Executive Summary

Overview

This Regulatory Impact Analysis (RIA) provides EPA's estimates of the range of the monetized human health benefits, control costs, and net benefits associated with meeting the revised suite of standards for fine particles ($PM_{2.5}$) that were promulgated by EPA on September 21, 2006, as well as for meeting a one alternative. The final rule established a 24-hour standard of 35 µg/m^3 and retained the annual standard of 15 µg/m^3. EPA also promulgated a final decision to retain the current 24-hour PM_{10} standards and to revoke the current annual PM_{10} standards, in order to maintain protection against the health and welfare effects of thoracic coarse particles ($PM_{10-2.5}$). As was the case for the interim RIA accompanying the proposed rulemaking, due to data and modeling limitations preclude EPA from assessing the costs and benefits of retaining the existing PM_{10} standards. This summary outlines the basis for and approach used in the RIA, presents the key results and insights derived from the analyses, and highlights key uncertainties and limitations.

In setting primary ambient air quality standards, EPA's responsibility under the law is to establish standards that protect public health. The Clean Air Act ("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 base this decision on health considerations; economic factors cannot be considered.

This prohibition against the consideration of cost in the setting of the primary air quality standards, however, does not mean that costs, benefits or other economic considerations are unimportant or should be ignored. The Agency believes that consideration of costs and benefits is an essential decision making tool for the efficient *implementation* of these standards. The impacts of cost, benefits, and efficiency are considered by the states during this process, when states are making decisions regarding what timelines, strategies, and policies make the most sense.

This $PM_{2.5}$ NAAQS RIA is focused on development and analyses of illustrative control strategies to meet alternative suites of standards in 2020, the latest year by which the Clean Air Act generally requires full attainment of the new standards. Because the states are ultimately responsible for implementing strategies to meet the revised standards, the RIA provides insights and analysis of a limited number of illustrative control strategies that states might adopt to meet the revised standards. These strategies are subject to a number of important assumptions, uncertainties and limitations, which we document in the relevant portions of the analysis.

EPA presents this analysis pursuant to Executive Order 12866 and the guidelines of OMB Circular A-4.[1] These documents present guidelines for EPA to assess the incremental benefits and costs of the selected regulatory approach as well as one less stringent, and one more stringent, option. In this RIA, the 1997 standards represent the less stringent option, and the

[1] For a copy of these requirements, see: http://www.whitehouse.gov/OMB/inforeg/eo12866.pdf and http://www.whitehouse.gov/omb/circulars/a004/a-4.html.

alternative suite of standards including a tighter annual standard of 14 µg/m^3 together with the revised 24-hour standard of 35 µg/m^3 represents the more stringent option.

ES.1 Approach to the Analysis

The RIA consists of multiple analyses including an assessment of the nature and sources of ambient $PM_{2.5}$; estimates of current and future emissions of relevant gases and particles that contribute to the problem; air quality analyses of baseline and alternative strategies; development of illustrative control strategies to attain the standards alternatives in future years; analyses of the incremental costs and benefits of attaining the alternative standards, together with an examination of key uncertainties and limitations; and a series of conclusions and insights gained from the analysis.

Nature of $PM_{2.5}$

Particulate matter (PM) is a highly complex mixture of solid particles and liquid droplets that occur in the atmosphere together with numerous pollutant gases that interact with them. Atmospheric particles can be grouped according to various characteristics. For regulatory purposes, fine PM are measured as $PM_{2.5}$. Particles are emitted directly from sources (referred to as primary PM) and are also formed through atmospheric chemical reactions (referred to as secondary PM). Primary $PM_{2.5}$ consists of carbonaceous material (e.g. soot, and accompanying organics)—emitted from cars, trucks, heavy equipment, forest fires, and burning waste, as well as from coke ovens, metals from combustion and industrial processes, with some small contribution from crustal materials. Secondary $PM_{2.5}$ forms in the atmosphere from precursor gases including sulfur and nitrogen oxides from power, industrial and other combustion and process sources, certain reactive organic gases from diesel and other mobile sources, solvents, fires, and biogenic sources such as trees, and ammonia from agricultural operations, natural, and other sources. Fine particles can be transported hundreds to thousands of miles from emissions sources. For this reason, fine particle concentrations in a particular area may have a substantial contribution from regional transport as well as local sources. As discussed more fully in Chapter 2, there are important regional differences in fine particle concentrations and composition that are important to recognize in developing control strategies.

