Interim Regulatory Impact Analysis for the $PM_{2.5}$ National Ambient Air Quality Standards

US Environmental Protection Agency
Office of Air Quality, Planning and Standards

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Executive Summary

Overview

This interim Regulatory Impact Analysis (RIA) summarizes our analysis to date of the monetized human health benefits and control costs associated with meeting revised standards for fine particles ($PM_{2.5}$) that were proposed by EPA on December 20, 2005, and several alternatives that are more and less stringent than the proposal. EPA also proposed revisions that would replace the current annual and daily PM_{10} standards with a new daily standard for thoracic coarse particles ($PM_{10-2.5}$). For reasons outlined more fully in Chapter 1, this RIA does not contain an analyses of these proposed revisions. In general, EPA expects that significantly fewer areas would violate these proposed standards as compared to the current PM_{10} standards. Due to data limitations and analytical issues, this analysis focuses on five urban areas. The RIA accompanying the final decision will include a national assessment. The analyses summarized in this chapter nevertheless provide a national overview of the effectiveness of current programs in attaining the alternative standards as well as implementation insights for illustrative control strategies to attain each alternative in the five selected areas. This summary provides an overview of the key data and preliminary conclusions of the RIA, including:

- Future-year predictions of $PM_{2.5}$ concentrations and attainment under current, proposed and alternative standards

- The nature of the $PM_{2.5}$ air quality problem

- Important limitations and uncertainties in our analysis that precluded an estimation of national benefits and costs

- Provisional conclusions from these interim analyses

Future-year predictions of $PM_{2.5}$ Concentrations and Attainment Under Alternative Standards

Alternative $PM_{2.5}$ NAAQS analyzed

The December 20, 2005 preamble to the proposed rule provides the rationale for EPA's proposed revisions to the primary $PM_{2.5}$ NAAQS and as well as other alternatives on which the Agency is requesting comment. In our analyses, we have selected a subset of options designed to encompass the range of alternative standards upon which the Agency is requesting comment. This analysis focused on both the incremental national air quality of the proposed and alternative standards, and the incremental costs and benefits in five urban areas, as compared to a regulatory base case and implementing the current standards as of 2015. The alternatives analyzed are summarized in the following table as combinations of the annual and daily $PM_{2.5}$ standards:

Table 1: Annual and Daily $PM_{2.5}$ NAAQS Considered in This Analysis

Combination of Annual and 98th percentile Daily Values, in µg/m^3	*Notes*
15/65	Current standards
15/40	Alternative for comment
15/35	Proposed revision
14/35	Alternative for comment
15/30	Alternative for comment

Overview of Air Quality Modeling Methodology

As a first step in the national assessment of alternatives, the analysis forecast emissions and air quality in 2015 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 affect the PM-related emissions from the power generation sector and a number of mobile source categories including 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 national mobile source 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 $PM_{2.5}$ projections using the CMAQ model.[1]

Summary of Attainment Analyses

Table 2 summarizes the results of these analyses in terms of the projected numbers of counties with monitors that would and would not attain the standards alternatives under the same regulatory base case for 2015. This is *not* a prediction of the air quality EPA would expect to occur in this future year because the baseline analyzed contains only current programs but not the additional reductions that will be made in response to State Implementation Plans (SIPs) designed to meet the current $PM_{2.5}$ or 8-hour ozone NAAQS. The PM2.5 SIPs are due in April 2008 and the ozone SIPS are due in June 2007. The Clean Air Act presumptively requires each area to attain the current $PM_{2.5}$ standards within 5 years of designation, by 2010, with authority for EPA to grant a state an attainment date extension of up to an additional 5 years for specific areas.

This regulatory base case scenario analysis suggests that EPA's recently promulgated national rules, in combination with existing state and local programs will make significant contributions to reducing projected $PM_{2.5}$ nonattainment in the eastern US under any of the standards alternatives analyzed, as compared to current air quality levels. EPA modeling indicates that by

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[1] 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 98th percentile 24-hour values is summarized in Appendix E of this RIA.

