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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.

The proposal would set a new short-term SO_2 standard based on the 3-year average of the 99th percentile of 1-hour daily maximum concentrations, establishing a new standard within the range of 50 to 100 ppb. The proposal also requests comment on standard levels ranging up to a high of 150 ppb. This RIA analyzes alternative primary standards of 50 parts per billion (ppb), 75 ppb, 100 ppb, and 150 ppb.

This RIA chiefly serves two purposes. First, it provides the public with an estimate of the expected 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. As stated above, we chose 50 ppb as an analytic lower bound, and 150 ppb as an upper bound. (We chose 50 ppb as an analytic lower bound before decisions were made about either the proposed range, or the range for requesting public comment.)

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 proposed rule would require a monitoring network wholly comprised of monitors sited at locations of expected maximum hourly concentrations. 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 proposed 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 may be higher than levels measured using the existing network. We recognize that once a network of monitors located at maximum-concentration is put in place, more areas could find themselves exceeding the new

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[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.

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. Therefore we lack a credible analytic path to estimating costs and benefits for such a future scenario.

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 NO_2 standard is implemented, but is not relevant to establishing the standards themselves.

ES.2 Summary of Analytic Approach

Our assessment of the lower bound SO_2 target NAAQS 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 based emissions data from the 2002 National Emissions Inventory (NEI), and baseline SO_2 concentration values from 2005-2007 across the community-wide monitoring network. We used results from the community multi-scale air quality model (CMAQ) simulations from the ozone NAAQS RIA to calculate the expected reduction in ambient SO_2 concentrations between the 2002 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 2002 and modeled air quality projections for 2020, countywide emissions inventory data for 2002 and 2005-7, 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 33 monitors in 57 counties were projected to exceed a 50 ppb lower bound target NAAQS in 2020, and 5 monitors in 5 counties were projected to exceed a 150 ppb upper bound target 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 all final decisions regarding implementation strategies once a final NAAQS has been set.

It also must be emphasized that 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 expect that EGUs will apply controls in the coming years in response to multiple rules. These include revisions to the $PM_{2.5}$ NAAQS, reconsideration of the Ozone NAAQS, the maximum achieveable control technology (MACT) rule for utility boilers, revisions to the Clean Air Interstate Rule, reconsideration of the Clean Air Mercury Rule. Therefore controls and costs attributed solely to the SO_2 NAAQS in this analysis will, in reality, be needed for compliance with many other rules as well.

The 2020 baseline air quality estimates revealed a range from 33 monitors in 57 counties with projected design values exceeding 50 ppb, down to 5 monitors in 5 counties which were projected to exceed a 150 ppb upper bound target 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 each alternative primary standard by 2020. Controls for four 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 that because it was not possible, in this analysis, to bring all areas into attainment with alternative standards in all areas using only identified 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 four alternative SO_2 NAAQS levels: 50 ppb, 75 ppb, 100 ppb, and 150 ppb (99th 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 assuming 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 primary 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. Although BenMAP has been used extensively in previous RIAs to estimate the health benefits of reducing exposure to $PM_{2.5}$ and ozone, this is the first RIA to use BenMAP to estimate the health benefits of reducing exposure to SO_2 to support a change in the NAAQS.

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 12km by 12km 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.

We then selected health endpoints to be consistent with the conclusions of the Integrated Science Assessment (ISA) for SO_2. 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_x is also a precursor to $PM_{2.5,}$ reducing SO_x 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 results reflect EPA's most current interpretation of the scientific literature and include three key changes from the 2008 ozone NAAQS RIA: (1) a no-threshold model for PM2.5 that calculates incremental benefits down to the lowest modeled air quality levels; (2) a different Value of Statistical Life (VSL); (3) two technical updates to the population dataset and aggregation method. 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 SOx emission controls. Higher or lower estimates of benefits are possible using other assumptions. Despite methodological limitations that 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, we have included a qualitative evaluation of these benefits. 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.

NonEGU and area source controls largely include measures from the AirControlNET control technology database. For these sources, we estimated costs based on the cost equations included in AirControlNET. The identified controls strategy for nonEGU Point and Area sources incorporated annualized engineering cost per ton caps. These caps were defined as the upper cost per ton for controls of nonEGU point and area sources. The caps used were originally developed for the Ozone NAAQS analysis. The number of applied control measures was much larger for that analysis, and therefore provides a more robust estimate of what a potential cap on SO_2 costs would look like.

The EGU analysis included in this RIA utilizes the integrated planning model (IPM) v3.0 as part of the updated modeling platform.[1] IPM v3.0 includes input and model assumption updates in modeling the power sector and incorporates Federal and State rules and regulations adopted before September 2006 and various new source review (NSR) settlements. The SO_2 control technology options used in IPM v3.0 includes flue gas desulfurization (FGD), also known as "scrubbers". It is important to note that beyond these emission control options, IPM offers other compliance options for meeting emission limits. These include fuel switching, re-powering, and adjustments in the dispatching of electric generating units.

Finally, 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.

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.

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[1] http://www.epa.gov/airmarkets/progsregs/epa-ipm/past-modeling.html.

Table ES.1. Number of monitors and counties projected to exceed 50, 75, 100, and 150 ppb alternative NAAQS target levels in 2020.