Overview of Air Quality Modeling Methodology/Baseline emissions forecasts

As a first step in the national assessment of alternatives, the analysis forecasts emissions and air quality in 2015 and 2020 under a *regulatory base case* that incorporates national, regional, state and local regulations that are already promulgated and/or adopted. This base case does not forecast actions states may take to implement the existing $PM_{2.5}$ standards. The regulatory base case includes recent rules that will significantly reduce $PM_{2.5}$ concentrations in future years by addressing emissions from the power generation sector - the Clean Air Interstate Rule (CAIR), the Clean Air Mercury Rule (CAMR), and the Clean Air Visibility Rule (CAVR, which also affects some industrial boiler emissions), and mobile sources through national rules for light and heavy-duty vehicles and non-road mobile sources. Current state programs that address these and other source categories that were on the books as of early 2005 are also modeled for future years. Based on the emissions forecasts, EPA developed annual and daily $PM_{2.5}$ design value projections using the CMAQ model.[2]

Development and Application of Illustrative Control Strategies

The air quality modeling results for the *regulatory base case* (Figure ES-1, ES-2) provided the starting point for developing illustrative control strategies to attain the 1997 as well as the revised and alternative suites of standards that are the focus of this RIA. The figures show that by 2020, while $PM_{2.5}$ air quality would be significantly better than today under current requirements, several eastern and western States will need to develop and adopt additional controls to attain the revised standards. The modeling shown in Figure ES-2 suggests that under the revised suite of standards, greater reductions will be needed in some Western areas, particularly in California.

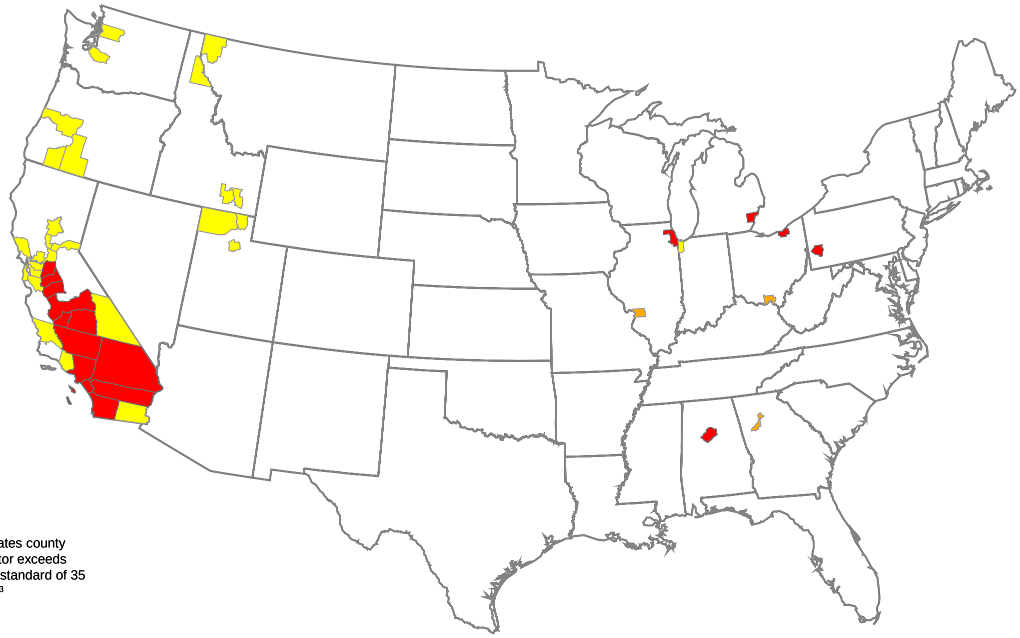
We followed a three-step process to simulate attainment in each of the areas forecast to need additional controls to meet the revised and alternative standards: 1) We identified cost-effective controls to apply in each projected nonattainment area and then simulated the resulting air quality change in an air quality model; 2) For those areas that did not attain under 1) we developed and simulated the results of applying additional known emission controls that were not applied in the initial strategy, and then evaluated attainment status considering the uncertainty in the analyses; 3) For areas that we determined would still not attain under the more readily identifiable control strategies in 1) and 2), we used a combination of qualitative and quantitative analysis to estimate the costs and benefits of fully attaining the standards. This included identification of potential trends in pollution control measures (such as greater adoption of hydrogen fuel cell vehicles), extrapolation of costs based on existing technologies, and estimation of benefits by “rolling back” monitor values to just attain the standards.

