Regulatory Impact Analysis for the Industrial, Commercial, and Institutional Boilers and Process Heaters NESHAP Amendments

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Regulatory Impact Analysis of the Industrial, Commercial, and Institutional Boilers and Process Heaters NESHAP Amendments

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
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1 INTRODUCTION

This report is the regulatory impact analysis (RIA) for the final amendments to the Industrial, Commercial, and Institutional (ICI) Boilers and Process Heaters NESHAP. The U.S. Environmental Protection Agency (EPA) is promulgating national emission standards for hazardous air pollutants (NESHAP) for new and existing industrial, commercial, and institutional boilers and process heaters. On January 31, 2013, the EPA finalized amendments to the national emission standards for the control of hazardous air pollutants at major sources from new and existing industrial, commercial, and institutional boilers and process heaters. Subsequently, the U.S. Court of Appeals for the District of Columbia Circuit remanded several of the emission standards to the EPA based on the court's review of the EPA's approach to setting those standards. On January 21, 2015, EPA issued a proposal in response to certain issues raised in petitions of reconsideration on the January 13, 2013 final rule. EPA subsequently published a final rule and notice of action on reconsideration on November 20, 2015. The 2015 final rule did not increase any new recordkeeping and reporting burdens. Subsequently, the United States Court of Appeals for the District of Columbia Circuit, in a decision issued in July 2016, vacated several of the emission standards to EPA based on the court's review of EPA's approach to setting those standards. The U.S. Court of Appeals for the District of Columbia Circuit issued its decision remanding emission standards where it held that the EPA had improperly excluded certain units in establishing the emission standards and remanded the use of carbon monoxide (CO) as a surrogate for organic HAP for further explanation. On December 23, 2016, the United States Court of Appeals for the District of Columbia Circuit granted EPA's motion for rehearing on remedy and remanded without vacatur these affected standards. Therefore, these emission standards have remained in effect since the court's decision. In March 2018, the court in a separate case remanded the EPA's decision to set a limit of 130 parts per million (ppm) CO as a minimum standard for certain subcategories for further explanation.

In response to these remands, this action amends several numeric emission limits for new and existing boilers and process heaters and set compliance dates for these new emission limits. The final amendments change several emission limits as part of the EPA's response to the remand granted on December 23, 2016, by the D.C. Circuit. The changes result in more stringent emission limits in some cases, which is expected to require additional recordkeeping and reporting burden. This increase is a result of additional monitoring and control devices anticipated to be installed to comply with the more stringent emission limits in the final amendments. With additional control devices, comes additional control device parametric monitoring, or in the case of CO, continuous emissions monitoring, and the associated records of that monitoring that must be maintained onsite and reported.

The revisions to the emission limits are solely to respond to the remands issued by the U.S. Court of Appeals for the District of Columbia Circuit since 2012. As part of its response, the EPA changed how co-fired (i.e., ICI boilers that use more than one fuel type) units are ranked and assessed from previous Maximum Achievable Control Technology (MACT) rulemakings, changed how small datasets are assessed, and made decisions to set certain emissions limits as beyond the MACT floor.[1] Typically we would assess technical achievability and cost effectiveness by assessing various levels of stringency of emission reductions, technical achievability of options and associated costs. For the emission limits calculated for this particular response to the remands, the revisions were very narrowly scoped. The EPA's response to the remands was to revise the rankings to address the co-firing issue, which required the EPA to identify a new set of best performing units, by including previously excluded co-fired units in the rankings and then re-calculate the limits based on the new set of best performer data while using the existing data set (including any necessary corrections). Given the direction provided by the remand, the only available alternative standard was to select standards that were beyond the MACT floor, which the EPA selected in limited circumstances as discussed above and in more detail in section III.B of the preamble and in the docketed memorandum.[2]

After consideration of public comments and additional review of compliance data, these changes yield 34 different emission limits that we are changing. Of these 34 emission limits, 28 of the limits became more stringent. Six of the limits became modestly less stringent, with no more than a 25 percent decrease in the stringency of the emission limit compared to the 2013

[1] We reviewed the recalculated MACT floor emission limits that were less stringent than those in the January 2013 final rule in order to assess whether a beyond-the-floor option was technically achievable and cost-effective. Further discussion is available in section III.B of the final rule preamble.

[2] Eastern Research Group (ERG). Memorandum, Revised MACT Floor Analysis (2021) for the Industrial, Commercial, and Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants – Major Source. August 2021.

final rule. A complete list of all the emission limits, for new and existing units, and with pollutant indicated for each emissions limit, and a summary of changes to the current limits is shown in Table 1-1. We note that particulate matter (PM) and CO are the most common pollutants for these emissions limits, and these pollutants serve as surrogates for the HAPs that are regulated. Other pollutants such as mercury (Hg) and total non-mercury selected metals (TSM), the latter of which is several metallic HAPs grouped together, have emissions limits defined in terms of those pollutants, not surrogates. More information on these emissions limits and the rationale for changes can be found in section IV.A of the preamble.

Table 1-1. Summary of Changes to Emissions Limits in the Final Rule

Subcategory	Pollutant	Current Emission Limit (2013 Final Rule) (lb/MMBtu of heat input or ppm @ 3 percent oxygen for CO)	Emission Limit in Final Rule (lb/MMBtu of heat input or ppm @ 3 percent oxygen for CO)
New-Solid	HCl	2.2E-02	2.1E-04
New-Dry Biomass Stoker	TSM	4.0E-03	5.0E-03
New-Biomass Fluidized Bed	CO	230	130
New- Biomass Fluidized Bed	PM	9.8E-03	4.1E-03
	TSM	8.3E-05	8.4E-06
New-Biomass Suspension Burner	CO	2,400	220
New-Biomass Suspension Burner	TSM	6.5E-03	8.0E-03
New – Biomass Hybrid Suspension Grate	CO	1,100	180
New-Biomass Dutch Oven/Pile Burner	PM	3.2E-03	2.5E-03
New-Biomass Fuel Cell	PM	2.0E-02	1.1E-02
New- Wet Biomass Stoker	CO	620	590
New- Wet Biomass Stoker	PM	0.03	0.013
New-Liquid	HCl	4.4E-04	1.5E-04
New-Heavy Liquid	PM	1.3E-02	1.9E-03
	TSM	7.5E-05	6.4E-06
New-Process Gas	PM	6.7E-03	7.3E-03
Existing-Solid	HCl	2.2E-02	2.0E-02
Existing-Solid	Hg	5.7E-06	5.4E-06
Existing-Coal	PM	4.0E-02	3.9E-02
Existing-Coal Stoker	CO	160	150
Existing-Dry Biomass Stoker	TSM	4.0E-03	5.0E-03
Existing-Wet Biomass Stoker	CO	1,500	1,100
Existing- Wet Biomass Stoker	PM	3.7E-02	3.4E-02
	TSM	2.4E-04	2.0E-04

Existing-Biomass Fluidized Bed	CO	470	210
Existing-Biomass Fluidized Bed	PM	1.1E-01	7.4E-03
	TSM	1.2E-03	6.4E-05
Existing-Biomass Suspension Burners	PM	5.1E-02	4.1E-02
	TSM	6.5E-03	8.0E-03
Existing-Biomass Dutch Oven/Pile Burner	PM	2.8E-01	1.8E-01
Existing-Liquid	Hg	2.0E-06	7.3E-07
Existing-Heavy Liquid	PM	6.2E-02	5.9E-02
Existing-Non-continental Liquid	PM	2.7E-01	2.2E-01
Existing-Process Gas	PM	6.7E-03	7.3E-03

According to CEDRI data through December 31, 2020, there are 577 boilers and process heaters, of which 485 remain operational and belong in one of the subcategories that are subject to numeric emission limits. This count excludes any boilers that are no longer operational, boilers that have refueled and switched to the natural gas subcategory and are, therefore, no longer impacted by changes to emission limits, or boilers that are classified as small or limited use. Of these units, we estimate that 54 units (individual boilers or process heaters) will incur cost or emissions impacts due to these final amendments. In addition, the EPA estimates that an additional six biomass boilers or process heaters will be constructed and subject to the revised emission limits over the next 8 years.

These facilities are expected to install new pollution control and monitoring equipment or increase the efficiency of existing control equipment. These costs include: the costs to install and maintain additional monitoring equipment, associated additional recordkeeping and reporting burden, changing records associated with adjusting operating parameter limit values, modifying monitoring plans, and familiarizing themselves with the changes in the final amendments that make up this rule.

The impacts estimated for this final rule are all additional to the reductions and control technology applications already accounted for in the January 2013 final ICI boiler rule for both new and existing sources. Thus, the baseline for this rule includes the impacts, and hence the installation and operation of HAP control devices at ICI boilers associated with the 2013 boilers rule.

The changes to the emissions limits shown in Table 1-1 will protect air quality and promote public health by reducing emissions of the HAP listed in section 112(b)(1) of the Clean Air Act. This action also addresses the aforementioned legal issues remanded to the EPA for further explanation and makes several technical clarifications and corrections.

In addition to directly controlling HAP, primarily metal HAP, this action is expected to yield reduced emissions of fine particulate matter ($PM_{2.5}$) and sulfur dioxide (SO_2) even though these pollutants are not directly regulated under this action. The improvements in public health and welfare from all these emission reductions constitute the benefits of this action. There are also minimal increases in carbon dioxide (CO_2) emissions associated with this action, and these increases are treated as a climate disbenefit. Our monetized estimate of benefits includes a subset of public health and welfare impacts from non-HAP emission reductions. There are no monetized benefits from the HAP emissions reductions directly regulated under this action due to lack of necessary input data, and there are monetized disbenefits from the CO_2 emission increases. More information on the benefits and disbenefits can be found in Chapter 4 of the RIA.

This rule is economically significant according to Executive Order 12866 (i.e., an annual effect of $100 million or greater – for either costs or benefits - in any one year or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities), and the EPA has therefore prepared an RIA. For this final rule, it is the monetized benefits that are sufficiently large to lead to an economic significance determination under Executive Order 12866 section 3(f), though the capital costs of more than $100 million could also potentially serve to trigger this determination. This RIA documents all methods and provides the results of the economic impact analysis (EIA), small business impacts analysis, and benefits analysis, among other impacts. With the purpose of this rule to provide necessary, non-discretionary changes in emissions limits to ICI boilers and process heaters in response to the decision by the U.S. Court of Appeals for the D.C. Circuit, the RIA presents an analysis of the regulatory impacts resulting from the final changes in emissions limits.

1.1 Significant Changes Since Proposal

- **Affected Sources**: The estimated number of affected sources impacted by this action increased from 48 units in the proposed rule to 60 units in the final rule. This is based on evaluating an additional year of compliance data in CEDRI and revisions to three emission limits since proposal.

- **Emission Limits**: As described in section III.A of the final rule preamble, three emission limits were revised following consideration of public comment - New-Solid (HCl), New-Liquid (HCl), and Existing-Biomass Fluidized Bed (PM).

- **Cost and Emission Changes**: Cost and emission reductions estimates increased between the proposed rule and final rule based on the increased number of affected sources (and, thus, an increase in the number of control technologies applied), an increase in baseline emissions due to the increased number of affected sources, and the revisions to emission limits. In addition, CO_2 emissions increased between the proposed rule and final rule due to the rise in energy use from the increased number of control technologies applied. See Chapter 3 of this RIA, along with the Impacts Memo in the docket for this action for further details.[3] We also note that economic impacts of the final rule have increased as a result of the increase in costs between the proposed rule and final rule.

- **Benefits**: The Agency has estimated short-term and long-term benefits for the SO_2 and $PM_{2.5}$ emission reductions expected for the final rule, a methodological change from the approach in the proposal RIA. In addition, the benefits per ton (BPT) estimates for these pollutants have also been updated based on additional air quality modeling, additional emissions data, and concentration response functions. See Chapter 4 of this RIA for further details.

- **SCC-CO_2**: Estimates of SCC-CO_2 used in the final RIA are interim values that reflect global impacts from the increase in CO_2 emissions instead of the domestic interim values used in the proposal RIA. The estimates used in the final RIA are much higher

[3] Eastern Research Group (ERG). Prepared for the US EPA/OAQPS/SPPD. Revised (2021) Methodology for Estimating Impacts for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants. August 2021.

than those for the proposal RIA, which affects estimates of climate disbenefits. See section 4.7 of this RIA for further details.

1.2 Summary of RIA Results

This final rule will impose costs and economic impacts on several industries and their consumers, while producing beneficial improvements in air quality and associated benefits. The key results of this RIA are as follows:

- **Engineering Compliance Costs**: Total annual costs are those costs incurred by affected industries that include pollution control and administrative (monitoring, recordkeeping, and reporting) costs. The EPA estimates that the facilities, including new as well as existing ones, that will need to implement compliance measures to meet the revised limits will incur $200.4 million in total capital costs (2016$) and $49.7 million in total annual costs (2016$). In addition, the PV of these costs is $264.9 million at a 7 percent discount rate, and $314.8 million at a 3 percent discount rate. Finally, consistent with the present value estimate, the annualized value of the costs, expressed as an equivalent annualized value (EAV), is $44.4 million at a 7 percent discount rate and $44.7 million at a 3 percent discount rate (again, 2016$).
- **Economic Impacts and Small Businesses**: The EPA prepared an analysis of economic impacts in which the annualized costs for affected companies are compared to their annual revenues, and considered these results in light of market information (e.g., price elasticities of demand). This analysis is required for compliance with the Regulatory Flexibility Act (RFA) as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA). We find that these impacts are relatively low from a cost to sales perspective, and minimal impacts are expected to affect companies and consumers of their products. The EPA used the economic impact analysis to estimate impacts on affected small businesses by analyzing annual compliance costs as a share of annual ultimate parent company revenues. Of the affected parent companies, two are small businesses according to current Small Business Administration (SBA) small business size guidelines. The EPA estimates that the potentially affected small businesses own two affected ICI boilers subject

to the requirements in this rule but will incur compliance costs, so there are no small business impacts associated with this rule. Therefore, the EPA can certify that this final rule will not have a significant economic impact on a substantial number of small entities (SISNOSE).

- **Emissions Impacts**: For HAP emissions, the final amendments are expected to result in an additional 110 tons per year (tpy) of reductions in HCl emissions, an acid gas. There will be reductions of 2.91 tpy in HF emissions, another acid gas. The final amendments are also expected to have a modest effect on mercury emissions from ICI boilers, with an estimated reduction of 7.54 pounds per year. Emissions of non-mercury metals (i.e., antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, nickel, and selenium) would decrease by 1.95 tpy. For non-HAP emissions, filterable PM emissions would decrease by 586 tpy, of which 446 tpy is fine PM ($PM_{2.5}$), due to the final amendments. In addition, the final amendments are estimated to result in an additional 1,141 tpy of reductions in sulfur dioxide (SO_2) emissions. Finally, carbon dioxide (CO_2) emissions increase by 32,910 short (English) tons as a result of operation of the additional control devices expected as a result of the final rule.
- **Benefits:** Benefits associated with reductions in the HAP emissions are not estimated in this RIA due to lack of appropriate valuation estimates. Estimated monetized benefits of this final rule are from reduced PM-attributable premature deaths and morbidity attributed to lower emissions of pollutants such as $PM_{2.5}$ and SO_2 achieved with the operation of the compliance technologies associated with the final HAP standards.[4] The benefit estimates also account for climate disbenefits, which result from increased emissions of CO_2 from those same compliance technologies. The estimated benefits in 2016$ are $112 million to

[4] To facilitate the estimation of the stream of potential benefits flowing from this rulemaking, we use available air quality modeling to estimate benefits in 2025, then assume that the level of impacts estimated for 2025 recurs annually during the years within the time horizon under analysis that facilities are expected to be in compliance and reducing emissions, or 2025 to 2029. The EPA estimates the monetized benefits from reductions in non-HAP pollutants such as $PM_{2.5}$ and SO_2 in 2016$ of this major source NESHAP are $123 million to $124 million at a 3 percent discount rate and $112 million to $113 million at a 7 percent discount rate for the snapshot year of 2025. We are not able to monetize the benefits from emission reductions of directly regulated HAP due to lack of necessary input data. More information on these benefits can be found in Chapter 4 of this RIA.

$113 million when using a 7 percent discount rate and $123 million to $124 million when using a 3 percent discount rate.[5] These estimates are presented in Table 1-2.