2015, 84 counties with monitors will attain the existing $PM_{2.5}$ standards out of the 116 such counties currently out of attainment just based on regulatory programs already in place. In addition, all areas in the eastern United States will have lower $PM_{2.5}$ concentrations in 2015 relative to present-day conditions. In most cases, the predicted improvement in $PM_{2.5}$ ranges from 10% to 20%.

Table 2. Summary of Projected County Attainment and Nonattainment Counts: Projected 2010 and 2015*

		Projected with Regulatory Base Case					
		2010			2015		
Standard Alternative (annual/daily in µg/m3)		National	East	West	National	East	West
15/65— current standard	Attain**	77	75	2	84	84	0
	Non-Attain	39	27	12	32	18	14
15/40	Attain**	81	75	6	90	84	6
	Non-Attain	57	27	30	48	18	30
15/35— Proposed	Attain**	102	98	4	115	111	4
	Non-Attain	89	43	46	76	30	46
14/35	Attain**	125	121	4	139	135	4
	Non-Attain	110	64	46	96	50	46
15/30	Attain**	129	129	0	148	148	0
	Non-Attain	197	135	62	178	116	62

*See Appendix E for details on projection method used here (i.e., Speciated Modeled Attainment Test--SMAT). There are some counties which may have complete ambient data for 24-hour standard, but incomplete data for the annual standard. These counties were not included in this analysis.

**These are counties with monitors that reported concentrations above the respective NAAQS alternative levels based on 2002-2004 data that are projected to attain the alternative in the forecast years noted.

Chapter 2 presents a series of maps with more specific details of the current, proposed and alternative $PM_{2.5}$ NAAQS attainment analyses results. Figure 1 below summarizes projected air quality and attainment status under each of the individual annual (14 and 15 µg/m^3) and daily (30, 35, 40, and 65 µg/m^3) standards considered in this analysis.

The major insights from this national scale analysis of alternatives include the following:

- As compared to the current standards, the proposed tighter daily standard of 35 ug/m^3 appears to have a bigger impact in the West than in the East, particularly after the forecast regulatory base case controls are more fully implemented. Most of the eastern counties that would not attain the standard in 2015 are part of nonattainment areas that are required to adopt further controls under the current standards. The increment above the daily standard is generally less than 5 µg/m^3.

- Southern and central California, which have a number of counties that violate the current daily standard, have increments in the range of 20 to 48 ug/m3 above the proposed daily standard.

- Most of the counties that would not attain the proposed daily standard in the northwestern quadrant of the US currently attain the annual and 24-hour NAAQS. These areas have lower annual averages, but can have high daily peaks during the winter months related to meteorological inversions and increased wood combustion emissions. The increment above the daily standard varies from 3 to 7 μg/m^3 in this region.