In developing strategies tailored to specific problem areas, we combined information from our air quality models and our emission control database. These combined data enabled us to selectively apply emission control measures on those industrial sources where it was most cost effective to do so—effectively generating the greatest estimated air quality improvement at the lowest cost. Because the national and regional programs summarized above (e.g. CAIR, mobile rules) will address a good portion of the regional transport contribution of $PM_{2.5}$, the first set of controls to meet the 1997 and revised standards focus on reductions in local emissions. These local emissions are defined as those occurring in the projected nonattainment county and immediate surrounding counties in the MSA. In some cases, the local control strategy did not provide enough emission reductions to attain the standards. In that case, we explored emission controls among a broader set of counties within the state containing the projected nonattainment area. The exception to this approach is California, where, due to the extreme and widespread nature of the nonattainment problem, we considered controls throughout Southern California in the attainment strategies.

[2] The methodologies for forecasting emissions and air quality and associated uncertainties are detailed in the Technical Support Document – “Air Quality Modeling Technique used for Multi-Pollutant Analysis?" (http://www.epa.gov/airmarkets/mp/aqsupport/airquality.pdf). The methodology used to derive the 98^{th} percentile 24-hour values is summarized in Chapter 4 of this RIA.

Figure ES-1. Counties Projected to Violate the Revised PM2.5 NAAQS in 2020

With CAIR/CAMR/CAVR and Some Current Rules** Absent Additional Local Controls



Indicates county monitor exceeds daily standard of 35 µg/m³

Indicates county monitor exceeds daily standard of 15 µg/m³

Indicates county monitor exceeds both the annual standard of 15 µg/m³ and the daily standard of 35 µg/m³

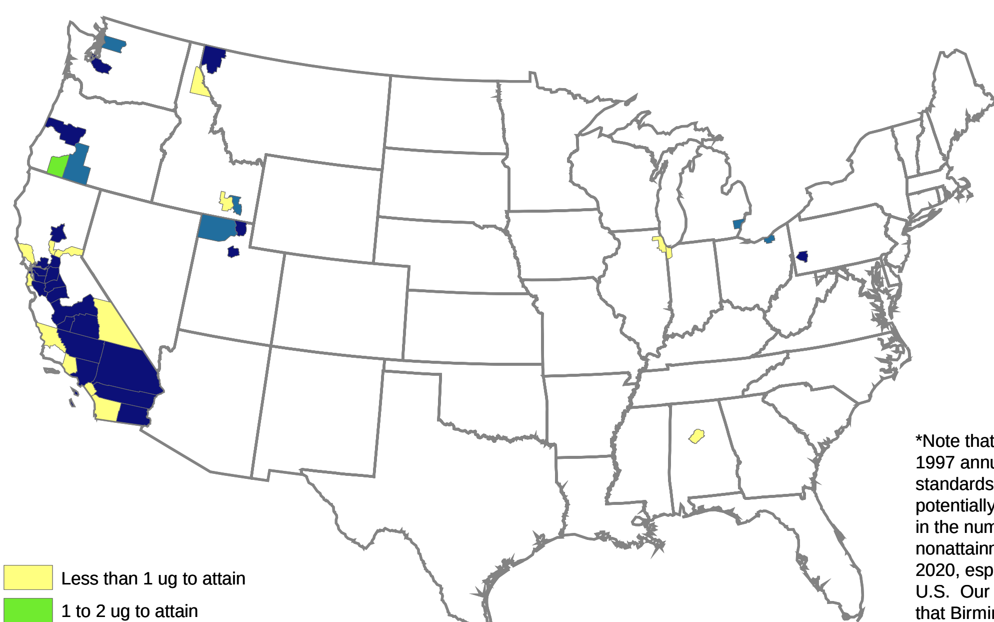
Counties Projected to Exceed Revised Standards

