

Chapter 7: Estimates of Costs and Benefits

Synopsis

As discussed above, this RIA analyzes alternative primary standards of 50 parts per billion (ppb), 75 ppb, 100 ppb, and 150 ppb. Our assessment of the lower bound SO₂ target NAAQS includes several key elements, including specification of baseline SO₂ 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. We also note that because it was not possible, in this analysis, to bring all areas into attainment with the alternative standard of 50 ppb in all areas using only identified controls, EPA conducted a second step in the analysis, and estimated the cost of unspecified emission reductions needed to attain the alternative primary NAAQS.

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 SO₂ 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 SO₂. 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 SO₂ 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.

7.1 Benefits and Costs

We estimated the benefits and costs for four alternative SO₂ 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 above and 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 and the partial attainment results for both benefits and costs.

Costs

Our analysis of the costs associated with the range of alternative NAAQS focuses on SO₂ 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, where NO_x controls were also applied.

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 SO₂ 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 SO₂ 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.

Benefits

EPA estimated the monetized human health benefits of reducing cases of morbidity and premature mortality among populations exposed to SO₂ and PM_{2.5} in 2020 for each of the alternative standard levels in 2006\$. For an SO₂ standard at 50 ppb (99th percentile daily 1-hour maximum), the total monetized benefits would be \$41 to \$100 billion at a 3% discount rate and \$37 to \$90 billion at a 7% discount rate. For an SO₂ standard at 75 ppb, the total monetized benefits would be \$22 to \$53 billion at a 3% discount rate and \$20 to \$48 billion at a

¹<http://www.epa.gov/airmarkets/progsregs/epa-ipm/past-modeling.html>.

7% discount rate. For an SO₂ standard at 100 ppb, the total monetized benefits would be \$16 to \$38 billion at a 3% discount rate and \$14 to \$35 billion at a 7% discount rate. For an SO₂ standard at 150 ppb, the total monetized benefits would be \$6.4 to \$16 billion at a 3% discount rate and \$5.8 to \$14 billion at a 7% discount rate.

These estimates 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 PM_{2.5} 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 SO_x emission controls. Higher or lower estimates of benefits are possible using other assumptions (see Figures 5.1-5.2). 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 SO₂ exposure have not been quantified, including reductions in premature mortality.

Table 7.1 presents total national primary estimates of costs and benefits for a 3% discount rate and a 7% discount rate. The total benefits estimates include SO₂-related benefits as well as PM_{2.5} co-benefits. The net benefits were calculated by subtracting the total cost estimate from the two estimates of total benefits. As indicated above, implementation of the SO₂ 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. Note also that In addition to separating full and partial attainment, the table separates the portion of benefits associated with reduced levels of SO₂ from the additional reductions in health effects that come with the implementation of the control strategy – (i.e., the PM_{2.5} co-benefits). For instance, for an alternative standard of 100 ppb,

\$1.9 million in benefits are associated with reductions in SO₂ while between 16,000 M and 39,000 M are associated with the PM_{2.5} co-benefits.

Table 7.1: 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 SO₂ did not provide the data needed to distinguish partial attainment benefits from full attainment benefits from reduced SO₂ exposure. Therefore, a portion of the SO₂ benefits are attributable to the known controls and a portion of the SO₂ benefits are attributable to the extrapolated controls. Because all SO₂-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.

7.2 Discussion of Uncertainties 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 PM_{2.5} 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 SO₂ 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 SO₂; 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 SO₂ 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 SO₂ 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 SO₂ 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 SO₂ 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 SO₂ in single pollutant models. Risks attributed to SO₂ might be overestimated where concentration-response functions are based on single pollutant models. If co-pollutants are highly correlated with SO₂, their inclusion in an SO₂ 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 SO₂ 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 SO₂ 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 SO₂ standard are minimal. Compared to the PM_{2.5} co-benefits, the benefits from reduced SO₂ exposure appear small. This is primary due to the decision not to quantify SO₂-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 SO₂ 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 SO₂ 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.