Estimating the Benefits and Costs for the Revised Particulate Matter and Ozone Standards in the United States*

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This paper provides an overview of some of the issues, procedures, and decisions associated with preparing a national benefit-cost analysis for revised air quality standards for particulate matter and ozone in the United States. Additionally, the paper presents the results of the analyses in terms of potential monetized benefits and costs that could be estimated for the revised standards in the year 2010.

1. INTRODUCTION

The purpose of this paper is to provide an overview of the methodological issues, procedures, and decisions that are associated with preparing benefit-cost analyses for the revised primary Ozone and Particulate Matter (PM) air quality standards recently promulgated (July 1997) in the United States by the U.S. Environmental Protection

*The majority of the information included in this paper was presented in April 1997. However, some details, such as the form and level of the final revised ozone and PM standards, have been updated to reflect the most recently available information.

** This paper summarizes work conducted by a team of analysts working for the United States Environmental Protection Agency. For a more detailed description of the analysis, please refer to the July 1997 RIA for the PM and Ozone NAAQS and Proposed Regional Haze Rule.

Agency (EPA). In December 1996, two separate Regulatory Impact Analyses (RIA's) were prepared for the proposal of revised standards for PM and ozone. The revised PM and ozone standards were promulgated in July 1997 and a revised set of benefit-cost analyses was published in a single document, titled "Regulatory Impact Analyses for the Particulate Matter and Ozone National Ambient Air Quality Standards (NAAQS) and Proposed Regional Haze Rule", at the same time.

Currently, the primary and secondary ozone standards are each set at a level of 0.12 parts per million (ppm), with a 1-hour averaging time and 1 expected exceedance form, such that the standards are attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1, averaged over 3 years. The Clean Air Act defines the purpose of the primary standard as one of protecting public health with an "adequate margin of safety'. The purpose of the secondary standard is to "protect the public welfare from any known or anticipated adverse effects". (42 U.S.C. 7409) Examples of welfare effects include, but are not limited to, effects on crops and vegetation, animals and wildlife, visibility and climate, and effects on economic values or personal comfort and well-being. (42 U.S.C. 7602) The revised ozone standards (once again, with the primary and secondary standards set equal to each other) will be met at an ambient air quality monitoring site when the 3-year average of the annual fourth-highest daily maximum 8-hour average ozone concentration is less than or equal to 0.08 ppm. For convenience, the revised ozone standards will be expressed in this paper as 0.08 ppm, 8-hour, 4th highest concentration. (U.S. EPA, 1997a)

The current PM standard specifies the indicator for PM as PM_{10}. PM_{10} refers to particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers. Identical primary and secondary PM_{10} standards were set for two averaging times: 50 $\mu g/m^3$, expected annual arithmetic mean, averaged over 3 years, and 150 $\mu g/m^3$, 24-hour average, with no more than 1 expected exceedance per year. The revised PM standards specify standards for several size-specific classes of particles. The current annual PM_{10} standard is retained at the level of 50 $\mu g/m^3$, which is met when the 3-year average of the annual arithmetic mean PM_{10} concentrations at each monitor within an area is less than or equal to 50 $\mu g/m^3$, with fractional parts of 0.5 or greater rounding up. The form of the current 24-hour PM_{10} standard is revised to be based on the 3-year average of the 99th percentile of 24-hour PM_{10} concentrations at each monitor within an area. Additionally, an annual and a 24-hour standard is specified for particles with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers ($PM_{2.5}$). The annual $PM_{2.5}$ standard is met when the 3-year average of the annual arithmetic mean $PM_{2.5}$ concentrations, from single or multiple community-oriented monitors, is less than or equal to 15 $\mu g/m^3$, with fractional parts of 0.05 or greater rounding up. The 24-hour $PM_{2.5}$ standard is met when the 3-year average of the 98th percentile of 24-hour $PM_{2.5}$ concentrations at each population -oriented monitor within an area is less than or equal to 65 $\mu g/m^3$, with fractional parts of 0.5 or greater rounding up. The revised secondary PM standards are set identical to the suite of revised primary PM standards. (U.S. EPA, 1997b)

This paper focuses on some of the methodological issues and decisions associated with attempting to conduct a national benefit-cost analysis for ubiquitous pollutants that are formed from a variety of anthropogenic and natural activities. This paper provides general descriptions of the analytical issues and may not be applicable to all circumstances within the analyses. Although the quantitative results presented at the end of this paper represent the monetized benefits and costs associated with the revised PM and ozone standards, the procedures and issues presented in this paper equally apply to other alternative standards that were examined in the RIA's.