	Annual and Daily	*Annual Only*	*Daily Only*
2015	18	2	32
2020	17	3	28

* Projections as of September 2006.
**Current rules include Title IV of CAA, NOx SIP Call, and some existing State rules

Figure ES-2. Projected Reduction in Daily Design Value Needed to Attain the Revised Daily Standard of 35 µg/m³ in 2020

*Incremental to baseline with CAIR/CAMR/CAVR and Mobile Source Rules without additional local controls for attainment of the current standards**



Less than 1 ug to attain
1 to 2 ug to attain
2 to 5 ug to attain
Greater than 5 ug to attain

*Note that attainment with the 1997 annual and daily standards by 2020 would potentially result in reductions in the number of nonattainment counties in 2020, especially in the Eastern U.S. Our modeling suggests that Birmingham and Chicago would attain the revised daily standard in 2020 with measures needed to attain the 1997 standards.

Given the baseline air quality forecast under the alternative standard (14, 35), we added a regional control program covering both utility and industrial sources of SO_2 in portions of the Eastern US due to the number of projected nonattainment areas under the alternative standard, and prevalence of sulfate in the Eastern U.S.

In general, we were able to model attainment with the alternative standard in most regions of the country with a mix of local or regional control strategies. The major exceptions are in California and Utah, where modeling of such strategies indicated that several counties would not attain the revised or alternative standards.

ES-2. Results of Benefit-Cost Analysis

Table ES-1 summarizes the net benefits of attaining a revised and alternative $PM_{2.5}$ NAAQS. The table summarizes the full attainment benefits, economic costs and net benefits at 3 and 7 percent discount rates.

A new component of our benefits analysis is the expanded characterization of uncertainty about the impacts of PM on the risk of premature death. Since the publication of the RIA for the Clean Air Interstate Rule, we have completed a full-scale expert elicitation designed to more fully characterize the state of our understanding of the concentration-response function for PM-related premature mortality. The elicitation results form a major component of the current effort to use probabilistic assessment techniques to integrate uncertainty into the main benefits analysis.

To reflect our expanded understanding of uncertainty, and to move us towards implementation of the recommendations of the National Research Council's 2002 report "Estimating the Public Health Benefits of Proposed Air Pollution Regulations," our summary benefits estimates are presented as ranges, and include additional information on the quantified uncertainty distributions surrounding the points on those ranges, derived from both the epidemiological studies and the expert elicitation.

Tables ES-2 and ES-3 summarize the estimated benefits associated with attaining the revised and alternative $PM_{2.5}$ standards, incremental to our modeled attainment strategy for the 1997 standards. These tables include both the estimated reductions in the incidence of mortality and morbidity and the monetized value associated with these reductions in incidence. In addition to these health benefits, we estimate that, incremental to our modeled attainment strategy for the 1997 standards, the monetary benefits associated with improvements in visibility in selected national parks and wilderness areas in 2020 will be $530 million for the revised standards, and $1,200 million for the alternative standards.

Table ES-2 and ES-3 summarize the range of incidence and the range of total monetized benefits (health plus visibility) across several sources of mortality effect estimates that we used in our analysis. The ranges reflect two different sources of information about the impact of reductions in PM on reductions in the risk of premature death, including both the published epidemiology literature and an expert elicitation study conducted by EPA in 2006. Estimates based on the American Cancer Society study show benefits of meeting the revised 24-hour PM2.5 standard at $17 billion a year in 2020. In order to provide an indication of the sensitivity of the benefits estimates to alternative assumptions, in Chapter 5 we present a variety of benefits estimates based on both epidemiological studies (including the American Cancer Society Study and the Six

Cities Study) and the expert elicitation. EPA intends to ask the Science Advisory Board to provide additional advice as to which scientific studies should be used in future RIAs to estimate the benefits of reductions in PM.