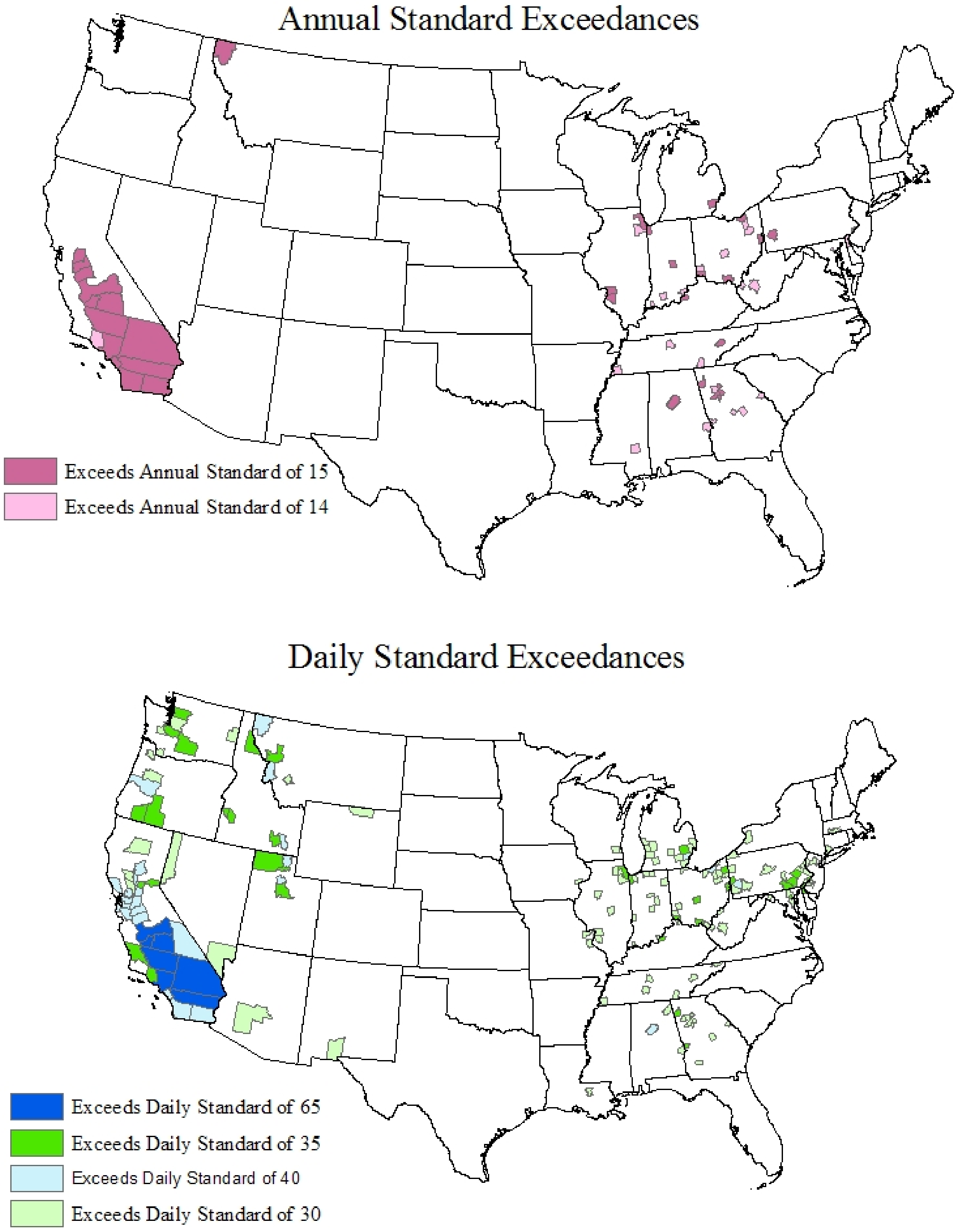

Figure 1: Counties Exceeding Current and Alterative Annual and 24-hour $PM_{2.5}$ NAAQS under Projected 2015 Regulatory Base Case

Nature of the $PM_{2.5}$ Air Quality Problem

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. Particles span many sizes and shapes and consist of thousands of different chemicals. Particles are emitted directly from sources and also are formed through atmospheric chemical reactions and are designated as ‘primary’ and ‘secondary’ particles, respectively. Particle pollution varies by season and location and is strongly affected by day to day variations in meteorology, such as temperature, stagnation, wind, cloud cover, and humidity. Daily $PM_{2.5}$ values at some locations can be high at any time of the year. For example in Seattle, which has low annual values, the highest levels of $PM_{2.5}$ concentrations occur during the winter months and are composed of carbon particles associated with wood and waste burning. By contrast, many areas in the eastern US have higher annual values with the highest daily values in the summer.

Because of their size and formation mechanisms, 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. The major $PM_{2.5}$ components, or species, are various elemental and organic carbonaceous compounds, sulfate and nitrate compounds, and crustal/metallic materials such as soil and ash.. Primary $PM_{2.5}$, that is matter which is originally emitted in particulate form, consists of carbonaceous material (e.g. soot)—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.

