Executive Summary

ES.1 Overview

This Regulatory Impact Analysis (RIA) provides illustrative estimates of the incremental costs and monetized human health benefits of attaining a revised short-term Sulfur Dioxide (SO_2) National Ambient Air Quality Standard (NAAQS) within the current monitoring network of 488 SO_2 monitors. Because this analysis only considers counties with an SO_2 monitor, the possibility exists that there may be many more potential nonattainment areas than have been analyzed in this RIA.

This RIA chiefly serves two purposes. First, it provides the public with an estimate of the costs and benefits of attaining a new SO_2 NAAQS. Second, it fulfills the requirements of Executive Order 12866 and the guidelines of OMB Circular A-4. [1] These documents present guidelines for EPA to assess the benefits and costs of the selected regulatory option, as well as one less stringent and one more stringent option. The RIA analyzes the new short-term SO_2 NAAQS of 75 parts per billion (ppb), based on the 3-year average of the 99th percentile of 1-hour daily maximum concentrations. This RIA also analyzes alternative primary standards of 50 and 100 ppb.

This analysis does not estimate the projected attainment status of areas of the country other than those counties currently served by one of the approximately 488 monitors in the current network. It is important to note that the final rule requires a monitoring network comprised of monitors sited at locations of expected maximum hourly concentrations, and also provides for nonattainment designations using air quality modeling near large stationary sources. Only about one third of the existing SO_2 network may be source-oriented and/or in the locations of maximum concentration required by the final rule because the current network is focused on population areas and community-wide ambient levels of SO_2. Actual monitored levels using the new monitoring network and/or air quality modeling results near large stationary sources may be higher than levels measured using the existing network. We recognize that once the new requirements are put in place, more areas could find themselves exceeding the new SO_2 NAAQS. However for this RIA analysis, we lack sufficient data to predict which counties might exceed the new NAAQS after implementation of the new monitoring network and modeling requirements. Therefore we lack a credible analytic path to estimating costs and benefits for such a future scenario.

[1] U.S. Office of Management and Budget. Circular A-4, September 17, 2003. Available at http://www.whitehouse.gov/omb/circulars/a004/a-4.pdf.

In setting primary ambient air quality standards, EPA's responsibility under the law is to establish standards that protect public health, regardless of the costs of implementing a new standard. The Clean Air Act requires EPA, for each criteria pollutant, to set a standard that protects public health with "an adequate margin of safety." As interpreted by the Agency and the courts, the Act requires EPA to create standards based on health considerations only.

The prohibition against the consideration of cost in the setting of the primary air quality standard, however, does not mean that costs or other economic considerations are unimportant or should be ignored. The Agency believes that consideration of costs and benefits is essential to making efficient, cost effective decisions for implementation of these standards. The impacts of cost and efficiency are considered by states during this process, as they decide what timelines, strategies, and policies are most appropriate. This RIA is intended to inform the public about the potential costs and benefits associated with a hypothetical scenario that may result when a new SO_2 standard is implemented, but is not relevant to establishing the standards themselves.

ES.2 Summary of Analytic Approach

This RIA includes several key elements, including specification of baseline SO_2 emissions and concentrations; development of illustrative control strategies to attain the standard in 2020; and analyses of the control costs and health benefits of reaching the various alternative standards. Additional information on the methods employed by the Agency for this RIA is presented below.

Overview of Baseline Emissions Forecast and Baseline SO_2 Concentrations

The baseline emissions and concentrations for this RIA are emissions data from the 2005 National Emissions Inventory (NEI), and baseline SO_2 concentration values from 2005-2007 across the community-wide monitoring network. We used results from community multi-scale air quality model (CMAQ) simulations to calculate the expected reduction in ambient SO_2 concentrations between the 2005 base year and 2020. More specifically, design values (i.e. air quality concentrations at each monitor) were calculated for 2020 using monitored air quality concentrations from 2005 and modeled air quality projections for 2020, countywide emissions inventory data for 2005 and 2006-8, and emissions inventory projections for 2020. These data were used to create ratios between emissions and air quality, and those ratios (relative response factors, or RRFs) were used to estimate air quality monitor design values for 2020. The 2020 baseline air quality estimates revealed that 27 monitors in 24 counties were projected to exceed the 75 ppb NAAQS in 2020.

