of capacity of each type of EGU) being substantially different than the mix of the share of total electricity produced by each type of EGU in a given season or year.

Most of the existing capacity generates electricity by creating heat to create high pressure steam that is released to rotate turbines which, in turn, create electricity. Natural gas combined cycle (NGCC) units have two generating components operating from a single source of heat. The first cycle is a gas-fired turbine, which generates electricity directly from the heat of burning natural gas. The second cycle reuses the waste heat from the first cycle to generate steam, which is then used to generate electricity from a steam turbine. Other EGUs generate electricity by using water or wind to rotate turbines, and a variety of other methods including direct photovoltaic generation also make up a small, but growing, share of the overall electricity supply. The generating capacity includes fossil-fuel-fired units, nuclear units, and hydroelectric and other renewable sources (see Table 2-1). Table 2-1 also shows the comparison between the generating capacity over the 2015 to 2021 period.

In 2021 the power sector comprised a total capacity[9] of 1,179 GW, an increase of 105 GW (or 10 percent) from the capacity in 2015 (1,074 GW). The largest change over this period was the decline of 70 GW of coal capacity, reflecting the retirement/rerating of over a third of the coal fleet. This reduction in coal capacity was offset by an increase in natural gas capacity of 52 GW, and an increase in solar (48 GW) and wind (60 GW) capacity over the same period. Additionally, significant amounts of distributed solar (23 GW) were also added.

Table 2-1 Total Net Summer Electricity Generating Capacity by Energy Source, 2015 and 2021

	2015		2021		Change Between '15 and '21	
Energy Source	**Net Summer Capacity (GW)**	**% Total Capacity**	**Net Summer Capacity (GW)**	**% Total Capacity**	**% Increase**	**Capacity Change (GW)**
Coal	280	26%	210	18%	-25%	-70
Natural Gas	439	41%	492	42%	12%	52
Nuclear	99	9%	96	8%	-3%	-3
Hydro	102	10%	103	9%	1%	1
Petroleum	37	3%	28	2%	-23%	-9
Wind	73	7%	133	11%	83%	60
Solar	14	1%	62	5%	350%	48
Distributed Solar	10	1%	33	3%	238%	23
Other Renewable	17	2%	15	1%	-10%	-2
Misc	4	0%	8	1%	91%	4
Total	**1,074**	**100%**	**1,179**	**100%**	**10%**	**105**

Note: This table presents generation capacity. Actual net generation is presented in Table 2-2.
Source: EIA. Electric Power Annual 2021, Tables 4.2.A

In 2021, electric generating sources produced a net 4,157 trillion kWh (TWh) to meet national electricity demand, which was around 2 percent higher than 2015. As presented in Table 2-1, 59 percent of electricity in 2021 was produced through the combustion of fossil fuels, primarily coal and natural gas, with natural gas accounting for the largest single share. The total generation share from fossil fuels in 2021 (60 percent) was 11 percent less than the share in 2010 (69 percent). Moreover, the share of fossil generation supplied by coal fell from 65 percent in 2010 to 36 percent by 2021, while the share of fossil generation supplied by natural gas rose

[9] This includes generating capacity at EGUs primarily operated to supply electricity to the grid and combined heat and power facilities classified as Independent Power Producers (IPP) and excludes generating capacity at commercial and industrial facilities that does not operate primarily as an EGU. Natural Gas information in this section (unless otherwise stated) reflects data for all generating units using natural gas as the primary fossil heat source. This includes Combined Cycle Combustion Turbine, Gas Turbine, steam, and miscellaneous (< 1 percent).

from 35 percent to 64 percent over the same period. In absolute terms, coal generation declined by 51 percent, while natural gas generation increased by 60 percent. This reflects both the increase in natural gas capacity during that period as well as an increase in the utilization of new and existing gas EGUs during that period. The combination of wind and solar generation also grew from 2 percent of the mix in 2010 to 13 percent in 2021.

Table 2-2 Net Generation in 2015 and 2021 (Trillion kWh = TWh)

	2015		2021		Change Between '15 and '21	
Energy Source	**Net Generation (TWh)**	**Fuel Source Share**	**Net Generation (TWh)**	**Fuel Source Share**	**% Increase**	**Generation Change (TWh)**
Coal	1352	33%	898	22%	-34%	-455
Natural Gas	1335	33%	1579	38%	18%	246
Nuclear	797	19%	778	19%	-2%	-19
Hydro	249	6%	252	6%	1%	2
Petroleum	28	1%	19	0%	-32%	-9
Wind	191	5%	378	9%	98%	187
Solar	25	1%	115	3%	363%	90
Distributed Solar	14	0%	49	1%	248%	35
Other Renewable	80	2%	70	2%	-12%	-9
Misc	27	1%	24	1%	-13%	-4
Total	**4,092**	**100%**	**4,157**	**100%**	**2%**	**66**

Source: EIA. Electric Power Annual 2021, Tables 3.1.A and 3.1.B

The average age of coal-fired power plants that have retired between 2015 and 2021 is over 50 years. Older power plants tend to become uneconomic over time as they become more costly to maintain and operate, and as newer and more efficient alternative generating technologies are built. As a result, coal's share of total U.S. electricity generation has been declining for over a decade, while generation from natural gas and renewables has increased significantly.[10] As shown in Figure 2-1 below, 65 percent of the coal fleet in 2021 had an average age of over 40 years.

[10] EIA, Today in Energy (April 17, 2017) *available at* https://www.eia.gov/todayinenergy/detail.php?id=30812

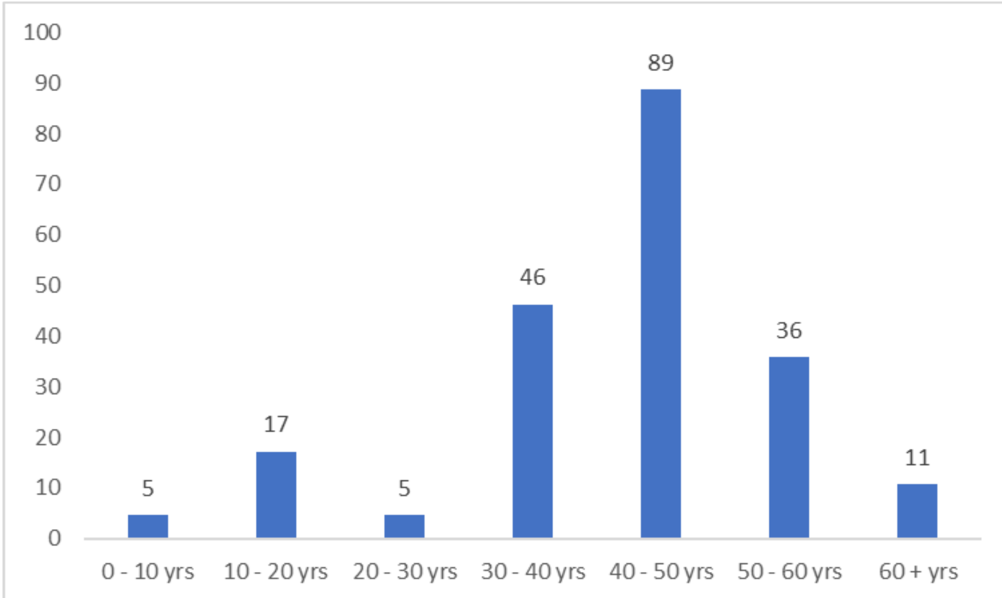

Figure 2-1 National Coal-fired Capacity (GW) by Age of EGU, 2021
Source: NEEDS v6

Coal-fired and nuclear generating units have historically supplied "base load" electricity, the portion of electricity loads that are continually present and typically operate throughout all hours of the year. Although much of the coal fleet has historically operated as base load, there can be notable differences across various facilities (see Table 2-3). For example, coal-fired units less than 100 megawatts (MW) in size comprise 18 percent of the total number of coal-fired units, but only 2 percent of total coal-fired capacity. Gas-fired generation is better able to vary output, and is therefore the primary option used to meet the variable portion of the electricity load. Gas-fired generation has historically supplied "peak" and "intermediate" power, when there is increased demand for electricity (for example, when businesses operate throughout the day or when people return home from work and run appliances and heating/air-conditioning), versus late at night or very early in the morning, when demand for electricity is reduced. Moreover, as shown in Figure 2-2, average annual coal capacity factors have declined from 67 percent to 49 percent over the 2010-2021 period, indicating that a larger share of units are operating in non-baseload fashion. Over the same period, natural gas combined cycle capacity factors have risen from an annual average of 44 percent to 55 percent.

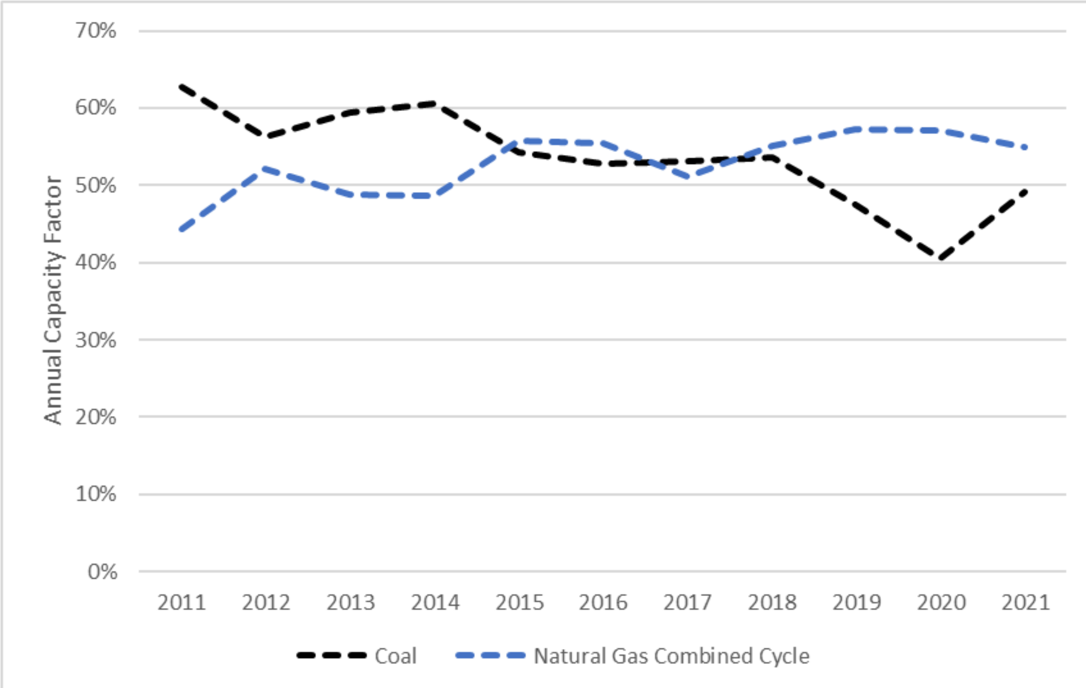

Figure 2-2 Average Annual Capacity Factor by Energy Source
Source: EIA. Electric Power Annual 2021, Table 4.08.A

Table 2-3 also shows comparable data for the capacity and age distribution of natural gas units. Compared with the fleet of coal EGUs, the natural gas fleet of EGUs is generally smaller and newer. While 67 percent of the coal EGU fleet capacity is over 500 MW per unit, 75 percent of the gas fleet is between 50 and 500 MW per unit.

Table 2-3 Coal and Natural Gas Generating Units, by Size, Age, Capacity, and Average Heat Rate in 2020

Unit Size Grouping (MW)	No. Units	% of All Units	Avg. Age	Avg. Net Summer Capacity (MW)	Total Net Summer Capacity (MW)	% Total Capacity	Avg. Heat Rate (Btu/kWh)
COAL							
0 – 24	31	6%	49	11	351	0%	11,379
25 – 49	32	6%	35	36	1,150	1%	11,541
50 – 99	24	5%	39	76	1,823	1%	11,649
100 - 149	36	7%	50	122	4,388	2%	11,167
150 - 249	61	12%	52	197	12,027	6%	10,910
250 - 499	132	26%	42	372	49,090	24%	10,700
500 - 749	138	27%	41	609	83,978	40%	10,315
750 - 999	50	10%	38	827	41,345	20%	10,135
1000 - 1500	11	2%	43	1,264	13,903	7%	9,834
Total Coal	515	100%	43	404	208,056	100%	10,718
NATURAL GAS							
0 – 24	4,329	54%	31	5	21,626	4%	13,244
25 – 49	932	12%	26	41	38,089	8%	11,759
50 – 99	1,018	13%	27	71	72,744	15%	12,163
100 - 149	410	5%	23	126	51,567	10%	9,447
150 - 249	1,041	13%	18	179	186,494	37%	8,226
250 - 499	293	4%	21	332	97,244	19%	8,293
500 - 749	37	0%	38	592	21,910	4%	10,384
750 - 999	10	0%	46	828	8,278	2%	11,294
1000 - 1500	1	0%	0	1,060	1,060	0%	7,050
Total Gas	8,060	100%	28	62	499,012	100%	11,900

Source: National Electric Energy Data System (NEEDS) v.6
Note: The average heat rate reported is the mean of the heat rate of the units in each size category (as opposed to a generation-weighted or capacity-weighted average heat rate.) A lower heat rate indicates a higher level of fuel efficiency.

In terms of the age of the generating units, almost 50 percent of the total coal generating capacity has been in service for more than 40 years, while nearly 50 percent of the natural gas capacity has been in service less than 15 years. Figure 2-3 presents the cumulative age distributions of the coal and gas fleets, highlighting the pronounced differences in the ages of the fleets of these two types of fossil-fuel generating capacity. Figure 2-3 also includes the distribution of generation, which is similar to the distribution of capacity.

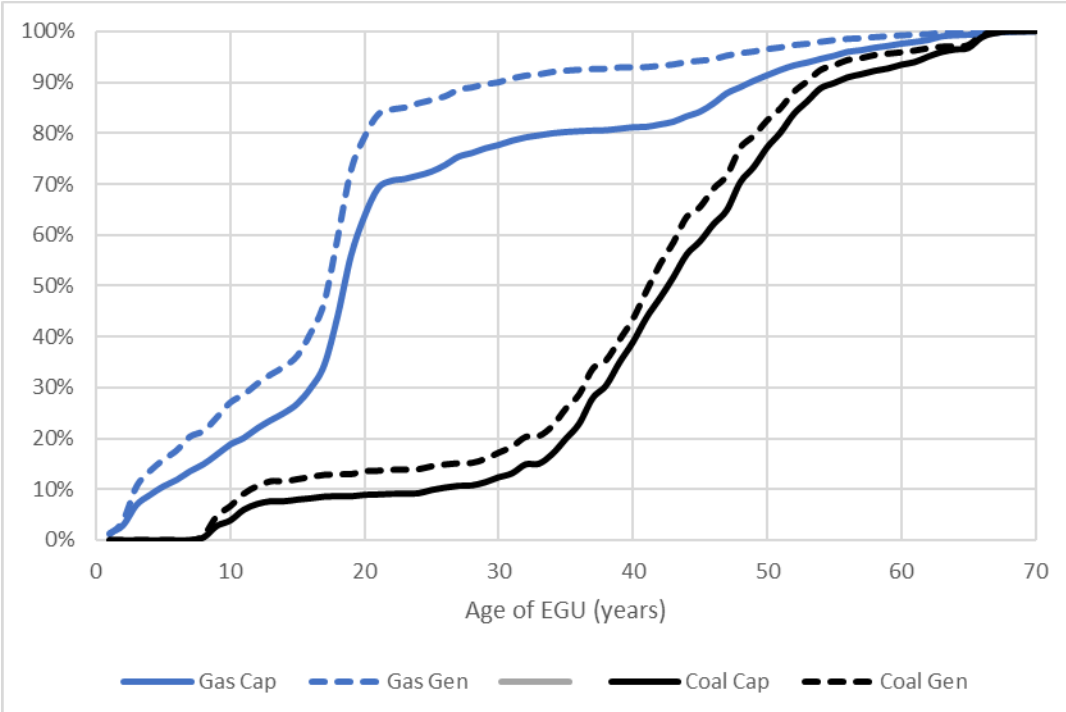

Figure 2-3 Cumulative Distribution in 2019 of Coal and Natural Gas Electricity Capacity and Generation, by Age

Source: eGRID 2020 (January 2022 release from EPA eGRID website). Figure presents data from generators that came online between 1950 and 2020 (inclusive); a 71-year period. Full eGRID data includes generators that came online as far back as 1915. Full data from 1915 onward is used in calculating cumulative distributions; figure truncation at 70 years is merely to improve visibility of diagram.

The locations of existing fossil units in EPA's National Electric Energy Data System (NEEDS) v.6 are shown in Figure 2-4.

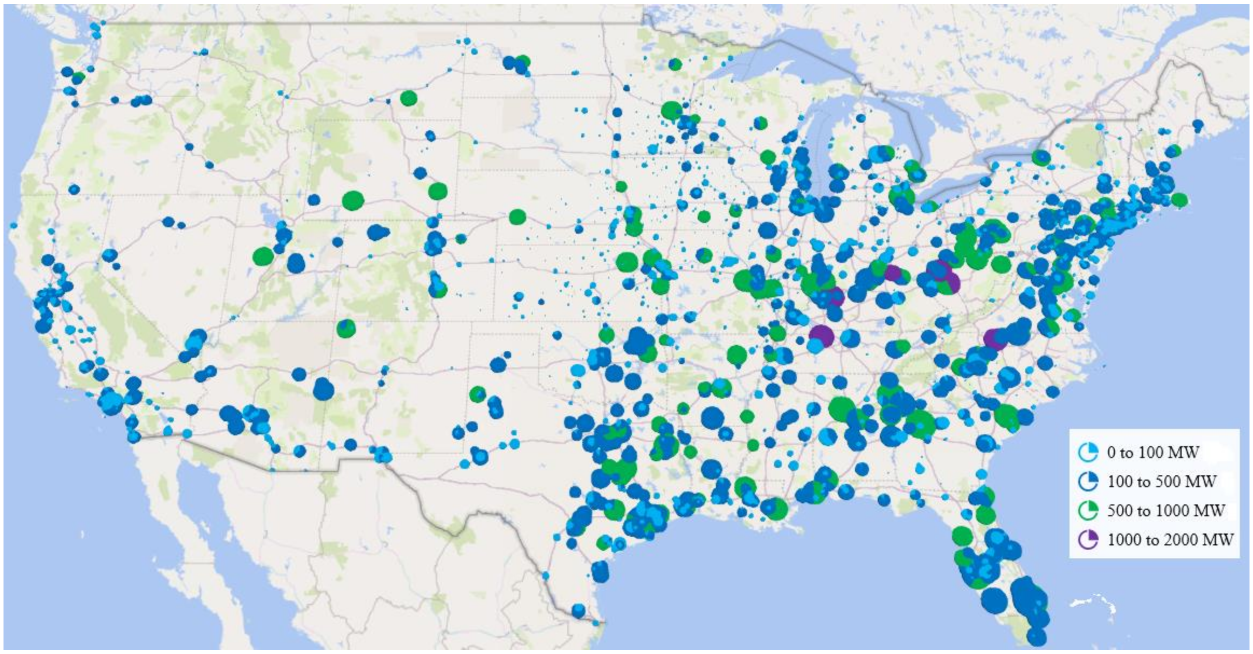

Figure 2-4 Fossil Fuel-Fired Electricity Generating Facilities, by Size
Source: National Electric Energy Data System (NEEDS) v.6
Note: This map displays fossil capacity at facilities in the NEEDS v.6 database, which reflects generating capacity expected to be on-line at the end of 2023. This includes planned new builds already under construction and planned retirements. In areas with a dense concentration of facilities, some facilities may be obscured.

2.2.2 Transmission

Transmission is the term used to describe the bulk transfer of electricity over a network of high voltage lines, from electric generators to substations where power is stepped down for local distribution. In the U.S. and Canada, there are three separate interconnected networks of high voltage transmission lines,[11] each operating synchronously. Within each of these transmission networks, there are multiple areas where the operation of power plants is monitored and controlled by regional organizations to ensure that electricity generation and load are kept in balance. In some areas, the operation of the transmission system is under the control of a single

[11] These three network interconnections are the Western Interconnection, comprising the western parts of both the U.S. and Canada (approximately the area to the west of the Rocky Mountains), the Eastern Interconnection, comprising the eastern parts of both the U.S. and Canada (except those part of eastern Canada that are in the Quebec Interconnection), and the Texas Interconnection (which encompasses the portion of the Texas electricity system commonly known as the Electric Reliability Council of Texas (ERCOT)). See map of all NERC interconnections at https://www.nerc.com/AboutNERC/keyplayers/PublishingImages/NERC%20Interconnections.pdf.

regional operator;[12] in others, individual utilities[13] coordinate the operations of their generation, transmission, and distribution systems to balance the system across their respective service territories.

2.2.3 Distribution

Distribution of electricity involves networks of lower voltage lines and substations that take the higher voltage power from the transmission system and step it down to lower voltage levels to match the needs of customers. The transmission and distribution system is a classic example of a natural monopoly, in part because it is not practical to have more than one set of lines running from the electricity generating sources to substations or from substations to residences and businesses.

Over the last few decades, several jurisdictions in the U.S. began restructuring the power industry to separate transmission and distribution from generation, ownership, and operation. Historically, vertically integrated utilities established much of the existing transmission infrastructure. However, as parts of the country have restructured the industry, transmission infrastructure has also been developed by transmission utilities, electric cooperatives, and merchant transmission companies, among others. Distribution, also historically developed by vertically integrated utilities, is now often managed by a number of utilities that purchase and sell electricity, but do not generate it. As discussed below, electricity restructuring has focused primarily on efforts to reorganize the industry to encourage competition in the generation segment of the industry, including ensuring open access of generation to the transmission and distribution services needed to deliver power to consumers. In many states, such efforts have also included separating generation assets from transmission and distribution assets to form distinct economic entities. Transmission and distribution remain price-regulated throughout the country based on the cost of service.

[12] For example, PMJ Interconnection, LLC, Western Area Power Administration (which comprises four sub-regions).
[13] For example, Los Angeles Department of Power and Water, Florida Power and Light.

2.3 Sales, Expenses, and Prices

These electric generating sources provide electricity for ultimate commercial, industrial and residential customers. Each of the three major ultimate categories consume roughly a quarter to a third of the total electricity produced[14] (see Table 2-4). Some of these uses are highly variable, such as heating and air conditioning in residential and commercial buildings, while others are relatively constant, such as industrial processes that operate 24 hours a day. The distribution between the end use categories changed very little between 2015 and 2021.

Table 2-4 Total U.S. Electric Power Industry Retail Sales, 2015 and 2021 (billion kWh)

		2015		2021	
		Sales/Direct Use (Billion kWh)	**Share of Total End Use**	**Sales/Direct Use (Billion kWh)**	**Share of Total End Use**
Sales	Residential	1,404	36%	1,470	37%
	Commercial	1,361	35%	1,328	34%
	Industrial	987	25%	1,001	25%
	Transportation	8	0%	6	0%
Total		3,759	96%	3,806	96%
Direct Use			141	4%	139
Total End Use			**3,900**	**100%**	**3,945**

Source: Table 2.2, EIA Electric Power Annual, 2021
Notes: Retail sales are not equal to net generation (Table 2-2) because net generation includes net imported electricity and loss of electricity that occurs through transmission and distribution, along with data collection frame differences and non-sampling error. Direct Use represents commercial and industrial facility use of onsite net electricity generation; electricity sales or transfers to adjacent or co-located facilities; and barter transactions.

2.3.1 Electricity Prices

Electricity prices vary substantially across the U.S., differing both between the ultimate customer categories and by state and region of the country. Electricity prices are typically highest for residential and commercial customers because of the relatively high costs of distributing electricity to individual homes and commercial establishments. The higher prices for residential and commercial customers are the result both of the necessary extensive distribution network reaching to virtually every part of the country and every building, and also the fact that generating stations are increasingly located relatively far from population centers (which

[14] Transportation (primarily urban and regional electrical trains) is a fourth ultimate customer category which accounts less than one percent of electricity consumption.

increases transmission costs). Industrial customers generally pay the lowest average prices, reflecting both their proximity to generating stations and the fact that industrial customers receive electricity at higher voltages (which makes transmission more efficient and less expensive). Industrial customers frequently pay variable prices for electricity, varying by the season and time of day, while residential and commercial prices historically have been less variable. Overall industrial customer prices are usually considerably closer to the wholesale marginal cost of generating electricity than residential and commercial prices.

On a state-by-state basis, all retail electricity prices vary considerably. In 2021, the national average retail electricity price (all sectors) was 11.10 cents/kWh, with a range from 8.17 cents (Idaho) to 30.31 cents (Hawaii).[15]

Average national retail electricity prices decreased between 2010 and 2021 by 8 percent in real terms (2019 dollars), and 5 percent between 2015-21.[16] The amount of decrease differed for the three major end use categories (residential, commercial, and industrial). National average industrial prices decreased the most (7 percent), and residential prices decreased the least (4 percent) between 2015-21. The real year prices for 2010 through 2021 are shown in Figure 2-5.

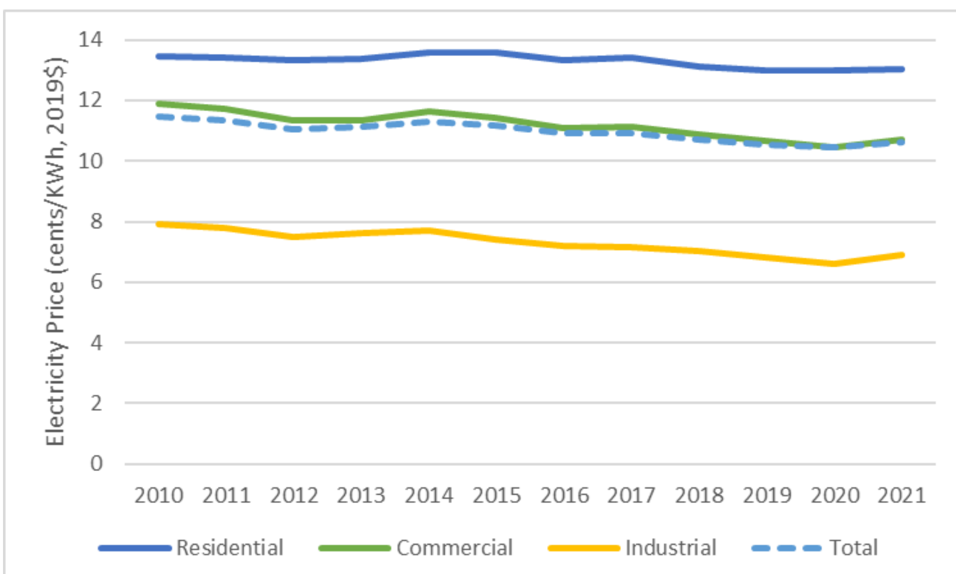

Figure 2-5 Real National Average Electricity Prices (including taxes) for Three Major End-Use Categories

[15] EIA State Electricity Profiles with Data for 2021 (http://www.eia.gov/electricity/state/)
[16] All prices in this section are estimated as real 2019 prices adjusted using the GDP implicit price deflator unless otherwise indicated.

Source: EIA. Electric Power Annual 2021, Table 2.4.

Most of these electricity price decreases occurred between 2014 and 2015, when nominal residential electricity prices followed inflation trends, while nominal commercial and industrial electricity prices declined. The years 2016 and 2017 saw an increase in nominal commercial and industrial electricity prices, while 2018 and 2019 saw flattening of this growth. Industrial electricity prices declined in 2019 and 2020 due to the effects of the pandemic. Prices rose in 2021 as a result of higher input fuel prices and increasing demand. The increase in nominal electricity prices for the major end use categories, as well as increases in the gross domestic product (GDP) price index for comparison, are shown in Figure 2-6.

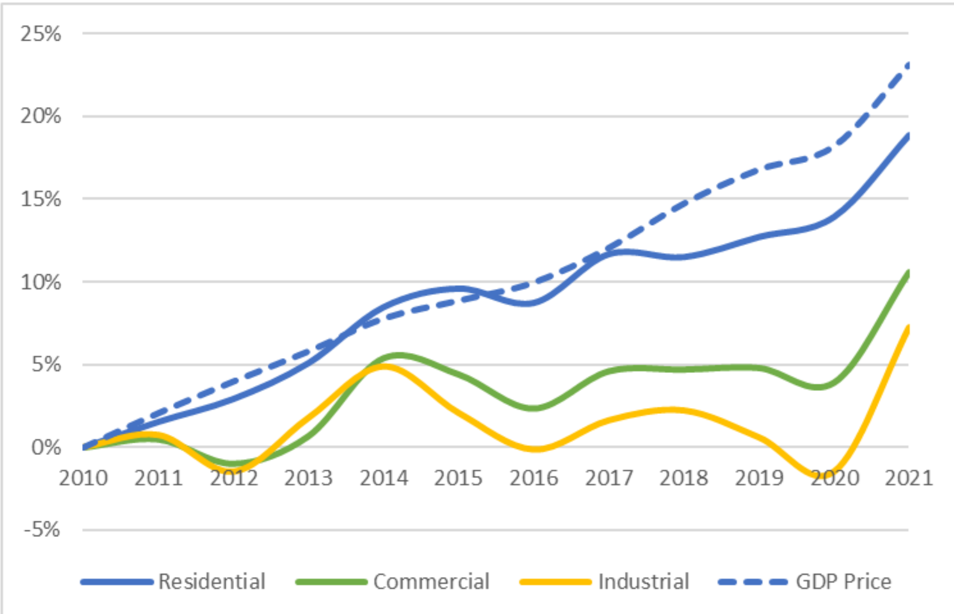

Figure 2-6 Relative Increases in Nominal National Average Electricity Prices for Major End-Use Categories (including taxes), With Inflation Indices
Source: EIA. Electric Power Annual 2021, Table 2.4.

2.3.2 Prices of Fossil Fuel Used for Generating Electricity

Another important factor in the changes in electricity prices are the changes in delivered fuel prices[17] for the three major fossil fuels used in electricity generation: coal, natural gas, and petroleum products. Relative to real prices in 2014, the national average real price (in 2019 dollars) of coal delivered to EGUs in 2020 had decreased by 26 percent, while the real price of

[17] Fuel prices in this section are all presented in terms of price per MMBtu to make the prices comparable.

natural gas decreased by 56 percent. The real price of delivered petroleum products also decreased by 55 percent, and petroleum products declined as an EGU fuel (in 2020 petroleum products generated 1 percent of electricity). The combined real delivered price of all fossil fuels (weighted by heat input) in 2020 decreased by 39 percent over 2014 prices. Figure 2-7 shows the relative changes in real price of all 3 fossil fuels between 2010 and 2021.

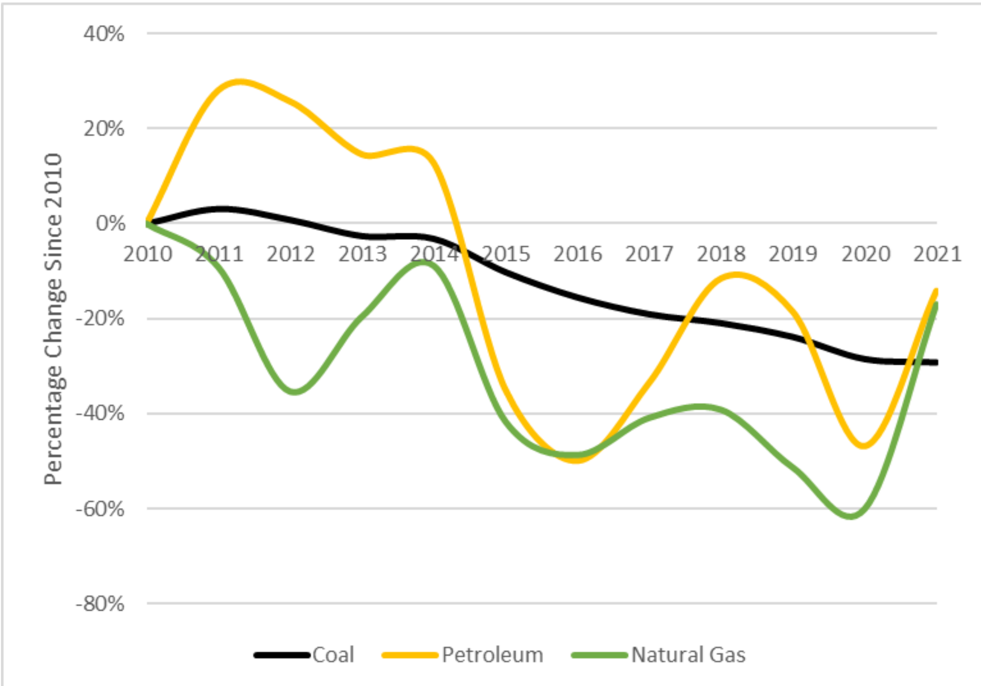

Figure 2-7 Relative Real Prices of Fossil Fuels for Electricity Generation; Change in National Average Real Price per MMBtu Delivered to EGU
Source: EIA. Electric Power Annual 2020 and 2021, Table 7.1.

2.3.3 Changes in Electricity Intensity of the U.S. Economy from 2010 to 2021

An important aspect of the changes in electricity generation (i.e., electricity demand) between 2010 and 2021 is that while total net generation increased by 1 percent over that period, the demand growth for generation was lower than both the population growth (7 percent) and real GDP growth (24 percent). Figure 2-8 shows the growth of electricity generation, population, and real GDP during this period.

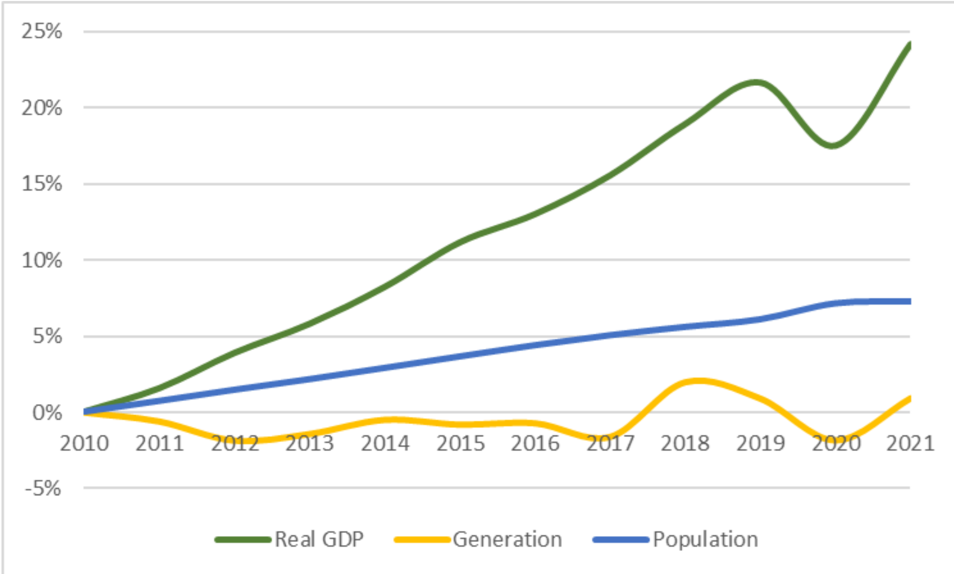

Figure 2-8 Relative Growth of Electricity Generation, Population and Real GDP Since 2014

Sources: Generation: U.S. EIA Electric Power Annual 2021 and 2020. Population: U.S. Census. Real GDP: 2022 Economic Report of the President, Table B-3.

Because demand for electricity generation grew more slowly than both the population and GDP, the relative electric intensity of the U.S. economy improved (i.e., less electricity used per person and per real dollar of output) during 2010 to 2021. On a per capita basis, real GDP per capita grew by 16 percent between 2010 and 2021. At the same time electricity generation per capita decreased by 6 percent. The combined effect of these two changes improved the overall electricity generation efficiency in the U.S. market economy. Electricity generation per dollar of real GDP decreased 19 percent. These relative changes are shown in Figure 2-9.

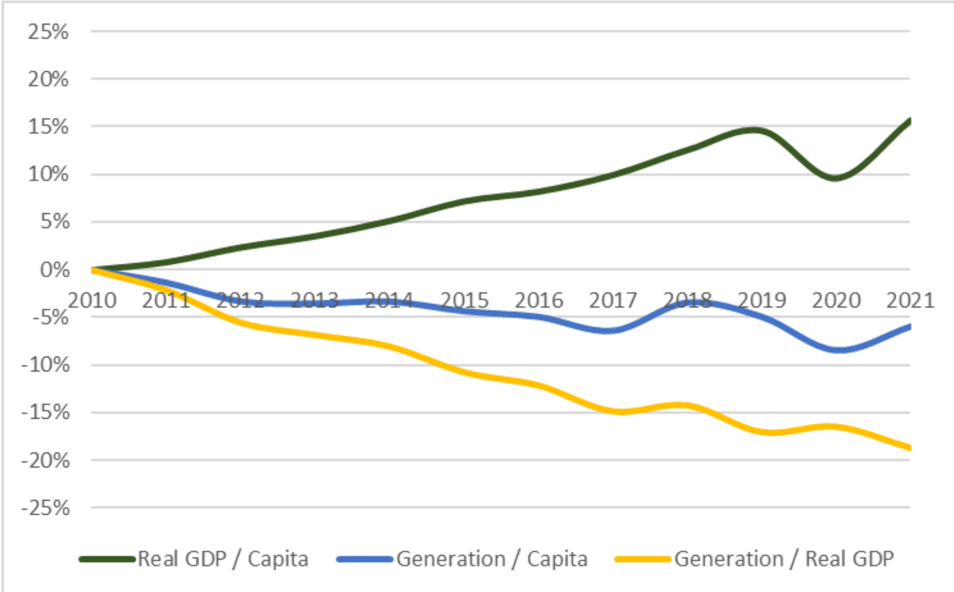

Figure 2-9 Relative Change of Real GDP, Population and Electricity Generation Intensity Since 2010

Sources: Generation: U.S. EIA Electric Power Annual 2021 and 2020. Population: U.S. Census. Real GDP: 2022 Economic Report of the President, Table B-3.

3 COSTS, EMISSIONS, AND ENERGY IMPACTS

3.1 Introduction

This section presents the compliance cost, emissions, and energy impact analysis performed for the MATS RTR. EPA used the Integrated Planning Model (IPM), developed by ICF Consulting, to conduct its analysis. IPM is a dynamic linear programming model that can be used to examine air pollution control policies for SO_2, NO_X, mercury, HCl, PM, and other air pollutants throughout the U.S. for the entire power system. Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model Post-IRA 2022 Reference Case (hereafter IPM Documentation) can be found at https://www.epa.gov/airmarkets/power-sector-modeling, and is available in the docket for this action.

3.2 EPA's Post-IRA 2022 Reference Case

IPM is a state-of-the-art, peer-reviewed, dynamic linear programming model that can be used to project power sector behavior under future business-as-usual conditions and to examine prospective air pollution control policies throughout the contiguous U.S. for the entire electric power system. For this RIA, EPA used IPM to project likely future electricity market conditions with and without this proposed rulemaking and a more stringent regulatory alternative.

IPM, developed by ICF, is a multi-regional, dynamic, deterministic linear programming model of the contiguous U.S. electric power sector. It provides estimates of least cost capacity expansion, electricity dispatch, and emissions control strategies while meeting energy demand and environmental, transmission, dispatch, and reliability constraints. IPM’s least-cost dispatch solution is designed to ensure generation resource adequacy, either by using existing resources or through the construction of new resources. IPM addresses reliable delivery of generation resources for the delivery of electricity between the 78 IPM regions, based on current and planned transmission capacity, by setting limits to the ability to transfer power between regions using the bulk power transmission system. Notably, the model includes cost and performance estimates for state-of-the-art air pollution control technologies with respect to mercury, filterable PM, and other HAP controls.

EPA has used IPM for almost three decades to better understand power sector behavior under future business-as-usual conditions and to evaluate the economic and emissions impacts of prospective environmental policies. The model is designed to reflect electricity markets as accurately as possible. EPA uses the best available information from utilities, industry experts, gas and coal market experts, financial institutions, and government statistics as the basis for the detailed power sector modeling in IPM. The model documentation provides additional information on the assumptions discussed here as well as all other model assumptions and inputs.[18]

The model incorporates a detailed representation of the fossil-fuel supply system that is used to estimate equilibrium fuel prices. The model uses natural gas fuel supply curves and regional gas delivery costs (basis differentials) to simulate the fuel price associated with a given level of gas consumption within the system. These inputs are derived using ICF's Gas Market Model (GMM), a supply/demand equilibrium model of the North American gas market.[19]

IPM also endogenously models the partial equilibrium of coal supply and EGU coal demand levels throughout the contiguous U.S., taking into account assumed non-power sector demand and imports/exports. IPM reflects 36 coal supply regions, 14 coal grades, and the coal transport network, which consists of over four thousand linkages representing rail, barge, and truck and conveyer linkages. The coal supply curves in IPM were developed during a thorough bottom-up, mine-by-mine approach that depicts the coal choices and associated supply costs that power plants would face if selecting that coal over the modeling time horizon. The IPM documentation outlines the methods and data used to quantify the economically recoverable coal reserves, characterize their cost, and build the 36 coal regions' supply curves.[20]

To estimate the annualized costs of additional capital investments in the power sector, EPA uses a conventional and widely accepted approach that applies a capital recovery factor (CRF) multiplier to capital investments and adds that to the annual incremental operating expenses. The CRF is derived from estimates of the power sector's cost of capital (i.e., private discount rate), the amount of insurance coverage required, local property taxes, and the life of

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[18] Detailed information and documentation of EPA's Baseline run using EPA's Post-IRA IPM 2022 Reference Case, including all the underlying assumptions, data sources, and architecture parameters can be found on EPA's website at: https://www.epa.gov/airmarkets/power-sector-modeling.

[19] See Chapter 8 of EPA's Post-IRA IPM 2022 Reference Case Documentation, available at: https://www.epa.gov/airmarkets/power-sector-modeling.

[20] See Chapter 7 EPA's Post-IRA IPM 2022 Reference Case Documentation, available at: https://www.epa.gov/airmarkets/power-sector-modeling.

capital.[21] It is important to note that there is no single CRF factor applied in the model; rather, the CRF varies across technologies, book life of the capital investments, and regions in the model in order to better simulate power sector decision-making.

EPA has used IPM extensively over the past three decades to analyze options for reducing power sector emissions. Previously, the model has been used to estimate the costs, emission changes, and power sector impacts in the RIAs for the Clean Air Interstate Rule (U.S. EPA, 2005), the Cross-State Air Pollution Rule (U.S. EPA, 2011a), the Mercury and Air Toxics Standards (U.S. EPA, 2011b), the Clean Power Plan for Existing Power Plants (U.S. EPA, 2015b), the Cross-State Air Pollution Update Rule (U.S. EPA, 2016), the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units (U.S. EPA, 2019), and the Revised Cross-State Air Pollution Update Rule (U.S. EPA, 2021).

EPA has also used IPM to estimate the air pollution reductions and power sector impacts of water and waste regulations affecting EGUs, including contributing to RIAs for the Cooling Water Intakes (316(b)) Rule (U.S. EPA, 2014), the Disposal of Coal Combustion Residuals from Electric Utilities rule (U.S. EPA, 2015c), the Steam Electric Effluent Limitation Guidelines (U.S. EPA, 2015a), and the Steam Electric Reconsideration Rule (U.S. EPA, 2020).

The model and EPA's input assumptions undergo periodic formal peer review. The rulemaking process also provides opportunity for expert review and comment by a variety of stakeholders, including owners and operators of capacity in the electricity sector that is represented by the model, public interest groups, and other developers of U.S. electricity sector models. The feedback that the Agency receives provides a highly detailed review of key input assumptions, model representation, and modeling results. IPM has received extensive review by energy and environmental modeling experts in a variety of contexts. For example, in October 2014 U.S. EPA commissioned a peer review[22] of EPA Baseline run version 5.13 using IPM. Additionally, and in the late 1990s, the Science Advisory Board reviewed IPM as part of the

[21] See Chapter 10 of
EPA's Post-IRA IPM 2022 Reference Case Documentation, available at:
https://www.epa.gov/airmarkets/power-sector-modeling.
[22] See Response and Peer Review Report EPA Baseline run Version 5.13 Using IPM, available at:
https://www.epa.gov/airmarkets/response-and-peer-review-report-epa-base-case-version-513-using-ipm.

CAA Amendments Section 812 prospective studies[23] that are periodically conducted. The Agency has also used the model in a number of comparative modeling exercises sponsored by Stanford University's Energy Modeling Forum over the past 20 years. IPM has also been employed by states (e.g., for the Regional Greenhouse Gas Initiative, the Western Regional Air Partnership, Ozone Transport Assessment Group), other Federal and state agencies, environmental groups, and industry.

3.3 Baseline

The modeled "baseline " for any regulatory impact analysis is a business-as-usual scenario that represents expected behavior in the electricity sector under market and regulatory conditions in the absence of a regulatory action. As such, the baseline run represents an element of the baseline for this RIA.[24] EPA frequently updates the baseline modeling to reflect the latest available electricity demand forecasts from the U.S. EIA as well as expected costs and availability of new and existing generating resources, fuels, emission control technologies, and regulatory requirements.

For our analysis of the proposed MATS RTR rule, EPA used EPA's Post-IRA 2022 Reference Case to provide power sector emissions projections for air quality modeling, as well as a companion updated database of EGU units (the National Electricity Energy Data System or NEEDS v621 rev: 10-14-22[25]) that is used in EPA's modeling applications of IPM. The baseline for this proposal includes the proposed GNP, the Revised CSAPR Update, CSAPR Update, and CSAPR, as well as MATS. The Baseline run also includes the 2015 Effluent Limitation Guidelines (ELG) and the 2015 Coal Combustion Residuals (CCR), and the recently finalized 2020 ELG and CCR rules.[26]

This version of the model, which is used as the baseline for this RIA, also includes recent updates to state and federal legislation affecting the power sector, including Public Law 117-169,

[23] http://www2.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act

[24] As described in Chapter 5 of EPA's *Guidelines for Preparing Economic Analyses*, the baseline "should incorporate assumptions about exogenous changes in the economy that may affect relevant benefits and costs (e.g., changes in demographics, economic activity, consumer preferences, and technology), industry compliance rates, other regulations promulgated by EPA or other government entities, and behavioral responses to the proposed rule by firms and the public." (USEPA, 2010).

[25] https://www.epa.gov/power-sector-modeling/national-electric-energy-data-system-needs-v6

[26] For a full list of modeled policy parameters, please see: https://www.epa.gov/airmarkets/power-sector-modeling.

136 Stat. 1818 (August 16, 2022), commonly known as the Inflation Reduction Act of 2022 (the IRA). The IPM Documentation includes a summary of all legislation reflected in this version of the model as well as a description of how that legislation is implemented in the model.

The inclusion of the proposed GNP and other regulatory actions (including federal, state, and local actions) in the base case is necessary in order to reflect the level of controls that are likely to be in place in response to other requirements apart from the scenarios analyzed in this section. As the GNP was finalized on March 15, 2023, any differences between the proposal and final GNP will not be reflected in the baseline for this proposal. This base case will provide meaningful projections of how the power sector will respond to the cumulative regulatory requirements for air emissions in totality, while isolating the incremental impacts of MATS RTR relative to a base case with other air emission reduction requirements separate from this proposed action.

The analysis of power sector cost and impacts presented in this section is based on a single baseline run, and represents incremental impacts projected solely as a result of compliance with the proposed MATS RTR or the analyzed alternatives

3.4 Regulatory Options Analyzed

For this RIA, EPA analyzed the three regulatory options summarized in the table below, which are described in more detail in Section 1.3.1. The remainder of this section discusses the approach used for estimating the costs and/or emissions impacts of each provision of the proposed rule.

Table 3-1 Summary of Proposed Regulatory Options Examined in this RIA

Provision	Regulatory Options Examined in this RIA		
	Less Stringent	**Proposed**	**More Stringent**
Filterable PM Standard (Surrogate Standard for Non-Hg metal HAP)	Retain existing filterable PM standard of 0.030 lb/MMBtu	revised filterable PM standard of 0.010 lb/MMBtu	revised filterable PM standard of 0.006 lb/MMBtu
Mercury Standard	Retain mercury standard for lignite-fired EGUs of 4.0 lb/TBtu	revised mercury standard for lignite-fired EGUs of 1.2 lb/TBtu	revised mercury standard for lignite-fired EGUs of 1.2 lb/TBtu
Continuous Emissions Monitoring Systems (PM CEMS)	Require installation of PM CEMS to demonstrate compliance	Require installation of PM CEMS to demonstrate compliance	Require installation of PM CEMS to demonstrate compliance
Startup definition	Remove startup definition #2	Remove startup definition #2	Remove startup definition #2

The revisions to the filterable PM standard and the mercury standard are modeled endogenously within IPM. For the filterable PM standard, emissions controls and associated costs are modeled based on information available in the memorandum titled: "2023 Technology Review for the Coal- and Oil-Fired EGU Source Category" which is available in the docket. This memorandum summarizes the filterable PM emissions rate for each existing EGU. Based on the emissions rates detailed in this memorandum, EPA assumed various levels of ESP upgrades, upgrades to existing fabric filters, or new fabric filter installations to comply with each of the proposed standards in the modeling. Those assumptions are detailed in Table 3-2.

Table 3-2 PM Control Technology Modeling Assumptions

PM Control Strategy	Capital Cost	Filterable PM Reduction
Minor ESP Upgrades	$16.5/kW	7.5%
Typical ESP Upgrades	$55/kW	15%
ESP Rebuild	$88/kW	40% (0.005lb/MMBtu floor)
Upgrade Existing FF Bags	Unit-specific, approximately $15K - $500K annual O&M	50% (0.002 lb/MMBtu floor)
New Fabric Filter (6.0 A/C Ratio)	Unit-specific, $150-360/kW*	90% (0.002 lb/MMBtu floor)

* https://www.epa.gov/system/files/documents/2021-09/attachment_5-7_pm_control_cost_development_methodology.pdf

The cost and reductions associated with control of mercury emissions at lignite-fired EGUs are also modeled endogenously and reflect the assumption that each of these EGUs replace standard powdered activated carbon (PAC) sorbent with halogenated PAC sorbent.