The chemical makeup of particles varies across the United States (Figure 2). For example, fine particles in the eastern half of the United States contain more sulfates than those in the West, while fine particles in southern California contain more nitrates than other areas of the country. Carbon is a substantial component of fine particles everywhere. Note that particle mass and composition can vary substantially by season, so annual averages should not be considered representative of specific high $PM_{2.5}$ days. These averages include both local and regional transport contributions to $PM_{2.5}$ based on recent data. Figure 3 focuses on estimates of the relative contribution of various components from local sources. Sources of carbonaceous particles appear to be the most important local contributors to fine particles in all of the urban areas shown.

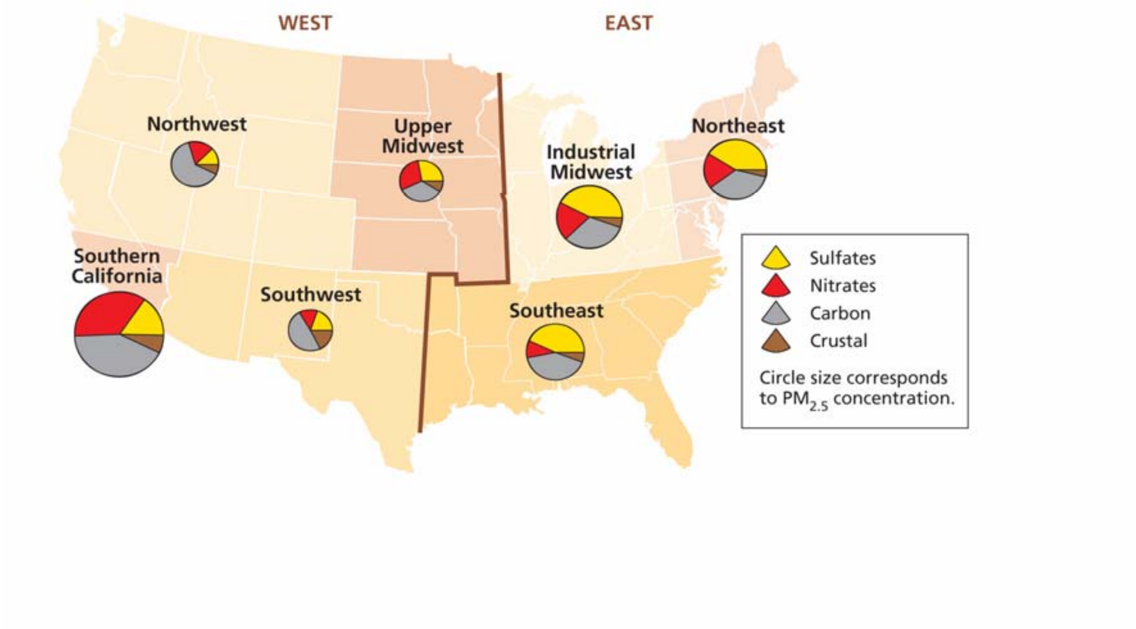

Figure 2. Average $PM_{2.5}$ composition in urban areas by region, 2003.