Development of Illustrative Control Strategies

For each alternative standard, we analyzed the impact that additional emissions controls applied to numerous sectors would have on predicted ambient SO_2 concentrations, incremental to the baseline set of controls. Thus the modeled analysis for a revised standard focuses specifically on incremental improvements beyond the current standards, and uses control options that might be available to states for application by 2020. The hypothetical modeled control strategy presented in this RIA is one illustrative option for achieving emissions reductions to move towards a national attainment of a tighter standard. It is not a recommendation for how a tighter SO_2 standard should be implemented, and states will make decisions regarding implementation strategies once a final NAAQS has been set.

The baseline for this analysis is complicated by the expected issuance of additional air quality regulations. The SO_2 NAAQS is only one of several regulatory programs that are likely to affect EGU emissions nationally in the next several years. We thus expect that EGUs will apply controls in the coming years in response to multiple rules. These include the maximum achievable control technology (MACT) rule for utility boilers, revisions to the Clean Air Interstate Rule, and reconsideration of the Clean Air Mercury Rule. Therefore controls and costs attributed solely to the SO_2 NAAQS in this analysis will likely be needed for compliance with other future rules as well.

The 2020 baseline air quality estimates revealed that 27 monitors in 24 counties were projected to exceed the 75 ppb NAAQS in 2020. We then developed hypothetical control strategies that could be adopted to bring the current highest emitting monitor in each of those counties into attainment with 75 ppb by 2020, as well as hypothetical control strategies for counties exceeding the lower bound analytic target of 50 ppb, and the upper bound analytic target of 100 ppb. Controls for three emissions sectors were included in the control analysis: non-electricity generating unit point sources (nonEGU), area sources (area), and electricity generating unit point sources (EGU). Finally, we note it was not possible, in this analysis, to bring all areas into attainment with alternative standards in all areas using identified engineering controls. For these monitor areas we estimated the cost of unspecified emission reductions.

Analysis of Costs and Benefits

We estimated the benefits and costs for the final NAAQS of 75 ppb, as well as alternative SO_2 NAAQS levels of 50 ppb and 100 ppb (99^{th} percentile). These costs and benefits are associated with an incremental difference in ambient concentrations between a baseline scenario and a pollution control strategy. As indicated in Chapter 4, several areas of the country may not be able to attain some alternative standard using known pollution control methods. Because some areas require substantial emission reductions from unknown sources to attain the various standards, the results are very sensitive to assumptions about the costs of full attainment. For this reason, we provide the full attainment results and the partial attainment results for both benefits and costs.

Benefits

Our benefits analysis estimates the human health benefits for each of the alternative standard levels including benefits related to reducing SO_2 concentrations and the co-benefits of reducing concentrations of fine particulate matter ($PM_{2.5}$). For the SO_2 benefits analysis, we use the Environmental Benefits Mapping and Analysis Program (BenMAP) to estimate the health benefits occurring as a result of implementing alternative SO_2 NAAQS levels. BenMAP has been used extensively in previous RIAs to estimate the health benefits of reducing exposure to various pollutants.

The primary input to the benefits assessment for SO_2 effects is the estimated changes in ambient air quality expected to result from a simulated control strategy or attainment of a particular standard. CMAQ projects both design values at SO_2 monitors and air quality concentrations at 12 km by 12 km grid cells nationwide. To estimate the benefits of fully attaining the standards in all areas, EPA employed the “monitor rollback” approach to approximate the air quality change resulting from just attaining alternative SO_2 NAAQS at each design value monitor. Under this approach, we use data from the existing SO_2 monitoring network and the inverse distance-squared variant of the Veronoi Neighborhood Averaging (VNA) interpolation method to adjust the air quality modeled concentrations such that each area just attains the target NAAQS levels.

