Chapter 3: Analysis Methodology and Summary Results

Chapter Overview

Costs and benefits for the proposed standards are estimated using EPA's available air quality, cost and benefits tools. Unless we note otherwise, this analysis follows the same analytical methodology for estimating monetized human health benefits as the CAIR Regulatory Impact Analysis (RIA).[1] This chapter summarizes the important differences and advances in the air quality modeling, cost analysis and benefits methodologies from earlier analysis; the technical detail associated with these analyses to technical support documents. This chapter concludes with an illustrative summary of the quantitative estimates of benefits and costs for attaining the current and proposed revised standards for $PM_{2.5}$.

Air Quality Modeling

In this analysis we use a Response Surface Model (RSM) tool that estimates the air quality changes associated with various pollution control strategies. The RSM is a screening-level air quality modeling tool built from a complex design of photochemical model simulations. Using this set of air quality model simulations allows users to quickly assess the estimated air quality changes at monitored locations 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 can be used for a variety of purposes, including: (1) strategy design and assessment (e.g. comparison of urban vs. regional controls; comparison across sectors; comparison across pollutants); (2) optimization (developing optimal combinations of controls to attain standards at minimum cost); and (3) evaluation of model sensitivity (systematically evaluating the relative sensitivity of modeled ozone and PM levels to changes in emissions inputs). Its flexibility and its ability to quickly simulate complicated air quality model results make it ideal for RIA use.

The RSM can analyze air quality changes resulting from the application of both local and regional controls within nine selected urban areas and the application of region-wide controls across the United States.[2] 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. While the RSM does not provide a complete picture of all changes necessary to reach various alternative standards nationwide, it is highly useful in the context of providing illustrative control scenarios for example areas, and understanding the contribution of different source categories and pollutants to air quality across the U.S. The subsections below summarize development of the RSM.

The PM NAAQS Final Rule (September 2006) will include control strategy confirmation runs utilizing photochemical grid modeling with EPA's Community Multi-Scale Air Quality (CMAQ)

[1] See: http://www.epa.gov/interstateairquality/pdfs/finaltech01.pdf. Additional information may be found in Appendix H of the CAIR TSD.

[2] These urban areas include Seattle WA, San Joaquin CA, Salt Lake City UT, Phoenix AZ, Denver CO, Dallas TX, Chicago IL, New York/Philadelphia NY/PA and Atlanta GA.

Modeling System and local scale dispersion modeling, as appropriate, with the AMS/EPA Regulatory Model (AERMOD). These CMAQ confirmation runs are intended to include national 36-km and local-scale 12-km modeling. The selection of 12-km areas to model is dependent on the nature of policy analysis (e.g. local-scale modeling to evaluate local carbon control impacts versus regional carbon control impacts). Likewise, the use of RSM will be extended to investigate and better inform sector-based control scenarios based on a multi-pollutant approach (i.e., ozone and PM analyses).

Developing the Response Surface Model

EPA has devoted significant efforts to developing air quality models for assessing regulatory impacts and designing effective emissions control strategies. From ozone and particulate matter control strategies assessment to evaluation of acid deposition and air toxics, photochemical air quality models are widely used to support policy analysis as part of the decision-making process. However, due to the high cost and complexity of the computations, using such air quality models to generate results for time-pressing analytical and policy needs is both challenging and often inefficient. Therefore, EPA has developed the RSM, by utilizing advanced statistical techniques to characterize the relationship between model outputs and input parameters in a highly economical manner. The RSM is simply a model of an air quality model; it is a reduced-form prediction model using statistical correlation structures to approximate model functions through the design of complex multi-dimensional experiments. The RSM technique has been successfully tested and evaluated for $PM_{2.5}$ and ozone, respectively. Cross-validation, out-of-sample validation, and a standard set of performance evaluation metrics was used to evaluate overall response-surface performance.[3] In this section, we describe the development of the multi-pollutant RSM application using EPA's CMAQ Modeling System. We discuss the selection of the modeling domain and its configuration; the development of a multi-dimensional experimental design for control strategies; and the implementation and verification of the RSM technique, including the generation of air quality model runs, statistical modeling and construction of representative surfaces, model validation, and RSM outcomes.

CMAQ Modeling Platform for Response Surface Modeling

CMAQ is a three-dimensional regional grid-based air quality model designed to simulate hourly particulate and ozone concentrations and deposition over large spatial scales (e.g., over the contiguous U.S.) over an extended period of time (e.g up to a year) (Dennis *et al.*, 1996; Byun and Ching, 1999; Byun and Schere, 2004). The CMAQ model includes state-of-the-science capabilities for conducting urban- to regional- scale simulations of multiple air quality issues, including tropospheric ozone, fine particles, toxics, acid deposition, and visibility degradation. The CMAQ model is a publicly available (supported by the Community Modeling and Analysis System (CMAS) Center; http://www.cmascenter.org/), peer reviewed, state-of-the-science model consisting of a number of science attributes that are critical for simulating the oxidant precursors and non-linear organic and inorganic chemical relationships associated with the formation of sulfate, nitrate, and organic aerosols. CMAQ also simulates the transport and removal of directly

[3] Response surface model evaluation techniques and metrics are discussed in the *Response Surface Model Technical Support Document*.

emitted particles which are speciated as elemental carbon, crustal material, nitrate, sulfate, and organic aerosols.

The RSM is based on air quality modeling using CMAQ version 4.4 with a 36 km horizontal domain (148 x 112 grid cells) and 14 vertical layers. The modeling domain encompasses the contiguous U.S. and extends from 126 degrees to 66 degrees west longitude and from 24 degrees north latitude to 52 degrees north latitude (Figure 3-1).

For this RIA, EPA performed multi-pollutant CMAQ air quality modeling for the development of an integrated $PM_{2.5}$ and ozone Response Surface Model (RSM). Precursors and direct emissions of $PM_{2.5}$ as well as ozone were modeled. For the purpose of this RIA, the model evaluation and control strategy assessment will focus exclusively on $PM_{2.5}$, its constituents and precursors.

A complete description of CMAQ version 4.4 and meteorological and emission inputs are discussed in the *Response Surface Model Technical Support Document (RSM TSD)*. In addition, an operational model performance evaluation for $PM_{2.5}$ and its related speciated components (e.g., sulfate, nitrate, elemental carbon, organic carbon, etc.) as well as deposition of ammonium, nitrate, and sulfate for 2001 was performed in order to estimate the ability of the CMAQ modeling system to replicate base year concentrations (EPA 2005a). The purpose of the base year PM air quality modeling was to reproduce the atmospheric processes resulting in formation and dispersion of fine particulate matter across the U.S.