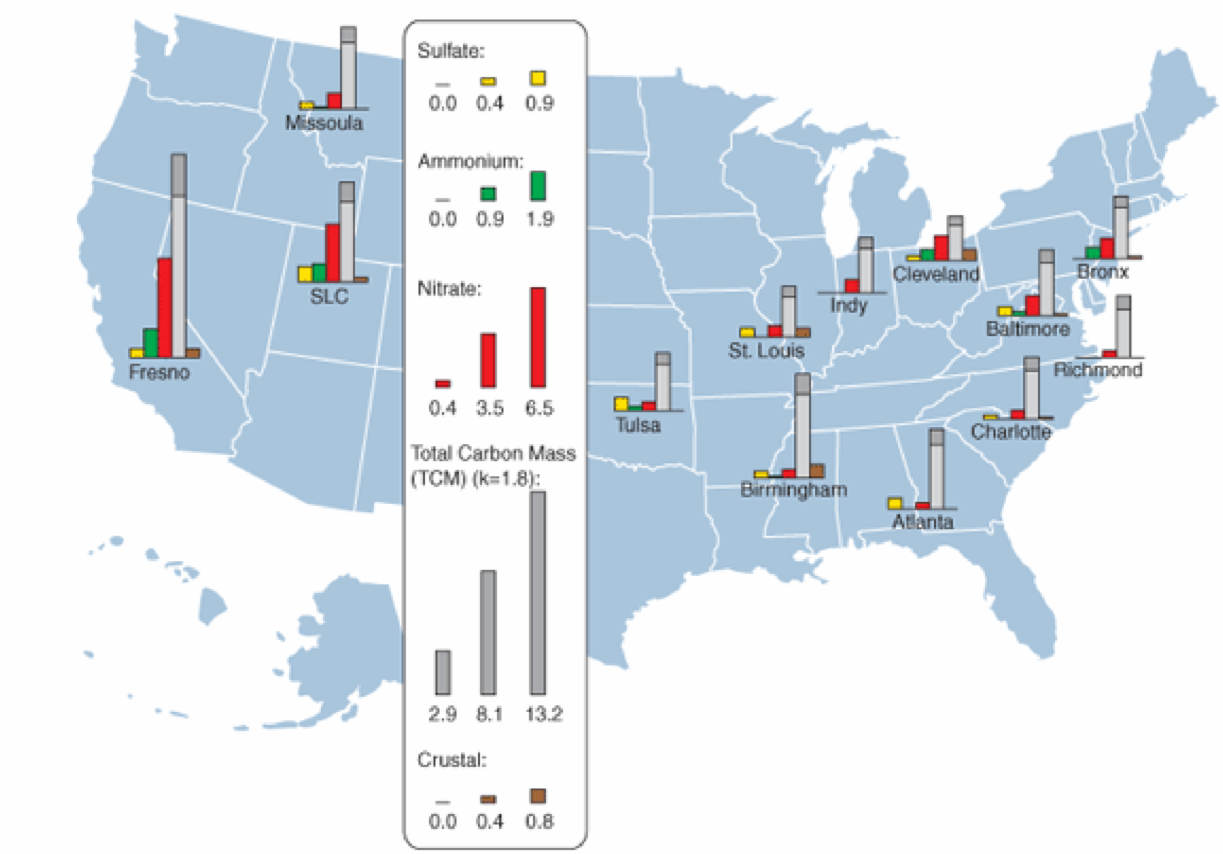

Figure 3. Estimated 'urban excess' of 13 urban areas by $PM_{2.5}$ species component 2003. The urban excess is estimated by subtracting the measured $PM_{2.5}$ species at a regional monitor location (assumed to be representative of regional background) from those measured at an urban location.[2]

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[2] The light grey in this bar graph is organic carbon and the dark grey is elemental carbon. Total Carbon Mass (TCM) is the sum of Organic Carbon (OC) and Elemental Carbon (EC).

Limitations and Uncertainties in this RIA that Precluded a National Assessment

In developing this RIA, we planned to provide national cost and benefit estimates of illustrative control strategies to assess the nation's ability to reach the proposed $PM_{2.5}$ standards and alternative standards options. As we developed that analysis, we reached the conclusion that, for the proposed rulemaking, our available data and tools are insufficient to develop cost and benefit information that would accurately reflect the range of possible options that the States may choose to implement.

The most significant data limitation we encountered is related to our controls and emissions inventory databases. In developing air quality modeling scenarios, we discovered significant limitations in both the number and effectiveness of control technologies for which adequate cost information is available. Further, existing emissions inventories appear to understate the extent of mobile source direct PM emissions and provide limited information on the extent of available controls that have already been applied to some source categories. These limitations prevented us from performing a national analysis. The scope of our air quality modeling was also constrained by both the time in which we had to complete the analysis and the breadth of controls available to evaluate in the model runs on a national basis. For this reason, we chose to perform air quality modeling on an urban scale in 5 areas by using a screening-level air quality model that we describe below.