We quantified SO_2-related health endpoints for which the SO_2 ISA provides the strongest evidence of an effect. In this analysis, we only estimated the benefits for those endpoints with sufficient evidence to support a quantified concentration-response relationship using the information presented in the SO_2 ISA, which contains an extensive literature review for several health endpoints related to SO_2 exposure. Based on our review of this information, we quantified three short-term morbidity endpoints that the SO_2 ISA identified as “sufficient to infer a likely causal relationship”: asthma exacerbation, respiratory-related emergency department visits, and respiratory-related hospitalizations. We then selected concentration-response functions and valuation functions based on criteria detailed in chapter 5. The valuation functions, ambient concentrations, and population data in the monitor areas are combined in BenMAP to provide the benefits estimates for this analysis. In this analysis, we decided not to quantify the premature mortality from SO_2 exposure in this analysis despite evidence suggesting a positive association. As the literature continues to evolve, we may revisit this decision in future benefits assessment for SO_2.

In addition, because SO_2 is also a precursor to $PM_{2.5,}$ reducing SO_2 emissions in the projected non-attainment areas will also reduce $PM_{2.5}$ formation, human exposure, and the incidence of $PM_{2.5}$-related health effects. In this analysis, we estimated the co-benefits of reducing $PM_{2.5}$ exposure for the alternative standards. Due to analytical limitations, it was not possible to provide a comprehensive estimate of $PM_{2.5}$-related benefits. Instead, we used the "benefit-per-ton" method to estimate these benefits. The $PM_{2.5}$ benefit-per-ton estimates provide the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of $PM_{2.5}$ from a specified source. EPA has used these estimates in previous RIAs, including the recent NO_2 NAAQS RIA.

These estimates reflect EPA's most current interpretation of the scientific literature and are consistent with the methodology used for the proposal RIA. These benefits are incremental to an air quality baseline that reflects attainment with the 2008 ozone and 2006 $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS). More than 99% of the total dollar benefits are attributable to reductions in $PM_{2.5}$ exposure resulting from SO_2 emission controls. Higher or lower estimates of benefits are possible using other assumptions; examples of this are provided in Figure 5.1 for the selected standard of 75 ppb. Methodological limitations prevented EPA from quantifying the impacts to, or monetizing the benefits from several important benefit categories, including ecosystem effects from sulfur deposition, improvements in visibility, and materials damage. Other direct benefits from reduced SO_2 exposure have not been quantified, including reductions in premature mortality.

Costs

Consistent with our development of the illustrative control strategies described above, our analysis of the costs associated with the range of alternative NAAQS focuses on SO_2 emission controls for electric generating units (EGU) and nonEGU stationary and area sources. EGU, nonEGU and area source controls largely include measures from the Control Strategy Tool (CoST), and the AirControlNET control technology database. For these sources, we estimated costs based on the cost equations included in AirControlNET.

As indicated in the above discussion on illustrative control strategies, implementation of the SO_2 control measures identified from AirControlNET and other sources does not result in attainment with the selected NAAQS in several areas. In these areas, additional unspecified emission reductions might be necessary to reach some alternative standard levels. In order to bring these monitor areas into attainment, we calculated controls costs using a fixed cost per ton approach similar to that used in the ozone RIA analysis. We recognize that a single fixed cost of control of $15,000 per ton of emissions reductions does not account for the significant emissions cuts that are necessary in some areas, and so its use provides an estimate that is likely to differ from actual future costs.

ES.3 Results of Analysis

Air Quality

Table ES.1 presents the number of monitors and counties exceeding the various target NAAQS levels in 2020 prior to control, out of 229 monitors from which a full set of data were available for this analysis.

Table ES.1. Number of monitors and counties projected to exceed 50, 75, and 100 ppb alternative NAAQS target levels in 2020.

Alternative standard (ppb)	Number of monitors	Number of counties
50	71	56
75	27	24
100	11	9

Table ES.2 presents the emission reductions achieved through applying identical control measures, both by sector and in total. As this table reveals, a majority of the emission reductions would be achieved through EGU emission controls.