Alternative standard (ppb)	Number of monitors	Number of counties
50	74	57
75	30	24
100	17	14
150	6	6

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, b] for Each Alternative Standard

	50 ppb	75 ppb	100 ppb	150 ppb
Total Emission Reductions from Identified Controls	760,000	439,000	343,000	162,000
EGUs	550,000	317,000	256,000	119,000
Non-EGUs	209,000	122,000	87,000	44,000
Area Sources	1,000	100	0	0

[a] All estimates rounded to two significant figures. As such, totals may not sum down columns.

[b] All estimates provided reflect the application of the identified control strategy analysis and the necessary emission reductions estimated for attainment as shown in Chapter 2 for the areas covered by this analysis.

[c] 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 SO_2 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	150 ppb
Total Emission Reductions from Identified and Unidentified Controls	1,061,000	566,000	404,000	165,000
Total Emission Reductions from Unidentified Controls	301,000	127,000	61,000	2,600
Unidentified Reductions from EGUs	217,000	91,000	46,000	1,900
Unidentified Reductions from non-EGUs	84,000	36,000	15,000	700
Unidentified Reductions from Area Sources	75	30	0	0

[a] All estimates rounded to two significant figures.

Benefit and Cost Estimates

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 (known controls)*, shows only those benefits and costs from control measures we were able to identify. The second part of the table, labeled *Extrapolated portion (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.

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$_2$ Health Benefits	Monetized PM$_{2.5}$ Health Co-benefits	Costs	Monetized Net Benefits
Partial attainment (known controls)	50 ppb	31	3%	--[b]	$29,000 to $76,000	$2,000	$27,000 to $74,000
			7%	--[b]	$27,000 to $69,000	$2,300	$25,000 to $67,000
	75 ppb	12	3%	--[b]	$17,000 to $41,000	$1,000	$16,000 to $40,000
			7%	--[b]	$15,000 to $37,000	$1,100	$14,000 to $36,000
	100 ppb	6	3%	--[b]	$13,000 to $33,000	$840	$12,000 to $32,000
			7%	--[b]	$12,000 to $29,000	$900	$11,000 to $28,000
	150 ppb	4	3%	--[b]	$6,300 to $15,000	$340	$6,000 to $16,000
			7%	--[b]	$5,700 to $14,000	$370	$5,300 to $14,000
Extrapolated portion (unidentified controls)	50 ppb	26	3%	--[b]	$12,000 to $24,000	$4,500	$7,500 to $20,000
			7%	--[b]	$10,000 to $21,000	$4,500	$5,500 to $17,000
	75 ppb	12	3%	--[b]	$5,000 to $12,000	$1,900	$3,100 to $10,000
			7%	--[b]	$5,000 to $11,000	$1,900	$3,100 to $9,100
	100 ppb	8	3%	--[b]	$3,000 to $5,000	$920	$2,000 to $4,000
			7%	--[b]	$2,000 to $5,000	$920	$1,100 to $4,000
	150 ppb	2	3%	--[b]	$100 to $250	$39	$60 to $180
			7%	--[b]	$90 to $220	$39	$50 to $180
Full attainment	50 ppb	57	3%	$12	$41,000 to $100,000	$6,500	$34,000 to $94,000
			7%	$12	$37,000 to $90,000	$6,800	$30,000 to $83,000
	75 ppb	24	3%	$4.6	$22,000 to $53,000	$2,900	$19,000 to $50,000
			7%	$4.6	$20,000 to $48,000	$3,000	$17,000 to $45,000
	100 ppb	14	3%	$1.9	$16,000 to $38,000	$1,800[c]	$14,000 to $36,000
			7%	$1.9	$14,000 to $35,000	$1,800[c]	$12,000 to $33,000
	150 ppb	6	3%	$0.6	$6,400 to $16,000	$380	$6,000 to $16,000
			7%	$0.6	$5,800 to $14,000	$410	$5,400 to $14,000

[a] Estimates have been rounded to two significant figures and therefore summation may not match table estimates. Benefits are shown as a range from Pope et al (2002) to Laden et al. (2006). Estimates reflect full attainment with the alternate standards, including emission reductions from known and unidentified controls. Monetized benefits do not include unquantified benefits, such as other health effects, reduced sulfur deposition, or improvements in visibility.

[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 potion of the SO$_2$ benefits are attributable to the known controls and a portion of the SO$_2$ benefits are attributable to the extrapolated controls. Because all SO$_2$-related benefits are short-term effects, the results are identical for all discount rates.

[c] Although the costs appear the same for full attainment of 100 ppb due to rounding, the unrounded costs are actually $67,000 higher at a 7% discount rate.

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.

- *Current PM2.5 Controls in Baseline*: Our 2020 analysis year baseline assumes that States will put in place the necessary control strategies to attain the current $PM_{2.5}$ standards. As States develop their plans for attaining these standards, their SO_2 control strategies may differ significantly from our analysis.

- *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:

1. The gradient of ambient SO_2 concentrations is difficult to estimate due to the sparsity of the monitoring network in some areas. The 12km 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.
2. 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 will 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.
3. 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.

4. 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'Conner et al. (2007). The remaining studies include single pollutant models.
5. 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.
6. 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.
7. $PM_{2.5}$ 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 within the range of ambient concentrations under consideration. 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. This is primary due to 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 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.