Cost-Benefit Comparison: As part of fulfilling analytical guidance with respect to E.O. 12866, EPA presents estimates of the present value (PV) of the benefits and costs over the period 2022 to 2029. To calculate the present value of the social net-benefits of the final rule, annual benefits and costs are discounted to 2020 at 3 percent and 7 discount rates as directed by OMB's Circular A-4. The EPA also presents the equivalent annualized value (EAV), which represents a flow of constant annual values that, had they occurred in each year from 2022 to 2029, 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, consistent with the estimate of the PV, in contrast to the year-specific estimates mentioned earlier in the RIA. The present value (PV) of the net benefits considering benefits and disbenefits, in 2016$ and discounted to 2020, is $80 million to $83 million when using a 7 percent discount rate and $178 million to $182 million when using a 3 percent discount rate. The equivalent annualized values (EAV), an estimate of the annualized value of the net benefits considering benefits and disbenefits consistent with the present values, is $13 million to $14 million per year when using a 7 percent discount rate and $25 million to $26 million per year when using a 3 percent discount rate. Table 1-3 below summarizes the costs, monetized benefits, and net benefits of the final rule all of which are shown as PV and EAV. Estimates in the table are presented as rounded values.

[5] The climate disbenefits included in the benefits estimates are calculated at a 3 percent discount rate. The disbenefits are calculated at three other discount rates, but the 3 percent discount rate is the basis for the climate disbenefits in our "main" range of benefit estimates as explained in Chapter 4 of this RIA.

Table 1-2. Estimated Benefits, Compliance Costs, and Net Benefits of the Final Rule for 2025 for the U.S. (millions of 2016$) [a,b,c]

	Final Rule
HAP Emission Reductions[d]	Unmonetized
$PM_{2.5}$ and SO_2 Related Health Benefits (3%)	$123 and $124
CO_2 Disbenefits (3%)	$2
Total Benefits	$121 and $122
Compliance Costs	$50
Net Benefits[e]	**$71 and $72 +A**
HAP Emission Reductions	Unmonetized
$PM_{2.5}$ and SO_2 Benefits (7%)	$112 and $113
CO_2 Disbenefits (3%)	$2
Total Benefits	$110 and $111
Compliance Costs	$50
Net Benefits	**$60 and $61 + A**

[a] We focus results to provide a snapshot of costs and benefits in 2025, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates. 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. Net benefits are equal to health benefits minus climate disbenefits and the approximate social costs.

[b] Benefits (incorporating disbenefits) include those related to public health and climate. The health benefits are a result of the $PM_{2.5}$ and SO2 emission reductions estimated for this final rule, and are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. Climate disbenefits are based on changes (increases) in CO_2 emissions and are calculated using four different estimates of the social cost of carbon (SC-CO_2) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the climate disbenefits 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. We emphasize the importance and value of considering the disbenefits calculated using all four SC-CO_2 estimates; the additional disbenefit estimates range from $0.52 million to $5.21 million in 2025 for the final rule. Please see Table 4-8 of this RIA or the full range of SC-CO_2 estimates. As discussed in Chapter 4, a consideration of climate disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. The costs presented in this table are 2025 annual estimates.

[c] Rows may not appear to add correctly due to rounding.

[d] The benefits from the approximately 115 tons of emission reductions that are mentioned earlier in this chapter for directly regulated HAP under this final rule are not monetized due to lack of appropriate valuation estimates. More information on these benefits can be found in Chapter 4 of this RIA.

[e] The letter "A" captures the unmonetized benefits from the emission reductions of directly regulated HAP and all other pollutants affected by this final rule. More information on the unmonetized benefits from HAP and non-HAP emission reductions can be found in Chapter 4 of this RIA.

Table 1-3. Summary of Annual Values, Present Values and Equivalent Annualized Values for the 2022-2029 Timeframe for Estimated Compliance Costs, Benefits, and Net Benefits for the Final Rule (millions of 2016$, discounted to 2020)[a,b]

	$PM_{2.5}$ and SO_2 Benefits[c]		CO_2 Disbenefits[d]	Compliance Cost[e]		Net Benefits[f]	
	3%	7%	3%	3%	7%	3%	7%
2022*	$0	$0	$0	$67		-$67 and -$67	-$67 and -$67
2023	$0	$0	$0	$67		-$67 and -$67	-$67 and -$67
2024	$0	$0	$0	$67		-$67 and -$67	-$67 and -$67
2025	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
2026	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
2027	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
2028	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
2029	$123 and $124	$112 and $113	$2	$32		$89 and $90	$79 and $79
PV 2022-2029	**$500 and $505**	**$350 and $353**	**$7**	**$315**	**$265**	**$178 and $182 + B**	**$80 and $83 + B**
EAV 2022-2029	**$71 and $72**	**$58 and $59**	**$1**	**$45**	**$44**	**$25 and $26 + C**	**$13 and $14 + C**

[a] Rows may not appear to add correctly due to rounding. 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. A "-" denotes a negative value.

[b] The annualized present value of costs and benefits are calculated over an 8-year period from 2022 to 2029, which are the eight years after the rule is promulgated.

[c] Benefits (incorporating disbenefits) include those related to public health. The health benefits are a result of the $PM_{2.5}$ and SO_2 emission reductions estimated for this final rule, and are associated with several point estimates and are presented at real discount rates of 3 and 7 percent.

[d] Climate disbenefits are based on changes (increases) in CO_2 emissions and are calculated using four different estimates of the social cost of carbon (SC-CO_2) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For purposes of this table, we show the

disbenefits associated with the model average at a 3 percent discount rate. However, we emphasize the importance and value of considering the benefits calculated using all four SC-CO_2 estimates. As discussed in Chapter 4, a consideration of climate disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts.

[e] The compliance costs presented in this table are consistent with the costs presented in Chapter 3. To estimate these annualized costs, the EPA uses a conventional and widely accepted approach, called the equivalent uniform annual cost (EUAC) that applies a capital recovery factor (CRF) multiplier to capital investments and adds that to the annual incremental operating expenses to estimate annual costs. Total capital investment costs are assumed to be expended over a 3 year period from 2022 to 2024, and an equal amount of these costs are assumed to be expended in each of these years. Operating and maintenance costs are expected to be incurred beginning in 2025. Capital recovery costs were calculated using a 5.5 percent nominal discount rate consistent with the rate used in the cost analysis for the proposal rule in 2020.

[f] The letter "B" captures the portion of the present value of net benefits due to the unmonetized benefits from the emission reductions of directly regulated HAP and all other emission changes resulting from this final rule. The letter "C" captures the portion of the equivalent annualized value of net benefits due to the unmonetized benefits from the emission reductions of directly regulated HAP and all other emission changes resulting from this final rule. The benefits from emission reductions of directly regulated HAP under this final rule are not monetized due to lack of appropriate valuation estimates. More information on the unmonetized benefits from HAP and non-HAP emission reductions can be found in Chapter 4 of this RIA.

*Benefits calculated as value of avoided: $PM_{2.5}$-attributable premature deaths (quantified using a concentration-response relationship from the Di et al. 2017 study); and, $PM_{2.5}$-related morbidity effects.

Given these results, the EPA expects that implementation of this final rule, based solely on an economic efficiency criterion, will provide society with a substantial net gain in welfare, notwithstanding the expansive set of health and environmental benefits and benefits or other impacts we were unable to quantify. Further quantification of directly emitted $PM_{2.5}$-, mercury-, acidification-, and eutrophication-related impacts would increase the estimated net benefits of the rule.

1.3 Organization of this Report

This report presents the EPA's analysis of the potential benefits, costs, and other economic effects of the final rule for ICI boilers. This RIA includes the following sections:

- Chapter 2 presents a profile of the affected industries, developed for the economic impact analysis.
- Chapter 3 describes the estimated costs and impacts of the regulation, providing a summary of the analysis inputs and methodology for assessing the economic impacts of the final regulation. The chapter provides the cost and economic impact analysis results, including impacts on industry overall and impacts on small businesses.
- Chapter 4 describes the benefits of this regulation considering both the directly regulated HAP and non-HAP emission reductions and the inputs and methods used for estimating and valuing reduced environmental and human exposure to air pollutant emissions. The chapter also describes the climate disbenefits of this final regulation.
- Chapter 5 presents the overall comparison of the total benefits (including disbenefits) and total costs.

2 INDUSTRY PROFILE

This final rule will affect facilities and companies using ICI boilers, based on the National Emission Standards for Hazardous Air Pollutants (NESHAP) source category (i.e., 40 CFR part 63, subpart DDDDD) standards. Of the 90 different emission limits included in the rule, the EPA is revising 34 of them depending on the type of boilers and fuel used. Of these 34 emission limits, 28 of the limits became more stringent and 6 of the limits became less stringent. Facilities would have up to three years after the effective date of the final rule to demonstrate compliance with these revised emission limits.

ICI boilers are found in many manufacturing sectors and other industries. The EPA used the North American Industrial Classification System (NAICS) code identified for the parent company owning each facility using an impacted ICI boiler to conduct this brief industry profile. This chapter summarizes in a high-level fashion the profiles of these industries using the NAICS codes for the ultimate parent companies that own affected boilers. The final rule only affects a subset of facilities using ICI boilers within each industry identified. This final rule does not impact all types of ICI boilers. The ICI boilers identified as having cost impacts from this rule are found in the following categories: existing biomass-fired, existing coal-fired, new biomass-fired, and new coal-fired. The EPA identified existing ICI boilers that will be affected by this final rule and expects new boilers to become part of the industry in the future, which are fired or expected to be fired by biomass (e.g., wood) or coal as fuels. None of the affected ICI boilers are oil-fired or gas-fired, and most of the affected boilers are biomass-fired. Table 2-1 provides a list of the industries by NAICS code with source categories affected by the final rule.

Table 2-1. Source Categories Affected by This Final Rule

NAICS code[1]	Examples of Industries with potentially regulated entities
221	Electric, gas, and sanitary services
321	Manufacturers of lumber and wood products
322	Pulp and paper mills
423	Merchant Trade, Durable Goods
424	Merchant Trade, Nondurable Goods
541	Professional, Scientific and Technical Services

[1] North American Industry Classification System.

The industry profile provided here is based on 2016 data from U.S. Census Bureau and U.S. Census Bureau American Fact Finder.[6] For some NAICS codes, 2016 data were not available, and in those instances the most up-to-date data available were used. This profile is not meant to serve as an exhaustive treatment for each affected industry and any subsectors of note, but is meant to serve as a high-level summary of useful information for these industries. It is important to note that only a very small fraction of the facilities in each affected industry own ICI boilers. Thus, only a small fraction of facilities in these industries are impacted by this final regulation.

2.1 Electric, Gas, and Sanitary Services

Activities in this sector, NAICS 221, include providing electric power, natural gas, steam supply, water supply, and sewage removal through a permanent infrastructure of lines, mains, and pipes. This final rule is anticipated to affect three ultimate parent companies owning three boilers in this sector. According to the U.S. Census Bureau American Fact Finder, in 2016, NAICS 221 had 5,893 ultimate parent companies that own 18,159 establishments. The sector employed 638,917 people, with payroll of around $654 billion.

2.2 Sawmills and Wood Preservation

This sector includes establishments whose primary production process begins with logs or bolts that are transformed into boards, dimension lumber, beams, timbers, poles, ties, shingles, shakes, siding, and wood chips. This industry also includes establishments that cut and treat round wood and/or treat wood products to prevent rotting by impregnation with creosote or other chemical compounds.

This final rule is anticipated to affect eight ultimate parent companies owning 8 boilers in this sector. According to the U.S. Census Bureau American Fact Finder, in 2016, the sawmills and wood preservation industry (NAICS 321) was comprised of 3,213 establishments employing 77,200 people and had a payroll of around $3.7 billion. The total value of shipments and receipts for services from this sector was around $30.5 billion.

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[6] US Census Bureau, Dept. of Commerce, https://www.census.gov/eos/www/naics/, and US Census Bureau American Fact Finder, Dept. of Commerce, https://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t

2.3 Converted Paper Product Manufacturing

This industry includes establishments primarily engaged in converting paper or paperboard, but they do not manufacture paper or paperboard. According to the U.S. Census Bureau American Fact Finder, in 2016 the converted paper product manufacturing industry (NAICS 322) had 3,638 establishments employing 233,866 people, with a payroll of around $13 billion. The total value of shipments and receipts for services was around $105 billion.

Paper bag and coated and treated paper manufacturing, NAICS 322220, is a subsector in this industry. It includes establishments primarily engaged in cutting and coating paper and paperboard, and/or cutting and laminating paper, paperboard, and other flexible materials (except plastics film to plastics film). There are seven boilers owned by 5 ultimate parent companies with this NAICS code anticipated to be affected by this final rule. In 2016, this industry employed 45,700 employees, and had a payroll of around $2.6 billion. The total value of shipments and receipts from this sector was around $20.6 billion.

2.4 Management of Companies and Enterprises

Industries in the Management of Companies and Enterprises sector (NAICS 551) include three main types of establishments: (1) those that hold the securities of (or other equity interests in) companies and enterprises; (2) those (except government establishments) that administer, oversee, and manage other establishments of the company or enterprise but do not hold the securities of these establishments; and (3) those that both administer, oversee, and manage other establishments of the company or enterprise and hold the securities of (or other equity interests in) these establishments. Those establishments that administer, oversee, and manage normally undertake the strategic or organizational planning and decision-making role of the company or enterprise.

Many of the companies in NAICS 551 are private equity firms that can own businesses in multiple industry sectors. There are three boilers owned by four ultimate parent companies (one boiler owned by a joint venture of two parent companies) under this NAICS code identified as impacted by this final rule. According to the American Fact Finder, in 2016 the sector had 27,184 parent companies that own 55,384 establishments. The sector had 3,380,437 employees, with a payroll of around $367.2 billion.

3 EMISSION REDUCTIONS, ENGINEERING COST AND ECONOMIC IMPACT ESTIMATES

This chapter presents the EPA's estimates of the emission reductions and compliance costs associated with the final rule. As discussed in Chapter 1, this final rule is expected to affect both existing and new boilers. As a result, the EPA expects that 60 boilers (49 existing, 11 new) would likely be affected by this final action in that they would likely have to perform additional compliance actions to meet the new emissions limits. The emission reductions are used to estimate the benefits shown in Chapter 4 of this RIA, and the costs are used to estimate the economic and small business impacts that are shown later in this RIA chapter.

The analysis in this RIA reflects final amendments to the 2013 standards, including revisions to emissions limits for a variety of different source types and other revisions to appropriately respond to the instructions within the U.S. Court of Appeals for the D.C. Circuit's decisions. This analysis presents incremental emission reductions and costs separate from those already accounted for in the RIA for the 2013 final rule. For existing units, the EPA conducted a review to see if the impacts of the control strategy expected to be necessary to meet the final emission limits had been accounted for in the previous RIA. If so, the same emissions control was not in this revised analysis of impacts to avoid double counting of the emission reductions and costs.

3.1 National Emissions Reductions and Other Emissions Changes

The EPA's estimates of emission reductions in tons per year (tpy) for the final reconsidered NESHAP are shown in Table 3-1 below. The baseline emissions are primarily based on compliance data available through the Compliance and Emissions Data Reporting Interface (CEDRI) and WebFIRE. Data are also sourced from reported emission test results collected for the previous ICI boilers rules, and from fuel and control devices installed on affected units. The final standard will result in reductions of HAP emissions. The HAP emissions reduced include hydrochloric acid (HCl), mercury (Hg), hydrogen fluoride (HF), and total non-mercury selected metals (TSM8).[7] We show these emission reductions by type of source and fuel type.

[7] Metals include antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, nickel, and selenium.

In addition, the final standard will yield reductions in emissions of criteria pollutants such as fine particulate matter ($PM_{2.5}$) and sulfur dioxide (SO_2) that are concurrent with the HAP emission reductions. In each case where there is an exceedance of the HCl, Hg, or PM emissions limits, the control strategy analysis compares the baseline emissions to the corresponding final emission limit for the unit's subcategory. The control device cost for a unit was estimated if its baseline emissions exceeded their applicable final emission limit for each pollutant requiring control. For PM and Hg, there is only one control technology that can be applied to meet the final emissions limits for each pollutant. For HCl, there is more than one control technology available.