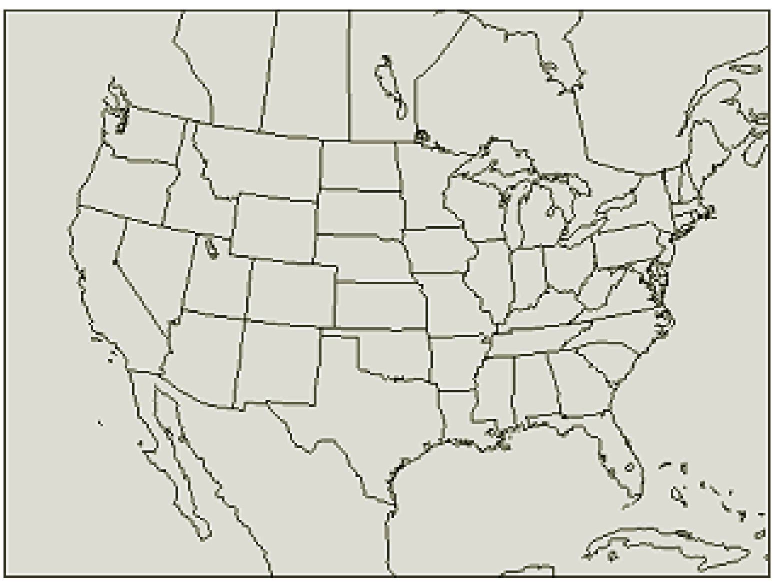

Figure 3-1. Map of the CMAQ and RSM modeling domain used for $PM_{2.5}$ NAAQS Review

Technical Approaches and Experimental Design of RSM

Statistical Technique used in RSM

Response surface models typically use a limited number of complex model runs at a set of statistically selected points in a design space, e.g. utility NOx emission levels 10 to 120 percent of current levels. By using design of experiments theory, the response surface method can improve the accuracy of model approximations while minimizing costly model runs.[4] The response-surface method uses statistical techniques to relate a response variable (in this case annual and 98th percentile daily $PM_{2.5}$ at receptor sites throughout the U.S.) to a set of factors that are of interest, e.g. emissions of precursor pollutants from particular sources and locations.

To develop a response surface approximation of CMAQ, a sophisticated interpolation approach was used (i.e., multidimensional kriging approach), implemented through the MIXED procedure in SAS (2005) software.[5] This modeling approach is well suited to data generated using a non-stochastic computer model, and can approximate highly nonlinear surfaces as long as they are locally continuous. The predicted changes in $PM_{2.5}$ in each CMAQ grid cell were modeled as a function of the weighted average of the modeled responses in the experimental design. Complete details on the modeling approach are documented in the *RSM TSD*.

The RSM experimental design covers a change in the baseline emissions of zero to 120 percent, utilizing a staged Latin Hypercube statistical method. This statistical method follows a space filling design within the policy space for emission controls in order to accurately capture the linear and nonlinear interactions among pollutants. The Latin hypercube design retains flexibility, which accommodates the number of runs selected based on limitations (computer resources). A total of 180 CMAQ model runs were conducted (a base case run plus 179 control runs). The model runs were broken into two stages, 120 runs in the first stage and 60 runs each in stage two. This allowed for faster development of preliminary surfaces and allowed testing of additional predictive power for additional model runs. A third stage will be conducted to include an additional 60 CMAQ model runs to enhance the development of RSM surfaces and predictability for the Final PM NAAQS. The set of CMAQ simulations provides inputs to the statistical response surface modeling. The complete list of model runs and corresponding control scenarios (selection of emissions control factors) are provided in Appendix A of the *RSM TSD*. The CMAQ model was applied for the 2010 CAIR projection baseline in order to provide annual $PM_{2.5}$ concentrations, visibility, and deposition estimates. The CMAQ model was run for 4 months, one month from each season, February, April, July, October, in order to reduce computational time for such a large number of annual model runs. These months were chosen

---

[4] The experimental design component consists of the selection of the sets of input variables, $d=(d_1, d_2, ..., d_k)$, (i.e., selection of the emissions control strategy within the defined experimental region) at which to run the experiment and obtain a response. There are a large number of methods, and a correspondingly large volume of literature, available for designing an experiment (Box, G.E.P., and Draper, N.R. (1987). Empirical Model-Building and Response Surfaces. John Wiley and Sons, New York.; Pukelsheim, F. (1993). Optimal Design of Experiments. John Wiley and Sons, New York. Dean, A.M. and Voss, D. (1999). Design and Analysis of Experiments. Springer-Verlag, New York.)

[5] SAS Institute, 2005. SAS Online Doc© 9.1.3. Accessed online at http://support.sas.com/onlinedoc/913/docMainpage.jsp

based on greatest predictability of the quarterly mean. Each quarterly run included a 5-day ramp-up period designed to minimize the influence of the initial concentration fields (i.e., initial conditions) used at the start of the model run. The development of initial condition concentrations is described in the *RSM TSD*. The ramp-up periods used for the RSM CMAQ applications are as follows:

- First quarter ramp-up period is January 27 - 31, 2001
- Second quarter ramp-up period is March 27 - 31, 2001
- Third quarter ramp-up period is June 26 - 30, 2001
- Fourth quarter ramp-up period is September 26 - 30, 2001

Model predictions from these ramp-up periods were discarded and not used in analyses of the modeling results.

Once the response surface model has been generated, it can be used to simulate the functions of the more computationally expensive atmospheric chemistry model. The RSM can be used to derive analytical representations of model sensitivities to changes in model inputs. For example, the RSM is designed to show how CMAQ predicts the atmosphere would respond to emissions reductions for selected sources and pollutants, though it does not provide how those reductions in pollutants can be accomplished (i.e. specific control technologies). The RSM allows for comparison on an equal footing of controls for different source/pollutant combinations, and between local and regional sources. It should be noted that because RSM is built from CMAQ air quality model runs, it has the same strengths and limitations of the underlying model and its inputs.

Modeling Scenarios and Emission Inventories and Sectors

This RIA models relative changes in air quality for the entire U.S. using the Response Surface Model (RSM) applied to the 2010 Base Case developed by EPA as part of the analysis for the Clean Air Interstate Rule (CAIR). While CAIR targets controls of SO_2 and NOx in the Eastern United States, the other rules/programs in the 2010 baseline include Clean Air Non-Road Diesel Rule, Heavy Duty Diesel Rule, Tier 2, and the NOx SIP Call. Because our base year of analysis is 2015, we extrapolate the baseline year from 2010 to 2015 and to include CAIR controls.[6] 2015 serves as a logical base year for analysis because it is a reasonable estimate of the date by which States would begin to implement controls to attain the revised standard; assuming promulgation in 2006, designations would require 3 years, and States would then have 5 years to attain. The RSM control strategy outputs are based on projected 2015 post-CAIR emissions inventories and therefore reflect any uncertainties in those inventories. Certain source/pollutant inventories may be more uncertain than others. More information on these uncertainties in source/pollutant inventories can be found in the *RSM TSD*.

[6] We developed the RSM with a 2010 baseline so that it could serve the analytical needs of both the final $PM_{2.5}$ NAAQS implementation rule (due in late 2006) for the current standard as well as the $PM_{2.5}$ NAAQS RIA for the revised standard.

Selection of Emissions Control Factors and Control Ranges

The main purpose of the RSM is to demonstrate the impact of various reductions in precursor emissions from different combinations of sources on air quality. In order to control the experimental design space, i.e. the region over which the response is studied, we established a set of 12 variable emissions control factors that could be adjusted (simulating increased or decreased emissions) and evaluated their impact on $PM_{2.5}$ levels in ambient air. Careful attention was paid to selecting factors that would provide maximum information for use in comparing relative efficacy of different emissions control strategies and to balancing the computational efficiency of model runs and the resources available. Factors were selected based on:

1. Type of PM and PM precursor emissions (NOx, SOx, NH_3, POC, PEC, or VOC);
2. Emissions source category (EGU point sources, NonEGU point sources, area sources (including agriculture); and
3. Location of urban areas contributing to residual $PM_{2.5}$ (including non-road sources) after implementation of the CAIR/CAMR/CAVR and geographically separated in contribution to downwind $PM_{2.5}$ concentrations.