While more detail on the costs associated with the proposal to require PM CEMS and the proposed change in the startup definition is presented in Section 3.5.2, we note here that these costs were estimated exogenously without the use of the model that provides the bulk of the cost analysis for this RIA. As a result, the results of the power sector modeling do not include costs associated with these provisions, but the costs associated with requiring PM CEMS and the change in the startup definition are included in the total cost projections for the rule for each of the regulatory options analyzed in this RIA. As the incremental costs of requiring PM CEMS is negative and small relative to other aspects of this proposed rulemaking, we do not think the endogenous incorporation of these costs would change any projected results in a meaningful way.

3.5 Power Sector Impacts

3.5.1 Emissions

As indicated previously, this RIA presents emissions reductions estimates in years 2028, 2030, and 2035 based on IPM projections. Table 3-3 presents the estimated impact on reduction in power sector emissions resulting from compliance with the evaluated regulatory control alternatives (i.e., filterable PM and mercury standards) in the contiguous U.S. Note the less stringent regulatory alternative in this RIA was not modeled using IPM. As a result, power sector impacts are not estimated for the less stringent regulatory option, but the costs associated with requiring PM CEMS are included in all options. The projections indicate that both the proposed rule and the more stringent alternative result in emissions reductions in all run years, and those emission reductions follow an expected pattern: the proposed rule, which revises the filterable PM standard to 0.010 lb/MMBtu, produces smaller emissions reductions than the more stringent alternative, which revises the filterable PM standard to 0.006 lb/MMBtu. The additional reductions of mercury emissions in the more stringent alternative result from the additional coal steam retirements in this scenario. Note the less stringent regulatory alternative has no quantified emissions reductions associated with the proposed requirements for PM CEMS and the removal of startup definition number two. As a result, there are no quantified benefits associated with this regulatory option.

Table 3-3 EGU Emissions and Emissions Changes for the Baseline Run and the Proposed Rule and More Stringent Alternatives for 2028, 2030, and 2035 [a]

		Total Emissions			Change from Baseline	
	Year	Baseline Run	Proposed Rule	More-Stringent Alternative	Proposed Rule	More-Stringent Alternative
Mercury (lbs.)	2028	5,019	4,957	4,811	-62	-208
	2030	4,206	4,139	4,037	-67	-169
	2035	3,219	3,137	3,052	-82	-168
$PM_{2.5}$ (thousand tons)	2028	74.6	74.2	72	-0.4	-2.6
	2030	65.5	65.1	64	-0.4	-1.5
	2035	46.6	45.8	45.3	-0.8	-1.3
SO_2 (thousand tons)	2028	394	393	382	-0.9	-11.6
	2030	282	282	282	-0.5	-0.3
	2035	130	128	121	-1.5	-8.8
Ozone-season NO_X (thousand tons)	2028	195	195	188	-0.2	-7.2
	2030	163	163	158	-0.4	-5.1
	2035	104	101	99	-3.2	-5.6
Annual NO_X (thousand tons)	2028	457	456	439	-0.4	-18.1
	2030	368	367	358	-0.8	-9.5
	2035	214	211	205	-3.4	-8.7
HCl (thousand tons)	2028	2.6	2.6	2.5	0.0	-0.2
	2030	1.8	1.8	1.7	0.0	-0.1
	2035	0.9	0.9	0.8	0.0	-0.1
CO_2 (million metric tons)	2028	1222	1222	1200	-0.2	-21.9
	2030	972	971	963	-0.8	-8.7
	2035	608	604	605	-4.6	-2.9

[a] This analysis is limited to the geographically contiguous lower 48 states.

3.5.2 Compliance Costs

3.5.2.1 Power Sector Costs

The power industry's "compliance costs" are represented in this analysis as the change in electric power generation costs between the baseline and policy scenarios and are presented in Table 3-4. In simple terms, these costs are an estimate of the increased power industry expenditures required to implement the proposed requirements. The total compliance costs, presented in section 3.5.2.4, are estimated for this RIA as the sum of two components. The first component, estimated using the modeling discussed above, is presented below in Table 3-4. This component constitutes the majority of the incremental costs for the proposal and more stringent option. The second component, the costs of the proposed PM CEMS requirement, is discussed in section 3.5.2.2.

EPA projects that the annual incremental compliance cost of the proposed rule is $62 million, $52 million, and $45 million (2019 dollars) annually in 2028, 2030, and 2035, respectively. The annual incremental cost is the projected additional cost of complying with the proposed rule in the year analyzed and includes the amortized cost of capital investment and any applicable costs of operating additional pollution controls, investments in new generating sources, shifts between or amongst various fuels, and other actions associated with compliance. This projected cost does not include the compliance calculated outside of IPM modeling, namely the compliance costs related to PM CEMS. See Section 3.5.2.2 for further details on these costs. EPA believes that the cost assumptions used for this RIA reflect, as closely as possible, the best information available to the Agency today.

Table 3-4 National Power Sector Compliance Cost Estimates (millions of 2019 dollars) for the Proposed Rule and More Stringent Alternative for 2028, 2030, and 2035

Analysis Year	Proposed Rule	More Stringent Alternative
2028 (Annualized)	62	928
2030 (Annualized)	52	1,061
2035 (Annualized)	45	290

Note: The less stringent regulatory alternative in this RIA was not modeled using IPM. As a result power sector impacts are not estimated for the less stringent regulatory option, but the costs associated with requiring PM CEMS are included in the total cost across regulatory options.

Additionally, EPA projects that the annual incremental compliance cost of the more stringent alternative is $928 million, $1 billion, and $290 million (2019 dollars) annually in 2028, 2030, and 2035, respectively. Relative to the proposed rule, these costs are notably higher. The difference in projected compliance costs results from EPA's assumption that more costly controls would be installed to comply with the lower filterable PM emissions limit. A small percentage of the total compliance costs for the more stringent alternative is attributable to the capital and operating costs of these additional controls, and the vast majority of the incremental cost is associated with the projected changes in operating capacity which decrease significantly by 2035 (e.g., construction of new capacity). See Section 3.5.4 for a discussion of projected capacity changes and Section 3.6 for a discussion of the uncertainty regarding necessary pollution controls.

3.5.2.2 PM CEMS Costs

In addition to revising the PM emission standard for existing coal-fired EGUs, EPA is proposing a revision to the requirements for demonstrating compliance with the PM emission standard for coal-fired EGUs. Either of the two filterable PM standards under consideration would render the current limit for the LEE program moot, since they would be two-thirds and two-fifths, respectively, of the current PM LEE limit. Therefore, EPA proposes to remove PM from the LEE program. Currently, EGUs that are not LEE units can demonstrate compliance with the filterable PM standard either by conducting performance testing quarterly, use of PM continuous parameter monitoring systems (CPMS) or using PM CEMS.

After considering updated information on the costs for performance testing compared to the cost of PM CEMS and capabilities of PM CEMS measurement abilities, as well as the benefits of using PM CEMS, which include increased transparency and accelerated identification of anomalous emissions, EPA is proposing to require that all MATS-affected EGUs demonstrate compliance with the PM emission standard by using PM CEMS.

The revision of PM limits in the proposal and more stringent alternative alters the composition and duration of testing runs in facilities that use either performance testing methodology. For units currently employing M5 quarterly testing, four tests would be required at an individual cost of $15,522 and an annual cost of $62,088.[27] EPA calibrated its cost estimates for PM CEMS in response to observed installations, manufacturer input, and engineering analyses. These calibrations include an assumed replacement lifespan of 15 years and an interest rate of 7 percent to approximate the prevailing bank prime rate. For the portion of EGUs that employ PM CEMS, manufacturer input leads to an annualized cost of $32,559, which is slightly lower than the current cost of $33,643 for firms utilizing PM CEMS. All installations of PM CEMS currently in place took place in between 2012 and 2015. With a 15-year expected useful life, the assumption is made that all units would require initial installation of new PM CEMS, including those that already utilize the technology.

[27] EGUs receiving contractual or quantity discounts from performance test provides may incur lower costs.

To produce an inventory of total units which would require the installation of PM CEMS in the proposal and more stringent alternative as well as their initial characterization for juxtaposition of current and proposal costs, EPA began with an inventory of all existing coal-fired EGUs with capacity great enough to be regulated by MATS. That inventory was then filtered to remove EGUs with planned retirements prior to 2028 from analysis of both the baseline and proposal. Within that remaining inventory of 358 EGUs, 126 units are assumed to have installed PM CEMS between 2012 and 2015, while the remaining 232 units are assumed to use quarterly testing and not have existing PM CEMS installations.

Table 3-5 Costs of Proposed Continuous Emissions Monitoring (PM CEMS) Requirement

Compliance Approach in Baseline	Units (no.)	Baseline Cost (per year per unit)	Total Baseline Costs (per year)	Proposed Rule (per year per unit)	Proposed Rule Costs (per year)	Incremental Costs (per year)
Quarterly Testing	200	$62,000	$12,000,000	$33,000	$6,300,000	-$5,800,000
PM CEMS	110	$34,000	$3,600,000	$33,000	$3,500,000	-$120,000
Total	**300**	**---**	**$16,000,000**	**---**	**$9,800,000**	**-$5,900,000**

Note: Values rounded to two significant figures

As detailed in Table 3-5, relative to the baseline scenario, revised PM CEMS cost estimates in the proposal lead to a reduction of costs of $1,000 year per unit and about $120,000 per year in total. For EGUs currently employing quarterly testing, the proposal results in cost reductions of $29,000 per year per unit and $5.8 million per year in total. The estimated aggregate sector impact thus sums to a cost reduction of about $5.9 million per year.

3.5.2.3 Startup Definition Costs

EPA is proposing to remove one of the two options for defining the startup period for EGUs. The first option defines startup as either the first-ever firing of fuel in a boiler for the purpose of producing electricity, or the firing of fuel in a boiler after a shutdown event for any purpose. Startup ends when any of the steam from the boiler is used to generate electricity for sale over the grid or for any other purpose (including on-site use). In the second option, startup is defined as the period in which operation of an EGU is initiated for any purpose. Startup begins with either the firing of any fuel in an EGU for the purpose of producing electricity or useful thermal energy (such as heat or steam) for industrial, commercial, heating, or cooling purposes (other than the first-ever firing of fuel in a boiler following construction of the boiler) or for any other purpose after a shutdown event. Startup ends four hours after the EGU generates electricity that is sold or used for any other purpose (including on-site use), or four hours after the EGU makes useful thermal energy (such as heat or steam) for industrial, commercial, heating, or cooling purposes, whichever is earlier. This second option, referred to as paragraph (2) of the definition of "startup," required clean fuel use to the maximum extent possible, operation of PM control devices within one hour of introduction of primary fuel (*i.e.*, coal, residual oil, or solid oil-derived fuel) to the EGU, collection and submission of records of clean fuel use and emissions control device capabilities and operation, as well as adherence to applicable numerical standards within four hours of the generation of electricity or thermal energy for use either on site or for sale over the grid (*i.e.*, the end of startup) and to continue to maximize clean fuel use throughout that period.

According to EPA analysis, the owners or operators of at least 98 percent of all other coal- and oil-fired EGUs have made the requisite adjustments, whether through greater clean fuel capacity, better tuned equipment, better trained staff, a more efficient or better design structure, or a combination of factors, to be able to meet the requirements of paragraph (1) of the definition of "startup." As demonstrated by the vast majority of EGUs currently relying on the work practice standards in paragraph (1) of the definition of "startup," we believe such a change is achievable by all EGUs; further, we expect such a change would result in little to no additional expenditure since the additional recordkeeping and reporting provisions associated with the work practice standards of paragraph (2) of the definition of "startup" were more expensive than the requirements of paragraph (1) of the definition of "startup." As a result, this RIA does not incorporate any additional costs as a result of this proposed provision.

3.5.2.4 Total Compliance Costs

The estimates of the total compliance costs are presented in Table 3-6. The total costs are composed of the change in electric power generation costs between the baseline and policy scenarios as presented in Table 3-4 and the incremental cost of the proposed PM CEMS requirement as detailed in Table 3-5.

Table 3-6 Stream of Projected Compliance Costs across Proposed Rule and Less and More Stringent Regulatory Alternatives (millions of 2019 dollars) [a]

	Regulatory Alternative		
Year	**Proposed Rule**	**Less Stringent[b]**	**More Stringent**
2028[b]	56	-5.9	920
2030[b] (mapped to 2029 to 2031)	46	-5.9	1,100
2035[b] (mapped to 2032 to 2037)	39	-5.9	280
3% Discount Rate			
Present Value (PV)	**330**	**-45**	**4,600**
Equivalent Annualized Value (EAV)	**38**	**-5.2**	**540**
7% Discount Rate			
Present Value (PV)	**230**	**-31**	**3,400**
Equivalent Annualized Value (EV)	**33**	**-4.5**	**490**

[a] Positive values indicate costs, and negative values indicate cost savings in this table. Values rounded to two significant figures
[b] IPM analysis years mapped to individual calendar years in order to calculate PV and EAVs. Values rounded to two significant figures

3.5.3 Projected Compliance Actions for Emissions Reductions

Electric generating units subject to the mercury and filterable PM emission limits in this proposed rule will likely use various mercury and PM control strategies to comply. This section summarizes the projected compliance actions related to each of these emissions limits.

The 2028 baseline includes approximately 7 GW of operational minemouth EGU capacity designed to burn low rank virgin coal. All of this capacity is currently equipped with Activated Carbon Injection (ACI) technology, and operation of this technology is reflected in the baseline. In the proposed and more stringent modeling scenarios, each of these EGUs projected to consume lignite is assigned an additional variable operating cost that is consistent with achieving a 1.2 lb/MMBtu limit. In the proposed option, this additional cost does not result in incremental retirements for these units, nor does it result in a significant change to the projected generation level for these units.

The baseline also includes 4.8 GW of operational coal capacity that, based on the analysis documented in the EPA docketed memorandum titled: "2023 Technology Review for the Coal- and Oil-Fired EGU Source Category," EPA assumes would either need to improve existing PM controls or install new PM controls to comply with the proposed option in 2028. The various PM control upgrades that EPA assumes would be necessary to achieve with the emissions limits analyzed are summarized in Table 3-7.

Table 3-7 Affected Capacity Operational in the Baseline by PM Control Strategy for the Proposed Rule and More Stringent Alternative in 2028 (GW)

	Proposed Rule		More Stringent Alternative	
PM Control Strategy	Affected Capacity Operational in Baseline	Projected Retrofits in Proposed Rule	Affected Capacity Operational in Baseline	Projected Retrofits in More-Stringent Alternative
Minor ESP upgrades	1.1	1.1	--	--
Typical ESP Upgrades	0.5	0	--	--
ESP Rebuild	0.4	0.4	--	--
FF Bag Upgrade	1.2	1.2	7.6	7.6
New Fabric Filter	1.5	1.5	15.0	3.6
Total	**4.8**	**4.3**	**22.7**	**11.3**

The vast majority of the 4.8 GW that EPA assumes would need to take some compliance action to meet the proposed standards is currently operating existing ESPs and/or fabric filters. Nearly all of that capacity is projected to install the controls summarized in Table 3-7 and remain operational in 2028, and about 500 MW of that coal steam capacity is projected to retire in response to the proposed rule.

Under the more stringent alternative, EPA assumes that 22.7 GW of capacity that is projected to be operational in the baseline would need to take some compliance action in order to meet the proposed standards. About half of that capacity (about 11.3 GW) is projected to remain operational with the installation of those controls in 2028.

3.5.4 Generating Capacity

In this section, we discuss the projected changes in capacity by fuel type, building on and adding greater context to the information presented in the previous section. We first look at total capacity by fuel type, then retirements by fuel type, and finally new capacity builds by fuel type for the 2028, 2030, and 2035 run years.

Table 3-8 shows the total net projected capacity by fuel type for the baseline run and regulatory control alternatives for 2028, 2030, and 2035. Here, we see the net effects of projected retirements (Table 3-9) and new capacity builds (see Table 3-10). All incremental changes in capacity projected to result in response to the proposed rule for any given fuel type are one percent or less, and all under 1 GW. The more stringent alternative, on the other hand, is projected to result in a fleet consisting of slightly more operational natural gas capacity by 2035, and slightly less operational coal capacity.

Table 3-8 2028, 2030, and 2035 Projected U.S. Capacity by Fuel Type for the Baseline and the Proposed Rule and More Stringent Alternative

	Total Generation Capacity (GW)			Incremental Change from Baseline			
	Baseline	Proposed Rule	More Stringent Alternative	Proposed Rule		More Stringent Alternative	
				GW	%	GW	%
2028							
Coal	100.5	99.9	88.2	-0.5	-0.5%	-12.2	-12.2%
Natural Gas	463.0	463.5	467.0	0.5	0.1%	4.0	0.9%
Oil/Gas Steam	62.8	62.7	62.8	-0.1	-0.1%	0.1	0.1%
Non-Hydro RE	314.8	314.6	316.5	-0.1	0.0%	1.8	0.6%
Hydro	102.1	102.1	102.1	0.0	0.0%	0.0	0.0%
Energy Storage	50.0	50.3	56.0	0.3	0.5%	6.0	11.9%
Nuclear	95.7	95.7	95.7	0.0	0.0%	0.0	0.0%
Other	6.9	6.9	6.9	0.0	0.0%	0.0	0.0%
Total	1,195.8	1,195.9	1,195.4	0.0	0.0%	-0.5	0.0%
2030							
Coal	68.9	68.4	63.5	-0.6	-0.8%	-5.5	-8.0%
Natural Gas	461.1	461.5	465.2	0.5	0.1%	4.1	0.9%
Oil/Gas Steam	60.4	60.3	60.1	-0.1	-0.1%	-0.3	-0.5%
Non-Hydro RE	403.4	403.3	405.1	-0.1	0.0%	1.7	0.4%
Hydro	103.6	103.6	103.6	0.0	0.0%	0.0	0.0%
Energy Storage	68.1	68.2	69.0	0.1	0.2%	1.0	1.4%
Nuclear	91.9	91.9	91.9	0.0	0.0%	0.0	0.0%
Other	6.9	6.9	6.9	0.0	0.0%	0.0	0.0%
Total	1,264.3	1,264.2	1,265.2	-0.1	0.0%	0.9	0.1%
2035							
Coal	44.0	43.7	39.3	-0.3	-0.8%	-4.7	-10.8%
Natural Gas	470.0	470.2	474.6	0.3	0.1%	4.6	1.0%
Oil/Gas Steam	59.2	59.1	59.2	-0.1	-0.1%	0.0	0.0%
Non-Hydro RE	667.6	668.4	667.6	0.8	0.1%	0.0	0.0%
Hydro	107.9	107.9	107.9	0.0	0.0%	0.0	0.0%
Energy Storage	98.2	98.3	98.4	0.1	0.1%	0.2	0.2%
Nuclear	83.6	83.6	83.6	0.0	0.0%	0.0	0.0%
Other	6.9	6.9	6.9	0.0	0.0%	0.0	0.0%
Total	1,537.4	1,538.2	1,537.5	0.8	0.0%	0.1	0.0%

Note: In this table, "Non-Hydro RE" includes biomass, geothermal, landfill gas, solar, and wind.

Table 3-9 shows the total capacity projected to retire by fuel type for the baseline run and the regulatory control alternatives in all run years. The incremental changes projected to occur in response to the proposed rule are very small. The proposed rule is projected to result in an additional 500 MW of retired coal capacity (less than one percent). The more stringent alternative is projected to result in additional incremental retirement of coal capacity: 12.2 GW of incremental coal retirements in 2028, decreasing to 5.4 GW of incremental coal retirements in 2035. This decrease over time reflects an acceleration of projected retirements (some capacity that was projected to retire in the 2035 baseline is projected to retire a few years earlier in the more stringent policy scenario). In all scenarios analyzed, the model's least-cost dispatch solution is designed to ensure generation resource adequacy, either by using existing resources or through the construction of new resources.

Table 3-9 2028, 2030, and 2035 Projected U.S. Retirements by Fuel Type for the Baseline Run and the Proposed Rule and More Stringent Alternative

	Retirements (GW)			Percent Change from Baseline	
	Baseline	Proposed Rule	More Stringent Alternative	Proposed Rule	More Stringent Alternative
2028					
Coal	56.5	57.0	68.7	0.9%	21.6%
Natural Gas	1.7	1.7	1.7	0.0%	0.0%
Oil/Gas Steam	8.4	8.5	8.4	0.7%	-0.7%
Non-Hydro RE	3.0	3.0	2.9	0.0%	-3.0%
Hydro	0.0	0.0	0.0	0%	0%
Nuclear	0.0	0.0	0.0	0%	0%
Other	0.0	0.0	0.0	0%	0%
Total	69.6	70.2	81.7	0.8%	17.3%
2030					
Coal	82.0	82.5	87.9	0.7%	7.3%
Natural Gas	2.4	2.4	2.4	0.0%	0.5%
Oil/Gas Steam	12.4	12.4	12.7	0.5%	2.7%
Non-Hydro RE	3.3	3.3	3.3	0.0%	0.0%
Hydro	0.0	0.0	0.0	0%	0%
Nuclear	2.7	2.7	2.7	0.0%	0.0%
Other	0.1	0.1	0.1	0.0%	0.0%
Total	102.8	103.5	109.1	0.6%	6.1%
2035					
Coal	105.0	105.4	110.4	0.3%	5.1%
Natural Gas	6.2	6.2	6.2	-0.1%	0.2%
Oil/Gas Steam	14.8	14.9	14.8	0.4%	-0.1%
Non-Hydro RE	3.3	3.3	3.3	0.0%	0.0%
Hydro	0.0	0.0	0.0	0%	0%
Nuclear	9.9	9.9	9.9	0.0%	0.0%
Other	0.1	0.1	0.1	0.0%	0.0%
Total	139.3	139.7	144.7	0.3%	3.9%

Note: In this table, "Non-Hydro RE" includes biomass, geothermal, landfill gas, solar, and wind.

Finally, Table 3-10 shows the projected U.S. new capacity builds by fuel type for the baseline run and the regulatory control alternatives in all run years. For the proposed rule, the incremental changes in projected new capacity for any given fuel type are one percent or less, and all under 1 GW. The more-stringent alternative is projected to result in an increase in incremental builds in the energy storage (6.0 GW), natural gas (3.9 GW), and renewables (1.7 GW) categories in 2028. Some of these incremental changes reflect a projected acceleration of new capacity that was projected to occur after 2028 in the baseline.

Table 3-10 2028, 2030, and 2035 Projected U.S. New Capacity Builds by Fuel Type for the Baseline Run and the Proposed Rule and More Stringent Alternative

	New Capacity (GW)			Percent Change from Baseline	
	Baseline	**Proposed Rule**	**More Stringent Alternative**	**Proposed Rule**	**More Stringent Alternative**
2028					
Coal	0.0	0.0	0.0	0.0%	0.0%
Natural Gas	31.6	32.0	35.5	1.4%	12.5%
Energy Storage	32.5	32.8	38.5	0.8%	18.3%
Non-Hydro RE	42.0	41.9	43.7	-0.3%	3.9%
Hydro	0.0	0.0	0.0	0.0%	0.0%
Nuclear	0.0	0.0	0.0	0.0%	0.0%
Other	0.0	0.0	0.0	0.0%	0.0%
Total	**106.2**	**106.8**	**117.8**	**0.5%**	**10.9%**
2030					
Coal	0.0	0.0	0.0	0.0%	0.0%
Natural Gas	31.6	32.0	35.7	1.5%	13.0%
Energy Storage	50.6	50.7	51.5	0.3%	1.9%
Non-Hydro RE	130.8	130.7	132.5	-0.1%	1.3%
Hydro	1.5	1.5	1.5	0.0%	0.0%
Nuclear	0.0	0.0	0.0	0.0%	0.0%
Other	0.0	0.0	0.0	0.0%	0.0%
Total	**214.5**	**215.0**	**221.2**	**0.2%**	**3.1%**
2035					
Coal	0.0	0.0	0.0	0.0%	0.0%
Natural Gas	45.0	45.2	49.6	0.5%	10.3%
Energy Storage	80.7	80.8	81.0	0.1%	0.3%
Non-Hydro RE	395.0	395.9	395.0	0.2%	0.0%
Hydro	5.8	5.8	5.8	0.0%	0.0%
Nuclear	0.0	0.0	0.0	0.0%	0.0%
Other	0.0	0.0	0.0	0.0%	0.0%
Total	**526.5**	**527.7**	**531.3**	**0.2%**	**0.9%**

Note: In this table, “Non-Hydro RE” includes biomass, geothermal, landfill gas, solar, and wind.

3.5.5 Generation Mix

In this section, we discuss the projected changes in generation mix for the 2028, 2030, and 2035 for the proposed rule and more stringent alternative. Table 3-11 presents the projected generation and percentage changes in national generation mix by fuel type for run years 2028, 2030, and 2035. These generation mix estimates reflect a very modest increase in natural gas and renewables and decrease in coal beginning in 2028 as a result of proposed rule and more stringent alternative. Estimated changes in coal and natural gas use as a result of each regulatory option are examined further in section 3.5.6

Table 3-11 2028, 2030, and 2035 Projected U.S. Generation by Fuel Type for the Baseline Run and the Proposed Rule and More Stringent Alternative

	Generation Mix (TWh)			Incremental Change from Baseline			
	Base Case	Proposed Rule	More Stringent Alternative	Proposed Rule		More Stringent Alternative	
				TWh	%	TWh	%
2028							
Coal	484	484	454	-0.3	-0.1%	-29.9	-6.2%
Natural Gas	1,773	1,774	1,802	0.7	0.0%	28.5	1.6%
Oil/Gas Steam	30	30	28	0.0	0.1%	-1.6	-5.5%
Non-Hydro RE	964	964	967	-0.3	0.0%	3.1	0.3%
Hydro	294	294	292	-0.2	-0.1%	-1.5	-0.5%
Energy Storage	68	69	76	0.3	0.5%	7.7	11.3%
Nuclear	765	765	765	0.0	0.0%	0.0	0.0%
Other	30	30	30	0.0	0.0%	0.0	0.0%
Total	4,409	4,409	4,415	0.2	0.0%	6.3	0.1%
2030							
Coal	309	307	292	-1.6	-0.5%	-17.1	-5.5%
Natural Gas	1,771	1,774	1,783	2.3	0.1%	12.1	0.7%
Oil/Gas Steam	33	33	33	-0.1	-0.5%	0.4	1.1%
Non-Hydro RE	1,269	1,268	1,274	-0.4	0.0%	5.1	0.4%
Hydro	303	303	303	-0.1	0.0%	0.0	0.0%
Energy Storage	98	98	99	0.1	0.1%	1.2	1.2%
Nuclear	734	734	734	0.0	0.0%	0.0	0.0%
Other	29	29	29	0.0	0.0%	0.0	0.0%
Total	4,545	4,545	4,546	0.3	0.0%	1.6	0.0%
2035							
Coal	120	115	104	-4.1	-3.5%	-15.3	-12.8%
Natural Gas	1,402	1,402	1,418	0.2	0.0%	16.1	1.1%
Oil/Gas Steam	16	16	16	-0.1	-0.4%	-0.3	-1.8%
Non-Hydro RE	2,180	2,183	2,178	2.4	0.1%	-2.2	-0.1%
Hydro	329	329	329	0.0	0.0%	0.0	0.0%
Energy Storage	154	154	155	0.2	0.1%	0.4	0.2%
Nuclear	660	660	660	0.0	0.0%	0.0	0.0%
Other	29	29	29	0.0	0.0%	0.0	0.0%
Total	4,891	4,889	4,889	-1.4	0.0%	-1.3	0.0%

Note: In this table, "Non-Hydro RE" includes biomass, geothermal, landfill gas, solar, and wind.

3.5.6 Coal and Natural Gas Use for the Electric Power Sector

In this section we discuss the estimated changes in coal use and natural gas use in 2028, 2030, and 2035. Table 3-12 and Table 3-13 present percentage changes in national coal usage by EGUs by coal supply region and coal rank, respectively. These fuel use estimates reflect virtually no reduction in coal use in the proposed rule relative to the baseline in 2028, and very modest reductions in coal use in 2030 and 2035. All regulatory options reflect a continuing trend of decreasing coal use nationwide; between 2015 and 2021, annual coal consumption in the electric power sector fell between 8 and 19 percent annually.[28] The proposed rule is projected to result in up to a 3 percent decrease in coal use in 2035 relative to the baseline. Additionally, the proposed rule is not projected to result in significant coal switching between supply regions or coal rank.

Table 3-12 2028, 2030, and 2035 Projected U.S. Power Sector Coal Use by Coal Supply Region for the Baseline Run and the Proposed Rule and More Stringent Alternative

		Million Tons			Percent Change from Baseline	
	Year	Baseline Run	Proposed Rule	More-Stringent Alt.	Proposed Rule	More-Stringent Alt.
Appalachia	2028	48.4	48.3	45.3	-0.2%	-6.3%
Interior		50.6	50.5	47.8	0.0%	-5.5%
Waste Coal		4.3	4.3	4.3	0.0%	0.0%
West		148.0	148.0	137.6	0.0%	-7.0%
Total		251.3	251.2	235.1	0.0%	-6.4%
Appalachia	2030	28.2	27.6	26.7	-2.1%	-5.3%
Interior		36.6	36.6	34.6	0.0%	-5.4%
Waste Coal		4.3	4.3	4.3	0.0%	0.0%
West		106.8	106.7	99.3	-0.1%	-7.0%
Total		176.0	175.3	165.0	-0.4%	-6.2%
Appalachia	2035	10.9	10.9	10.0	0.0%	-7.9%
Interior		19.6	19.7	18.2	0.7%	-7.3%
Waste Coal		2.0	1.9	2.0	-3.4%	-0.2%
West		47.9	45.3	39.4	-5.3%	-17.8%
Total		80.4	77.9	69.6	-3.1%	-13.4%

[28] U.S. EIA Monthly Energy Review, Table 6.2, January 2022.

Table 3-13 2028, 2030, and 2035 Projected U.S. Power Sector Coal Use by Rank for the Baseline Run and the Proposed Rule and More Stringent Alternative

		Million Tons			Percent Change from Baseline	
Rank	**Year**	**Baseline Run**	**Proposed Rule**	**More-Stringent Alt.**	**Proposed Rule**	**More-Stringent Alt.**
Bituminous	2028	94.0	93.9	88.2	-0.1%	-6.2%
Subbituminous		126.3	126.3	117.5	0.0%	-6.9%
Lignite		27.2	27.2	25.6	-0.2%	-6.1%
Total		247.5	247.4	231.3	0.0%	-6.5%
Bituminous	2030	59.5	58.9	56.1	-1.0%	-5.8%
Subbituminous		86.8	86.7	80.7	-0.1%	-7.0%
Lignite		25.4	25.4	23.9	0.0%	-5.9%
Total		171.6	171.0	160.6	-0.4%	-6.4%
Bituminous	2035	25.2	25.3	22.9	0.5%	-8.9%
Subbituminous		35.9	33.3	27.4	-7.1%	-23.7%
Lignite		17.4	17.4	17.3	0.0%	-0.2%
Total		78.4	76.0	67.6	-3.1%	-13.8%

Table 3-14 presents the projected changes in national natural gas usage by EGUs in the 2028, 2030, and 2035 run years. These fuel use estimates reflect very modest changes to projected gas generation in 2028, 2030 and 2035.

Table 3-14 2028, 2030, and 2035 Projected U.S. Power Sector Natural Gas Use for the Baseline Run and the Proposed Rule and More Stringent Alternative

	Trillion Cubic Feet			Percent Change from Baseline	
Year	**Baseline Run**	**Proposed Rule**	**More-Stringent Alternative**	**Proposed Rule**	**More-Stringent Alternative**
2028	12.5	12.5	12.7	0.0%	1.3%
2030	12.6	12.7	12.7	0.1%	0.5%
2035	9.9	9.9	10.0	-0.1%	0.9%

3.5.7 Fuel Price, Market, and Infrastructure

The projected impacts of the proposed rule and more stringent alternative on coal and natural gas prices are presented below in Table 3-15 and Table 3-16, respectively. As with the projected impact on fuel use, the projected impact of the proposed rule on minemouth and delivered coal prices is very small. The small increase in the national weighted average price of coal reflects the small projected decrease in the use of western subbituminous coal (see Table 3-12) which is characterized by a lower price on a MMBtu basis than bituminous coal.

Table 3-15 2028, 2030, and 2035 Projected Minemouth and Power Sector Delivered Coal Price (2019 dollars) for the Baseline and the Proposed Rule and More Stringent Alternative

		$/MMBtu			Percent Change from Baseline	
	Year	**Baseline**	**Proposed Rule**	**More-Stringent Alternative**	**Proposed Rule**	**More-Stringent Alternative**
Minemouth	2028	1.16	1.16	1.15	0.00%	-0.50%
Delivered		1.59	1.59	1.57	0.00%	-1.50%
Minemouth	2030	1.17	1.17	1.18	-0.10%	0.60%
Delivered		1.47	1.47	1.47	-0.20%	0.00%
Minemouth	2035	1.34	1.35	1.38	0.90%	2.90%
Delivered		1.38	1.40	1.40	1.70%	2.00%

Consistent with the projected change in natural gas use under the proposed rule, Henry Hub and power sector delivered natural gas prices are not projected to significantly change under the proposed rule over the period analyzed. Under the more stringent alternative, the small projected increase in natural gas demand is projected to result in a similarly small impact on average natural gas prices. Table 3-16 summarizes the projected impacts on Henry Hub and delivered natural gas prices in 2028, 2030, and 2035.

Table 3-16 2028, 2030, and 2035 Projected Henry Hub and Power Sector Delivered Natural Gas Price (2019 dollars) for the Baseline and the Proposed Rule and More Stringent Alternative

		$/MMBtu			Percent Change from Baseline	
	Year	**Baseline**	**Proposed Rule**	**More-Stringent Alternative**	**Proposed Rule**	**More-Stringent Alternative**
Henry Hub	2028	2.98	2.98	3.03	0.00%	1.80%
Delivered		3.02	3.02	3.08	0.00%	2.00%
Henry Hub	2030	2.41	2.41	2.45	0.00%	1.70%
Delivered		2.53	2.53	2.57	0.00%	1.50%
Henry Hub	2035	1.88	1.89	1.89	0.10%	0.20%
Delivered		2.10	2.10	2.10	0.09%	0.10%

3.5.8 Retail Electricity Prices

EPA estimated the change in the retail price of electricity (2019 dollars) using the Retail Price Model (RPM).[29] The RPM was developed by ICF for EPA and uses the IPM estimates of changes in the cost of generating electricity to estimate the changes in average retail electricity prices. The prices are average prices over consumer classes (i.e., consumer, commercial, and industrial) and regions, weighted by the amount of electricity used by each class and in each region. The RPM combines the IPM annual cost estimates in each of the 64 IPM regions with EIA electricity market data for each of the 25 electricity supply regions (shown in Figure 3-1) in the electricity market module of the National Energy Modeling System (NEMS).[30]

Table 3-17, Table 3-18, and Table 3-19 present the projected percentage changes in the retail price of electricity for the regulatory control alternatives in 2028, 2030, and 2035, respectively. Consistent with other projected impacts presented above, average retail electricity prices at both the national and regional level are projected to be small in each year. In 2028, EPA estimates that this proposed rule will result in a one tenth of one percent increase in national average retail electricity price, or by less than one tenth of one mill/kWh.

[29] See documentation available at: https://www.epa.gov/airmarkets/retail-price-model
[30] See documentation available at:
https://www.eia.gov/outlooks/aeo/nems/documentation/electricity/pdf/m068(2020).pdf

Table 3-17 Average Retail Electricity Price by Region for the Baseline and the Proposed Rule and More Stringent Alternative, 2028

All Sectors	2028 Average Retail Electricity Price (2019 mills/kWh)			Percent Change from Baseline	
Region	**Baseline**	**Proposed Rule**	**More-Stringent Alternative**	**Proposed Rule**	**More-Stringent Alternative**
TRE	99.4	99.3	100.0	-0.1%	0.6%
FRCC	99.7	99.7	100.3	0.0%	0.6%
MISW	79.4	79.4	79.9	0.0%	0.6%
MISC	101.7	101.7	103.2	0.0%	1.5%
MISE	123.0	123.1	123.7	0.0%	0.6%
MISS	105.1	105.0	105.7	0.0%	0.6%
ISNE	142.3	142.1	144.0	-0.1%	1.2%
NYCW	213.4	211.8	212.1	-0.7%	-0.6%
NYUP	142.1	141.1	141.7	-0.6%	-0.2%
PJME	121.5	121.7	123.9	0.1%	2.0%
PJMW	105.5	106.3	109.7	0.7%	3.9%
PJMC	92.3	92.4	93.4	0.0%	1.1%
PJMD	82.8	83.6	86.9	1.0%	5.0%
SRCA	109.8	109.9	110.1	0.0%	0.3%
SRSE	112.1	112.1	112.2	0.0%	0.1%
SRCE	74.2	74.2	74.1	0.0%	-0.1%
SPPS	85.4	85.5	85.3	0.1%	-0.1%
SPPC	84.1	84.0	83.2	0.0%	-1.0%
SPPN	77.3	77.3	77.4	0.0%	0.2%
SRSG	92.8	92.8	93.2	0.0%	0.4%
CANO	149.9	149.9	150.2	0.0%	0.2%
CASO	198.7	198.7	198.9	0.0%	0.1%
NWPP	78.3	78.5	78.7	0.3%	0.6%
RMRG	87.3	87.3	88.4	0.0%	1.3%
BASN	86.5	86.5	86.3	0.1%	-0.2%
National	**107.0**	**107.0**	**107.9**	**0.1%**	**0.9%**

Table 3-*18* Average Retail Electricity Price by Region for the Baseline and the Proposed Rule and More Stringent Alternative, 2030

All Sectors	2030 Average Retail Electricity Price (2019 mills/kWh)			Percent Change from Baseline	
Region	**Baseline**	**Proposed Rule**	**More-Stringent Alternative**	**Proposed Rule**	**More-Stringent Alternative**
TRE	78.4	78.4	78.6	0.0%	0.2%
FRCC	88.7	88.7	89.2	0.0%	0.5%
MISW	80.5	80.5	80.5	0.0%	0.0%
MISC	88.9	88.9	88.9	0.0%	0.0%
MISE	96.7	96.8	99.1	0.1%	2.5%
MISS	89.4	89.4	89.6	0.0%	0.3%
ISNE	146.9	146.9	147.1	0.0%	0.2%
NYCW	202.3	202.9	202.9	0.3%	0.3%
NYUP	121.6	121.9	121.9	0.3%	0.3%
PJME	101.5	102.1	102.1	0.5%	0.5%
PJMW	94.0	94.0	94.3	0.0%	0.3%
PJMC	77.8	77.8	80.6	0.1%	3.6%
PJMD	72.3	72.3	71.9	0.0%	-0.6%
SRCA	96.8	96.8	96.7	0.0%	0.0%
SRSE	90.4	90.4	90.5	0.0%	0.1%
SRCE	104.9	104.9	105.1	0.0%	0.2%
SPPS	69.0	69.0	68.9	0.0%	-0.1%
SPPC	80.3	80.3	80.4	0.0%	0.2%
SPPN	59.9	59.9	59.8	0.0%	-0.2%
SRSG	83.0	83.0	83.0	0.1%	0.1%
CANO	154.8	154.8	154.7	0.0%	-0.1%
CASO	187.0	186.9	187.4	0.0%	0.2%
NWPP	73.8	73.9	74.1	0.2%	0.4%
RMRG	86.4	86.5	87.1	0.1%	0.9%
BASN	88.4	88.5	89.3	0.1%	1.0%
National	**97.0**	**97.0**	**97.3**	**0.1%**	**0.3%**

Table 3-19 Average Retail Electricity Price by Region for the Baseline and the Proposed Rule and More Stringent Alternative, 2035

All Sectors	2035 Average Retail Electricity Price (2019 mills/kWh)			Percent Change from Baseline	
Region	**Baseline**	**Proposed Rule**	**More-Stringent Alternative**	**Proposed Rule**	**More-Stringent Alternative**
TRE	68.3	68.3	68.3	0.0%	0.0%
FRCC	81.0	81.0	81.0	0.0%	0.1%
MISW	80.2	80.2	80.3	0.0%	0.0%
MISC	80.2	80.2	80.2	0.0%	0.1%
MISE	88.9	88.8	88.9	0.0%	0.0%
MISS	84.4	84.4	84.5	0.0%	0.0%
ISNE	150.4	150.4	150.4	0.0%	0.0%
NYCW	187.2	187.2	187.3	0.0%	0.0%
NYUP	106.7	106.7	106.7	0.0%	0.0%
PJME	105.3	105.2	105.2	0.0%	0.0%
PJMW	82.4	82.3	82.3	0.0%	-0.1%
PJMC	82.4	82.4	82.5	0.0%	0.1%
PJMD	73.3	73.3	73.2	0.0%	-0.1%
SRCA	92.9	92.9	93.0	0.0%	0.1%
SRSE	113.5	113.5	113.5	0.0%	0.0%
SRCE	69.1	69.1	69.1	0.0%	0.0%
SPPS	70.3	70.3	70.4	0.0%	0.1%
SPPC	67.9	67.9	67.9	0.0%	0.1%
SPPN	62.8	62.8	62.9	0.0%	0.0%
SRSG	93.5	93.5	93.5	0.0%	0.0%
CANO	150.9	150.9	150.9	0.0%	0.0%
CASO	177.8	177.8	177.8	0.0%	0.0%
NWPP	79.6	79.6	79.6	0.0%	0.0%
RMRG	91.5	91.5	91.6	0.0%	0.1%
BASN	78.2	78.5	79.1	0.3%	1.1%
National	**92.7**	**92.8**	**92.8**	**0.0%**	**0.0%**

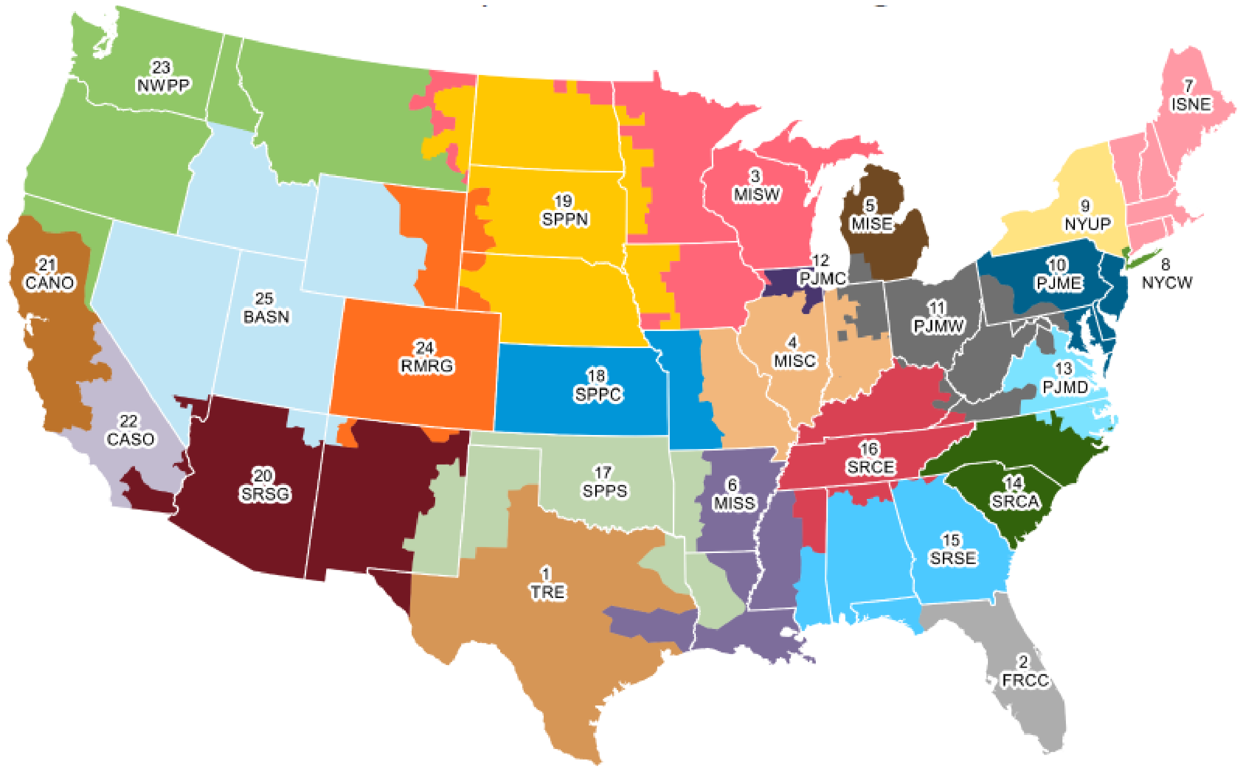

Figure 3-1 Electricity Market Module Regions
Source: EIA (http://www.eia.gov/forecasts/aeo/pdf/nerc_map.pdf)

3.6 Limitations of Analysis and Key Areas of Uncertainty

EPA's power sector modeling is based on expert judgment of various input assumptions for variables whose outcomes are uncertain. As a general matter, the Agency reviews the best available information from engineering studies of air pollution controls and new capacity construction costs to support a reasonable modeling framework for analyzing the cost, emission changes, and other impacts of regulatory actions for EGUs. The annualized cost of the proposed rule, as quantified here, is EPA's best assessment of the cost of implementing the proposed rule on the power sector.

The IPM-projected annualized cost estimates of private compliance costs provided in this analysis are meant to show the increase in production (generating) costs to the power sector in response to the proposed rule. To estimate these annualized costs, as discussed earlier, the EPA uses a conventional and widely accepted approach that applies a CRF multiplier to capital investments and adds that to the annual incremental operating expenses to calculate annual costs. The CRF is derived from estimates of the cost of capital (private discount rate), the amount of insurance coverage required, local property taxes, and the life of capital. The private compliance costs presented earlier are EPA's best estimate of the direct private compliance costs of the rule.

In addition, there are several key areas of uncertainty related to the electric power sector that are worth noting, including:

- **Electricity demand:** The analysis includes an assumption for future electricity demand. To the extent electricity demand is higher and lower, it may increase/decrease the projected future composition of the fleet.
- **Natural gas supply and demand:** To the extent natural gas supply and delivered prices are higher or lower, it would influence the use of natural gas for electricity generation and overall competitiveness of other EGUs (e.g., coal and nuclear units).
- **Longer-term planning by utilities:** Many utilities have announced long-term clean energy and/or climate commitments, with a phasing out of large amounts of coal capacity by 2030 and continuing through 2050. These announcements, some of which are not legally binding, are not necessarily reflected in the baseline, and may alter the amount of coal capacity projected in the baseline that would be covered under this proposed rule or the more stringent alternative.
- **Filterable PM emissions and control:** As discussed above, the baseline filterable PM emissions rates for each unit are based on the analysis documented in the memorandum titled: "2023 Technology Review for the Coal- and Oil-Fired EGU Source Category." For those EGUs with rates greater than the proposed limit or more stringent alternative, EPA assumes that control technology summarized in Section 3.4 would be necessary to remain operational. While the baseline emissions rate for each EGU and the cost and performance assumption for each PM control technology are the best available to EPA at this time, it is possible that some EGUs may be able to achieve the proposed or alternative filterable PM emissions limits with less costly control technology (e.g., an ESP upgrade instead of a fabric filter installation). It is also possible that EPA's cost assumptions reflect higher technology costs than might be incurred by EGUs.

These are key uncertainties that may affect the overall composition of electric power generation fleet and/or compliance with the proposed emissions limits and could thus have an effect on the estimated costs and impacts of this proposed action. While it is important to recognize these key areas of uncertainty, they do not change the EPA's overall confidence in the projected impacts of the proposed rule presented in this section. EPA continues to monitor industry developments and makes appropriate updates to the modeling platforms in order to reflect the best and most current data available.

The impacts of the Later Model Year Light-Duty Vehicle GHG Emissions Standards[31] are not captured in the baseline. This rule is projected to increase the total demand for electricity by 0.5 percent in 2030 and 1 percent in 2040 relative to 2020 levels.[32] This translates into a 0.4 percent increase in electricity demand in 2030 and a 0.8 percent increase in electricity demand in 2040 relative to the baseline electricity demand projections assumed in this analysis. The impacts of the Proposed Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review[33] are also not included in this analysis. Inclusion of these standards would likely increase the price of natural gas modestly as a result of limitations on the usage of reciprocating internal combustion engines in the pipeline transportation of natural gas. All else equal inclusion of these two programs would likely result in a modest increase in the total cost of compliance for this rule.

3.7 References

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4 BENEFITS ANALYSIS

4.1 Introduction

This proposed rule is projected to reduce emissions of mercury and non-mercury metal HAP, fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and carbon dioxide (CO_2) nationwide relative to emissions in the Post-IRA 2022 Reference Case that constitutes the baseline for this RIA. The projected reductions in mercury are expected to reduce the bioconcentration of methylmercury in fish. Subsistence fishing is associated with vulnerable populations, including minorities and those of low socioeconomic status. Further reductions in mercury emissions should reduce fish concentrations and exposure to HAP particularly for the subsistence fisher sub-population. The projected reductions in HAP emissions should help EPA maintain an ample margin of safety by reducing exposure to methylmercury and carcinogenic metal HAP.

Regarding the potential benefits of the rule from projected HAP reductions, we note that these are discussed only qualitatively and not quantitatively. Exposure to the HAP emitted by the source category, depending on the exposure duration and level of exposure, is associated with a variety of adverse health effects. These adverse health effects may include chronic health disorders (e.g., irritation of the lung, skin, and mucus membranes; decreased pulmonary function, pneumonia, or lung damage; detrimental effects on the central nervous system; cardiovascular disease; damage to the kidneys; and alimentary effects such as nausea and vomiting), adverse neurodevelopmental impacts, and increased risk of cancer. See 76 FR 25003–25005 for a fuller discussion of the health effects associated with HAP pollutants.

The analysis of the overall EGU sector completed for EPA's review of the 2020 appropriate and necessary finding (2023 Final A&N Review) identified significant reductions in cardiovascular and neuro-developmental effects from exposure to methylmercury (88 FR 13956). However, the amount of mercury reduction expected is a fraction of the mercury estimates used in the 2023 Final A&N Review. Overall, the uncertainty associated with modeling potential benefits of mercury reduction for fish consumers would be sufficiently large as to compromise the utility of those benefit estimates—though importantly such uncertainty does not decrease our confidence that reductions in emissions should result in reduced exposures of HAP to the general population, including methylmercury exposures to subsistence fishers located near these facilities. Further, estimated risks from exposure to non-mercury metal HAP were not expected to exceed acceptable levels. s , although we note that these emissions reductions should result in decreased exposure to HAP for individuals living near these facilities.