Table ES-1: Comparison of Full Attainment Benefits with Social Costs[f], Incremental to Attainment of 1997 Standards (Billion 1999$)

	Revised standard of 15/35 ($\mu g/m^3$)			Alternative standards of 14/35 ($\mu g/m^3$)		
	Benefits[a]	*Costs*[b]	*Net benefits*[c]	*Benefits*[a]	*Costs*[b]	*Net benefits*[c]
Benefits Based on Mortality Function from the American Cancer Society Study and Morbidity Functions from the Published Scientific Literature[d]						
3%	$17	$5.4	$12	$30	$7.9	$22
7%	$15	$5.4	$9	$26	$7.9	$18

Benefits Range Based on Expert Elicitation Derived Mortality Functions and Morbidity Functions from the Published Scientific Literature[e]

	Revised 15/35: Benefits Low Mean	Revised 15/35: Benefits High Mean	Revised 15/35: Costs	Revised 15/35: Net benefits Low Mean	Revised 15/35: Net benefits High Mean	Alternative 14/35: Benefits Low Mean	Alternative 14/35: Benefits High Mean	Alternative 14/35: Costs	Alternative 14/35: Net benefits Low Mean	Alternative 14/35: Net benefits High Mean
3%	$9	$76	$5.4	$3.5	$70	$17	$140	$7.9	$8.7	$130
7%	$8	$64	$5.4	$2.4	$59	$15	$120	$7.9	$6.7	$110

[a] Results reflect the use of two different discount rates: 3% and 7%, as recommended in EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b) and OMB Circular A-4 (OMB, 2003). Results are rounded to two significant digits

[b] Includes roughly $180 Million in supplemental engineering costs.

[c] Estimates rounded to two significant digits after calculations.

[d] based on Pope et al 2002, used as primary estimate in previous RIAs.

[e] Although the overall range across experts is summarized in this table, the full uncertainty in the estimates is reflected by the results for the full set of 12 experts. The twelve experts' judgments as to the likely mean effect estimate are not evenly distributed across the range illustrated by arraying the highest and lowest expert means. The distribution of benefits estimates associated with each of the twelve expert responses can be found in Chapter 5.

[f] For the purposes of comparison with the benefits, EPA uses the total social cost estimate which is slightly higher than the engineering cost

Table ES-2. Estimated Reduction in Incidence of Adverse Health and Welfare Effects Associated with Attaining the Revised and Alternative Standards, Incremental to Attainment of the 1997 Standards (95 Percent Confidence Intervals Provided in Parentheses)

Estimate	Revised Standards (15/35)	Alternative Revised Standards (14/35)
Mortality		
Estimate based on American Cancer Society study[a]	2,500 (1,000 – 4,100)	4,400 (1,700 – 7,100)
Range based on expert elicitation results[b]		
Low Mean	1,200 (0 – 5,800)	2,200 (0 – 11,000)
High Mean	13,000 (6,400 – 19,000)	24,000 (12,000 – 35,000)
Morbidity		
Chronic bronchitis (age >25 and over)	2,600 (490 – 4,800)	4,600 (850—8,300)
Nonfatal myocardial infarction (age >17)	5,000 (2,700 – 7,200)	8,700 (4,800 – 13,000)
Hospital admissions—respiratory (all ages)[b]	530 (260 – 800)	980 (490 – 1,500)
Hospital admissions—cardiovascular (age >17)[c]	1,100 (690 – 1,500)	2,100 (1,300 – 2,800)
Emergency room visits for asthma (age <19)	1,200 (730 – 1,700)	3,200 (1,900 – 4,500)
Acute bronchitis (age 8–12)	7,300 (–260 – 15,000)	13,000 (–440 – 25,000)
Lower respiratory symptoms (age 7–14)	56,000 (27,000 – 84,000)	88,000 (43,000 – 130,000)
Upper respiratory symptoms (asthmatic children, age 9–18)	41,000 (13,000 – 70,000)	65,000 (20,000 – 110,000)
Asthma exacerbation (asthmatic children, age 6–18)	51,000 (5,600 – 150,000)	79,000 (8,900 – 230,000)
Work loss days (age 18–65)	350,000 (300,000 – 390,000)	550,000 (480,000 – 620,000)
Minor restricted-activity days (age 18–65)	2,000,000 (1,700,000 – 2,300,000)	3,300,000 (2,700,000 – 3,800,000)

[a] The estimate is based on the concentration-response (C-R) function developed from the study of the American Cancer Society cohort reported in Pope et al (2002), which has previously been reported as the primary estimate in recent RIAs.