The RSM can evaluate air quality changes that result from adjusting each of the following 12 emissions control factors on a local or regional basis:

1. NOx EGU = NOx EGU point source emissions
2. NOx NonEGU Point and Area = NOx Non-EGU point source, area source, and agricultural source emissions
3. NOx Mobile = NOx nonroad source and mobile source emissions
4. SOx EGU = SOx EGU point source emissions
5. SOx NonEGU Point = SOx Non-EGU point source emissions
6. SOx Area = SOx area source and agricultural source emissions
7. NH_3 Area = Ammonia area source and agricultural source emissions
8. NH_3 Mobile = Ammonia non-road source and mobile source sources
9. POC/PEC Point (EGU and NonEGU) = Elemental carbon and organic carbon EGU point source and Non-EGU point source emissions
10. POC/PEC Mobile = Elemental carbon and organic carbon nonroad source and mobile source emissions
11. POC/PEC Area = Elemental carbon and organic carbon area source and agricultural source emissions
12. VOC All = Volatile organic carbon EGU point source, Non-EGU point source, area source, agricultural source, nonroad source, and mobile source emissions[7]

Source categories with relatively small emissions were grouped with similar larger source categories for efficiency (Figure 3-2). NonEGU Area NOx and SOx sources were primarily smaller industrial combustion sources, such as coal, oil, and natural gas powered boilers and internal combustion engines. Agricultural area sources were only significant contributors to ammonia emissions. VOC sources were lumped together in the model because VOCs are not

[7] This version of the RSM did not address direct emissions of inorganic metallic particles from sources such as steel mills and other industrial processes.

expected to influence PM levels significantly (due to current limitations in the ability of CMAQ to simulate secondary formation of organic particles).

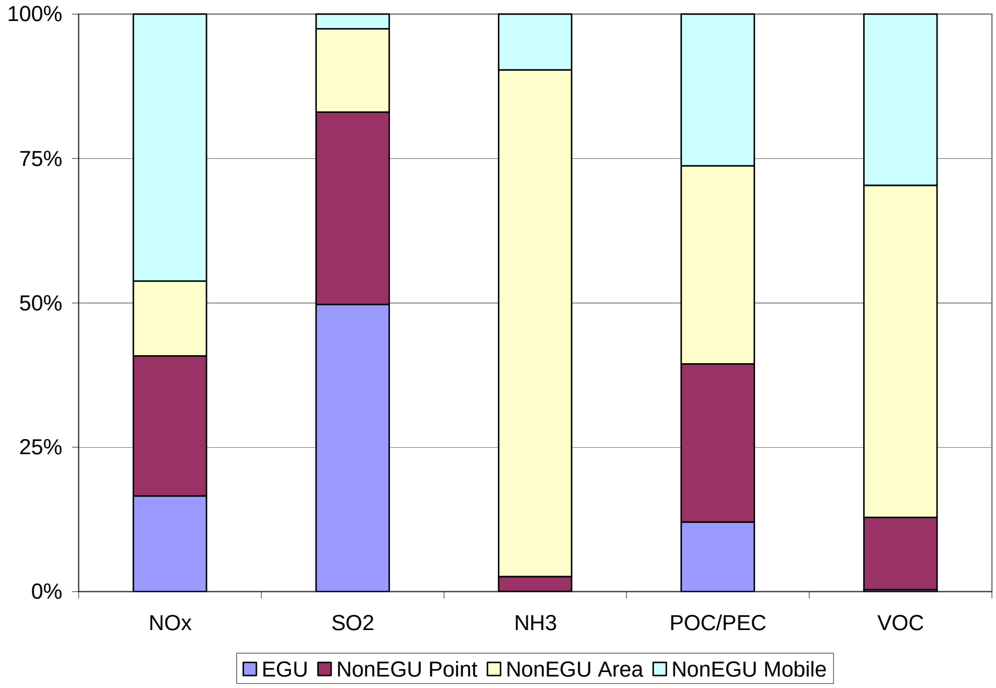

Figure 3-2. National analysis of source contributions to emissions sectors.[8]

Selection of Regional vs. Local Impact

Based on these 12 control factors, the RSM incorporates a regional design allowing for development of independent response surfaces (i.e. independent air quality responses) for particular urban areas, as well as a generalized response surface (i.e. air quality response) for all other locations (outside of the particular urban areas). A rigorous area-of-influence analysis was conducted for the selection of RSM urban locations to discern the degree of overlap between different urban areas in terms of emissions and air quality impacts, and to tease out local versus regional impacts. The area-of-influence analysis incorporated control model runs where emissions were zeroed out in many urban areas. Results of these control runs for the months of February and July are shown in Figures 3-3 and 3-4. The area-of-influence analysis concluded that ambient $PM_{2.5}$ in each of the 9 urban areas is largely independent of the precursor emissions in all other included urban areas. Thus, this allows the RSM to analyze air quality changes in these 9 urban areas and associated counties independently of one another. These 9 urban areas include New York / Philadelphia (combined), Chicago, Atlanta, Dallas, San Joaquin, Salt Lake City, Phoenix, Seattle, and Denver. Figure 3-5 displays these 9 urban areas based on the CMAQ model 36-km grids.

---

[8] The data in Figure 3-2, which are based on the emissions inventory developed for CAIR, suggest EGUs contribute on the order of 10% of primary organic carbon. More recently, EPA has reviewed data on primary EGU emissions and concluded these estimates are approximately an order of magnitude too high. This suggests that the control costs and reductions associated with any controls for EGU POC in, e.g. Tables 3-1, 3-2, and 3-3 are of little relevance. EPA has since corrected this portion of the inventory for future analyses and modeling.

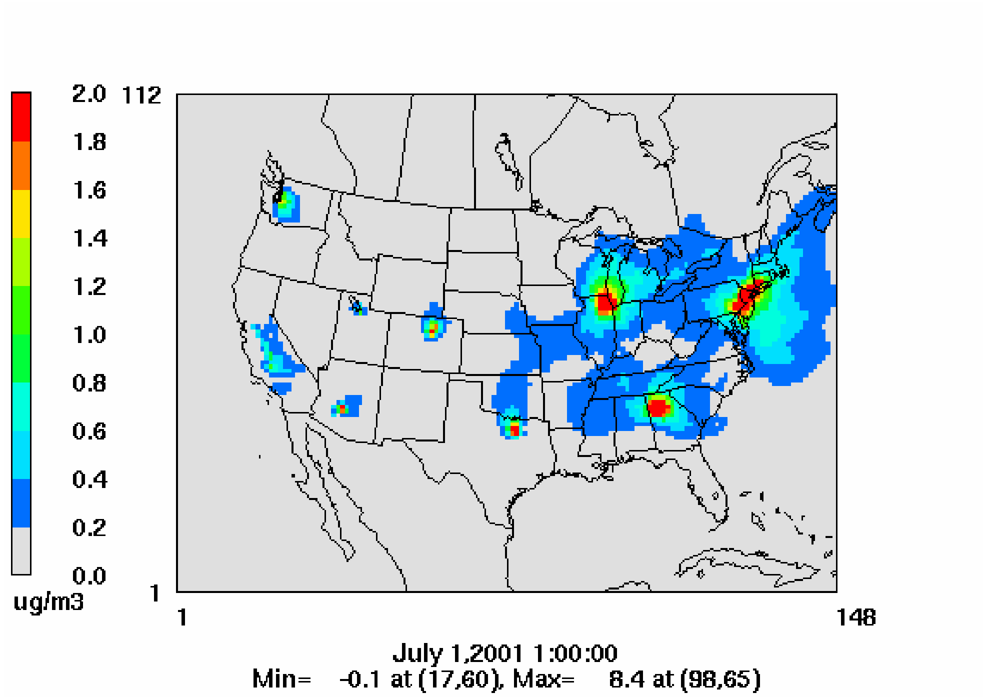

Figure 3-3. $PM_{2.5}$: Areas of influence for nine selected RSM urban locations for the monthly average of July 2001.