2. BACKGROUND

Reviewers of the benefit-cost analyses should be aware of the purpose of the analyses within the context of the NAAQS rulemakings. As the introduction explains, the Clean Air Act (CAA) directs the EPA to identify and set national standards for pollutants that may reasonably be anticipated to cause adverse effects to public health and the environment. In setting the primary air quality standards, the EPA's first responsibility under the law is to select standards that protect public health. As interpreted by the EPA and the courts, this decision is a health-based decision that specifically precludes cost or other economic considerations. By contrast, the EPA believes that consideration of cost is an essential decision-making tool for the cost-effective *implementation* of these standards. Given the guidance of the Clean Air Act, it is clear that the appropriate place for cost and efficiency considerations is during the development of implementation strategies, strategies that will allow communities to meet the health-based standards in a cost-effective manner over time.

In addition to complying with the CAA, the EPA must also comply with other Federal requirements for analyses. For example, Executive Order 12866, signed by the President of the United States, directs all Federal agencies to "assess all costs and benefits of available regulatory alternatives... Costs and benefits shall be understood to include both quantifiable measures... and qualitative measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider... Further, in choosing among alternative regulatory approaches, agencies should select those approaches that maximize net benefits..., unless a statute requires another regulatory approach". Another example of a Federal requirement is the Unfunded Mandates Reform Act of 1995 (UMRA). The UMRA directs agencies to provide a qualitative and quantitative assessment of the anticipated costs and benefits of a Federal mandate resulting in annual; expenditures of $100 million or more, including the costs and benefits to State, local, and tribal governments, or the private sector. (Chapter 2 of the 1997 RIA provides additional information on these and other Federal requirements, including one that is concerned with the potential economic impacts affecting small entities).

These examples of the types of Federal requirements under which the EPA operates provides the regulatory framework under which benefit-cost analysis is used. Since the CAA precludes consideration of costs or technological feasibility in determining the ambient standards, the results of the RIA's are not taken into account by the Administrator in her decision regarding the appropriate level of the NAAQS. Within this regulatory setting however, benefit-cost analysis can provide a valuable framework for organizing and evaluating information on the effects of environmental programs. When used properly, benefit-cost analysis helps illuminate important potential effects of changes in policy and helps set priorities for closing information gaps and reducing uncertainty. In this context, the objectives of the RIA's for PM and ozone were to: (1)

assess the potential costs and economic impacts of regulatory alternatives, including economic incentives and alternatives to command and control technologies; (2) assess the potential environmental and public health benefits; and (3) assess potential impacts on industries and small businesses.

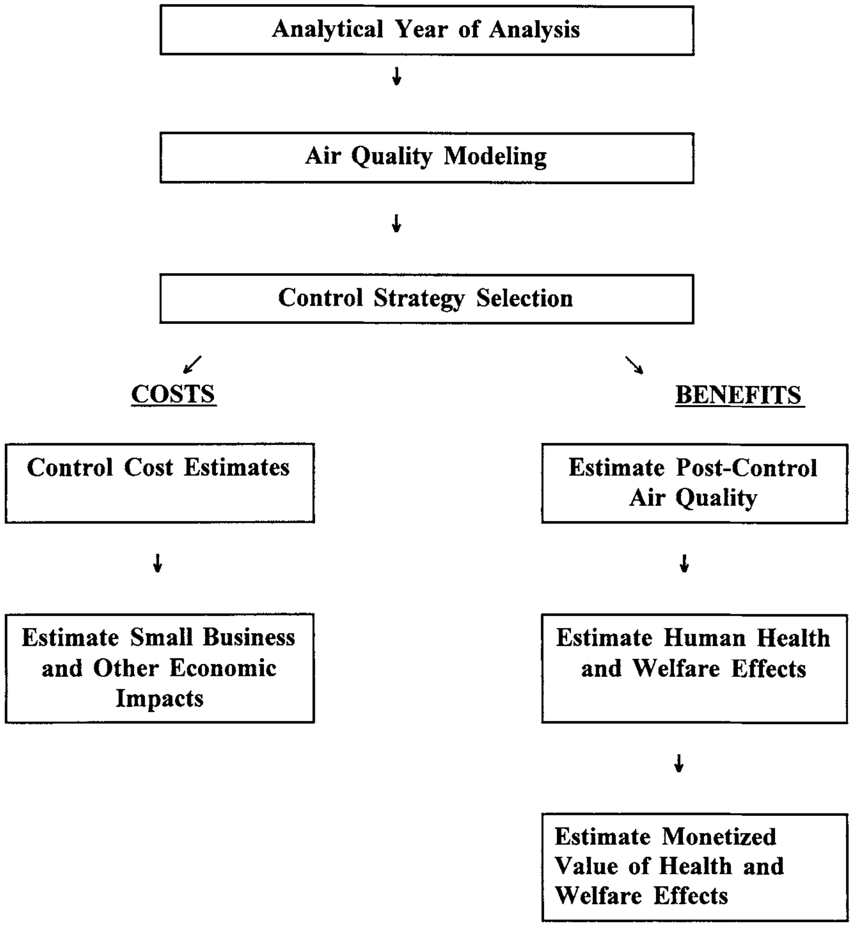
In order to accomplish the above goals, a series of methodological steps were followed to develop the benefit-cost analysis. These steps are presented in Figure 1. The rest of this presentation will focus on issues associated with each step and finally, the results of the analyses will be presented at the end of this presentation. The diagram presented in Figure 1 represents broad subject categories included in the RIA but does not provide information on the details of the analysis.