Thus, we concluded that the national-scale analysis based on our current data and tools would not properly reflect the incremental costs and benefits of moving from the current standards to progressively more health-protective standards. We are taking steps to ensure that we will complete this national-scale analysis in time for publication with the final rule (September 2006).

Overview of the Five City Analysis and Provisional Conclusions

Analytical Approach

In this RIA we selected a handful of urban areas in which to estimate control costs and monetized human health benefits. Our selection of these urban areas was greatly influenced by the air quality model that we utilized to perform the analysis. The Response Surface Model (RSM) discussed in Chapter 2 can analyze air quality changes resulting from the application of both local and regional controls within nine pre-selected urban areas. These nine urban areas represent areas within the air quality modeling domain for which we could analyze control strategies without such controls affecting other RSM urban areas. The air quality model estimated that six of these urban areas would be out of attainment for some level of the annual and daily standard under analysis; these areas include Atlanta, New York/Philadelphia, Chicago, Seattle, San Joaquin and Salt Lake City, Utah.[3] The latter area was excluded from the detailed analysis because of an inadequate specification of the initial modeling domain. Although limited, these areas do reflect a span of different nonattainment/source/composition characteristics across the US (e.g. Figure 2), including areas with high and low regional backgrounds, and different

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[3] These nine urban areas include Seattle WA, San Joaquin CA, Phoenix AZ, Denver CO, Dallas TX, Chicago IL, New York/Philadelphia NY/PA, Atlanta GA and Salt Lake City UT. We excluded Phoenix, Denver and Dallas because they did not violate any of the standard alternatives we analyzed.

local source characteristics ranging from midwestern industry to woodsmoke and agricultural sources. Table 3 summarizes some of the key characteristics of these 5 cities.

Table 3: Summary of Current and 2015 Future Projected Emissions and Air Quality Information Across Modeled Urban Areas

	Atlanta	*Chicago*	*New York/ Philadelphia‡*	*Seattle*	*San Joaquin*
2002-2004 Design Value					
Annual Mean	17.5	16	16.8 / 15.4	10.5	21.7
98th Percentile Daily Average	39	43	42 / 38	41	62
2015 Basecase Design Value					
Annual Mean	16.4	16.9	14.3 / 14.6	10.5	26.1
98th Percentile Daily Average	35	39	34 / 36	39	83
2015 Basecase Precursor Emissions (thousands of tons)					
NOx	128	282	617	74.5	161
SO2	89.7	286	341	7.4	15.8
VOC	156	309	674	90.8	111
NH3	26	24.2	67.6	10.5	156
Primary Organic and Primary Elemental Carbon	15	22.7	43.3	4.8	9.1
2015 Percentage of Emissions Reduced After Application of All Effective Controls in AirControlNet*					
NOx**	---	---	---	10.3%	13.6%
SO2	66.1%	48.9%	16.5%	12%	20%
VOC**	---	---	---	---	---
NH3**	---	---	---	---	---
Primary Organic and Primary Elemental Carbon	23.6%	34%	31.8%	34.4%	9.1%

*Calculations do not reflect EGU NOx and SO_2 controls in Eastern U.S. urban areas (Atlanta, Chicago, NY/Philadelphia)

**We chose not to include NOx controls in the eastern U.S. and VOC and NH_3 controls in either the eastern or western U.S.

***2015 future projected design values were based on the 1999-2003 five year weighted average concentrations.

‡New York / Philadelphia 2002-2004 design values and 2015 base design values are based New York Co. and Philadelphia Co., respectively.