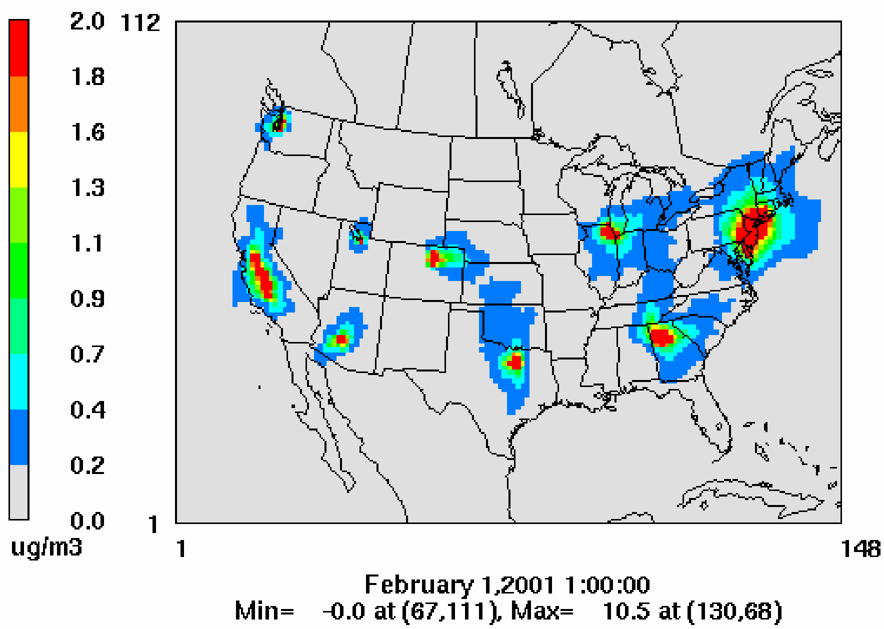

Figure 3-4. $PM_{2.5}$: Areas of influence for nine selected RSM urban locations for the monthly average of February 2001.

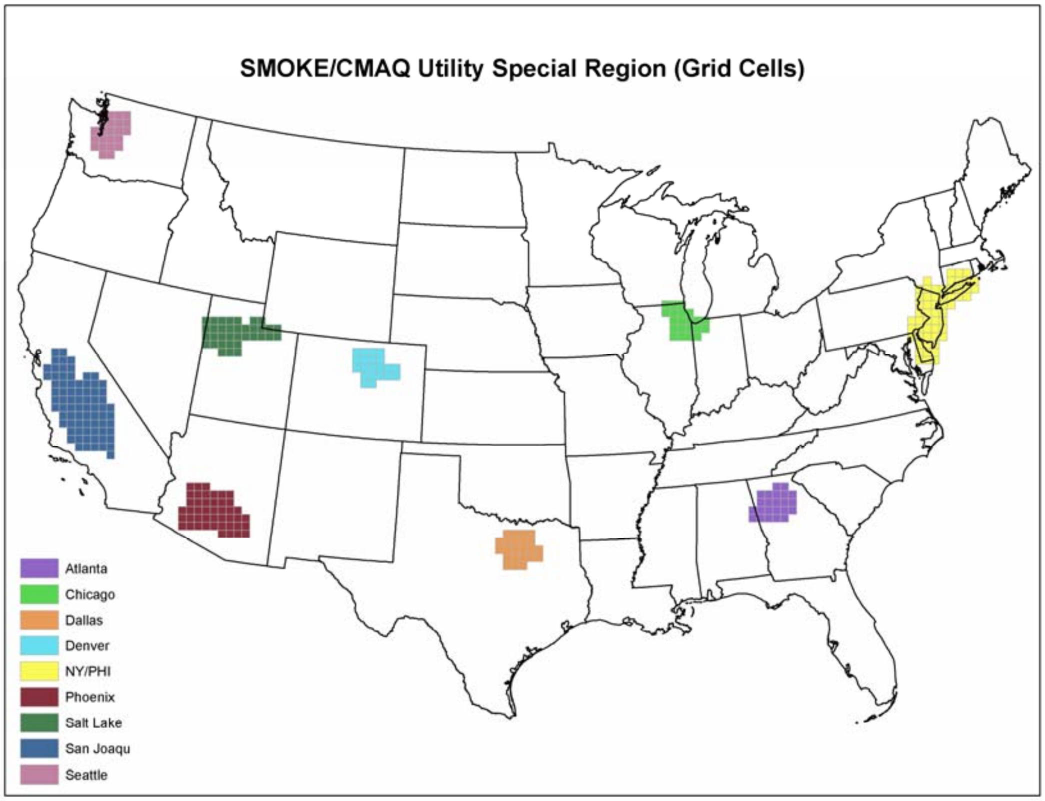

Figure 3-5. Map of the CMAQ modeled 36-km grids for nine urban areas modeled

<u>Output Metrics for CMAQ RSM $PM_{2.5}$</u>

Several output measures of $PM_{2.5}$ levels were extracted from the CMAQ model runs which are of particular interest for this PM NAAQS RIA. The quarterly mean and annual 98th percentile daily average of sulfate, nitrate, crustal, elemental carbon, organic carbon, and ammonium concentrations were outputted for development of RSM surfaces. Projected $PM_{2.5}$ annual and daily design values at monitored locations were used to assess how the attainment status of an area might be affected by different control strategies.

In general, the procedures for projecting both the annual and daily $PM_{2.5}$ design values are based on using model predictions in a relative sense. In this manner, the 2001 Base Year predictions and the 2015 future predictions are coupled with ambient data to forecast future concentrations. This approach is consistent with the EPA draft guidance documents for modeling $PM_{2.5}$.[9] Reference the RSM TSD for details on the projection method.

We used the RSM to evaluate the air quality changes associated with a variety of control strategies. Below we describe our source of information for both existing and emerging $PM_{2.5}$ controls.

[9] EPA (2001): Draft Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the $PM_{2.5}$ NAAQS.

Control Cost Analysis Methodology

To generate estimates of control cost, we use the AirControlNET controls database. We supplement the controls found in this database with additional information regarding innovative and emerging PM controls whose cost and control efficiency is less well characterized.

AirControlNET

Our primary source of control cost and efficiency information was AirControlNET. This desktop-based computer program overlays a detailed control measures database on EPA emissions inventories to compute source- and pollutant-specific emissions reductions and associated costs at various geographic levels.[10] Controls found in AirControlNET are largely well-demonstrated add-on control measures for which there is reliable documentation of their control efficiency and costs based on Alternative Control Techniques (ACTs), Control Technique Guidelines (CTGs), and other technical documents prepared by EPA and other entities. AirControlNET contains an extensive set of control measures for achieving direct $PM_{2.5}$ and precursor emission reductions from point and area sources, and a small set of control measures for mobile (onroad and nonroad) sources. AirControlNET has few control measures for ammonia or area source SO2. The version of AirControlNET applied in these analyses, version 4.1, is the same one applied in the non-EGU control strategy analyses for the Clean Air Visibility Rule (CAVR) issued in 2005 except for the addition of some direct PM-reducing controls.

AirControlNET contains a least-cost module that can generate a list of control measures in rank order of annualized cost-effectiveness (cost-per-ton reduction) for each pollutant. Emissions reduction effects on other pollutants are also estimated but are not part of the rank-ordering carried out in the least-cost module. This module was utilized extensively in producing analyses for some of the control strategies listed in the following chapter.