Reducing emissions of fine $PM_{2.5}$ and SO_2 emissions is expected to reduce ground-level $PM_{2.5}$ concentrations. Reducing NO_X emissions is expected to reduce both ground-level ozone and $PM_{2.5}$ concentrations. Below we present the estimated number and economic value of these avoided $PM_{2.5}$ and ozone-attributable premature deaths and illnesses. We also present the estimated monetized climate and health benefits associated with emission reductions for each of three regulatory options described in prior sections.

In addition to reporting results, this section details the methods used to estimate the benefits to human health of reducing concentrations of $PM_{2.5}$ and ozone resulting from the projected emissions reductions from EGUs under this proposal. This analysis uses methods for determining air quality changes that has been used in the RIAs from multiple previous proposed and final rules (U.S. EPA, 2019b, 2020a, 2020b, 2021, 2022c). The approach involves two major steps: (1) developing spatial fields of air quality across the U.S. for a baseline scenario and the proposed and more stringent regulatory options examined in this RIA for 2028, 2030 and 2035 using nationwide photochemical modeling and related analyses; and (2) using these spatial fields in BenMAP-CE to quantify the benefits under each regulatory control alternative and each year as compared to the baseline in that year.[34] See Section 4.3.3 for more detail on BenMAP-CE. When estimating the value of improved air quality over a multi-year time horizon, the analysis applies population growth and income growth projections for each future year through 2037 and estimates of baseline mortality incidence rates at five-year increments.

Elevated concentrations of GHGs in the atmosphere have been warming the planet, leading to changes in the Earth's climate including changes in the frequency and intensity of heat waves, precipitation, and extreme weather events, rising seas, and retreating snow and ice. The well-documented atmospheric changes due to anthropogenic GHG emissions are changing the climate at a pace and in a way that threatens human health, society, and the natural environment.

[34] Note we do not perform air quality analysis on the less stringent regulatory option because it has no quantified emissions reductions associated with the proposed requirements for CEMS and the removal of startup definition number two.

There will be important climate benefits associated with the CO_2 emissions reductions expected from this proposed rule. Climate benefits from reducing emissions of CO_2 can be monetized using estimates of the SC-CO_2.

Though the proposed rule is likely to also yield positive benefits associated with reducing pollutants other than mercury, non-mercury metal HAP, $PM_{2.5}$, ozone, and CO_2, time, resource, and data limitations prevented us from quantifying and estimating the economic value of those reductions. Specifically, in this RIA EPA does not monetize health benefits of reducing direct exposure to NO_2 and SO_2 nor ecosystem effects and visibility impairment associated with changes in air quality. In addition, this RIA does not include monetized impacts from changes in pollutants in other media, such as water effluents. We qualitatively discuss these unquantified impacts in this section.

4.2 Hazardous Air Pollutant Benefits

This proposed rule is projected to reduce emissions of mercury and non-mercury metal HAP. Specifically, projected reductions in mercury are expected to help reduce exposure to methylmercury for sub-populations that rely on subsistence fishing. In addition, projected emissions reductions should also reduce exposure to non-mercury metal HAP including carcinogens such as nickel, arsenic, and hexavalent chromium, for residents located in the vicinity of these facilities.

4.2.1 Mercury

Mercury is a persistent, bioaccumulative toxic metal that is emitted from power plants in three forms: gaseous elemental mercury (Hg0), oxidized mercury compounds (Hg+2), and particle-bound mercury (HgP). Elemental mercury does not quickly deposit or chemically react in the atmosphere, resulting in residence times that are long enough to contribute to global scale deposition. Oxidized mercury and HgP deposit quickly from the atmosphere impacting local and regional areas in proximity to sources. Methylmercury is formed by microbial action in the top layers of sediment and soils, after mercury has precipitated from the air and deposited into waterbodies or land. Once formed, methylmercury is taken up by aquatic organisms and bioaccumulates up the aquatic food web. Larger predatory fish may have methylmercury concentrations many times, typically on the order of one million times, that of the concentrations in the freshwater body in which they live. Methylmercury can adversely impact ecosystems and wildlife.

Human exposure to methylmercury is known to have several adverse neurodevelopmental impacts, such as IQ loss measured by performance on neurobehavioral tests, particularly on tests of attention, fine motor-function, language, and visual spatial ability. In addition, evidence in humans and animals suggests that methylmercury can have adverse effects on both the developing and the adult cardiovascular system, including fatal and non-fatal ischemic heart disease (IHD). Further, nephrotoxicity, immunotoxicity, reproductive effects (impaired fertility), and developmental effects have been observed with methylmercury exposure in animal studies (Agency for Toxic Substances and Disease Registry, 2022). Methylmercury has some genotoxic activity and is capable of causing chromosomal damage in a number of experimental systems. The EPA has classified methylmercury as a "possible" human carcinogen.

The projected reductions in mercury under this proposed rule are expected to reduce the bioconcentration of methylmercury in fish due to mercury emissions from MATS-affected sources. Risk from near-field deposition of mercury to subsistence fishers has previously been evaluated, using a site-specific assessment of a lake near three lignite-fired facilities (U.S. EPA, 2020d). The results suggest that methylmercury exposure to subsistence fishers from lignite-fired units is below the current reference dose (RfD) for methylmercury neurodevelopmental toxicity or IQ loss, with an estimated hazard quotient (HQ) of 0.06. In general, the EPA believes that exposures at or below the RfD are unlikely to be associated with appreciable risk of deleterious effects. However, no RfD defines an exposure level corresponding to zero risk; moreover, the RfD does not represent a bright line above which individuals are at risk of adverse effects. In addition, there was no evidence of a threshold for methylmercury-related neurotoxicity within the range of exposures in the Faroe Islands study which served as the primary basis for the RfD (U.S. EPA, 2001).

Regarding the potential magnitude of human health risk reductions and benefits associated with this proposed rule, we make the following observations. All of the exposure results generated as part of the 2020 Residual Risk analysis were below the presumptive acceptable cancer risk threshold and noncancer health-based thresholds. While these results suggest that the residual risks from HAP exposure are low, we do recognize that this proposed regulation should still reduce exposure to HAP.

Regarding potential benefits of the rule to the general population of fish consumers, while we note that the analysis of the overall EGU sector completed for the 2023 Final A&N Review did identify significant reductions in cardiovascular and neuro-developmental effects, given the substantially smaller mercury reduction associated with this proposed rule (approximately 60 to 80 pounds per year under the proposal compared to the approximately 29 tons of mercury evaluated in the 2023 Final A&N Review), overall uncertainty associated with modeling potential benefits for the broader population of fish consumers would be sufficiently large as to compromise the utility of those benefit estimates.

Despite the lack of quantifiable risks from mercury emissions, reductions would be expected to have some impact (reduction) on the overall methylmercury burden in fish for waterbodies near covered facilities. In the Appropriate and Necessary determination, EPA illustrated that the burden of mercury exposure is not equally distributed across the population and that some subpopulations bore disproportionate risks associated with exposure to emissions from U.S. EGUs. High levels of fish consumption observed with subsistence fishing were associated with vulnerable populations, including minorities and those with low socioeconomic status (SES). Reductions in mercury emissions should reduce methylmercury exposure and body burden for subsistence fishers.

U.S. EGU mercury emissions can lead to increased deposition of mercury to nearby waterbodies. Deposition of mercury to waterbodies can also have an impact on ecosystems and wildlife. Mercury contamination is present in all environmental media with aquatic systems being particularly impacted due to bioaccumulation. Bioaccumulation refers to the net uptake of a contaminant from all possible pathways and includes the accumulation that may occur by direct exposure to contaminated media as well as uptake from food. Atmospheric mercury enters freshwater ecosystems by direct deposition and through runoff from terrestrial watersheds. Once mercury deposits, it may be converted to organic methylmercury mediated primarily by sulfate-reducing bacteria. Methylation is enhanced in anaerobic and acidic environments, greatly increasing mercury toxicity and potential to bioaccumulate in aquatic foodwebs (Munthe et al. 2007). The highest levels of methylmercury accumulation are most often measured in fish eating (piscivorous) animals and those which prey on other fish eaters. In laboratory studies, adverse effects from exposure to methylmercury in wildlife have been observed in fish, mink, otters, and several avian species at exposure levels as low as 0.25 μg/g bw/day (U.S. EPA, 1997). The risk of mercury exposure may also extend to insectivorous terrestrial species such as songbirds, bats, spiders, and amphibians that receive mercury deposition or from aquatic systems near the forest areas they inhabit (Bergeron et al., 2010, b; Cristol et al., 2008; Rimmer et al., 2005; Wada et al., 2009 & 2010). The proposed emissions reductions of mercury are expected to lower deposition of mercury into ecosystems and reduce U.S. EGU attributable bioaccumulation of methylmercury in wildlife, particularly for areas closer to the effected units subject to near-field deposition. Because mercury emissions from U.S. EGUs can both become deposited in or bioaccumulate in organisms living in foreign and international waters, reduction of mercury emissions from U.S. EGUs could lead to some benefits internationally as well. EPA is currently unable to quantify or monetize such effects.

4.2.2 Metal HAP

U.S. EGUs are the largest source of selenium (Se) emissions and a major source of metallic HAP emissions including arsenic (As), chromium (Cr), nickel (Ni), and cobalt (Co). Additionally, U.S. EGUs emit cadmium (Cd), beryllium (Be), lead (Pb), and manganese (Mn). These emissions include metal HAP that are persistent and bioaccumulative (Cd, As, and Pb) and others have the potential to cause cancer (Ni, Cr, Cd, Be, Co, and Pb). PM controls are expected to reduce metal HAP emissions and therefore reduce exposure to metal HAP for the general population including those living near these facilities.

Exposure to these metal HAP, depending on exposure duration and levels of exposures, is associated with a variety of adverse health effects. These adverse health effects may include chronic health disorders (e.g., irritation of the lung, skin, and mucus membranes; decreased pulmonary function, pneumonia, or lung damage; detrimental effects on the central nervous system; damage to the kidneys; and alimentary effects such as nausea and vomiting). As of 2023, three of the key metal HAP or their compounds emitted by EGUs (As, Cr, and Ni) have been classified as human carcinogens, while two others (Cd and Se) are classified as probable human carcinogens. See 76 FR 25003–25005 for a fuller discussion of the health effects associated with these pollutants.

The emission estimates for this source category were obtained in 2020 from two main sources: EPA's Air Markets Program Data and EPA's WebFIRE. U.S. EGU source category emissions of non-mercury HAP are not expected to exceed 1 in a million for inhalation cancer risk for those facilities impacted by the proposed controls.. Further, cancer risk was determined to fall within the acceptable range for multipathway exposure to the persistent and bioaccumulative non-mercury metal HAP, such as arsenic, cadmium, and lead.[35] However, the proposed controls should reduce levels of exposure to carcinogenic HAP in communities near the impacted facilities.

EPA also evaluated the potential for noncancer risks from exposure to non-mercury metal HAP in 2020. To address the risk from chronic inhalation exposure to multiple pollutants, we aggregated the health risks associated with pollutants that affect the same target organ. Further, we examined the potential for adverse health effects from acute inhalation exposure to individual pollutants. Lastly, we also examined the potential for health impacts stemming from multiple pathways of exposure for arsenic, cadmium, and lead. The estimated risks were not expected to exceed current health thresholds for adverse effects (U.S. EPA, 2020d). Therefore, we are unable to identify or quantify noncancer benefits from the proposed non-mercury metal HAP emission reductions, although we do note that emissions reductions associated with this rule should further reduce exposure to these non-mercury metal HAP in communities near these facilities.

4.2.3 Additional HAP Benefits

As discussed in detail in the 2023 Final A&N Review, it is challenging to quantify the full range of benefits of HAP reductions. But that does not mean that these benefits are small, insignificant, or nonexistent. In the 2011 MATS RIA (U.S. EPA, 2011), EPA discussed the potential for non-monetizable benefits from effects on fish, birds, and mammals, in part represented through the commercial and recreational fishing economy. A report submitted to EPA in comment concluded that recreational and commercial fishing are substantial contributors to regional U.S. economies with dollar values in the tens of billions (IEc, 2019). At this scale of economic activity, even small shifts in consumer behavior prompted by further HAP reductions can result in substantial economic impacts.

[35] https://www.regulations.gov/document/EPA-HQ-OAR-2018-0794-0014

As another example of the potential value of these emissions reductions, EPA received numerous comments in the public comment periods of past EGU HAP regulation highlighting that benefits of mercury reductions to tribal health, subsistence, fishing rights, and cultural identity, while not easily quantified or monetized, are nonetheless important to consider. Finally, EPA also qualitatively considers impacts on ecosystem services, which are generally defined as the economic benefits that individuals and organizations obtain from ecosystems. The monetization of endpoints like ecosystem services, tribal culture, and the activity related to fishing remains challenging. While EPA is not able to monetize the impacts of reduced HAP exposures resulting from this proposal, we note the importance of the contributions of further reductions of HAP emissions to the sustainability of these important economic and cultural values.

4.3 Criteria Pollutant Benefits

The benefits analysis presented in this section applies methods consistent with those applied most recently in the RIA for the proposed PM National Ambient Air Quality Standards (NAAQS). EPA's approach for selecting $PM_{2.5}$ and ozone-related health endpoints to quantify and monetize is detailed in the interest of brevity, we summarize our approach below and refer readers to the referenced Health Benefits TSD (U.S. EPA, 2023). In the interest of brevity, we summarize our approach below and refer readers to the referenced the Health Benefits TSD for a full description of the methodology.

Estimating the health benefits of reductions in $PM_{2.5}$ and ozone exposure begins with estimating the change in exposure for each individual and then estimating the change in each individual's risks for those health outcomes affected by exposure. The benefit of the reduction in each health risk is based on the exposed individual's willingness to pay (WTP) for the risk change, assuming that each outcome is independent of one another. The greater the magnitude of the risk reduction from a given change in concentration, the greater the individual's WTP, all else equal. The social benefit of the change in health risks equals the sum of the individual WTP estimates across all of the affected individuals residing in the U.S.[36] We conduct this analysis by

[36] This RIA also reports the change in the sum of the risk, or the change in the total incidence, of a health outcome across the population. If the benefit per unit of risk is invariant across individuals, the total expected change in the

adapting primary research—specifically, air pollution epidemiology studies and economic value studies—from similar contexts. This approach is sometimes referred to as "benefits transfer." Below we describe the procedure we follow for: (1) developing spatial fields of air quality for baseline and three regulatory control alternatives (2) selecting air pollution health endpoints to quantify; (3) calculating counts of air pollution effects using a health impact function; (4) specifying the health impact function with concentration-response parameters drawn from the epidemiological literature to calculate the economic value of the health impacts. We estimate the quantity and economic value of air pollution-related effects using a "damage-function." This approach quantifies counts of air pollution-attributable cases of adverse health outcomes and assigns dollar values to those counts, while assuming that each outcome is independent of one another.

As structured, the proposed rule would affect the distribution of ozone and $PM_{2.5}$ concentrations in much of the U.S. This RIA estimates avoided ozone- and $PM_{2.5}$-related health impacts that are distinct from those reported in the RIAs for both ozone and PM NAAQS (U.S. EPA, 2015c, 2022d) The ozone and PM NAAQS RIAs illustrate, but do not predict, the benefits and costs of strategies that states may choose to enact when implementing a revised NAAQS; these costs and benefits are illustrative and cannot be added to the costs and benefits of policies that prescribe specific emission control measures. This RIA estimates the benefits (and costs) of specific emissions control measures. The benefit estimates are based on these modeled changes in $PM_{2.5}$ and summer season average ozone concentrations.

4.3.1 Air Quality Modeling Methodology

The proposed rule influences the level of pollutants emitted in the atmosphere that adversely affect human health, including directly emitted $PM_{2.5}$, as well as SO_2 and NO_X, which are both precursors to ambient $PM_{2.5}$. NO_X emissions are also a precursor to ambient ground-level ozone. EPA used air quality modeling to estimate changes in ozone and $PM_{2.5}$ concentrations that may occur as a result of the proposed regulatory option and the more stringent regulatory option in the proposed rule relative to the baseline

incidence of the health outcome across the population can be multiplied by the benefit per unit of risk to estimate the social benefit of the total expected change in the incidence of the health outcome.

As described in the Air Quality Modeling Appendix (Appendix A), gridded spatial fields of ozone and $PM_{2.5}$ concentrations representing the baseline and two regulatory options were derived from CAMx source apportionment modeling in combination with NO_X, SO_2, and primary $PM_{2.5}$ EGU emissions obtained from the outputs of the IPM runs described in Section 3 of this RIA. While the air quality modeling includes all inventoried pollution sources in the contiguous U.S., contributions from all sources other than EGUs are held constant at projected 2026 levels in this analysis, and the only changes quantified between the baseline and the regulatory options are those associated with the projected impacts of the proposed rule on EGU emissions. EPA prepared gridded spatial fields of air quality for the baseline and the regulatory options for two health-impact metrics: annual mean $PM_{2.5}$ and April through September seasonal average eight-hour daily maximum (MDA8) ozone (AS-MO3). These ozone and $PM_{2.5}$ gridded spatial fields cover all locations in the contiguous U.S. and were used as inputs to BenMAP-CE which, in turn, was used to quantify the benefits from this proposed rule.

The basic methodology for determining air quality changes is the same as that used in the RIAs from multiple previous rules (U.S. EPA, 2019b, 2020a, 2020b, 2021, 2022c). The Air Quality Modeling Appendix (Appendix A) provides additional details on the air quality modeling and the methodologies EPA used to develop gridded spatial fields of summertime ozone and annual $PM_{2.5}$ concentrations. The appendix also provides figures showing the geographical distribution of air quality changes.

4.3.2 Selecting Air Pollution Health Endpoints to Quantify

The methods used in this RIA incorporate evidence reported in the most recent completed PM and Ozone ISAs and accounts for recommendations from the Science Advisory Board (U.S. EPA, 2022f). When updating each health endpoint 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. Our approach for updating the endpoints and to identify suitable epidemiologic studies, baseline incidence rates, population demographics, and valuation estimates is summarized below. Detailed descriptions of these updates are available in the Health Benefits TSD, which is in the docket for this rulemaking. The Health Benefits TSD fully describes the Agency's approach for quantifying the number and value of estimated air pollution-related impacts. In this document the reader can find the rationale for selecting health endpoints to quantify; the demographic, health and economic data used; modeling assumptions; and our techniques for quantifying uncertainty.[37]

[37] The analysis was completed using BenMAP-CE version 1.5.8, which is a variant of the current publicly available version.

Table 4-1 Health Effects of Ambient Ozone and $PM_{2.5}$ and Climate Effects

Category	Effect	Effect Quantified	Effect Monetized	More Information
Premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimates and expert elicitation estimates (age 65-99 or age 30-99)	✓	✓	PM ISA
	Infant mortality (age <1)	✓	✓	PM ISA
Nonfatal morbidity from exposure to $PM_{2.5}$	Heart attacks (age > 18)	✓	✓[1]	PM ISA
	Hospital admissions—cardiovascular (ages 65-99)	✓	✓	PM ISA
	Emergency department visits— cardiovascular (age 0-99)	✓	✓	PM ISA
	Hospital admissions—respiratory (ages 0-18 and 65-99)	✓	✓	PM ISA
	Emergency room visits—respiratory (all ages)	✓	✓	PM ISA
	Cardiac arrest (ages 0-99; excludes initial hospital and/or emergency department visits)	✓	✓[1]	PM ISA
	Stroke (ages 65-99)	✓	✓[1]	PM ISA
	Asthma onset (ages 0-17)	✓	✓	PM ISA
	Asthma symptoms/exacerbation (6-17)	✓	✓	PM ISA
	Lung cancer (ages 30-99)	✓	✓	PM ISA
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	✓	PM ISA
	Lost work days (age 18-65)	✓	✓	PM ISA
	Minor restricted-activity days (age 18-65)	✓	✓	PM ISA
	Hospital admissions—Alzheimer's disease (ages 65-99)	✓	✓	PM ISA
	Hospital admissions—Parkinson's disease (ages 65-99)	✓	✓	PM ISA
	Other cardiovascular effects (e.g., other ages)	—	—	PM ISA[2]
	Other respiratory effects (e.g., pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA[2]
	Other nervous system effects (e.g., autism, cognitive decline, dementia)	—	—	PM ISA[2]
	Metabolic effects (e.g., diabetes)	—	—	PM ISA[2]
	Reproductive and developmental effects (e.g., low birth weight, pre-term births, etc.)	—	—	PM ISA[2]
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA[2]
Mortality from exposure to ozone	Premature respiratory mortality based on short-term study estimates (0-99)	✓	✓	Ozone ISA
	Premature respiratory mortality based on long-term study estimates (age 30–99)	✓	✓	Ozone ISA
Nonfatal morbidity from exposure to ozone	Hospital admissions—respiratory (ages 0-99)	✓	✓	Ozone ISA
	Emergency department visits—respiratory (ages 0-99)	✓	✓	Ozone ISA
	Asthma onset (0-17)	✓	✓	Ozone ISA
	Asthma symptoms/exacerbation (asthmatics age 2-17)	✓	✓	Ozone ISA
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	✓	Ozone ISA
	Minor restricted-activity days (age 18–65)	✓	✓	Ozone ISA
	School absence days (age 5–17)	✓	✓	Ozone ISA
	Decreased outdoor worker productivity (age 18–65)	—	—	Ozone ISA[2]
	Metabolic effects (e.g., diabetes)	—	—	Ozone ISA[2]
	Other respiratory effects (e.g., premature aging of lungs)	—	—	Ozone ISA[2]

Table 4-1 Health Effects of Ambient Ozone and $PM_{2.5}$ and Climate Effects

Category	Effect	Effect Quantified	Effect Monetized	More Information
	Cardiovascular and nervous system effects	—	—	Ozone ISA[2]
	Reproductive and developmental effects	—	—	Ozone ISA[2]
Climate effects	Climate impacts from carbon dioxide (CO_2)	—	✓	Section 5.2
	Other climate impacts (e.g., ozone, black carbon, aerosols, other impacts)	—	—	IPCC, Ozone ISA, PM ISA

[1] Valuation estimate excludes initial hospital and/or emergency department visits.
[2] Not quantified due to data availability limitations and/or because current evidence is only suggestive of causality.

4.3.3 Calculating Counts of Air Pollution Effects Using the Health Impact Function

We use the environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE) software program to quantify counts of premature deaths and illnesses attributable to photochemical modeled changes in annual mean $PM_{2.5}$ and summer season average ozone concentrations for the years 2030, 2035, and 2040 using health impact functions (Sacks et al., 2020). A health impact function combines information regarding: the concentration-response relationship between air quality changes and the risk of a given adverse outcome; the population exposed to the air quality change; the baseline rate of death or disease in that population; and, the air pollution concentration to which the population is exposed.

BenMAP quantifies counts of attributable effects using health impact functions, which combine 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.

The following provides an example of a health impact function, in this case for $PM_{2.5}$ mortality risk. We estimate counts of $PM_{2.5}$-related total deaths (y_{ij}) during each year *i* among adults aged 18 and older (*a*) in each county *j* in the contiguous U.S. (where $j = 1, \ldots, J$ and *J* is the total number of counties) as:

$$y_{ij} = \Sigma_a \, y_{ija}$$

$$y_{ija} = mo_{ija} \times (e^{\beta \cdot \Delta C_{ij}} - 1) \times P_{ija}, \qquad \text{Eq[1]}$$

where mo_{ija} is the baseline total mortality rate for adults aged a = 18-99 in county j in year i stratified in 10-year age groups, β is the risk coefficient for total mortality for adults associated with annual average $PM_{2.5}$ exposure, C_{ij} is the annual mean $PM_{2.5}$ concentration in county j in year i, and P_{ija} is the number of county adult residents aged a = 18-99 in county j in year i stratified into 5-year age groups.[38]

The BenMAP-CE tool is pre-loaded with projected population from the Woods & Poole company; cause-specific and age-stratified death rates from the Centers for Disease Control and Prevention, projected to future years; recent-year baseline rates of hospital admissions, emergency department visits and other morbidity outcomes from the Healthcare Cost and Utilization Program and other sources; concentration-response parameters from the published epidemiologic literature cited in the ISAs for fine particles and ground-level ozone; and cost of illness or willingness to pay economic unit values for each endpoint.

To assess economic value in a damage-function framework, the changes in environmental quality must be translated into effects on people or on the things that people value. In some cases, the changes in environmental quality can be directly valued. In other cases, such as for changes in ozone and PM, a health and welfare impact analysis must first be conducted to convert air quality changes into effects that can be assigned dollar values.

We note at the outset that EPA rarely has the time or resources to perform extensive new research to measure directly either the health outcomes or their values for regulatory analyses. Thus, similar to work by Künzli et al. (2000) and co-authors and other, more recent health impact analyses, our estimates are based on the best available methods of benefits transfer. Benefits transfer is the science and art of adapting primary research from similar contexts to obtain the most accurate measure of benefits for the environmental quality change under analysis. Adjustments are made for the level of environmental quality change, the socio-demographic and economic characteristics of the affected population, and other factors to improve the accuracy and robustness of benefits estimates.

[38] In this illustrative example, the air quality is resolved at the county level. For this RIA, we simulate air quality concentrations at 12 km^2 grids. The BenMAP-CE tool assigns the rates of baseline death and disease stored at the county level to the 12 km^2 grid cells using an area-weighted algorithm. This approach is described in greater detail in the appendices to the BenMAP-CE user manual.

4.3.4 Calculating the Economic Valuation of Health Impacts

After quantifying the change in adverse health impacts, the final step is to estimate the economic value of these avoided impacts. The appropriate economic value for a change in a health effect depends on whether the health effect is viewed ex ante (before the effect has occurred) or ex post (after the effect has occurred). Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects by a small amount for a large population. The appropriate economic measure is therefore ex ante WTP for changes in risk. However, epidemiological studies generally provide estimates of the relative risks of a particular health effect avoided due to a reduction in air pollution. A convenient way to use these data in a consistent framework is to convert probabilities to units of avoided statistical incidences. This measure is calculated by dividing individual WTP for a risk reduction by the related observed change in risk. For example, suppose a regulation reduces the risk of premature mortality from 2 in 10,000 to 1 in 10,000 (a reduction of 1 in 10,000). If individual WTP for this risk reduction is $1000, then the WTP for an avoided statistical premature mortality amounts to $10 million ($1000/0.0001 change in risk). Hence, this value is population-normalized, as it accounts for the size of the population and the percentage of that population experiencing the risk. The same type of calculation can produce values for statistical incidences of other health endpoints.

For some health effects, such as hospital admissions, WTP estimates are generally not available. In these cases, we instead use the cost of treating or mitigating the effect to economically value the health impact. For example, for the valuation of hospital admissions we use the avoided medical costs as an estimate of the value of avoiding the health effects causing the admission. These cost-of-illness (COI) estimates generally (although not in every case) understate the true value of reductions in risk of a health effect. They tend to reflect the direct expenditures related to treatment but not the value of avoided pain and suffering from the health effect.

4.3.5 Benefits Analysis Data Inputs

In Figure 4-1, we summarize the key data inputs to the health impact and economic valuation estimates, which were calculated using BenMAP-CE tool version 1.5.1. (Sacks et al., 2020). In the sections below we summarize the data sources for each of these inputs, including demographic projections, incidence and prevalence rates, effect coefficients, and economic valuation.

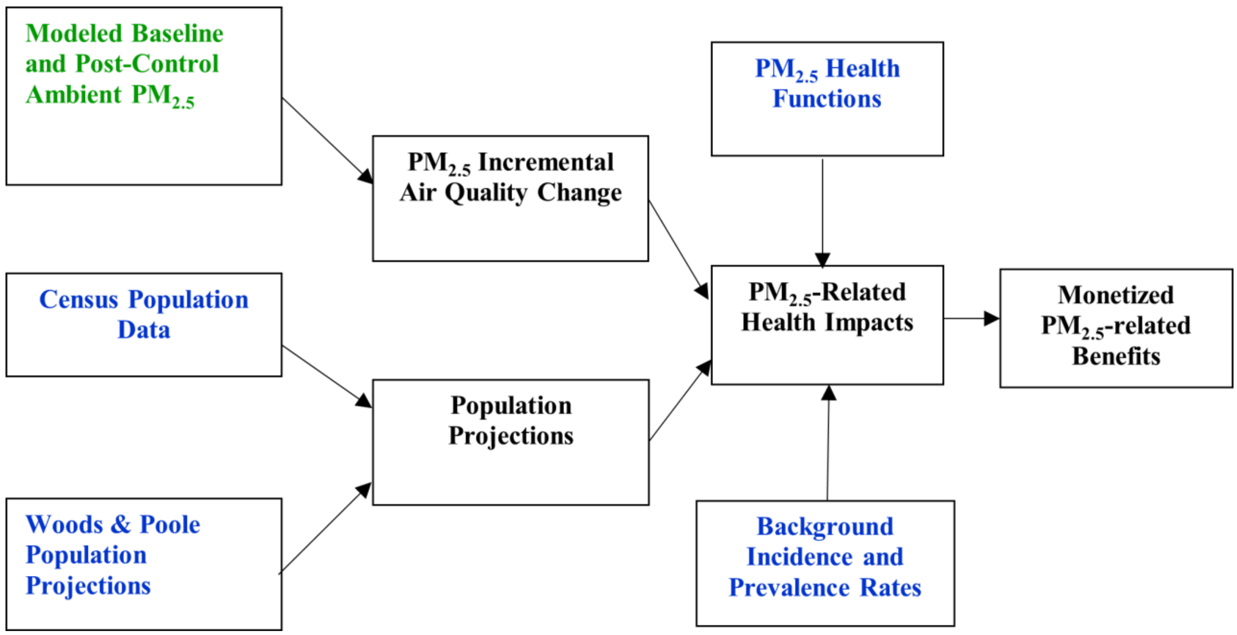


Figure 4-1 Data Inputs and Outputs for the BenMAP-CE Tool

4.3.5.1 Demographic Data

Quantified and monetized human health impacts depend on the demographic characteristics of the population, including age, location, and income. We use projections based on economic forecasting models developed by Woods & Poole, Inc. (2015). The Woods & Poole database contains county-level projections of population by age, sex, and race to 2060, relative to a baseline using the 2010 Census data. Projections in each county are determined simultaneously with every other county in the U.S. to consider patterns of economic growth and migration. The sum of growth in county-level populations is constrained to equal a previously determined national population growth, based on Bureau of Census estimates (Hollmann et al., 2000). According to Woods & Poole, linking county-level growth projections together and constraining the projected population to a national-level total growth avoids potential errors introduced by forecasting each county independently (for example, the projected sum of county-level populations cannot exceed the national total). County projections are developed in a four-stage process:

- First, national-level variables such as income, employment, and populations are forecasted.
- Second, employment projections are made for 179 economic areas defined by the Bureau of Economic Analysis, using an "export-base" approach, which relies on linking industrial-sector production of non-locally consumed production items, such as outputs from mining, agriculture, and manufacturing with the national economy. The export-based approach requires estimation of demand equations or calculation of historical growth rates for output and employment by sector.
- Third, population is projected for each economic area based on net migration rates derived from employment opportunities and following a cohort-component method based on fertility and mortality in each area.
- Fourth, employment and population projections are repeated for counties, using the economic region totals as bounds. The age, sex, and race distributions for each region or county are determined by aging the population by single year by sex and race for each year through 2060 based on historical rates of mortality, fertility, and migration.

4.3.5.2 Baseline Incidence and Prevalence Estimates

Epidemiological studies of the association between pollution levels and adverse health effects generally provide a direct estimate of the relationship of air quality changes to the relative risk of a health effect, rather than estimating the absolute number of avoided cases. For example, a typical result might be that a 5 $\mu g/m^3$ decrease in daily $PM_{2.5}$ levels is associated with a decrease in hospital admissions of 3 percent. A baseline incidence rate, necessary to convert this relative change into a number of cases, is the estimate of the number of cases of the health effect per year in the assessment location, as it corresponds to baseline pollutant levels in that location. To derive the total baseline incidence per year, this rate must be multiplied by the corresponding population number. For example, if the baseline incidence rate is the number of cases per year per million people, that number must be multiplied by the millions of people in the total population.

The Health Benefits TSD (see Table 12) summarizes the sources of baseline incidence rates and reports average incidence rates for the endpoints included in the analysis. For both baseline incidence and prevalence data, we used age-specific rates where available. We applied concentration-response functions to individual age groups and then summed over the relevant age range to provide an estimate of total population benefits. National-level incidence rates were used for most morbidity endpoints, whereas county-level data are available for premature mortality. Whenever possible, the national rates used are national averages, because these data are most applicable to a national assessment of benefits. For some studies, however, the only available incidence information comes from the studies themselves; in these cases, incidence in the study population is assumed to represent typical incidence at the national level.

We projected mortality rates such that future mortality rates are consistent with our projections of population growth. To perform this calculation, we began first with an average of 2007-2016 cause-specific mortality rates. Using Census Bureau projected national-level annual mortality rates stratified by age range, we projected these mortality rates to 2060 in 5-year increments (U.S. Census Bureau). Further information regarding this procedure may be found in the Health Benefits TSD and the appendices to the BenMAP user manual (U.S. EPA, 2022a).

The baseline incidence rates for hospital admissions and emergency department visits reflect the revised rates first applied in the Revised Cross-State Air Pollution Rule Update cross-state (U.S. EPA, 2021). In addition, we revised the baseline incidence rates for acute myocardial infarction. These revised rates are more recent than the rates they replace and more accurately represent the rates at which populations of different ages, and in different locations, visit the hospital and emergency department for air pollution-related illnesses. Lastly, these rates reflect unscheduled hospital admissions only, which represents a conservative assumption that most air pollution-related visits are likely to be unscheduled. If air pollution-related hospital admissions are scheduled, this assumption would underestimate these benefits.

4.3.5.3 Effect Coefficients

Our approach for selecting and parametrizing effect coefficients for the benefits analysis is described fully in the Health Benefits TSD. Because of the substantial economic value associated with estimated counts of $PM_{2.5}$-attributable deaths, we describe our rationale for selecting among long-term exposure epidemiologic studies below; a detailed description of all remaining endpoints may be found in the Health Benefits TSD.

A substantial body of published scientific literature documents the association between $PM_{2.5}$ concentrations and the risk of premature death integrated (U.S. EPA, 2019a, 2022f). This body of literature reflects thousands of epidemiology, toxicology, and clinical studies. The PM ISA, completed as part of this review of the filterable PM standards and reviewed by the Clean Air Scientific Advisory Committee (CASAC) (U.S. EPA Science Advisory Board, 2022) concluded that there is a causal relationship between mortality and both long-term and short-term exposure to $PM_{2.5}$ based on the full body of scientific evidence. The size of the mortality effect estimates from epidemiologic studies, the serious nature of the effect itself, and the high monetary value ascribed to prolonging life make mortality risk reduction the most significant health endpoint quantified in this analysis.

EPA selects Hazard Ratios from cohort studies to estimate counts of PM-related premature death, following a systematic approach detailed in the Health Benefits TSD accompanying this RIA that is generally consistent with previous RIAs (e.g. (U.S. EPA, 2019b, 2020a, 2020b, 2021, 2022c)). Briefly, clinically significant epidemiologic studies of health endpoints for which ISAs report strong evidence are evaluated using established minimum and preferred criteria for identifying studies and hazard ratios best characterizing risk. Following this systematic approach led to the identification of three studies best characterizing the risk of premature death associated with long-term exposure to $PM_{2.5}$ in the U.S. (Pope et al., 2019; Turner et al., 2016; Wu et al., 2020). The PM ISA, Supplement to the ISA, and 2022 Policy Assessment also identified these three studies as providing key evidence of the association between long-term $PM_{2.5}$ exposure and mortality. These studies used data from three U.S. cohorts: (1) an analysis of Medicare beneficiaries (Medicare); (2) the American Cancer Society (ACS); and (3) the National Health Interview Survey (NHIS). As premature mortality typically constitutes the vast majority of monetized benefits in a $PM_{2.5}$ benefits assessment, quantifying effects using risk estimates reported from multiple long-term exposure studies using different cohorts helps account for uncertainty in the estimated number of PM-related premature deaths. Below we summarize the three identified studies and hazard ratios and then describe our rationale for quantifying premature PM-attributable deaths using two of these studies.

Wu et al., 2020 evaluated the relationship between long-term $PM_{2.5}$ exposure and all-cause mortality in more than 68.5 million Medicare enrollees (over the age of 64), using Medicare claims data from 2000-2016 representing over 573 million person-years of follow up and over 27 million deaths. This cohort included over 20 percent of the U.S. population and was, at the time of publishing, the largest air pollution study cohort to date. The authors modeled $PM_{2.5}$ exposure at a 1 km^2 grid resolution using a hybrid ensemble-based prediction model that combined three machine learning models and relied on satellite data, land-use information, weather variables, chemical transport model simulation outputs, and monitor data. Wu et al., 2020 fit five different statistical models: a Cox proportional hazards model, a Poisson regression model, and three causal inference approaches (GPS estimation, GPS matching, and GPS weighting). All five statistical approaches provided consistent results; we report the results of the Cox proportional hazards model here. The authors adjusted for numerous individual-level and community-level confounders, and sensitivity analyses suggest that the results are robust to unmeasured confounding bias. In a single-pollutant model, the coefficient and standard error for $PM_{2.5}$ are estimated from the hazard ratio (1.066) and 95 percent confidence interval (1.058-1.074) associated with a change in annual mean $PM_{2.5}$ exposure of 10.0 µg/m^3 (Wu et al., 2020, Table S3, Main analysis, 2000-2016 Cohort, Cox PH). We use a risk estimate from this study in place of the risk estimate from (Di et al., 2017). These two epidemiologic studies share many attributes, including the Medicare cohort and statistical model used to characterize population exposure to $PM_{2.5}$. As compared to Di et al., 2017, Wu et al., 2020 includes a longer follow-up period and reflects more recent $PM_{2.5}$ concentrations.

Pope III et al., 2019 examined the relationship between long-term $PM_{2.5}$ exposure and all-cause mortality in a cohort of 1,599,329 U.S. adults (aged 18-84 years) who were interviewed in the National Health Interview Surveys (NHIS) between 1986 and 2014 and linked to the National Death Index (NDI) through 2015. The authors also constructed a sub-cohort of 635,539 adults from the full cohort for whom body mass index (BMI) and smoking status data were available. The authors employed a hybrid modeling technique to estimate annual-average $PM_{2.5}$ concentrations derived from regulatory monitoring data and constructed in a universal kriging framework using geographic variables including land use, population, and satellite estimates. Pope et al., 2019 assigned annual-average $PM_{2.5}$ exposure from 1999-2015 to each individual by census tract and used complex (accounting for NHIS's sample design) and simple Cox proportional hazards models for the full cohort and the sub-cohort. We select the Hazard Ratio calculated using the complex model for the sub-cohort, which controls for individual-level covariates including age, sex, race-ethnicity, inflation-adjusted income, education level, marital status, rural versus urban, region, survey year, BMI, and smoking status. In a single-pollutant model, the coefficient and standard error for $PM_{2.5}$ are estimated from the hazard ratio (1.12) and 95 percent confidence interval (1.08-1.15) associated with a change in annual mean $PM_{2.5}$ exposure of 10.0 µg/m^3 (Pope et al., 2019, Table 2, Subcohort). This study exhibits two key strengths that makes it particularly well suited for a benefits analysis: (1) it includes a long follow-up period with recent (and thus relatively low) $PM_{2.5}$ concentrations; (2) the NHIS cohort is representative of the U.S. population, especially with respect to the distribution of individuals by race, ethnicity, income, and education.

EPA has historically used estimated Hazard Ratios from extended analyses of the ACS cohort (Krewski et al., 2009; Pope et al., 2002; Pope et al., 1995) to estimate PM-related risk of premature death. More recent ACS analyses (Turner et al. 2016):

- extended the follow-up period of the ACS CSP-II to 22 years (1982-2004),
- evaluated 669,046 participants over 12,662,562 person-years of follow up and 237,201 observed deaths, and
- applied a more advanced exposure estimation approach than had previously been used when analyzing the ACS cohort, combining the geostatistical Bayesian Maximum Entropy framework with national-level land use regression models.

The total mortality hazard ratio best estimating risk from these ACS cohort studies was based on a random-effects Cox proportional hazard model incorporating multiple individual and ecological covariates (relative risk =1.06, 95 percent confidence intervals 1.04–1.08 per 10µg/m^3 increase in $PM_{2.5}$) from Turner et al., 2016. The relative risk estimate is identical to a risk estimate drawn from earlier ACS analysis of all-cause long-term exposure $PM_{2.5}$-attributable mortality (Krewski et al., 2009). However, as the ACS hazard ratio is quite similar to the Medicare estimate of (1.066, 1.058-1.074), especially when considering the broader age range (greater than 29 versus greater than 64), only the Wu et al., 2020 and Pope et al., 2019 are included in the main benefits assessments, with Wu et al., 2020 representing results from both the Medicare and ACS cohorts.

4.3.6 Quantifying Cases of Ozone-Attributable Premature Death

Mortality risk reductions account for the majority of monetized ozone-related and $PM_{2.5}$-related benefits. For this reason, this subsection and the following provide a brief background of the scientific assessments that underly the quantification of these mortality risks and identifies the risk studies used to quantify them in this RIA, for ozone and $PM_{2.5}$ respectively. As noted above, (U.S. EPA, 2023) describes fully the Agency's approach for quantifying the number and value of ozone and $PM_{2.5}$ air pollution-related impacts, including additional discussion of how the Agency selected the risk studies used to quantify them in this RIA. The Health Benefits TSD also includes additional discussion of the assessments that support quantification of these mortality risk than provide here.

In 2008, the National Academies of Science (NRC, 2008) issued a series of recommendations to EPA regarding the procedure for quantifying and valuing ozone-related mortality due to short-term exposures. Chief among these was that "…short-term exposure to ambient ozone is likely to contribute to premature deaths" and the committee recommended that "ozone-related mortality be included in future estimates of the health benefits of reducing ozone exposures…" The NAS also recommended that "…the greatest emphasis be placed on the multicity and [National Mortality and Morbidity Air Pollution Studies (NMMAPS)] …studies without exclusion of the meta-analyses" (NRC, 2008). Prior to the 2015 Ozone NAAQS RIA, the Agency estimated ozone-attributable premature deaths using an NMMAPS-based analysis of total mortality (Bell et al., 2004), two multi-city studies of cardiopulmonary and total mortality (Huang et al., 2005; Schwartz, 2005) and effect estimates from three meta-analyses of non-accidental mortality (Bell et al., 2005; Ito et al., 2005; Levy et al., 2005). Beginning with the 2015 Ozone NAAQS RIA, the Agency began quantifying ozone-attributable premature deaths using two newer multi-city studies of non-accidental mortality smith (Smith et al., 2009; Zanobetti and Schwartz, 2008) and one long-term cohort study of respiratory mortality (Jerrett et al. 2009). The 2020 Ozone ISA included changes to the causality relationship determinations between short-term exposures and total mortality, as well as including more recent epidemiologic analyses of long-term exposure effects on respiratory mortality. We estimate counts of ozone-attributable respiratory death from short-term exposures a pooled risk estimate calculated using parameters from Zanobetti and Schwartz (2008) and Katsouyanni et al. (2009).Consistent with the RIA for the Final Revised Cross-State Air Pollution Rule (CSAPR) Update for the 2008 Ozone NAAQSRCU analysis (U.S. EPA, 2021), we use two estimates of ozone-attributable respiratory deaths from short-term exposures are estimated using the risk estimate parameters from Zanobetti and Schwartz (2008) and Katsouyanni et al. (2009). Ozone-attributable respiratory deaths from long-term exposures are estimated using Turner et al. (2016). Due to time and resource limitations, we were unable to reflect the warm season defined by Zanobetti and Schwartz (2008) as June-August. Instead, we apply this risk estimate to our standard warm season of May-September.

4.3.7 *Quantifying Cases of $PM_{2.5}$-Attributable Premature Death*

When quantifying PM-attributable cases of adult mortality, we use the effect coefficients from two epidemiology studies examining two large population cohorts: the American Cancer Society cohort (Turner et al., 2016) and the Medicare cohort (Di et al., 2017). The Integrated Science Assessment for Particulate Matter (PM ISA) (U.S. EPA, 2019a) indicates that the ACS and Medicare cohorts provide strong evidence of an association between long-term $PM_{2.5}$ exposure and premature mortality with support from additional cohort studies. There are distinct attributes of both the ACS and Medicare cohort studies that make them well-suited to being used in a PM benefits assessment and so here we present $PM_{2.5}$ related effects derived using relative risk estimates from both cohorts.

The PM ISA, which was reviewed by the Clean Air Scientific Advisory Committee of EPA's Science Advisory Board (U.S. EPA Science Advisory Board, 2022), concluded that there is a causal relationship between mortality and both long-term and short-term exposure to $PM_{2.5}$ based on the entire body of scientific evidence. The PM ISA also concluded that the scientific literature supports the use of a no-threshold log-linear model to portray the PM-mortality concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response relationship. The 2019 PM ISA, which informed the setting of the 2020 PM NAAQS, reviewed available studies that examined the potential for a population-level threshold to exist in the concentration-response relationship. Based on such studies, the ISA concluded that the evidence supports the use of a "no-threshold" model and that "little evidence was observed to suggest that a threshold exists" (U.S. EPA, 2009a). Consistent with this evidence, the Agency historically has estimated health impacts above and below the prevailing NAAQS (U.S. EPA, 2019b, 2021, 2022c)

4.3.8 *Characterizing Uncertainty in the Estimated Benefits*

In any complex analysis using estimated parameters and inputs from numerous models, there are likely to be many sources of uncertainty. This analysis is no exception. The Health Benefits TSD details our approach to characterizing uncertainty in both quantitative and qualitative terms (U.S. EPA, 2023). The Health Benefits TSD describes the sources of uncertainty associated with key input parameters 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 country (i.e., regulations, technology, and human behavior). Each of these inputs is uncertain and affects the size and distribution of the estimated benefits. When the uncertainties from each stage of the analysis are compounded, even small uncertainties can have large effects on the total quantified benefits.

To characterize uncertainty and variability into this assessment, we incorporate three quantitative analyses described below and in greater detail within the Health Benefits TSD (Section 7.1):

1. A Monte Carlo assessment that accounts for random sampling error and between study variability in the epidemiological and economic valuation studies;
2. The quantification of PM-related mortality using alternative $PM_{2.5}$ mortality effect estimates drawn from two long-term cohort studies; and
3. Presentation of 95th percentile confidence interval around each risk estimate.

Quantitative characterization of other sources of $PM_{2.5}$ uncertainties are discussed only in Section 7.1 of the Health Benefits TSD:

1. For adult all-cause mortality:
    a. The distributions of air quality concentrations experienced by the original cohort population (Health Benefits TSD Section 7.1.2.1);
    b. Methods of estimating and assigning exposures in epidemiologic studies (Health Benefits TSD Section 7.1.2.2);
    c. Confounding by ozone (Health Benefits TSD Section 7.1.2.3); and
    d. The statistical technique used to generate hazard ratios in the epidemiologic study (Health Benefits TSD Section 7.1.2.4).
2. Plausible alternative risk estimates for asthma onset in children (TSD Section 7.1.3), cardiovascular hospital admissions (Health Benefits TSD Section 7.1.4,), and respiratory hospital admissions (Health Benefits TSD Section 7.1.5);
3. Effect modification of $PM_{2.5}$-attributable health effects in at-risk populations (Health Benefits TSD Section 7.1.6).

Quantitative consideration of baseline incidence rates and economic valuation estimates are provided in Section 7.3 and 7.4 of the Health Benefits TSD, respectively. Qualitative discussions of various sources of uncertainty can be found in Section 7.5 of the Health Benefits TSD.

4.3.8.1 Monte Carlo Assessment

Similar to other recent RIAs, we used Monte Carlo methods for characterizing random sampling error associated with the concentration response functions from epidemiological studies and random effects modeling to characterize both sampling error and variability across the economic valuation functions. The Monte Carlo simulation in the BenMAP-CE software randomly samples from a distribution of incidence and valuation estimates to characterize the effects of uncertainty on output variables. Specifically, we used Monte Carlo methods to generate confidence intervals around the estimated health impact and monetized benefits. The reported standard errors in the epidemiological studies determined the distributions for individual effect estimates for endpoints estimated using a single study. For endpoints estimated using a pooled estimate of multiple studies, the confidence intervals reflect both the standard errors and the variance across studies. The confidence intervals around the monetized benefits incorporate the epidemiology standard errors as well as the distribution of the valuation function. These confidence intervals do not reflect other sources of uncertainty inherent within the estimates, such as baseline incidence rates, populations exposed, and transferability of the effect estimate to diverse locations. As a result, the reported confidence intervals and range of estimates give an incomplete picture about the overall uncertainty in the benefits estimates.

4.3.8.2 Sources of Uncertainty Treated Qualitatively

Although we strive to incorporate as many quantitative assessments of uncertainty as possible, there are several aspects we are only able to address qualitatively. These attributes are summarized below and described more fully in the Health Benefits TSD.

Key assumptions underlying the estimates for premature mortality, which account for over 98 percent of the total monetized benefits in this analysis, include the following:

1. We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ varies considerably in composition across sources, but the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. The PM ISA, which was reviewed by CASAC, concluded that “across exposure durations and health effects categories … the evidence does not indicate that any one

source or component is consistently more strongly related with health effects than $PM_{2.5}$ mass" (U.S. EPA Science Advisory Board, 2022).

2. We assume that the health impact function for fine particles is log-linear down to the lowest air quality levels modeled in this analysis. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5}$, including both regions that are in attainment with the fine particle standard and those that do not meet the standard down to the lowest modeled concentrations. The PM ISA concluded that "the majority of evidence continues to indicate a linear, no-threshold concentration-response relationship for long-term exposure to $PM_{2.5}$ and total (nonaccidental) mortality" (U.S. EPA Science Advisory Board, 2022).

3. We assume that there is a "cessation" lag between the change in PM exposures and the total realization of changes in mortality effects. Specifically, we assume that some of the incidences of premature mortality related to $PM_{2.5}$ exposures occur in a distributed fashion over the 20 years following exposure based on the advice of the board (U.S. EPA Science Advisory Board, 2004), which affects the valuation of mortality benefits at different discount rates. Similarly, we assume there is a cessation lag between the change in PM exposures and both the development and diagnosis of lung cancer.

