Chapter 1: Introduction and Background

Synopsis

This chapter summarizes the purpose and results of this Regulatory Impact Analysis (RIA). This RIA estimates the costs and monetized human health and welfare benefits of attaining a revised $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) nationwide and one more stringent alternative. This document contains illustrative analyses that consider a limited number of emission control scenarios that States, Tribes and Regional Planning Organizations might implement to achieve the revised $PM_{2.5}$ NAAQS. According to the Clean Air Act, EPA must use health-based criteria in setting the NAAQS and cannot consider estimates of compliance cost. EPA is producing this RIA both to provide the public a sense of the benefits and costs of meeting a new $PM_{2.5}$ NAAQS and to meet the requirements of Executive Order 12866. This analysis contains several important improvements from the interim RIA that EPA issued January 17th, 2006, including refinements to EPA's control measures database, emissions inventories, air quality modeling and benefits assessment.

1.1 Background

On December 20th, 2005 EPA proposed to revise the National Ambient Air Quality Standards for fine particles ($PM_{2.5}$) and to replace the current standards for PM_{10} with a new standard for inhalable coarse particles based on a qualified $PM_{10-2.5}$ indicator.[1] On January 17th, 2006 EPA published an interim RIA for the $PM_{2.5}$ standard. That interim RIA considered the costs and monetized human health benefits of attaining the proposed $PM_{2.5}$ standards and three alternative $PM_{2.5}$ standard options in five urban areas in 2015. Due to data and modeling limitations, that RIA did not address the proposed new $PM_{10-2.5}$ standard. These same data and modeling limitations preclude EPA from assessing the costs and benefits of retaining the existing PM_{10} standards. This $PM_{2.5}$ NAAQS RIA builds upon the approach in the five-city analysis to perform a national-scale assessment of costs and monetized human health and welfare benefits associated with illustrative scenarios for attainment of the revised and more stringent alternative revised $PM_{2.5}$ NAAQS.

1.2 Role of this RIA in the Process of Setting the NAAQS

This $PM_{2.5}$ NAAQS RIA is an illustrative analysis that provides useful insights into a limited number of emission control strategies States might adopt to achieve the revised $PM_{2.5}$ standard and one more stringent alternative. Because States are ultimately responsible for implementing strategies to meet the revised standard, the control scenarios in this RIA are necessarily illustrative in nature. They are therefore subject to important uncertainties and limitations, which we document in the relevant portions of the analysis. EPA in some cases weighed the available empirical data to make a judgment regarding the projected attainment status of certain urban areas. The subsections below describe each of these elements in greater depth.

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[1] See: http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_cr_fr.html

1.2.1 Understanding the Role of the RIA in the Context of the Clean Air Act and Executive Order Requirements

In setting primary ambient air quality standards, EPA's responsibility under the law is to establish standards that protect public health. The Clean Air Act ("Act") requires EPA, for each criteria pollutant, to set a standard that protects public health with "an adequate margin of safety." As interpreted by the Agency and the courts, the Act requires EPA to base this decision on health considerations; economic factors cannot be considered

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

This RIA is intended to inform the public about the potential costs and benefits that may result when a new $PM_{2.5}$ standard is implemented, but it is not relevant to establishing the standards themselves. EPA presents this analysis pursuant to Executive Order 12866 and the guidelines of OMB Circular A-4.[2] These documents present guidelines for EPA to assess the benefits and costs of the selected regulatory approach as well as one less stringent, and one more stringent, option.

1.2.2 The RIA as an Illustrative Analysis

The analytical goals of this RIA are somewhat different from other EPA analyses of national rules, or the implementation plans States develop, and the distinctions are worth brief mention. This RIA does not assess the regulatory impact of an EPA-prescribed national or regional rule such as the Clean Air Interstate Rule. Nor does this RIA attempt to model the specific actions that each State will take to implement a revised standard. Rather, this analysis attempts to estimate the costs and human health and welfare benefits of a reasonable array of cost-effective State implementation strategies. These strategies represent EPA's best approximation as to one set of actions that States might consider cost-effective to attain a revised $PM_{2.5}$ NAAQS. Because States—and not EPA—would implement a revised NAAQS, they will ultimately determine the appropriate emissions control scenario. While EPA used the best available data currently available to develop its illustrative control strategies, State implementation plans would likely vary from EPA's estimates due to differences in the data and assumptions that States use to develop these plans.

In particular, there are inherent uncertainties in our projection of future emissions out to 2020 and our use of regional scale air quality modeling. For example, a number of uncertainties arise from the baseline data incorporated in the analysis (especially the mobile source inventory and the projection of future year emissions). The regional scale used for air quality modeling may understate the effectiveness of controls on local sources in urban areas as compared to area-wide or regional controls.