<u>Types of Controls in AirControlNET</u>

Control measures taken from AirControlNET and discussed herein consist primarily of controls already in use, and are intended to be illustrative of measures that could be chosen by states or local areas. Measures such as material substitution, source minimization, work practices, and fuel switching are considered to a lesser degree. Technologies emerging now, or to be developed in the future, will likely play a key role in attaining the new standards and are discussed below and in greater depth in Appendix B of this RIA.

AirControlNET contains a variety of control measures available for primary $PM_{2.5}$ and organic and elemental carbon (OC and EC), $PM_{2.5}$ precursors (SO2, nitrogen oxides (NOx), ammonia (NH3), and volatile organic compounds (VOC)). For purposes of brevity, we do not include an exhaustive list of these controls. Readers interested in this detail should consult the TSD.

[10] U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. AirControlNET version 4.1. Control Measure Documentation Report. August 2005.

Table 3-1 below provides a highly summarized overview of the types of controls in AirControlNET that apply to some of the RSM control factors that we describe in the previous section of this chapter.[11]

Table 3-1: Example RSM Control Measures for Selected Factors

Factor Name	*Control Measure*
SOx NonEGU_Point	Flue Gas Desulfurization (FGD) In-duct Dry Sorbent Injection Spray Dryer Absorber Wet Flue Gas Desulfurization Vacuum Carbonate Plus Sulfur Recovery Plant Increase % Conversion to Meet NSPS (99.7)
NH3 Area	Chemical Additives to Waste
POC_PEC EGU + NonEGU	Fabric Filter (Pulse Jet Type) Fabric Filter (Mech. Shaker Type) Paper/Nonwoven Filters - Cartridge Collector Type Fabric Filter (Reverse-Air Cleaned Type) Increased Monitoring Frequency (IMF) of PM Control CEM Upgrade and Increased Monitoring Frequency of PM Controls Wet ESP - Wire Plate Type Venturi Scrubber Coal Washing
POC_PEC Area	Education and Advisory Program

Absent from the table above is a summary of the mobile source control information. AirControlNET currently contains a very limited array of mobile source controls. While the source apportionment data in chapter two suggests that this source sector is an important contributor to total $PM_{2.5}$, for this analysis we are unable to simulate significant reductions in this sector with AirControlNET controls. We look to address this limitation in the final RIA.

Influence of societal trends and technological improvements

In our analysis we consider emissions reductions from the imposition of control strategies which are innovative in nature and still nascent in development. In the subsection below we describe how we have estimated the control costs for these technologies. Beyond our consideration of innovative control techniques in our cost analysis for specific attainment strategies, we also discuss several broad social trends which we expect to influence the nation's ability to attain a standard and the cost of attainment.

[11] For additional information regarding the methods by which we derived RSM control factor costs from AirControlNET controls, see the Technical Support Document (TSD) found in the docket. Readers interested in reviewing each of the control measures in AirControlNET can consult Appendix C & D. Appendix C includes a list of the AircontrolNET measures, including average control costs and control efficiencies. Appendix D contains the AircontrolNET measures mapped to the RSM control factors.

Generally, we expect these trends to provide cost savings and enable the nation to meet its air quality goals more easily. However, some of these trends could result in greater challenges, at least in the short term. This section outlines several of these trends and describes how they may influence the nation's ability to reach its air quality targets. For this analysis we treat these trends qualitatively; in the final RIA we plan to treat at least some of these features in a quantitative fashion.

Estimating the Cost and Control Efficiency of Innovative and Emerging Technologies

It is likely that additional control technologies that are not well characterized in our AirControlNET database will become available between the development of this document and state implementation of a new NAAQS in time for attainment by 2015 or 2020. We anticipate that as demand for PM pollution control equipment increases, firms will innovate and provide new technologies to meet this future increase in demand. For an exhaustive list of these innovative and emerging controls, readers can consult the technical support document for this analysis.

To incorporate the availability of these technologies in our analysis, we adopted two alternative scenarios as the basis for the estimates of the cost of these emerging technologies. To generate an estimate of the control cost-per-ton for emissions reductions not associated with identified control technologies, for each of the 12 RSM control factors, we calculated the 50th and 90^{th} percentile of the total cost distribution for all AirControlNET controls in that factor. For example, to estimate the cost of innovative controls for the area source carbon emissions, we would identify the 50^{th} and 90^{th} percentile cost-per-ton estimate based on the distribution of all control costs in AirControlNET for that control factor.[12]

[12] In two instances, we determined that there were no existing AirControlNET controls for which to calculate a cost distribution. These include Area SO_2 and Mobile NH_3. For Area SO_2, we calculated these percentiles based on the SO_2 Non-EGU point factor. For Mobile NH3, we used the distribution of costs for the NH_3 Area factor to develop the 50^{th} and 90^{th} percentile cost estimates.

Table 3-2: 50th Percentile Cost per Ton in 6 RSM Urban Areas for each of the 12 RSM Urban Control Factors (1999$)[13]

	50th Percentile Cost per Ton by RSM Urban Area				
RSM Control Factor	Chicago	San Joaquin	Atlanta	Seattle	NY/Phil
NOx EGU	$919	$568	$1,066	$529	$885
NOx NonEGU + Area	$1,054	$919	$810	$870	$1,017
NOx Mobile	$41,418	$46,427	$46,738	$42,747	$46,396
SOx EGU	$1,492	$348	$783	$348	$1,239
SOx NonEGU_Point	$707	$34,114	$1,973	$226	$4,524
VOC All	$3,803	$6,388	$5,206	$3,803	$3,803
NH3 Area	$3,677	$3,677	$3,677	$3,677	$3,677
POC_PEC EGU + NonEGU	$106	$113	$56	$93	$230
POC_PEC Mobile	$46,988	$45,259	$51,917	$47,735	$46,989
POC_PEC Area	$2,059	$2,046	$1,920	$1,920	$1,920

Table 3-3: 90th Percentile Cost per Ton 5 RSM Urban Areas for each of the 12 RSM Urban Control Factors (1999$)

	90th Percentile Cost per Ton by RSM Urban Area				
RSM Control Factor	Chicago	San Joaquin	Atlanta	Seattle	NY/Phil
NOx EGU	$1,684	$1,137	$4,456	$530	$1,948
NOx NonEGU + Area	$2,879	$3,355	$3,552	$2,879	$1,932
NOx Mobile	$55,663	$56,884	$59,261	$58,226	$59,589
SOx EGU	$1,852	$3,851	$45,998	$348	$53,636
SOx NonEGU_Point	$4,524	$44,800	$2,107	$2,107	$7,087
VOC All	$34,034	$51,022	$44,613	$39,185	$39,002
NH3 Area	$45,901	$45,901	$45,901	$45,901	$45,901
POC_PEC EGU + NonEGU	$6,654	$41,465	$811	$129	$27,076
POC_PEC Mobile	$57,743	$56,883	$65,333	$59,989	$60,260
POC_PEC Area	$2,076	$2,066	$2,065	$2,064	$2,044

When we apply these innovative controls above, we first determine the remaining air quality increment to attainment for the given standard. Next, we select the control that, on the margin, is most cost effective at either the 50th or 90th percentile. We then apply this control until we hit a maximum of 80% control. Once we have exhausted this control, we then apply the next most

[13] The cost estimates below may vary significantly from those found in Appendix C. This is due to the fact that Appendix C provides average cost estimates for each control measure, whereas the cost estimates in tables 3-2 and 3-3 are estimated at the 50th and 90th percentile. Moreover, to the extent that there are very few emissions available for control in each urban area, the cost will be significantly higher than those costs found in Appendix C.

cost-effective control. We follow this process until we either reach attainment or exhaust all cost-effective controls. An exception is that EGU SO2 and NOx controls are treated separately as described in Appendix A.