4.3.9 Estimated Number and Economic Value of Health Benefits

To directly compare benefits estimates associated with a rulemaking to cost estimates, the number of instances of each air pollution-attributable health impact must be converted to a monetary value. This requires a valuation estimate for each unique health endpoint, and potentially also discounting if the benefits are expected to accrue over more than a single year, as recommended by the Guidelines for Preparing Economic Analyses (U.S. EPA, 2014). Below we report the estimated number of reduced premature deaths and illnesses in each year relative to the baseline along with the 95 percent confidence interval (Table 4-2 and Table 4-3 for ozone-related health impacts and Table 4-4 and Table 4-5 for $PM_{2.5}$-related impacts). The number of reduced estimated deaths and illnesses from the proposed regulatory option and more stringent regulatory alternative are calculated from the sum of individual reduced mortality and illness risk across the population.

To directly compare benefits estimates associated with a rulemaking to cost estimates, the number of instances of each air pollution-attributable health impact must be converted to a monetary value. This requires a valuation estimate for each unique health endpoint, and potentially also discounting if the benefits are expected to accrue over more than a single year, as recommended by the U.S. EPA (2014). Table 4-6 and Table 4-7 report the estimated economic value of avoided premature deaths and illness in each year relative to the baseline along with the 95 percent confidence interval. We also report the stream of benefits from 2028 through 2037 for the proposed regulatory option and the unselected more stringent regulatory alternative, using the monetized sums of long-term ozone and $PM_{2.5}$ mortality and morbidity impacts (Table 4-8 and Table 4-9).[39] Note the less stringent regulatory alternative has no quantified emissions reductions associated with the proposed requirements for PM CEMS and the removal of startup definition number two. As a result, there are no quantified benefits associated with this regulatory option.

Table 4-2 Estimated Avoided Ozone-Related Premature Respiratory Mortalities and Illnesses for the Proposed Regulatory Option for 2028, 2030, and 2035 (95 percent confidence interval) [a]

		2028	2030	2035
Avoided premature respiratory mortalities				
Long-term exposure	Turner et al. (2016)[b]	2.6 (1.8 to 3.4)	5.7 (3.9 to 7.4)	15 (10 to 19)
Short-term exposure	Katsouyanni et al. (2009)[b,c] and Zanobetti et al. (2008)[c] pooled	0.12 (0.048 to 0.19)	0.26 (0.10 to 0.40)	0.66 (0.27 to 1.0)
Morbidity effects				
Long-term exposure	Asthma onset[d]	19 (16 to 22)	37 (31 to 42)	95 (82 to 110)
	Allergic rhinitis symptoms[f]	110 (59 to 160)	210 (110 to 310)	560 (300 to 820)
Short-term exposure	Hospital admissions—respiratory[c]	0.33 (-0.087 to 0.74)	0.71 (-0.18 to 1.6)	1.9 (-0.49 to 4.2)
	ED visits—respiratory[e]	6.3 (1.7 to 13)	13 (3.5 to 27)	32 (8.9 to 68)
	Asthma symptoms	3,600 (-440 to 7,500)	6,900 (-850 to 14,000)	18,000 (-2,200 to 37,000)
	Minor restricted-activity days[c,e]	1,700 (680 to 2,700)	3,300 (1,300 to 5,100)	8,100 (3,300 to 13,000)
	School absence days	1,300 (-180 to 2,700)	2,500 (-350 to 5,200)	6,500 (-910 to 14,000)

[a] Values rounded to two significant figures.
[b] Applied risk estimate derived from April-September exposures to estimates of ozone across the May-September warm season.
[c] Converted ozone risk estimate metric from MDA1 to MDA8.
[d] Applied risk estimate derived from June-August exposures to estimates of ozone across the May-September warm season.
[e] Applied risk estimate derived from full year exposures to estimates of ozone across the May-September warm season.
[f] Converted ozone risk estimate metric from DA24 to MDA8.

[39] EPA continues to refine its approach for estimating and reporting PM-related effects at lower concentrations. The Agency acknowledges the additional uncertainty associated with effects estimated at these lower levels and seeks to develop quantitative approaches for reflecting this uncertainty in the estimated PM benefits.

Table 4-3 Estimated Avoided Ozone-Related Premature Respiratory Mortalities and Illnesses for the More Stringent Regulatory Option for 2028, 2030, and 2035 (95 percent confidence interval) [a]

		2028	2030	2035
Avoided premature respiratory mortalities				
Long-term exposure	Turner et al. (2016)[b]	51 (35 to 66)	40 (28 to 52)	39 (27 to 51)
Short-term exposure	Katsouyanni et al. (2009)[b,c] and Zanobetti et al. (2008)[c] pooled	2.3 (0.92 to 3.6)	1.8 (0.73 to 2.9)	1.8 (0.72 to 2.8)
Morbidity effects				
Long-term exposure	Asthma onset[d]	370 (320 to 420)	270 (230 to 310)	250 (220 to 290)
	Allergic rhinitis symptoms[f]	2,100 (1,100 to 3,100)	1,600 (840 to 2,300)	1,500 (790 to 2,200)
Short-term exposure	Hospital admissions—respiratory[c]	6.3 (-1.6 to 14)	5.0 (-1.3 to 11)	5.2 (-1.3 to 11)
	ED visits—respiratory[e]	120 (33 to 250)	87 (24 to 180)	89 (24 to 190)
	Asthma symptoms	69,000 (-8,500 to 140,000)	51,000 (-6,300 to 110,000)	48,000 (-5,900 to 99,000)
	Minor restricted-activity days[c,e]	32,000 (13,000 to 51,000)	23,000 (9,400 to 37,000)	22,000 (8,800 to 35,000)
	School absence days	24,000 (-3,400 to 51,000)	18,000 (-2,600 to 38,000)	17,000 (-2,400 to 36,000)

[a] Values rounded to two significant figures.

[b] Applied risk estimate derived from April-September exposures to estimates of ozone across the May-September warm season.

[c] Converted ozone risk estimate metric from MDA1 to MDA8.

[d] Applied risk estimate derived from June-August exposures to estimates of ozone across the May-September warm season.

[e] Applied risk estimate derived from full year exposures to estimates of ozone across the May-September warm season.

[f] Converted ozone risk estimate metric from DA24 to MDA8.

Table 4-4 Estimated Avoided $PM_{2.5}$-Related Premature Respiratory Mortalities and Illnesses for the Proposed Regulatory Option in 2028, 2030, and 2035 (95 percent confidence interval)

Avoided Mortality	**2028**	**2030**	**2035**
(Pope et al., 2019) (adult mortality ages 18-99 years)	11 (7.7 to 14)	8.2 (5.8 to 10)	15 (11 to 19)
(Wu et al., 2020) (adult mortality ages 65-99 years)	5.1 (4.5 to 5.7)	4.0 (3.5 to 4.4)	7.4 (6.5 to 8.2)
(Woodruff et al., 2008) (infant mortality)	0.013 (-0.0079 to 0.032)	0.0079 (-0.0049 to 0.020)	0.014 (-0.0087 to 0.036)
Avoided Morbidity	**2028**	**2030**	**2035**
Hospital admissions—cardiovascular (age > 18)	0.76 (0.55 to 0.96)	0.57 (0.41 to 0.72)	1.1 (0.78 to 1.4)
Hospital admissions—respiratory	0.42 (0.19 to 0.65)	0.27 (0.12 to 0.41)	0.48 (0.21 to 0.74)
ED visits--cardiovascular	1.6 (-0.61 to 3.7)	1.1 (-0.44 to 2.7)	2.2 (-0.84 to 5.1)
ED visits—respiratory	3.1 (0.61 to 6.4)	2.2 (0.44 to 4.7)	4.2 (0.82 to 8.7)
Acute Myocardial Infarction	0.17 (0.10 to 0.25)	0.13 (0.073 to 0.18)	0.24 (0.14 to 0.33)
Cardiac arrest	0.082 (-0.033 to 0.19)	0.059 (-0.024 to 0.13)	0.11 (-0.044 to 0.24)
Hospital admissions--Alzheimer's Disease	2.6 (1.9 to 3.2)	1.7 (1.3 to 2.1)	3.8 (2.9 to 4.8)
Hospital admissions--Parkinson's Disease	0.35 (0.18 to 0.51)	0.28 (0.14 to 0.41)	0.49 (0.25 to 0.72)
Stroke	0.32 (0.084 to 0.55)	0.24 (0.062 to 0.41)	0.44 (0.11 to 0.76)
Lung cancer	0.37 (0.11 to 0.61)	0.27 (0.082 to 0.45)	0.52 (0.16 to 0.87)
Hay Fever/Rhinitis	82 (20 to 140)	55 (13 to 95)	100 (24 to 170)
Asthma Onset	13 (12 to 13)	8.4 (8.1 to 8.8)	15 (15 to 16)
Asthma symptoms – Albuterol use	2,400 (-1,200 to 5,800)	1,600 (-780 to 3,900)	2,900 (-1,400 to 7,200)
Lost work days	630 (530 to 720)	420 (360 to 490)	770 (650 to 880)
Minor restricted-activity days	3,700 (3,000 to 4,400)	2,500 (2,000 to 2,900)	4,500 (3,700 to 5,300)

Note: Values rounded to two significant figures.

Table 4-5 Estimated Avoided $PM_{2.5}$-Related Premature Respiratory Mortalities and Illnesses for the More Stringent Regulatory Option in 2028, 2030, and 2035 (95 percent confidence interval)[a,b]

Avoided Mortality	2028	2030	2035
(Pope et al., 2019) (adult mortality ages 18-99 years)	240 (170 to 300)	38 (27 to 48)	96 (69 to 120)
(Wu et al., 2020) (adult mortality ages 65-99 years)	110 (100 to 130)	19 (16 to 21)	47 (41 to 52)
(Woodruff et al., 2008) (infant mortality)	0.24 (-0.15 to 0.63)	0.031 (-0.019 to 0.080)	0.10 (-0.064 to 0.26)
Avoided Morbidity	**2028**	**2030**	**2035**
Hospital admissions—cardiovascular (age > 18)	18 (13 to 22)	2.7 (2.0 to 3.5)	6.9 (5.0 to 8.7)
Hospital admissions—respiratory	8.0 (3.5 to 12)	0.83 (0.36 to 1.3)	3.5 (1.5 to 5.4)
ED visits--cardiovascular	35 (-14 to 83)	5.8 (-2.2 to 13)	14 (-5.5 to 34)
ED visits—respiratory	68 (13 to 140)	10 (2.0 to 22)	27 (5.4 to 57)
Acute Myocardial Infarction	3.9 (2.3 to 5.5)	0.55 (0.32 to 0.77)	1.6 (0.93 to 2.2)
Cardiac arrest	1.8 (-0.72 to 4.0)	0.27 (-0.11 to 0.62)	0.69 (-0.28 to 1.6)
Hospital admissions--Alzheimer's Disease	56 (42 to 70)	2.0 (1.5 to 2.5)	26 (19 to 32)
Hospital admissions--Parkinson's Disease	7.7 (3.9 to 11)	1.2 (0.61 to 1.8)	3.0 (1.5 to 4.4)
Stroke	7.5 (1.9 to 13)	1.2 (0.30 to 2.0)	2.8 (0.73 to 4.8)
Lung cancer	8.2 (2.5 to 14)	1.3 (0.40 to 2.2)	3.3 (1.0 to 5.5)
Hay Fever/Rhinitis	1,500 (360 to 2,600)	220 (54 to 390)	670 (160 to 1,200)
Asthma Onset	230 (220 to 240)	35 (33 to 36)	100 (98 to 110)
Asthma symptoms – Albuterol use	43,000 (-21,000 to 100,000)	6,600 (-3,200 to 16,000)	20,000 (-9,600 to 48,000)
Lost work days	12,000 (10,000 to 14,000)	1,800 (1,600 to 2,100)	5,000 (4,200 to 5,800)
Minor restricted-activity days[d,f]	70,000 (57,000 to 83,000)	11,000 (8,800 to 13,000)	30,000 (24,000 to 35,000)

[a] Values rounded to two significant figures.

[b] We estimated ozone benefits for changes in NOx for the ozone season and changes in $PM_{2.5}$ and $PM_{2.5}$ precursors for EGUs in 2026.

[c] Applied risk estimate derived from April-September exposures to estimates of ozone across the May-September warm season.

[d] Converted ozone risk estimate metric from MDA1 to MDA8.

[e] Applied risk estimate derived from June-August exposures to estimates of ozone across the May-September warm season.

[f] Applied risk estimate derived from full year exposures to estimates of ozone across the May-September warm season.

[g] Converted ozone risk estimate metric from DA24 to MDA8.

Table 4-6 Estimated Discounted Economic Value of Avoided Ozone and $PM_{2.5}$-Attributable Premature Mortality and Illness for the Proposed Regulatory Option in 2028, 2030, and 2035 (95 percent confidence interval; millions of 2019 dollars)[a,b]

Disc. Rate	Pollutant	2028	2030	2035
3%	Ozone Benefits	$4 ($1 to $8) *and* $30 ($3 to $78)	$7 ($2 to $16) *and* $64 ($7 to $170)	$19 ($5 to $41) *and* $170 ($18 to $450)
	$PM_{2.5}$ Benefits	$55 ($6 to $140) *and* $110 ($11 to $300)	$43 ($4 to $110) *and* $87 ($8 to $230)	$81 ($8 to $210) *and* $160 ($15 to $430)
	Ozone plus $PM_{2.5}$ Benefits	$59 ($7 to $150)[c] *and* $140 ($14 to $380)[d]	$50 ($6 to $130)[c] *and* $150 ($15 to $400)[d]	$100 ($13 to $250)[c] *and* $330 ($33 to $880)[d]
7%	Ozone Benefits	$3 ($1 to $7) *and* $27 ($3 to $70)	$7 ($1 to $15) *and* $58 ($6 to $150)	$17 ($3 to $39) *and* $150 ($15 to $400)
	$PM_{2.5}$ Benefits	$49 ($5 to $130) *and* $100 ($10 to $270)	$39 ($4 to $100) *and* $79 ($7 to $210)	$73 ($7 to $190) *and* $150 ($14 to $390)
	Ozone plus $PM_{2.5}$ Benefits	$52 ($6 to $140)[c] *and* $130 ($12 to $340)[d]	$46 ($5 to $120)[c] *and* $140 ($13 to $360)[d]	$90 ($10 to $230)[c] *and* $300 ($29 to $790)[d]

[a] Values rounded to two significant figures. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates and should not be summed.
[b] We estimated changes in NO_X for the ozone season and changes in $PM_{2.5}$ and $PM_{2.5}$ precursors in 2028, 2030, and 2035.
[c] Sum of ozone mortality estimated using the pooled short-term ozone exposure risk estimate and the Wu et al. (2020) long-term $PM_{2.5}$ exposure mortality risk estimate.
[d] Sum of the Turner et al. (2016) long-term ozone exposure risk estimate and the Pope et al. (2019) long-term $PM_{2.5}$ exposure mortality risk estimate.

Table 4-7 Estimated Discounted Economic Value of Avoided Ozone and $PM_{2.5}$-Attributable Premature Mortality and Illness for the More Stringent Regulatory Option in 2028, 2030, and 2035 (95 percent confidence interval; millions of 2019 dollars)[a,b]

Disc. Rate	Pollutant	2028			2030			2035		
3%	Ozone Benefits	$69 ($17 to $150)	*and*	$570 ($62 to $1,500)	$53 ($13 to $110)	*and*	$460 ($48 to $1,200)	$51 ($12 to $110)	*and*	$460 ($48 to $1,200)
	$PM_{2.5}$ Benefits	$1,200 ($120 to $3,200)	*and*	$2,500 ($240 to $6,700)	$200 ($20 to $520)	*and*	$410 ($38 to $1,100)	$520 ($53 to $1,300)	*and*	$1,100 ($99 to $2,800)
	Ozone plus $PM_{2.5}$ Benefits	$1,300 ($140 to $3,400)[c]	*and*	$3,100 ($300 to $8,200)[d]	$250 ($33 to $630)[c]	*and*	$870 ($86 to $2,300)[d]	$570 ($65 to $1,400)[c]	*and*	$1,600 ($150 to $4,000)[d]
7%	Ozone Benefits	$62 ($11 to $140)	*and*	$510 ($51 to $1,300)	$48 ($8 to $110)	*and*	$410 ($40 to $1,100)	$46 ($8 to $110)	*and*	$410 ($40 to $1,100)
	$PM_{2.5}$ Benefits	$1,100 ($110 to $2,900)	*and*	$2,300 ($210 to $6,000)	$180 ($18 to $470)	*and*	$370 ($34 to $970)	$470 ($46 to $1,200)	*and*	$950 ($88 to $2,500)
	Ozone plus $PM_{2.5}$ Benefits	$1,200 ($120 to $3,000)[c]	*and*	$2,800 ($260 to $7,300)[d]	$230 ($26 to $580)[c]	*and*	$780 ($74 to $2,100)[d]	$520 ($54 to $1,300)[c]	*and*	$1,400 ($130 to $3,600)[d]

[a] Values rounded to two significant figures. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates and should not be summed.
[b] We estimated changes in NO_X for the ozone season and changes in $PM_{2.5}$ and $PM_{2.5}$ precursors in 2028, 2030, and 2035.
[c] Sum of ozone mortality estimated using the pooled short-term ozone exposure risk estimate and the Wu et al. (2020) long-term $PM_{2.5}$ exposure mortality risk estimate.
[d] Sum of the Turner et al. (2016) long-term ozone exposure risk estimate and the Pope et al. (2019) long-term $PM_{2.5}$ exposure mortality risk estimate.

Table 4-8 Stream of Estimated Human Health Benefits from 2028 through 2037: Monetized Benefits Quantified as Sum of Long-Term Ozone Mortality and Long-Term $PM_{2.5}$ Mortality (discounted at 3 percent; millions of 2019 dollars)[a]

Year	Proposed Regulatory Option	More Stringent Regulatory Option
2028*	$140	$3,100
2029	$150	$840
2030*	$150	$860
2031	$160	$890
2032	$310	$1,400
2033	$320	$1,400
2034	$320	$1,500
2035*	$330	$1,500
2036	$340	$1,600
2037	$350	$1,600
Present Value	**$1,900**	**$11,000**
Equivalent Annualized Value	**$220**	**$1,300**

*Year in which air quality models were run. Benefits for all other years were extrapolated from years with model-based air quality estimates. Benefits calculated as value of avoided: $PM_{2.5}$-attributable deaths (quantified using a concentration-response relationship from the Wu et al. 2020 study and the Pope et al. 2019 study); Ozone-attributable deaths (quantified using a concentration-response relationship from the Turner et al. 2017 study); and $PM_{2.5}$ and ozone-related morbidity effects.

[a] For the years 2023 to 2027, benefits associated with emissions reductions are not included as implementation of standards will not be complete until 2028.

Table 4-9 Stream of Estimated Human Health Benefits from 2028 through 2037: Monetized Benefits Quantified as Sum of Long-Term Ozone Mortality and Long-Term $PM_{2.5}$ Mortality (discounted at 7 percent; millions of 2019 dollars)[a]

Year	Proposed Regulatory Option	More Stringent Regulatory Option
2028*	$130	$2,800
2029	$130	$750
2030*	$140	$770
2031	$140	$800
2032	$270	$1,200
2033	$280	$1,300
2034	$290	$1,300
2035*	$300	$1,400
2036	$310	$1,400
2037	$310	$1,400
Present Value	**$1,200**	**$7,100**
Equivalent Annualized Value	**$170**	**$1,000**

*Year in which air quality models were run. Benefits for all other years were extrapolated from years with model-based air quality estimates. Benefits calculated as value of avoided: $PM_{2.5}$-attributable deaths (quantified using a concentration-response relationship from the Wu et al. 2020 study and the Pope et al. 2019 study); Ozone-attributable deaths (quantified using a concentration-response relationship from the Turner et al. 2017 study); and $PM_{2.5}$ and ozone-related morbidity effects.

[a] For the years 2023 to 2027, benefits associated with emissions reductions are not included as implementation of standards will not be complete until 2028.

4.3.10 Additional Unquantified Criteria Pollutant Benefits

Data, time, and resource limitations prevented EPA from quantifying the estimated health impacts or monetizing estimated benefits associated with direct exposure to NO_2 and SO_2 (independent of the role NO_2 and SO_2 play as precursors to $PM_{2.5}$ and ozone), as well as ecosystem effects, and visibility impairment due to the absence of air quality modeling data for these pollutants in this analysis. While all health benefits and welfare benefits were not able to be quantified, it does not imply that there are not additional benefits associated with reductions in exposures to ozone, $PM_{2.5}$, NO_2 or SO_2. In this section, we provide a qualitative description of these and water quality benefits, which are listed in Table 4-10. Criteria pollutants from U.S. EGUs can also be transported downwind into foreign countries, in particular Canada and Mexico. Therefore, reduced criteria pollutants from U.S. EGUs can lead to public health and welfare benefits in foreign countries. EPA is currently unable to quantify or monetize these effects.

Table 4-10 Additional Unquantified Benefit Categories

Category	Effect	Effect Quantified	Effect Monetized	More Information
Improved Human Health				
Reduced incidence of morbidity from exposure to NO_2	Asthma hospital admissions	—	—	NO_2 ISA[1]
	Chronic lung disease hospital admissions	—	—	NO_2 ISA[1]
	Respiratory emergency department visits	—	—	NO_2 ISA[1]
	Asthma exacerbation	—	—	NO_2 ISA[1]
	Acute respiratory symptoms	—	—	NO_2 ISA[1]
	Premature mortality	—	—	NO_2 ISA[1,2,3]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	—	—	NO_2 ISA[2,3]
Reduced incidence of mortality and morbidity through drinking water from reduced effluent discharges.	Bladder, colon, and rectal cancer from halogenated disinfection byproducts exposure.	—	—	SE ELG BCA[4]
	Reproductive and developmental effects from halogenated disinfection byproducts exposure.	—	—	SE ELG BCA[4]
Reduced incidence of morbidity and mortality from toxics through fish consumption from reduced effluent discharges.	Neurological and cognitive effects to children from lead exposure from fish consumption (including need for specialized education).	—	—	SE ELG BCA[4]
	Possible cardiovascular disease from lead exposure	—	—	SE ELG BCA[4]
	Neurological and cognitive effects from in-utero mercury exposure from maternal fish consumption	—	—	SE ELG BCA[4]
	Skin and gastrointestinal cancer incidence from arsenic exposure	—	—	SE ELG BCA[4]
	Cancer and non-cancer incidence from exposure to toxic pollutants (lead, cadmium, thallium, hexavalent chromium etc. Neurological, alopecia, gastrointestinal effects, reproductive and developmental damage from short-term thallium exposure.	—	—	SE ELG BCA[4]
Reduced incidence of morbidity and mortality from recreational water exposure from reduced effluent discharges.	Cancer and Non-Cancer incidence from exposure to toxic pollutants (methylmercury, selenium, and thallium.)	—	—	SE ELG BCA[4]
Improved Environment				
Reduced visibility impairment	Visibility in Class 1 areas	—	—	PM ISA[1]
	Visibility in residential areas	—	—	PM ISA[1]

Table 4-10 Additional Unquantified Benefit Categories

Category	Effect	Effect Quantified	Effect Monetized	More Information
Reduced effects on materials	Household soiling	—	—	PM ISA[1,2]
	Materials damage (e.g., corrosion, increased wear)	—	—	PM ISA[2]
Reduced effects from PM deposition (metals and organics)	Effects on individual organisms and ecosystems	—	—	PM ISA[2]
Reduced vegetation and ecosystem effects from exposure to ozone	Visible foliar injury on vegetation	—	—	Ozone ISA[1]
	Reduced vegetation growth and reproduction	—	—	Ozone ISA[1]
	Yield and quality of commercial forest products and crops	—	—	Ozone ISA[1]
	Damage to urban ornamental plants	—	—	Ozone ISA[2]
	Carbon sequestration in terrestrial ecosystems	—	—	Ozone ISA[1]
	Recreational demand associated with forest aesthetics	—	—	Ozone ISA[2]
	Other non-use effects			Ozone ISA[2]
	Ecosystem functions (e.g., water cycling, biogeochemical cycles, net primary productivity, leaf-gas exchange, community composition)	—	—	Ozone ISA[2]
Reduced effects from acid deposition	Recreational fishing	—	—	NO_x SO_x ISA[1]
	Tree mortality and decline	—	—	NO_x SO_x ISA[2]
	Commercial fishing and forestry effects	—	—	NO_x SO_x ISA[2]
	Recreational demand in terrestrial and aquatic ecosystems	—	—	NO_x SO_x ISA[2]
	Other non-use effects			NO_x SO_x ISA[2]
	Ecosystem functions (e.g., biogeochemical cycles)	—	—	NO_x SO_x ISA[2]
Reduced effects from nutrient enrichment from deposition.	Species composition and biodiversity in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[2]
	Coastal eutrophication	—	—	NO_x SO_x ISA[2]
	Recreational demand in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[2]
	Other non-use effects			NO_x SO_x ISA[2]
	Ecosystem functions (e.g., biogeochemical cycles, fire regulation)	—	—	NO_x SO_x ISA[2]

Table 4-10 Additional Unquantified Benefit Categories

Category	Effect	Effect Quantified	Effect Monetized	More Information
Reduced vegetation effects from ambient exposure to SO_2 and NO_x	Injury to vegetation from SO_2 exposure	—	—	NO_x SO_x ISA[2]
	Injury to vegetation from NO_x exposure	—	—	NO_x SO_x ISA[2]
Improved water aesthetics from reduced effluent discharges.	Improvements in water clarity, color, odor in residential, commercial, and recreational settings.	—	—	SE ELG BCA[4]
Effects on aquatic organisms and other wildlife from reduced effluent discharges	Protection of Threatened and Endangered (T&E) species from changes in habitat and potential population effects.	—	—	SE ELG BCA[4]
	Other non-use effects	—	—	SE ELG BCA[4]
	Changes in sediment contamination on benthic communities and potential for re-entrainment.	—	—	SE ELG BCA[4]
	Quality of recreational fishing and other recreational use values.	—	—	SE ELG BCA[4]
	Commercial fishing yields and harvest quality.	—	—	SE ELG BCA[4]
Reduced water treatment costs from reduced effluent discharges	Reduced drinking, irrigation, and other agricultural use water treatment costs.	—	—	SE ELG BCA[4]
Reduced sedimentation from effluent discharges	Increased storage availability in reservoirs	—	—	SE ELG BCA[4]
	Improved functionality of navigable waterways	—	—	SE ELG BCA[4]
	Decreased cost of dredging	—	—	SE ELG BCA[4]
Benefits of reduced water withdrawal	Benefits from effects aquatic and riparian species from additional water availability.	—	—	SE ELG BCA[4]
	Increased water availability in reservoirs increasing hydropower supply, recreation, and other services.	—	—	SE ELG BCA[4]

[1] We assess these benefits qualitatively due to data and resource limitations for this RIA.
[2] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.
[3] We assess these benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.
[4] Benefit and Cost Analysis (BCA) for Revisions to the Effluent Limitations Guidelines (ELG) and Standards for the Steam Electric (SE) Power Generating Point Source Category.

4.3.10.1 NO_2 Health Benefits

In addition to being a precursor to $PM_{2.5}$ and ozone, NOx emissions are also linked to a variety of adverse health effects associated with direct exposure. We were unable to estimate the health benefits associated with reduced NO_2 exposure in this analysis. Following a comprehensive review of health evidence from epidemiologic and laboratory studies, the Integrated Science Assessment for Oxides of Nitrogen —Health Criteria (NO_X ISA) (U.S. EPA, 2016) concluded that there is a likely causal relationship between respiratory health effects and short-term exposure to NO_2. These epidemiologic and experimental studies encompass a number of endpoints including emergency department visits and hospitalizations, respiratory symptoms, airway hyperresponsiveness, airway inflammation, and lung function. The NO_X ISA also concluded that the relationship between short-term NO_2 exposure and premature mortality was "suggestive but not sufficient to infer a causal relationship," because it is difficult to attribute the mortality risk effects to NO_2 alone. Although the NO_X ISA stated that studies consistently reported a relationship between NO_2 exposure and mortality, the effect was generally smaller than that for other pollutants such as PM.

4.3.10.2 SO_2 Health Benefits

In addition to being a precursor to $PM_{2.5}$, SO_2 emissions are also linked to a variety of adverse health effects associated with direct exposure. We were unable to estimate the health benefits associated with reduced SO_2 in this analysis. Therefore, this analysis only quantifies and monetizes the $PM_{2.5}$ benefits associated with the reductions in SO_2 emissions. Following an extensive evaluation of health evidence from epidemiologic and laboratory studies, the Integrated Science Assessment for Oxides of Sulfur —Health Criteria (SO_2 ISA) concluded that there is a causal relationship between respiratory health effects and short-term exposure to SO_2 sulfur (U.S. EPA, 2017). The immediate effect of SO_2 on the respiratory system in humans is bronchoconstriction. Asthmatics are more sensitive to the effects of SO_2, likely resulting from preexisting inflammation associated with this disease. A clear concentration-response relationship has been demonstrated in laboratory studies following exposures to SO_2 at concentrations between 20 and 100 parts per billion (ppb), both in terms of increasing severity of effect and percentage of asthmatics adversely affected. Based on our review of this information, we identified three short-term morbidity endpoints that the SO_2 ISA identified as a "causal relationship": asthma exacerbation, respiratory-related emergency department visits, and respiratory-related hospitalizations. The differing evidence and associated strength of the evidence for these different effects is described in detail in the SO_2 ISA. The SO_2 ISA also concluded that the relationship between short-term SO_2 exposure and premature mortality was "suggestive of a causal relationship" because it is difficult to attribute the mortality risk effects to SO_2 alone. Although the SO_2 ISA stated that studies are generally consistent in reporting a relationship between SO_2 exposure and mortality, there was a lack of robustness of the observed associations to adjustment for other pollutants.

4.3.10.3 Ozone Welfare Benefits

Exposure to ozone has been associated with a wide array of vegetation and ecosystem effects in the published literature ecological (U.S. EPA, 2020c). Sensitivity to ozone is highly variable across species, with over 65 plant species identified as "ozone-sensitive," many of which occur in state and national parks and forests. These effects include those that damage or impair the intended use of the plant or ecosystem. Such effects can include reduced growth and/or biomass production in sensitive plant species, including forest trees, reduced yield and quality of crops, visible foliar injury, species composition shift, and changes in ecosystems and associated ecosystem services. See Section F of the *Ozone Transport Policy Analysis Proposed Rule TSD* (U.S. EPA, 2022g) for a summary of an assessment of risk of ozone-related growth impacts on selected forest tree species.

4.3.10.4 NO_2 and SO_2 Welfare Benefits

As described in the Integrated Science Assessment (ISA) for Oxides of Nitrogen, Oxides of Sulfur and Particulate Matter Ecological Criteria (U.S. EPA, 2020c), NO_X and SO_2 emissions also contribute to a variety of adverse welfare effects, including those associated with acidic deposition, visibility impairment, and nutrient enrichment. Deposition of nitrogen and sulfur causes acidification, which can cause a loss of biodiversity of fishes, zooplankton, and macro invertebrates in aquatic ecosystems, as well as a decline in sensitive tree species, such as red spruce (Picea rubens) and sugar maple (Acer saccharum) in terrestrial ecosystems. In the northeastern U.S., the surface waters affected by acidification are a source of food for some recreational and subsistence fishermen and for other consumers and support several cultural services, including aesthetic and educational services and recreational fishing. Biological effects of acidification in terrestrial ecosystems are generally linked to aluminum toxicity, which can cause reduced root growth, restricting the ability of the plant to take up water and nutrients.

These direct effects can, in turn, increase the sensitivity of these plants to stresses, such as droughts, cold temperatures, insect pests, and disease, leading to increased mortality of canopy trees. Terrestrial acidification affects several important ecological services, including declines in habitat for threatened and endangered species (cultural), declines in forest aesthetics (cultural), declines in forest productivity (provisioning), and increases in forest soil erosion and reductions in water retention (cultural and regulating).

Deposition of nitrogen is also associated with aquatic and terrestrial nutrient enrichment. In estuarine waters, excess nutrient enrichment can lead to eutrophication. Eutrophication of estuaries can disrupt an important source of food production, particularly fish and shellfish production, and a variety of cultural ecosystem services, including water-based recreational and aesthetic services. Terrestrial nutrient enrichment is associated with changes in the types and number of species and biodiversity in terrestrial systems. Excessive nitrogen deposition upsets the balance between native and nonnative plants, changing the ability of an area to support biodiversity. When the composition of species changes, then fire frequency and intensity can also change, as nonnative grasses fuel more frequent and more intense wildfires.

4.3.10.5 Visibility Impairment Benefits

Reducing secondary formation of $PM_{2.5}$ would improve levels of visibility in the U.S. because suspended particles and gases degrade visibility by scattering and absorbing light (U.S. EPA 2009). Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil. Visibility has direct significance to people's enjoyment of daily activities and their overall sense of wellbeing. Good visibility increases the quality of life where individuals live and work, and where they engage in recreational activities. Particulate sulfate is the dominant source of regional haze in the eastern U.S. and particulate nitrate is an important contributor to light extinction in California and the upper Midwestern U.S., particularly during winter (U.S. EPA, 2009b). Previous analyses (U.S. EPA, 2012) show that visibility benefits can be a significant welfare benefit category. Without air quality modeling, we are unable to estimate visibility-related benefits, and we are also unable to determine whether the emission reductions associated with this proposed rule would be likely to have a significant impact on visibility in urban areas or Class I areas.

Reductions in emissions of NO_2 will improve the level of visibility throughout the U.S. because these gases (and the particles of nitrate and sulfate formed from these gases) impair visibility by scattering and absorbing light (U.S. EPA, 2009b). Visibility is also referred to as visual air quality (VAQ), and it directly affects people's enjoyment of a variety of daily activities (U.S. EPA, 2009b). Good visibility increases quality of life where individuals live and work, and where they travel for recreational activities, including sites of unique public value, such as the Great Smoky Mountains National Park (U.S. EPA, 2009b).

4.4 Climate Pollutant Benefits

We estimate the climate benefits from this proposed rule using estimates of the social cost of greenhouse gases (SC-GHG), specifically the SC-CO_2. The SC-CO_2 is the monetary value of the net harm to society associated with a marginal increase in CO_2 emissions in a given year, or the benefit of avoiding that increase. In principle, SC-CO_2 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 natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-CO_2, therefore, reflects the societal value of reducing emissions of the gas in question by one metric ton and is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect CO_2 emissions. In practice, data and modeling limitations naturally restrain the ability of SC-CO_2 estimates to include all the important physical, ecological, and economic impacts of climate change, such that the estimates are a partial accounting of climate change impacts and will therefore, tend to be underestimates of the marginal benefits of abatement. The EPA and other Federal agencies began regularly incorporating SC-CO_2 estimates in their benefit-cost analyses conducted under E.O. 12866[40]

[40] Presidents since the 1970s have issued executive orders requiring agencies to conduct analysis of the economic consequences of regulations as part of the rulemaking development process. E.O. 12866, released in 1993 and still in effect today, requires that for all economically significant regulatory actions, an agency provide an assessment of the potential costs and benefits of the regulatory action, and that this assessment include a quantification of benefits and costs to the extent feasible. Many statutes also require agencies to conduct at least some of the same analyses required under E.O. 12866, such as the Energy Policy and Conservation Act which mandates the setting of fuel economy regulations. For purposes of this action, monetized climate benefits are presented for purposes of providing a complete benefit-cost economic impact analysis under E.O. 12866 and other relevant executive orders. The estimates of change in GHG emissions and the monetized benefits associated with those changes play no part in the record basis for this action.

since 2008, following a Ninth Circuit Court of Appeals remand of a rule for failing to monetize the benefits of reducing CO_2 emissions in that rulemaking process.

In 2017, the National Academies of Sciences, Engineering, and Medicine published a report that provides a roadmap for how to update SC-GHG estimates used in Federal analyses going forward to ensure that they reflect advances in the scientific literature (National Academies, 2017). The National Academies' report recommended specific criteria for future SC-GHG updates, 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. The research community has made considerable progress in developing new data and methods that help to advance various components of the SC-GHG estimation process in response to the National Academies' recommendations.

In a first-day executive order (E.O. 13990), Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, President Biden called for a renewed focus on updating estimates of the SC-GHG to reflect the latest science, noting that "it is essential that agencies capture the full benefits of reducing greenhouse gas emissions as accurately as possible." Important steps have been taken to begin to fulfill this directive of E.O. 13990. In February 2021, the Interagency Working Group on the SC-GHG (IWG) released a technical support document (hereinafter the "February 2021 SC-GHG TSD") that provided a set of IWG recommended SC-GHG estimates while work on a more comprehensive update is underway to reflect recent scientific advances relevant to SC-GHG estimation (IWG 2021). In addition, as discussed further below, EPA has developed a draft updated SC-GHG methodology within a sensitivity analysis in the regulatory impact analysis of EPA's November 2022 supplemental proposal for oil and gas standards that is currently undergoing external peer review and a public comment process.[41]

The EPA has applied the IWG's recommended interim SC-GHG estimates in the Agency's regulatory benefit-cost analyses published since the release of the February 2021 TSD and is likewise using them in this RIA. We have evaluated the SC-GHG estimates in the February 2021 TSD and have determined that these estimates are appropriate for use in estimating the social benefits of GHG reductions expected to occur as a result of the proposed

[41] See https://www.epa.gov/environmental-economics/scghg

and alternative standards. These SC-GHG estimates are interim values developed for use in benefit-cost analyses until updated estimates of the impacts of climate change can be developed based on the best available science and economics. After considering the TSD, and the issues and studies discussed therein, the EPA concludes that these estimates, while likely an underestimate, are the best currently available SC-GHG estimates until revised estimates have been developed reflecting the latest, peer-reviewed science.

The SC-GHG estimates presented in the February 2021 SC-GHG TSD and used in this RIA were developed over many years, using a transparent process, peer-reviewed methodologies, the best science available at the time of that process, and with input from the public. Specifically, in 2009, an interagency working group (IWG) that included the EPA and other executive branch agencies and offices was established to develop estimates relying on the best available science for agencies to use. The IWG published SC-CO_2 estimates in 2010 that were developed from an ensemble of three widely cited integrated assessment models (IAMs) that estimate global climate damages using highly aggregated representations of climate processes and the global economy combined into a single modeling framework. The three IAMs were run using a common set of input assumptions in each model for future population, economic, and CO_2 emissions growth, as well as equilibrium climate sensitivity (ECS) – a measure of the globally averaged temperature response to increased atmospheric CO_2 concentrations. These estimates were updated in 2013 based on new versions of each IAM.[42] In August 2016 the IWG published estimates of the social cost of methane (SC-CH_4) and nitrous oxide (SC-N_2O) using methodologies that are consistent with the methodology underlying the SC-CO_2 estimates. The modeling approach that extends the IWG SC-CO_2 methodology to non-CO_2 GHGs has undergone multiple stages of peer review. The SC-CH_4 and SC-N_2O estimates were developed by Marten et al. (2015) and underwent a standard double-blind peer review process prior to journal publication. These estimates were applied in RIAs of EPA proposed rulemakings with CH_4 and N_2O emissions impacts.[43] The EPA also sought additional external peer review of technical issues associated with its application to regulatory analysis. Following

[42] Dynamic Integrated Climate and Economy (DICE) 2010 (Nordhaus, 2010), Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) 3.8 (Anthoff and Tol, 2013a, 2013b), and Policy Analysis of the Greenhouse Gas Effect (PAGE) 2009 (Hope, 2013).

[43] The SC-CH_4 and SC-N_2O estimates were first used in sensitivity analysis for the Proposed Rulemaking for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles–Phase 2 (U.S. EPA, 2015a).

the completion of the independent external peer review of the application of the Marten et al. (2015) estimates, the EPA began using the estimates in the primary benefit-cost analysis calculations and tables for a number of proposed rulemakings (U.S. EPA, 2015b, 2015d). The EPA considered and responded to public comments received for the proposed rulemakings before using the estimates in final regulatory analyses in 2016.[44] In 2015, as part of the response to public comments received to a 2013 solicitation for comments on the SC-CO_2 estimates, the IWG announced a National Academies of Sciences, Engineering, and Medicine review of the SC-CO_2 estimates to offer advice on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies. In January 2017, the National Academies released their final report, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide (National Academies, 2017), and recommended 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). Shortly thereafter, in March 2017, President Trump issued E.O. 13783, which disbanded the IWG, withdrew the previous SC-GHG TSDs, and directed agencies to ensure SC-GHG estimates used in regulatory analyses are consistent with the guidance contained in OMB's Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (E.O. 13783, Section 5(c)). Benefit-cost analyses following E.O. 13783 used SC-CO_2 estimates that attempted to focus on the specific share of climate change damages in the U.S. as captured by the models (which did not reflect many pathways by which climate impacts affect the welfare of U.S. citizens and residents) and were calculated using two default discount rates recommended by Circular A-4, 3 percent and 7 percent.[45] All other methodological

[44] See IWG (2016b) for more discussion of the SC-CH_4 and SC-N_2O and the peer review and public comment processes accompanying their development.
[45] The EPA regulatory analyses under E.O. 13783 included sensitivity analyses based on global SC-GHG values and using a lower discount rate of 2.5 percent. OMB Circular A-4 (OMB, 2003) recognizes that special considerations arise when applying discount rates if intergenerational effects are important. In the IWG's 2015 Response to Comments, OMB—as a co-chair of the IWG—made clear that "Circular A-4 is a living document," that "the use of 7 percent is not considered appropriate for intergenerational discounting," and that "[t]here is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself." OMB, as part of the IWG, similarly repeatedly confirmed that "a focus on global SCC estimates in [regulatory impact analyses] is appropriate" (IWG 2015).

decisions and model versions used in SC- CO_2 calculations remained the same as those used by the IWG in 2010 and 2013, respectively.

On January 20, 2021, President Biden issued E.O. 13990, which re-established an IWG and directed it to develop an update of the SC-CO_2 estimates that reflect the best available science and the recommendations of the National Academies. In February 2021, the IWG recommended the interim use of the most recent SC- CO_2 estimates developed by the IWG prior to the group being disbanded in 2017, adjusted for inflation (IWG, 2021) (IWG, 2021). As discussed in the February 2021 SC-GHG TSD, the IWG's selection of these interim estimates reflected the immediate need to have SC- CO_2 estimates available for agencies to use in regulatory benefit-cost analyses and other applications that were developed using a transparent process, peer reviewed methodologies, and the science available at the time of that process.

As noted above, the EPA participated in the IWG but has also independently evaluated the interim SC-CO_2 estimates published in the February 2021 SC-GHG TSD and determined they are appropriate to use to estimate climate benefits for this action. The EPA and other agencies intend to undertake a fuller update of the SC- CO_2 estimates that takes into consideration the advice of the National Academies (2017) and other recent scientific literature. The EPA has also evaluated the supporting rationale of the February 2021 SC-GHG TSD, including the studies and methodological issues discussed therein, and concludes that it agrees with the rationale for these estimates presented in the SC-GHG TSD and summarized below.

In particular, the IWG found that the SC-CO_2 estimates used under E.O. 13783 fail to reflect the full impact of GHG emissions in multiple ways. First, the IWG concluded that those estimates fail to capture many climate impacts that can affect the welfare of U.S. citizens and residents. 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, public health, and humanitarian concerns. Those impacts are better captured within global measures of the SC-GHGs.

In addition, 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. A wide range of scientific and economic experts have emphasized the issue of reciprocity as support for considering global damages of GHG emissions. 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 take significant steps to reduce emissions. The only way to achieve an efficient allocation of resources for emissions reduction on a global basis—and so benefit the U.S. and its citizens—is for all countries to base their policies on global estimates of damages.

As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, the EPA agrees with this assessment and, therefore, in this proposed rule the EPA centers attention on a global measure of SC-CO_2. This approach is the same as that taken in EPA regulatory analyses over 2009 through 2016. A robust estimate of climate damages only to U.S. citizens and residents that accounts for the myriad of ways that global climate change reduces the net welfare of U.S. populations does not currently exist in the literature. As explained in the February 2021 SC-GHG TSD, existing estimates are both incomplete and an underestimate of total damages that accrue to the citizens and residents of the U.S. because they do not fully capture the regional interactions and spillovers discussed above, nor do they include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature, as discussed further below. The EPA, as a member of the IWG, 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 carbon impacts.

Second, the IWG concluded that the use of the social rate of return on capital (7 percent under current OMB Circular A-4 guidance) to discount the future benefits of reducing GHG emissions inappropriately underestimates the impacts of climate change for the purposes of estimating the SC-CO_2. Consistent with the findings of the National Academies (2017) and the economic literature, the IWG continued to conclude that the consumption rate of interest is the theoretically appropriate discount rate in an intergenerational context (IWG, 2016b) (IWG, 2010, 2013, 2016a) and recommended that discount rate uncertainty and relevant aspects of intergenerational ethical considerations be accounted for in selecting future discount rates.[46] Furthermore, the damage estimates developed for use in the SC-GHG are estimated in consumption-equivalent terms, and so an application of OMB Circular A-4's guidance for regulatory analysis would then use the consumption discount rate to calculate the SC-GHG. The EPA agrees with this assessment and will continue to follow developments in the literature pertaining to this issue. The EPA also notes that while OMB Circular A-4, as published in 2003, recommends using 3 percent and 7 percent discount rates as “default” values, Circular A-4 also reminds agencies that "different regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions.” On discounting, Circular A-4 recognizes that “special ethical considerations arise when comparing benefits and costs across generations,” and Circular A-4 acknowledges that analyses may appropriately “discount future costs and consumption benefits…at a lower rate than for intragenerational analysis.” In the 2015 Response to Comments on the Social Cost of Carbon for Regulatory Impact Analysis, OMB, EPA, and the other IWG members recognized that "Circular A-4 is a living document" and “the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself.” Thus, the EPA concludes that a 7 percent discount rate is not appropriate to apply to value the SC-GHGs in the analysis presented in this RIA. In this analysis, to calculate the present and annualized values of climate benefits, the EPA uses the same discount rate as the rate used to discount the value of damages from future GHG emissions, for internal consistency. That approach to discounting follows the same approach that the February 2021 SC-GHG TSD recommends “to ensure internal consistency—i.e., future damages from climate change using the SC-GHG at 2.5 percent should be discounted to the base year of the analysis using the same 2.5 percent rate.” EPA has also consulted the National Academies' 2017 recommendations on how SC-GHG estimates can “be combined in RIAs with other cost and benefits estimates that may use different discount

[46] GHG emissions are stock pollutants, where damages are associated with what has accumulated in the atmosphere over time, and they are long lived such that subsequent damages resulting from emissions today occur over many decades or centuries depending on the specific GHG under consideration. In calculating the SC-GHG, the stream of future damages to agriculture, human health, and other market and non-market sectors from an additional unit of emissions are estimated in terms of reduced consumption (or consumption equivalents). Then that stream of future damages is discounted 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.

rates." The National Academies reviewed "several options," including "presenting all discount rate combinations of other costs and benefits with [SC-GHG] estimates."

While the IWG works to assess how best to incorporate the latest, peer reviewed science to develop an updated set of SC-GHG estimates, it recommended the interim estimates to be the most recent estimates developed by the IWG prior to the group being disbanded in 2017. The estimates rely on the same models and harmonized inputs and are calculated using a range of discount rates. As explained in the February 2021 SC-GHG TSD, the IWG has concluded that it is appropriate for agencies to revert to the same set of four values drawn from the SC-GHG distributions based on three discount rates as were used in regulatory analyses between 2010 and 2016 and subject to public comment. For each discount rate, the IWG combined the distributions across models and socioeconomic emissions scenarios (applying equal weight to each) and then selected a set of four values for use in agency analyses: an average value resulting from the model runs for each of three discount rates (2.5 percent, 3 percent, and 5 percent), plus a fourth value, selected as the 95th percentile of estimates based on a 3 percent discount rate. The fourth value was included to provide information on potentially higher-than-expected economic impacts from climate change, conditional on the 3 percent estimate of the discount rate. As explained in the February 2021 SC-GHG TSD, this update reflects the immediate need to have an operational SC-GHG that was developed using a transparent process, peer-reviewed methodologies, and the science available at the time of that process. Those estimates were subject to public comment in the context of dozens of proposed rulemakings as well as in a dedicated public comment period in 2013.

Table 4-11 summarizes the interim SC-CO_2 estimates for the years 2025 to 2040. These estimates are reported in 2019 dollars but are otherwise identical to those presented in the IWG's 2016 SC-GHG TSD (IWG, 2016b). For purposes of capturing uncertainty around the SC-CO_2 estimates in analyses, the 2021 SC-GHG TSD emphasizes the importance of considering all four of the SC-CO_2 values. The SC-CO_2 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 2025 – 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.