[b] The low mean estimate is based on the C-R function provided Expert K. The high mean estimate is based on the C-R function provided by Expert E. The expert elicitation project is described in greater detail in Chapter 5, and a complete report of the project is available on EPA's website. . Although the overall range across experts is summarized in this table, the full uncertainty in the estimates is reflected by the results for the full set of 12 experts. The twelve experts' judgments as to the likely mean effect estimate are not evenly distributed across the range illustrated by arraying the highest and lowest expert means. Likewise the 5th and 95th percentiles for these highest and lowest judgments of the effect estimate do not imply any particular distribution within those bounds. The distribution of mortality estimates associated with each of the twelve expert responses can be found in Chapter 5.

Table ES-3. Estimated Annual Monetized Benefits in 2020 of Illustrative Implementation Strategies for the Selected and Alternative $PM_{2.5}$ NAAQS, Incremental to Attainment of the 1997 Standards

Note: Unquantified benefits are not included in these estimates, thus total benefits are likely to be larger than indicated in this table.

	Total Full Attainment Benefits[a] (billions 1999$)			
	15/35 (μg/m3)		*14/35 (μg/m3)*	
Benefits Based on Mortality Function from the American Cancer Society Study and Morbidity Functions from the Published Scientific Literature [b]				
Using a 3% discount rate	$17 ($4.1 – $36)		$30 ($7.3 - $63)	
Using a 7% discount rate	$15 ($3.5 – $31)		$26 ($6.4 - $54)	
Benefits Range Based on Expert Elicitation Derived Mortality Functions and Morbidity Functions from the Published Scientific Literature[c]				
	Low Mean	High Mean	Low Mean	High Mean
Using a 3% discount rate	$9 ($0.8 - $42)	$76 ($19-$150)	$17 ($1.7 - $77)	$140 ($36 - $280)
Using a 7% discount rate	$8 ($0.8 - $36)	$64 ($16 - $130)	$15 ($1.6 - $66)	$120 ($31 - $240)

[a] Results reflect the use of two different discount rates: 3% and 7%, as recommended in EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b) and OMB Circular A-4 (OMB, 2003). Results are rounded to two significant digits.

[b] The estimate is based on the concentration-response (C-R) function developed from the study of the American Cancer Society cohort reported in Pope et al (2002), which has previously been reported as the primary estimate in recent RIAs.

[c] Although the overall range across experts is summarized in this table, the full uncertainty in the estimates is reflected by the results for the full set of 12 experts. The twelve experts' judgments as to the likely mean effect estimate are not evenly distributed across the range illustrated by arraying the highest and lowest expert means. Likewise the 5th and 95th percentiles for these highest and lowest judgments of the effect estimate do not imply any particular distribution within those bounds. The distribution of benefits estimates associated with each of the twelve expert responses can be found in Chapter 5.

Table ES-4 summarizes the total annualized engineering and social costs of meeting the current standard and the alternative scenarios using 3 and 7 percent discount rates. Total annualized costs are estimated from a baseline inventory in 2020 that reflects controls for CAIR/CAMR/CAVR and other on-the-books rules. Based on engineering cost estimates, the incremental cost of the revised standards (15/35) is approximately $5.0 to $5.1 billion using 3 and 7 percent discount rates, respectively. The incremental costs for the alternative standards are $6.8 to $6.9 billion using 3 and 7 percent discount rates, respectively. These cost numbers are highly uncertain because they include the extrapolated costs of full attainment in California and Salt Lake City. Approximately $4.5 billion of the incremental cost of achieving both 15/35 and 14/35 is attributable to these extrapolated full attainment costs. An analysis of the costs and benefits of attaining the 1997 standards in 2015 is provided in Appendix A.

For the purposes of comparison with the benefits, EPA uses the total social cost estimate which is slightly higher than the engineering cost. Total social costs (including the general equilibrium impacts on GDP) are estimated to be $5.4 billion in 2020 for the revised standards, and $7.9 billion for the alternative standards.