Most of the Hg emissions reductions are expected to be achieved through the installation of new fabric filters. Where baseline Hg emissions are found to be greater than the revised emission limits, the cost of a fabric filter was estimated for an individual boiler or process heater unless the unit already had a fabric filter.

When baseline PM emissions exceeded the revised emission limits, reductions are expected to be achieved by the installation of new ESPs unless the unit already had a fabric filter in the analysis for Hg reduction or unless an ESP was already reported to be installed as a baseline control and the unit still required more than 5 percent PM emission reductions.

When HCl baseline emissions are greater than the revised emission limits, increasing the sorbent rate on an existing scrubber, adding a new scrubber, or installing a combination fabric filter and dry injection (DIFF) system is applied to achieve the necessary HCl emissions reductions. Of these options, scrubbers and DIFF systems are estimated to attain similar levels of HCl control.

Our analysis of the cost of compliance options listed above finds that the choice of options is insensitive to nominal interest rates of 10 percent and 15 percent, which are much higher rates than that for our main cost analysis (5.5 percent). The discussion and presentation of these cost sensitivity analysis results can be found in the Impacts and Cost Methodology

Memoranda for this final rule.[8] We note that this same sensitivity analysis was also prepared as part of the cost analysis for the proposed rule.

In total, including affected existing and new ICI boilers and based on full implementation of the final rule as estimated in this analysis, the emission controls listed above yield HAP emission reductions of about 110 tpy of HCl, 2.91 tpy of HF, and 0.004 tpy of Hg. Reductions in $PM_{2.5}$ from this final rule are estimated at 446 tpy (out of 586 tpy of total PM, which includes PM_{10}), and SO_2 reductions are estimated at 1,141 tpy.

Table 3-1. Nationwide Annual Emission Reductions from ICI Boilers (Existing and New) Affected by the Final Rule

	Annual Emission Reductions, tons/year (tpy)						
Source Type	**Hg**	**HCl**	**HF**	**SO_2**	**PM**	**$PM_{2.5}$**	**TSM8**
Existing-Biomass	1.65E-03	13.6	0.10	42.7	521.4	392.5	3.844
Existing-Coal	2.12E-03	44.1	0.91	515	54	48	0.12
Total Existing	3.77E-03	57.7	1.01	557	575	440	3.96
New-Biomass	0	52.3	1.90	583.5	10	6	0.14
Total	**3.77E-03**	**110**	**2.91**	**1,141**	**586**	**446**	**4.1**

This final rule is also expected to lead to an increase in the greenhouse gas pollutant carbon dioxide (CO_2) emissions incremental to the baseline as a result of increased electricity consumption associated with operating existing and new control devices to meet the revised emissions limits. The EPA estimates an increase in CO_2 emissions of 32,910 short tons per year.[9] These calculations use the same baseline as that for the other analyses presented in this RIA, and are thus incremental from those already accounted for in the January 2013 final ICI boilers MACT rule RIA as mentioned earlier in this chapter.

[8] The sensitivity analyses were prepared to explore the concept of hurdle rates (minimum required rates of return on corporate capital investments) as applied to investments in emission control technologies included in the cost analysis for this final rule. In this analysis, the limited effects of hurdle rate may be in part due to limited number of facilities that are affected by this decision variable and the limited number of control technology options available for needed emission reductions. More discussion on hurdle rates and how this concept is considered in our analysis can be found in the Cost Methodology Memorandum for this final rule.

[9] In order to calculate these values, it is necessary to convert tons (short) of emissions to metric tons. These values may be converted to $/short ton using the conversion factor 0.90718474 metric tons per short ton for application to the short ton CO_2 emissions impacts (32,910) provided in this rulemaking. We note that this estimate becomes 329,855 when converted from short tons to metric tons. Such conversion is needed to facilitate calculation of the climate-related co-disbenefits, as discussed in Chapter 4 of this RIA.

Details on the emission reductions estimates and other emissions changes in this RIA, including emissions and control device data, can be found in the Impacts Memorandum prepared by the Eastern Research Group (ERG).[10]

3.2 Compliance Costs

Estimated compliance costs associated with meeting the requirements of this final rule include the costs of pollution control capital as well as operating and maintenance costs, such as additional labor, materials, or energy used for compliance activities, monitoring, and testing. Table 3-2 presents selected pollution control and compliance costs such as the TCI and O&M costs for each control technology included in the analysis and for monitoring.

Table 3-2. Selected Pollution Control and Compliance Costs for the Final Rule by Technology Type (2016$)*

Cost by Technology	Total Capital Investment	Operating and Maintenance (O&M)
Electrostatic Precipitators (ESP)	$1,480,000	$130,000
Fabric Filter and Dry Injection (DIFF)	$1,910,000	$850,000
Fabric Filter	$156,700,000	$22,500,000
Packed Bed Scrubber	$38,600,000	$8,300,000
Testing and Monitoring Costs	$2,200,000	$340,000
Total	**$200,860,000**	***$32,200,000**

*This value is the highest O&M estimate for any year for which an annual cost estimate is provided. See Table 3-3 and Appendix E of the Impacts Memorandum. The O&M value is equivalent to those for 2027 and 2028. Costs include those for existing and new affected boilers. Annualized capital costs are included in the total annual costs, and these can be found by control technology in the Impacts Memorandum for this final rule.

The present value (PV) is a single estimate of costs (or other impacts) that reflect a stream of annual compliance costs that are discounted to obtain an estimate for a specific date, which can be in the present, past, or future. Values are discounted to reflect the impact of time preferences. Guidance for E.O. 12866 requests impact estimates using a PV metric. To implement E.O. 12866, the U.S. Office of Management and Budget (OMB) has requested Federal agencies calculate the PV of the costs or cost savings of an action using both 7 percent

[10] Eastern Research Group (ERG). Prepared for the US EPA/OAQPS/SPPD. Revised (2021) Methodology for Estimating Impacts for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants. August 2021.

and 3 percent end-of-period discount rates for those actions, including actions not deemed economically significant.[11]

For this analysis an eight-year time period was selected as a measure of the full duration of the expected effects of this action, as section 112 of the Clean Air Act (CAA) requires emissions standards such as this one to be reviewed every eight years. We consider an eight-year time period for this analysis to be appropriate given the CAA statutory review requirement. Given a compliance period of three years from promulgation, full compliance (that is, impacts such as emission reductions in response to the requirements of the final rule) is projected to begin in 2025. The eight years over which these calculations are made thus includes the years 2022-2029.

Table 3-3 below shows the undiscounted stream of annual costs for the final rule, as well as their present values discounted to 2020. As seen below, the PV at a real discount rate of 3 percent is $314.9 million and $264.9 million at a real discount rate of 7 percent. Total capital costs are expected to be incurred up to the date of full implementation of the promulgated rule in 2025. Thus, we assumed total capital costs are incurred in equal shares across 2022, 2023, and 2024 as affected firms approach the compliance period. Very small additional capital requirements are incurred in 2025 and 2027 by affected new units that are expected to install pollution control devices and monitors.[12]

We assume operating and maintenance (O&M) costs are incurred beginning in 2025 and continue until the final year of this analysis (2029). These annual costs start at about $32.2 million (2016$) in 2022 with very small increments in 2027 and 2029 that are associated with the pollution control devices and monitors expected to be installed in 2025 and 2027. More information on these costs can be found in the Impacts Memorandum and associated appendices.[13]

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[11] U.S. Office of Management and Budget. Memorandum. Executive Order 12866, "Regulatory Planning and Review." September 30, 1993. Federal Register, Vol. 58, No. 190. Available on the Internet at https://www.archives.gov/files/federal-register/executive-orders/pdf/12866.pdf.

[12] Eastern Research Group (ERG). Revised (2021) Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants. August 2021. Appendix E.

[13] Eastern Research Group (ERG). Prepared for the US EPA/OAQPS/SPPD. Revised (2021) Methodology for Estimating Impacts for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants. August 2021.

Table 3-3. Undiscounted Costs, Discounted Costs, and 2020 Present Value Analysis for the Final Rule (2016$)*

	Undiscounted (Annual) Cost		Total Discounted Costs	
Year	**Capital**	**O&M**	**3%**	**7%**
2022	$66,953,000	$0	$ 63,100,000	$ 58,500,000
2023	66,953,000	0	61,300,000	54,700,000
2024	66,953,000	0	59,500,000	51,100,000
2025	0	32,196,000	27,800,000	23,000,000
2026	0	32,196,000	27,000,000	21,500,000
2027	0	32,196,000	26,200,000	20,100,000
2028	0	32,196,000	25,400,000	18,700,000
2029	0	32,196,000	24,700,000	17,500,000
	2020 Present Value		**$314,800,000**	**$264,900,000**

*Total estimates may differ due to rounding conventions. Estimates are for 2022 through 2029. EPA has assumed that capital for compliance purposes will be expended in an equal amount each year between promulgation and the implementation deadline (3 years) due to a lack of information on precisely when affected facilities could be expected to install control technologies and monitors in response to this final rule.

Table 3-4 summarizes the present value of the costs in 2020 accounting for the additional compliance costs to industry, as well as the equivalent annualized value (EAV) over the selected 8-year time frame. The EAV is the annualized present value of the costs. As seen below, the EAV for the final rule in 2016$ at a discount rate of 3 percent is approximately $40.7 million and $40.4 million at a discount rate of 7 percent.

Table 3-4. 2020 Present Value (PV) of Costs and Equivalent Annualized Values (EAV) for the Final Rule for E.O. 12866 (2016$)*

	2020 Present Value of Costs	Equivalent Annualized Value of Costs
7% Discount Rate	$264,900,000	$44,400,000
3% Discount Rate	$314,800,000	$44,700,000

*PV and EAV are calculated over an eight-year period from 2022 to 2029.

3.3 Economic Impact and Small Business Analysis

Although facility-specific economic impacts (e.g., closures) cannot be estimated by this analysis, the EPA did conduct a screening analysis to quantify some economic impacts on individual firms. For economic impact analyses of rules that directly affect one or several industries, such as this final rule, the EPA often prepares a partial equilibrium analysis. In this type of economic analysis, the focus of the effort is on estimating impacts to a single affected industry or several affected industries, and all impacts of this rule to industries outside of those affected are assumed to be zero or inconsequential.[14] If the compliance costs, which are key inputs to an economic impact analysis, are small relative to the receipts of the affected industries, then the impact analysis could consist of a calculation of annual (or annualized) costs as a percent of sales for affected parent companies. This latter type of analysis is called a screening analysis and is applied when a partial equilibrium or more complex economic impact analysis approach is deemed unnecessary given the expected size of the impacts.

We conduct a screening analysis to estimate the economic impacts of this final rule, given that the annualized total compliance costs are about $50 million in 2016$, and are distributed over multiple industries as described in Chapter 2. The annualized cost estimates is also a relatively small amount relative to the revenues for the affected industries listed in Chapter 2. This estimate of annual total compliance costs is much less than those of previous NESHAPs for this source category.[15] The analysis employed here is a "sales test", which determines annualized compliance costs as a share of annual sales for each impacted parent company. The annualized cost per sales for a company represents the maximum price increase in the affected product or service needed for the company to completely recover the annualized costs imposed by the regulation.

The "sales test" is the impact methodology the EPA employs in economic impact analysis such as this one as opposed to a "profits test," in which annualized compliance costs are calculated as a share of profits. This is because revenues or sales data are commonly available data for entities normally impacted by EPA regulations and profits data normally made available are often accounting but not the true economic profits earned by firms due to accounting and tax considerations. In addition, EPA would need to invoke further assumptions about cost pass through for both sales and profit tests.

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[14] U.S. EPA. Guidelines for Preparing Economic Analyses. May 2016. p. 9-17. Available at https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-09.pdf.

[15] For example, the total annual compliance costs estimated by the EPA for the 2013 final rule were $1.4 to $1.6 billion (2008 dollars). Adjusting the annual compliance costs estimates for the 2013 final rule to 2016$ would make the difference in costs even larger in a real (inflation-adjusted) sense. See https://www3.epa.gov/ttn/ecas/docs/ria/ici-boilers_ria_reconsider-neshap_2012-12.pdf, p. 3 of cover memo for the RIA prepared for the 2013 final ICI boiler MACT reconsideration.

The EPA prefers a "sales test" as the impact methodology in economic impact analyses as opposed to a "profits test", in which annualized compliance costs are calculated as a share of profits.[16] This is consistent with guidance published by the U.S. Small Business Administration (SBA)'s Office of Advocacy, which suggests that cost as a percentage of total revenues is a metric for evaluating cost impacts on small entities relative to large entities.[17] This is because revenues or sales data are commonly available for entities impacted by the EPA regulations and profits data are often private or tend to misrepresent true profits earned by firms after undertaking accounting and tax considerations.

While screening analyses are often employed to estimate impacts to small businesses or entities as part an analysis in compliance with the Regulatory Flexibility Act (RFA) as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA), a screening analysis can also be employed in an economic impact analysis such as this one whose focus is on all regulated companies, big and small. In addition, we also include a brief discussion of measures of producer and consumer responsiveness to price changes (i.e., supply and demand elasticities) to further characterize the economic impacts of these rules.

While a "sales test" can provide some insight as to the economic impact of an action such as this one, it assumes that the impacts of a rule are solely incident on a directly affected firm (therefore, no impact to consumers of affected product), or solely incident on consumers of output directly affected by this action (therefore, no impact to companies that are producers of affected product). Thus, an analysis such as this one is best viewed as providing insight on the polar examples of economic impacts: maximum impact to either directly affected companies or their consumers. A "sales test" analysis does not consider shifts in supply and demand curves to reflect intermediate economic outcomes that are much more likely to occur than polar examples More information on sales and profit tests as used in analyses done by the EPA can be found at https://www.epa.gov/system/files/documents/2021-07/guidance-regflexact.pdf. Use of partial equilibrium or computable general equilibrium (CGE) economic impact models such as US EPA's SAGE model will provide more robust analyses of economic impacts for regulatory

[16] More information on sales and profit tests as used in analyses done by U.S. EPA can be found in the Final Guidance for EPA Rulewriters: Regulatory Flexibility Act as Amended by the Small Business Regulatory Enforcement Fairness Act, November 2006, pp. 32-33.

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

actions if the model appropriate and available for use with the actions' costs, as is not the case for this particular regulatory action, and if data and resources permit their use.

It should be noted that the compliance costs for the final rule were estimated in 2016$. Hence, we use 2016 revenues to the extent possible for affected firms and entities in this report in order to be consistent in estimating economic impacts. We find that the great majority of the 30 entities affected are large, U.S.-owned multinational companies with substantial revenues from paper, timber, and milling operations. Among such companies impacted by this final rule are Louisiana Pacific, Weyerhaeuser, and Boise Cascade.

Using the current SBA small business size definitions, which is defined using employee size or annual revenues depending on the sector to which a given parent company belongs, two of the affected companies are small according to the SBA small business size standards.[18] These small business size standards for the industries in which these boilers operate range from 250 to 1,250 employees, or $1.0 million to $41.5 million in annual revenues, where appropriate. We generally find that the cost imposed on these companies is a very small fraction of the parent companies' revenues and should yield small economic impacts on wood products producers and the wood products market. The revenue estimate for these ultimate parent companies reflects all product sales worldwide. In turn, such small economic impacts should lead to small impacts on customers (regardless of whether they are consumers of intermediate or end-use goods).