3. ANALYTICAL YEAR AND SCOPE OF ANALYSIS

Two immediate decisions affecting the direction of the benefit-cost analysis are the temporal and geographical scope of the analysis. One of the first steps in preparing the RIA was to decide on an analytical year that would serve as the basis of the analysis. The year of the analysis must be a future year because the year must represent a time period during which the standards would be implemented. A constraint on the RIA was the length of time over which the analysis could span. Resource and related constraints such as data management and modeling capabilities made a multi-year analysis infeasible. Therefore, the choice of the analysis year was limited to a single calendar year. This temporal constraint makes it important to choose a "representative" year during which the standards will be implemented. This year is described as the year during which we expect most (but not all) programs to be in place for implementation of these standards. For the proposal of these standards in 1996, the analytical year of the analysis was 2007. In 1997, during the promulgation of these standards, the year 2010 was chosen as a more representative year. The RIA refers to the analysis year as a "snapshot in time" approach. The decision on the geographical scope of the analysis is based on the geographic scope of the standards. All areas of the U.S. are required to comply with the national PM and ozone standards.

Figure 1

Analytical Steps in Developing a Benefit-Cost Analysis



It was therefore decided that the scope of the benefit-cost analyses include all areas within the continental U.S. (Modeling limitations prevented other U.S. areas such as Alaska and Hawaii from being included in the analysis.) Such broad geographical coverage and forecasting horizon place significant limitations on the details that can be included in the analysis.

4. AIR QUALITY MODELING

In the RIA's prepared for the proposal of these standards in 1996, two separate benefit-cost documents, one for ozone and one for PM, were prepared. The analyses were prepared under a constraint of using separate air quality models for estimating ambient concentrations of PM and ozone. The models provided projections of ambient concentrations of PM and ozone for a "baseline" scenario in the year 2007. A baseline scenario represents a scenario in the absence of implementation of the revised air quality standards. In order to establish the baseline projection, the analysis used present-day conditions and then attempted to account for factors such as population growth, economic growth, and additional levels of pollution control mandated by the Clean Air Act during the intervening years. These projections established an emissions inventory, air quality, and population baseline for the analysis year.

Once the analytical baseline was established, it was then possible to evaluate the baseline PM and ozone air quality data against alternative PM and ozone standards. This evaluation allowed the analysis to identify potential areas that would violate a particular standard. The analysis labels these areas as potential nonattainment areas. For example, given the baseline air quality data, which areas in the continental United States would potentially violate the .08 ppm, 8-hour, 4th highest concentration ozone standard?