Table ES.2: Emission Reductions from Identified Controls in 2020 in Total and by Sector (Tons) [a] for Each Alternative Standard

	50 ppb	75 ppb	100 ppb
Total Emission Reductions from Identified Controls [b]	800,000	370,000	190,000
EGUs	540,000	260,000	110,000
Non-EGUs	250,000	110,000	79,000
Area Sources	15,000	200	100

[a] All estimates rounded to two significant figures. As such, totals may not sum down columns.
[b] These values represent emission reductions for the identified control strategy analysis. There were locations not able to attain the alternative standard being analyzed with identified controls only.

Table ES.3 shows the emission reductions needed beyond identified controls for counties to attain the alternative standards being analyzed.

Table ES.3: Total Emission Reductions and those from Extrapolated Controls in 2020 in Total and by Sector (Tons) [a] for Each Alternative Standard

	50 ppb	75 ppb	100 ppb
Total Emission Reductions from Identified and Unidentified Controls	920,000	350,000	170,000
Total Emission Reductions from Unidentified Controls	110,000	33,000	18,000
Unidentified Reductions from EGUs	33,000	5,000	-
Unidentified Reductions from non-EGUs	54,000	22,000	15,000
Unidentified Reductions from Area Sources	19,000	6,400	3,000

[a] All estimates rounded to two significant figures.

Benefit and Cost Estimates

When estimating the SO_2- and $PM_{2.5}$-related human health benefits and compliance costs in Table ES.4 below, EPA applied methods and assumptions consistent with the state-of-the-science for human health impact assessment, economics and air quality analysis. EPA applied its best professional judgment in performing this analysis and believes that these estimates provide a reasonable indication of the expected benefits and costs to the nation of the selected SO_2 standard and alternatives considered by the Agency. The Regulatory Impacts Analysis (RIA) available in the docket describes in detail the empirical basis for EPA's assumptions and characterizes the various sources of uncertainties affecting the estimates below.

EPA's 2009 Integrated Science Assessment for Particulate Matter concluded, based on the scientific literature, that a no-threshold log-linear model most adequately portrays the PM-mortality concentration-response relationship. Nonetheless, consistent with historical practice and our commitment to characterizing the uncertainty in our benefits estimates, EPA has included a sensitivity analysis with an assumed threshold in the PM-mortality health impact function in the RIA. EPA has included a sensitivity analysis in the RIA to help inform our understanding of the health benefits which can be achieved at lower air quality concentration levels. While the primary estimate and the sensitivity analysis are not directly comparable, due to differences in population data and use of different analysis years, as well as the difference in the assumption of a threshold in the sensitivity analysis, comparison of the two results provide a rough sense of the proportion of the health benefits that occur at lower $PM_{2.5}$ air quality levels. Using a threshold of 10 $\mu g/m^3$ is an arbitrary choice (EPA could have assumed 6, 8, or 12 µg/m3 for the sensitivity analysis). Assuming a threshold of 10 $\mu g/m^3$, the sensitivity analysis shows that roughly one-third of the benefits occur at air quality levels below that threshold. Because the primary estimates reflect EPA's current methods and data, EPA notes that caution should be exercised when comparing the results of the primary and sensitivity analyses. EPA appreciates the value of sensitivity analyses in highlighting the uncertainty in the benefits estimates and will continue to work to refine these analyses, particularly in those instances in which air quality modeling data are available.

Table ES.4 shows the results of the cost and benefits analysis for each standard alternative. As indicated above, implementation of the SO_2 control measures identified from AirControlNET and other sources does not result in attainment with the all target NAAQS levels in several areas. In these areas, additional unspecified emission reductions might be necessary to reach some alternative standard levels. The first part of the table, labeled *Partial attainment (identified controls)*, shows only those benefits and costs from control measures we were able to identify. The second part of the table, labeled *Unidentified Controls*, shows only additional benefits and costs resulting from unidentified controls. The third part of the table, labeled *Full attainment*, shows total benefits and costs resulting from both identified and unidentified controls. It is important to emphasize that we were able to identify control measures for a significant portion of attainment for many of those counties that would not fully attain the target NAAQS level with identified controls. Note also that in addition to separating full and partial attainment, the table also separates the portion of benefits associated with reduced SO_2 exposure (i.e., SO_2 benefits) from the additional benefits associated with reducing SO_2 emissions, which are precursors to $PM_{2.5}$ formation – (i.e., the $PM_{2.5}$ co-benefits). For instance, for the selected standard of 75 ppb, $2.2 million in benefits are associated with reduced SO_2 exposure while $15 billion to $37 billion are associated with reduced $PM_{2.5}$ exposure.