Based on the fact that the small businesses impacted by this final rule will incur a small amount of impact based on a metric of annual compliance costs as a percent of sales or revenues, we can certify that there is no significant economic impact on a substantial number of small entities (SISNOSE) for this rule. Details on the impacts by ultimate parent company can be found in the spreadsheet that accompanies the economic impact analysis report.[19] Neither of the two affected small companies could experience annual costs of 1.0 percent of these sales or greater. Two companies have annualized compliance costs of more than 1.0 percent of their sales out of the two affected parent companies.   One of these companies could experience an annual cost to sales of 7.65 percent, an impact which is by far the maximum cost to sales estimate for any affected entity. The boiler owned by this company affected by this final rule, however, is

[18] SBA's small business size standards can be found on the Internet at https://www.sba.gov/document/support--table-size-standards. These standards were updated on August 19, 2019.
[19] Ibid.

shut down as of October 2021, and the company that now owns the mill provides services including industrial liquidation.[20] Thus, there is some likelihood that this ICI boiler may not be in operation, either at its current Wisconsin location or elsewhere, by the time that this final rule has been fully implemented. In summary, we find that the average cost to sales across all affected entities is 0.36 percent, and the median cost to sales ratio across all affected entities is 0.0042 percent. Thus, the economic impacts should be relatively minimal for these entities. A list of affected ultimate parent entities and their economic impacts is found in Table 3-5. More information on these impacts can be found in the spreadsheet for these calculations.[21] No proprietary or confidential business information (PBI or CBI) was used in preparing these estimates. We note that there are firms listed in this table with boilers listed as subject to this final rule but with no costs associated with the revised HAP emissions limits. These firms own facilities that should only need to incur extremely minimal costs (e.g., adjustments in fuel specifications) in order to meet the requirements of this final rule. For more information, please review the Cost Methodology Memorandum for this rule.[22]

We note that the final rule does not contain any provisions reserved exclusively for the benefit of small entities. However, the regulation does contain several provisions that reduce the impact on all regulated entities, which include small entities. For instance, operating parameter monitoring is required instead of continuous emissions monitors (CEMS). The rule provides an option to demonstrate compliance with fuel analysis in lieu of stack testing for boilers combusting fuels with mercury, TSM8, or chlorine contents less than their associated emission limit. In addition, providing a work practice standard for small and limited use boilers and process heaters firing all fuel types and for boilers of all sizes firing natural gas, refinery gas, or other gas 1 fuels, the EPA has substantially reduced the burden of the rule, including reducing the burden on small entities. For example, for small entities with only small or limited use boilers and process heaters installed, the option to demonstrate compliance using an annual, biennial, or

[20] The mill at which this boiler is located, formerly known as Flambeau River Papers, is scheduled to have its components subject to an auction conducted by the current owner, Maynards Industries, in early November, 2021 according to https://maynards.com/flambeau-river-papers-day-1/. All impacts in this RIA assume that this boiler will be in operation and install emission controls as stated in the Impacts memo for this final rule.

[21] U.S. EPA. FinalICIBoilerMACTremand_econsmallbuslist_October2021.xls. Available in the docket for the final rule.

[22] Eastern Research Group (ERG). Revised (2021) Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants. August 2021.

every five-year tune-up is a substantial savings compared with the requiring stack testing, parameter monitoring, and add-on air pollution control devices. Additionally, compliance flexibilities exist for boilers and process heaters burning ultra-low sulfur liquid fuels, by reducing the requirement for subsequent performance tests.

Due to technical considerations involving the process operations and the types of control equipment employed, the recordkeeping and reporting requirements are the same for both small and large entities. The Agency considers these to be the minimum requirements needed to ensure compliance with a NESHAP such as this one and, therefore, cannot reduce them further for small entities. To the extent that larger businesses can use economies of scale to reduce their regulatory burden, the overall burden of the final rule will be reduced.

Table 3-5. Impacts for Affected Ultimate Parent Businesses

Ultimate Parent Business	Total Annualized Costs (2016$)	Annualized Cost to Sales (%)
Orbia	$300,000	0.0047
Basin Electric Power Cooperative	0	0
Anthony Timberlands, Inc. (ATI)	987,500	0.455
IHI Corp.	4,161,801	0.032
Coastal Forest Resources Company*	0	0
Hood Companies, Inc.	80,900	0.006
Resolute Forest Products	9,317,038	0.333
Canfor, Inc.	561,900	0.014
Packaging Corporation of America	1,968,678	0.030
Nine Dragons Paper	1,686,544	0.022
CMS Energy/Fortistar LLC	2,337,400	0.035
Louisiana Pacific Corp.	574,400	0.021
Hankins Lumber Company*	0	0
International Paper	4,385,004	0.021
Clayton Dubilier & Rice LLC/Illinois Tool Works	190,200	0.0038
Marsh Furniture Company	438,900	0.102
Pixelle Specialty Solutions	0	0
Domtar Corp.	702,400	0.092
Dominion Energy	0	0
WestRock	50,442	0.0003
Nippon Paper Industries Co., Ltd.	64,600	0.0007
Novolex/The Carlyle Group	0	0
Weyerhaeuser Company	40,400	0.0006
West Fraser Timber Co., Ltd.	41,600	0.0007
Idaho Forest Group LLC	41,600	0.056
UNC System/State of N.C.	69,100	0.0005
U.S. Sugar Corp.	8,924,400	1.375
Simpson Investment Company	2,976,910	0.828
Boise Cascade	124,900	0.0023
Rayonier Advanced Materials	4,424,466	0.260
Maynards Industries	1,683,000	7.650
Koch Industries, Inc.	0	0

*Small business according to current SBA size guidelines.

Regarding possible impacts to markets, it should be noted that available estimates of long-run responsiveness of price changes for output likely to be affected by this final rule show that the price elasticity of demand for output from two of the most impacted industries, wood products (NAICS 321) is -0.81,[23] and for paper products (NAICS 322) is -0.85. The price

[23] ICF International. U.S. LNG Exports: Impacts on Energy Markets and the Economy. May 15, 2013. Submitted to the American Petroleum Institute. Table 3-4. Estimate is prepared for NAICS 321. Available on the Internet at https://fossil.energy.gov/ng_regulation/sites/default/files/programs/gasregulation/authorizations/2013/orders/Ex_Parte07_03_13.pdf. Accessed July 25, 2019.

elasticity of supply for wood products is 3.0 to 5.0,[24] and 0.28 to 1.65 for paper products.[25] Assuming the affected industries are imperfectly competitive, based on this information, one can conclude that demand will respond relatively close to 1:1 to a change in output price, and that supply is fairly elastic (i.e., will respond more than 1:1) to a change in output price. The direct economic impact of this rule as measured by changes in price and output appears relatively minor based on the low annualized cost to sales estimates and these elasticities, and thus it is reasonable to infer that the price impacts on consumers from this final rule should also be relatively minor. In addition, any other economic impacts, such as changes in firm concentration within the affected industries, should be relatively minor.

Unfunded Mandates Reform Act (UMRA) Statement

Title II of the Unfunded Mandates Reform Act of 1995 (Public Law 104-4) (UMRA) establishes requirements for federal agencies to assess the effects of their regulatory actions on State, local, and Tribal governments and the private sector. Under section 202 of the UMRA, 2 U.S.C. 1532, EPA generally must prepare a written statement, including a cost-benefit analysis, for any proposed or final rule that includes any Federal mandate that may result in the expenditure by State, local, and Tribal governments, in the aggregate, or by the private sector, of $100 million or more in any one year. A Federal mandate is defined under section 421(6) of the UMRA, 2 U.S.C. 658(6), to be either a Federal intergovernmental mandate or a Federal private sector mandate, as defined by the UMRA. A Federal intergovernmental mandate, in turn, is defined to include a regulation that would impose an enforceable duty upon State, Local, or Tribal governments, UMRA section 421(5)(A)(i), 2 U.S.C. 658(5)(A)(i), except for, among other things, a duty that is a condition of Federal assistance, UMRA section 421(5)(A)(i)(I). A Federal private sector mandate includes a regulation that would impose an enforceable duty upon the private sector, with certain exceptions, UMRA section 421(7)(A), 2 U.S.C. 658(7)(A). This final action does contain an unfunded mandate of $100 million or more as described in UMRA, 2 U.S.C. 1531–1538, but this final rule will not significantly or uniquely affect small governments.

[24] U.S. International Trade Commission. Hardwood Plywood from China. Investigation Nos. 701-TA-565 and 731-TA-1341 (Final). Publication 4747. December 2017. Available on the Internet at https://www.usitc.gov/publications/701_731/pub4747.pdf.

[25] U.S. EPA. Economic Impact Analysis. Proposed Revisions to the National Emissions Standards for Hazardous Air Pollutants, Subpart MM for the Pulp and Paper Industry. October 2016. p. 4-8. Available on the Internet at https://www.epa.gov/sites/production/files/2016-12/documents/subpart_mm_eia_10_31_2016_final.pdf.

Thus, under this final rule, EPA is not obligated under Section 203 of the UMRA to prepare a small government agency plan. Note that EPA expects the final rule to potentially have an impact on only one government-owned entity – a public university in the UNC System, as mentioned earlier in Section 3.3. This analysis does not examine potential indirect economic impacts associated with the final rule, such as the potential effects of electricity or other energy price increases on government entities.

3.4 Employment Impacts

Regarding employment impacts, environmental regulation may affect groups of workers differently, as changes in abatement and other compliance activities cause labor and other resources to shift. Standard benefit-cost analyses have not typically included a separate analysis of regulation-induced employment impacts.[26] In this section we discuss qualitatively the potential employment impacts of this final rule.

An environmental regulation affecting these sectors is expected to have a variety of transitional employment impacts, which may include reduced employment at facilities, as well as increased employment for the manufacture, installation, and operation of pollution control equipment.[27] Labor costs and the amount of labor needed for operation of control devices, and installation and operation of monitoring equipment and recordkeeping procedures can be found in the control cost memorandum and related appendices and reports for this final rule as discussed earlier in this RIA chapter. As one example of these impacts, the annual labor costs for operation and maintenance of monitoring and recordkeeping procedures is $316,400 (2016$), based on an estimate of 518 labor hours per year needed for these compliance categories.[28] For this final rule, the EPA expects some potential for small changes in the amount of labor needed in different parts of the affected sectors.[29] These employment impacts, both negative and

[26] Labor costs associated with regulatory compliance activities are included as part of total costs in EPA's standard benefit-cost analyses. See Section 3.1 of this RIA for a discussion of operating, supervisory, and maintenance labor hours for the operation of control devices, other labor costs associated with operation and maintenance, and labor expenses required for monitoring, reporting, and record keeping.

[27] Schmalansee, R. and R. Stavins (2011). "A Guide to Economic and Policy Analysis for the Transport Rule." White Paper. Boston, MA. Exelon Corp.

[28] U.S. EPA. Information Collection Request Supporting Statement. NESHAP for Industrial, Commercial, and Institutional Boilers and Process Heaters: Amendments. ICR #2028.12. August 2021. Annual labor and cost estimates here are derived from those in the ICR.

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

positive, are likely to be small or *de minimus*, particularly when considering the relatively small economic impacts to affected sectors and firms as discussed earlier in Section 3.3 of this RIA.

3.5 Social Welfare Considerations

As stated in E.O. 12866, when a regulatory action is deemed “significant”, an estimate of the regulation’s social cost is compared to its social benefits to determine whether the benefits justify the costs. The value of a regulatory action is traditionally measured by the change in economic welfare that it generates. The regulation’s welfare impacts, or the social costs required to achieve environmental improvements, will extend to consumers and producers. Consumers experience welfare impacts due to changes in market prices and consumption levels associated with the rule. Producers experience welfare impacts resulting from changes in profits corresponding with the changes in production costs, output levels, and market prices. However, it is important to emphasize that these welfare impacts or social costs do not include benefits (or disbenefits) that occur outside markets directly impacted by this action, that is, the value of reduced or increased levels of air pollution with the regulation. These benefits are estimated separately, and those for this final action can be found in Chapter 4. The net monetized benefits of this final action account for both the social costs presented in this chapter and the social benefits (both monetized benefits from reduced $PM_{2.5}$ and SO_2 emissions and disbenefits from increased CO_2 emissions) presented in Chapter 4. Net benefits are presented in Chapter 5.

4 BENEFITS ANALYSIS

The final NESHAP amendments set emission limits on HAPs that are expected to reduce HAP emissions, including emissions of mercury (Hg), hydrochloric acid (HCl), hydrofluoric acid (HF), and other HAPs. The emission controls expected to be adopted to meet the HAP emission limits in the final NESHAP amendments are also expected to reduce emissions of non-HAP pollutants, such as particulate matter (including $PM_{2.5}$) and SO_2. In this chapter, we provide the benefits analysis for this final rule. Data, resource, and methodological limitations prevented the EPA from monetizing the human health benefits from reduced exposure to mercury, HCl, and other HAP whose emissions are reduced by this final rule. In addition, the potential benefits from reduced ecosystem effects and reduced visibility impairment from the reduction in $PM_{2.5}$ and SO_2 emissions are also not monetized here. The EPA provides a qualitative discussion of mercury, HCl, and other HAP benefits later in this chapter. This discussion can also be found in section 4.7 of the RIA for the promulgated Affordable Clean Energy (ACE) rule. Finally, we include an analysis of the climate disbenefits for this final rule.

In this chapter, we quantify the economic value of benefits of this final rule such as those associated with potential reduction in PM-attributable premature deaths and illnesses expected to occur as a result of implementing this rule. $PM_{2.5}$ and SO_2 emissions reductions occur as a result of implementing the HAP emission controls described earlier in the RIA.

We estimate the total annual monetized benefits of the final rule from $PM_{2.5}$ and SO_2 emissions reductions to be $123 million to $124 million at a 3 percent discount rate and $112 million to $113 million at a 7 percent discount rate in 2025, a snapshot year that is consistent with approximation of the impacts in 2025 (the year of full implementation).[30] All estimates are reported in 2016$ and reflect the benefits associated with reductions in both directly emitted $PM_{2.5}$ and SO_2. In addition, the climate disbenefits resulting from additional emissions of CO_2 are included in these monetized estimates. The disbenefits associated with CO_2 emissions in 2025, which are calculated using interim benefit per ton estimates as explained later in this RIA chapter, are estimated at $1.7 million at a 3 percent discount rate.

[30] Benefit per ton estimates are available in five-year intervals (2020, 2025, 2030, and 2035). With 2025 as the first year of full implementation or 3 years after the final rule's effective date (in 2022), we apply benefit per ton estimates for that year to best approximate the monetized benefits of the final rule from a snapshot perspective.

4.1 Approach to Estimating Human Health Benefits

This section summarizes the EPA's approach to estimating the incidence and economic value of the $PM_{2.5}$-related benefits estimated for this rule. The Regulatory Impact Analysis (RIA) Final Revised Cross-State Air Pollution Rule[31] and its corresponding Technical Support Document Estimating $PM_{2.5}$ -and Ozone – Attributable Health Benefits[32] (TSD) provide a full discussion of the EPA's approach for quantifying the incidence and value of estimated air pollution-related health impacts. In these documents, the reader can find the rationale for selecting the health endpoints quantified; the demographic, health and economic data applied in the environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE); modeling assumptions; and the EPA's techniques for quantifying uncertainty.

Implementing this rule will affect the distribution of $PM_{2.5}$ concentrations throughout the U.S.; this includes locations both meeting and exceeding the NAAQS for PM and ozone. This RIA estimates avoided $PM_{2.5}$-related health impacts that are distinct from those reported in the RIAs for the PM NAAQS.[33] The $PM_{2.5}$ NAAQS RIAs hypothesize, 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.

4.2 Estimating $PM_{2.5}$, Ozone, and HAP Related Health Impacts

We estimate the quantity and economic value of air pollution-related effects by estimating counts of air pollution-attributable cases of adverse health outcomes, assigning dollar values to these counts, and assuming that each outcome is independent of one another. We construct these estimates by adapting primary research—specifically, air pollution epidemiology studies and economic value studies—from similar contexts. This approach is sometimes referred

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[31] U.S. EPA. 2021. Regulatory Impact Analysis Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS. Available at https://www.epa.gov/sites/default/files/2021-03/documents/revised_csapr_update_ria_final.pdf.

[32] U.S. EPA. 2021. Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS Estimating PM2.5- and Ozone-Attributable Health Benefits. Available at https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd.pdf.

[33] U.S. EPA. 2012. Regulatory Impact Analysis for the Proposed Revisions to the National Ambient Air Quality Standards for Particulate Matter. Available at https://www3.epa.gov/ttn/ecas/docs/ria/naaqs-pm_ria_final_2012-12.pdf.

to as "benefits transfer." Below we describe the procedure we follow for: (1) selecting air pollution health endpoints to quantify; (2) calculating counts of air pollution effects using a health impact function; (3) specifying the health impact function with concentration-response parameters drawn from the epidemiological literature.

4.2.1 Selecting air pollution health endpoints to quantify

As a first step in quantifying $PM_{2.5}$-related human health impacts, the EPA consults the *Integrated Science Assessment for Particulate Matter* (PM ISA) [34] as summarized in the TSD for the Final Revised Cross State Air Pollution Rule Update.[35] This document synthesizes the toxicological, clinical, and epidemiological evidence to determine whether each pollutant is causally related to an array of adverse human health outcomes associated with either acute (i.e., hours or days-long) or chronic (i.e., years-long) exposure. For each outcome, the ISA reports this relationship to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship, or not likely to be a causal relationship.