Broad societal trends

Since the $PM_{2.5}$ NAAQS was finalized in 1997, there have been important changes in American society in how people work, where they work, and the type of work they perform. More people are employed in the service sector and fewer work in manufacturing. There are changes in the prices people face for fuel and energy and the mix of sources of energy is changing. Wind power and other renewable sources of energy are available; cleaner and more efficient gasoline and diesel engines now power our vehicles; energy saving hybrid engines using both electricity and gasoline engines are now readily available in the marketplace.

Conversely, some trends may have either a detrimental or positive impact on air quality. For example, the recent increase in the price of gasoline is likely to either reduce, or reduce the increase in, the number of vehicle miles traveled; in turn, this will decrease vehicle emissions. Conversely, an increase in home heating fuel prices may encourage increased residential wood burning. While newer woodstoves efficiently burn wood with limited air pollution, many older style woodstoves still exist. These older stoves can be a significant source of particulate matter in certain local areas and make it more difficult for areas to improve their air quality.

Technological change

This analysis discusses the costs and benefits of reaching different standard options beginning in 2015 and focuses mainly on using currently existing and well-characterized control technology. Ten years is an extended period in which to project technology choice and cost. Since the $PM_{2.5}$ NAAQS was finalized in 1997, numerous improvements in pollution control equipment and techniques have occurred. The 1997 RIA listed several promising types of pollution abatement technologies that we expected to contribute to reducing air pollution. Some of these controls now see common application and in fact, technological innovation in other areas such as information technology has improved these controls beyond initial expectations. Another factor that tends to reduce costs over time is the "learning curve" effect. Studies have documented that as larger quantities of an item are manufactured, the cost per unit tends to go down. Similar studies have documented and quantified this effect on the costs of certain air pollution control technologies. This "learning curve" effect is not taken into account in this analysis, but would be expected to reduce estimated costs. EPA has sponsored several studies outlining how technological change has resulted in improvements in air quality over time (The Clean Air Act Amendments: Spurring Innovation and Growth While Cleaning the Air, ICF October 27, 2005).

Innovative Approaches

The Acid Rain trading program is widely recognized as one of the most successful approaches to reducing air pollution. The 2004 compliance year marked the 10th year of the program. During that period, the Acid Rain Program has:

- Reduced SO_2 emissions by over 5 million tons from 1990 levels, or about 34 percent of total emissions from the power sector. Compared to 1980 levels, SO_2 emissions from power plants have dropped by 7 million tons, or more than 40 percent.
- Cut NO_x emissions by about 3 million tons from 1990 levels, so that emissions in 2004 were less than half the level anticipated without the program.
- Led to significant cuts in acid deposition, including reductions in sulfate deposition of about 36 percent in some regions of the United States and improvements in environmental indicators, such as fewer acidic lakes.[14]

EPA and its partners across the nation have also established a variety of different mechanisms for improving air quality in a cost effective and efficient manner. For example, there are a number of partners working to electrify truck stops to reduce the need to idle diesel engines when off road. Programs have been established to retrofit diesel trucks and our nation's school buses. EPA and its partners are sponsoring a woodstove change-out program, which promises to reduce a significant source of particulate matter in some local areas. Other examples of technological change and innovative approaches can be found in "The Clean Air Act Amendments: Spurring Innovation and Growth While Cleaning the Air", ICF October 27, 2005; (Technological Innovations and Environmental Regulation, ICF April 7, 2005).

Numerous factors indicate the illustrative control strategies outlined in this RIA will not successfully predict what actual strategies will be used by the states. Ten years is a long time over which to predict costs. It is certain that technological improvements will occur; costs are likely to fall over that period based on past successes. Societal trends in the more efficient production and use of energy are likely to lead to reduced pollution per unit as well.

Benefits Estimation Methodology

The benefits analysis presented in this RIA uses a methodology generally consistent with benefits analyses performed for the recent analysis of final Clean Air Interstate Rule (CAIR) of 2005 (EPA, 2005). Readers interested in the specific details are referred to the appropriate sections of the Final CAIR RIA.

A wide range of human health and welfare effects are linked to exposure to direct and precursor $PM_{2.5}$ emissions. Potential human health effects associated with $PM_{2.5}$ range from premature mortality to morbidity effects linked to long-term (chronic) and shorter-term (acute) exposures (e.g., respiratory and cardiovascular symptoms resulting in hospital admissions, asthma exacerbations, and acute and chronic bronchitis [CB]). Welfare effects potentially linked to PM include materials damage and visibility impacts, as well as effects linked to deposition of nitrate and sulfate. Although methods exist for quantifying the benefits associated with many of these

[14] See: http://www.epa.gov/air/acidrain.html

human health and welfare categories, not all can be evaluated at this time because of limitations in methods and/or data.

Key Technical Differences between this Benefits Analysis and the Analysis Completed for the Final CAIR Rule

While the analytical approach used in this benefits analysis is largely the same approach used in the Final CAIR benefits analysis, there are several enhancements and modifications that have been incorporated into the benefits methodology as applied for the analysis of the proposed $PM_{2.5}$ NAAQS including:

<u>Air Quality</u>

- Use of the RSM, a reduced form model designed to predict changes in annual mean and daily 98th percentile $PM_{2.5}$.

<u>Health Effects Incidence Estimation</u>

- Use of an updated dataset projecting county-level age-specific mortality rates for future scenarios (1997-2050). This approach combines Centers for Disease Control (CDC) county-level mortality rate data for the years 1996-1998 with US Census Bureau mortality projections out to 2050.
- Application of Concentration-Response functions with adjustments for assumed thresholds.

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:

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 current scientific information is that it 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 $PM_{2.5}$. The nature of the hypothesized relationship is the possibility that there exists a PM concentration level below which further reductions no longer yield premature mortality reduction benefits.

An important source of uncertainty resulting in an under-prediction of benefits is the exclusion of a range of potential health endpoints and welfare effects in this benefits analysis due either to limitations in modeling methods or available data, or schedule constraints. The list of excluded endpoints is presented below and is discussed in greater detail in the CAIR RIA. (Note that although ozone-related benefits were modeled for the final CAIR Rule, due to schedule constraints, we did not include any ozone modeling for this RIA.)

Table 3-4 below lists the full complement of human health and welfare effects that are modeled for this benefits analysis. In addition to these quantified benefits, there are a wide array of benefits which remain unquantified because of current limitations in methods, lack of available data, or schedule constraints. These include : (a) additional health and welfare effects associated with $PM_{2.5}$ (e.g., subchronic bronchitis cases, visibility): (b) welfare impacts to commercial and recreational resources associated with nitrogen and sulfate deposition as well as ambient ozone (e.g., reduced agricultural yields): and (c) health effects related to exposure to SO_2, NO_x and Ozone (e.g., mortality for ozone) (see the Final CAIR RIA (EPA, 2005) for a full list of unquantified health and welfare effects). Note, that visibility and health and welfare effects associated with ozone formation were evaluated quantitatively for the Final CAIR RIA, but were excluded from this benefits analysis due to schedule constraints.