Table ES-4. Comparison of Total Annualized Engineering Costs Across PM NAAQS Scenarios (millions of 1999 dollars, 7% interest rate) [a]

	Scenario	
Source Category	*Revised Stds: 15/35*	*Alternative Revised Stds: 14/35*
EGU's	**$400**	**$1,100**
Mobile Sources	**$60**	**$60**
Non-EGU's	**$380**	**$1,300**
Incremental Residual Cost of Full Attainment[b]		
East	$3	$180
West	$300	$300
California	$4,000	$4,000
Total of Residual Costs of Full Attainment	**$4,300**	**$4,500**
Total Annualized Costs (incremental to the current standard) – using a 7% interest rate	**$5,100**	**$7,000**
Total Annualized Costs (incremental to the current standard) – using a 3% interest rate	**$5,050**	**$6,800**

a Upon review of emissions and air quality results of the control strategies applied in this RIA, some areas had residual nonattainment problems (requiring additional emissions reductions to meet the standard) as a result of our initial selection of controls. The incremental costs of fully attaining in these areas (the residual cost of full attainment) reflect extrapolated costs of additional control measures that would be necessary to bring areas with residual nonattainment into compliance. Chapter 4 provides details of the assessment.

b The incremental cost of residual nonattainment (beyond our modeled control strategy) for the West and California are extrapolated. The methodology used to derive these estimates is described in Chapter 6. These estimates are derived using a 7 percent discount rate. The incremental cost of residual non-attainment in the East are based on supplemental carbonaceous particle emission controls, which are detailed in Chapter 4.

ES-3. Uncertainties and Limitations

Air Quality Modeling and Emissions

- Overall, the air quality model performs well in predicting monthly to seasonal concentrations, similar to other state-of-the-science air quality model applications for $PM_{2.5}$. However, there is less certainty in analyses involving 24-hour model predictions than those involving longer-term averages concentrations and performance is better for the Eastern U.S. than for the West. In both the East and West, secondary carbonaceous aerosols are the most challenging species for the modeling system to predict in terms of evaluation against ambient data.

- Underestimation biases in the mobile source emission inventories lead to uncertainty as to the relative contribution of mobile source emissions to overall PM levels.

- Additional uncertainty is introduced as a result of our limited understanding concerning the collective impact on future-year emission estimates from economic growth estimates, increases in technological efficiencies, and limited information on the effectiveness of future control programs.

- The regional scale used for air quality modeling can understate the effectiveness of controls on local sources in urban areas as compared to area-wide or regional controls. This serves to obscure local-scale air quality improvements that result from urban-area controls.

Controls and Cost

- The technologies applied and the emission reductions achieved in these analyses may not reflect emerging control devices that could be available in future years to meet any requirements in SIPs or upgrades to some current devices that may serve to increase control levels.

- The effects from "learning by doing" are not accounted for in the emission reduction estimates for point and area sources. It is possible that an emissions control technology may have better performance in reducing emissions due to greater understanding of how best to operate and maintain the technology. As a result, we may understate the emission reductions estimated by these analyses. The mobile source control measures do account for these learning by doing effects.

- The effectiveness of the control measures in these analyses is based on an assumption that these controls are well maintained throughout their equipment life (the amount of time they are assumed to operate). To the extent that a control measure is not well maintained, the control efficiency may be less than estimated in these analyses. Since these control measures must operate according to specified permit conditions, however, it is expected that the maintenance of controls should yield control efficiencies at or very close to those used in these analyses. As a result, we may overstate the emission reductions estimated by these analyses.

- The application of area source control technologies in these analyses assume that a constant estimate for emission reduction is reasonable despite variation in the extent or scale of application (e.g. dust control plans at construction sites). To the extent that there are economies of scale in area source control applications, we may overstate the emission reductions estimated by these analyses.

- The cost extrapolation method used to develop full attainment costs is highly uncertain and may significantly under or overstate future costs of full attainment.

Benefits

- This analysis assumes that inhalation of fine particles is causally associated with premature death at concentrations near those experienced by most Americans on a daily basis. Although biological mechanisms for this effect have not yet been specifically identified, the weight of the available epidemiological, toxicological, and experimental evidence supports an assumption of causality. The impacts of including a probabilistic representation of causality are explored using the results of the expert elicitation.

- This analysis assumes that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because the composition of PM produced via transported precursors emitted from EGUs may differ significantly from direct PM released from automotive engines and other industrial sources. In accordance with advice from the CASAC, EPA has determined that no clear scientific grounds exist for supporting differential effects estimates by particle type, based on information in the most recent Criteria Document. In chapter 5, we provide a decomposition of benefits by PM component species to provide additional insights into the makeup of the benefits associated with reductions in overall $PM_{2.5}$ mass (See Tables 5-32 and 5-33).