Having established the degree of potential violation in each nonattainment area, the analysis relied on information from a variety of prognostic and empirical models to determine the amount of emission reductions that would be required in each nonattainment area to enable the area to attain the standard. For ozone, the pollutants of concern are volatile organic compounds (VOC's) and nitrogen oxides (NOx). In addition to VOC's and NOx, the pollutants of concern for PM are sulfur oxides (SOx), primary particles (PM), and ammonium. The use of the various models in combination allowed the analysis to discern a relationship between emissions and ambient concentrations of PM and ozone. [*Note*: This explanation oversimplifies the analyses for ozone and PM. The analyses used separate models to estimate emission reductions and air quality changes. For example, the ozone analysis used separate models to sequentially estimate necessary the emission reductions and resulting air quality changes while the PM analysis used one model that was capable of manipulating both types of information simultaneously. The oversimplified explanation is provided only for the purpose of describing the type of information that is necessary for estimating potential costs and benefits.]

As mentioned earlier, the 1996 PM and ozone analyses were prepared separately. Although the analyses shared a common baseline, the estimation of potential emission reductions and resulting air quality ("post-control" air quality) were conducted independently for PM and ozone. These estimates were calculated separately for PM and ozone because a model integrating both pollutants was not available. Despite this model constraint, the 1997 RIA improved on the previous analyses by partially "integrating" the analyses. (An adjustment was also made to adjust the analytical year or the analysis to the year 2010.) Although the RIA continued to use the same models, the analyses were "integrated" by using the air quality models jointly rather than separately. The previous 1996 analyses evaluated only ozone air quality changes within the ozone analysis and only PM air quality changes within the PM analysis. However, air quality modeling shows that VOC and NOx emissions affect ambient concentrations of both ozone and PM. The joint use of the air quality models allowed the ozone analysis to provide information on the co-benefits for reducing ambient PM concentrations due to the application of controls strategies specifically employed to reduce ozone. A new baseline of lower PM concentrations would thus be established for the PM analysis.

5. CONTROL STRATEGY SELECTION

The air quality and emission reduction information developed during the air quality modeling phase of the analysis are used in conjunction with a database of control measures in order to develop cost estimates. In general, the database consists of known "command and control" technologies (add-on control devices installed downstream from an air pollution source) because quantitative information is most often available for these types of controls. To a smaller extent, less conventional approaches such as pollution prevention measures, trading programs, and educational and advisory measures are also included in the 1997 RIA. Recognizing the analysis is a future year analysis, the 1997 RIA also includes a discussion of technological advancements that might be viable within the next decade. The control measure database does not include these "emerging technologies" due to an inability to reliably quantify the effects of these measures.

Additional information within the database include the types of emission sources (e.g., utilities versus automobiles) to which each control measure can be applied, the types of pollutants that the measure can control, and the average annual incremental cost per ton of pollutant reduction associated with each potential application of the control measure. For the purposes of the analysis, the average annual incremental cost per ton is defined as the difference in the annual cost of a control measure and the annual cost of the baseline control (if any), divided by the difference in the annual mass of pollutant emissions removed by the control measure and the emissions removed by the baseline control.

The database allows control measures to be ranked by the average annual incremental cost information associated with each measure. Upon determining the amount of emission reductions that are required, the analyst can use the database to choose the lowest cost per ton technology first, the second-lowest cost per ton technology second, etc. Within each potential nonattainment area, the analyst applied additional levels of control until either: (1) the required emission reductions were met and the area was classified as being able to attain the standard or (2) the control measure database was exhausted for the nonattainment area before all emission reduction goals were met. In the second case, the analysis was labeled a "partial attainment" analysis since some areas were projected to encounter difficulty in attaining the standard by 2010 using currently well-documented technologies. (Each alternative standard analyzed in the RIA included some areas that could only partially attain the standard.) [*Note:* Although the RIA imposes controls on specific emission sources, the decision on which sources to control will ultimately be made by the individual States.]

6. COST AND ECONOMIC IMPACT ESTIMATION

The purpose of the cost and economic analyses is to estimate potential private and social costs due to implementation of the revised air quality standards. Information within the control measure database allows the estimation of both emission reductions and costs. As explained in the precious section, the database allows the control measures to be matched to specific emission source categories in specific areas. Once the control measures are selected, it is possible to: (1) estimate national control costs associated with a specific air quality scenario and (2) examine potential distributional effects. Cost information is expressed in dollar terms (dollar per ton of pollutant removed) and includes costs for typical factors such as new equipment and additional operation and maintenance costs. A national cost estimate is calculated by summing the cost per ton data for all tons of pollutants removed across all emission source categories.