Table ES.4: Monetized Benefits and Costs to Attain Alternate Standard Levels in 2020 (millions of 2006$)[a]

		# Counties Fully Controlled	Discount Rate	Monetized SO_2 Benefits	Monetized $PM_{2.5}$ Co-Benefits[c,d]	Costs	Net Benefits
Partial Attainment (identified controls)	**50 ppb**	40	3%	-[b]	$30,000 to $74,000	$2,600	$27,000 to $71,000
			7%		$28,000 to $67,000		$25,000 to $64,000
	75 ppb	20	3%	-[b]	$14,000 to $35,000	$960	$13,000 to $34,000
			7%		$13,000 to $31,000		$12,000 to $30,000
	100 ppb	6	3%	-[b]	$6,900 to $17,000	$470	$6,400 to $17,000
			7%		$6,200 to $15,000		$5,700 to $15,000
Unidentified Controls	**50 ppb**	16	3%	-[b]	$4,000 to $9,000	$1,800	$2,200 to $7,200
			7%		$3,000 to $8,000		$1,200 to $6,200
	75 ppb	4	3%	-[b]	$1,000 to $3,000	$500	$500 to $1,500
			7%		$1,000 to $3,000		$500 to $2,500
	100 ppb	3	3%	-[b]	$500 to $1,000	$260	$240 to $740
			7%		$500 to $1,000		$240 to $740
Full Attainment	**50 ppb**	56	3%	$8.50	$34,000 to $83,000	$4,400	$30,000 to $79,000
			7%		$31,000 to $75,000		$27,000 to $71,000
	75 ppb	24	3%	$2.20	$15,000 to $37,000	$1,500	$14,000 to $36,000
			7%		$14,000 to $34,000		$13,000 to $33,000
	100 ppb	9	3%	$0.60	$7,400 to $18,000	$730	$6,700 to $17,000
			7%		$6,700 to $16,000		$6,000 to $15,000

[a] Estimates have been rounded to two significant figures and therefore summation may not match table estimates.
[b] The approach used to simulate air quality changes for SO_2 did not provide the data needed to distinguish partial attainment benefits from full attainment benefits from reduced SO_2 exposure. Therefore, a portion of the SO_2 benefits is attributable to the known controls and a portion of the SO_2 benefits are attributable to the unidentified controls. Because all SO_2-related benefits are short-term effects, the results are identical for all discount rates.
[c] Benefits are shown as a range from Pope et al (2002) to Laden et al. (2006). Monetized benefits do not include unquantified benefits, such as other health effects, reduced sulfur deposition, or improvements in visibility.
[d] These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because there is no clear scientific evidence that would support the development of differential effects estimates by particle type. Reductions in SO_2 emissions from multiple sectors to meet the SO_2 NAAQS would primarily reduce the sulfate fraction of $PM_{2.5}$. Because this rule targets a specific particle precursor (i.e., SO_2), this introduces some uncertainty into the results of the analysis.

ES.4. Caveats and Limitations

Air Quality, Emissions, and Control Strategies

The estimates of emission reductions associated with the control strategies described above are subject to important limitations and uncertainties. We summarize these limitations as follows:

- *Actual State Implementation Plans May Differ from our Simulation*: In order to reach attainment with the proposed NAAQS, each state will develop its own implementation plan implementing a combination of emissions controls that may differ from those simulated in this analysis. This analysis therefore represents an approximation of the emissions reductions that would be required to reach attainment and should not be treated as a precise estimate.