- This analysis assumes that the concentration-response (CR) function for fine particles is approximately linear within the range of ambient concentrations under consideration (above the assumed threshold of 10 $\mu g/m^3$). Thus, we assume that the CR functions are applicable to estimates of health benefits associated with reducing fine particles in areas with varied concentrations of PM, including both regions that are in attainment with $PM_{2.5}$ standards and those that do not meet the standards. However, we examine the impact of this assumption by looking at alternative thresholds in a sensitivity analysis.

- A key assumption underlying the entire analysis is that the forecasts for future emissions and associated air quality modeling are valid. Because we are projecting emissions and air quality out to 2020, there are inherent uncertainties in all of the factors that underlie the future state of emissions and air quality levels.

ES-4. Conclusions and Insights

EPA's analysis has estimated the health and welfare benefits of reductions in ambient concentrations of particulate matter resulting from a set of illustrative control strategies to reduce emissions of $PM_{2.5}$ precursors. The results suggest there will be significant additional health and welfare benefits arising from reducing emissions from a variety of sources in and around projected nonattaining counties in 2020. While 2020 is the latest date by which states would generally need to demonstrate attainment with the revised standards, it is expected that benefits (and costs) will begin occurring earlier, as states begin implementing control measures to show progress towards attainment.

There are several important factors to consider when evaluating the relative benefits and costs of the attainment strategies for the revised 15/35 and alternative 14/35 standards:

- California accounts for a large share of the total benefits and costs for both of the evaluated standards (80 percent of the benefits and 78 percent of the costs of attaining the revised standards, and 50 percent of the benefits and 58 percent of the costs of attaining the alternative standards). Because we were only able to model a small fraction of the emissions controls that might be needed to reach attainment in California, the proportion of California benefits in the "residual attainment" category are large relative to other areas of the U.S. Both the benefits and the costs associated with the assumed reductions in California are particularly uncertain.

- The comparative magnitudes and distributions of benefits estimates for the revised and alternative standards are significantly affected by differences in assumed attainment strategies. As noted above, attainment with the revised standards was simulated using mainly local reductions, while a supplemental eastern regional SO2 reduction program was used for the alternative. Under the assumptions in the analyses, the regional strategy used in meeting the alternative standard resulted in significant additional benefits in attainment areas than the local area strategy used for the revised standard. This makes the difference in benefits between the revised and alternative standards larger than can be accounted for by only the 1 µg/m3 lower annual level for the alternative standards.

- Given current scientific uncertainties regarding the contribution of different components to the effects associated with $PM_{2.5}$ mass, this analysis continues to assume the contribution is directly proportional to their mass. In the face of uncertainties regarding this assumption, we believe that strategies which reduce a wide array of types of PM and precursor emissions will have more certain health benefits than strategies that are more narrowly focused. For this reason, the analysis provides a rough basis for comparing the assumed benefits associated with different components for different strategies. The illustrative attainment strategy for the revised standards results in a more balanced mix of reductions in different $PM_{2.5}$ components than does the regional strategy for the alterative standards. Until a more robust scientific basis exists for making reliable judgments about the relative toxicity of PM, it will not be possible to determine whether the strategy of reducing a wide array of PM types is the optimal approach.

- Because of the limitations and uncertainties in the emissions and air quality components of our assessment, the specific control strategies that might be the most effective in helping areas to reach attainment are still very uncertain. For example, the high likelihood of mobile sources emissions being significantly understated biases the analyses by requiring additional controls from other sources in both the base case and the analyses of the 1997, revised, and alternative standards.

- Previous analyses have focused on measuring cost-effectiveness by comparing control measures in terms of cost per ton of emissions reduced. In those analyses, direct PM controls usually appear to be less cost-effective because the cost per ton is in the tens of thousands of dollars per ton, while SO2 and NOx controls are on the order of thousands of dollars per ton. The current analysis demonstrates that when considered on a cost per microgram reduced basis, controls on directly emitted PM are often the most cost-effective, because of the significant local contribution of direct PM emissions to nonattaining monitors in urban areas. This finding suggests that states should consider ranking controls on a cost per microgram basis rather than a cost per ton basis to increase the overall cost-effectiveness of attainment strategies.