The analysis of the 5 cities used a reduced form air quality model called the Response Surface Model (RSM). The RSM is a screening-level air quality modeling tool built from a complex design of photochemical model simulations using the CMAQ Modeling System. Using this set of air quality model simulations permits a quick assessment of the estimated air quality changes at monitored locations (and elsewhere) throughout the United States for any combination of emissions reductions within a range of 10 to 120 percent of baseline emissions for a set of 12 source/emission factors. The RSM was used in the interim RIA to identify effective emissions reductions strategies (e.g. comparison across sectors; comparison across pollutants) and to develop (in combination with cost and effectiveness information) appropriate area specific combinations of controls to attain standards.

The details of these analyses are presented in Appendix A. Chapter 3 summarizes illustrative estimates of control costs and the monetized human health benefits to simulating attainment, or near-attainment, with each of the standard alternatives in the five urban areas in 2015. In developing insights and conclusions from these results, there are several important strengths, limitations and uncertainties that apply to our air quality modeling, controls analysis and benefits assessment that are important to note. Collectively, these limitations argue against placing significant weight on the specific quantitative estimates presented. The following sections summarize the key issues and uncertainties in each of these general categories of the analysis.

Emissions Forecasting and Air Quality Modeling Uncertainties

Chapters 2 and 3 summarize some of the key uncertainties associated with forecasting emissions and modeling air quality for the multiple pollutants that contribute to ambient fine particle concentrations. While EPA's regional scale air quality modeling system has been extensively peer reviewed and represents the state of the science in terms of the formation and fate of $PM_{2.5}$ in the atmosphere, a number of factors affect the conclusions that can be reached about the effectiveness, costs, and benefits of alternative control strategies in the five city analyses:

- Overall, the air quality model performs well in predicting monthly to seasonal concentrations, similar to other recent model applications for $PM_{2.5}$. The model is less well suited to predicting 24-hour values.

- In general, model performance is better for the eastern U.S. than for the West. The air quality model performs well in predicting the formation of sulfates, which are the dominant species in the East. It does not perform as well for nitrates and secondary organic particles from anthropogenic and natural sources.

- A number of uncertainties arise from use of baseline data from EPA's National Emissions Inventory, especially in terms of the overall magnitude of emissions of primary particles from stationary and mobile sources, spatial allocation of area and other source categories, and the relative split of emissions into $PM_{2.5}$ species. Of particular concern is the apparent disparity between estimated contributions of mobile source emissions with receptor modeling results based on ambient air quality data. These comparisons suggest that our base emissions inventory significantly underestimates the emissions of mobile sources. In addition, the RSM system does not include primary emissions of metals or related inorganic emissions from industrial processes or combustion. This limits control options for primary particles to carbonaceous emissions.

- Additional uncertainty is introduced through our future year projections of emissions due to unrefined growth rates and limited information on the effectiveness of control programs.

- The RSM based air quality modeling likely understates the effectiveness of urban-area controls. The CMAQ air quality model that provides the basis for the RSM uses a 36 kilometer receptor grid, which effectively spreads point and mobile source emissions that may be concentrated in particular locations across a wide area. The serves to obscure local-scale air quality improvements that result from urban-area controls.[4] To the extent that this occurs, our estimates may underestimate the effectiveness of local or urban-area controls relative as compared to broad scale regional controls.

Cost and Emissions Uncertainties

The limitations in our control strategy technology and cost data noted above also affect the five city analyses. As discussed more fully in the RIA and appendix, a number of approximations and assumptions were required to complete the analysis for all of the standards alternatives analyzed. The more important of these include:

- Progress attainable through controls known to be available is underestimated. The analysis does not consider all known control measures, and as a result understates the emissions reductions and progress toward attainment that can be achieved through known measures.

- Attainment cost estimates are highly dependent on costs of measures not currently in EPA's database. In part due to the database limitations discussed above, the analysis of the costs of meeting the current standards and more stringent alternatives rely on innovative and emerging controls with derived costs. Many emission controls employed to meet the more stringent standards are based on unspecified measures with assumed costs. Therefore the incremental attainment cost estimates for more stringent standards, and any cost-benefit comparisons, are subject to an unusually high degree of uncertainty.