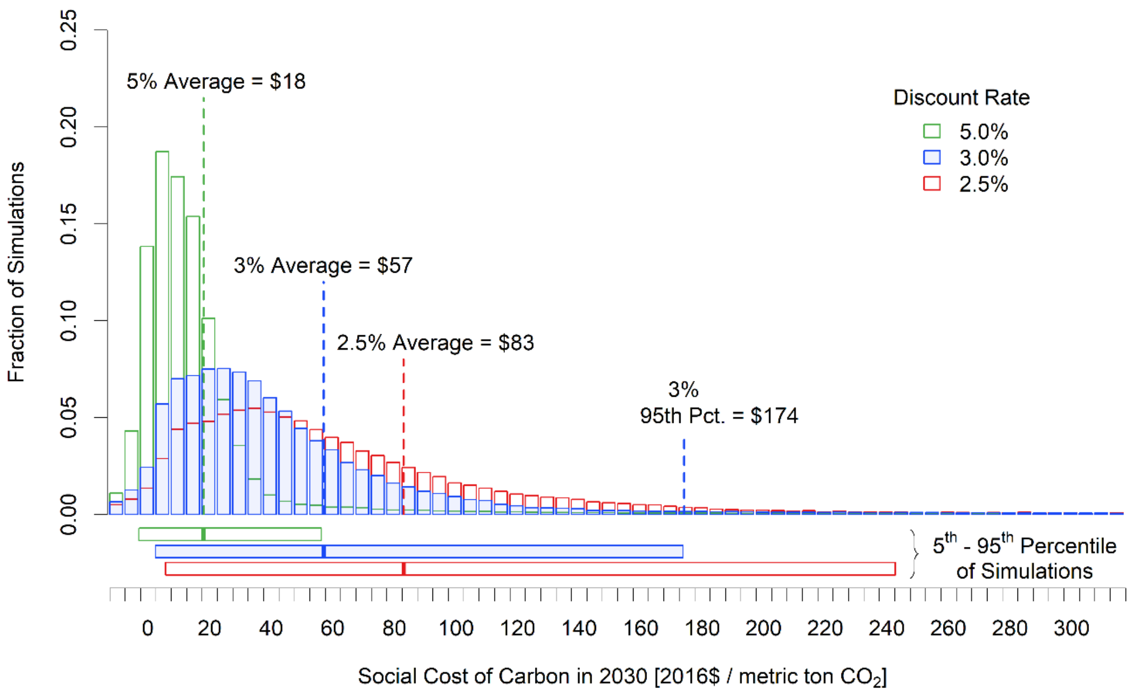
Table 4-11 Interim Social Cost of Carbon Values, 2025-2040 (2019 dollars per Metric Tonne CO_2)

	Discount Rate and Statistic			
	5%	3%	2.50%	3%
Emissions Year	Average	Average	Average	95th Percentile
2025	$17	$56	$82	$167
2026	$17	$57	$83	$171
2027	$18	$58	$85	$174
2028	$18	$59	$86	$178
2029	$19	$60	$87	$181
2030	$19	$61	$88	$184
2031	$20	$62	$90	$188
2032	$20	$63	$91	$192
2033	$21	$64	$92	$196
2034	$21	$66	$94	$200
2035	$22	$67	$95	$203
2036	$23	$68	$96	$207
2037	$23	$69	$98	$211
2038	$24	$70	$99	$215
2039	$24	$71	$101	$218
2040	$25	$72	$102	$222

Note: These SC-CO_2 values are identical to those reported in the 2016 SC-GHG TSD (IWG 2016a) 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 (U.S. BEA 2021). The values are stated in $/metric tonne CO_2 (1 metric tonne equals 1.102 short tons) and vary depending on the year of CO_2 emissions. This table displays the values rounded to the nearest dollar; the annual unrounded values used in the calculations in this RIA are available on OMB's website: https://www.whitehouse.gov/omb/information-regulatory-affairs/regulatory-matters/#scghgs.
Source: Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under E.O. 13990 (IWG 2021)

There are a number of limitations and uncertainties associated with the SC-CO_2 estimates presented in Table 4-11. Some uncertainties are captured within the analysis, while other areas of uncertainty have not yet been quantified in a way that can be modeled. Figure 4-2 presents the quantified sources of uncertainty in the form of frequency distributions for the SC-CO_2 estimates for emissions in 2030. The distributions of SC-CO_2 estimates reflect uncertainty in key model parameters such as the equilibrium climate sensitivity, as well as uncertainty in other parameters set by the original model developers. To highlight the difference between the impact of the discount rate and other quantified sources of uncertainty, the bars below the frequency distributions provide a symmetric representation of quantified variability in the SC-CO_2 estimates for each discount rate. As illustrated by the figure, the assumed discount rate plays a critical role in the ultimate estimate of the SC-CO_2. This is because CO_2 emissions today continue to impact society far out into the future, so with a higher discount rate, costs that accrue to future generations are weighted less, resulting in a lower estimate. As discussed in the 2021 SC-GHG TSD, there are other sources of uncertainty that have not yet been quantified and are thus not reflected in these estimates.

Figure 4-2 Frequency Distribution of SC-CO_2 Estimates for 2030



The interim SC-CO_2 estimates presented in Table 4-11 have a number of limitations. First, the current scientific and economic understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change are likely to be less than 3 percent, near 2 percent or lower (IWG, 2021). Second, the IAMs used to produce these interim estimates do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature and the science underlying their "damage functions" – i.e., the core parts of the IAMs that map global mean temperature changes and other physical impacts of climate change into economic (both market and nonmarket) damages – lags behind the most recent research. For example, limitations include the incomplete treatment of catastrophic and non-catastrophic impacts in the integrated assessment models, their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation of the relationship between the discount rate and uncertainty in economic growth over long time horizons. Likewise, the socioeconomic and emissions scenarios used as inputs to the models do not reflect new information from the last decade of scenario generation or the full range of projections.

The modeling limitations do not all work in the same direction in terms of their influence on the SC-CO_2 estimates. However, as discussed in the February 2021 SC-GHG TSD, the IWG has recommended that, taken together, the limitations suggest that the SC-CO_2 estimates used in this RIA likely underestimate the damages from CO_2 emissions. EPA concurs that the values used in this RIA conservatively underestimate the rule's climate benefits. In particular, the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007), which was the most current IPCC assessment available at the time when the IWG decision over the ECS input was made, concluded that SC-CO_2 estimates "very likely…underestimate the damage costs" due to omitted impacts. Since then, the peer-reviewed literature has continued to support this conclusion, as noted in the IPCC's Fifth Assessment report and other recent scientific assessments (IPCC, 2014, 2018, 2019a, 2019b; National Academies of Sciences and Medicine, 2016; USGCRP, 2016, 2018)

These assessments confirm and strengthen the science, updating projections of future climate change and documenting and attributing ongoing changes. For example, sea level rise projections from the IPCC's Fourth Assessment report ranged from 18 to 59 centimeters by the 2090s relative to 1980-1999, while excluding any dynamic changes in ice sheets due to the limited understanding of those processes at the time (IPCC 2007). A decade later, the Fourth National Climate Assessment projected a substantially larger sea level rise of 30 to 130 centimeters by the end of the century relative to 2000, while not ruling out even more extreme outcomes (USGCRP, 2018). EPA has reviewed and considered the limitations of the models used to estimate the interim SC-GHG estimates and concurs with the February 2021 SC-GHG TSD's assessment that, taken together, the limitations suggest that the interim SC-GHG estimates likely underestimate the damages from GHG emissions.

The February 2021 SC-GHG TSD briefly previews some of the recent advances in the scientific and economic literature that the IWG is actively following and that could provide guidance on, or methodologies for, addressing some of the limitations with the interim SC-GHG estimates. The IWG is currently working on a comprehensive update of the SC-GHG estimates taking into consideration recommendations from the National Academies of Sciences, Engineering and Medicine, recent scientific literature, public comments received on the February 2021 SC-GHG TSD and other input from experts and diverse stakeholder groups (National Academies 2017). While that process continues, 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. Most recently, the EPA presented a draft set of updated SC-GHG estimates within a sensitivity analysis in the regulatory impact analysis of the EPA's November 2022 supplemental proposal for oil and gas standards that that aims to incorporate recent advances in the climate science and economics literature (U.S. EPA, 2022b, 2022e). Specifically, the draft updated methodology incorporates new literature and research consistent with the National Academies near-term recommendations on socioeconomic and emissions inputs, climate modeling components, discounting approaches, and treatment of uncertainty, and an enhanced representation of how physical impacts of climate change translate to economic damages in the modeling framework based on the best and readily adaptable damage functions available in the peer reviewed literature. The EPA solicited public comment on the sensitivity analysis and the accompanying draft technical report, which explains the methodology underlying the new set of estimates, in the docket for the proposed Oil and Gas rule. The EPA is also embarking on an external peer review of this technical report. More information about this process and public comment opportunities is available on EPA's website.[47] EPA's draft technical report will be among the many technical inputs available to the IWG as it continues its work.

[47] See https://www.epa.gov/environmental-economics/scghg

Table 4-12 shows the estimated monetized value of the estimated changes in CO_2 emissions the proposed option and the more-stringent alternative. EPA estimated the dollar value of the CO_2-related effects for each analysis year between 2028 and 2037 by applying the SC-CO_2 estimates, shown in Table 4-12, to the estimated changes in CO_2 emissions in the corresponding year under the regulatory options. Note the less stringent regulatory alternative has no quantified emissions reductions associated with the proposed requirements for PM CEMS and the removal of startup definition number two. As a result, there are no quantified benefits associated with this regulatory option.

Table 4-12 Estimated Climate Benefits from Changes in CO_2 Emissions for 2028, 2030, and 2035 (millions of 2019 dollars)[a]

Regulatory Alternative	Year	5% Average	3% Average	2.5% Average	3% 95th Percentile
Proposed Option	2028	$4	$13	$19	$40
	2030	$16	$50	$72	$150
	2035	$102	$308	$439	$939
More-Stringent Alternative	2028	$398	$1,292	$1,882	$3,893
	2030	$166	$528	$765	$1,597
	2035	$64	$193	$275	$588

[a] Climate benefits are based on changes (reductions) in CO_2 emissions and are calculated using four different estimates of the SC-CO_2 (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). We emphasize the importance and value of considering the benefits calculated using all four SC-CO_2 estimates. As discussed in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under E.O. 13990 (IWG 2021), a consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, are also warranted when discounting intergenerational impacts.

Table 4-13 Stream of Projected Climate Benefits under Proposed Rule from 2028 through 2037 (millions of 2019 dollars)

Emissions Year	SC-CO_2 Discount Rate and Statistic			
	5%	3%	2.50%	3%
	Average	Average	Average	95th Percentile
2028*	$4	$13	$19	$40
2029	$15	$49	$71	$150
2030*	$16	$50	$72	$150
2031	$16	$51	$73	$150
2032	$94	$290	$420	$890
2033	$96	$300	$430	$900
2034	$99	$300	$430	$920
2035*	$100	$310	$440	$940
2036	$100	$310	$450	$960
2037	$110	$320	$450	$970
	3% Discount Rate for PV and EAV Calculations			
Present Value	**$470**	**$1,400**	**$2,100**	**$4,400**
Equivalent Annualized Value	**$55**	**$170**	**$240**	**$510**

* IPM analysis years.

Table 4-14 Stream of Projected Climate Benefits under More Stringent Regulatory Option from 2028 through 2037 (millions of 2019 dollars)

Emissions Year	SC-CO_2 Discount Rate and Statistic			
	5%	**3%**	**2.50%**	**3%**
	Average	**Average**	**Average**	**95th Percentile**
2028*	$400	$1,300	$1,900	$3,900
2029	$160	$520	$750	$1,600
2030*	$170	$530	$770	$1,600
2031	$170	$540	$780	$1,600
2032	$59	$180	$260	$560
2033	$60	$190	$270	$570
2034	$62	$190	$270	$580
2035*	$64	$190	$280	$590
2036	$65	$200	$280	$600
2037	$67	$200	$280	$610
3% Discount Rate for PV and EAV Calculations				
Present Value	**$1,000**	**$3,200**	**$4,700**	**$9,700**
Equivalent Annualized Value	**$120**	**$380**	**$550**	**$1,100**

* IPM analysis years.

4.5 Water Quality and Availability Benefits

As described in Section 3, this rule is expected to lead to shifts in electricity production away from fossil-fired steam generation towards renewable and natural gas generation. There are several negative health, ecological, and productivity effects associated with water effluent and intake from coal generation that will be avoided, and the benefits are qualitatively described below. For additional discussion of these effects and their consequent effect on welfare, see the *Benefit and Cost Analysis for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (U.S. EPA 2020b).

4.5.1.1 Potential Water Quality Benefits of Reducing Coal-Fired Power Generation

Discharges of wastewater from coal-fired power plants can contain toxic and bioaccumulative pollutants (e.g., selenium, mercury, arsenic, nickel), halogen compounds (containing bromide, chloride, or iodide), nutrients, and total dissolved solids (TDS), which can cause human health and environmental harm through surface water and fish tissue contamination. Pollutants in coal combustion wastewater are of particular concern because they can occur in large quantities (i.e., total pounds) and at high concentrations in discharges and leachate to groundwater and surface waters. These potential beneficial effects follow directly from reductions in pollutant loadings to receiving waters, and indirectly from other changes in plant operations. The potential benefits come in the form of reduced morbidity, mortality, and on environmental quality and economic activities; reduction in water use, which provides benefits in the form of increased availability of surface water and groundwater; and reductions in the use of surface impoundments to manage Coal Combustion Residual wastes, with benefits in the form of avoided cleanup and other costs associated with impoundment releases.

Reducing coal-fired power generation affects human health risk by changing exposure to pollutants in water via two principal exposure pathways: (1) treated water sourced from surface waters affected by coal-fired power plant discharges and (2) fish and shellfish taken from waterways affected by coal-fired power plant discharges. The human health benefits from surface water quality improvements may include drinking water benefits, fish consumption benefits, and other complimentary measures.

In addition, reducing coal-fired power generation can affect the ecological condition and recreation use effects from surface water quality changes. EPA expects the ecological impacts from reducing coal-fired power plant discharges could include habitat changes for fresh- and saltwater plants, invertebrates, fish, and amphibians, as well as terrestrial wildlife and birds that prey on aquatic organisms exposed to pollutants from coal combustion. The change in pollutant loadings has the potential to result in changes in ecosystem productivity in waterways and the health of resident species, including threatened and endangered (T&E) species. Loadings from coal-fired power generation have the potential to impact the general health of fish and invertebrate populations, their propagation to waters, and fisheries for both commercial and recreational purposes. Changes in water quality also have the potential to impact recreational activities such as swimming, boating, fishing, and water skiing.

Potential economic productivity effects may stem from changes in the quality of public drinking water supplies and irrigation water; changes in sediment deposition in reservoirs and navigational waterways; and changes in tourism, commercial fish harvests, and property values.

4.5.1.2 Drinking Water

Pollutants discharged by coal-fired power plants to surface waters may affect the quality of water used for public drinking supplies. In turn these impacts to public water supplies have the potential to affect the costs of drinking water treatment (e.g., filtration and chemical treatment) by changing eutrophication levels and pollutant concentrations in source waters. Eutrophication is one of the main causes of taste and odor impairment in drinking water, which has a major negative impact on public perceptions of drinking water safety. Additional treatment to address foul tastes and odors to bring the finished water into compliance with EPA's National Secondary Drinking Water Treatment Standards can significantly increase the cost of public water supply. Likewise, public drinking water supplies are subject to National Primary Drinking Water Standards that have set legally enforceable maximum contaminant levels (MCLs), for a number of pollutants, like metals, discharged from coal-fired power plants. Drinking water systems downstream from these power plants may be required to treat source water to remove the contaminants to levels below the MCL in the finished water. This treatment will also increase costs at drinking water treatment plants. Episodic releases from coal fired power plants may be detected only after the completion of a several month round of compliance monitoring at drinking water treatment plants, and there could also be a lag between detection of changes in source water contaminants and the system implementing treatment to address the issue. This lag may result in consumers being exposed to these contaminants through ingestion, inhalation, and skin absorption. The constituents found in the power plant discharge may also interact with drinking water treatment processes and contribute to the formation of disinfection byproducts that can have adverse human health impacts.

4.5.1.3 Fish Consumption

Recreational and subsistence fishers (and their household members) who consume fish caught in the reaches downstream of coal-fired power plants may value changes in pollutant concentrations in fish tissue. See U.S. EPA (2020b) for a demonstration of the changes in risk to human health from exposure to contaminated fish tissue. This document describes the neurological effects to children ages 0 to 7 from exposure to lead; the neurological effects to infants from in-utero exposure to mercury; the incidence of skin cancer from exposure to arsenic; and the reduced risk of other cancer and non-cancer toxic effects.

4.5.1.4 Changes in Surface Water Quality

Reducing coal-fired power plant discharges may affect the value of ecosystem services provided by surface waters through changes in the habitats or ecosystems (aquatic and terrestrial). Society values changes in ecosystem services by a number of mechanisms, including increased frequency of use and improved quality of the habitat for recreational activities (e.g., fishing, swimming, and boating). Individuals also value the protection of habitats and species that may reside in waters that receive water discharges from coal-fired power plants, even when those individuals do not use or anticipate future use of such waters for recreational or other purposes, resulting in nonuse values.

4.5.1.5 Impacts on Threatened and Endangered Species

For T&E species, even minor changes to reproductive rates and mortality levels may represent a substantial portion of annual population variation. Therefore, changing the discharge of coal-fired power plant pollutants to aquatic habitats has the potential to impact the survivability of some T&E species living in these habitats. The economic value for these T&E species primarily comes from the nonuse values people hold for the survivorship of both individual organisms and species survival.

4.5.1.6 Changes in Sediment Contamination

Water effluent discharges from coal-fired power plants can also contaminate waterbody sediments. For example, sediment adsorption of arsenic, selenium, and other pollutants found in water discharges can result in accumulation of contaminated sediment on stream and lake beds, posing a particular threat to benthic (i.e., bottom-dwelling) organisms. These pollutants can later be re-released into the water column and enter organisms at different trophic levels. Concentrations of selenium and other pollutants in fish tissue of organisms of lower trophic levels can bio-magnify through higher trophic levels, posing a threat to the food chain at large (Ruhl et al., 2012)

4.5.1.7 Reservoir Capacity and Sedimentation Changes in Navigational Waterways

Reservoirs serve many functions, including storage of drinking and irrigation water supplies, flood control, hydropower supply, and recreation. Streams can carry sediment into reservoirs, where it can settle and cause buildup of sediment layers over time, reducing reservoir capacity (Graf et al., 2010, 2011) and the useful life of reservoirs unless measures such as dredging are taken to reclaim capacity (Hargrove et al., 2010; Miranda, 2017). Likewise, navigable waterways, including rivers, lakes, bays, shipping channels and harbors, are prone to reduced functionality due to sediment build-up, which can reduce the navigable depth and width of the waterway (Clark et al., 1985; Ribaudo and Johansson, 2006). For many navigable waters, periodic dredging is necessary to remove sediment and keep them passable. Dredging of reservoirs and navigable waterways can be costly. EPA expects that changes in suspended solids effluent discharge from coal-fired power plants could reduce sediment loadings to surface waters decreasing reservoir and navigable waterway maintenance costs by changing the frequency or volume of dredging activity.

4.5.1.8 Changes in Water Withdrawals

A reduction in water consumption from coal-fired power plants may benefit aquatic and riparian species downstream of the power plant intake through the provision of additional water resources in the face of drying conditions and increased rainfall variability. In a study completed, in 2011, by the U.S. Department of Energy's National Renewable Energy Laboratory (2011), water consumption, which is defined as water removed from the immediate water environment and can include cooling water evaporation, cleaning, and process related water use including flue gas desulfurization, was found to range from 100 – 1,100 gal/MWh at generic coal-fired power plants. This study also found that water withdraws, defined as the amount of water removed from the ground or diverted from a water source for use, ranged from 300 – 50,000 gal/MWh at a generic coal-fired power plant. Reductions in water consumption and withdraws will lower the number of aquatic organisms impinged and entrained by the power plant's water filtration and cooling systems.

4.6 Total Benefits

Table 4-15 through Table 4-17 present the total health and climate benefits for the proposed rule and the more stringent alternative.

Table 4-15 Combined $PM_{2.5}$ and O_3-related Health Benefits and Climate Benefits for the Proposed Requirements and More Stringent Alternative for 2028 (millions of 2019 dollars)

$SC\text{-}CO_2$ Discount Rate and Statistic	$PM_{2.5}$ and O_3-related Health Benefits and Climate Benefits (Discount Rate Applied to Health Benefits) 3%	7%	Climate Benefits Only[a]
Proposed Rule			
5% (average)	150	130	4.1
3% (average)	160	140	13
2.5% (average)	160	150	19
3% (95th percentile)	180	170	40
More Stringent Alternative			
5% (average)	3,500	3,200	400
3% (average)	4,400	4,100	1,300
2.5% (average)	5,000	4,700	1,900
3% (95th percentile)	7,000	6,700	3,900

[a] Climate benefits are based on changes (reductions) in CO_2 emissions and are calculated using four different estimates of the $SC\text{-}CO_2$ (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate).

Table 4-16 Combined $PM_{2.5}$ and O_3-related Health Benefits and Climate Benefits for the Proposed Requirements and More Stringent Alternative for 2030 (millions of 2019 dollars)

$SC\text{-}CO_2$ Discount Rate and Statistic	$PM_{2.5}$ and O_3-related Health Benefits and Climate Benefits (Discount Rate Applied to Health Benefits) 3%	7%	Climate Benefits Only[a]
Proposed Rule			
5% (average)	170	150	16
3% (average)	200	190	50
2.5% (average)	220	210	72
3% (95th percentile)	300	290	150
More Stringent Alternative			
5% (average)	1,000	940	170
3% (average)	1,400	1,300	530
2.5% (average)	1,600	1,500	770
3% (95th percentile)	2,500	2,400	1,600

[a] Climate benefits are based on changes (reductions) in CO_2 emissions and are calculated using four different estimates of the $SC\text{-}CO_2$ (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate).

Table 4-17 Combined $PM_{2.5}$ and O_3-related Health Benefits and Climate Benefits for the Proposed Requirements and More Stringent Alternative for 2035 (millions of 2019 dollars)

$SC\text{-}CO_2$ Discount Rate and Statistic	$PM_{2.5}$ and O_3-related Health Benefits and Climate Benefits (Discount Rate Applied to Health Benefits)		
	3%	7%	Climate Benefits Only[a]
Proposed Rule			
5% (average)	430	400	100
3% (average)	640	610	310
2.5% (average)	770	740	440
3% (95th percentile)	1,300	1,200	940
More Stringent Alternative			
5% (average)	1,600	1,400	64
3% (average)	1,700	1,600	190
2.5% (average)	1,800	1,600	280
3% (95th percentile)	2,100	1,900	590

[a] Climate benefits are based on changes (reductions) in CO_2 emissions and are calculated using four different estimates of the $SC\text{-}CO_2$ (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate).

Table 4-18 Stream of Combined $PM_{2.5}$ and O_3-related Health Benefits and Climate Benefits for the Proposed Rule from 2028 through 2037 (millions of 2019 dollars)[a]

Year	Values Calculated using 3% Discount Rate			Values Calculated using 7% Discount Rate		
	$PM_{2.5}$ and O_3-related Health Benefits	Climate Benefits[a]	Total Benefits	$PM_{2.5}$ and O_3-related Health Benefits	Climate Benefits (discounted at 3%)	Total Benefits
2028	140	13	160	130	13	140
2029	150	49	200	130	49	180
2030	150	50	200	140	50	190
2031	190	51	240	170	51	220
2032	220	290	520	200	290	490
2033	260	300	560	230	300	530
2034	300	300	600	270	300	570
2035	330	310	640	300	310	610
2036	370	310	680	330	310	650
2037	410	320	720	360	320	680
Present Value	1,900	1,400	3,300	1,100	1,400	2,600
Equivalent Annualized Value	220	170	390	160	170	330

[a] Climate benefits are based on reductions in CO_2 emissions and are calculated using four different estimates of the social cost of carbon dioxide (SC-CO_2): model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate. The 95th percentile estimate is included to provide information on potentially higher-than-expected economic impacts from climate change, conditional on the 3 percent estimate of the discount rate. For the presentational purposes of this table, we show the climate benefits associated with the average SC-CO_2 at a 3 percent discount rate, but the Agency does not have a single central SC-CO_2 point estimate. Climate benefits in this table are discounted using a 3 percent discount rate to obtain the PV and EAV estimates in the table. We emphasize the importance and value of considering the benefits calculated using all four SC-CO_2 estimates. Section 4.4 of the RIA presents estimates of the projected climate benefits of this proposal using all four rates. We note that consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, is warranted when discounting intergenerational impacts.

Table 4-19 Stream of Combined $PM_{2.5}$ and O_3-related Health Benefits and Climate Benefits for the More Stringent Regulatory Option from 2028 through 2037 (millions of 2019 dollars)[a]

	Values Calculated using 3% Discount Rate			Values Calculated using 7% Discount Rate		
Year	**$PM_{2.5}$ and O_3-related Health Benefits**	**Climate Benefits**	**Total Benefits**	**$PM_{2.5}$ and O_3-related Health Benefits**	**Climate Benefits (discounted at 3%)**	**Total Benefits**
2028	3,100	1,300	4,400	2,800	1,300	4,100
2029	2,000	520	2,500	1,800	520	2,300
2030	860	530	1,400	770	530	1,300
2031	990	540	1,500	890	540	1,400
2032	1,100	180	1,300	1,000	180	1,200
2033	1,300	190	1,400	1,100	190	1,300
2034	1,400	190	1,600	1,200	190	1,400
2035	1,500	190	1,700	1,400	190	1,600
2036	1,600	200	1,800	1,500	200	1,700
2037	1,800	200	2,000	1,600	200	1,800
Present Value	12,000	3,200	15,000	7,700	3,200	11,000
Equivalent Annualized Value	1,400	380	1,800	1,100	380	1,500

[a] Climate benefits are based on reductions in CO_2 emissions and are calculated using four different estimates of the social cost of carbon dioxide (SC-CO_2): model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate. The 95th percentile estimate is included to provide information on potentially higher-than-expected economic impacts from climate change, conditional on the 3 percent estimate of the discount rate. For the presentational purposes of this table, we show the climate benefits associated with the average SC-CO_2 at a 3 percent discount rate, but the Agency does not have a single central SC-CO_2 point estimate. Climate benefits in this table are discounted using a 3 percent discount rate to obtain the PV and EAV estimates in the table. We emphasize the importance and value of considering the benefits calculated using all four SC-CO_2 estimates. Section 4.4 of the RIA presents estimates of the projected climate benefits of this proposal using all four rates. We note that consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, is warranted when discounting intergenerational impacts.

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5 ECONOMIC IMPACTS

5.1 Overview

Economic impact analyses focus on changes in market prices and output levels. If changes in market prices and output levels in the primary markets are significant enough, impacts on other markets may also be examined. Both the magnitude of costs needed to comply with a rule and the distribution of these costs among affected facilities can have a role in determining how the market will change in response to a rule. This section analyzes the potential impacts on small entities and the potential labor impacts associated with this rulemaking. For additional discussion of impacts on fuel use and electricity prices, see Section 3.

5.2 Small Entity Analysis

For the proposed rule, EPA performed a small entity screening analysis for impacts on all affected EGUs and non-EGU facilities by comparing compliance costs to historic revenues at the ultimate parent company level. This is known as the cost-to-revenue or cost-to-sales test, or the "sales test." The sales test is an impact methodology EPA employs in analyzing entity impacts as opposed to a "profits test," in which annualized compliance costs are calculated as a share of profits. The sales test is frequently used because revenues or sales data are commonly available for entities impacted by EPA regulations, and profits data normally made available are often not the true profit earned by firms because of accounting and tax considerations. Also, the use of a sales test for estimating small business impacts for a rulemaking is consistent with guidance offered by EPA on compliance with the Regulatory Flexibility Act (RFA)[48] and is consistent with guidance published by the U.S. Small Business Administration's (SBA) Office of Advocacy that suggests that cost as a percentage of total revenues is a metric for evaluating cost increases on small entities in relation to increases on large entities.[49]

[48] See U.S. EPA. (2006). *Final Guidance for EPA Rulewriters: Regulatory Flexibility Act as Amended by the Small Business and Regulatory Enforcement Fairness Act.* Available at: https://www.epa.gov/sites/production/files/2015-06/documents/guidance-regflexact.pdf
[49] See U.S. SBA Office of Advocacy. (2017). *A Guide For Government Agencies: How To Comply With The Regulatory Flexibility Act.* Available at: https://advocacy.sba.gov/2017/08/31/a-guide-for-government-agencies-how-to-comply-with-the-regulatory-flexibility-act

5.2.1 Methodology

This section presents the methodology and results for estimating the impact of the rule on small EGU entities in the year of compliance, 2028, based on the following endpoints:

- annual economic impacts of the proposal on small entities, and
- ratio of small entity impacts to revenues from electricity generation.

In this analysis, we chose to examine the projected impacts of the more stringent regulatory option on small entities in order to present a scenario of "maximum cost impact". As we explain in the Section 5.2.3, we conclude that the projected impacts of the more stringent regulatory alternative do not constitute a Significant Impact on a Substantial Number of Small Entities (SISNOSE). As projected cost impacts of the proposed rule less stringent options are dominated by cost impacts of the more stringent alternative, a no SISNOSE conclusion for the more stringent option can be extended to the proposed rule and less stringent option.

For this analysis, EPA first considered EGUs that are subject to MATS requirements and for which EPA assumed additional controls would be necessary to meet the requirements constituted by the more stringent regulatory option. We then refined this list of MATS-affected EGUs, complementing the list with units for which the projected impact of the more stringent option exceeds either of the two criteria below relative to the baseline:

- Fuel use (BTUs) changes by +/- 1 percent or more
- Generation (GWh) changes by +/- 1 percent or more

Please see Section 3 for more discussion of the power sector modeling.

Based on these criteria, EPA identified a total of 358 potentially affected EGUs warranting examination in 2028 in this RFA analysis. Next, we determined power plant ownership information, including the name of associated owning entities, ownership shares, and each entity's type of ownership. We primarily used data from Hitachi - Power Grids, The Velocity Suite (c) 2020 ("VS"), supplemented by limited research using publicly available data. Majority owners of power plants with affected EGUs were categorized as one of the seven ownership types. These ownership types are:

1. **Investor-Owned Utility (IOU):** Investor-owned assets (e.g., a marketer, independent power producer, financial entity) and electric companies owned by stockholders, etc.
2. **Cooperative (Co-Op):** Non-profit, customer-owned electric companies that generate and/or distribute electric power.
3. **Municipal:** A municipal utility, responsible for power supply and distribution in a small region, such as a city.
4. **Sub-division**: Political subdivision utility is a county, municipality, school district, hospital district, or any other political subdivision that is not classified as a municipality under state law.
5. **Private:** Similar to an investor-owned utility, however, ownership shares are not openly traded on the stock markets.
6. **State:** Utility owned by the state.
7. **Federal:** Utility owned by the federal government.

Next, EPA used both the D&B Hoovers online database and the VS database to identify the ultimate owners of power plant owners identified in the VS database. This was necessary, as many majority owners of power plants (listed in VS) are themselves owned by other ultimate parent entities (listed in D&B Hoovers). In these cases, the ultimate parent entity was identified via D&B Hoovers, whether domestically or internationally owned.

EPA followed SBA size standards to determine which non-government ultimate parent entities should be considered small entities in this analysis. These SBA size standards are specific to each industry, each having a threshold level of either employees, revenue, or assets below which an entity is considered small. SBA guidelines list all industries, along with their associated North American Industry Classification System (NAICS) code and SBA size standard. Therefore, it was necessary to identify the specific NAICS code associated with each ultimate parent entity in order to understand the appropriate size standard to apply. Data from D&B Hoovers was used to identify the NAICS codes for most of the ultimate parent entities. In many cases, an entity that is a majority owner of a power plant is itself owned by an ultimate parent entity with a primary business other than electric power generation. Therefore, it was necessary to consider SBA entity size guidelines for the range of NAICS codes listed in Table 5-1. This table represents the range of NAICS codes and areas of primary business of ultimate parent entities that are majority owners of potentially affected EGUs in EPA's IPM base case.

Table 5-1 SBA Size Standards by NAICS Code

NAICS Code	NAICS U.S. Industry Title	Size Standard (millions of dollars)	Size Standard (number of employees)
211120	Crude Petroleum Extraction		1,250
212221	Gold Ore Mining		1,500
221111	Hydroelectric Power Generation		500
221112	Fossil Fuel Electric Power Generation		750
221113	Nuclear Electric Power Generation		750
221114	Solar Electric Power Generation		250
221115	Wind Electric Power Generation		250
221116	Geothermal Electric Power Generation		250
221117	Biomass Electric Power Generation		250
221118	Other Electric Power Generation		250
221121	Electric Bulk Power Transmission and Control		500
221122	Electric Power Distribution		1,000
221210	Natural Gas Distribution		1,000
221310	Water Supply and Irrigation Systems	$41.00	
221320	Sewage Treatment Facilities	$35.00	
221330	Steam and Air Conditioning Supply	$30.00	
311221	Wet Corn Milling		1,250
311224	Soybean and Other Oilseed Processing		1,000
322121	Paper (except Newsprint) Mills		1,250
325611	Soap and Other Detergent Manufacturing		1,000
325920	Explosives Manufacturing		750
331110	Iron and Steel Mills and Ferroalloy Manufacturing		1,500
332313	Plate Work Manufacturing		750
332911	Industrial Valve Manufacturing		750
333611	Turbine and Turbine Generator Set Unit Manufacturing		1,500
333613	Mechanical Power Transmission Equipment Manufacturing		750
423520	Coal and Other Mineral and Ore Merchant Wholesalers		200
423990	Other Miscellaneous Durable Goods Merchant Wholesalers		100
424690	Other Chemical and Allied Products Merchant Wholesalers		175
424720	Petroleum and Petroleum Products Merchant Wholesalers		200
522110	Commercial Banking	$750.00	
523210	Securities and Commodity Exchanges	$47.00	
523910	Miscellaneous Intermediation	$44.25	
523930	Investment Advice	$41.50	
524126	Direct Property and Casualty Insurance Carriers		1,500
525910	Open-End Investment Funds	$37.50	
525990	Other Financial Vehicles	$40.00	
541330	Engineering Services	$22.50	
541611	Administrative Management and General Management Consulting Services	$21.50	
541715	Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)		1,000
551112	Offices of Other Holding Companies	$45.50	

NAICS Code	NAICS U.S. Industry Title	Size Standard (millions of dollars)	Size Standard (number of employees)
611310	Colleges, Universities and Professional Schools	$30.50	
721110	Hotels (except Casino Hotels) and Motels	$35.00	
813910	Business Associations	$13.50	

Note: Based on size standards effective at the time EPA conducted this analysis (SBA size standards, effective December 19, 2022. Available at the following link: https://www.sba.gov/document/support--table-size-standards).
Source: SBA, 2022.

EPA compared the relevant entity size criterion for each ultimate parent entity to the SBA size standard noted in Table 5-1. We used the following data sources and methodology to estimate the relevant size criterion values for each ultimate parent entity:

- **Employment, Revenue, and Assets**: EPA used the D&B Hoovers database as the primary source for information on ultimate parent entity employee numbers, revenue, and assets.[50] In parallel, EPA also considered estimated revenues from affected EGUs based on analysis of IPM parsed-file[51] estimates for the baseline run for 2028. EPA assumed that the ultimate parent entity revenue was the larger of the two revenue estimates. In limited instances, supplemental research was also conducted to estimate an ultimate parent entity's number of employees, revenue, or assets.

- **Population**: Municipal entities are defined as small if they serve populations of less than 50,000.[52] EPA primarily relied on data from the Ventyx database and the U.S. Census Bureau to inform this determination.

Ultimate parent entities for which the relevant measure is less than the SBA size standard were identified as small entities and carried forward in this analysis.

In the projected results for 2028, EPA identified 358 potentially affected EGUs, owned by 107 entities. Of these, EPA identified 41 potentially affected EGUs owned by 26 small entities included in the power sector baseline.

[50] Estimates of sales were used in lieu of revenue estimates when revenue data was unavailable.
[51] IPM output files report aggregated results for "model" plants (i.e., aggregates of generating units with similar operating characteristics). Parsed files approximate the IPM results at the generating unit level.
[52] The Regulatory Flexibility Act defines a small government jurisdiction as the government of a city, county, town, township, village, school district, or special district with a population of less than 50,000 (5 U.S.C. section 601(5)). For the purposes of the RFA, States and tribal governments are not considered small governments. EPA's *Final Guidance for EPA Rulewriters: Regulatory Flexibility Act* is located here: https://www.epa.gov/sites/default/files/2015-06/documents/guidance-regflexact.pdf.

The chosen compliance strategy will be primarily a function of the unit's marginal control costs and its position relative to the marginal control costs of other units. To attempt to account for each potential control strategy, EPA estimates compliance costs as follows:

$$C_{Compliance} = \Delta\, C_{Operating+Retrofit} + \Delta\, C_{Fuel} + \Delta\, R$$

where C represents a component of cost as labeled and Δ R represents the change in revenues, calculated as the difference in value of electricity generation between the baseline case and the rule in in 2028.

Realistically, compliance choices and market conditions can combine such that an entity may actually experience a reduction in any of the individual components of cost. Under the rule, some units will forgo some level of electricity generation (and thus revenues) to comply, and this impact will be lessened on these entities by the projected increase in electricity prices under the rule. On the other hand, those units increasing generation levels will see an increase in electricity revenues and as a result, lower net compliance costs. If entities are able to increase revenue more than an increase in fuel cost and other operating costs, ultimately, they will have negative net compliance costs (or increased profit). Overall, small entities are not projected to install relatively costly emissions control retrofits but may choose to do so in some instances. Because this analysis evaluates the total costs along each of the compliance strategies laid out above for each entity, it inevitably captures gains such as those described. As a result, what we describe as cost is actually a measure of the net economic impact of the rule on small entities.

For this analysis, EPA used IPM-parsed output to estimate costs based on the parameters above, at the unit level. These impacts were then summed for each small entity, adjusting for ownership share. Net impact estimates were based on the following: operating and retrofit costs, sale or purchase of allowances, and the change in fuel costs or electricity generation revenues under the proposed MATS requirements relative to the base case. These individual components of compliance costs were estimated as follows:

1. **Operating and retrofit costs** ($\Delta\, C_{Operating+Retrofit}$)**:** EPA projected which compliance option would be selected by each EGU in 2028 and applied the appropriate cost to this choice (for details, please see Section 3 of this RIA). For 2028, IPM projected retrofit costs were also included in the calculation.

2. **Fuel costs** (*Δ C_{Fuel}*)**:** The change in fuel expenditures under the proposed requirements was estimated by taking the difference in projected fuel expenditures between the IPM estimates under the proposed requirements and the baseline.

3. **Value of electricity generated** (*Δ C_{Fuel}*)**:** To estimate the value of electricity generated, the projected level of electricity generation is multiplied by the regional-adjusted retail electricity price ($/MWh) estimate, for all entities except those categorized as private in Ventyx. See Section 3 for a discussion of the Retail Price Model, which was used to estimate the change in the retail price of electricity. For private entities, EPA used the wholesale electricity price instead of the retail electricity price because most of the private entities are independent power producers (IPP). IPPs sell their electricity to wholesale purchasers and do not own transmission facilities. Thus, their revenue was estimated with wholesale electricity prices.

5.2.2 Results

As indicated above, the use of a sales test for estimating small business impacts for a rulemaking is consistent with guidance offered by the EPA on compliance with the RFA and is consistent with guidance published by the SBA's Office of Advocacy that suggests that cost as a percentage of total revenues is a metric for evaluating cost increases on small entities in relation to increases on large entities. EPA assessed the economic and financial impacts of the rule using the ratio of compliance costs to the value of revenues from electricity generation, focusing in particular on entities for which this measure is greater than 1 percent.

The projected impacts, including compliance costs, of the proposed rule on small entities are summarized in Table 5-25-2. All costs are presented in 2019 dollars. We projected the annual net compliance cost to small entities to be approximately $26 million in 2028. Relative to the baseline, the proposed rule is projected to generate compliance cost reductions greater than 1 percent of baseline revenue for two of the 26 small entities directly impacted, and compliance cost increases greater than 1 percent are projected for two. The remaining 22 entities are not projected to experience compliance cost changes of more than 1 percent. Of the 26 entities considered in this analysis, two are holding units projected to experience compliance cost increases greater than 1 percent of generation revenue at a facility level as well as at a parent holding company level.

Table 5-2 Projected Impacts of Proposal on Small Entities in 2028

EGU Ownership Type	Number of Potentially Affected Entities	Total Net Compliance Cost (millions 2019 dollars)	Number of Small Entities with Compliance Costs >1% of Generation Revenues
Municipal	0	0	0
Private	12	-3.9	1
Co-op	14	30	1
Total	**26**	**26**	**2**

A similar analysis of the projected impacts, including compliance costs, of the more stringent alternative on small entities is summarized in Table 5-3. We projected annual net compliance cost to small entities to be approximately -$6.0 million in 2028. Relative to the baseline, the more stringent alternative is projected to generate compliance cost reductions greater than 1 percent of baseline revenues for 15 of the 26 entities directly impacted, and compliance cost increases greater than 1 percent are projected for three. The remaining eight small entities are not projected to experience compliance cost changes of more than 1 percent.

Table 5-3 Projected Impacts of More Stringent Alternative on Small Entities in 2028

EGU Ownership Type	Number of Potentially Affected Entities	Total Net Compliance Cost (millions 2019 dollars)	Number of Small Entities with Compliance Costs >1% of Generation Revenues
Municipal	0	0	0
Private	12	-62	0
Co-op	14	56	3
Total	**26**	**-6.0**	**3**

5.2.3 Conclusion

Making a determination that there is not a significant economic impact on a substantial number of small entities (often referred to as a “SISNOSE”) requires an assessment of whether an estimated economic impact is significant and whether that impact affects a substantial number of small entities. The analysis indicates that 8 small entities see a +/- 1 percent change in either emissions, fuel use, or generation, and 3 of these are projected to have a cost impact of greater than 1 percent of their revenues. EPA identified 107 potentially affected EGU entities in the projection year of 2028. Of these, EPA identified 26 small entities affected by the rule, and of these, three small entities may experience costs of greater than 1 percent of revenues. Based on this analysis, for this rule overall we conclude that the estimated costs for the proposed rule will not have a significant economic impact on a substantial number of small entities.

5.3 Labor Impacts

This section discusses potential employment impacts of this regulation. As economic activity shifts in response to a regulation, typically there will be a mix of declines and gains in employment in different parts of the economy over time and across regions. To present a complete picture, an employment impact analysis will describe the potential positive and negative changes in employment levels. There are significant challenges when trying to evaluate the employment effects of an environmental regulation due to a wide variety of other economic changes that can affect employment, including the impact of the coronavirus pandemic on labor markets and the state of the macroeconomy generally. Considering these challenges, we look to the economics literature to provide a constructive framework and empirical evidence. To simplify, we focus on impacts on labor demand related to compliance behavior. Environmental regulation may also affect labor supply through changes in worker health and productivity (Zivin and Neidell, 2018).

Economic theory of labor demand indicates that employers affected by environmental regulation may increase their demand for some types of labor, decrease demand for other types, or for still other types, not change their demand at all(Berman and Bui, 2001; Deschenes, 2018; Morgenstern et al., 2002). To study labor demand impacts empirically, a growing literature has compared employment levels at facilities subject to an environmental regulation to employment levels at similar facilities not subject to that environmental regulation; some studies find no employment effects, and others find significant differences. For example, see Berman and Bui (2001), Greenstone (2002), Ferris et al. (2014), and Curtis (2018, 2020). A variety of conditions can affect employment impacts of environmental regulation, including baseline labor market conditions and employer and worker characteristics such as occupation and industry. Changes in employment may also occur in different sectors related to the regulated industry, both upstream and downstream, or in sectors producing substitute or complimentary products. Employment impacts in related sectors are often difficult to measure. Consequently, we focus our labor impacts analysis primarily on the directly regulated facilities and other EGUs and related fuel markets.

This section discusses and projects potential employment impacts for the utility power, coal and natural gas production sectors that may result from the proposed rule. EPA has a long history of analyzing the potential impacts of air pollution regulations on changes in the amount of labor needed in the power generation sector and directly related sectors. The analysis conducted for this RIA builds upon the approaches used in the past and takes advantage of newly available data to improve the assumptions and methodology.[53]

The results presented in this section are based on a methodology that estimates the impact on employment based on the differences in projections between two modeling scenarios: the baseline scenario, and a scenario that represents the implementation of the rule. The estimated employment difference between these scenarios can be interpreted as the incremental effect of the rule on employment in this sector. As discussed in Section 3, there is uncertainty related to the future baseline projections. Because the incremental employment estimates presented in this section are based on projections discussed in Section 3, it is important to highlight the relevance of the Section 3 uncertainty discussion to the analysis presented in this section. Note that there is also uncertainty related to the employment factors applied in this analysis, particularly factors informing job-years related to relatively new technologies, such as energy storage, on which there is limited data to base assumptions.

Like previous analyses, this analysis represents an evaluation of "first-order employment impacts" using a partial equilibrium modeling approach. It includes some of the potential ripple effects of these impacts on the broader economy. These ripple effects include the secondary job impacts in both upstream and downstream sectors. The analysis includes impacts on upstream sectors including coal, natural gas, and uranium. However, the approach does not analyze impacts on other fuel sectors, nor does it analyze potential impacts related to transmission or distribution. This approach excludes the economy-wide employment effects of changes to energy markets (such as higher or lower forecasted electricity prices). This approach also excludes labor impacts that are sometimes reflected in a benefits analysis for an environmental policy, such as increased productivity from a healthier workforce and reduced absenteeism due to fewer sick days of employees and dependent family members (e.g., children).

[53] For a detailed overview of this methodology, including all underlying assumptions, see the U.S. EPA Methodology for Power Sector-Specific Employment Analysis, available in the docket.

5.3.1 Overview of Methodology

The methodology includes the following two general approaches, based on the available data. The first approach utilizes the rich employment data that is available for several types of generation technologies in the 2020 U.S. Energy and Employment Report.[54] For employment related to other electric power sector generating and pollution control technologies, the second approach utilizes information available in the U.S. Economic Census.

Detailed employment inventory data is available regarding recent employment related to coal, hydro, natural gas, geothermal, wind, and solar generation technologies. The data enables the creation of technology-specific factors that can be applied to model projections of capacity (reported in megawatts, or MW) and generation (reported in megawatt-hours, or MWh) in order to estimate impacts on employment. Since employment data is only available in aggregate by fuel type, it is necessary to disaggregate by labor type in order to differentiate between types of jobs or tasks for categories of workers. For example, some types of employment remain constant throughout the year and are largely a function of the size of a generator, e.g., fixed operation and maintenance activities, while others are variable and are related to the amount of electricity produced by the generator, e.g., variable operation and maintenance activities.

The approach can be summarized in three basic steps:

- Quantify the total number of employees by fuel type in a given year;
- Estimate total fixed operating & maintenance (FOM), variable operating & maintenance (VOM), and capital expenditures by fuel type in that year; and
- Disaggregate total employees into three expenditure-based groups and develop factors for each group (FTE/MWh, FTE/MW-year, FTE/MW new capacity).

Where detailed employment data is unavailable, it is possible to estimate labor impacts using labor intensity ratios. These factors provide a relationship between employment and economic output and are used to estimate employment impacts related to construction and operation of pollution control retrofits, as well as some types of electric generation technologies.

[54] https://www.usenergyjobs.org/

For a detailed overview of this methodology, including all underlying assumptions and the types of employment represented by this analysis, see the U.S. EPA Methodology for Power Sector-Specific Employment Analysis, available in the docket.

5.3.2 Overview of Power Sector Employment

In this section we focus on employment related to electric power generation, as well as coal and natural gas extraction because these are the segments of the power sector that are most relevant to the projected impacts of the rule. Other segments not discussed here include other fuels, energy efficiency, and transmission, distribution, and storage. The statistics presented here are based on the 2020 USEER, which reports data from 2019.[55]

In 2019, the electric power generation sector employed nearly 900,000 people. Relative to 2018, this sector grew by over 2 percent, despite job losses related to nuclear and coal generation. These losses were offset by increases in employment related to other generating technologies, including natural gas, solar, and wind. The largest component of total 2019 employment in this sector is construction (33 percent). Other components of the electric power generation workforce include: utility workers (20 percent), professional and business service employees (20 percent), manufacturing (13 percent), wholesale trade (8 percent), and other (5 percent). In 2019, jobs related to solar and wind generation represent 31 percent and 14 percent of total jobs, respectively, and jobs related to coal generation represent 10 percent of total employment.

In addition to generation-related employment we also look at employment related to coal and natural gas use in the electric power sector. In 2019, the coal industry employed about 75,000 workers. Mining and extraction jobs represent the vast majority of total coal-related employment in 2019 (74 percent). The natural gas fuel sector employed about 276,000 employees in 2019. About 60 percent of those jobs were related to mining and extraction.

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[55] While 2020 data is available in the 2021 version of this report, this section of the RIA utilizes 2019 data because this year does not reflect any short-term trends related to the COVID-19 pandemic. The annual report is available at: https://www.usenergyjobs.org/.

5.3.3 Projected Sectoral Employment Changes due to the Proposed Rule

Electric generating units subject to the mercury and filterable PM emission limits in this proposed rule will likely use various mercury and PM control strategies to comply. Under the modeling of the proposed rule, about 2 GW of coal capacity is estimated to install ESP upgrades, and about 3 GW of coal capacity is estimated to either upgrade existing fabric filters or construct new fabric filter controls by 2028. Additionally, the proposed rule is projected to result in an additional 500 MW of retired coal capacity (less than one percent) in 2028, and small increase in new natural gas and energy storage capacity (each significantly less than 1 GW and less than 1 percent) in that year.

Based on these power sector modeling projections, we estimate an increase in construction-related job-years related to the installation of new pollution controls under the rule, as well as the construction of new generating capacity. In 2028, we estimate an increase of approximately 800 construction-related job-years related to the construction of new pollution controls. We estimate an increase of over 20,00 job-years in 2028 related to the construction of new capacity in that year. In 2030 and 2035, we estimate decreases in construction-related job-years. This near-term increase followed by subsequent decreases results from the projected acceleration of a small amount of new capacity that is projected to be built in the baseline in 2030 and beyond. Construction-related job-year changes are one-time impacts, occurring during each year of the multi-year periods during which construction of new capacity is completed. Construction-related figures in Table 5-3 represent a point estimate of incremental changes in construction jobs for each year (for a three-year construction projection, this table presents one-third of the total jobs for that project).

Table 5-3 Changes in Labor Utilization: Construction-Related (Number of Job-Years of Employment in a Single Year)

	2028	**2030**	**2035**
New Pollution Controls	800	<100	<100
New Capacity	20,600	-8,700	-500

Notes: "<100" denotes an increase or decrease of less than 100 job-years; A large share of the construction-related job years is attributable to construction of energy storage, a relatively new technology on which there is limited data to base labor assumptions.

We also estimate changes in the number of job-years related to recurring non-construction employment. Recurring employment changes are job-years associated with annual recurring jobs including operating and maintenance activities and fuel extraction jobs. Newly built generating capacity creates a recurring stream of positive job-years, while retiring generating capacity, as well as avoided capacity builds, create a stream of negative job-years. The rule is projected to result, generally, in a replacement of relatively labor-intensive coal capacity with less labor-intensive capacity, which results in an overall decrease of non-construction jobs in 2028 and 2030. The total net estimated decrease in recurring employment is about 300 job-years in over 2028-2035, which is a very small percentage of total 2019 power sector employment reported in the 2020 USEER (approximately 900,000 generation-related jobs, 75,000 coal-related jobs, and 276,000 natural gas-related jobs). Table 5-4 provide detailed estimates of recurring non-construction employment changes.