The ISA for $PM_{2.5}$ found acute exposure to $PM_{2.5}$ to be causally related to cardiovascular effects and PM-attributable premature deaths, and respiratory effects as likely-to-be-causally related. The ISA identified cardiovascular effects and total PM-attributable premature deaths as being causally related to long-term exposure to $PM_{2.5}$ and respiratory effects as likely-to-be-causal; and the evidence was suggestive of a causal relationship for reproductive and developmental effects as well as cancer, mutagenicity, and genotoxicity.

The EPA estimates the incidence of air pollution effects for those health endpoints listed above where the ISA classified the impact as either causal or likely-to-be-causal. Table 4-1 reports the effects we quantified and those we did not quantify in this RIA. The list of benefit categories not quantified shown in that table is not exhaustive. And, among the effects we quantified, we might not have been able to completely quantify either all human health impacts or economic values. The table below omits health effects associated with SO_2 and NO_2, and any welfare effects such as acidification and nutrient enrichment. These effects are described in

[34]U.S. EPA. 2019. Integrated Science Assessment for Particulate Matter. EPA/600/R-08/139F.
[35] U.S. EPA. 2021. Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS Estimating PM2.5- and Ozone-Attributable Health Benefits. https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd.pdf.

Chapters 5 and 6 of the PM NAAQS RIA.[36] Table 4-1 includes health effects associated with HAP that were qualitatively evaluated: Hg, HCl, HF, and TSM.

4.2.2 Health Effects from exposure to HAP

4.2.2.1 Mercury

Mercury (Hg) in the environment is transformed into a more toxic form, methylmercury (MeHg). Because Hg is a persistent pollutant, MeHg accumulates in the food chain, especially the tissue of fish. When people consume these fish, they consume MeHg. In 2000, the NAS Study was issued which provides a thorough review of the effects of MeHg on human health.[37] Many of the peer-reviewed articles cited in this section are publications originally cited in the Mercury Study.[38] In addition, the EPA has conducted literature searches to obtain other related and more recent publications to complement the material summarized by the NRC in 2000.

In its review of the literature, the NAS found neurodevelopmental effects to be the most sensitive and best documented endpoints and appropriate for establishing a reference dose (RfD)[39]; in particular, NAS supported the use of results from neurobehavioral or neuropsychological tests. The NAS report noted that studies on animals reported sensory effects as well as effects on brain development and memory functions and supported the conclusions based on epidemiology studies. The NAS noted that their recommended endpoints for a RfD are associated with the ability of children to learn and to succeed in school. They concluded the following: "The population at highest risk is the children of women who consumed large amounts of fish and seafood during pregnancy. The committee concludes that the risk to that population is likely to be sufficient to result in an increase in the number of children who have to struggle to keep up in school."

The NAS summarized data on cardiovascular effects available up to 2000. Based on these and other studies, the NRC concluded that "Although the data base is not as extensive for

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[36] U.S. EPA. 2012. Regulatory Impact Assessment for the Particulate Matter National Ambient Air Quality Standards.
[37] National Research Council (NRC). 2000. *Toxicological Effects of Methylmercury*. Washington, DC: National Academies Press.
[38] U.S. Environmental Protection Agency (U.S. EPA). 1997. *Mercury Study Report to Congress*, EPA–HQ–OAR–2009–0234–3054. December. Available at http://www.epa.gov/hg/report.htm.
[39] National Research Council (NRC). 2000. *Toxicological Effects of Methylmercury*. Washington, DC: National Academies Press.

cardiovascular effects as it is for other end points (i.e., neurologic effects), the cardiovascular system appears to be a target for MeHg toxicity in humans and animals." The NRC also stated that "additional studies are needed to better characterize the effect of methylmercury exposure on blood pressure and cardiovascular function at various stages of life."

Additional cardiovascular studies have been published since 2000. The EPA did not develop a quantitative dose-response assessment for cardiovascular effects associated with MeHg exposures, as there is no consensus among scientists on the dose-response functions for these effects. In addition, there is inconsistency among available studies as to the association between MeHg exposure and various cardiovascular system effects. The pharmacokinetics of some of the exposure measures (such as toenail Hg levels) are not well understood. The studies have not yet received the review and scrutiny of the more well-established neurotoxicity data base.

The Mercury Study noted that MeHg is not a potent mutagen but is capable of causing chromosomal damage in a number of experimental systems. The NAS concluded that evidence that human exposure to MeHg caused genetic damage is inconclusive; they note that some earlier studies showing chromosomal damage in lymphocytes may not have controlled sufficiently for potential confounders. One study of adults living in the Tapajós River region in Brazil reported a direct relationship between MeHg concentration in hair and DNA damage in lymphocytes, as well as effects on chromosomes.[40] Long-term MeHg exposures in this population were believed to occur through consumption of fish, suggesting that genotoxic effects (largely chromosomal aberrations) may result from dietary and chronic MeHg exposures similar to and above those seen in the Faroes and Seychelles populations.

Although exposure to some forms of Hg can result in a decrease in immune activity or an autoimmune response[41], evidence for immunotoxic effects of MeHg is limited.[42] Based on limited human and animal data, MeHg is classified as a "possible" human carcinogen by the

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[40] Amorim, M.I.M., D. Mergler, M.O. Bahia, H. Dubeau, D. Miranda, J. Lebel, R.R. Burbano, and M. Lucotte. 2000. Cytogenetic damage related to low levels of methyl mercury contamination in the Brazilian Amazon. An. Acad. Bras. Ciênc. 72(4): 497-507.

[41] Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological Profile for Mercury. U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA.

[42] National Research Council (NRC). 2000. *Toxicological Effects of Methylmercury*. Washington, DC: National Academies Press.

International Agency for Research on Cancer[43] and in IRIS.[44] The existing evidence supporting the possibility of carcinogenic effects in humans from low-dose chronic exposures is tenuous. Multiple human epidemiological studies have found no significant association between Hg exposure and overall cancer incidence, although a few studies have shown an association between Hg exposure and specific types of cancer incidence (e.g., acute leukemia and liver cancer).[45]

There is also some evidence of reproductive and renal toxicity in humans from MeHg exposure. However, overall, human data regarding reproductive, renal, and hematological toxicity from MeHg are very limited and are based on either studies of the two high-dose poisoning episodes in Iraq and Japan or animal data, rather than epidemiological studies of chronic exposures at the levels of interest in this analysis.

4.2.2.2 Hydrogen Chloride

Hydrogen chloride (HCl) is a gas that forms corrosive hydrochloric acid when it comes into contact with water. It can cause irritation of the mucous membranes of the nose, throat, and respiratory tract. Brief exposure to 35 ppm causes throat irritation, and levels of 50 to 100 ppm are barely tolerable for 1 hour.[46] Concentrations in typical human exposure environments are much lower than these levels and rarely exceed the reference concentration.[47] The greatest impact is on the upper respiratory tract; exposure to high concentrations can rapidly lead to swelling and spasm of the throat and suffocation. Most seriously exposed persons have immediate onset of rapid breathing, blue coloring of the skin, and narrowing of the bronchioles. Exposure to HCl can lead to Reactive Airways Dysfunction Syndrome (RADS), a chemically, or

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[43] International Agency for Research on Cancer (IARC). 1994. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans and their Supplements: Beryllium, Cadmium, Mercury, and Exposures in the Glass Manufacturing Industry. Vol. 58. Jalili, H.A., and A.H. Abbasi. 1961. Poisoning by ethyl mercury toluene sulphonanilide. Br. J. Indust. Med. 18(Oct.):303-308 (as cited in NRC, 2000).

[44] U.S. Environmental Protection Agency (EPA). 2002. Integrated Risk Information System (IRIS) on Methylmercury. National Center for Environmental Assessment. Office of Research and Development. Available at https://iris.epa.gov/static/pdfs/0073_summary.pdf.

[45] National Research Council (NRC). 2000. *Toxicological Effects of Methylmercury*. Washington, DC: National Academies Press.

[46]Agency for Toxic Substances and Disease Registry (ATSDR). Medical Management Guidelines for Hydrogen Chloride. Atlanta, GA: U.S. Department of Health and Human Services. Available at https://www.atsdr.cdc.gov/MHMI/mmg173.pdf

[47]Table of Prioritized Chronic Dose-Response Values: https://www.epa.gov/system/files/documents/2021-09/chronicfinaloutput_9_29_2021-12-46-18-pm_0.pdf

irritant-induced type of asthma. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed. HCl has not been classified for carcinogenic effects.[48]

4.2.2.3 Hydrogen Fluoride

Hydrogen fluoride (HF) is a gas that forms corrosive hydrofluoric acid when it comes in contact with water. HF can cause eye irritation and irritation and congestion of the nose, throat, and lungs.[49] Exposure to 0.5 ppm for one hour causes upper respiratory tract irritation. Brief inhalation exposure to high concentrations of gaseous HF can cause severe respiratory damage in humans, including severe irritation and lung edema. Severe eye irritation and skin burns may occur following eye or skin exposure in humans. Chronic (long-term) exposure in workers has resulted in skeletal fluorosis, a bone disease. Animal studies have reported effects on the lungs, liver, and kidneys from acute and chronic inhalation exposure to HF. Studies investigating the carcinogenic potential of HF are inconclusive. The EPA has not classified HF for carcinogenicity.

4.2.2.4. Total non-mercury selected metals (TSM)

TSM include antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, nickel, and selenium. The acute health effects associated with inhalation of these metals are primarily respiratory system effects that include respiratory irritation, shortness of breath, coughing and wheezing, inflammation of the lungs, pneumonia, lung congestion, lung edema, and hemorrhage of the lung.[50] Other organs and organ systems affected by acute inhalation exposure to some TSM include skin, eyes, gastrointestinal system, and central nervous system. Chronic effects of inhalation exposure to TSM include respiratory system effects such as

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[48]U.S. Environmental Protection Agency (U.S. EPA). 1995. “Integrated Risk Information System File of Hydrogen Chloride.” Washington, DC: Research and Development, National Center for Environmental Assessment. This material is available at http://www.epa.gov/iris/subst/0396.htm.

[49]Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Fluorides, Hydrogen Fluoride and Fluorine. U.S. Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA. 2003. http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=212&tid=38

[50] The main sources of information for the TSM health effects information are EPA's Integrated Risk Information System (IRIS) the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profiles. Information on individual chemicals can be found at https://cfpub.epa.gov/ncea/iris_drafts/atoz.cfm?list_type=alpha and https://www.atsdr.cdc.gov/toxprofiledocs/index.html.

respiratory irritation, inflammation of the lungs, chronic bronchitis, chronic emphysema, wheezing, asthma, and lung fibrosis. Effects of chronic inhalation exposure on other organs or organ systems include irritation of the skin and mucous membranes, central nervous system effects, kidney disease, and effects on the liver and immune system. Some TSM are also known to be human carcinogens or reasonably anticipated to be human carcinogens. Lead is a TSM that is of particular concern due to its developmental toxicity. While ingestion is usually the primary route of exposure for children, the health effects are the same for both oral and inhalation routes of exposure. Early childhood and prenatal exposures to lead are associated with slowed cognitive development, learning deficits and other effects.

Table 4-1. Human Health Effects of Ambient $PM_{2.5}$ and HAP

Category	Effect	Effect Quantified	Effect Monetized	More Information
PM-attributable premature deaths from exposure to $PM_{2.5}$	Adult PM-attributable premature deaths from long-term exposure (age 65-99 or age 30-99)	✓	✓	PM ISA
	Infant PM-attributable premature deaths (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]

Morbidity from exposure to methyl mercury	Neurologic effects – IQ loss	—	—	IRIS; NRC, 2000[1]
	Other neurologic effects (e.g., developmental delays, memory, behavior	—	—	IRIS; NRC, 2000[2]
	Cardiovascular effects	—	—	IRIS; NRC, 2000[2,3]
	Genotoxic, immunologic, and other toxic effects	—	—	IRIS; NRC, 2000[2,3]
Morbidity from exposure to hydrogen chloride	Upper respiratory tract irritation	—	—	ATSDR
	Asthma	—	—	ATSDR
Morbidity from exposure to hydrogen fluoride	Eye irritation	—	—	ATSDR
	Upper respiratory tract irritation and inflammation	—	—	ATSDR
	Bone disease	—	—	ATSDR
	Damage to liver, kidney, or lungs	—	—	ATSDR
Morbidity from exposure to total non-mercury selected metals (TSM)	Respiratory system effects such as irritation, inflammation of the lungs, chronic bronchitis, and pneumonia	—	—	IRIS; ATSDR
	Cancer – lung, nasal, and potentially other sites	—	—	IRIS; ATSDR

[1] We assess these benefits qualitatively due to data and resource limitations for this analysis. In other analyses we quantified these effects as a sensitivity analysis.
[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.

4.3 Quantifying Cases of PM-Attributable Premature Deaths

This section summarizes our approach to estimating the incidence and economic value of the $PM_{2.5}$-related ancillary co-benefits estimated for this rule. A full discussion of EPA's approach to selecting human health endpoints, epidemiologic studies and economic unit values can be found in the Technical Support Document (TSD) supporting the final Cross-State Update rule.[51] The user manual for the environmental Benefits Mapping and Analysis Program-Community Edition (BenMAP-CE) program[52] separately details EPA's approach for quantifying and monetizing PM-attributable effects in the BenMAP-CE program. In these documents the reader can find the rationale for selecting health endpoints to quantify; the demographic, health and economic data we apply within BenMAP-CE; modeling assumptions; and our techniques for quantifying uncertainty.

[51] U.S. EPA, 2021. https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd_march_2021.pdf.

[52] U.S. EPA, April 2021. Environmental Benefits Mapping and Analysis Program-Community Edition (BenMAP-CE), User Manual. Available at https://www.epa.gov/sites/default/files/2015-04/documents/benmap-ce_user_manual_march_2015.pdf.

The PM ISA, which was reviewed by the Clean Air Scientific Advisory Committee of the EPA's Science Advisory Board (SAB-CASAC),[53,54] concluded that there is a causal relationship between PM-attributable premature deaths and both long-term and short-term exposure to $PM_{2.5}$ based on the 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-attributable premature deaths concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response function. The PM ISA identified epidemiologic 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 from recent studies reduce uncertainties related to potential co-pollutant confounding and continues to provide strong support for a linear, no-threshold concentration-response relationship." [55] Consistent with this evidence, the EPA historically has estimated health impacts above and below the prevailing NAAQS.[56]

Following this approach, we report the estimated $PM_{2.5}$-related benefits (in terms of both health impacts and monetized values) calculated using a log-linear concentration-response function that quantifies risk from the full range of simulated $PM_{2.5}$ exposures.[57] As noted in the preamble to the 2020 PM NAAQS final rule, the "health effects can occur over the entire distributions of ambient PM2.5 concentrations evaluated, and epidemiological studies do not identify a population-level threshold below which it can be concluded with confidence that PM-

[53] https://casac.epa.gov/ords/sab/apex_util.get_blob?s=5172167726459&a=105&c=7666586094252581&p=12&k1=1073&k2=&ck=EEWpmVTwoNtrPO767tm9112jjvw1rE-d_DUvOMwG8WWNSri2KZdAY1oWeigjqkrRE9-oxt6JyxN4y5jhQgogFg&rt=IR
[54] https://casac.epa.gov/ords/sab/apex_util.get_blob?s=5172167726459&a=105&c=7666586094252581&p=12&k1=1073&k2=&ck=EEWpmVTwoNtrPO767tm9112jjvw1rE-d_DUvOMwG8WWNSri2KZdAY1oWeigjqkrRE9-oxt6JyxN4y5jhQgogFg&rt=IR
[55] U.S. EPA. 2019. Integrated Science Assessment for Particulate Matter. EPA/600/R-08/139F.
[56] The Federal Register Notice for the 2012 PM NAAQS notes that "[i]n reaching her final decision on the appropriate annual standard level to set, the Administrator is mindful that the CAA does not require that primary standards be set at a zero-risk level, but rather at a level that reduces risk sufficiently so as to protect public health, including the health of at-risk populations, with an adequate margin of safety. On balance, the Administrator concludes that an annual standard level of 12 ug/m3 would be requisite to protect the public health with an adequate margin of safety from effects associated with long- and short-term PM2.5 exposures, while still recognizing that uncertainties remain in the scientific information."
[57] U.S. EPA. 2021. Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS Estimating PM2.5- and Ozone-Attributable Health Benefits. https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd.pdf.

associated health effects do not occur."[58] In general, we are more confident in the size of the risks we estimate from simulated $PM_{2.5}$ concentrations that coincide with the bulk of the observed PM concentrations in the epidemiological studies that are used to estimate the benefits. Likewise, we are less confident in the risk we estimate from simulated $PM_{2.5}$ concentrations that fall below the bulk of the observed data in these studies.[59] The photochemical modeled emissions of the industrial boiler sector-attributable $PM_{2.5}$ concentrations used to derive the BPT values may not match perfectly the change in air quality resulting from the emissions controls described in Section 3. For this reason, the estimated health benefits reported here may be larger, or smaller, than those realized through this rule. However, when choosing to use a BPT for this analysis, the spatial distribution of emissions for this particular sector matches well the inventory used to derive the industrial boiler BPT. We report the estimated number of PM-attributable premature deaths occurring at or above various concentration levels and thus report the total number of avoided PM-attributable premature deaths using the traditional log-linear no-threshold model noted above.