- Analysis assumes attainment of new standards within 5 years. Although subpart 1 of Part D of the Clean Air Act allows nonattainment areas to qualify for an extension of up to 10 years from designation for an area to attain, the analysis for simplicity assumes that all areas must attain within 5 years (i.e., in 2015). This assumption tends to overestimate costs associated with attainment for areas qualifying for an extension (to 2020) because federal programs (e.g., on-road and non-road vehicle and engine standards and the Clean Air Interstate Rule) achieve greater emissions reductions over time, so that most areas become cleaner in the base case beyond 2015. Based on current information, it does not appear possible to attain the proposed NAAQS in the San Joaquin area by 2015.

Benefits Uncertainty

The benefits estimates generated for this proposal RIA are subject to a number of assumptions and uncertainties, which are discussed throughout the document. For example, key assumptions underlying the primary estimate for the mortality category include the following:

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[4] This is illustrated in figure 2-26, in chapter 2, which displays the geographical distribution of the results of the local scale modeling within a 36-kilometer CMAQ grid cell.

1. Inhalation of fine particles is causally associated with premature death at concentrations experienced by many Americans on a regular basis. Although biological mechanisms for this effect have not yet been completely established, the weight of the available epidemiological and experimental evidence supports an assumption of causality

2. The analysis also assumes that all components of fine particles have equal toxicity. While it is reasonable to expect that the potency of components may vary across the numerous effect categories associated with particulate matter, EPA's interpretation of scientific information considered to date is that such information does not yet provide a basis for quantification beyond using fine particle mass. While EPA has not performed formal sensitivity analysis of this assumption in its analysis for the proposed PM NAAQS RIA, the Agency is exploring ways to present the importance of this assumption in estimating benefits and its implications for control strategy development and assessment as a part of the analysis for the final RIA.

3. One source of uncertainty that has received recent attention from several scientific review panels is the shape of the concentration-response function for PM-related mortality, and specifically whether there exists a threshold below which there would be no benefit to further reductions in $PM_{2.5}$. That is, the hypothesized relationship includes the possibility that there exists a PM concentration level below which further reductions no longer yield premature mortality reduction benefits. To consider the impact of a threshold in the response function for the chronic mortality endpoint on the primary benefits estimates, we constructed a sensitivity analysis by assigning different cutpoints below which changes in $PM_{2.5}$ are assumed to have no impact on premature mortality.

Conclusions

While the results of the analyses presented in this RIA must be interpreted within the context of uncertainties and limitations summarized above, we believe that the following conclusions are appropriate:

- Recently promulgated regional and national programs will make significant progress in reducing daily as well as annual PM2.5 by 2015 under the current and proposed NAAQS as well as the alternatives.

- Current standards can be met in all areas analyzed with no additional controls beyond the current regulatory base case programs (2 areas) or with the addition of controls on local sources.

- The proposed new daily NAAQS would be met in 2 of the 3 eastern areas through programs designed to meet the current annual NAAQS. The proposed daily NAAQS can be met with local controls in Seattle and New York/Philadelphia. Based on current information, it does not appear possible to attain the proposed NAAQS in the San Joaquin area by 2015. They would likely need to consider a combination of intrastate regional and technology forcing local controls appear to be necessary to attain by 2020 or beyond.

- Based on the current analyses, it appears that the more stringent annual and daily alternatives (14 µg/m^3 or 30 µg/m^3) would drive States to consider additional regional reductions in the Eastern US, as well as new intrastate regional reductions in the West. Because the limitations of the analyses likely understate the cost-effectiveness of existing and new controls on local sources, the point at which incremental regional controls would become necessary or significantly more cost effective is not clear because the limitations of the analyses may understate the cost-effectiveness of existing and new controls on local sources.

- Within the context of the limitations of the analysis, costs and benefits of the proposed NAAQS and alternatives are generally within the same order of magnitude. Given the uncertainties and limitations, no general conclusions are possible with respect to the most optimal approach.