Table 5-4 Changes in Labor Utilization: Recurring Non-Construction (Number of Job-Years of Employment in a Single Year)

	2028	2030	2035
Pollution Controls	<100	<100	<100
Existing Capacity	-200	-200	-200
New Capacity	<100	<100	300
Fuels (Coal, Natural Gas, Uranium)	<100	<100	<100
Coal	<100	<100	<100
Natural Gas	<100	<100	<100
Uranium	<100	<100	<100

Note: "<100" denotes an increase or decrease of less than 100 job-years; Numbers may not sum due to rounding

5.3.4 Conclusions

Generally, there are significant challenges when trying to evaluate the employment effects due to an environmental regulation from employment effects due to a wide variety of other economic changes, including the impact of the coronavirus pandemic on labor markets and the state of the macroeconomy generally. For EGUs, this proposed rule may result in a sizable near-term increase in construction-related jobs related to the installation of new pollution controls, as well as the acceleration of small amounts of new generating capacity construction. The rule is also projected to result, generally, in a replacement of relatively labor-intensive coal capacity with less labor-intensive capacity (primarily solar), which results in an overall decrease of non-construction jobs. Speaking generally, a variety of federal programs are available to invest in communities potentially affected by coal mine and coal power plant closures. An initial report by The Interagency Working Group on Coal and Power Plant Communities and Economic

Revitalization (April 2021) identifies funding available to invest in such "energy communities" through existing programs from agencies including Department of Energy, Department of Treasury, Department of Labor, and others.[56] The Inflation Reduction Act also provides incentives to encourage investment in communities affected by coal mine and coal power plant closures.[57]

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[56] See "Initial Report to the President on Empowering Workers Through Revitalizing Energy Communities" April 2021 at https://energycommunities.gov/wp-content/uploads/2021/11/Initial-Report-on-Energy-Communities_Apr2021.pdf

[57] For more details see Congressional Research Service. "Inflation Reduction Act of 2022 (IRA): Provisions Related to Climate Change" October 3, 2022 at https://crsreports.congress.gov/product/pdf/R/R47262

6 ENVIRONMENTAL JUSTICE IMPACTS

6.1 Introduction

E.O. 12898 directs EPA to "achiev[e] environmental justice (EJ) by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects" (59 FR 7629, February 16, 1994), termed disproportionate impacts in this section. Additionally, E.O. 13985 was signed to advance racial equity and support underserved communities through Federal government actions (86 FR 7009, January 20, 2021). EPA defines EJ 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 further defines the term fair treatment to mean that "no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental, and commercial operations or programs and policies."[58] Meaningful involvement means that: (1) potentially affected populations have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory Agency's decision; (3) the concerns of all participants involved will be considered in the decision-making process; and (4) the rule-writers and decision-makers seek out and facilitate the involvement of those potentially affected.

The term "disproportionate impacts" refers to differences in impacts or risks that are extensive enough that they may merit Agency action.[59] In general, the determination of whether a disproportionate impact exists is ultimately a policy judgment which, while informed by analysis, is the responsibility of the decision-maker. The terms "difference" or "differential" indicate an analytically discernible distinction in impacts or risks across population groups. It is the role of the analyst to assess and present differences in anticipated impacts across population groups of concern for both the baseline and proposed regulatory options, using the best available information (both quantitative and qualitative) to inform the decision-maker and the public.

[58] See, e.g., "Environmental Justice." *Epa.gov*, U.S. Environmental Protection Agency, 4 Mar. 2021, https://www.epa.gov/environmentaljustice.

[59] See https://www.epa.gov/environmentaljustice/technical-guidance-assessing-environmental-justice-regulatory-analysis.

A regulatory action may involve potential EJ concerns if it could: (1) create new disproportionate impacts on minority populations, low-income populations, and/or Indigenous peoples; (2) exacerbate existing disproportionate impacts on minority populations, low-income populations, and/or Indigenous peoples; or (3) present opportunities to address existing disproportionate impacts on minority populations, low-income populations, and/or Indigenous peoples through the action under development.

The Presidential Memorandum on Modernizing Regulatory Review (86 FR 7223; January 20, 2021) calls for procedures to "take into account the distributional consequences of regulations, including as part of a quantitative or qualitative analysis of the costs and benefits of regulations, to ensure that regulatory initiatives appropriately benefit, and do not inappropriately burden disadvantaged, vulnerable, or marginalized communities." Under E.O. 13563, federal agencies may consider equity, human dignity, fairness, and distributional considerations, where appropriate and permitted by law. For purposes of analyzing regulatory impacts, EPA relies upon its June 2016 "Technical Guidance for Assessing Environmental Justice in Regulatory Analysis,"[60] which provides recommendations that encourage analysts to conduct the highest quality analysis feasible, recognizing that data limitations, time, resource constraints, and analytical 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.

[60] See https://www.epa.gov/environmentaljustice/technical-guidance-assessing-environmental-justice-regulatory-analysis.

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

6.2 Analyzing EJ Impacts in This Proposal

In addition to the benefits assessment (see Section 4), EPA considers potential EJ concerns associated with this proposed rulemaking. A potential EJ concern is defined as "the actual or potential lack of fair treatment or meaningful involvement of minority populations, low-income populations, tribes, and Indigenous peoples in the development, implementation and enforcement of environmental laws, regulations and policies."[61] For analytical purposes, this concept refers more specifically to "disproportionate impacts on minority populations, low-income populations, and/or Indigenous peoples that may exist prior to or that may be created by the proposed regulatory action." Although EJ concerns for each rulemaking are unique and should be considered on a case-by-case basis, EPA's EJ Technical Guidance states that "[t]he analysis of potential EJ concerns for regulatory actions should address three questions:

1. Are there potential EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern in the baseline?
2. Are there potential EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern for the regulatory option(s) under consideration?
3. For the regulatory option(s) under consideration, are potential EJ concerns created [, exacerbated,] or mitigated compared to the baseline?"

To address these questions, EPA developed an analytical approach that considers the purpose and specifics of the rulemaking, as well as the nature of known and potential exposures across various demographic groups. While the proposal targets HAP emissions, other local air pollutants emissions may also be reduced, such as NO_X and SO_2. These emissions can lead to localized exposures that may be associated with health effects in nearby populations at

[61] See https://www.epa.gov/environmentaljustice/technical-guidance-assessing-environmental-justice-regulatory-analysis.

sufficiently high concentrations and certain populations may be at increased risk of exposure-related health effects, such as people with asthma.

As HAP exposure results generated as part of the 2020 Residual Risk analysis were below both the presumptive acceptable cancer risk threshold and the noncancer health benchmarks, and this proposed regulation should further reduce exposure to HAP, there are no 'disproportionate and adverse effects' of potential EJ concern. Therefore, we did not perform a quantitative EJ assessment of HAP risk. In addition, technical limitations prevented analysis of NO_X and SO_2 emission reductions. While HAP, NO_2, and SO_2 exposures and concentrations were not directly evaluated as part of this EJ assessment, due to the potential for reductions in these and other environmental stressors nearby affected sources, EPA qualitatively discussed EJ impacts of HAP (Section 6.3) and conducted a proximity analysis to evaluate the potential EJ implications of changes in localized exposures (Section 6.4).[62]

As this proposed rule is also expected to reduce ambient $PM_{2.5}$ and ozone concentrations, EPA conducted a quantitative analysis of modeled changes in $PM_{2.5}$ and ozone concentrations across the continental U.S. resulting from the control strategies projected to occur under the rule, characterizing aggregated and distributional exposures both prior to and following implementation of the proposed regulatory and more stringent regulatory options in 2028, 2030, and 2035 (Section 6.5).

Unique limitations and uncertainties are specific to each type of analysis, which are described prior to presentation of analytic results in the subsections below.

6.3 Qualitative Assessment of HAP Impacts

As required by Section 112(n)(1)(A) of the Clean Air Act, the EPA has determined that it is appropriate and necessary to regulate HAP emissions from coal- and oil-fired EGUs. This determination is driven by the significant public health risks and harms posed by these emissions as evaluated against the availability and costs of emissions controls that could be employed to reduce this harmful pollution. As part of the appropriate and necessary determination, the Administrator specifically considered the impacts of EGU HAP emissions on different

[62] The 2016 NOx ISA and 2017 Sox ISA identified people with asthma, children, and older adults as being at increased risk of NO_2- and SO_2- related health effects and the 2017 SOx ISA.

populations and concluded that certain parts of the U.S. population may be especially vulnerable to mercury emissions based on their characteristics or circumstances. In some cases, the enhanced vulnerability relates to life stage (e.g., fetuses, infants, young children). In other cases, the enhanced vulnerability can be ascribed to the communities in which the population lives. Higher cumulative levels of pollution are often associated with areas affected by past and present environmental injustice. In this second category, the greater sensitivity to HAP emissions can be attributed to poorer levels of overall health (e.g., higher rates of cardiovascular disease, nutritional deficiencies) or to dietary practices which are more common in low-income communities of color (e.g., subsistence fishers). The net effect is that certain sub-populations may be especially vulnerable to EGU HAP emissions and that these emissions are a potential EJ concern.

Of the HAP potentially impacted by this proposed rulemaking, mercury is a persistent and bioaccumulative toxic metal that can be readily transported and deposited to soil and aquatic environments where it is transformed by microbial action into methylmercury.[63] Consumption of fish is the primary pathway for human exposure to methylmercury. Methylmercury bioaccumulates in the aquatic food web eventually resulting in highly concentrated levels of methylmercury within larger fish.[64] A NAS Study reviewed the effects of methylmercury on human health and concluded that it is highly toxic to multiple human and animal organ systems. Of particular concern is chronic prenatal exposure via maternal consumption of foods containing methylmercury. Elevated exposure has been associated with developmental neurotoxicity and manifests as poor performance on neurobehavioral tests, particularly on tests of attention, fine motor function, language, verbal memory, and visual-spatial ability. Because the impacts of the neurodevelopmental effects of methylmercury are greatest during periods of rapid brain development, developing fetuses, infants, and young children are particularly vulnerable. In particular, children born to populations with high fish consumption (e.g., people consuming fish as a dietary staple) or impaired nutritional status may be especially susceptible to adverse neurodevelopmental outcomes. As part of the 2023 Final A&N Review, EPA evaluated how the neurodevelopmental and cardiovascular risks varied across populations. That analysis completed

[63] U.S. EPA. 1997. Mercury Study Report to Congress. EPA–452/R–97–003 December 1997.
[64] National Research Council (NAS). 2000. Toxicological Effects of Methylmercury. Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology, National Research Council.

in support of the appropriate and necessary determination (addressing the EGU sector collectively) suggested that subsistence fisher populations that are racially, culturally, geographically, and/or income-differentiated could experience elevated exposures relative to not only the general population but also the population of subsistence fishers generally. As noted in Section 4 of this document, while previous EPA studies have shown that current modeled exposures are well below the RfD, we conclude that further reductions in mercury emissions from lignite-fired EGUs covered in this proposed action should further reduce exposures for the subsistence fisher sub-population. However, as we do not expect appreciable adverse health effects as a result of HAP emissions from this source category we have not conducted quantitative or qualitative analyses to assess specific mercury-related impacts of this action for EJ communities of potential concern or how those impacts differ from U.S. population-wide effects.

6.4 Demographic Proximity Analyses of Existing Facilities

Demographic proximity analyses allow one to assess the potentially vulnerable populations residing near affected facilities as a proxy for exposure and the potential for adverse health impacts that may occur at a local scale due to economic activity at a given location including noise, odors, traffic, and emissions such as NO_2 and SO_2 covered under this EPA action and not modeled elsewhere in this RIA.

Although baseline proximity analyses are presented here, several important caveats should be noted. Emissions are expected to both decrease and increase from the rulemaking in the three modeled future years, so communities near affected facilities could experience either improvements or worsening in air quality from directly emitted pollutants. It should also be noted that facilities may vary widely in terms of the impacts they already pose to nearby populations. In addition, proximity to affected facilities does not capture variation in baseline exposure across communities, nor does it indicate that any exposures or impacts will occur and should not be interpreted as a direct measure of exposure or impact. These points limit the usefulness of proximity analyses when attempting to answer questions from EPA’s EJ Technical Guidance.

Demographic proximity analyses were performed for all plants with at least one coal-fired unit greater than 25 MW without retirement or gas conversion plans before 2029 affected by this proposed rulemaking. Due to the distinct regulatory requirements, the following subsets of affected facilities were separately evaluated:

- Lignite plants (12 facilities) with units potentially subject to the proposed mercury standard revision: Comparison of the percentage of various populations (race/ethnicity, age, education, poverty status, income, and linguistic isolation) living near the facilities to average national levels.
- Coal plants (12 facilities) with units potentially subject to the proposed filterable PM standard revision: Comparison of the percentage of various populations (race/ethnicity, age, education, poverty status, income, and linguistic isolation) living near the facilities to average national levels.
- Coal plants (48 facilities) with units potentially subject to the alternate filterable PM standard revision: Comparison of the percentage of various populations (race/ethnicity, age, education, poverty status, income, and linguistic isolation) living near the facilities to average national levels.

The current analysis identified all census blocks with centroids within a 10 km radius of the latitude/longitude location of each facility, and then linked each block with census-based demographic data.[65] The total population within a specific radius around each facility is the sum of the population for every census block within that specified radius, based on each block's population provided by the 2020 decennial Census.[66] Statistics on race, ethnicity, age, education level, poverty status and linguistic isolation were obtained from the Census' American Community Survey (ACS) 5-year averages for 2016-2020. These data are provided at the block group level. For the purposes of this analysis, the demographic characteristics of a given block group – that is, the percentage of people in different races/ethnicities, the percentage without a high school diploma, the percentage that are below the poverty level, the percentage that are below two times the poverty level, and the percentage that are linguistically isolated – are presumed to also describe each census block located within that block group.

In addition to facility-specific demographics, the demographic composition of the total population within the specified radius (e.g., 10 km) for all facilities was also computed (e.g., all EGUs potentially subject to the mercury standard revision). In calculating the total populations,

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[65] The 10 km distance was determined to be the shortest radius around these units that captured a large enough population to avoid excessive demographic uncertainty.

[66] The location of the Census block centroid is used to determine if the entire population of the Census block is assumed to be within the specified radius. It is unknown how sensitive these results may be to different methods of population estimation, such as aerial apportionment.

to avoid double-counting, each census block population was only counted once. That is, if a census block was located within the selected radius (i.e., 10 km) for multiple facilities, the population of that census block was only counted once in the total population. Finally, this analysis compares the demographics at each specified radius (i.e., 10 km) to the demographic composition of the nationwide population.

Table 6-1 shows the results of the proximity analysis for the three sets of affected facilities investigated. The analysis indicates that, on average, the percentage of the population living within 10 km of these units that is African American, Hispanic/Latino, and Other/Multiracial is significantly lower than the national average. One exception is the percent of the population that is Native American within 10 km of the lignite plants (0.9 percent) that is above the national average (0.6 percent). This is driven by four facilities that have a percent Native American population living within 10 km ranging from 1.3 percent up to 5.9 percent. Also, on average, the populations living within 10 km of the units subject to the proposed or alternate filterable PM standards have a higher percentage of people living below two times the poverty level than the national average (30 to 33 percent versus 29 percent).

Table 6-1 Proximity Demographic Assessment Results Within 10 km of Coal-Fired Units Greater than 25 MW Without Retirement or Gas Conversion Plans Before 2029 Affected by this Proposed Rulemaking [a,b]

		Population within 10 km		
Demographic Group	**Nationwide Average for Comparison**	**Lignite plants potentially subject to proposed mercury standard**	**Coal plants potentially subject to proposed filterable PM standard**	**Coal plants potentially subject to alternate filterable PM standard**
Total Population	329,824,950	17,790	233,575	854,120
Number of Facilities	-	12	12	48
Race and Ethnicity by Percent				
White	60%	79%	80%	74%
African American	12%	12%	4%	6%
Native American	0.60%	0.9%	0.40%	0.40%
Hispanic or Latino[2]	19%	5%	12%	15%
Other and Multiracial	9%	2%	3%	4%
Income by Percent				
Below Poverty Level	13%	12%	14%	13%
Below 2x Poverty Level	29%	28%	33%	30%
Education by Percent				
>25 and w/o a HS Diploma	12%	13%	13%	11%
Linguistically Isolated by Percent				
Linguistically Isolated	5%	2%	3%	2%

[a] The nationwide population count and all demographic percentages are based on the Census' 2016-2020 American Community Survey five-year block group averages and include Puerto Rico. Demographic percentages based on different averages may differ. The total population counts are based on the 2020 Decennial Census block populations.
[b] To avoid double counting, the "Hispanic or Latino" category is treated as a distinct demographic category for these analyses. A person is identified as one of five racial/ethnic categories above: White, African American, Native American, Other and Multiracial, or Hispanic/Latino. A person who identifies as Hispanic or Latino is counted as Hispanic/Latino for this analysis, regardless of what race this person may have also identified as in the Census. Includes white and nonwhite.

6.5 EJ $PM_{2.5}$ and Ozone Exposure Impacts

This EJ air pollutant exposure[67] analysis aims to evaluate the potential for EJ concerns related to $PM_{2.5}$ and ozone exposures[68] among potentially vulnerable populations. To assess EJ ozone and $PM_{2.5}$ exposure impacts, we focus on the first and third of the three EJ questions from

[67] The term exposure is used here to describe estimated $PM_{2.5}$ and ozone concentrations and not individual dosage.
[68] Air quality surfaces used to estimate exposures are based on 12 km^2 grids. Additional information on air quality modeling can be found in the air quality modeling information section.

the EPA's 2016 EJ Technical Guidance,[69] which ask if there are potential EJ concerns associated with stressors affected by the regulatory action for population groups of concern in the baseline and if those potential EJ concerns in the baseline are exacerbated, unchanged, or mitigated under the regulatory options being considered.[70]

To address these questions with respect to the $PM_{2.5}$ and ozone exposures, EPA developed an analytical approach that considers the purpose and specifics of this proposed rulemaking, as well as the nature of known and potential exposures and impacts. Specifically, as 1) this proposed rule affects EGUs across the U.S., which typically have tall stacks that result in emissions from these sources being dispersed over large distances, and 2) both ozone and $PM_{2.5}$ can undergo long-range transport, it is appropriate to conduct an EJ assessment of the contiguous U.S. Given the availability of modeled $PM_{2.5}$ and ozone air quality surfaces under the baseline and proposed regulatory options, we conduct an analysis of changes in $PM_{2.5}$ and ozone concentrations resulting from the emission changes projected by IPM[71] to occur under the proposed rule as compared to the baseline scenario, characterizing average and distributional exposures following implementation of the proposed regulatory options in the implementation year (2028), 2030, and 2035. However, several important caveats of this analysis are as follows:

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[69] U.S. Environmental Protection Agency (EPA), 2015. Guidance on Considering Environmental Justice During the Development of Regulatory Actions. https://www.epa.gov/sites/default/files/2015-06/documents/considering-ej-in-rulemaking-guide-final.pdf

[70] EJ question 2, which asks if there are potential EJ concerns (i.e., disproportionate burdens across population groups) associated with environmental stressors affected by the regulatory action for population groups of concern for the regulatory options under consideration, was not focused on for several reasons. Importantly, the total magnitude of differential exposure burdens with respect to ozone and $PM_{2.5}$ among population groups at the national scale has been fairly consistent pre- and post-policy implementation across recent rulemakings. As such, differences in nationally aggregated exposure burden averages between population groups before and after the rulemaking tend to be very similar. Therefore, as disparities in pre- and post-policy burden results appear virtually indistinguishable, the difference attributable to the rulemaking can be more easily observed when viewing the change in exposure impacts, and as we had limited available time and resources, we chose to provide quantitative results on the pre-policy baseline and policy-specific impacts only, which related to EJ questions 1 and 3. We do however use the results from questions 1 and 3 to gain insight into the answer to EJ question 2 in the summary (Section 6.7).

[71] As discussed in greater detail in Section 3, IPM is a comprehensive electricity market optimization model that can evaluate the impacts of regulatory actions affecting the power sector within the context of regional and national electricity markets. IPM generates least-cost resource dispatch decisions based on user-specified constraints such as environmental, demand, and other operational constraints. IPM uses a long-term dynamic linear programming framework that simulates the dispatch of generating capacity to achieve a demand-supply equilibrium on a seasonal basis and by region. The model computes optimal capacity that combines short-term dispatch decisions with long-term investment decisions. IPM runs under the assumption that electricity demand must be met and maintains a consistent expectation of future load. IPM outputs include the air emissions resulting from the simulated generation mix.

- The baseline scenarios for 2028, 2030 and 2035 represent EGU emissions expected in 2028, 2030 and 2035 respectively, but emissions from all other sources are projected to the year 2026. The 2028, 2030 and 2035 baselines therefore do not capture any anticipated changes in ambient ozone and $PM_{2.5}$ between 2026 and 2028, 2030 or 2035 that would occur due to emissions changes from sources other than EGUs.
- Modeling of post-policy air quality concentration changes are based on state-level emission data paired with facility-level baseline 2026 emissions that were available in the summer 2021 version of IPM. While the baseline spatial patterns represent ozone and $PM_{2.5}$ concentrations associated with the facility level emissions described above, the post-policy air quality surfaces will capture expected ozone and $PM_{2.5}$ changes that result from state-to-state emissions changes but will not capture heterogenous changes in emissions from multiple facilities within a single state.
- Air quality simulation input information are at a 12 km^2 grid resolution and population information is either at the Census tract- or county-level, potentially masking impacts at geographic scales more highly resolved than the input information.
- The two specific air pollutant metrics evaluated in this assessment, warm season maximum daily eight-hour ozone average concentrations and average annual $PM_{2.5}$ concentrations, are focused on longer-term exposures that have been linked to adverse health effects. This assessment does not evaluate disparities in other potentially health-relevant metrics, such as shorter-term exposures to ozone and $PM_{2.5}$.
- $PM_{2.5}$ EJ impacts were limited to exposures, and do not extend to health effects, given additional uncertainties associated with estimating health effects stratified by demographic population and the ability to predict differential $PM_{2.5}$-attributable EJ health impacts.

Population variables considered in this EJ exposure assessment include race, ethnicity, educational attainment, employment status, health insurance status, linguistic isolation, poverty status, age, and sex (Table 6-2).[72]

[72] Population projections stratified by race/ethnicity, age, and sex are based on economic forecasting models developed by Woods and Poole (2015). The Woods and Poole database contains county-level projections of population by age, sex, and race out to 2050, relative to a baseline using the 2010 Census data. Population projections for each county are determined simultaneously with every other county in the U.S to consider patterns of economic growth and migration. County-level estimates of population percentages within the poverty status and educational attainment groups were derived from 2015-2019 5-year average ACS estimates. Additional information can be found in Appendix J of the BenMAP-CE User's Manual (https://www.epa.gov/benmap/benmap-ce-manual-and-appendices).

Table 6-2 Demographic Populations Included in the $PM_{2.5}$ and Ozone EJ Exposure Analyses

Demographic	Groups	Ages	Spatial Scale of Population Data
Race	Asian; American Indian; Black; White	0-99	Census tract
Ethnicity	Hispanic; Non-Hispanic	0-99	Census tract
Educational Attainment	High school degree or more; No high school degree	25-99	Census tract
Employment Status	Employed; Unemployed; Not in the labor force	0-99	County
Health Insurance	Insured; Uninsured	0-64	County
Linguistic Isolation	Speaks English "very well" or better; Speaks English less than "very well" OR Speaks English "well" or better; Speaks English less than "well"	0-99	Census tract
Poverty Status	Above the poverty line; Below the poverty line OR Above 2x the poverty line; Below 2x the poverty line	0-99	Census tract
Age	Children Adults Older Adults	0-17 18-64 65-99	Census tract
Sex	Female; Male	0-99	Census tract

6.5.1 Populations Predicted to Experience $PM_{2.5}$ and Ozone Air Quality Changes

As IPM predicts the proposed rule will lead to both decreases and increases in emissions, the contiguous U.S. was grouped into areas where air quality 1) improves or does not change, or 2) worsens as a result of the proposed rulemaking. Figure 6-1 shows the average $PM_{2.5}$ and ozone concentration in the two above categories for both the proposed and more stringent regulatory options in each of the three future years for which air quality modeling is available. In general, the more stringent regulatory option leads to large portions of the population experiencing greater average $PM_{2.5}$ and ozone concentration reductions than the proposed policy option, but also results in portions of the population experiencing greater average $PM_{2.5}$ and ozone concentration increases. However, the magnitude of the air pollution exposure changes from both proposed regulatory options is quite small and somewhat variable across the three future years analyzed.

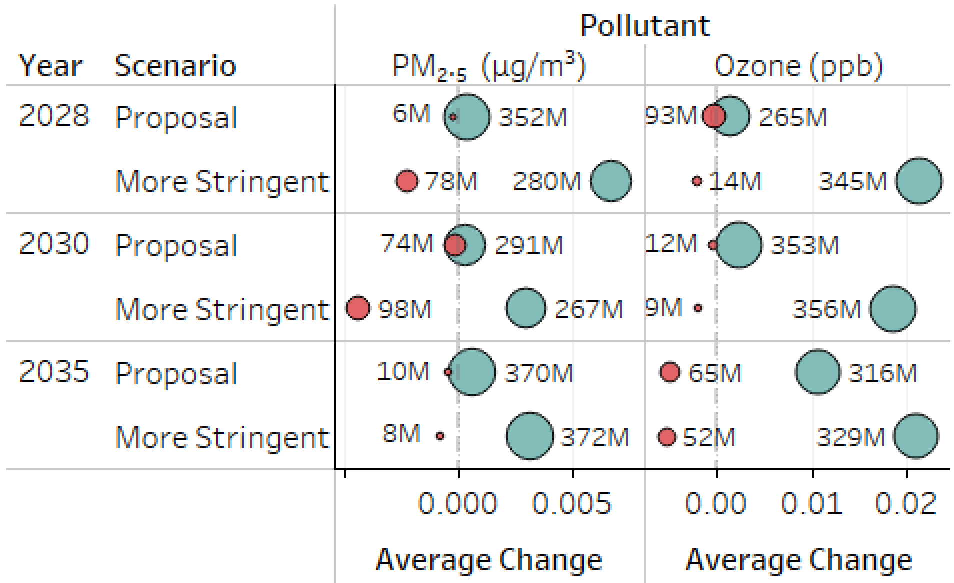

Figure 6-1 Number of People Residing in the Contiguous U.S., Areas Improving or Not Changing (Teal) or Worsening (Red) in 2028, 2030, and 2035 for $PM_{2.5}$ and Ozone and the National Average Magnitude of Pollutant Concentration Changes (µg/m^3 and ppb) for the Proposed and More Stringent Regulatory Options

6.5.2 $PM_{2.5}$ EJ Exposure Analysis

We evaluated the potential for EJ concerns among potentially vulnerable populations resulting from exposure to $PM_{2.5}$ under the baseline and proposed regulatory options in this rule. This was done by characterizing the distribution of $PM_{2.5}$ exposures both prior to and following implementation of the proposed regulatory option, as well as under the more stringent regulatory option, in 2028, 2030, and 2035.

As this analysis is based on the same $PM_{2.5}$ spatial fields as the benefits assessment (see Appendix A for a discussion of the spatial fields), it is subject to similar types of uncertainty (see Section 4.3.8for a discussion of the uncertainty). A particularly germane limitation for this analysis is that the expected concentration changes are quite small, likely making uncertainties associated with the various input data more relevant.

6.5.2.1 National Aggregated Results

National average baseline $PM_{2.5}$ concentrations in micrograms per cubic meter (µg/m^3) in 2028, 2030, and 2035 are shown in the colored column labeled “baseline” in the Figure 6-2 heat map. Concentrations in the “baseline” columns represent the total estimated $PM_{2.5}$ exposure burden averaged over the 12-month calendar year and are colored to visualize differences more easily in average concentrations (lighter blue coloring representing smaller average concentrations and darker blue coloring representing larger average concentrations). Average national disparities observed in the baseline of this rule are similar to those described by recent rules (e.g., the PM NAAQS Proposal), that is, populations with national average $PM_{2.5}$ concentrations higher than the reference population ordered from most to least difference were: those linguistically isolated, Hispanics, Asians, Blacks, the less educated, and children. Average national disparities observed in the baseline of this rule are generally consistent across the three future years and similar to those described by recent rules (e.g., the PM NAAQS Proposal).

Columns labeled "Proposal" and "More Stringent" provide information regarding how the proposed regulatory and more stringent options will impact $PM_{2.5}$ concentrations across various populations, respectively.[73] For all three future years evaluated, there were no discernable $PM_{2.5}$ changes under the proposed regulatory option for any population analyzed when showing concentrations out to the thousandths digit, reiterating the small magnitude of national average $PM_{2.5}$ changes. Going to the thousandths digit showed small national-level $PM_{2.5}$ concentration reductions for the more stringent regulatory option in all three future years. While the national-level $PM_{2.5}$ concentration reductions were identical for all population groups evaluated in 2030 and 2035, there were some differences observed in 2028. For example, on average, the Black population, which has higher average baseline exposures, is predicted to experience a slightly greater $PM_{2.5}$ concentration reduction than the overall reference population. In contrast, the Asian population, which also has higher average baseline exposures, is estimated to experience a smaller $PM_{2.5}$ concentration reduction than the overall reference population.

The national-level assessment of $PM_{2.5}$ before and after implementation of this proposed rulemaking suggests that while EJ exposure disparities are present in the pre-policy scenario, meaningful EJ exposure concerns are not likely created or exacerbated by the rule for the population groups evaluated, due to the small magnitude of the $PM_{2.5}$ concentration reductions.

[73] We report average exposure results to the decimal place where difference between demographic populations become visible, as we cannot provide a quantitative estimate of the air quality modeling precision uncertainty. Using this approach allows for a qualitative consideration of uncertainties and the significance of the relatively small differences.

Group	Population	2028			2030			2035		
		Baseline	Proposal	More Stringent	Baseline	Proposal	More Stringent	Baseline	Proposal	More Stringent
-	Reference (0-99)	7.186	0.000	0.006	7.136	0.000	0.001	7.079	0.000	0.002
Race	White (0-99)	7.092	0.000	0.006	7.044	0.000	0.001	6.991	0.000	0.002
	American Indian (0-99)	6.716	0.000	0.003	6.681	0.000	0.000	6.644	0.000	0.002
	Asian (0-99)	7.788	0.000	0.004	7.719	0.000	0.001	7.631	0.000	0.002
	Black (0-99)	7.449	0.000	0.007	7.385	0.000	0.001	7.295	0.000	0.003
Ethnicity	Non-Hispanic (0-99)	6.963	0.000	0.006	6.909	0.000	0.001	6.838	0.000	0.002
	Hispanic (0-99)	8.008	0.000	0.005	7.942	0.000	0.001	7.865	0.000	0.002
Educational Attainment	More educated (>24: HS or more)	7.089	0.000	0.006	7.039	0.000	0.001	6.984	0.000	0.002
	Less educated (>24; no HS)	7.530	0.000	0.006	7.478	0.000	0.001	7.432	0.000	0.002
Employment Status	Employed	7.343	0.000	0.006	7.292	0.000	0.001	7.237	0.000	0.002
	Unemployed	7.186	0.000	0.006	7.136	0.000	0.001	7.079	0.000	0.002
	Not in the labor force	7.187	0.000	0.006	7.136	0.000	0.001	7.081	0.000	0.002
Insurance Status	Insured	7.230	0.000	0.006	7.181	0.000	0.001	7.122	0.000	0.002
	Unisured	7.307	0.000	0.006	7.258	0.000	0.001	7.203	0.000	0.003
Linguistic Isolation	English "well or better" (0-99)	7.140	0.000	0.006	7.090	0.000	0.001	7.032	0.000	0.002
	English < "well" (0-99)	8.154	0.000	0.005	8.099	0.000	0.001	8.054	0.000	0.002
Poverty Status	>Poverty line (0-99)	7.155	0.000	0.006	7.104	0.000	0.001	7.048	0.000	0.002
	<Poverty line (0-99)	7.358	0.000	0.006	7.307	0.000	0.001	7.251	0.000	0.002
Age	Children (0-17)	7.252	0.000	0.006	7.200	0.000	0.001	7.139	0.000	0.002
	Adults (18-64)	7.233	0.000	0.006	7.184	0.000	0.001	7.127	0.000	0.002
	Older Adults (65-99)	6.972	0.000	0.007	6.925	0.000	0.001	6.882	0.000	0.002
Sex	Females (0-99)	7.197	0.000	0.006	7.147	0.000	0.001	7.091	0.000	0.002
	Males (0-99)	7.175	0.000	0.006	7.125	0.000	0.001	7.068	0.000	0.002

Figure 6-2 Heat Map of the National Average $PM_{2.5}$ Concentrations in the Baseline and Reductions in Concentrations Due to the Proposed and More Stringent Regulatory Options Across Demographic Groups in 2028, 2030, and 2035 (µg/m^3)

6.5.2.2 State Aggregated Results

We also provide $PM_{2.5}$ concentration reductions by state and demographic population in 2028, 2030, and 2035 for the 48 states in the contiguous U.S, for the proposed and more stringent regulatory options (Figure 6-3). In this heat map, darker blue again indicates larger $PM_{2.5}$ reductions and red indicates $PM_{2.5}$ concentration increases with states shown as columns and demographic groups as rows. In order to show all the information in a single heat map, only colors are used to show relative $PM_{2.5}$ concentrations and only the overall reference group (i.e., everyone ages 0-99) is included.

Compared to the magnitude of state-level $PM_{2.5}$ concentration changes under the more stringent regulatory option, the magnitude of state-level $PM_{2.5}$ concentration changes under the proposed regulatory scenario is very small. State-level average populations are projected to experience reductions in $PM_{2.5}$ concentrations by up to 0.05 µg/m^3 in Florida (FL) in 2028 under the more stringent regulatory option and increases of up to 0.02 µg/m^3 in Missouri (MO) in 2030, also under the more stringent regulatory option. However, under both regulatory options, populations potentially of concern are projected to experience similar $PM_{2.5}$ concentration changes as the state-level reference population.[74] Therefore, whereas $PM_{2.5}$ exposure impacts vary considerably across states, the small magnitude of differential impacts expected by the proposed rule is not likely to meaningfully exacerbate or mitigate EJ concerns within individual states.

Figure 6-3 Heat Map of the State Average $PM_{2.5}$ Concentration Reductions (Blue) and Increases (Red) Due to the Proposed and More Stringent Regulatory Options Across Demographic Groups in 2028, 2030, and 2035 (µg/m³)

[74] Please note that population counts vary greatly by state, and that averaging results of the 48 states shown here will not reflect national population-weighted exposure estimates.

6.5.2.3 *Distributional Results*

We also present cumulative proportion of each population exposed to ascending levels of $PM_{2.5}$ concentration changes across the contiguous U.S. Results allow evaluation of what percentage of each subpopulation (e.g., Hispanics) in the contiguous U.S. experience what change in $PM_{2.5}$ concentrations compared to what percentage of the overall reference group (i.e., the total population of contiguous U.S.) experiences similar concentration changes from EGU emission changes under the two regulatory options in 2028, 2030, and 2035 (Figure 6-4).

This distributional EJ analysis is also subject to additional uncertainties related to more highly resolved input parameters and additional assumptions. For example, this analysis does not account for potential difference in underlying susceptibility, vulnerability, or risk factors across populations to $PM_{2.5}$ exposure. Nor could we include information about differences in other factors that could affect the likelihood of adverse impacts (e.g., exercise patterns) across groups. Therefore, this analysis should not be used to assert that there are meaningful differences in $PM_{2.5}$ exposure impacts associated with either the baseline or the rule across population groups.

As the baseline scenario is similar to that described by other RIAs, we focus on the $PM_{2.5}$ changes due to this proposed rulemaking. Distributions of 12 km^2 gridded $PM_{2.5}$ concentration changes from EGU control strategies of affected facilities under the two regulatory options analyzed in this proposed rulemaking in 2028, 2030, and 2035 are shown in Figure 6-4. For clarity, only above/below the poverty line and those who speak English "well or better"/"less than well" are shown and sex and the overall reference group are excluded from the cumulative distribution figures.

The vast majority of $PM_{2.5}$ concentration changes for each population distribution are less than 0.02 $\mu g/m^3$ under either regulatory option for all three future years analyzed. Therefore, the distributions of $PM_{2.5}$ concentration changes across population demographics are all reasonably similar and the very small difference in impacts shown in the distributional analyses of $PM_{2.5}$ concentration changes under the various regulatory options provides additional evidence that the proposed rule is not likely to meaningfully exacerbate or mitigate EJ $PM_{2.5}$ exposure concerns for population groups evaluated.

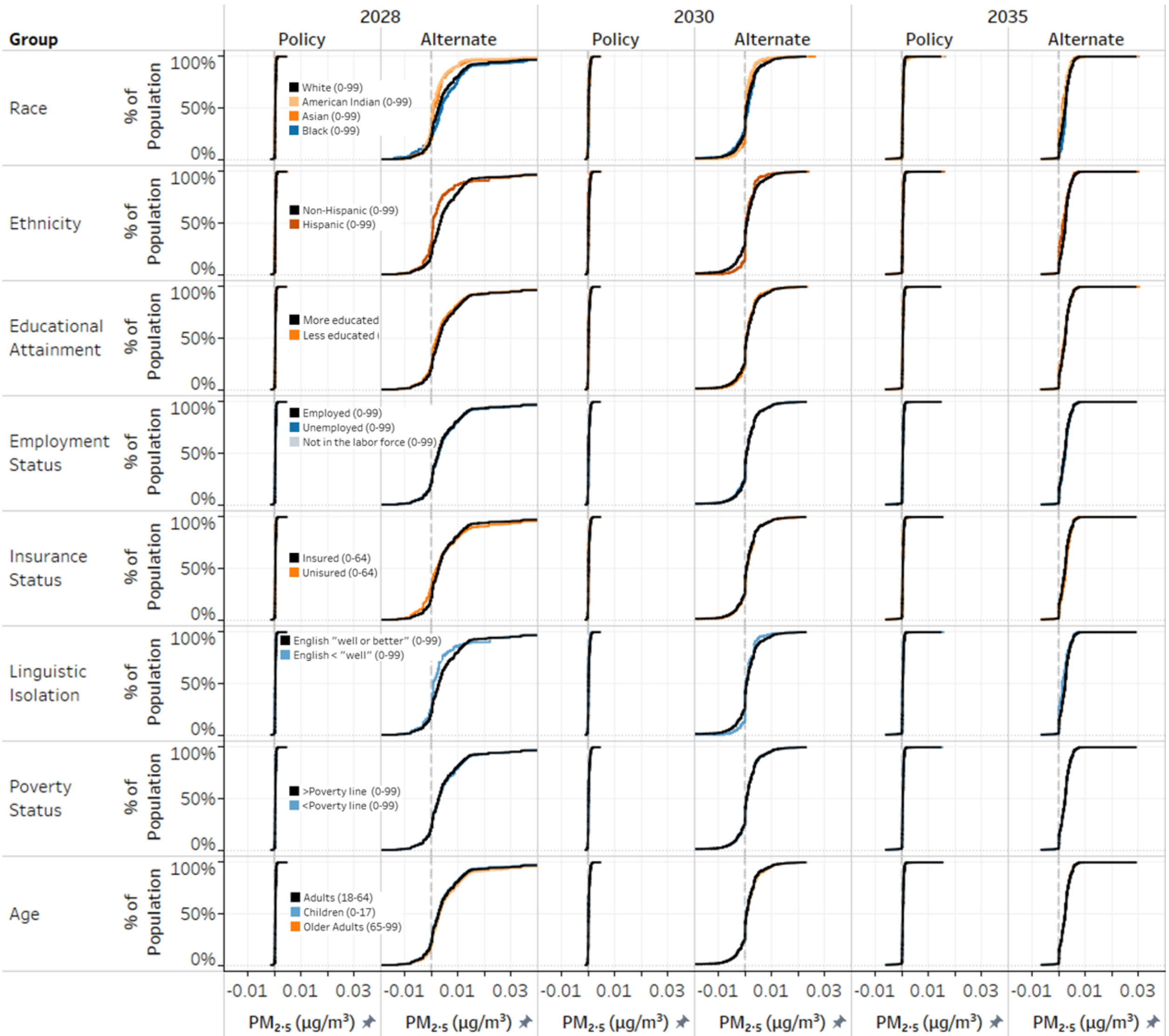

Figure 6-4 Distributions of $PM_{2.5}$ Concentration Changes Across Populations, Future Years, and Regulatory Options

6.5.3 Ozone EJ Exposure Analysis

To evaluate the potential for EJ concerns among potentially vulnerable populations resulting from exposure to ozone under the baseline and regulatory options proposed in this rule, we characterize the distribution of ozone exposures both prior to and following implementation of the proposed rule, as well as under the more stringent regulatory option, in 2028, 2030, and 2035.

As this analysis is based on the same ozone spatial fields as the benefits assessment (see Appendix A for a discussion of the spatial fields), it is subject to similar types of uncertainty (see Section 4.3.8 for a discussion of the uncertainty). In addition to the small magnitude of differential ozone concentration changes associated with this proposed rulemaking when comparing across demographic populations, a particularly germane limitation is that ozone, being a secondary pollutant, is the byproduct of complex atmospheric chemistry such that direct linkages cannot be made between specific affected facilities and downwind ozone concentration changes based on available air quality modeling.

Ozone concentration and exposure metrics can take many forms, although only a small number are commonly used. The analysis presented here is based on the average April-September warm season maximum daily eight-hour average ozone concentrations (AS-MO3), consistent with the health impact functions used in the benefits assessment (Section 4). As developing spatial fields is time and resource intensive, the same spatial fields used for the benefits analysis were also used for the ozone exposure analysis performed here to assess EJ impacts.

The construct of the AS-MO3 ozone metric used for this analysis should be kept in mind when attempting to relate the results presented here to the ozone NAAQS and when interpreting the confidence in the association between exposures and health effects. Specifically, the seasonal average ozone metric used in this analysis is not constructed in a way that directly relates to NAAQS design values, which are based on daily maximum eight-hour concentrations.[75] Thus, AS-MO3 values reflecting seasonal *average* concentrations well below the level of the NAAQS at a particular location do not necessarily indicate that the location does not experience any *daily* (eight-hour) exceedances of the ozone NAAQS. Relatedly, EPA is confident that reducing the highest ambient ozone concentrations will result in substantial improvements in public health, including reducing the risk of ozone-associated mortality. However, the Agency is less certain about the public health implications of changes in relatively low ambient ozone concentrations. Most health studies rely on a metric such as the warm-season average ozone concentration; as a result, EPA typically utilizes air quality inputs such as the AS-MO3 spatial fields in the benefits

[75] Level of 70 ppb with an annual fourth-highest daily maximum eight-hour concentration, averaged over three years.

assessment, and we judge them also to be the best available air quality inputs for this EJ ozone exposure assessment.

6.5.3.1 National Aggregated Results

National average baseline ozone concentrations in ppb in 2028, 2030, and 2035 are shown in the colored column labeled "baseline" in the heat map (Figure 6-5). Concentrations in the "baseline" columns represent the total estimated daily eight-hour maximum ozone exposure burden averaged over the 6-month April-September ozone season and are colored to visualize differences more easily in average concentrations, with lighter green coloring representing smaller average concentrations and darker green coloring representing larger average concentrations. Populations with national average ozone concentrations higher than the reference population ordered from most to least difference were: American Indians, Hispanics, linguistically isolated, Asians, the less educated, and children. Average national disparities observed in the baseline of this rule are fairly consistent across the three future years and similar to those described by recent rules (e.g., the proposed GNP rule).

Columns labeled "Proposal" and "More Stringent" provide information regarding how the proposed regulatory and more stringent options will impact ozone concentrations across various populations, respectively.[76] For all three future years evaluated, there were no discernable ozone changes under the proposed regulatory option for any population analyzed when showing concentrations out to the hundredths digit, reiterating the small magnitude of national average ozone changes. Going to the hundredths digit did show small national-level ozone concentration reductions for the more stringent regulatory option in all three future years, that were very similar across all population groups evaluated.

The national-level assessment of ozone burden concentrations in the baseline and ozone exposure changes due to the regulatory options suggests that while EJ exposure disparities are present in the pre-policy scenario, meaningful EJ exposure concerns are not likely created or

[76] We report average exposure results to the decimal place where difference between demographic populations become visible, as we cannot provide a quantitative estimate of the air quality modeling precision uncertainty. Using this approach allows for a qualitative consideration of uncertainties and the significance of the relatively small differences.

exacerbated by the rule for the population groups evaluated, due to the small magnitude of the ozone concentration changes.

Group	Population	2028 Baseline	2028 Proposal	2028 More Stringent	2030 Baseline	2030 Proposal	2030 More Stringent	2035 Baseline	2035 Proposal	2035 More Stringent
-	Reference (0-99)	40.80	0.00	0.02	40.70	0.00	0.01	40.51	0.00	0.01
Race	White (0-99)	40.89	0.00	0.02	40.79	0.00	0.01	40.61	0.00	0.01
	American Indian (0-99)	42.93	0.00	0.02	42.86	0.00	0.01	42.74	0.01	0.01
	Asian (0-99)	41.98	0.00	0.01	41.85	0.00	0.01	41.60	0.00	0.01
	Black (0-99)	39.54	0.00	0.02	39.42	0.00	0.01	39.17	0.01	0.01
Ethnicity	Non-Hispanic (0-99)	40.27	0.00	0.02	40.15	0.00	0.02	39.91	0.01	0.01
	Hispanic (0-99)	42.75	0.00	0.02	42.64	0.00	0.01	42.44	0.00	0.01
Educational Attainment	More educated (>24: HS or more)	40.63	0.00	0.02	40.53	0.00	0.01	40.34	0.00	0.01
	Less educated (>24; no HS)	41.22	0.00	0.02	41.13	0.00	0.01	40.97	0.00	0.01
Employment Status	Employed	41.23	0.00	0.02	41.13	0.00	0.01	40.95	0.00	0.01
	Unemployed	40.80	0.00	0.02	40.70	0.00	0.01	40.51	0.00	0.01
	Not in the labor force	40.77	0.00	0.02	40.67	0.00	0.01	40.48	0.00	0.01
Insurance Status	Insured	40.95	0.00	0.02	40.85	0.00	0.01	40.66	0.00	0.01
	Unisured	40.46	0.00	0.02	40.36	0.00	0.01	40.17	0.00	0.01
Linguistic Isolation	English "well or better" (0-99)	40.74	0.00	0.02	40.63	0.00	0.01	40.44	0.00	0.01
	English < "well" (0-99)	42.15	0.00	0.01	42.06	0.00	0.01	41.90	0.00	0.01
Poverty Status	>Poverty line (0-99)	40.80	0.00	0.02	40.70	0.00	0.01	40.51	0.00	0.01
	<Poverty line (0-99)	40.80	0.00	0.02	40.70	0.00	0.01	40.52	0.00	0.01
Age	Children (0-17)	41.02	0.00	0.02	40.92	0.00	0.01	40.72	0.00	0.01
	Adults (18-64)	40.85	0.00	0.02	40.75	0.00	0.01	40.56	0.00	0.01
	Older Adults (65-99)	40.41	0.00	0.02	40.30	0.00	0.01	40.13	0.00	0.01
Sex	Females (0-99)	40.79	0.00	0.02	40.69	0.00	0.01	40.50	0.00	0.01
	Males (0-99)	40.81	0.00	0.02	40.71	0.00	0.01	40.52	0.00	0.01

Figure 6-5 Heat Map of the National Average Ozone Concentrations in the Baseline and Reductions in Concentrations Due to the Proposed and More Stringent Regulatory Options Across Demographic Groups in 2028, 2030, and 2035 (ppb)

6.5.3.2 State Aggregated Results

We also provide ozone concentration reductions by state and demographic population in 2028, 2030, and 2035 for the 48 states in the contiguous U.S, for the policy and more stringent regulatory alternatives (Figure 6-6). In this heat map, darker green again indicates larger ozone reductions, with demographic groups shown as rows and each state as a column. On average, the state-specific reference populations are projected to experience reductions in ozone concentrations by up to 0.10 ppb for American Indian populations in Montana (MT) under the proposed and more stringent regulatory options. Ozone increases are only observed in Utah (UT) and Nevada (NV) in both policy options in 2035, with the maximum ozone increases of 0.02 ppb being predicted for several populations in Utah (UT).

Outside of MT, South Dakota (SD), and Wyoming (WY), population averages within individual states do not vary by more than 0.02 ppb. Elsewhere, populations potentially of concern are projected to experience similar ozone concentration reductions as the state-level reference population. Please note that population counts vary greatly by state and that as of 2022, MT, SD, and WY were the 43rd, 46th, and 50th least populated states.[77]

Therefore, ozone exposure impacts vary considerably across states. In addition, although American Indians in MT, SD, and WY may experience slightly greater reductions due to this proposed rulemaking, the small magnitude of differential impacts expected by the proposed rule is not likely to meaningfully exacerbate or mitigate EJ concerns within individual states.

[77] Averaging results of the 48 states shown here will not reflect national population-weighted exposure estimates, due to different populations within each state.

