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, and 100 ppb. 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. We also note that because it was not possible, in this analysis, to bring all areas into attainment with the selected standard of 75 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 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 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.

7.1 Benefits and Costs

We estimated the benefits and costs for four alternative SO_2 NAAQS levels: 50 ppb, 75 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 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 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.

Benefits

EPA estimated the monetized human health benefits of reducing cases of morbidity among populations exposed to SO_2 and cases of morbidity and premature mortality among populations exposed to $PM_{2.5}$ in 2020 for the selected standard and alternative standard levels in 2006$. 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. For the selected SO_2 standard at 75 ppb (99th percentile, daily 1-hour maximum), the total monetized benefits would be $15 to $37 billion at a 3% discount rate and $14 to $33 billion at a 7% discount rate. For an SO_2 standard at 50 ppb, the total monetized benefits would be $34 to $83 billion at a 3% discount rate and $31 to $75 billion at a 7% discount rate. For an SO_2 standard at 100 ppb, the total monetized benefits would be $7.4 to $18 billion at a 3% discount rate and $6.7 to $16 billion at a 7% discount rate.

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 reductions. 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.

When estimating the SO_2- and $PM_{2.5}$-related human health benefits and compliance costs in Table 7.1 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 µg/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 µg/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 7.1 presents total national primary estimates of costs and benefits for a 3% discount rate and a 7% discount rate. The net benefits were calculated by subtracting the total cost estimate from the two estimates of total benefits. 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 U*nidentified 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 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 Benefits	Monetized $PM_{2.5}$ Co-Benefits [c,d]	Costs	Net Benefits
Partial Attainment (identified controls)	**50 ppb**	40	3% 7%	-[b]	\$30,000 to \$74,000 \$28,000 to \$67,000	\$2,600	\$27,000 to \$71,000 \$25,000 to \$64,000
	75 ppb	20	3% 7%	-[b]	\$14,000 to \$35,000 \$13,000 to \$31,000	\$960	\$13,000 to \$34,000 \$12,000 to \$30,000
	100 ppb	6	3% 7%	-[b]	\$6,900 to \$17,000 \$6,200 to \$15,000	\$470	\$6,400 to \$17,000 \$5,700 to \$15,000
Unidentified Controls	**50 ppb**	16	3% 7%	-[b]	\$4,000 to \$9,000 \$3,000 to \$8,000	\$1,800	\$2,200 to \$7,200 \$1,200 to \$6,200
	75 ppb	4	3% 7%	-[b]	\$1,000 to \$3,000 \$1,000 to \$3,000	\$500	\$500 to \$1,500 \$500 to \$2,500
	100 ppb	3	3% 7%	-[b]	\$500 to \$1,000 \$500 to \$1,000	\$260	\$240 to \$740 \$240 to \$740
Full Attainment	**50 ppb**	56	3% 7%	\$8.50	\$34,000 to \$83,000 \$31,000 to \$75,000	\$4,400	\$30,000 to \$79,000 \$27,000 to \$71,000
	75 ppb	24	3% 7%	\$2.20	\$15,000 to \$37,000 \$14,000 to \$34,000	\$1,500	\$14,000 to \$36,000 \$13,000 to \$33,000
	100 ppb	9	3% 7%	\$0.60	\$7,400 to \$18,000 \$6,700 to \$16,000	\$730	\$6,700 to \$17,000 \$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.

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.

- *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 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.
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'Connor et al. (2008). 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. 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.