4.4 Economic Valuation

After quantifying the change in adverse health impacts, we estimate the economic value of these avoided impacts. Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects by a small amount for a large population. Therefore, the appropriate economic measure is willingness to pay (WTP) for changes in risk of a health effect. For some health effects, such as hospital admissions, WTP estimates are generally not available, so we use the cost of treating or mitigating the effect. These cost-of-illness (COI) estimates generally (although not necessarily 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

[58] https://www.govinfo.gov/content/pkg/FR-2020-12-18/pdf/2020-27125.pdf

[59] U.S. EPA. 2021. Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS Estimating PM2.5- and Ozone-Attributable Health Benefits. https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd.pdf.

value of avoided pain and suffering from the health effect. The unit values applied in this analysis are provided in Section 5.1 of the TSD for the Revised Cross State Update rule.[60]

Avoided PM-attributable premature deaths account for 98 percent of monetized PM-related benefits. The economics literature concerning the appropriate method for valuing reductions in PM-attributable premature deaths risk is still developing. The value for the projected reduction in the risk of PM-attributable premature deaths is the subject of continuing discussion within the economics and public policy analysis community. Following the advice of the SAB's Environmental Economics Advisory Committee (SAB-EEAC), the EPA currently uses the value of statistical life (VSL) approach in calculating estimates of PM-attributable premature deaths benefits, because we believe this calculation provides the most reasonable single estimate of an individual's WTP for reductions in PM-attributable premature deaths risk.[61] The VSL approach is a summary measure for the value of small changes in PM-attributable premature deaths risk experienced by a large number of people.

The EPA continues work to update its guidance on valuing PM-attributable premature deaths risk reductions and consulted several times with the SAB-EEAC on the issue. Until updated guidance is available, the EPA determined that a single, peer-reviewed estimate applied consistently best reflects the SAB-EEAC advice it has received. Therefore, the EPA applies the VSL that was vetted and endorsed by the SAB in the *Guidelines for Preparing Economic Analyses* while the EPA continues its efforts to update its guidance on this issue.[62] This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $6.3 million (2000$).[63]

The EPA is committed to using scientifically sound, appropriately reviewed evidence in valuing changes in the risk of PM-attributable premature deaths and continues to engage with the SAB to identify scientifically sound approaches to update its PM-attributable premature deaths

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[60] U.S. EPA. 2021. Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS Estimating PM2.5- and Ozone-Attributable Health Benefits. https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd.pdf.

[61] U.S. EPA-SAB. 2000. An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction.

[62] U.S. EPA. Guidelines for Preparing Economic Analyses. 2016.

[63] In 1990$, this base VSL is $4.8 million. In 2016$, this base VSL is $10.7 million.

risk valuation estimates. Most recently, the Agency proposed new meta-analytic approaches for updating its estimates which were subsequently reviewed by the SAB-EEAC. The EPA is taking the SAB's formal recommendations under advisement.[64]

4.5 Benefit-per-Ton Estimates

EPA did not conduct air quality modeling for this final rule. Specifically, EPA believes that the emissions reductions due to this rule are small and EPA did not expect full air quality modeling to show a significant difference between the policy and baseline model runs. Instead, we used a "benefit-per-ton" (BPT) approach to estimate the benefits of this rulemaking. These BPT estimates provide the total monetized human health benefits (the sum of PM-attributable premature deaths and premature morbidity) of reducing one ton of $PM_{2.5}$ (or $PM_{2.5}$ precursor such as NOx or SO_2) from a specified source. Specifically, in this analysis, we multiplied the estimates from the "Industrial Boiler" sector by the corresponding emission reductions. The method used to derive these estimates is described in the BPT Technical Support Document (BPT TSD) on Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5,}$ $PM_{2.5}$ Precursors and Ozone Precursors from 21 Sectors and its precursors from 21 sectors.[65] One limitation of using the BPT approach is an inability to provide estimates of the health benefits associated with exposure to HAP, CO, and NO_2.

As noted below in the characterization of uncertainty, all BPT estimates have inherent limitations. Specifically, all national-average BPT estimates reflect the geographic distribution of the modeled emissions, which may not exactly match the emission reductions that would occur due to rulemaking, and they may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors for any specific location. The photochemical modeled emissions of the industrial point source sector-attributable $PM_{2.5}$ concentrations used to derive the BPT values may not match the change in air quality resulting from the emissions controls described in Section 3. For this reason, the health benefits reported here may be larger, or smaller, than those realized through this rule. However, when choosing to utilize the EPA's BPT approach for this analysis, the spatial distribution of emissions for this

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[64] U.S. EPA. SAB Review of EPA's Proposed Methodology for Updating PM-attributable premature deaths Risk Valuation Estimates for Policy Analysis. 2017.

[65] U.S. EPA. 2021. Estimating the Benefit per Ton of Reducing PM2.5 Precursors from 21 Sectors. Technical Support Document. Available at: https://www.epa.gov/benmap/reduced-form-tools-calculating-pm25-benefits

particular sector is similar to that of the inventory used to derive the BPT. EPA confirmed that the spatial distribution of the industrial boiler facility locations was not unusually concentrated in one particular region of the country and tend to be located in areas with industrial point sources.

The new BPT estimates developed for the Industrial Boiler sector in 2021 developed state-level estimates that addressed some of the limitations of the national analysis. Given the use of state level, sector specific air quality modeling and the small changes in emissions considered in this rulemaking, the difference in the quantified health benefits that result from the BPT approach compared with if EPA had used a full-form air quality model should be minimal.

Even though we assume that all fine particles have equivalent health effects, the BPT estimates vary across precursors depending on the location and magnitude of their impact on $PM_{2.5}$ levels, which drive population exposure. The sector-specific modeling does not provide estimates of the $PM_{2.5}$-related benefits associated with reducing VOC emissions, but these unquantified benefits are generally small compared to other $PM_{2.5}$ precursors.[66]

Over the last year and a half, the EPA systematically compared the changes in benefits, and concentrations where available, from its BPT technique and other reduced-form techniques to the changes in benefits and concentrations derived from full-form photochemical model representation of a few different specific emissions scenarios. Reduced form tools are less complex than the full air quality modeling, requiring less agency resources and time. That work, in which we also explore other reduced form models is referred to as the "Reduced Form Tool Evaluation Project" (Project), began in 2017, and the initial results were available at the end of 2018. The Agency's goal was to create a methodology by which investigators could better understand the suitability of alternative reduced-form air quality modeling techniques for estimating the health impacts of criteria pollutant emissions changes in the EPA's benefit-cost analysis, including the extent to which reduced form models may over- or under-estimate benefits (compared to full-scale modeling) under different scenarios and air quality concentrations. The EPA Science Advisory Board (SAB) recently convened a panel to review this report.[67] In particular, the SAB will assess the techniques the Agency used to appraise these

[66] U.S. EPA. 2012. Regulatory Impact Analysis for the Proposed Revisions to the National Ambient Air Quality Standards for Particulate Matter.
[67] 85 FR 23823. April 29, 2020.

tools; the Agency's approach for depicting the results of reduced-form tools; and steps the Agency might take for improving the reliability of reduced-form techniques for use in future Regulatory Impact Analyses (RIAs).

The scenario-specific emission inputs developed for this project are currently available online. The study design and methodology are described in the final report summarizing the results of the project, available here.[68] Results of this project found that total $PM_{2.5}$ BPT values were within approximately 10 percent of the health benefits calculated from full-form air quality modeling when analyzing the Pulp and Paper sector as an example in the study. The ratios for individual species varied, and the report found that the ratio for the directly emitted $PM_{2.5}$ for the pulp and paper sector was 0.7 for the BPT approach compared to 1.0 for full air quality modeling combined with BenMAP. As the Pulp and Paper sector and the Industrial Boilers sector share a similar spatial distribution, we have greater confidence that this ratio reflected in the pulp and paper sector would also apply to the Industrial Boiler sector. This provides some initial understanding of the uncertainty which is associated with using the BPT approach instead of full air quality modeling.

4.6 $PM_{2.5}$ and SO_2 Benefits Results

Table 4-2 lists the estimated $PM_{2.5}$-related benefits per ton applied in this benefits analysis at the state-level. Table 4-3 presents the estimated $PM_{2.5}$ benefits from emission reductions for affected existing units. Table 4-4 presents the estimated $PM_{2.5}$ benefits from emission reductions for affected new units. Tables 4-5 and 4-6 shows the estimated SO_2-related benefits per ton applied in this analysis at the state-level for affected existing and new units, respectively. Finally, Table 4-7 presents the total health related benefits of reducing emissions of $PM_{2.5}$ and SO_2. For each table, we summarize the monetized $PM_{2.5}$ and/or the SO_2-related health benefits, including the BPT estimates using discount rates of 3 percent and 7 percent.

[68] Industrial Economics Inc. (IEc), for U.S. EPA/OAQPS. October 31, 2019. Evaluating Reduced-Form Tools for Estimating Air Quality Benefits. Final Report.

Table 4-2. Estimated $PM_{2.5}$ -related Benefits per Ton of the Final NESHAP Amendments (2016$)

State	*Benefit per ton Low (3% discount rate)*	*Benefit per ton Low (7% discount rate)*	*Benefit per ton High (3% discount rate)*	*Benefit per ton High (7% discount rate)*
CA	$503,000	$452,000	$510,000	$459,000
FL	$140,000	$126,000	$141,000	$127,000
GA	$151,000	$136,000	$156,000	$141,000
LA	$117,000	$105,000	$123,000	$110,000
ME	$48,200	$43,400	$50,500	$45,500
MI	$259,000	$233,000	$262,000	$236,000
NC	$171,000	$154,000	$173,000	$156,000
OK	$103,000	$92,600	$106,000	$95,8000
TN	$227,000	$204,000	$235,000	$212,000
WI	$148,000	$133,000	$156,000	$140,000

Table 4-3. Estimated $PM_{2.5}$-related Benefits for Existing Units (millions 2016$)

State	*Benefit per ton Low (3% discount rate)*	*Benefit per ton Low (7% discount rate)*	*Benefit per ton High (3% discount rate)*	*Benefit per ton High (7% discount rate)*
CA	$13	$12	$14	$12
FL	$2.4	$2.2	$2.4	$2.2
GA	$1.5	$1.3	$1.5	$1.4
LA	$3.2	$2.8	$3.3	$3.0
ME	$.0.26	$0.23	$0.27	$0.24
MI	$1.1	$1.0	$1.1	$1.0
NC	$0.27	$0.24	$0.27	$0.25
OK	$26	$24	$27	$25
TN	$9.1	$8.0	$9.3	$8.4
WI	$7.5	$6.8	$5.8	$7.0

Table 4-4. Estimated $PM_{2.5}$-related Benefits for New Units (millions 2016$)

State	*Benefit per ton Low (3% discount rate)*	*Benefit per ton Low (7% discount rate)*	*Benefit per ton High (3% discount rate)*	*Benefit per ton High (7% discount rate)*
CA	$3.2	$2.9	$3.3	$1.6

Table 4-5. Estimated SO_2-related Benefits per Ton of the Final NESHAP Amendments (2016$)

State	*Benefit per ton Low (3% discount rate)*	*Benefit per ton Low (7% discount rate)*	*Benefit per ton High (3% discount rate)*	*Benefit per ton High (7% discount rate)*
AL	$50,600	$45,500	$52,100	$46,900
AR	$42,300	$38,100	$43,000	$38,700
FL	$45,600	$41,000	$46,400	$41,800
IL	$54,800	$49,300	$55,300	$51,300
MI	$56,000	$50,300	$57,000	$49,800
NC	$45,300	$40,700	$45,600	$41,000
TX	$14,900	$13,400	$15,100	$13,600
VA	$53,400	$48,100	$54,100	$48,700
WA	$20,300	$18,300	$20,800	$18,700

Table 4-6. Estimated SO_2-related Benefits for Existing Units (millions 2016$)

State	*Benefit per ton Low (3% discount rate)*	*Benefit per ton Low (7% discount rate)*	*Benefit per ton High (3% discount rate)*	*Benefit per ton High (7% discount rate)*
AR	$<0.01	$<0.01	$<0.01	$<0.01
IL	$17	$15	$17	$16
MI	$2.3	$2.0	$2.3	$2.0
NC	$8.0	$7.3	$8.1	$7.3
TX	$0.01	$0.01	$0.01	$0.01
VA	$1.6	$1.5	$1.7	$1.5
WA	$0.03	$0.03	$0.03	$0.03

Table 4-7. Estimated SO_2-related Benefits for New Units (millions 2016$)

State	*Benefit per ton Low (3% discount rate)*	*Benefit per ton Low (7% discount rate)*	*Benefit per ton High (3% discount rate)*	*Benefit per ton High (7% discount rate)*
AL	$1.3	$1.2	$1.4	$1.2
FL	$25	$23	$26	$23
NC	$0.03	$0.02	$0.03	$0.02
WA	$<0.01	$<0.01	$<0.01	$<0.01

Table 4-8. Summary of Estimated $PM_{2.5}$ and SO_2-related Benefits and Total Monetized Health Benefits of the Final NESHAP Amendments (millions of 2016$)

Pollutant	*Benefits Low (3% discount rate)*	*Benefits Low (7% discount rate)*	*Benefits High (3% discount rate)*	*Benefits High (7% discount rate)*
$PM_{2.5}$	$68	$62	$68	$62
SO_2	$55	$50	$56	$51
Total	**$123**	**$112**	**$124**	**$113**

*Columns may not sum due to rounding.

Characterizing Uncertainty in the Estimated $PM_{2.5}$ Benefits

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

This RIA does not include the type of detailed uncertainty assessment found in the 2021 Revised Cross State Update RIA because we lack the necessary air quality input and monitoring data. Criteria pollutant emissions changes were relatively small on a percentage basis, which made air quality modeling impractical. However, the results of the uncertainty analyses presented in the 2021 Revised Cross State Update RIA can provide some information regarding the uncertainty inherent in the benefits results presented in this analysis. Sensitivity analyses conducted for the 2012 PM NAAQS RIA indicate that alternate cessation lag assumptions could change the PM-attributable premature deaths benefits discounted at 3 percent by between 10 percent and −27 percent and that alternate income growth adjustments could change the PM-attributable premature deaths benefits by between 33 percent and −14 percent.

4.7 Climate Impacts

With the additional operation of control devices associated with the final rule, CO_2 emissions will be generated as a result of the additional electricity required to operate them. The estimate of additional CO_2 emissions is presented in Chapter 3. We monetize the social disbenefits associated with these additional CO_2 emissions using an interim measure of the social cost of carbon (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 positive and negative), including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-CO_2, therefore, reflects the societal value of reducing CO_2 emissions by one metric ton. The SC-CO_2 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-GHG estimates to include all of 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.

We estimate the social disbenefits of CO_2 emission increases expected from this final rule using the SC-CO_2 estimates presented in the *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990* (IWG 2021) (hereafter, “February 2021 TSD”). 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 value of CO_2 emission changes expected from this final rule. These SC-CO_2 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, EPA finds that these estimates, while likely an underestimate, are the best currently available SC-CO_2 estimates.