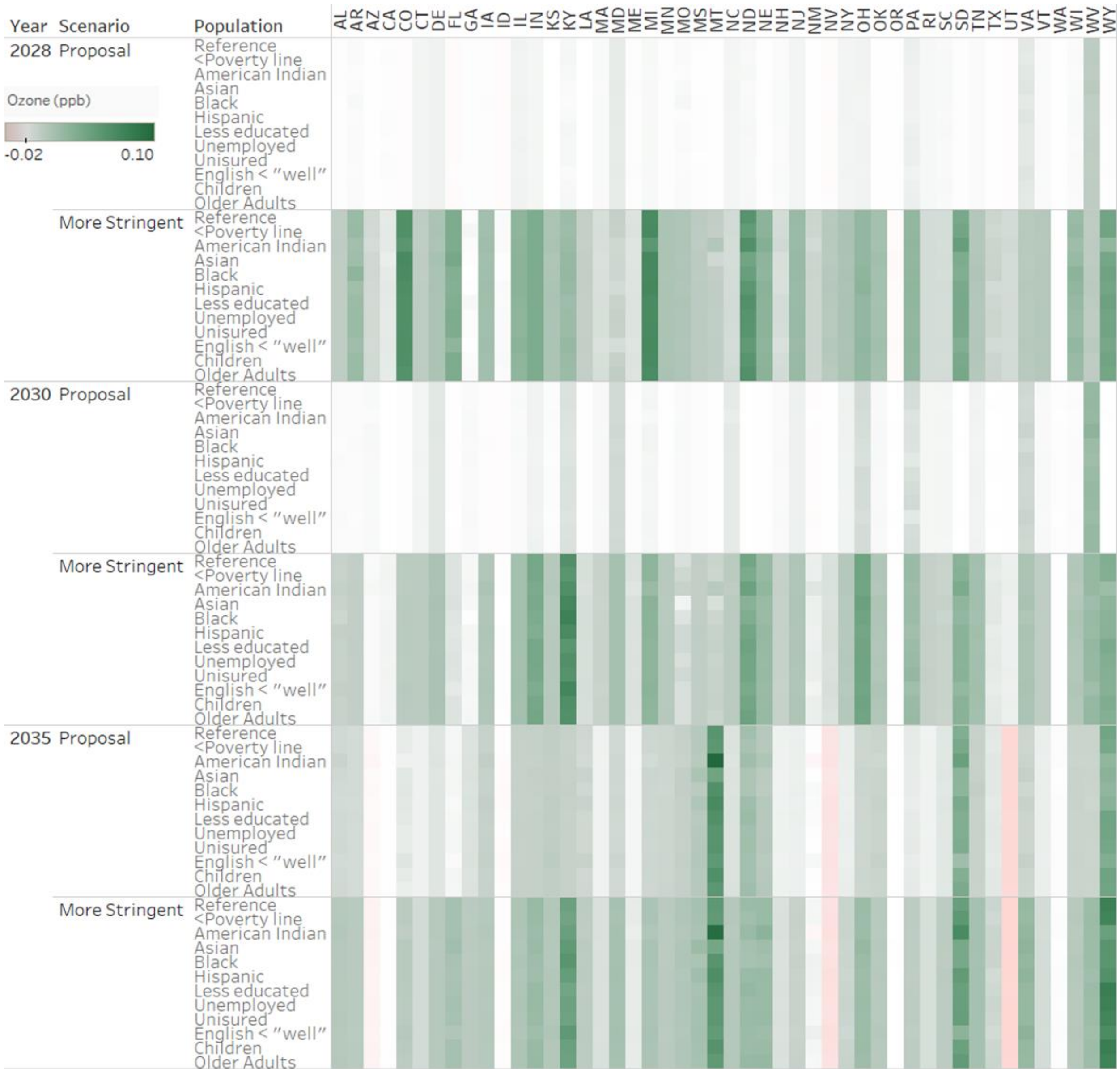

Figure 6-6 Heat Map of the State Average Ozone Concentrations Reductions (Green) and Increases (Red) Due to the Proposed and More Stringent Regulatory Options Across Demographic Groups in 2028, 2030, and 2035 (ppb)

6.5.3.3 Distributional Results

We also present cumulative proportion of each population exposed to ascending levels of ozone concentration changes across the contiguous U.S. Results allow evaluation of what percentage of each subpopulation (e.g., Hispanics) in the contiguous U.S. experience what change in ozone concentrations compared to what percentage of the overall reference group (i.e., the total population of contiguous U.S.) experiences similar concentration changes from EGU emission changes under the two regulatory options in 2028, 2030, and 2035.

This distributional EJ analysis is also subject to additional uncertainties related to more highly resolved input parameters and additional assumptions. For example, this analysis does not account for potential difference in underlying susceptibility, vulnerability, or risk factors across populations expected to experience post-policy ozone exposure changes. Nor could we include information about differences in other factors that could affect the likelihood of adverse impacts (e.g., exercise patterns) across groups. Therefore, this analysis should not be used to assert that there are meaningful differences in ozone exposures impacts in either the baseline or the rule across population groups.

As the baseline scenario is similar to that described by other RIAs, we focus on the ozone changes due to this proposed rulemaking. Distributions of 12 km^2 gridded ozone concentration changes from EGU control strategies of affected facilities under the regulatory options analyzed in this proposed rulemaking are shown in Figure 6-7. For clarity, only above/below the poverty line and those who speak English “well or better”/“less than well” are shown and sex and the overall reference group are excluded from the cumulative distribution figures.

The vast majority of ozone concentration changes are less than 0.05 ppb under either regulatory option for all three future years analyzed. Therefore, the distributions of ozone concentration changes across population demographics are all reasonably similar and the very small difference shown in the distributional analyses of ozone concentration changes under the two regulatory options provides additional evidence that the proposed rule is not likely to meaningfully exacerbate or mitigate EJ ozone exposure concerns for population groups evaluated.

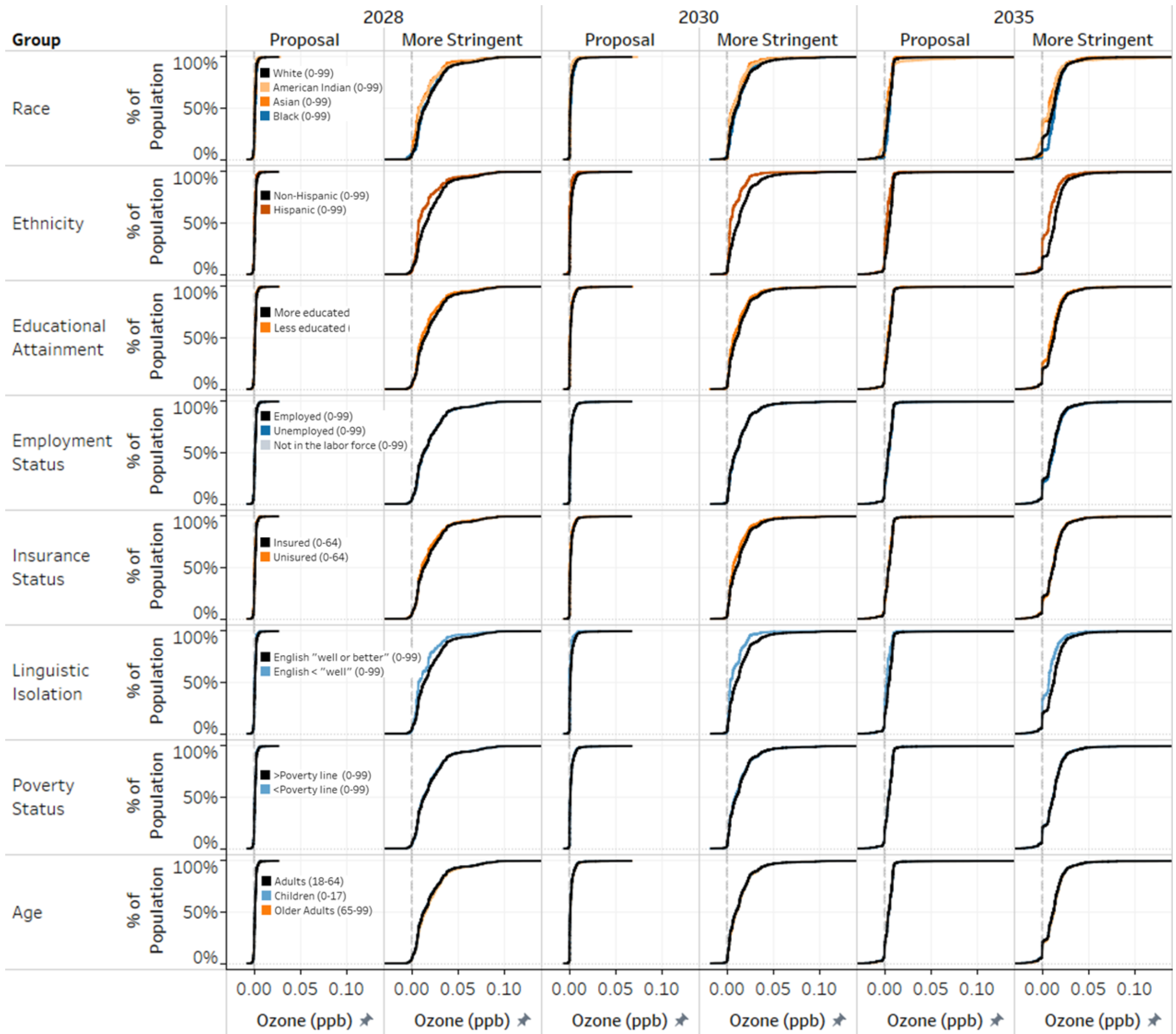

Figure 6-7 Distributions of Ozone Concentration Changes Across Populations, Future Years, and Regulatory Options

6.6 Qualitative Assessment of Climate Impacts

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, she also considered risks to minority and low-income individuals and communities, 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 disadvantaged communities; individuals at vulnerable lifestages, 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 minority populations 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),[78,79] the IPCC,[80,81,82,83] and the National Academies of Science, Engineering, and Medicine[84,85] add more evidence that the impacts of climate change raise potential EJ concerns. These reports conclude that poorer or predominantly non-White communities can be especially vulnerable to climate change impacts because they tend to have

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[78] USGCRP, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

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

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[82] Smith, K.R., A.Woodward, D. Campbell-Lendrum, D.D. Chadee, Y. Honda, Q. Liu, J.M. Olwoch, B. Revich, and R. Sauerborn, 2014: Human health: impacts, adaptation, and co-benefits. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel,A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 709-754.

[83] IPCC, 2018: Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

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[85] National Academies of Sciences, Engineering, and Medicine. 2017. Communities in Action: Pathways to Health Equity. Washington, DC: The National Academies Press. https://doi.org/10.17226/24624.

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*[86] found with high confidence that vulnerabilities are place- and time-specific, lifestages 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.

In a 2021 report, 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.[87] The report found that Blacks and African American populations are approximately 40 percent more likely to live in areas of the U.S. projected to experience the highest increases in mortality rates due to changes in extreme temperatures. 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 extreme temperatures. 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 disproportionate risks of experiencing the most damaging impacts of climate change.

These findings suggest that CO_2 reductions may benefit disproportionately impacted populations. However, as we have not conducted the wide-ranging analyses that would be needed to assess the specific impacts of this rule on the multiple climate-EJ interactions described above, we cannot analyze the potential impacts of the proposed rule quantitatively.

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[86] USGCRP, 2016: The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment
[87] EPA 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003.

6.7 Summary

As with all EJ analyses, data limitations make it quite possible that disparities may exist that our analysis did not identify. This is especially relevant for potential EJ characteristics, environmental impacts, and more granular spatial resolutions that were not evaluated. For example, here we provide qualitative EJ assessment of ozone and $PM_{2.5}$ concentration changes from this rule but can only qualitatively discuss EJ impacts of CO_2 emission reductions. Therefore, this analysis is only a partial representation of the distributions of potential impacts. Additionally, EJ concerns for each rulemaking are unique and should be considered on a case-by-case basis, so results similar to those presented here should not be assumed for other rulemakings.

For the rule, we quantitatively evaluate the proximity of affected facilities populations of potential EJ concern (Section 6.4) and the potential for disproportionate pre- and policy-policy $PM_{2.5}$ and ozone exposures across different demographic groups (Section 6.5). As exposure results generated as part of the 2020 Residual Risk analysis were below both the presumptive acceptable cancer risk threshold and the noncancer health benchmarks, and this proposed regulation should still reduce exposure to HAP, there are no 'disproportionate and adverse effects' of potential EJ concern. Therefore, we did not perform a quantitative EJ assessment of HAP risk. Each of these analyses presented depend on mutually exclusive assumptions, was performed to answer separate questions, and is associated with unique limitations and uncertainties.

Baseline demographic proximity analyses provide information as to whether there may be potential EJ concerns associated with local environmental stressors such as local NO_2 and SO_2 emitted from sources affected by the regulatory action, traffic, or noise for certain population groups of concern in the baseline (Section 6.4). The baseline demographic proximity analyses examined the demographics of populations living within 10 km of the following sources: lignite plants with units potentially subject to the proposed mercury standard revision, coal plants with units potentially subject to the proposed filterable PM standard revision, and coal plants with units potentially subject to the alternate filterable PM standard revision. The proximity demographic analysis indicates that on average the percentage of the population living within 10 km of coal plants potentially subject to the proposed or alternate filterable PM standards have a higher percentage of people living below two times the poverty level than the national average. In addition, on average the percentage of the Native American population living within 10 km of lignite plants potentially subject to proposed mercury standard is higher than the national average. Relating these results to question 1 from Section 6.3, we conclude that there may be potential EJ concerns associated with directly emitted pollutants that are affected by the regulatory action (e.g., local NO_X or SO_2) for certain population groups of concern in the baseline (question 1). However, as proximity to affected facilities does not capture variation in baseline exposure across communities, nor does it indicate that any exposures or impacts will occur, these results should not be interpreted as a direct measure of exposure or impact.

While the demographic proximity analyses may appear to parallel the baseline analysis of nationwide ozone and $PM_{2.5}$ exposures in certain ways, the two should not be directly compared. The baseline ozone and $PM_{2.5}$ exposure assessments are in effect an analysis of total burden in the contiguous U.S., and include various assumptions, such as the implementation of promulgated regulations. It serves as a starting point for both the estimated ozone and $PM_{2.5}$ changes due to this proposal as well as a snapshot of air pollution concentrations in the near future.

As HAP exposure results generated as part of the 2020 Residual Risk analysis were below both the presumptive acceptable cancer risk threshold and the noncancer health benchmarks, and this proposed regulation should further reduce exposure to HAP, there are no 'disproportionate and adverse effects' of potential EJ concern. Therefore, we did not perform a quantitative EJ assessment of HAP risk.

This proposed rule is also expected to reduce emissions of direct $PM_{2.5}$, NO_X, and SO_2 nationally throughout the year. Because NO_X and SO_2 are also precursors to secondary formation of ambient $PM_{2.5}$ and NO_X is a precursor to ozone formation, reducing these emissions would impact human exposure. Quantitative ozone and $PM_{2.5}$ exposure analyses can provide insight into all three EJ questions, so they are performed to evaluate potential disproportionate impacts of this rulemaking.

The baseline ozone and $PM_{2.5}$ exposure analyses respond to question 1 from EPA's EJ Technical Guidance document more directly than the proximity analyses, as they evaluate a form of the environmental stressor primarily affected by the regulatory action (Section 6.5). Baseline

$PM_{2.5}$ and ozone exposure analyses show that certain populations, such as Hispanic, Asian, those linguistically isolated, those less educated, and children may experience disproportionately higher ozone and $PM_{2.5}$ exposures as compared to the national average. American Indian populations may also experience disproportionately higher ozone concentrations than the reference group. Therefore, there likely are potential EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern in the baseline.

Finally, we evaluate how the post-policy options of this proposed rulemaking are expected to differentially impact demographic populations, informing questions 2 and 3 from EPA's EJ Technical Guidance with regard to ozone and $PM_{2.5}$ exposure changes. Due to the small magnitude of the exposure changes across population demographics associated with the rulemaking relative to the magnitude of the baseline disparities, we infer that baseline disparities in ozone and $PM_{2.5}$ concentration burdens are likely to remain after implementation of the regulatory or more stringent option under consideration (question 2). Also due to the very small differences in the magnitude of post-policy ozone and $PM_{2.5}$ exposure impacts across demographic populations, we do not find evidence that potential EJ concerns related to ozone or $PM_{2.5}$ exposures will be meaningfully exacerbated or mitigated in the regulatory alternatives under consideration, compared to the baseline (question 3). Importantly, the action described in this rule is expected to lower ozone and $PM_{2.5}$ in many areas, including those areas that struggle to attain or maintain the NAAQS, and thus mitigate some pre-existing health risks across all populations evaluated.

This EJ air quality analysis concludes that there are $PM_{2.5}$ and ozone exposure disparities across various populations in the pre-policy baseline scenario (EJ question 1) and infer that these disparities are likely to persist after promulgation of this proposed rulemaking (EJ question 2). This EJ assessment also suggests that this action will neither mitigate nor exacerbate $PM_{2.5}$ and ozone exposure disparities across populations of EJ concern analyzed (EJ question 3) at the national scale in a meaningful way.

7 COMPARISON OF BENEFITS AND COSTS

7.1 Introduction

This section presents the estimates of the health benefits, compliance costs, and net benefits associated with the proposed MATS review relative to baseline MATS requirements. All analysis begins in the year 2028, the compliance year for the proposed standards. In this RIA, the regulatory impacts are evaluated for the specific years of 2028, 2030, and 2035. We also evaluate the potential regulatory impacts of the regulatory options using the present value (PV) and equivalent annualized value (EAV) of costs, benefits, and net benefits, calculated for the years 2028 to 2037 from the perspective of 2023, using both a three percent and seven percent end-of-period discount rate.

There are potential benefits and costs that may result from this proposed rule that have not been quantified or monetized. Due to current data and modeling limitations, quantified and monetized benefits from the proposed requirements from reducing mercury and non-mercury metal HAP emissions are not included in the monetized benefits presented here.

The compliance costs reported in this RIA are not social costs, although in this analysis we use compliance costs as a proxy for social costs. We do not account for changes in costs and benefits due to changes in economic welfare of suppliers to the electricity market or to non-electricity consumers from those suppliers. Furthermore, costs due to interactions with pre-existing market distortions outside the electricity sector are omitted.

7.2 Methods

EPA calculated the PV of costs, benefits, and net benefits for the years 2028 through 2037, using both a three percent and seven percent end-of-period discount rate from the perspective of 2023. All dollars are in 2019 dollars. In order to implement the OMB Circular A-4 requirement for fulfilling E.O. 12866, we assess one less stringent and one more stringent alternative to the proposed requirements.

This calculation of a PV requires an annual stream of values for each year of the 2028 to 2037 timeframe. EPA used IPM to estimate cost and emission changes for the projection years

2028, 2030, and 2035. The year 2028 is an approximation of the compliance year for the proposed requirements. In the IPM modeling for this RIA, the 2028 projection year is representative of 2028 alone, the 2030 projection year is representative of 2029 through 2031, and the 2035 projection year is representative of 2032 to 2037.[88] Estimates of costs and emission changes in other years are determined from the mapping of projection years to the calendar years that they represent. Consequently, the cost and emission estimates from IPM in each projection year are applied to the years which it represents.[89]

Health benefits are based on projection year emission estimates and also account for year-specific variables that influence the size and distribution of the benefits. These variables include population growth, income growth, and the baseline rate of death.[90] Climate benefits estimates are based on these projection year emission estimates, and also account for year-specific interim SC-CO_2 values.[91]

EPA calculated the PV and EAV of costs, benefits, and net benefits over the 2028 through 2037 timeframe for the three regulatory options examined in this RIA. The EAV represents a flow of constant annual values that, had they occurred in each year from 2028 to 2037, would yield an equivalent present value. The EAV represents the value of a typical cost or benefit for each year of the analysis, in contrast to the year-specific estimates presented elsewhere for the snapshot years of 2028, 2030, and 2035.

7.3 Results

We first present net benefit analysis for the three years of detailed analysis, 2028, 2030, and 2035. Table 7-1, Table 7-2, and Table 7-3 present the estimates of the projected compliance costs, health benefits, climate benefits, and net benefits across the regulatory options examined in this proposal, respectively. The comparison of benefits and costs in PV and EAV terms for the proposed rule can be found in Table 7-4 for the proposed regulatory option. Table 7-5 presents

[88] For more information regarding the mapping of projection years to calendar years, see Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model (2022), available at: https://www.epa.gov/airmarkets/clean-air-markets-power-sector-modeling
[89] MR&R costs estimates are not based on IPM. For information on MR&R costs, see Section 3.
[90] As these variables differ by year, the health benefit estimates vary by year, including when different years are based on the same IPM projection year emission estimate.
[91] As the interim SC-CO_2 estimates vary by year, the climate benefit also estimates vary by year, even when different years are based on the same IPM projection year emission estimate.

the results for the less stringent regulatory option, and Table 7-6 presents results for the more stringent regulatory option. Estimates in the tables are presented as rounded values. Note the less stringent regulatory option has no quantified emissions reductions associated with the proposed requirements for PM CEMS and the removal of startup definition number two. As a result, there are no quantified benefits associated with this regulatory option.

Table 7-1 Monetized Benefits, Costs, and Net Benefits of the Proposed Rule and Less and More Stringent Alternatives for 2028 for the U.S. (millions of 2019 dollars) [a,b]

	Proposed Rule			Less Stringent Alternative			More Stringent Alternative		
$PM_{2.5}$ and O_3-related Health Benefits [c]	58	and	140	0.0	and	0.0	1,300	and	3,100
Climate Benefits[d]		13			0.0			1,300	
Total Benefits[e]	71	and	160	0.0	and	0.0	2,600	and	4,400
Compliance Costs		56			-5.9			920	
Net Benefits	**16**	**and**	**100**	**5.9**	**and**	**5.9**	**1,700**	**and**	**3,500**

[a] We focus results to provide a snapshot of costs and benefits in 2028, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates.

[b] Values have been rounded to two significant figures. Rows may not appear to add correctly due to rounding.

[c] Monetized benefits include those related to public health associated with reductions in $PM_{2.5}$ and ozone concentrations. The health benefits are associated with several point estimates and are presented at a real discount rate of 3 percent.

[d] Climate benefits are based on reductions in CO_2 emissions and are calculated using four different estimates of the social cost of carbon dioxide (SC-CO_2): model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate. The 95th percentile estimate is included to provide information on potentially higher-than-expected economic impacts from climate change, conditional on the 3 percent estimate of the discount rate. For the presentational purposes of this table, we show the climate benefits associated with the average SC-CO_2 at a 3 percent discount rate, but the Agency does not have a single central SC-CO_2 point estimate. Climate benefits in this table are discounted using a 3 percent discount rate to obtain the PV and EAV estimates in the table. We emphasize the importance and value of considering the benefits calculated using all four SC-CO_2 estimates. Section 4.4 of the RIA presents estimates of the projected climate benefits of this proposal using all four rates. We note that consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, is warranted when discounting intergenerational impacts.

[e] Several categories of benefits remain unmonetized and are thus not directly reflected in the quantified benefit estimates in the table. Non-monetized benefits include benefits from reductions in mercury and non-mercury metal HAP emissions and from the increased transparency and accelerated identification of anomalous emission anticipated from requiring CEMS.

Table 7-2 Monetized Benefits, Costs, and Net Benefits of the Proposed Rule and Less and More Stringent Alternatives for 2030 for the U.S. (millions of 2019 dollars) [a,b]

	Proposed Rule			Less Stringent Alternative			More Stringent Alternative		
$PM_{2.5}$ and O_3-related Health Benefits [c]	50	and	150	0.0	and	0.0	250	and	860
Climate Benefits[d]		50			0			530	
Total Benefits[e]	100	and	200	0.0	and	0.0	780	and	1,400
Compliance Costs		46			-5.9			1,100	
Net Benefits	**54**	**and**	**160**	**5.9**	**and**	**5.9**	**-270**	**and**	**340**

[a] We focus results to provide a snapshot of costs and benefits in 2028, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates.

[b] Values have been rounded to two significant figures. Rows may not appear to add correctly due to rounding.

[c] Monetized benefits include those related to public health associated with reductions in $PM_{2.5}$ and ozone concentrations. The health benefits are associated with several point estimates and are presented at a real discount rate of 3 percent.

[d] Climate benefits in this table are based on estimates of the SC-CO_2 at a 3 percent discount rate.

[e] Several categories of benefits remain unmonetized and are thus not directly reflected in the quantified benefit estimates in the table. Non-monetized benefits include benefits from reductions in mercury and non-mercury metal HAP emissions and from the increased transparency and accelerated identification of anomalous emission anticipated from requiring CEMS.

Table 7-3 Monetized Benefits, Costs, and Net Benefits of the Proposed Rule and Less and More Stringent Alternatives for 2035 for the U.S. (millions of 2019 dollars) [a,b]

	Proposed Rule			Less Stringent Alternative			More Stringent Alternative		
$PM_{2.5}$ and O_3-related Health Benefits [c]	100	and	330	0.0	and	0.0	570	and	1,500
Climate Benefits[d]		310			0.0			190	
Total Benefits[e]	410	and	640	0.0	and	0.0	760	and	1,700
Compliance Costs		39			-5.9			280	
Net Benefits	**370**	**and**	**600**	**5.9**	**and**	**5.9**	**480**	**and**	**1,400**

[a] We focus results to provide a snapshot of costs and benefits in 2028, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates.

[b] Values have been rounded to two significant figures. Rows may not appear to add correctly due to rounding.

[c] Monetized benefits include those related to public health associated with reductions in $PM_{2.5}$ and ozone concentrations. The health benefits are associated with several point estimates and are presented at a real discount rate of 3 percent.

[d] Climate benefits in this table are based on estimates of the SC-CO_2 at a 3 percent discount rate.

[e] Several categories of benefits remain unmonetized and are thus not directly reflected in the quantified benefit estimates in the table. Non-monetized benefits include benefits from reductions in mercury and non-mercury metal HAP emissions and from the increased transparency and accelerated identification of anomalous emission anticipated from requiring CEMS.

Table 7-4 Proposed Rule: Present Values and Equivalent Annualized Values of Projected Monetized Compliance Costs, Benefits, and Net Benefits for 2028 to 2037 (millions of 2019 dollars, discounted to 2023) [a]

	$PM_{2.5}$ and O_3-related Health Benefits		Climate Benefits	Compliance Costs	Net Benefits	
	3%	7%	3%		3%	7%
2028	140	130	13	56	100	87
2029	150	130	49	46	150	140
2030	150	140	50	46	160	140
2031	160	140	51	46	160	140
2032	310	270	290	39	560	530
2033	320	280	300	39	570	540
2034	320	290	300	39	590	550
2035	330	300	310	39	600	570
2036	340	310	310	39	620	580
2037	350	310	320	39	630	590

	$PM_{2.5}$ and O_3-related Health Benefits		Climate Benefits	Compliance Costs		Net Benefits	
	Discount Rate						
	3%	7%	3%	3%	7%	3%	7%
Present Value	**1,900**	**1,200**	**1,400**	**330**	**230**	**3,000**	**2,400**
Equivalent Annualized Value	**220**	**170**	**170**	**38**	**33**	**350**	**300**

[a] Values have been rounded to two significant figures. Rows may not appear to add correctly due to rounding.
[b] The health benefits estimates use the larger of the two benefits estimates presented in Table 7-1 . Monetized benefits include those related to public health associated with reductions in $PM_{2.5}$ and ozone concentrations. The health benefits are associated with several point estimates.
[c] Climate benefits in this table are based on estimates of the SC-CO_2 at a 3 percent discount rate.
[d] Several categories of benefits remain unmonetized and are thus not reflected in the table. Nonmonetized benefits include important benefits from reductions in mercury and non-mercury metal HAP.

Table 7-5 Less Stringent Regulatory Option: Present Values and Equivalent Annualized Values for the 2028 to 2037 Timeframe for Estimated Monetized Compliance Costs, Benefits, and Net Benefits (millions of 2019 dollars, discounted to 2023) [a]

	$PM_{2.5}$ and O_3-related Health Benefits		Climate Benefits	Compliance Costs		Net Benefits	
	3%	7%	3%			3%	7%
2028	0.0	0.0	0.0	-5.9		5.9	5.9
2029	0.0	0.0	0.0	-5.9		5.9	5.9
2030	0.0	0.0	0.0	-5.9		5.9	5.9
2031	0.0	0.0	0.0	-5.9		5.9	5.9
2032	0.0	0.0	0.0	-5.9		5.9	5.9
2033	0.0	0.0	0.0	-5.9		5.9	5.9
2034	0.0	0.0	0.0	-5.9		5.9	5.9
2035	0.0	0.0	0.0	-5.9		5.9	5.9
2036	0.0	0.0	0.0	-5.9		5.9	5.9
2037	0.0	0.0	0.0	-5.9		5.9	5.9
	$PM_{2.5}$ and O_3-related Health Benefits		**Climate Benefits**	**Compliance Costs**		**Net Benefits**	
	Discount Rate						
	3%	**7%**	**3%**	**3%**	**7%**	**3%**	**7%**
Present Value	**0.0**	**0.0**	**0.0**	**-45**	**-31**	**45**	**31**
Equivalent Annualized Value	**0.0**	**0.0**	**0.0**	**-5.2**	**-4.5**	**5.2**	**4.5**

[a] Values have been rounded to two significant figures. Rows may not appear to add correctly due to rounding.
[b] The health benefits estimates use the larger of the two benefits estimates presented in Table 7-. Monetized benefits include those related to public health associated with reductions in $PM_{2.5}$ and ozone concentrations. The health benefits are associated with several point estimates.
[c] Climate benefits in this table are based on estimates of the SC-CO_2 at a 3 percent discount rate
[d] Several categories of benefits remain unmonetized and are thus not reflected in the table. Nonmonetized benefits include important benefits from reductions in mercury and non-mercury metal HAP.

Table 7-6 More Stringent Regulatory Option: Present Values and Equivalent Annualized Values for the 2028 to 2037 Timeframe for Estimated Monetized Compliance Costs, Benefits, and Net Benefits (millions of 2019 dollars, discounted to 2023) [a]

	$PM_{2.5}$ and O_3-related Health Benefits		Climate Benefits	Compliance Costs	Net Benefits	
	3%	7%	3%		3%	7%
2028	3,100	2,800	1,300	920	3,500	3,200
2029	840	750	520	1,100	300	210
2030	860	770	530	1,100	330	250
2031	890	800	540	1,100	370	280
2032	1,400	1,200	180	280	1,300	1,100
2033	1,400	1,300	190	280	1,300	1,200
2034	1,500	1,300	190	280	1,400	1,200
2035	1,500	1,400	190	280	1,400	1,300
2036	1,600	1,400	200	280	1,500	1,300
2037	1,600	1,400	200	280	1,500	1,300

	$PM_{2.5}$ and O_3-related Health Benefits		Climate Benefits	Compliance Costs		Net Benefits	
	Discount Rate						
	3%	7%	3%	3%	7%	3%	7%
Present Value	**11,000**	**7,100**	**3,200**	**4,600**	**3,400**	**9,800**	**6,900**
Equivalent Annualized Value	**1,300**	**1,000**	**380**	**540**	**490**	**1,100**	**900**

[a] Values have been rounded to two significant figures. Rows may not appear to add correctly due to rounding.
[b] The health benefits estimates use the larger of the two benefits estimates presented in Table 7-. Monetized benefits include those related to public health associated with reductions in $PM_{2.5}$ and ozone concentrations. The health benefits are associated with several point estimates.
[c] Climate benefits in this table are based on estimates of the SC-CO_2 at a 3 percent discount rate.
[d] Several categories of benefits remain unmonetized and are thus not reflected in the table. Nonmonetized benefits include important benefits from reductions in mercury and non-mercury metal HAP.

The results presented in this section provide an incomplete overview of the effects of the proposal, because important categories of benefits, including benefits from reducing mercury and non-mercury metal HAP emissions, were not monetized and are therefore not directly reflected in the quantified benefit-cost comparisons. We anticipate that taking non-monetized effects into account would show the proposal to be more net beneficial than the tables in this section reflect.

APPENDIX A: AIR QUALITY MODELING

A.1 Introduction

As noted in Section 4, EPA used photochemical modeling to create air quality surfaces[92] that were then used in air pollution health benefits calculations of the three regulatory control alternatives of the proposed rule. The modeling-based surfaces captured air pollution impacts resulting from changes in NO_X, SO_2, and direct $PM_{2.5}$ emissions from EGUs. This appendix describes the source apportionment modeling and associated methods used to create air quality surfaces for the baseline scenario and two regulatory options (the proposed regulatory options and the more stringent regulatory option) in three analytic years: 2028, 2030 and 2035. EPA created air quality surfaces for the following pollutants and metrics: annual average $PM_{2.5}$; April-September average of 8-hr daily maximum (MDA8) ozone (AS-MO3).

The ozone source apportionment modeling outputs are the same as those created for the Regulatory Impact Analysis for the proposed Federal Implementation Plan Addressing Regional Ozone Transport for the 2015 Ozone National Ambient Air Quality Standard (U.S. EPA, 2022c). New PM source apportionment modeling outputs were created using the same inputs and modeling configuration as were used for the available ozone source apportionment modeling. The basic methodology for determining air quality changes is the same as that used in the RIAs from multiple previous rules (U.S. EPA, 2019, 2020a, 2020b, 2021b, 2022c). EPA calculated baseline and regulatory option EGU emissions estimates of NO_X and SO_2 for all three analysis years using IPM (Section 3 of this RIA). EPA also used IPM outputs to estimate EGU emissions of $PM_{2.5}$ based on emission factors described in flat (U.S. EPA, 2021a). This appendix provides additional details on the source apportionment modeling simulations and the associated analysis used to create ozone and $PM_{2.5}$ air quality surfaces.

A.2 Air Quality Modeling Simulations

The air quality modeling utilized a 2016-based modeling platform which included meteorology and base year emissions from 2016 and projected future-year emissions for

[92] "air quality surfaces" refers to continuous gridded spatial fields using a 12 km^2 grid-cell resolution

2026.[93,94] The air quality modeling included photochemical model simulations for a 2016 base year and 2026 future year to provide hourly concentrations of ozone and $PM_{2.5}$ component species nationwide. In addition, source apportionment modeling was performed for 2026 to quantify the contributions to ozone from NO_X emissions and to $PM_{2.5}$ from NO_X, SO_2 and directly emitted $PM_{2.5}$ emissions from EGUs on a state-by-state basis. As described below, the modeling results for 2016 and 2026, in conjunction with EGU emissions data for the baseline and three regulatory options in 2028, 2030 and 2035 were used to construct the air quality surfaces that reflect the influence of emissions changes between the baseline and two regulatory options in each year.

The air quality model simulations (i.e., model runs) were performed using the Comprehensive Air Quality Model with Extensions (CAMx) version 7.10[95] (Ramboll Environ, 2021). The 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 km^2 shown in Figure A-1. Model predictions of ozone and $PM_{2.5}$ concentrations were compared against ambient measurements (U.S. EPA, 2022a, 2022b). Ozone and $PM_{2.5}$ model evaluations showed model performance that was adequate for applying these model simulations for the purpose of creating air quality surfaces to estimate ozone and $PM_{2.5}$ benefits.

[93] Information on the emissions inventories used for the modeling described in U.S. EPA (2022d)
[94] The air quality modeling performed to support the analyses in this proposed RIA can be found in U.S. EPA (2022b).
[95] This CAMx simulation set the Rscale NH_3 dry deposition parameter to 0 which resulted in more realistic model predictions of $PM_{2.5}$ nitrate concentrations than using a default Rscale parameter of 1

Figure A-1 Air Quality Modeling Domain

The contributions to ozone and $PM_{2.5}$ component species (e.g., sulfate, nitrate, ammonium, elemental carbon (EC), organic aerosol (OA), and crustal material[96]) from EGU emissions in individual states were modeled using the "source apportionment" tool approach. 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[97] contributions from the emissions in each individual tag to hourly gridded modeled concentrations. For this RIA we used the source apportionment contribution data to provide a means to estimate of the effect of changes in emissions from each group of emissions sources (i.e., each tag) to changes in ozone and $PM_{2.5}$ concentrations. Specifically, we applied outputs from source apportionment modeling for ozone and $PM_{2.5}$ component species using the 2026 modeled case to obtain the contributions from EGUs emissions in each state to ozone and $PM_{2.5}$ component species concentrations in each 12 km^2 model grid cell nationwide. Ozone contributions were modeled using the Anthropogenic Precursor Culpability Assessment (APCA) tool and $PM_{2.5}$ contributions were modeled using the Particulate Matter Source Apportionment Technology (PSAT) tool (Ramboll Environ, 2021). The ozone source apportionment modeling was performed for the period April through

[96] Crustal material refers to elements that are commonly found in the earth's crust such as Aluminum, Calcium, Iron, Magnesium, Manganese, Potassium, Silicon, Titanium and the associated oxygen atoms.
[97] Hourly contribution information is provided for each grid cell to provide spatial patterns of the contributions from each tag

September to provide data for developing spatial fields for the April through September maximum daily eight-hour (MDA8) (i.e., AS-MO3) average ozone concentration exposure metric. The $PM_{2.5}$ source apportionment modeling was performed for a full-year to provide data for developing annual average $PM_{2.5}$ spatial fields. Table A-1 provides state-level 2026 EGU emissions that were tracked for each source apportionment tag.

Table A-1 2026 Emissions Allocated to Each Modeled State-EGU Source Apportionment Tag

State Tag	Ozone Season NO_X Emissions (tons)	Annual NO_X emissions (tons)	Annual SO_2 emissions (tons)	Annual $PM_{2.5}$ emissions (tons)
AL	6,205	9,319	1,344	2,557
AR	5,594	9,258	22,306	1,075
AZ	1,341	3,416	2,420	814
CA	6,627	16,286	249	4,810
CO	5,881	12,725	7,311	1,556
CT	1,673	3,740	845	467
DC	37	39	0	53
DE	203	320	126	119
FL	11,590	22,451	8,784	6,555
GA	3,199	5,937	1,177	2,452
IA	8,008	17,946	9,042	1,182
ID	375	705	1	185
IL	8,244	16,777	31,322	3,018
IN	11,052	36,007	34,990	6,281
KS	3,166	4,351	854	709
KY	11,894	25,207	22,940	10,476
LA	10,895	16,949	11,273	3,119
MA	2,115	4,566	839	384
MD	1,484	3,008	273	783
ME	1,233	3,063	1,147	414
MI	11,689	22,378	31,387	3,216
MN	4,192	9,442	7,189	481
MO	10,075	34,935	105,916	3,617
MS	3,631	5,208	30	1,240
MT	3,908	8,760	3,527	1,426
NC	7,175	15,984	6,443	2,720
ND	8,053	19,276	26,188	1,265
NE	8,670	20,274	45,869	1,530
NH	224	483	159	93
NJ	1,969	4,032	915	729
NM	1,266	1,987	0	304
NV	1,577	3,017	0	901
NY	6,248	11,693	1,526	1,649

Table A-1 2026 Emissions Allocated to Each Modeled State-EGU Source Apportionment Tag

State Tag	Ozone Season NO_X Emissions (tons)	Annual NO_X emissions (tons)	Annual SO_2 emissions (tons)	Annual $PM_{2.5}$ emissions (tons)
OH	9,200	27,031	46,780	4,543
OK	2,412	3,426	2	828
OR	1,122	2,145	29	455
PA	12,386	23,965	9,685	3,785
RI	233	476	0	68
SC	3,251	7,134	6,292	2,082
SD	478	1,054	889	55
TL*	1,337	2,970	6,953	1,329
TN	790	2,100	1,231	845
TX	16,548	27,164	19,169	5,027
UT	3,571	10,915	11,040	693
VA	3,607	7,270	820	1,805
VT	2	4	0	4
WA	11,78	2,532	158	384
WI	2,097	4,304	821	1,084
WV	7,479	21,450	28,513	2,180
WY	5,026	11,036	8,725	629

* TL represents emissions occurring on tribal lands

Examples of the magnitude and spatial extent of ozone and $PM_{2.5}$ contributions are provided in Figure A-2 through Figure A-5 for EGUs in California, Texas, Iowa, and Ohio. These figures show how the magnitude and the spatial patterns of contributions of EGU emissions to ozone and $PM_{2.5}$ component species depend on multiple factors including the magnitude and location of emissions as well as the atmospheric conditions that influence the formation and transport of these pollutants. For instance, NO_X emissions are a precursor to both ozone and $PM_{2.5}$ nitrate. However, ozone and nitrate form under very different types of atmospheric conditions, with ozone formation occurring in locations with ample sunlight and ambient VOC concentrations while nitrate formation requires colder and drier conditions and the presence of gas-phase ammonia. California's complex terrain that tends to trap air and allow pollutant build-up combined with warm sunny summer and cooler dry winters and sources of both ammonia and VOCs make its atmosphere conducive to formation of both ozone and nitrate. While the magnitude of EGU NO_X emissions in Iowa and California are similar in the 2026 modeling (Table A-1) the emissions from California lead to larger contributions to the formation of those pollutants due to the conducive conditions in that state. Texas and Ohio both had larger

NO_X emissions than California or Iowa. While maximum ozone impacts shown for Texas and Ohio EGUs are similar order of magnitude to maximum ozone impacts from California EGUs, nitrate impacts are much smaller in Ohio and negligible in Texas due to less conducive atmospheric conditions for nitrate formation in those locations. California EGU SO_2 emissions in the 2026 modeling are several orders of magnitude smaller than SO_2 emissions in Ohio and Texas (Table A-1) leading to much smaller sulfate contributions from California EGUs than from Ohio and Texas EGUs. $PM_{2.5}$ organic aerosol EGU contributions in this modeling come from primary $PM_{2.5}$ emissions rather than secondary atmospheric formation. Consequently, the impacts of EGU emissions on this pollutant tend to occur closer to the EGU sources than impacts of secondary pollutants (ozone, nitrate, and sulfate) which have spatial patterns showing a broader regional impacts. These patterns demonstrate how the model is able to capture important atmospheric processes which impact pollutant formation and transport from emissions sources.

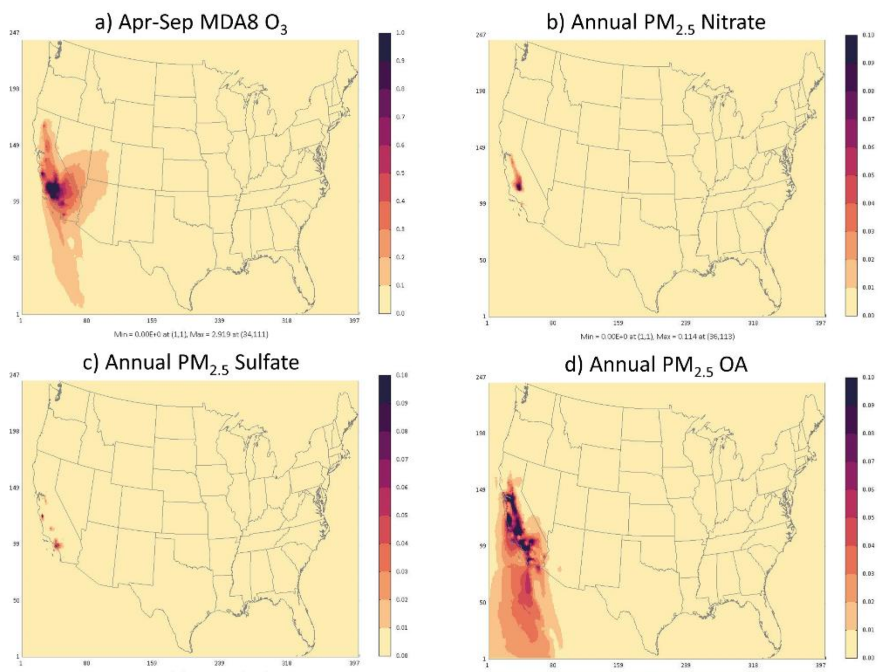

Figure A-2 Maps of California EGU Tag Contributions to a) April-September Seasonal Average MDA8 Ozone (ppb); b) Annual Average $PM_{2.5}$ Nitrate (μg/m^3); c) Annual Average $PM_{2.5}$ Sulfate (μg/m^3); d) Annual Average $PM_{2.5}$ Organic Aerosol (μg/m^3)

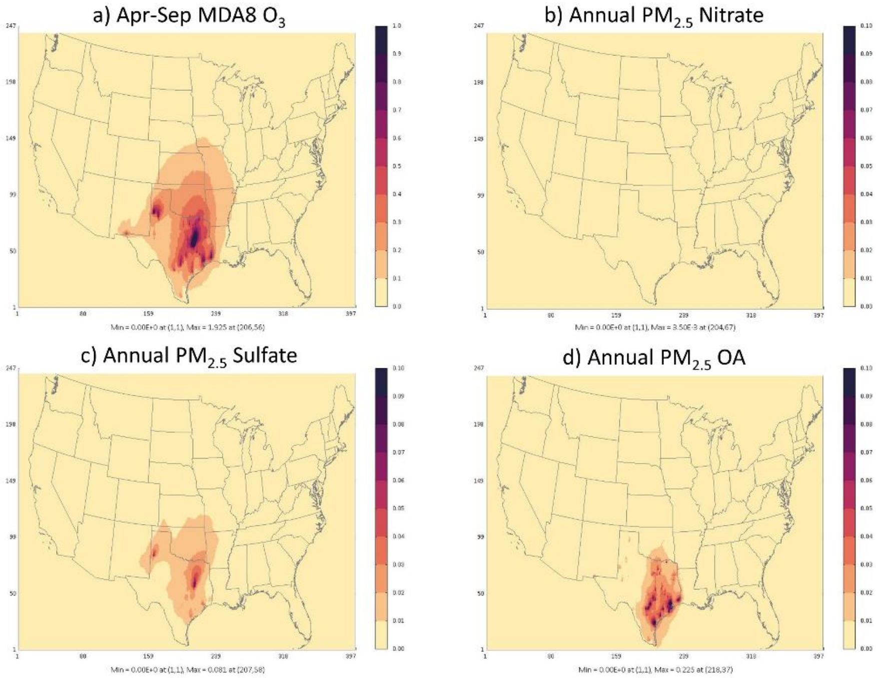

Figure A-3 Maps of Texas EGU Tag Contributions to a) April-September Seasonal Average MDA8 Ozone (ppb); b) Annual Average $PM_{2.5}$ Nitrate µg/m^3); c) Annual Average $PM_{2.5}$, Sulfate (µg/m^3); d) Annual Average $PM_{2.5}$ Organic Aerosol (µg/m^3)

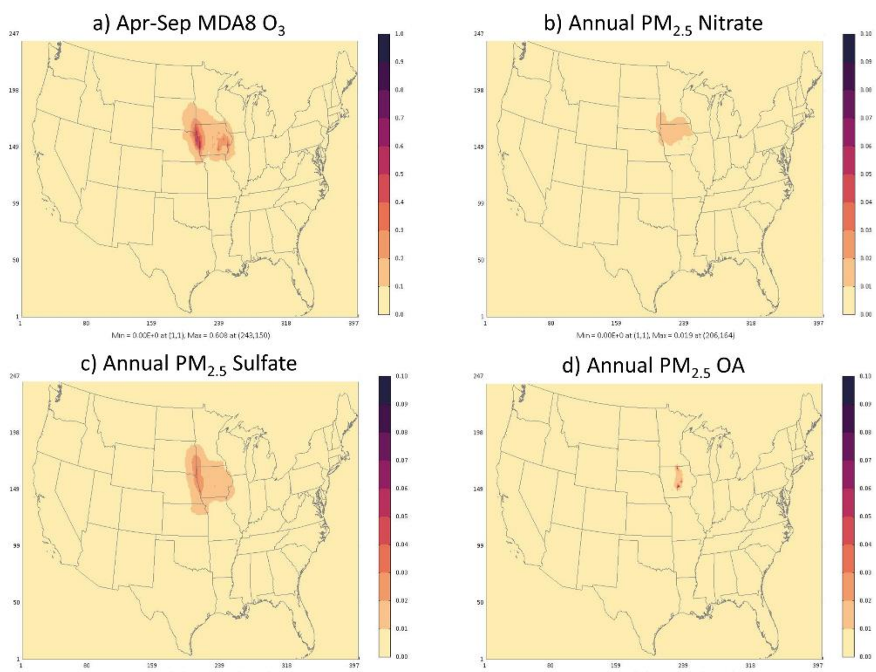

Figure A-4 Maps of Iowa EGU Tag contributions to a) April-September Seasonal Average MDA8 Ozone (ppb); b) Annual Average $PM_{2.5}$ Nitrate (µg/m^3); c) Annual Average $PM_{2.5}$ Sulfate (µg/m^3); d) Annual Average $PM_{2.5}$ Organic Aerosol (µg/m^3)

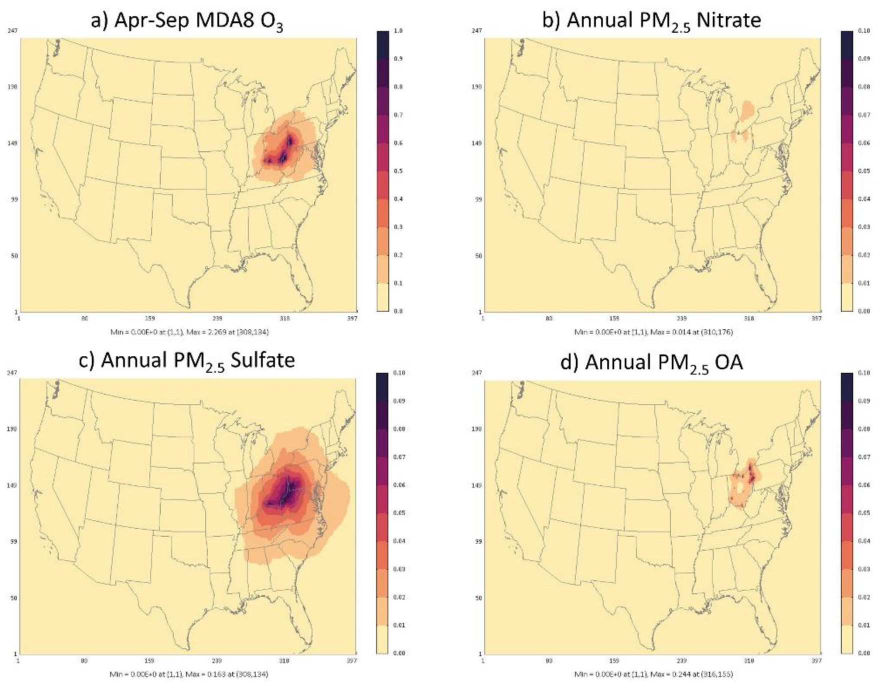

Figure A-5 Maps of Ohio EGU Tag Contributions to a) April-September Seasonal Average MDA8 Ozone (ppb); b) Annual Average $PM_{2.5}$ Nitrate ($\mu g/m^3$); c) Annual Average $PM_{2.5}$ Sulfate ($\mu g/m^3$); d) Annual Average $PM_{2.5}$ Organic Aerosol ($\mu g/m^3$)

A.3 Applying Modeling Outputs to Create Spatial Fields

In this section we describe the method for creating spatial fields of AS-MO3 and annual average $PM_{2.5}$ based on the 2016 and 2026 modeling. The foundational data include (1) ozone and speciated $PM_{2.5}$ concentrations in each model grid cell from the 2016 and 2026 modeling, (2) ozone and speciated $PM_{2.5}$ contributions in 2026 of EGUs emissions from each state in each model grid cell,[98] (3) 2026 emissions from EGUs that were input to the contribution modeling (Table A-1) and (4) the EGU emissions from IPM for baseline and the two regulatory options in each analytic year. The method to create spatial fields applies scaling factors to gridded source apportionment contributions based on emissions changes between 2026 projections and the baseline and the two regulatory options to the 2026 contributions. This method is described in detail below.