- *Use of Existing CMAQ Model Runs*: This analysis represents a screening level analysis. We did not conduct new regional scale modeling specifically targets to SO_2; instead we relied upon impact ratios developed from model runs used in the analysis underlying the $PM_{2.5}$ NAAQS.

- *Unidentified controls*: We have limited information on available controls for some of the monitor areas included in this analysis. For a number of small non-EGU and area sources, there is little or no information available on SO_2 controls.

Costs

- We do not have sufficient information for all of our known control measures to calculate cost estimates that vary with an interest rate. We are able to calculate annualized costs at an interest rate other than 7% (e.g., 3% interest rate) where there is sufficient information—available capital cost data, and equipment life—to annualize the costs for individual control measures. For the vast majority of nonEGU point source control measures, we do have sufficient capital cost and equipment life data for individual control measures to prepare annualized capital costs using the standard capital recovery factor. Hence, we are able to provide annualized cost estimates at different interest rates for the point source control measures.

- There are some unquantified costs that are not adequately captured in this illustrative analysis. These costs include the costs of federal and State administration of control programs, which we believe are less than the alternative of States developing approvable SIPs, securing EPA approval of those SIPs, and Federal/State enforcement. Additionally, control measure costs referred to as “no cost” may require limited government agency resources for administration and oversight of the program not included in this analysis; those costs are generally outweighed by the saving to the industrial, commercial, or private sector. The Agency also did not consider transactional costs and/or effects on labor supply in the illustrative analysis.

Benefits

Although we strive to incorporate as many quantitative assessments of uncertainty, there are several aspects for which we are only able to address qualitatively. These aspects are important factors to consider when evaluating the relative benefits of the attainment strategies for each of the alternative standards:

- The 12 km CMAQ grid, which is the air quality modeling resolution, may be too coarse to accurately estimate the potential near-field health benefits of reducing SO_2 emissions. These uncertainties may under- or over-estimate benefits.
- The interpolation techniques used to estimate the full attainment benefits of the alternative standards contributed some uncertainty to the analysis. The great majority of benefits estimated for the various standard alternatives were derived through interpolation. As noted previously in this chapter, these benefits are likely to be more uncertain than if we had modeled the air quality scenario for both SO_2 and $PM_{2.5}$. In general, the VNA interpolation approach may under-estimate benefits because it does not account for the broader spatial distribution of air quality changes that may occur due to the implementation of a regional emission control program.
- There are many uncertainties associated with the health impact functions used in this modeling effort. These include: within study variability (the precision with which a given study estimates the relationship between air quality changes and health effects); across study variation (different published studies of the same pollutant/health effect relationship typically do not report identical findings and in some instances the differences are substantial); the application of C-R functions nationwide (does not account for any relationship between region and health effect, to the extent that such a relationship exists); extrapolation of impact functions across population (we assumed that certain health impact functions applied to age ranges broader than that considered in the original epidemiological study); and various uncertainties in the C-R function,

including causality and thresholds. These uncertainties may under- or over-estimate benefits.

- Co-pollutants present in the ambient air may have contributed to the health effects attributed to SO_2 in single pollutant models. Risks attributed to SO_2 might be overestimated where concentration-response functions are based on single pollutant models. If co-pollutants are highly correlated with SO_2, their inclusion in an SO_2 health effects model can lead to misleading conclusions in identifying a specific causal pollutant. Because this collinearity exists, many of the studies reported statistically insignificant effect estimates for both SO_2 and the co-pollutants; this is due in part to the loss of statistical power as these models control for co-pollutants. Where available, we have selected multipollutant effect estimates to control for the potential confounding effects of co-pollutants; these include NYDOH (2006), Schwartz et al. (1994) and O'Connor et al. (2008). The remaining studies include single pollutant models.
- This analysis is for the year 2020, and projecting key variables introduces uncertainty. Inherent in any analysis of future regulatory programs are uncertainties in projecting atmospheric conditions and source level emissions, as well as population, health baselines, incomes, technology, and other factors.
- This analysis omits certain unquantified effects due to lack of data, time and resources. These unquantified endpoints include other health effects, ecosystem effects, and visibility. EPA will continue to evaluate new methods and models and select those most appropriate for estimating the benefits of reductions in air pollution. Enhanced collaboration between air quality modelers, epidemiologists, toxicologists, ecologists, and economists should result in a more tightly integrated analytical framework for measuring benefits of air pollution policies.
- $PM_{2.5}$ co-benefits represent a substantial proportion of total monetized benefits (over 99% of total monetized benefits), and these estimates are subject to a number of assumptions and uncertainties.
    a. $PM_{2.5}$ co-benefits were derived through benefit per-ton estimates, which do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual benefits of controlling directly emitted fine particulates.
    b. We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ produced via transported precursors emitted from EGUs may differ significantly from direct $PM_{2.5}$ released from diesel engines and other industrial sources, but no clear scientific grounds exist for supporting differential effects estimates by particle type.