Table 3-4. Human Health and Welfare Effects Modeled for the Proposed $PM_{2.5}$ NAAQS

Pollutant/Effect	*Quantified and Monetized in Base Estimates*[a]	*Quantified and/or Monetized Effects in Sensitivity Analyses*
PM/Health[b]	Premature mortality based on cohort study estimates[c] Hospital admissions: respiratory and cardiovascular Emergency room visits for asthma Nonfatal heart attacks (myocardial infarction) Lower and upper respiratory illness Minor restricted-activity days Work loss days Asthma exacerbations (asthmatic population) Respiratory symptoms (asthmatic population) Infant mortality	Premature mortality: short term exposures[d] Subchronic bronchitis cases

[a] Primary quantified and monetized effects are those included when determining the primary estimate of total monetized benefits of attaining the proposed $PM_{2.5}$ NAAQS.

[b] In addition to primary economic endpoints, there are a number of biological responses that have been associated with PM health effects including morphological changes and altered host defense mechanisms. The public health impact of these biological responses may be partly represented by our quantified endpoints.

[c] Cohort estimates are designed to examine the effects of long term exposures to ambient pollution, but relative risk estimates may also incorporate some effects due to shorter term exposures (see Kunzli, 2001 for a discussion of this issue).

[d] While some of the effects of short term exposure are likely to be captured by the cohort estimates, there may be additional premature mortality from short term PM exposure not captured in the cohort estimates included in the primary analysis.

Summary of Estimated Control Cost and Monetized Human Health Benefits

Key Issues and Uncertainties in the Analyses

In considering the illustrative results of the cost and benefit analyses summarized below, it is important to outline a number of important strengths, limitations and uncertainties that apply to our air quality modeling, controls analysis and benefits assessment.. The preliminary cost and benefit estimates for the five cities are significantly affected by these aspects of the analysis. We believe we can make improvements for the final RIA, and the estimates presented here are very likely to change in the final version. While all estimates in an RIA are uncertain, we believe the results of this 5-city analysis are particularly uncertain, and accordingly we have not included them in the Executive Summary. We present the estimates here and more fully in Appendix A to encourage public comment that will help improve future analyses.

In particular, the estimates are based on an incomplete menu of known control strategies that needs to be supplemented. Some controls involve a cost of more than $1 million a ton; we do not believe States will adopt control measures requiring control cost of this magnitude. Incremental costs of meeting more stringent standards are highly dependent on assumptions about the feasibility of additional control measures that have not been identified. The benefits of emission reductions in this analysis appear to be smaller than in past RIAs. For the 5-city analysis, where we assume the presence of regional controls, we do not include the costs and benefits of these controls because it is not clear what fraction of the costs and benefits of regional controls should be apportioned to an individual city. In the next stage of analysis we will address these and other issues, and produce an improved estimate of costs and benefits for the final RIA. The discussion below outlines the major uncertainties and limitations in the areas of emissions forecasting and air quality modeling, costs and control strategy development, and monetized benefits.

Emissions Forecasting and Air Quality Modeling Uncertainties

While EPA's regional scale air quality modeling system summarized above 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 limitations and uncertainties 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 and 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 estimates of 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. These serve to obscure local-scale air quality improvements that result from urban-area controls. To the extent that this occurs, our estimates may underestimate the effectiveness of local or urban-area controls as compared to broad scale regional controls.

Cost and Control Strategy Development Uncertainties

As discussed more fully in the RIA and appendix C and D, 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 known to be available or not identified in EPA's AirControlNET 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 controls employed to meet the more stringent standards include some of these unknown measures with assumed costs. The feasibility of these assumed controls is discussed in Appendix F. Therefore the incremental attainment cost estimates for more stringent standards, and any cost-benefit comparisons, are subject to an unusually high degree of uncertainty.

- The 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 5 years after the initial 5-year period, 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 Uncertainties

The benefits estimates for the attainment strategies assessed in this appendix are subject to a number of assumptions and uncertainties, which are discussed throughout this document:

1. The first 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 $PM_{2.5}$. Although the consistent advice from EPA's Science Advisory Board (SAB) that provides advice on benefits analysis methods[15] has

[15] The advice from the 2004 SAB-HES (EPA-SAB-COUNCIL-ADV-04-002) is characterized by the following: "For the studies of long-term exposure, the HES notes that Krewski et al. (2000) have conducted the most careful work on this issue. They report that the associations between $PM_{2.5}$ and both all-cause and cardiopulmonary mortality were near linear within the relevant ranges, with no apparent threshold. Graphical analyses of these studies (Dockery et al., 1993, Figure 3, and Krewski et al., 2000, page 162) also suggest a continuum of effects

been to model premature mortality associated with PM exposure as a non-threshold effect, that is, with harmful effects to exposed populations regardless of the absolute level of ambient PM concentrations, EPA's most recent $PM_{2.5}$ Criteria Document concludes that "the available evidence does not either support or refute the existence of thresholds for the effects of PM on mortality across the range of concentrations in the studies" (U.S. EPA, 2004, p. 9-44). Some researchers have hypothesized the presence of a threshold relationship. 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.

2. 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. In applying the cutpoints, we adjusted the mortality function slopes accordingly.[16] This sensitivity analysis allows us to determine the change in avoided mortality cases and associated monetary benefits associated with alternative cutpoints. Four cutpoints were included in this sensitivity analysis: (a) 15 $\mu g/m^3$ (based on the current NAAQS); (b) 10 $\mu g/m^3$ (reflects comments from CASAC, 2005); (c) 7.5 $\mu g/m^3$ (reflects recommendations from SAB-HES, 2004 to consider estimating mortality benefits down to the lowest exposure levels considered in the Pope 2002 study used as the basis for modeling chronic mortality); and (d) background or 3 $\mu g/m^3$ (reflects NAS, 2002 recommendation to consider effects all the way to background).

3. Another source of uncertainty is the relative potency of $PM_{2.5}$ components. All fine particles, regardless of their chemical composition, are assumed to be equally potent in causing premature mortality. This is an important assumption, because there may be significant differences between PM produced via transported precursors, direct PM released from automotive engines, and direct PM from other industrial sources. 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.

Summary of Cost/Benefit Results for Current and Proposed Revisions to Standards

---

down to lower levels. Therefore, it is reasonable for EPA to assume a no threshold model down to, at least, the low end of the concentrations reported in the studies."

[16] Note, that the adjustment to the mortality slopes was only done for the 10 $\mu g/m^3$ and 15 $\mu g/m^3$ cutpoints since the 7.5 $\mu g/m^3$ and background cutpoints are at or below the lowest measured exposure levels reported in the Pope 2002, for the combined exposure dataset.

Tables 3-5 and 3-6 provide estimates of the costs and benefits of attaining the current 15/65 $PM_{2.5}$ standard according to a 3% and 7% discount rate. Table 3-7 provide the incremental costs and benefits at a 3% and 7% discount rate to reaching the 15/35 standard. As discussed above, we were unable to apply a sufficient number of controls to meet attainment in all urban areas. In the tables below, the cost estimate ranges reflect varying assumptions regarding the future cost of $PM_{2.5}$ controls beyond those available in our controls database. Appendix A provides additional information regarding our methodology for calculating these costs. We performed a screening-level cost analysis to estimate the control costs associated with meeting a 15/40 $PM_{2.5}$ air quality standard in San Joaquin; this was the only urban area we modeled that would be out of attainment for a 15/40 standard. We calculated the costs and benefits for San Joaquin to attain 15/40 by using simple linear interpolation; the results are in tables 3-9 and 3-10.

Table 3-8 provides analyses of the sensitivity of the monetized value of the incremental mortality benefits associated with the proposed NAAQS revisions in 3 cities to alternative assumptions about possible thresholds in the mortality concentration-response function. Because the current NAAQS and the alternative have a value of 15 $\mu g/m^3$, we did not include the alternative threshold value of 15 ug/m3, since the incremental benefits would, by definition, be zero. We believe it will be more meaningful to explore alternative intermediate thresholds between 10 and 15 $\mu g/m^3$, and to consider use of the short-term mortality studies in a sensitivity analyses for the benefits of the short term standards.