[98] Contributions from EGUs were modeled using projected emissions for 2026. The resulting contributions were used to construct spatial fields in 2030, 2035 and 2040.

Spatial fields of ozone and $PM_{2.5}$ in 2026 were created based on "fusing" modeled data with measured concentrations at air quality monitoring locations. To create the spatial fields for each future emissions scenario these fused 2026 model fields are used in combination with 2026 state-EGU source apportionment modeling and the EGU emissions for each scenario and analytic year. Contributions from each state-EGU contribution "tag" were scaled based on the ratio of emissions in the year/scenario being evaluated to the emissions in the modeled 2026 scenario. Contributions from tags representing sources other than EGUs are held constant at 2026 levels for each of the scenarios and year. For each scenario and year analyzed, the scaled contributions from all sources were summed together to create a gridded surface of total modeled ozone and $PM_{2.5}$. The process is described in a step-by-step manner below starting with the methodology for creating AS-MO3 spatial fields followed by a description of the steps for creating annual $PM_{2.5}$ spatial fields.

Ozone:

1. Create fused spatial fields of 2026 AS-MO3 incorporating information from the air quality modeling and from ambient measured monitoring data. The enhanced Voronoi Neighbor Average (eVNA) technique (Ding et al., 2016; Gold et al., 1997; U.S. EPA, 2007)was applied to ozone model predictions in conjunction with measured data to create modeled/measured fused surfaces that leverage measured concentrations at air quality monitor locations and model predictions at locations with no monitoring data.

   1.1. The AS-MO3 eVNA spatial fields are created for the 2016 base year with EPA's software package, Software for the Modeled Attainment Test – Community Edition (SMAT-CE)[99] (U.S. EPA, 2022f) using three years of monitoring data (2015-2017) and the 2016 modeled data.

   1.2. The model-predicted spatial fields (i.e., not the eVNA fields) of AS-MO3 in 2016 were paired with the corresponding model-predicted spatial fields in 2026 to calculate the ratio of AS-MO3 between 2016 and 2026 in each model grid cell.

[99] SMAT-CE available for download at https://www.epa.gov/scram/photochemical-modeling-tools.

1.3. To create a gridded 2026 eVNA surfaces, the spatial fields of 2016/2026 ratios created in step 1.2 were multiplied by the corresponding eVNA spatial fields for 2016 created in step 1.1 to produce an eVNA AS-MO3 spatial field for 2026 using (Eq-1).

$$\mathrm{eVNA}_{\mathrm{g},2026} = \left(\mathrm{eVNA}_{\mathrm{g},2016}\right) \times \frac{\mathrm{Model}_{\mathrm{g},2026}}{\mathrm{Model}_{\mathrm{g},2016}} \qquad \text{Eq-1}$$

- $\mathrm{eVNA}_{\mathrm{g},2026}$ is the eVNA concentration of AS-MO3 or $PM_{2.5}$ component species in grid-cell, g, in the 2026 future year
- $\mathrm{eVNA}_{\mathrm{g},2016}$ is the eVNA concentration of AS-MO3 or $PM_{2.5}$ component species in grid-cell, g, in 2016
- $\mathrm{Model}_{\mathrm{g},2026}$ is the CAMx modeled concentration of AS-MO3 or $PM_{2.5}$ component species in grid-cell, g, in the 2026 future year
- $\mathrm{Model}_{\mathrm{g},2016}$ is the CAMx modeled concentration of AS-MO3 or $PM_{2.5}$ component in grid-cell, g, in 2016

2. Create gridded spatial fields of total EGU AS-MO3 contributions for each combination of scenario and analytic year evaluated.

2.1. Use the EGU ozone season NO_X emissions for the 2028 baseline and the corresponding 2026 modeled EGU ozone season emissions (Table A-1) to calculate the ratio of 2028 baseline emissions to 2026 modeled emissions for each EGU state contribution tag (i.e., an ozone scaling factor calculated for each state).[100] These scaling factors are provided in Table A-2.

2.2. Calculate adjusted gridded AS-MO3 EGU contributions that reflect differences in state-EGU NO_X emissions between 2026 and the 2028 baseline by multiplying the ozone

[100] Preliminary testing of this methodology showed unstable results when very small magnitudes of emissions were tagged especially when being scaled by large factors. To mitigate this issue, scaling factors of 1.00 were applied to any tags that tracked less than 100 tpy emissions in the original source apportionment modeling. Any emissions changes in the low emissions state were assigned to a nearby state as denoted in Table A-2 through Table A-5.

season NO_X scaling factors by the corresponding gridded AS-MO3 ozone contributions[101] from each state-EGU tag.

2.3. Add together the adjusted AS-MO3 contributions for each EGU-state tag to produce spatial fields of adjusted EGU totals for the 2028 baseline.[102]

2.4. Repeat steps 2.1 through 2.3 for the two 2028 regulatory options and for the baseline and regulatory options for each additional analytic year. All scaling factors for the baseline scenario and the regulatory control alternatives are provided in Table A-2.

3. Create a gridded spatial field of AS-MO3 associated with IPM emissions for the 2028 baseline by combining the EGU AS-MO3 contributions from step 2.3 with the corresponding contributions to AS-MO3 from all other sources. Repeat for each of the EGU contributions created in step 2.4 to create separate gridded spatial fields for the baseline and two regulatory options for the two other analytic years.

Steps 2 and 3 in combination can be represented by equation 2:

$$\text{AS-MO3}_{g,i,y} = \text{eVNA}_{g,2026} \times \left(\frac{C_{g,BC}}{C_{g,Tot}} + \frac{C_{g,int}}{C_{g,Tot}} + \frac{C_{g,bio}}{C_{g,Tot}} + \frac{C_{g,fires}}{C_{g,Tot}} + \frac{C_{g,USanthro}}{C_{g,Tot}} + \sum_{t=1}^{T} \frac{C_{EGUVOC,g,t}}{C_{g,Tot}} + \sum_{t=1}^{T} \frac{C_{EGUNOx,g,t}\, S_{NOx,t,i,y}}{C_{g,Tot}} \right) \qquad \text{Eq-2}$$

- $\text{AS-MO3}_{g,i,y}$ is the estimated fused model-obs AS-MO3 for grid-cell, “g,” scenario, “i,”[103] and year, “y;”[104]
- $\text{eVNA}_{g,2026}$ is the 2026 eVNA future year AS-MO3 concentration for grid-cell “g” calculated using Eq-1.
- $C_{g,Tot}$ is the total modeled AS-MO3 for grid-cell “g” from all sources in the 2026 source apportionment modeling

[101] The source apportionment modeling provided separate ozone contributions for ozone formed in VOC-limited chemical regimes (O3V) and ozone formed in NO_X-limited chemical regimes (O3N). The emissions scaling factors are multiplied by the corresponding O3N gridded contributions to MDA8 concentrations. Since there are no predicted changes in VOC emissions in the control scenarios, the O3V contributions remain unchanged.
[102] The contributions from the unaltered O3V tags are added to the summed adjusted O3N EGU tags.
[103] Scenario “i" can represent either the baseline or one of the two regulatory options
[104] Year “y” can represent 2028, 2030 or 2035

- $C_{g,BC}$ is the 2026 AS-MO3 modeled contribution from the modeled boundary inflow;
- $C_{g,int}$ is the 2026 AS-MO3 modeled contribution from international emissions within the modeling domain;
- $C_{g,bio}$ is the 2026 AS-MO3 modeled contribute/on from biogenic emissions;
- $C_{g,fires}$ is the 2026 AS-MO3 modeled contribution from fires;
- $C_{g,USanthro}$ is the total 2026 AS-MO3 modeled contribution from U.S. anthropogenic sources other than EGUs;
- $C_{EGUVOC,g,t}$ is the 2026 AS-MO3 modeled contribution from EGU emissions of VOCs from state, "t";
- $C_{EGUNOx,g,t}$ is the 2026 AS-MO3 modeled contribution from EGU emissions of NO_X from state, "t"; and
- $S_{NOx,t,i,y}$ is the EGU NO_X scaling factor for state, "t," scenario, "i," and year, "y."

$PM_{2.5}$

4. Create fused spatial fields of 2026 annual $PM_{2.5}$ component species incorporating information from the air quality modeling and from ambient measured monitoring data. The eVNA technique was applied to $PM_{2.5}$ component species model predictions in conjunction with measured data to create modeled/measured fused surfaces that leverage measured concentrations at air quality monitor locations and model predictions at locations with no monitoring data.

   4.1. The quarterly average $PM_{2.5}$ component species eVNA spatial fields are created for the 2016 base year with EPA's SMAT-CE software package using three years of monitoring data (2015-2017) and the 2016 modeled data.

   4.2. The model-predicted spatial fields (i.e., not the eVNA fields) of quarterly average $PM_{2.5}$ component species in 2016 were paired with the corresponding model-predicted spatial fields in 2026 to calculate the ratio of $PM_{2.5}$ component species between 2016 and 2026 in each model grid cell.

   4.3. To create a gridded 2026 eVNA surfaces, the spatial fields of 2016/2026 ratios created in step 4.2 were multiplied by the corresponding eVNA spatial fields for 2016 created in step 4.1 to produce an eVNA annual average $PM_{2.5}$ component species spatial field for 2026 using Eq-1.

5. Create gridded spatial fields of total EGU speciated $PM_{2.5}$ contributions for each combination of scenario and analytic year evaluated.

   5.1. Use the EGU annual total NO_X, SO_2 and $PM_{2.5}$ emissions for the 2028 baseline scenario and the corresponding 2026 modeled EGU NO_X, SO_2 and $PM_{2.5}$ emissions from Table A-1 to calculate the ratio of 2028 baseline emissions to 2026 modeled emissions for each EGU state contribution tag (i.e., annual nitrate, sulfate and directly emitted $PM_{2.5}$ scaling factors calculated for each state).[105] These scaling factors are provided in Table A-3 through Table A-5.

   5.2. Calculate adjusted gridded annual $PM_{2.5}$ component species EGU contributions that reflect differences in state-EGU NO_X, SO_2 and primary $PM_{2.5}$ emissions between 2026 and the 2028 baseline by multiplying the annual nitrate, sulfate and directly emitted $PM_{2.5}$ scaling factors by the corresponding annual gridded $PM_{2.5}$ component species contributions from each state-EGU tag.[106]

   5.3. Add together the adjusted $PM_{2.5}$ contributions of for each EGU state tag to produce spatial fields of adjusted EGU totals for each $PM_{2.5}$ component species.

   5.4. Repeat steps 5.1 through 5.3 for the two regulatory options in 2028 and for the baseline and regulatory options for each additional analytic year. The scaling factors for all $PM_{2.5}$ component species for the baseline and regulatory control alternatives are provided in Table A-3 through Table A-5.

6. Create gridded spatial fields of each $PM_{2.5}$ component species for the 2028 baseline by combining the EGU annual $PM_{2.5}$ component species contributions from step 5.3 with the

[105] Preliminary testing of this methodology showed unstable results when very small magnitudes of emissions were tagged especially when being scaled by large factors. To mitigate this issue, scaling factors of 1.00 were applied to any tags that had less than 100 tpy emissions in the original source apportionment modeling. Any emissions changes in the low emissions state were assigned to a nearby state as denoted in Table A-2 through Table A-5.

[106] Scaling factors for components that are formed through chemical reactions in the atmosphere were created as follows: scaling factors for sulfate were based on relative changes in annual SO_2 emissions; scaling factors for nitrate were based on relative changes in annual NO_X emissions. Scaling factors for $PM_{2.5}$ components that are emitted directly from the source (OA, EC, crustal) were based on the relative changes in annual primary $PM_{2.5}$ emissions between the 2026 modeled emissions and the baseline and the three regulatory control alternatives in each year.

corresponding contributions to annual $PM_{2.5}$ component species from all other sources. Repeat for each of the EGU contributions created in step 5.4 to create separate gridded spatial fields for the baseline and three regulatory control alternatives for all other analytic years.

7. Create gridded spatial fields of total $PM_{2.5}$ mass by combining the component species surfaces for sulfate, nitrate, organic aerosol, elemental carbon, and crustal material with ammonium, and particle-bound. Ammonium and particle-bound water concentrations are calculated for each scenario based on nitrate and sulfate concentrations along with the ammonium degree of neutralization in the base year modeling (2016) in accordance with equations from the SMAT-CE modeling software (U.S. EPA, 2022f).

Steps 5 and 6 result in Eq-3 for $PM_{2.5}$ component species: sulfate, nitrate, organic aerosol, elemental carbon, and crustal material.

$$PM_{s,g,i,y} = eVNA_{s,g,2026} \times \left(\frac{C_{s,g,BC}}{C_{s,g,Tot}} + \frac{C_{s,g,int}}{C_{s,g,Tot}} + \frac{C_{s,g,bio}}{C_{s,g,Tot}} + \frac{C_{s,g,fires}}{C_{s,g,Tot}} + \frac{C_{s,g,USanthro}}{C_{s,g,Tot}} + \sum_{t=1}^{T} \frac{C_{EGUs,g,t}\, S_{s,t,i,y}}{C_{s,g,Tot}} \right) \qquad \text{Eq-3}$$

- $PM_{s,g,i,y}$ is the estimated fused model-obs PM component species “s” for grid-cell, “g,” scenario, “i,”[107] and year, “y;”[108]
- $eVNA_{s,g,2026}$ is the 2026 eVNA PM concentration for component species “s” in grid-cell “g” calculated using Eq-1.
- $C_{s,g,Tot}$ is the total modeled PM component species “s” for grid-cell “g” from all sources in the 2026 source apportionment modeling
- $C_{s,g,BC}$ is the 2026 PM component species “s” modeled contribution from the modeled boundary inflow;
- $C_{s,g,int}$ is the 2026 PM component species “s” modeled contribution from international emissions within the modeling domain;

[107] Scenario “i" can represent either baseline or one of the regulatory options.
[108] Year “y” can represent 2028, 2030 or 2035.

- $C_{s,g,bio}$ is the 2026 PM component species “s” modeled contribution from biogenic emissions;
- $C_{s,g,fires}$ is the 2026 PM component species “s” modeled contribution from fires;
- $C_{s,g,USanthro}$ is the total 2026 PM component species “s” modeled contribution from U.S. anthropogenic sources other than EGUs;
- $C_{EGUs,g,t}$ is the 2026 PM component species “s” modeled contribution from EGU emissions of NO_X, SO_2, or primary $PM_{2.5}$ from state, “t”; and
- $S_{s,t,i,y}$ is the EGU scaling factor for component species “s,” state “t,” scenario “i,” and year “y.” Scaling factors for nitrate are based on annual NO_x emissions, scaling factors for sulfate are based on annual SO_2 emissions, scaling factors for primary $PM_{2.5}$ components are based on primary $PM_{2.5}$ emissions

A.4 Scaling Factors Applied to Source Apportionment Tags

Table A-2 Ozone Scaling Factors for EGU Tags in the Baseline, the Proposed Rule, and More Stringent Alternative

	Baseline			Proposed Regulatory Option			More Stringent Regulatory Option		
State Tag	2028	2030	2035	2028	2030	2035	2028	2030	2035
AL	0.85	0.85	0.85	0.89	0.89	0.89	0.58	0.59	0.58
AR	0.38	0.38	0.33	0.27	0.27	0.28	0.20	0.20	0.20
AZ	1.28	1.29	1.27	2.05	2.04	2.05	2.80	2.81	2.82
CA	0.69	0.69	0.69	0.37	0.37	0.37	0.27	0.28	0.28
CO	0.71	0.72	0.61	0.16	0.16	0.16	0.16	0.16	0.16
CT	0.71	0.71	0.72	0.70	0.70	0.70	0.66	0.66	0.66
DC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DE	1.68	1.68	1.68	1.68	1.68	1.68	0.96	0.95	0.95
FL	1.09	1.09	1.03	1.02	1.02	1.01	0.91	0.91	0.88
GA	1.23	1.23	1.29	1.32	1.32	1.36	0.70	0.70	0.70
IA	1.28	1.28	1.28	0.96	0.96	0.96	0.05	0.04	0.04
ID	1.06	1.09	1.10	1.16	1.19	1.19	0.37	0.43	0.43
IL	0.42	0.41	0.42	0.40	0.40	0.40	0.27	0.27	0.27
IN	0.75	0.74	0.70	0.55	0.55	0.51	0.22	0.22	0.22
KS	1.02	1.02	1.03	0.16	0.16	0.16	0.06	0.06	0.06
KY	0.36	0.36	0.36	0.40	0.39	0.32	0.20	0.20	0.14
LA	0.47	0.47	0.46	0.46	0.46	0.46	0.32	0.32	0.32
MA	1.20	1.20	1.22	1.21	1.21	1.21	1.17	1.17	1.17
MD	0.74	0.74	0.83	0.74	0.74	0.73	0.70	0.69	0.70
ME	1.63	1.63	1.63	1.14	1.14	1.14	1.07	1.07	1.07
MI	0.73	0.73	0.60	0.74	0.73	0.70	0.57	0.57	0.56
MN	0.67	0.67	0.67	0.31	0.31	0.31	0.14	0.14	0.13
MO	0.53	0.53	0.54	0.25	0.25	0.27	0.04	0.03	0.03

State Tag	Baseline			Proposed Regulatory Option			More Stringent Regulatory Option		
	2028	2030	2035	2028	2030	2035	2028	2030	2035
MS	0.73	0.73	0.73	0.73	0.73	0.73	0.62	0.57	0.57
MT	1.01	1.01	1.01	0.97	0.97	0.97	0.93	0.01	0.12
NC	0.56	0.56	0.57	0.36	0.36	0.36	0.33	0.34	0.34
ND	1.46	1.46	1.20	1.07	1.07	0.87	0.50	0.50	0.50
NE	1.15	1.15	1.12	0.91	0.91	0.88	0.13	0.14	0.11
NH	1.25	1.24	1.33	1.30	1.30	1.30	1.04	1.04	1.04
NJ	1.06	1.06	1.03	1.07	1.07	1.07	0.96	0.96	0.95
NM	0.58	0.58	0.58	0.58	0.60	0.61	0.46	0.46	0.46
NV	0.74	0.75	0.68	1.12	1.13	1.10	0.98	1.04	1.04
NY	0.89	0.89	0.90	0.85	0.85	0.85	0.64	0.64	0.64
OH	0.78	0.78	0.79	0.59	0.60	0.53	0.32	0.33	0.33
OK	0.74	0.74	0.69	0.67	0.67	0.62	0.12	0.12	0.12
OR	0.33	0.33	0.34	0.10	0.10	0.10	0.00	0.00	0.00
PA	0.65	0.65	0.61	0.74	0.75	0.73	0.57	0.58	0.58
RI	1.26	1.26	1.27	1.26	1.26	1.26	1.13	1.13	1.13
SC	0.98	0.98	0.98	0.61	0.61	0.60	0.43	0.43	0.43
SD	1.33	1.33	1.37	1.06	1.06	1.17	0.08	0.08	0.08
TL	1.08	1.08	1.08	1.03	1.02	1.00	0.00	0.00	0.00
TN	1.99	1.99	2.00	0.92	0.92	0.82	0.57	0.57	0.57
TX	0.73	0.73	0.73	0.64	0.64	0.64	0.44	0.44	0.44
UT	1.02	1.02	1.01	1.10	1.10	1.10	0.97	1.08	1.09
VA	1.22	1.21	1.20	1.00	1.00	1.00	0.89	0.88	0.84
VT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WA	0.71	0.71	0.71	0.79	0.78	0.78	0.49	0.49	0.49
WI	1.29	1.29	1.29	0.96	0.96	0.96	0.51	0.51	0.51
WV	1.03	1.01	1.04	0.82	0.77	0.85	0.28	0.27	0.28
WY	0.70	0.70	0.49	0.61	0.61	0.38	0.62	0.62	0.38

*TL = tribal lands

**Scaling factors of 1.00 were applied to tags that had less than 100 tons per year (tpy) emissions assigned in the original source apportionment modeling. Any emissions changes in that state were assigned to a nearby state. For NO_X, the following emissions change assignments were applied: DC → MD, VT → NY.

Table A-3 Nitrate Scaling Factors for EGU Tags in the Baseline, the Proposed Rule, and More Stringent Alternative

	Baseline			Proposed Regulatory Option			More Stringent Regulatory Option		
State Tag	**2028**	**2030**	**2035**	**2028**	**2030**	**2035**	**2028**	**2030**	**2035**
AL	1.08	1.07	1.07	1.13	1.13	1.13	0.63	0.63	0.62
AR	0.43	0.43	0.44	0.34	0.34	0.34	0.17	0.17	0.17
AZ	1.36	1.36	1.30	1.66	1.66	1.66	1.80	1.81	1.81
CA	0.59	0.59	0.59	0.42	0.42	0.42	0.30	0.30	0.30
CO	0.57	0.57	0.52	0.16	0.16	0.16	0.18	0.18	0.18
CT	0.68	0.68	0.68	0.65	0.65	0.64	0.58	0.58	0.58
DC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DE	1.66	1.65	1.66	1.66	1.65	1.66	0.94	0.93	0.94
FL	1.15	1.15	1.06	1.04	1.04	1.04	0.98	0.98	0.96
GA	1.30	1.30	1.51	1.28	1.28	1.30	0.72	0.72	0.72
IA	1.28	1.28	1.31	0.98	0.98	0.99	0.04	0.04	0.04
ID	0.98	1.02	1.03	1.07	1.10	1.11	0.66	0.70	0.71
IL	0.41	0.41	0.41	0.40	0.40	0.40	0.21	0.20	0.21
IN	0.77	0.77	0.69	0.57	0.57	0.51	0.15	0.15	0.15
KS	1.73	1.73	1.63	0.20	0.20	0.19	0.09	0.09	0.09
KY	0.47	0.47	0.45	0.41	0.41	0.32	0.25	0.25	0.17
LA	0.62	0.62	0.63	0.60	0.60	0.60	0.35	0.35	0.35
MA	1.22	1.22	1.24	1.22	1.22	1.22	1.18	1.18	1.18
MD	0.84	0.84	0.90	0.81	0.81	0.81	0.72	0.71	0.72
ME	1.49	1.49	1.49	1.08	1.08	1.08	0.93	0.93	0.93
MI	0.70	0.70	0.57	0.73	0.73	0.68	0.47	0.47	0.47
MN	0.62	0.62	0.63	0.27	0.27	0.27	0.13	0.13	0.12
MO	0.83	0.83	0.83	0.56	0.56	0.63	0.05	0.05	0.05
MS	0.88	0.88	0.87	0.99	0.99	0.99	0.66	0.63	0.62
MT	1.05	1.05	1.05	1.01	1.01	1.01	1.06	0.64	0.69
NC	0.75	0.75	0.69	0.32	0.32	0.32	0.30	0.30	0.30
ND	1.48	1.47	1.20	1.01	1.01	0.90	0.52	0.52	0.52
NE	1.11	1.11	1.08	0.88	0.88	0.85	0.14	0.15	0.14
NH	1.11	1.11	1.16	1.13	1.13	1.13	1.00	1.00	1.00
NJ	1.06	1.06	1.05	1.08	1.08	1.08	0.87	0.87	0.87
NM	0.56	0.56	0.56	0.57	0.59	0.59	0.48	0.48	0.48
NV	0.58	0.58	0.57	0.88	0.88	0.89	0.76	0.78	0.79
NY	0.94	0.93	0.95	0.92	0.92	0.92	0.70	0.70	0.70
OH	0.83	0.83	0.80	0.57	0.57	0.51	0.30	0.31	0.29
OK	0.85	0.85	0.81	0.80	0.79	0.76	0.18	0.18	0.17
OR	0.54	0.54	0.56	0.24	0.24	0.24	0.12	0.12	0.12
PA	0.65	0.65	0.63	0.75	0.75	0.74	0.54	0.54	0.54
RI	1.19	1.19	1.22	1.19	1.19	1.19	1.07	1.07	1.07
SC	1.01	1.01	1.01	0.63	0.63	0.62	0.49	0.49	0.49

State Tag	Baseline			Proposed Regulatory Option			More Stringent Regulatory Option		
	2028	2030	2035	2028	2030	2035	2028	2030	2035
SD	1.28	1.28	1.30	1.01	1.01	1.06	0.04	0.04	0.04
TL	0.93	0.93	0.93	0.93	0.93	0.93	0.00	0.00	0.00
TN	1.58	1.57	1.57	0.69	0.69	0.66	0.48	0.47	0.47
TX	0.97	0.97	0.98	0.85	0.85	0.85	0.54	0.54	0.54
UT	0.56	0.56	0.56	0.60	0.59	0.60	0.56	0.59	0.60
VA	1.29	1.27	1.27	1.08	1.08	1.08	0.89	0.89	0.87
VT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WA	0.72	0.72	0.73	0.97	0.97	0.98	0.94	0.88	0.88
WI	1.46	1.46	1.48	1.02	1.02	1.02	0.45	0.45	0.45
WV	1.08	1.07	1.04	0.70	0.68	0.75	0.30	0.30	0.31
WY	0.68	0.68	0.50	0.59	0.59	0.37	0.61	0.61	0.38

*TL = tribal lands

**Scaling factors of 1.00 were applied to tags that had less than 100 tpy emissions assigned in the original source apportionment modeling. Any emissions changes in that state were assigned to a nearby state. For NO_X, the following emissions change assignments were applied: DC → MD, VT → NY.

Table A-4 Sulfate Scaling Factors for EGU Tags in the Baseline, the Proposed Rule, and More Stringent Alternative

State Tag	Baseline			Proposed Regulatory Option			More Stringent Regulatory Option		
	2028	**2030**	**2035**	**2028**	**2030**	**2035**	**2028**	**2030**	**2035**
AL	1.88	1.88	1.88	1.79	1.79	1.83	0.61	0.62	0.64
AR	0.06	0.06	0.08	0.01	0.01	0.01	0.00	0.00	0.00
AZ	1.02	0.91	1.18	1.86	1.86	1.86	3.55	3.55	3.55
CA	2.42	2.42	2.42	0.43	0.43	0.43	0.40	0.40	0.40
CO	0.16	0.16	0.17	0.04	0.04	0.04	0.00	0.00	0.00
CT	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
DC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DE	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
FL	1.50	1.50	0.64	0.99	0.99	0.83	0.81	0.81	0.77
GA	3.61	3.61	4.84	2.75	2.75	3.14	0.00	0.00	0.00
IA	1.23	1.23	1.25	0.95	0.95	0.96	0.04	0.04	0.04
ID	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
IL	0.29	0.29	0.29	0.22	0.22	0.22	0.09	0.09	0.09
IN	1.18	1.17	1.14	0.64	0.64	0.62	0.16	0.16	0.16
KS	3.03	3.03	2.92	0.00	0.00	0.00	0.00	0.00	0.00
KY	0.31	0.31	0.27	0.31	0.31	0.18	0.17	0.18	0.08
LA	0.18	0.18	0.18	0.03	0.03	0.03	0.03	0.03	0.03
MA	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
MD	2.62	2.62	3.95	1.99	1.99	1.99	0.99	0.99	0.99
ME	1.11	1.11	1.11	0.88	0.88	0.88	0.81	0.81	0.81
MI	0.24	0.24	0.20	0.41	0.41	0.40	0.40	0.40	0.40
MN	0.61	0.61	0.61	0.47	0.47	0.47	0.13	0.13	0.13
MO	0.43	0.43	0.43	0.31	0.31	0.43	0.03	0.03	0.04
MS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MT	1.36	1.36	1.36	1.15	1.15	1.15	1.10	0.69	0.74
NC	0.65	0.65	0.61	0.10	0.10	0.12	0.05	0.05	0.05
ND	1.10	1.09	1.14	0.95	0.95	1.02	0.71	0.71	0.71
NE	1.05	1.05	1.01	0.97	0.97	0.93	0.17	0.17	0.16
NH	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
NJ	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NV	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NY	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
OH	0.70	0.70	0.65	0.45	0.45	0.30	0.07	0.07	0.06
OK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PA	0.78	0.78	0.80	0.58	0.56	0.60	0.30	0.27	0.30
RI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SC	1.44	1.43	1.44	0.55	0.55	0.55	0.24	0.24	0.24

State Tag	Baseline			Proposed Regulatory Option			More Stringent Regulatory Option		
	2028	2030	2035	2028	2030	2035	2028	2030	2035
SD	1.33	1.33	1.33	1.00	1.00	1.05	0.00	0.00	0.00
TL	0.98	0.98	0.98	0.98	0.98	0.98	0.00	0.00	0.00
TN	2.33	2.32	2.34	0.19	0.19	0.13	0.00	0.00	0.00
TX	1.48	1.47	1.74	0.66	0.66	0.67	0.72	0.72	0.72
UT	0.89	0.89	0.89	1.03	1.03	1.03	1.03	1.03	1.03
VA	1.13	1.13	1.13	1.13	1.13	1.12	0.93	0.93	0.93
VT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WA	0.34	0.34	0.34	0.21	0.21	0.21	0.21	0.21	0.21
WI	2.83	2.83	2.94	1.00	0.99	1.00	0.00	0.00	0.00
WV	1.15	1.15	1.06	0.58	0.57	0.66	0.17	0.17	0.16
WY	1.30	1.30	0.99	0.99	0.98	0.53	1.07	1.07	0.53

*TL = tribal lands

**Scaling factors of 1.00 were applied to tags that had less than 100 tpy emissions assigned in the original source apportionment modeling. Any emissions changes in that state were assigned to a nearby state. For SO_2, the following emissions change assignments were applied: DC → MD, ID → MT, MS → AL, NV → UT, NM → AZ, OK → TX, OR → WA, RI → CT, VT → NY.

Table A-5 Primary $PM_{2.5}$ Scaling Factors for EGU Tags in the Baseline, the Proposed Rule, and More Stringent Alternative

	Baseline			Proposed Regulatory Option			More Stringent Regulatory Option		
State Tag	**2028**	**2030**	**2035**	**2028**	**2030**	**2035**	**2028**	**2030**	**2035**
AL	1.06	1.06	1.05	1.08	1.08	1.08	0.80	0.80	0.80
AR	0.85	0.85	0.89	0.73	0.73	0.74	0.39	0.39	0.40
AZ	1.14	1.14	1.02	1.59	1.59	1.59	1.45	1.45	1.46
CA	0.68	0.68	0.68	0.54	0.54	0.54	0.40	0.40	0.40
CO	0.63	0.63	0.58	0.34	0.34	0.34	0.35	0.35	0.35
CT	0.59	0.59	0.61	0.53	0.53	0.53	0.39	0.39	0.39
DC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DE	1.35	1.34	1.35	1.36	1.34	1.34	0.96	0.96	0.96
FL	0.98	0.98	0.91	0.93	0.93	0.92	0.89	0.89	0.88
GA	0.86	0.86	0.88	0.91	0.91	0.90	0.76	0.76	0.76
IA	1.45	1.42	1.40	1.20	1.17	1.16	0.18	0.18	0.18
ID	0.99	1.05	1.07	1.15	1.20	1.23	0.78	0.85	0.86
IL	0.41	0.41	0.41	0.42	0.42	0.42	0.25	0.25	0.25
IN	0.77	0.77	0.71	0.61	0.61	0.57	0.32	0.32	0.32
KS	1.06	1.06	0.94	0.12	0.12	0.12	0.05	0.05	0.05
KY	0.14	0.14	0.14	0.13	0.13	0.12	0.09	0.09	0.09
LA	0.87	0.87	0.87	0.87	0.87	0.86	0.68	0.68	0.68
MA	0.99	0.99	1.01	0.99	0.99	0.99	0.85	0.85	0.85
MD	0.67	0.67	0.73	0.65	0.65	0.65	0.51	0.50	0.50
ME	1.08	1.08	1.09	1.03	1.03	1.03	0.98	0.98	0.98
MI	0.58	0.58	0.60	0.65	0.65	0.66	0.49	0.49	0.51
MN	1.02	1.02	1.02	0.44	0.44	0.43	0.26	0.26	0.26
MO	0.46	0.46	0.45	0.29	0.29	0.31	0.07	0.07	0.07
MS	1.11	1.11	1.09	1.14	1.14	1.13	0.84	0.83	0.83
MT	0.97	0.74	0.74	0.96	0.72	0.72	0.97	0.46	0.49
NC	0.94	0.94	0.89	0.53	0.53	0.53	0.53	0.53	0.53
ND	2.03	2.02	1.71	1.51	1.51	1.43	0.62	0.62	0.59
NE	0.39	0.39	0.38	0.26	0.26	0.25	0.05	0.05	0.05
NH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NJ	1.17	1.17	1.15	1.20	1.20	1.21	0.92	0.92	0.92
NM	0.46	0.46	0.46	0.45	0.46	0.46	0.57	0.57	0.57
NV	0.66	0.67	0.69	0.76	0.76	0.78	0.70	0.70	0.70
NY	1.07	1.06	1.08	1.00	1.00	1.00	0.68	0.68	0.68
OH	0.78	0.79	0.78	0.65	0.66	0.63	0.50	0.51	0.51
OK	0.70	0.70	0.67	0.70	0.70	0.67	0.12	0.12	0.12
OR	0.64	0.63	0.68	0.32	0.32	0.32	0.17	0.18	0.18
PA	0.98	0.98	0.97	0.97	0.97	0.97	0.84	0.84	0.84
RI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SC	0.96	0.95	0.96	0.74	0.74	0.74	0.68	0.68	0.68

State Tag	Baseline			Proposed Regulatory Option			More Stringent Regulatory Option		
	2028	2030	2035	2028	2030	2035	2028	2030	2035
SD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TL	1.31	1.31	1.31	1.31	1.31	1.31	0.00	0.00	0.00
TN	1.17	1.17	1.17	0.50	0.50	0.49	0.41	0.41	0.41
TX	1.29	1.29	1.27	1.09	1.09	1.05	0.74	0.74	0.69
UT	1.20	1.20	1.22	1.26	1.24	1.26	1.23	1.26	1.27
VA	0.95	0.95	0.95	0.94	0.94	0.93	0.69	0.66	0.65
VT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WA	1.39	1.39	1.43	1.77	1.75	1.76	1.78	1.69	1.68
WI	0.66	0.66	0.66	0.59	0.59	0.58	0.43	0.43	0.43
WV	1.14	1.14	0.95	0.81	0.81	0.82	0.08	0.08	0.08
WY	1.24	1.24	0.89	1.41	1.41	0.99	1.56	1.55	1.11

*TL = tribal lands
**Scaling factors of 1.00 were applied to tags that had less than 100 tpy emissions assigned in the original source apportionment modeling. Any emissions changes in that state were assigned to a nearby state. For primary $PM_{2.5}$, the following emissions change assignments were applied: DC → MD, NH → ME, RI → CT, SD → ND, VT → NY.

A.5 Air Quality Surface Results

The spatial fields of baseline AS-MO3 and Annual Average $PM_{2.5}$ in 2028, 2030 and 2035 are presented in Figure A-6 through Figure A-11. It is important to recognize that ozone is a secondary pollutant, meaning that it is formed through chemical reactions of precursor emissions in the atmosphere. As a result of the time necessary for precursors to mix in the atmosphere and for these reactions to occur, ozone can either be highest at the location of the precursor emissions or peak at some distance downwind of those emissions sources. The spatial gradients of ozone depend on a multitude of factors including the spatial patterns of NO_X and VOC emissions and the meteorological conditions on a particular day. Thus, on any individual day, high ozone concentrations may be found in narrow plumes downwind of specific point sources, may appear as urban outflow with large concentrations downwind of urban source locations or may have a more regional signal. However, in general, because the AS-MO3 metric is based on the average of concentrations over more than 180 days in the spring and summer, the resulting spatial fields are rather smooth without sharp gradients, compared to what might be expected when looking at the spatial patterns of MDA8 ozone concentrations on specific high ozone episode days. $PM_{2.5}$ is made up of both primary and secondary components. Secondary $PM_{2.5}$ species sulfate and nitrate often demonstrate regional signals without large local gradients while primary $PM_{2.5}$ components often have heterogenous spatial patterns with larger gradients near emissions sources.

Figure A-6 through Figure A-11 also present the model-predicted air quality changes between the baseline and the two regulatory options in 2028, 2030 and 2035 for AS-MO3 and $PM_{2.5}$. Air quality changes in these figures are calculated as the regulatory option minus the baseline. The spatial patterns shown in the figures are a result of (1) the spatial distribution of EGU sources that are predicted to have changes in emissions and (2) the physical or chemical processing that the model simulates in the atmosphere. The spatial fields used to create these maps serve as an input to the benefits analysis and the EJ analysis.

While total U.S. NO_X emissions are predicted to decrease in both the proposed policy scenario and the more stringent policy scenario for all years when compared to the baseline, predicted NO_X emissions changes are heterogeneous across the country with increases predicted in some states. Figure A-6 and Figure A-7 show that the two policy options are predicted to predominantly result in ozone decreases in 2028 and 2030 with the largest predicted ozone decreases in the proposed policy option occuring due to decreased NO_X emissions in West Virginia and the largest predicted ozone decreases in the more stringent policy option occuring due to decreased NO_X emissions across multiple states in the Northern Plains and Midwest regions. Figure A-8 shows that for 2035, increased NO_X emissions that are predicted in both policy options in Nevada and Utah would result in ozone increases in those states while decreases in predicted NO_X emissions would result in ozone decreases in other parts of the country. For the proposed policy option, the 2035 NO_X emissions decreases and resulting ozone decreases are largest in Mississippi and Montana, while for the more stringent policy option, the 2035 NO_X emissions decreases and resulting ozone decreases are predicted to occur over a large number of states in the Northern Plains and the Eastern U.S.

Both secondary and primary $PM_{2.5}$ contribute to the spatial patterns shown in Figure A-9 through Figure A-11. For the proposed policy option, the predicted $PM_{2.5}$ decreases evident in the Northwestern U.S. and Northern Plains regions are predominantly driven by predicted primary $PM_{2.5}$ emissions reductions in 2028 and 2030 and by a mix of predicted primary $PM_{2.5}$ and SO_2 emissions reductions in 2035. For the proposed policy option, SO_2 emissions reductions play an important role in the predicted ambient $PM_{2.5}$ reductions in the Ohio Valley and Mid-

Atlantic regions. For the more stringent policy option, the $PM_{2.5}$ decreases evident in Montana and North Dakota are primarily driven by predicted changes in primary $PM_{2.5}$ emissions. $PM_{2.5}$ decreases evident from the more stringent policy option in Wyoming are driven by a mix of primary $PM_{2.5}$ and SO_2 emissions decreases and the $PM_{2.5}$ changes in other areas of the country are primary driven by predicted changes in SO_2 emissions. In 2028 and 2030, SO_2 emissions are predicted to decrease when totaled across the U.S. but are predicted to increase in some locations and decrease in others, leading to predictions of heterogeneous ambient $PM_{2.5}$ changes. Specifically, predicted increases in SO_2 emissions in Texas and Georgia lead to predicted local $PM_{2.5}$ increases in 2028 and predicted increases in SO_2 emissions in Missouri lead to predicted local $PM_{2.5}$ increases in 2030. Predicted 2028 SO_2 decreases greater than 1,000 tpy in Florida, Indiana, Michigan, Nebraska, Ohio, West Virginia, and Wyoming lead to predicted $PM_{2.5}$ decreases in those locations. Predicted 2030 SO_2 decreases greater than 1,000 tpy in Florida, Kentucky, Nebraska, Ohio, and Wyoming lead to predicted $PM_{2.5}$ decreases in those locations. Predicted 2035 SO_2 decreases greater than 1,000 tpy in Kentucky, Montana, and Wyoming lead to predicted $PM_{2.5}$ decreases in those locations.

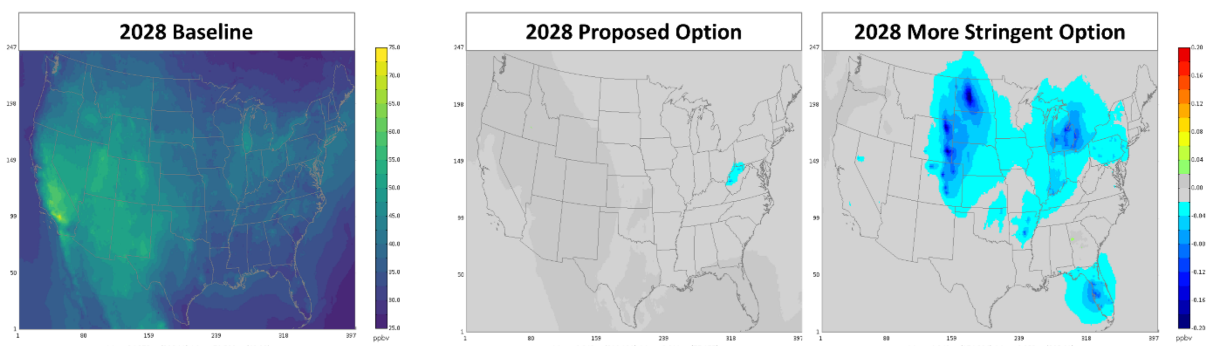

Figure A-6 Maps of ASM-O3 in 2028. Baseline ozone concentrations (ppb) shown in left panel. Change in ozone in proposed policy option compared to baseline values (ppb) shown in center panel. Change in ozone in more stringent policy option compared to baseline values (ppb) shown in right panel.

Figure A-7 Maps of ASM-O3 in 2030. Baseline ozone concentrations (ppb) shown in left panel. Change in ozone in proposed policy option compared to baseline values (ppb) shown in center panel. Change in ozone in more stringent policy option compared to baseline values (ppb) shown in right panel.

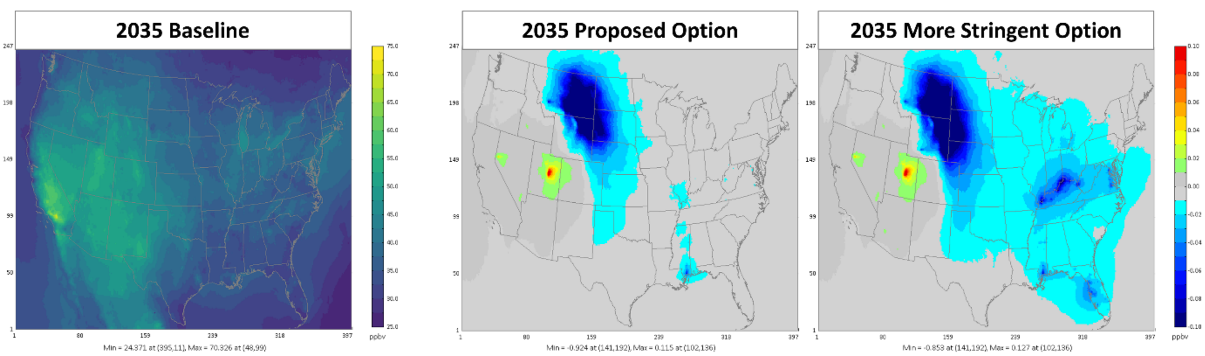

Figure A-8 Maps of ASM-O3 in 2035. Baseline ozone concentrations (ppb) shown in left panel. Change in ozone in proposed policy option compared to baseline values (ppb) shown in center panel. Change in ozone in more stringent policy option compared to baseline values (ppb) shown in right panel.

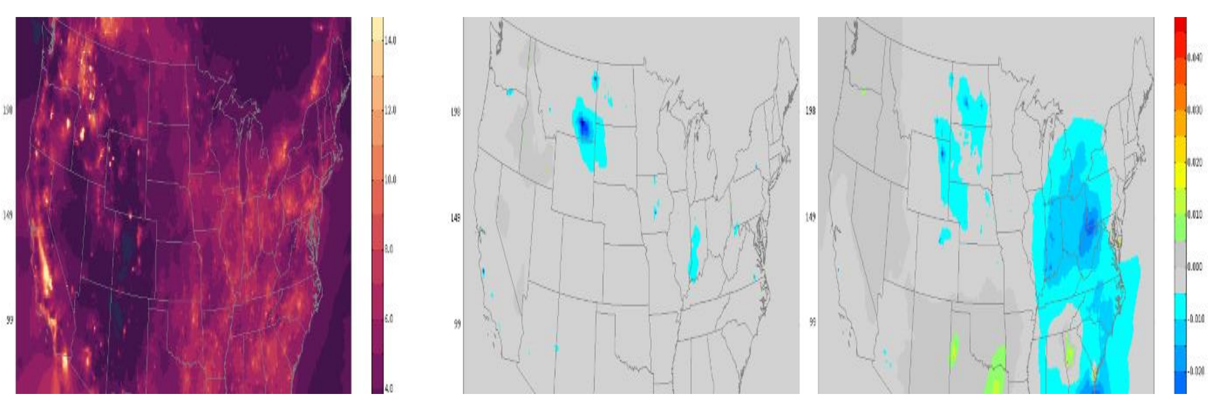

Figure A-9 Maps of $PM_{2.5}$ in 2028. Baseline $PM_{2.5}$ concentrations (μg/m^3) shown in left panel. Change in $PM_{2.5}$ in proposed policy option compared to baseline values (μg/m^3)

shown in center panel. Change in $PM_{2.5}$ in more stringent policy option compared to baseline values ($\mu g/m^3$) shown in right panel.

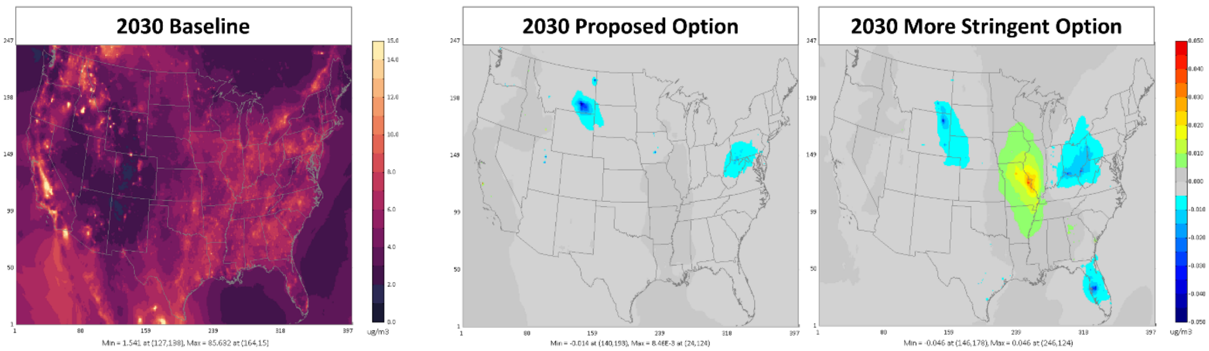

Figure A-10 Maps of $PM_{2.5}$ in 2030. Baseline $PM_{2.5}$ concentrations ($\mu g/m^3$) shown in left panel. Change in $PM_{2.5}$ in proposed policy option compared to baseline values ($\mu g/m^3$) shown in center panel. Change in $PM_{2.5}$ in more stringent policy option compared to baseline values ($\mu g/m^3$) shown in right panel.

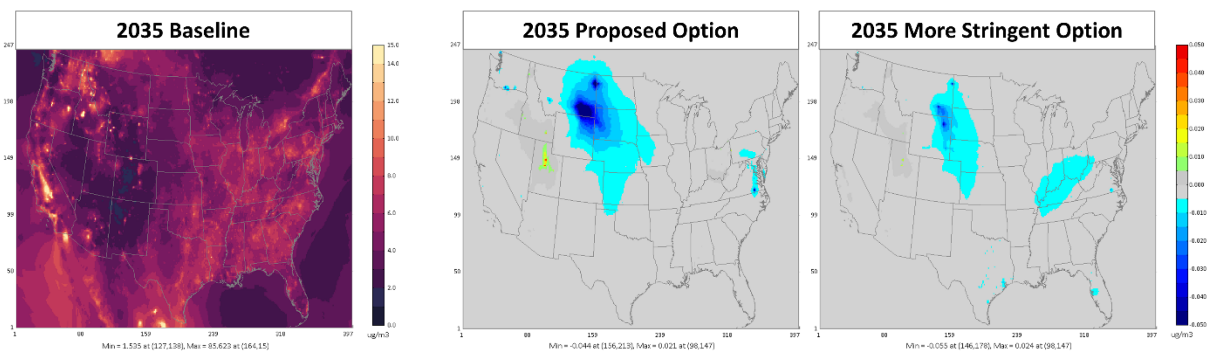

Figure A-11 Maps of $PM_{2.5}$ in 2035. Baseline $PM_{2.5}$ concentrations ($\mu g/m^3$) shown in left panel. Change in $PM_{2.5}$ in proposed policy option compared to baseline values ($\mu g/m^3$) shown in center panel. Change in $PM_{2.5}$ in more stringent policy option compared to baseline values ($\mu g/m^3$) shown in right panel.

A.6 Uncertainties and Limitations of the Air Quality Methodology

One limitation of the scaling methodology for creating ozone and $PM_{2.5}$ surfaces associated with the baseline or regulatory control alternatives described above is that the methodology treats air quality changes from the tagged sources as linear and additive. It therefore does not account for nonlinear atmospheric chemistry and does not account for interactions between emissions of different pollutants and between emissions from different tagged sources. The method applied in this analysis is consistent with how air quality estimations have been made in several prior regulatory analyses (U.S. EPA, 2012, 2019, 2020a). We note that air quality is calculated in the same manner for the baseline and for the regulatory control alternatives, so any uncertainties associated with these assumptions is propagated through results for both the baseline and the regulatory control alternatives in the same manner. In addition, emissions changes between baseline and regulatory control alternatives are relatively small compared to modeled 2026 emissions that form the basis of the source apportionment approach described in this appendix. Previous studies have shown that air pollutant concentrations generally respond linearly to small emissions changes of up to 30 percent Cohan (Cohan et al., 2005; Cohan and Napelenok, 2011; Dunker et al., 2002; Koo et al., 2007; Napelenok et al., 2006; Zavala et al., 2009). A second limitation is that the source apportionment contributions are informed by the spatial and temporal distribution of the emissions from each source tag as they occur in the 2026 modeled case. Thus, the contribution modeling results do not allow us to consider the effects of any changes to spatial distribution of EGU emissions within a state between the 2026 modeled case and the baseline and regulatory control alternatives analyzed in this RIA. Finally, the 2026 CAMx-modeled concentrations themselves have some uncertainty. While all models have some level of inherent uncertainty in their formulation and inputs, the base-year 2016 model outputs have been evaluated against ambient measurements and have been shown to adequately reproduce spatially and temporally varying concentrations (U.S. EPA, 2022a).

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