EPA and other federal agencies began regularly incorporating SC-CO_2 estimates in benefit-cost analyses conducted under Executive Order (E.O.) 12866[69] in 2008, following a court ruling in which an agency was ordered to consider the value of reducing CO2 emissions in a rulemaking process. The SC-CO_2 estimates presented here were developed over many years, using 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.[70] 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. In 2015, as part of the response to public comments received

[69] Under E.O. 12866, agencies are required, to the extent permitted by law and where applicable, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs."

[70] 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).

to a 2013 solicitation for comments on the $SC\text{-}CO_2$ estimates, the IWG announced a National Academies of Sciences, Engineering, and Medicine review of the $SC\text{-}CO_2$ 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,* and recommended specific criteria for future updates to the $SC\text{-}CO_2$ 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.[71] Shortly thereafter, in March 2017, President Trump issued Executive Order 13783, which disbanded the IWG, withdrew the previous TSDs, and directed agencies to ensure $SC\text{-}CO_2$ 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, including the benefit-cost analysis in the proposal ICI Boilers RIA[72], used $SC\text{-}CO_2$ estimates that attempted to focus on the U.S.-specific share of climate change damages as estimated by the models and were calculated using two default discount rates recommended by Circular A-4, 3 percent and 7 percent. All other methodological 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 Executive Order 13990, which re-established the IWG and directed it to develop updated estimates of the social cost of carbon, methane, and nitrous oxide (collectively referred to as social cost of greenhouse gases (SC-GHG)) that reflect the best available science and the recommendations of the National Academies (2017). The IWG was tasked with first reviewing the SC-GHG estimates currently used in Federal analyses and publishing interim estimates within 30 days of the E.O. that reflect the full impact of GHG emissions, including by taking global damages into account. As noted

[71] National Academies of Sciences, Engineering, and Medicine (National Academies). 2017. Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide. Washington, D.C.: National Academies Press.
[72] The values used in the proposal RIA were interim values developed under E.O. 13783 for use in regulatory analyses. EPA followed E.O. 13783 by using SC-CO2 estimates reflecting an approximation of some of the U.S.-specific climate damages from GHG emissions and 3% and 7% discount rates in our central analysis for the proposal RIA.

above, EPA participated in the IWG but has also independently evaluated the interim SC-CO_2 estimates published in the February 2021 TSD and determined they are appropriate to use here to estimate the climate disbenefits for this final rule. EPA and other agencies intend to undertake a fuller update of the SC-GHG estimates that takes into consideration the advice of the National Academies and other recent scientific literature.

The EPA has also evaluated the content of the February 2021 TSD, including the studies and methodological issues discussed therein and concludes that it agrees with the rationale for these estimates presented in the TSD and summarized below.

In particular, the IWG found that the SC-GHG 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, U.S. military assets and interests abroad, 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 social cost of greenhouse gases.

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.

Therefore, in this final rule EPA centers attention on a global measure of SC-GHG. This approach is the same as that taken in EPA regulatory analyses over 2009 through 2016. A robust estimate of climate damages to U.S. citizens and residents does not currently exist in the literature. 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. 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-GHG. Consistent with the findings of the National Academies 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 2010, 2013, 2016a, 2016b), and recommended that discount rate uncertainty and relevant aspects of intergenerational ethical considerations be accounted for in selecting future discount rates.[73] 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. EPA agrees with this assessment and will continue to follow developments in the literature pertaining to this issue. EPA also notes that while OMB Circular A-4, as published in 2003, recommends using 3% and 7% 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

[73] Interagency Working Group on Social Cost of Carbon (IWG). 2010. Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. February. United States Government. Interagency Working Group on Social Cost of Carbon (IWG). 2013. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. May. United States Government. Interagency Working Group on Social Cost of Greenhouse Gases (IWG). 2016a. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. August. United States Government. Interagency Working Group on the Social Cost of Greenhouse Gases. 2016b. Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide. August. United Stated Government. Available at: https://www.epa.gov/sites/production/files/2016-12/documents/addendum_to_sc-ghg_tsd_august_2016.pdf (accessed February 5, 2021).

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, EPA concludes that a 7% discount rate is not appropriate to apply to value the social cost of greenhouse gases in this regulatory analysis. In this analysis, to calculate the present and annualized values of climate disbenefits, 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 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 rates." The National Academies reviewed "several options," including "presenting all discount rate combinations of other costs and benefits with [SC-GHG] estimates." Later in this RIA chapter, EPA presents all combinations of the SC-GHG values at the different discount rates appropriate to climate effects (2.5%, 3%, and 5%) together with other benefits discounted at the 3% and 7% rates, consistent with the options outlined by the National Academies.

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 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 benefit-cost 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 TSD, this update reflects the immediate need to have an operational SC-GHG for use in regulatory benefit-cost analyses and other applications 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 4-9 summarizes the interim SC-CO_2 estimates for the years 2020 to 2030, the bounding years of which are close to the analysis timeframe for this final rule (2022-2029). These estimates are reported in 2016$ but are otherwise identical to those presented in the IWG's 2016 TSD (IWG 2016a). For purposes of capturing uncertainty around the SC-CO_2 estimates in analyses, the IWG's February 2021 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 4-9. Interim Social Cost of Carbon Values, 2020-2030 (2016$/Metric Tonne CO_2)

Emissions Year	Discount Rate and Statistic			
	5% Average	**3% Average**	**2.5% Average**	**3% 95th Percentile**
2020	$13	$47	$71	$140
2025	$15	$52	$77	$160
2030	$18	$57	$83	$170

Note: These SC-CO_2 values are identical to those reported in the 2016 TSD (IWG 2016a, cited in footnote 43 above) adjusted for inflation to 2016$ using the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9 found at https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=3&isuri=1&1921=survey&1903=13#reqid=19&step=3&isuri=1&1921=survey&1903=13, revised October 28, 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: <https://www.whitehouse.gov/briefing-room/blog/2021/02/26/a-return-to-science-evidence-based-estimates-of-the-benefits-of-reducing-climate-pollution/>

There are a number of limitations and uncertainties associated with the SC-CO_2 estimates presented in Table 4-9. 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 4-1 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 February 2021 TSD, there are other sources of uncertainty that have not yet been quantified and are thus not reflected in these estimates.

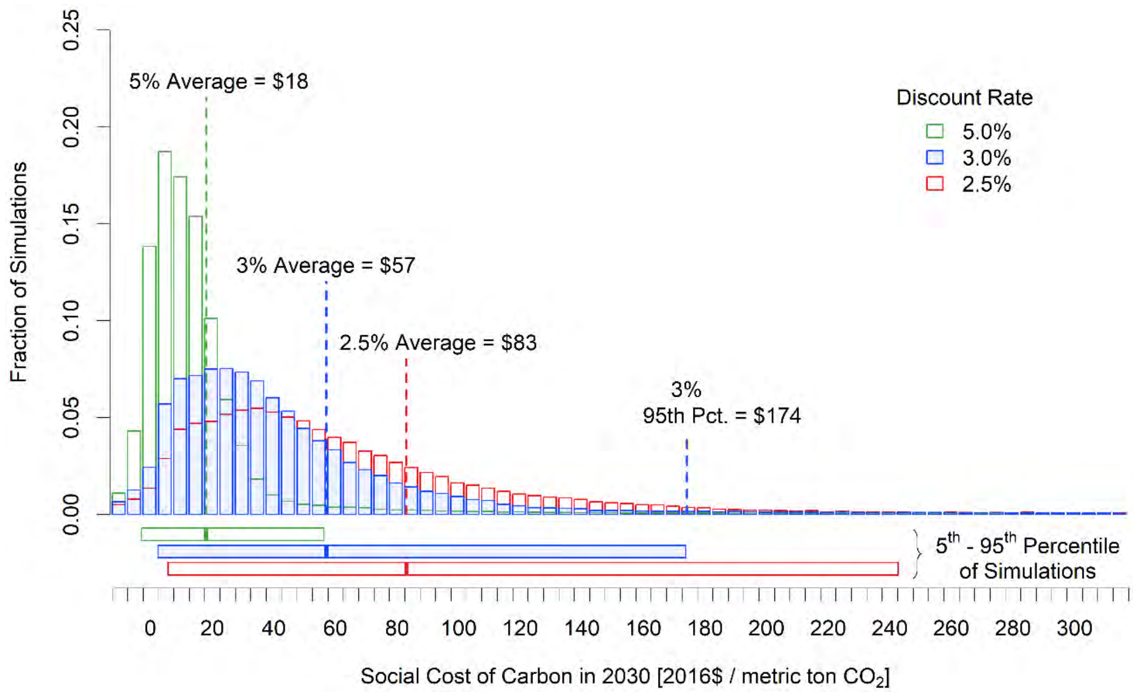

Figure 4-1. Frequency Distribution of SC-CO_2 Estimates for 2030[74]

In addition, the interim SC-CO_2 estimates presented in Table 4-8 have a number of other 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.[75] 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

[74] Although the distributions and numbers in Figure 4-1 are based on the full set of model results (150,000 estimates for each discount rate), for display purposes the horizontal axis is truncated with 0.78 percent of the estimates falling below the lowest bin displayed and 3.64 percent of the estimates falling above the highest bin displayed.
[75] Interagency Working Group on Social Cost of Greenhouse Gases (IWG). 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. February. United States Government. Available at: <https://www.whitehouse.gov/briefing-room/blog/2021/02/26/a-return-to-science-evidence-based-estimates-of-the-benefits-of-reducing-climate-pollution/.

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 TSD, the IWG has recommended that, taken together, the limitations suggest that the interim SC-CO_2 estimates used in this final rule likely underestimate the damages from CO_2 emissions. EPA concurs with this assessment. 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 (IPCC 2014) and other recent scientific assessments.[76] 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

[76] Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

of those processes at the time.[77,78,79,80,81,82,83,84] 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.[85] The February 2021 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-CO_2 estimates. The IWG, of which EPA is a member, 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, and public comments received on the February 2021 TSD.

Table 4-10 shows the estimated climate disbenefits from changes in CO_2 emissions expected to occur for the final rule. For 2022-2024, no changes in CO_2 emissions occur since the control technologies included in the cost analysis mentioned in Chapter 3 of the RIA are not

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[77] IPCC, 2007. Fourth Assessment Report. https://www.ipcc.ch/assessment-report/ar4/.

[78] Intergovernmental Panel on Climate Change (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.)].

[79] Intergovernmental Panel on Climate Change (IPCC). 2019a. Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)].

[80] Intergovernmental Panel on Climate Change (IPCC). 2019b. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)].

[81] U.S. Global Change Research Program (USGCRP). 2016. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Crimmins, A., J. Balbus, J.L. Gamble, C.B. Beard, J.E. Bell, D. Dodgen, R.J. Eisen, N. Fann, M.D. Hawkins, S.C. Herring, L. Jantarasami, D.M. Mills, S. Saha, M.C. Sarofim, J. Trtanj, and L. Ziska, Eds. U.S. Global Change Research Program, Washington, DC, 312 pp. https://dx.dio.org/10.7930/J0R49NQX.

[82] U.S. Global Change Research Program (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.

[83] National Academies of Sciences, Engineering, and Medicine (National Academies). 2016b. Attribution of Extreme Weather Events in the Context of Climate Change. Washington, DC: The National Academies Press. https://dio.org/10.17226/21852.

[84] National Academies of Sciences, Engineering, and Medicine (National Academies). 2019. Climate Change and Ecosystems. Washington, DC: The National Academies Press. https://doi.org/10.17226/25504.

[85] USGCRP. 2018. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, 4th National.; doi:http://dx.doi.org/10.7930/J0R49NQX.

expected to begin operation until 3 years after the effective date of the final rule, or 2025. Hence, there are no climate disbenefits for these 3 years. In 2025, EPA estimated the dollar value of the CO_2-related effects by applying the SC-CO_2 estimates, shown in Table 4-9, to the estimated changes in CO_2 emissions in the corresponding year under the final rule.[86] EPA calculated the present value and annualized value from the perspective of 2020 by discounting each year-specific value to the year 2020 using the same discount rate used to calculate the SC-CO_2.[87]

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[86] CO_2 emissions increases above the baseline as a result of the modeled policy are first expected in 2025, as control technologies applied in response to the final rule first begin operation in that year, and those emissions increase remain at that level afterwards, according to the cost analysis for this rule.

[87] According to OMB's Circular A-4 (2003), an "analysis should focus on benefits and costs that accrue to citizens and residents of the United States", and international effects should be reported separately. Circular A-4 also reminds analysts that "[d]ifferent regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues." To correctly assess the total climate damages to U.S. citizens and residents, an analysis must account for all the ways climate impacts affect the welfare of U.S. citizens and residents, how U.S. GHG mitigation activities affect mitigation activities by other countries, and spillover effects from climate action elsewhere. The SC-GHG estimates used in regulatory analysis under revoked E.O. 13783 were an approximation of some of the U.S.-specific climate damages from GHG emissions (e.g., \$7/mtCO_2 (2016\$) using a 3% discount rate for emissions occurring in 2025). Applying the same estimate (based on a 3% discount rate) to the CO_2 emission reduction expected under the finalized option in this final rule would yield disbenefits from climate impacts of \$0.2 million (2016\$) in 2025. However, as discussed at length in the February 2021 TSD, these estimates are an underestimate of the damages of CO_2 emissions accruing to U.S. citizens and residents, as well as being subject to a considerable degree of uncertainty due to the manner in which they are derived. In particular, the estimates developed under revoked E.O. 13783 did not capture significant regional interactions, spillovers, and other effects and so are incomplete underestimates. As the U.S. Government Accountability Office (GAO) concluded in a June 2020 report examining the SC-GHG estimates developed under E.O. 13783, the models "were not premised or calibrated to provide estimates of the social cost of carbon based on domestic damages" (U.S. GAO 2020, p. 29). Further, the report noted that the National Academies found that country-specific social costs of carbon estimates were "limited by existing methodologies, which focus primarily on global estimates and do not model all relevant interactions among regions" (U.S. GAO 2020, p. 26). It is also important to note that the SC-GHG estimates developed under E.O. 13783 were never peer reviewed, and when their use in a specific regulatory action was challenged, the U.S. District Court for the Northern District of California determined that use of those values had been "soundly rejected by economists as improper and unsupported by science," and that the values themselves omitted key damages to U.S. citizens and residents including to supply chains, U.S. assets and companies, and geopolitical security. The Court found that by omitting such impacts, those estimates "fail[ed] to consider…important aspect[s] of the problem" and departed from the "best science available" as reflected in the global estimates. *California v. Bernhardt*, 472 F. Supp. 3d 573, 613-14 (N.D.Cal. 2020). EPA continues to center attention in this regulatory analysis on the global measures of the SC-GHG as the appropriate estimates and as necessary for all countries to use to achieve an efficient allocation of resources for emissions reduction on a global basis, and so benefit the U.S. and its citizens.

Table 4-10. Estimated Climate Disbenefits from Changes in CO_2 Emissions for 2025 (Millions of 2016$)[a]

		Discount Rate and Statistic			
Final Rule	Year	5% Average	3% Average	2.5% Average	3% 95th Percentile
	2025	0.5	1.7	2.5	5.2

[a] Climate disbenefits are based on changes (increases) in CO_2 emissions and are calculated using four different estimates of the social cost of carbon (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 disbenefits 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 Executive Order 13990 (IWG 2021), a consideration of climate disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, are also warranted when discounting intergenerational impacts.

The climate disbenefits associated with the additional 32,910 short tons (or 29,855 metric tons) of CO_2 emissions generated as a result of the requirements of this final rule are therefore $1.7 million at a 3 percent discount rate, and range from $0.5 million at a 2.5 percent discount rate to $5.2 million at a 3 percent discount rate (95th percentile), all in 2016$.[88] These disbenefits are estimated for 2025, the year of full implementation of this final rule (3 years after the effective date) using the interim social cost of carbon (SC-CO_2) for 2025 as shown in Table 4-9 to be consistent with the year for the $PM_{2.5}$ and SO_2 BPTs applied to generate those monetized benefits presented earlier in this RIA chapter. The climate disbenefits offset less than 6 percent of the monetized health benefits lower bound estimate even at the 3 percent (95th percentile), the discount rate yielding the highest climate disbenefit estimate. At a discount rate of 3 percent (model average), the climate disbenefits offset less than 3 percent of the monetized health benefits. Thus, the monetized climate disbenefits are relatively small when compared to the monetized health benefits.