Table 3-5 : Costs of Attaining 15/65 Standard: 3% and 7% Discount Rate (Billion 1999$)

Urban Area	*2015 Base case*	*Costs of Urban Area Controls (3%)*	*Costs of Urban Area Controls (7%)*
Atlanta	Regulatory Base Case for Each Urban Area	$1.9*	$2.1*
Chicago		$1.9 to $2.3*	$2.1 to $2.4*
NY/Philadelphia		*Attains standard with regulatory baseline*	
San Joaquin		$1.4 to $1.7*	$1.4 to $1.8*
Seattle		*Attains standard with regulatory baseline*	

**Note: Different combinations of emission controls were cost-minimizing using the different cost-estimation techniques. The low end of the benefits range is associated with the mix of controls using the upper-bound cost assumption; the upper end of the benefits range is associated with the mix of controls using the lower-bound cost assumption.

Table 3-6 : Benefits of Attaining 15/65 Standard: 3% and 7% Discount Rate (Billion 1999$) (threshold of 7.5ug/m^3. No data on other thresholds.)

Urban Area	*2015 Base case*	*Benefits of Urban Area Controls (3%)*	*Benefits of Urban Area Controls (7%)*
Atlanta	Regulatory Base Case for Each Urban Area	$2.5	$2.2
Chicago		$7.9 to $8.8**	$6.8 to $7.5**
NY/Philadelphia		*Attains standard with regulatory baseline*	
San Joaquin		$8 to $8.3**	$6.9 to $7.1**
Seattle		*Attains standard with regulatory baseline*	

**Note: Different combinations of emission controls were cost-minimizing using the different cost-estimation techniques. The low end of the benefits range is associated with the mix of controls using the upper-bound cost assumption; the upper end of the benefits range is associated with the mix of controls using the lower-bound cost assumption. This range does not reflect sensitivity to thresholds or various other sources of uncertainty discussed elsewhere in this document.

Table 3-7: Costs of Attaining 15/35 Incremental to Attainment of the Current 15/65 Standard: 3% and 7% Discount Rate (Billion 1999$)

Urban Area	*2015 Base case*	*Costs of Urban Area Controls (3%)*	*Costs of Urban Area Controls (7%)*
Atlanta	Regulatory Base Case for Each Urban Area	*Attains with 15/65 Strategy—no incremental costs or benefits*	
New York/Philadelphia		$4.2	$4.3
Chicago		*Attains with 15/65 Strategy—no incremental costs or benefits*	
Seattle		$0.75 to $0.76*	$0.76 to $0.77*
San Joaquin‡		$3.7 to $13.4*	$3.7 to $13.6*
San Joaquin	Regulatory Base case +20% Reduction in Regional NonEGU and EGU Emissions for San Joaquin	$2.6 to $12.1*	$3.6 to $12.2*

‡ San Joaquin unable to attain with urban area emissions reductions alone. Cost and benefit estimates for partial attainment.

* Note: Cost numbers expressed as a point estimate are comprised entirely of AirControlNET controls. Cost numbers expressed as a range are comprised of both AirControlNET costs and innovative control costs, which introduces additional uncertainty. This range reflects two different approaches to estimating future-year $PM_{2.5}$ control costs, providing an upper and lower bound to our cost estimate.

Table 3-8: Benefits of 15/35 Standard Incremental to Attainment of the 15/65 Standard

Certainty that Benefits are At Least Specified Value	*Level of Assumed Threshold*[e]	*Discount Rate*	**Monetized Benefits for Urban Area Emission Reductions Only (Billion 1999$): (Note: Chicago and Atlanta attain with 15/65 Strategy—no incremental costs or benefits)**		
			NY/Philly	Seattle	San Joaquin‡
More Certain	<15 and >10 μg/m³ [a]	3%	No Data	No Data	No Data
		7%	No Data	No Data	No Data
	10 μg/m³ [b]	3%	$2.3	$0	$3.2
		7%	$2.0	$0	$2.8
	7.5 μg/m³ [c]	3%	$2.9	$0.5	$3.0
		7%	$2.5	$0.5	$2.6
	3 μg/m³ [d]	3%	$2.9	$0.6	$3.0
Less Certain		7%	$2.5	$0.5	$2.6

‡ San Joaquin unable to attain with urban area emissions reductions alone. Cost and benefit estimates for partial attainment.
[a] Not analyzed in this analysis. EPA intends to analyze a cutpoint between 12 μg/m³and 15 μg/m³ for the final RIA.
[b] CASAC (2005)
[c] SAB-HES (2004)
[d] NAS (2002)
[e] Assumed threshold applied to mortality. No assumed threshold applied to morbidity.

Table 3-9: Screening-Level Estimate of Costs to Attaining 15/40Standard Option in the San Joaquin Area Incremental to Attainment of the Current 15/65 Standard (Billion 1999$)

Urban Area	*2015 Base Case*	*Costs of Urban Area Controls (3%)*	*Costs of Urban Area Controls (7%)*
15/40	Regulatory Base Case + 20% Reduction in Regional NonEGU Emissions	$3-10	*$3-$10*

Note: Estimates rounded to one significant figure.
Note: This interpolated estimate is subject to even greater uncertainties than the other options because the costs and benefits may not scale in a linear way with the 24-hour design value.

Table 3-10: Screening-Level Estimate of Benefits to Attaining 15/40 Standard Option in the San Joaquin Area Incremental to Attainment of the Current 15/65 Standard (Billion 1999$) (threshold of 7.5ug/m^3. No data on other thresholds.)

Urban Area	*2015 Base Case*	Benefits of Urban Area Controls (3%)	Benefits of Urban Area Controls (7%)
15/40	Regulatory Base Case + 20% Reduction in Regional NonEGU Emissions	$10	$9

Note: Estimates rounded to one significant figure.
Note: This interpolated estimate is subject to even greater uncertainties than the other options because the costs and benefits may not scale in a linear way with the 24-hour design value.

The results of this urban-area analysis suggest that for several of the alternatives, estimated monetized benefits are roughly equivalent (within the same order of magnitude) as the estimated control costs. These estimates are not consistent with the results of previous EPA rulemakings, for which benefits tend to be significantly higher than costs (see Table A-62 in appendix A). Due to time constraints the urban-area analysis does not express benefits per-ton; thus it is not possible to explore the specific source of the apparent differences between our prior analyses and these results. Given both the uncertainties and potential biases summarized above as well as the consistent findings of significantly higher benefit/cost for analyses of multiple source categories and controls from past analyses, we do not believe significant weight should be given to quantitative comparisons of costs and benefits in this interim analysis. The presentation of costs and benefits in separate tables in this chapter reflects our belief that a quantitative comparison is significantly less informative than in other RIAs where we present costs and benefits together. We will continue to develop improved approaches for developing a national assessment in the final RIA.

Conclusions

While the results of the 5 City cost/benefit analyses summarized above and in Appendix A and the national forecast of air quality in Chapter 2 A must be interpreted within the context of several important uncertainties and limitations, they do yield a number of important preliminary conclusions:

- Recently promulgated regional and national programs will make significant progress in reducing daily and 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 and 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 $\mu g/m^3$ or 30 $\mu g/m^3$) would drive consideration and analyses of 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 may become necessary or significantly more cost effective is not clear.

- 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 to meet a revised $PM_{2.5}$ NAAQS.