It is important to recognize that although the benefit-cost analysis uses a set of assumptions to develop cost estimates, the actual determination of how areas will meet the air quality standards will be determined by the individual states within the United States. The states must develop State Implementation Plans based on more detailed area-specific models using more complete information that is available to the EPA for the development of its national analysis. For this reason, while the national benefit-cost analysis may provide a good approximation of the national costs and benefits of the revised standards, this analysis cannot accurately predict what will occur in individual areas.

In addition to facilitating a national cost estimate, the availability of cost data on an industry-specific basis allows the analyst to focus additional economic analyses on industry sectors or areas that might be significantly affected. The estimation of economic impacts (e.g., price, quantity, or employment changes) requires the cost data to be used in conjunction with economic data such as sales revenue, market conditions, and employment data. The impracticality of modeling all market sectors in the U.S. forces the analyst to screen for sectors that might be disproportionately affected. A simple calculation of cost-to-sales revenue may provide useful information for screening purposes. However, it is important to recognize that many uncertainties are associated with the economic impact analysis. For example, it is not possible to know the specific establishments or firms that will be required to implement control strategies. Both cost and revenue (or sales) data only represent national average statistics. A simple calculation of an average cost-to-sales percentage does not provide economic impact information for specific establishments.

7. BENEFITS ESTIMATION

The purpose of the benefits analyses is to estimate potential human health and welfare (defined here as all benefits categories except human health) effects that may be associated with changing the nation's air quality. Ideally, the goal is to assign a monetary value to each benefits category or endpoint so that benefits and costs can be expressed in the same unit. In reality, benefits analysis often falls short of quantifying all effects categories due to information deficiencies.

Assessing the benefits of the PM and ozone regulatory actions is dependent upon the ability to model air quality. Upon the selection of control measures, the analyst can tally all expected emission reductions specific to each geographic (nonattainment) area. The air quality models translate the emission reductions into reduced ambient concentrations of ozone or particulate matter (PM). The ambient ozone and PM concentrations resulting from the application of control measures is referred to as "post-control" air quality. The change in air quality from baseline conditions to post-control is a key element in the estimation of benefits.

A second key factor in benefits estimation is the estimation of concentration-response functions. A concentration-response function specifies a relationship between the presence of a pollutant (e.g., the measured concentration of PM or ozone in a specified environment) and a physical response (e.g., coughing, reduced plant yields). Each concentration-response function is used in conjunction with the estimated air quality changes to quantify the physical effects believed to be associated with the air quality changes. For example, completion of this step allows the analyst to estimate the number of fewer coughs a person might experience due to improved air quality. This quantified effects information provides useful information for evaluating potential air quality changes. However, it is not possible to quantify all effects categories. For example, we may suspect an association between chronic exposure to air pollution and adverse health effects but data is not yet available for the quantification of these effects. These effects are referred to as unquantified benefits and are discussed in a qualitative manner in the analysis.

A third key factor in benefits estimation is to assign an appropriate monetary value to the physical effects that have been valued. As explained earlier, it is important to complete this step so that benefits and costs may be compared in the same terms. In order to accomplish this objective, the analyst must determine the value individuals place on avoiding the adverse physical effects associated with exposure to air pollution. For example, what is the value of avoiding a cough or hospital visit for a respiratory illness? In the case of welfare benefits, what is the value of increasing yields of the nation's wheat crops? The social benefits associated with a change in the environment is calculated as the sum of each individual's willingness to pay for the change.

In the case of valuing human health benefits, the analyses use a concept called willingness-to-pay (WTP). A WTP value is estimated for the majority (but not all, due to data limitations) of physical effects endpoints. The values attempt to incorporate factors such as the direct cost of becoming ill (e.g., hospitalization costs), the change in quality of life due to discomfort, pain and suffering, or limitations on physical activities. The method for valuing agricultural benefits is through the use of computer-simulated supply and demand models that provide information on changes to producer and consumer surplus due to a change in crop yields.

Lack of information often prevents analysts from identifying, quantifying, and monetizing all potential benefits categories that may result from environmental regulation. As a contrasting example, a cost analysis is expected to provide a more comprehensive estimate of the cost of an environmental regulation because technical information is available for identifying the technologies that would be necessary to achieve the desired pollution reduction. In addition, market or economic information is available for the many components of a cost analysis (e.g., energy prices, pollution control equipment, etc.). A similar situation typically does not exist for estimating the benefits of environmental regulation. The nature of this problem is due to the non-market characteristic of many benefits categories. Since many pollution effects (e.g., adverse health or agricultural effects) traditionally have not been traded as market commodities, economists and analysts cannot look to changes in market prices and quantities to estimate the value of these effects. The inability to quantify all benefits categories as well as the possible omission of relevant environmental benefits categories leads to a likely underestimation of the monetized benefits. Although it is not possible to estimate the magnitude of the potential underestimation, it is important to highlight potential benefits categories for which quantitative information is not available at this time. Table 1 lists the anticipated health and welfare benefits categories that are reasonably associated with reducing PM and ozone in the atmosphere, specifying those for which sufficient quantitative information exists to permit benefits estimation.