[88] In order to calculate these values, it is necessary to convert tons (short) of emissions to metric tons. These values may be converted to $/short ton using the conversion factor 0.90718474 metric tons per short ton for application to the short ton CO_2 emissions impacts provided in this rulemaking. Hence, 32,910 short tons of emissions become 29,855 metric tons (tonnes) of emissions.

4.8 Total Benefits Results

In this section of the chapter, we present the sum of monetized health benefits and monetized climate disbenefits for the final rule, discounted to 2020, in 2016$. As mentioned previously in this chapter, we presume that emission changes from the final rule, and hence any benefits or disbenefits associated with these emission changes, will begin in 2025 when emissions controls begin operation for purposes of compliance with this rule (3 years after the effective date). Table 4-11 presents the total monetized benefits of this final rule. In this table, for each discount rate applied to health benefits, multiple benefits estimates are presented reflecting alternative $PM_{2.5}$ -attributable premature deaths risk estimates and related BPT.

Table 4-11. Combined Health Benefits and Climate Disbenefits for the Final Rule for 2025 (millions of 2016$)[a]

$SC\text{-}CO_2$ Discount Rate and Statistic	Health Benefits (Discount Rate Applied to Health Benefits)		Climate Disbenefits Only[b]
	3%	7%	
Final Rule			
5% (average)	$122 and $123	$111 and $112	$1
3% (average)	$121 and $122	$110 and $111	$2
2.5% (average)	$120 and $121	$109 and $110	$3
3% (95th percentile)	$118 and $119	$107 and $108	$5

[a] 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. The health benefits are a result of the $PM_{2.5}$ and SO_2 emission reductions estimated for this final rule, are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. The benefits from the approximately 115 tons of emission reductions for directly regulated HAP under this final rule are not monetized due to lack of appropriate valuation estimates.

[b] Climate disbenefits are based on changes (increases) in CO_2 emissions and are calculated using four different estimates of the social cost of carbon ($SC\text{-}CO_2$) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For purposes of this table, we show the disbenefits associated with the model average at a 3 percent discount rate. However, we emphasize the importance and value of considering the disbenefits calculated using all four $SC\text{-}CO_2$ estimates; the additional disbenefit estimates range from $0.5 million to $5.2 million in 2025 for the final rule. As discussed in Chapter 4, a consideration of climate disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts.

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5 BENEFIT-COST COMPARISON

In this chapter, we present a comparison of the benefits and costs of this final regulation. As explained in the previous chapters, all costs and benefits outlined in this RIA are estimated as the change from the baseline, which reflects the requirements already promulgated in the 2013 final rule. As stated earlier in this RIA, there is no monetized estimate of the benefits for the HAP emission reductions expected to occur as a result of the HAP emission limits promulgated in this final rule. We do present monetized estimates for other impacts expected as a result of this final rule, such as benefits from reductions in $PM_{2.5}$ and SO_2 emissions that are expected to occur as entities install controls to comply with the HAP emission limits promulgated in this final rule and disbenefits from increases in CO_2 emissions.

5.1 Results

As shown in Chapter 4, the estimated monetized benefits from the HAP emission reductions are not quantified, but the total estimated monetized benefits due to reductions in pollutants such as $PM_{2.5}$ and SO_2 from implementation of the final rule are approximately $123 million to $124 million in 2025 (2016$) at a 3 percent discount rate, where 2025 is the year of full implementation (or 3 years after the effective date of the final rule). In addition, the total estimated monetized benefits are approximately $112 million to $113 million at a 7 percent discount rate in 2025 (2016$). The two estimates of the benefits and net-benefits for each discount rate reflect alternative estimates of PM-attributable premature deaths as reflected in the benefits per ton (BPT) applied in these estimates. The estimated monetized climate disbenefits are approximately $2 million in 2025 (using a 3 percent discount rate).

As shown in Chapter 3, the estimate annualized costs from implementation of the final rule, as described in this document and support documentation, are approximately $50 million (2016$). Also, this RIA uses these compliance costs as a proxy for social costs.

EPA calculates the net benefits of the rule by subtracting the estimated compliance costs from the estimated benefits in 2025. The benefits (in which disbenefits are incorporated) include those to public health and climate. The annual net benefits of the rule in 2025 (in 2016$) are approximately $71 and $72 million using a 3 percent real discount rate.

Table 5-1 presents a summary of the health benefits, climate disbenefits, costs, and net benefits of the rule for 2025.

Table 5-1. Benefits, Costs, and Net Benefits of the Final Rule for 2025 (millions of 2016$) [a,b,c]

	Final Rule
HAP Emission Reductions[d]	Unmonetized
$PM_{2.5}$ and SO_2 Benefits (3%)	$123 and $124
CO_2 Disbenefits (3%)	$2
Total Benefits	$121 and $122
Compliance Costs	$50
Net Benefits[e]	**$71 and $72 + A**
HAP Emission Reductions	Unmonetized
$PM_{2.5}$ and SO_2 Benefits (7%)	**$112 and $113**
CO_2 Disbenefits (3%)	$2
Total Benefits	$110 and $111
Compliance Costs	$50
Net Benefits	**$60 and $61 + A**

[a] We focus results to provide a snapshot of costs and benefits in 2025, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates. 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] Benefits (incorporating disbenefits) include those related to public health and climate. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. Climate disbenefits are based on changes (increases) in CO_2 emissions and are calculated using four different estimates of the social cost of carbon (SC-CO_2) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For the presentational purposes of this table, we show the disbenefits 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. We emphasize the importance and value of considering the disbenefits calculated using all four SC-CO_2 estimates; the additional disbenefit estimates range from $0.52 million to $5.21 million in 2025 for the final rule. Please see Table 4-8 for the full range of SC-CO_2 estimates. As discussed in Chapter 4, a consideration of climate disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. The costs presented in this table are 2025 annual estimates.

[c] Rows may not appear to add correctly due to rounding.

[d] The benefits from the approximately 115 tons of emission reductions that are mentioned earlier for directly regulated HAP under this final rule are not monetized due to lack of appropriate valuation estimates. More information on these benefits can be found in Chapter 4 of this RIA.
[e] The letter "A" captures the unmonetized benefits from the emission reductions of directly regulated HAP and all other pollutants affected by this final rule. More information on the unmonetized benefits from HAP and non-HAP emission reductions can be found in Chapter 4 of this RIA.

As part of fulfilling analytical guidance with respect to E.O. 12866, EPA presents estimates of the present value (PV) of the benefits and costs over the period 2022 to 2029. To calculate the present value of the social net benefits of the final rule, annual benefits and costs are discounted to 2020 at 3 percent and 7 discount rates as directed by OMB's Circular A-4. The EPA also presents the equivalent annualized value (EAV), which represents a flow of constant annual values that, had they occurred in each year from 2022 to 2029, 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, consistent with the estimate of the PV, in contrast to the year-specific estimates mentioned earlier in the RIA.

For the eight-year period of 2022 to 2029, the PV of the net benefits, in 2016$ and discounted to 2020, is $178 million and $182 million when using a 3 percent discount rate and $80 million and $83 million when using a 7 percent discount rate. The EAV is $25 million and $26 million per year when using a 3 percent discount rate and $13 million and $14 million when using a 7 percent discount rate. The comparison of benefits and costs in PV and EAV terms for the rule can be found in Table 5-2. Estimates in the table are presented as rounded values.

Table 5-2. Summary of Annual Values, Present Values and Equivalent Annualized Values for the 2022-2029 Timeframe for Estimated Compliance Costs, Benefits, and Net Benefits for the Final Rule (millions of 2016$, discounted to 2020)[a,b]

	$PM_{2.5}$ and SO_2 Benefits[c]		CO_2 Disbenefits[d]	Compliance Cost[e]		Net Benefits[f]	
	3%	**7%**	**3%**	**3%**	**7%**	**3%**	**7%**
2022*	$0	$0	$0	$67		-$67 and $67	-$67 and $67
2023	$0	$0	$0	$67		-67$ and -$67	-$67 and $67
2024	$0	$0	$0	$67		-$67 and -$67	-$67 and $67
2025	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
2026	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
2027	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
2028	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
2029	$123 and $124	$112 and $113	$2	$32		$89 and $90	$78 and $79
PV 2022-2029	**$500 and $505**	**$350 and $353**	**$7**	**$315**	**$265**	**$178 and $182 + B**	**$80 and $83 + B**
EAV 2022 - 2029	**$71 and $72**	**$58 and $59**	**$1**	**$45**	**$44**	**$25 and $26 + C**	**$13 and $14 + C**

[a] Rows may not appear to add correctly due to rounding. 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] The annualized present value of costs and benefits are calculated over an 8-year period from 2022 to 2029, which are the eight years after the rule is promulgated.

[c] Benefits (incorporating disbenefits) include those related to public health. The health benefits are a result of the $PM_{2.5}$ and SO_2 emission reductions estimated for this final rule, are associated with several point estimates and are presented at real discount rates of 3 and 7 percent.

[d] Climate disbenefits are based on changes (reductions) in CO_2 emissions and are calculated using four different estimates of the social cost of carbon (SC-CO_2) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For purposes of this table, we show the disbenefits associated with the model average at a 3 percent discount rate. However, we emphasize the importance and value of considering the disbenefits calculated using all four SC-CO_2 estimates. As discussed in Chapter 4, a consideration of climate disbenefits calculated using discount rates below 3 percent, including 2 percent and lower, are also warranted when discounting intergenerational impacts.

[e] The compliance costs presented in this table are consistent with the costs presented in Chapter 3. To estimate these annualized costs, EPA uses a conventional and widely accepted approach, called the equivalent uniform annual cost (EUAC) that applies a capital recovery factor (CRF) multiplier to capital investments and adds that to the annual incremental operating expenses to estimate annual costs. Total capital investment costs are assumed to be expended over a 3 year period from 2022 to 2024, and an equal amount of these costs are assumed to be expended in each of these years. Operating and maintenance costs are expected to be incurred beginning in 2025. Capital recovery costs were calculated using a 5.5% nominal discount rate consistent with the rate used in the cost analysis for the proposed rule in 2020.

[f] The letter "B" captures the portion of the present value of net benefits due to the unmonetized benefits from the emission reductions of directly regulated HAP and all other emission changes resulting from this final rule. The letter "C" captures the portion of the equivalent annualized value of net benefits due to the unmonetized benefits from the emission reductions of directly regulated HAP and all other emission changes resulting from this final rule. The benefits from emission reductions of directly regulated HAP under this final rule are not monetized due to lack of appropriate valuation estimates. More information on the unmonetized benefits from HAP and non-HAP emission reductions can be found in Chapter 4 of this RIA.

*Benefits calculated as value of avoided: $PM_{2.5}$-attributable premature deaths (quantified using a concentration-response relationship from the Di et al. 2017 and Turner et al. 2016 studies); and, $PM_{2.5}$-related morbidity effects

As noted earlier, we are unable to monetize the benefits from the HAP emissions reductions expected as a result of the HAP emission limits established in this final rule due to lack of necessary input data. However, based on the additional emissions reductions expected as entities comply with the HAP emission limits, the EPA expects that implementation of this rule, based solely on an economic efficiency criterion, will provide society with a relatively substantial net gain in welfare The expansive set of health and environmental benefits we were unable to quantify would further increase the estimated net benefits of the final rule.

5.2 Uncertainties and Limitations

Throughout the RIA, we considered a number of sources of uncertainty, both quantitatively and qualitatively, regarding the benefits, and costs of the final rule. We summarize the key elements of our discussions of uncertainty here:

- **Projection methods and assumptions**: Over time, more facilities are newly established or modified in each year, and to the extent the facilities remain in operation in future years, the total number of facilities subject to the final rule could change. We assume 100 percent compliance with the rule, starting from when the source becomes affected. If sources do not comply with the rule, at all or as written, the cost impacts may be overestimated. Additionally, new control technology may become available in the future at lower cost, and we are unable to predict exactly how industry will comply with the final rule in the future.

- **Years of analysis**: The years of the cost analysis are 2022, to represent the first-year facilities are affected by this rule, through 2029, to represent impacts of the rule over a longer period, as discussed in Chapter 3. Extending the analysis beyond 2029 would introduce substantial and increasing uncertainties in projected impacts of the final regulation.

- **Compliance Costs**: There may be an opportunity cost associated with the installation of environmental controls (for purposes of mitigating the emission of pollutants) that is not reflected in the compliance costs included in Chapter 3. If environmental investment displaces investment in productive capital, the difference between the rate of return on the marginal investment (which is discretionary in nature) displaced by the mandatory environmental investment is a measure of the opportunity cost of the environmental requirement to the regulated entity. To the extent that any opportunity costs are not added to the control costs, the compliance costs presented above for this final rule may be underestimated.

- **BPT estimates:** All national-average BPT estimates reflect the geographic distribution of the modeled emissions, which may not exactly match the emission reductions that would occur due to rulemaking, and they may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors for any specific location. In 2021 EPA developed new BPT for the Industrial Boiler Sector estimated at the state level to improve our ability to estimate the benefits of regionally heterogenous emission changes in key sectors. Recently, the EPA systematically compared the changes in benefits, and concentrations where available, from its BPT technique and other reduced-form techniques to the changes in benefits and concentrations derived from full-form photochemical model representation of a few different specific emissions scenarios. Reduced form tools are less complex than the full air quality modeling, requiring less agency resources and time. That work, in which we also explore other reduced form models is referred to as the "Reduced Form Tool Evaluation Project" (Project), began in 2017, and the initial results were available at the end of 2018. The Agency's goal was to better understand the suitability of alternative reduced-form air quality modeling techniques for estimating the health impacts of criteria pollutant emissions changes in the EPA's benefit-cost analysis. The EPA continues to work to develop refined reduced-form approaches for estimating $PM_{2.5}$ benefits. The scenario-specific emission inputs developed for this project are currently available online. The study design and methodology are described in the final report summarizing the results of the project, available at https://www.epa.gov/sites/production/files/2019-11/documents/rft_combined_report_10.31.19_final.pdf.

- **Non-monetized benefits:** Numerous categories of health and welfare benefits are not quantified and monetized in this RIA. These unquantified benefits, including benefits from reductions in emissions of pollutants such as mercury, HCl, and other HAP for which emissions are to be reduced by this final rule, are described in detail in Chapter 4 of this RIA, various $PM_{2.5}$ NAAQS RIAs and in Chapter 4 of the RIA for the promulgated ACE rule.

- **PM health impacts**: In this RIA, we quantify an array of adverse health impacts attributable to emissions of $PM_{2.5}$. The Integrated Science Assessment for Particulate Matter ("PM ISA") (U.S. EPA, 2019) identifies the human health effects associated with ambient particles, which include premature death and a variety of illnesses associated with acute and chronic exposures. We report the estimated PM2.5-related benefits (in terms of both health impacts and monetized values) calculated using a log-linear concentration-response function that quantified risk from the full range of simulated PM2.5 exposures.[89] As noted in the preamble to the 2020 PM NAAQS final rule, the "health effects can occur over the entire distributions of ambient PM2.5 concentrations evaluated, and epidemiological studies do not identify a population-level threshold below which it can be concluded with confidence that PM-associated health effects do not occur."[90] In general, we are more confident in the size of the risks we estimate from simulated PM2.5 concentrations that coincide with the bulk of the observed PM concentrations in the epidemiological studies that are used to estimate the benefits. Likewise, we are less confident in the risk we estimate from simulated PM2.5 concentrations that fall below the bulk of the observed data in these studies.[91]

- **Monetized climate disbenefits**: The EPA considered the uncertainty associated with the interim social cost of carbon (SC-CO_2) estimates, which were used to calculate the climate disbenefits from the increase in CO_2 emissions projected under the final

[89] U.S. EPA, 2021. Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS Estimating PM2.5- and Ozone-Attributable Health Benefits. Available at https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5_and_ozone-attributable_health_benefits_tsd.pdf.
[90] Available at https://www.govinfo.gov/content/pkg/FR-2020-12-18/pdf/2020-27125.pdf.
[91] U.S. EPA, 2021. Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS Estimating PM2.5- and Ozone-Attributable Health Benefits. Available at https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5_and_ozone-attributable_health_benefits_tsd.pdf.

rule. Some uncertainties are captured within the analysis, while other areas of uncertainty have not yet been quantified in a way that can be modeled. A full list and discussion of uncertainties in the analysis of monetized climate disbenefits can be found in section 4.7 of this RIA.

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