c. We assume that the health impact function for fine particles is linear down to the lowest air quality levels modeled in this analysis. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5,}$ including both regions that are in attainment with fine particle standard and those that do not meet the standard down to the lowest modeled concentrations.

d. To characterize the uncertainty in the relationship between $PM_{2.5}$ and premature mortality (which typically accounts for 85% to 95% of total monetized benefits), we include a set of twelve estimates based on results of the expert elicitation study in addition to our core estimates. Even these multiple characterizations omit the uncertainty in air quality estimates, baseline incidence rates, populations exposed and transferability of the effect estimate to diverse locations. As a result, the reported confidence intervals and range of estimates give an incomplete picture about the overall uncertainty in the $PM_{2.5}$ estimates. This information should be interpreted within the context of the larger uncertainty surrounding the entire analysis. For more information on the uncertainties associated with $PM_{2.5}$ co-benefits, please consult the $PM_{2.5}$ NAAQS RIA (Table 5.5).

While the monetized benefits of reduced SO_2 exposure appear small when compared to the monetized benefits of reduced $PM_{2.5}$ exposure, readers should not necessarily infer that the total monetized benefits of attaining a new SO_2 standard are minimal. For this rule, the monetized $PM_{2.5}$ co-benefits represent over 99% of the total monetized benefits. This result is consistent with other recent RIAs, where the $PM_{2.5}$ co-benefits represent a large proportion of total monetized benefits. This result is amplified in this RIA by the decision not to quantify SO_2-related premature mortality and other morbidity endpoints due to the uncertainties associated with estimating those endpoints. Studies have shown that there is a relationship between SO_2 exposure and premature mortality, but that relationship is limited by potential confounding. Because premature mortality generally comprises over 90% of the total monetized benefits, this decision may substantially underestimate the monetized health benefits of reduced SO_2 exposure.

In addition, we were unable to quantify the benefits from several welfare benefit categories. We lacked the necessary air quality data to quantify the benefits from improvements in visibility from reducing light-scattering particles. Previous RIAs for ozone (U.S. EPA, 2008a) and $PM_{2.5}$ (U.S. EPA, 2006a) indicate that visibility is an important benefit category, and previous efforts to monetize those benefits have only included a subset of visibility benefits, excluding benefits in urban areas and many national and state parks. Even this subset accounted for up to 5% of total monetized benefits in the Ozone NAAQS RIA (U.S. EPA, 2008a).

We were also unable to quantify the ecosystem benefits of reduced sulfur deposition because we lacked the necessary air quality data, and the methodology to estimate ecosystem benefits is still being developed. Previous assessments (U.S. EPA, 1999; U.S. EPA, 2005; U.S. EPA, 2009e) indicate that ecosystem benefits are also an important benefits category, but those efforts were only able to monetize a tiny subset of ecosystem benefits in specific geographic locations, such as recreational fishing effects from lake acidification in the Adirondacks. We were also unable to quantify the benefits of decreased mercury methylation from sulfate deposition. Quantifying the relationship between sulfate and mercury methylation in natural settings is difficult, but some studies have shown that decreasing sulfate deposition can also decrease methylmercury.

ES.5. References

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