8. COMPARISON OF MONETIZED BENEFITS AND COSTS

The completion of the benefits and cost analyses makes possible one method for quantitatively evaluating the revised standards (since an effort has been made to express as many factors in the same units (dollars) as possible). The monetized benefits, costs, net benefits, and, for the promulgated PM and ozone standards are presented in Table 2. Note that the estimates represent a "partial attainment" scenario for the promulgated standards. As previously explained, in some projected nonattainment areas, the control measure database was not able to the level of emission reductions that would have been necessary to model the area as an attainment area. The analysis cannot model additional control measures that are not currently in the database and therefore, does not arbitrarily assume all areas will attain the standards in the year 2010. This partial attainment scenario may not be an unrealistic snapshot of the year 2010 since many areas will be given more time to attain the revised standards. Therefore, the year 2010 reflects progress towards attainment but not complete attainment.

Table 1: Particulate Matter and Ozone Benefits Categories

	Unquantified Benefit Categories	Quantified Benefit Categories (incidences reduced and/or dollars)
Health Categories (reduced incidences of ...)	Morphological changes Altered host defense mechanisms Cancer Other chronic respiratory disease Infant mortality Mercury emission reductions Airway responsiveness Pulmonary inflammation and respiratory cell damage Chronic respiratory damage/premature aging of lungs	Premature Mortality Hospital admissions for: all respiratory illnesses congestive heart failure ischemic heart disease pneumonia chronic obstructive pulmonary disease Acute and chronic bronchitis Lower, upper, and acute respiratory symptoms Respiratory activity days Moderate or worse asthma Self-reported asthma attacks Cancer from air toxics Shortness of breath Work loss days Coughs Pain upon deep inhalation Changes in lung function
Welfare Categories (increased value or reduced damage to...)	Materials damage (other than consumer cleaning cost savings) Damage to ecosystems (e.g., acid sulfate deposition) Ecosystem and vegetation effects in Class I areas (e.g., national parks) Damage to urban ornamentals (e.g., grass, flowers, shrubs and trees in urban areas) Reduced yields of tree seedlings and forests Nitrates in drinking water Brown clouds	Commodity crops Fruit and vegetable crops Consumer cleaning cost savings Visibility Nitrogen deposition in estuarine and coastal waters Worker productivity

Table 2: Estimated Benefits and Costs of the PM and Ozone NAAQS
(1990 $; year = 2010; partial attainment)

PM and Ozone NAAQS Combined		
Monetized Benefits	=	$19.4 billion to $106 billion
Costs	=	$9.7 billion
Net Benefits	=	$9.7 billion to $96 billion
PM NAAQS		
Monetized Benefits	=	$19 billion to $104 billion
Costs	=	$8.6 billion
Net Benefits	=	$10 billion to $95 billion
Ozone NAAQS		
Monetized Benefits	=	$0.4 billion to $2.1 billion
Costs	=	$1.1 billion
Net Benefits	=	$(0.7) billion to $1.0 billion

Non-Monetized Benefits Categories:

-Reduced chronic respiratory damage/premature aging of lungs
-Reduced susceptibility to respiratory infection
-Reduced cancer and other air toxics health effects
-Reduced incidence of significant decreases in pulmonary function
-Reduced acute inflammation and cell damage in respiratory systems
-Reduced infant mortality
-Protection of national parks, forests and ecosystems (e.g., from acid sulfate deposition)
-Increased yields of tree seedlings
-Reduced damage to urban ornamentals (e.g., grass, flowers, shrubs, and trees in urban areas)
-Reduced nitrates in drinking water

Notes: PM NAAQS = annual $PM_{2.5}$ standard of 15 $\mu g/m^3$
24-hour $PM_{2.5}$ standard of 65 $\mu g/m^3$
Ozone NAAQS = .08 ppm, 8-hour, 4th highest concentration

( ) denotes negative values

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