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

It is also worth noting that during the time span for implementation of the PM2.5 standards there are likely to be development and implementation of emerging technologies and innovative measures that could achieve additional pollution reductions not identified in this analysis, or could achieve emissions reductions at lower cost than measures included in this analysis. EPA's experiences with technology advances over the past 30 years, and the promise of numerous cleaner technologies emerging today, strongly suggest that technological innovation and "learning by doing" will continue to produce new, cleaner processes and performance improvements that reduce air pollution at reasonable cost. The Clean Air Act itself has spurred such advances, as innovative companies have responded to the challenges of the Act with great success, producing breakthroughs such as alternatives to ozone-depleting chemicals and new super-performing catalysts for automobile emissions, as well as improvements in control efficiency and cost for technologies such as scrubbers and SCR. The estimates in this RIA of the cost and feasibility of emissions reductions do not reflect technological advances that may occur between now and the analysis years of 2015 and 2020. In addition, stationary and area source control cost estimates in this RIA do not reflect the phenomenon, documented in the economic literature, that "learning by doing" over time tends to reduce the per-unit cost of producing a product, including pollution control technologies, and can lead to achieving better control efficiency as well. The issue of technology development is especially relevant for our estimates of costs in California and Salt Lake City, where current control technologies are not expected to be sufficient to achieve attainment, and where our cost estimates are based on extrapolations from the cost of current technologies.

Finally, EPA recognizes that data on ammonia emissions from animal operations are currently very uncertain, and are likely inadequate for making specific regulatory and/or control decisions for these emissions in some locations. EPA anticipates that the National Air Emissions Monitoring Study (NAEMS) for animal operations will provide a more scientific basis for estimating emissions, as well as defining the scope of air quality impacts, from these sources. As such, an appropriate strategy for estimating and regulating emissions from animal operations will be developed as a result of the NAEMS, and further guidance regarding the need for, and scope of, potential ammonia controls from these sources will also be developed at that time. As such, we emphasize the illustrative nature of the specific ammonia control measures applied in this RIA, and potential air quality impacts associated with changes in ammonia emissions, and remind the reader that this analysis is not intended to recommend any particular control strategy for specific areas. To the extent that States consider ammonia controls, EPA anticipates that they would consult the results of the NAEMS when determining appropriate control strategies for individual nonattainment areas as part of the State Implementation Plan process.

1.2.3 Illustrative Attainment Determinations

EPA constructed illustrative attainment scenarios understanding that certain emissions inventory, emission control, air quality modeling and monitoring uncertainties are likely to inhibit our ability to model full attainment in all areas. For example, there are certain instances in which the modeled air quality results might not agree with data at the air quality monitor.[3] In other cases, well-defined uncertainties limit the air quality model's performance in specific geographical areas. In these cases EPA weighed the available empirical data as part of an informed judgment regarding the projected attainment status of that area; later in this document we clearly designate where such judgments were applied in attainment/nonattainment determinations and include the relevant rationale. This approach is consistent with the analytical objectives of the RIA—to provide an illustrative attainment analysis of projected costs and benefits to the nation, and is also consistent with the use of models in SIP guidance.

1.2.4 Role of this RIA in Implementing the Current Standard

While this RIA is principally designed to illustrate the costs and monetized human health benefits of attaining the revised and alternative revised standards in 2020, it also includes an appendix summarizing the costs and benefits of attaining the current standard in 2015. This analysis will provide useful information for States to consider in identifying potential emissions reductions for meeting the current standard, and as such is included as a stand-alone document in Appendix A. Note that because this analysis was intended to compare costs and benefits of attaining alternative standards by fixed dates, it did not attempt to identify for each designated $PM_{2.5}$ area measures that may be needed to meet subpart 1 Clean Air Act requirements, such as reasonably available measures and attainment as expeditiously as practicable. It is expected that additional costs and benefits will begin to accrue in earlier years as states comply with these requirements.

1.3 Statement of Need for the Regulation

Two sections of the Clean Air Act govern the establishment and revision of NAAQS. Section 108 (42 U.S.C. 7408) directs the Administrator to identify pollutants which "may reasonably be anticipated to endanger public health or welfare" and to issue air quality criteria for them. These air quality criteria are intended to "accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in the ambient air . . . ."

Section 109 (42 U.S.C. 7409) directs the Administrator to propose and promulgate "primary" and "secondary" NAAQS for pollutants identified under section 108. Section 109(b)(1) defines a primary standard as one "the attainment and maintenance of which in the judgment of the Administrator, based on [the] criteria and allowing an adequate margin of safety, [are] requisite to protect the public health."[4] A secondary standard, as defined in section 109(b)(2), must "specify a level of air quality the attainment and maintenance of which in the judgment of the Administrator, based on [the] criteria, [are] requisite to protect the public welfare from any

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[3] For example, the causes for such disagreement can be attributable to inconsistencies in the speciation profile used in developing the model-based design values, and the speciation profile at the nearest speciation monitor; this difference can significantly understate the effectiveness of certain control strategies that affect primarily one $PM_{2.5}$ species. A complete technical discussion can be found in chapter three.

[4] The legislative history of section 109 indicates that a primary standard is to be set at "the maximum permissible ambient air level . . . which will protect the health of any [sensitive] group of the population," and that for this purpose "reference should be made to a representative sample of persons comprising the group rather than to a single person in such a group." (S. Rep. No. 91-1196, 91st Cong., 2d Sess. 10 (1970)).

known or anticipated adverse effects associated with the presence of [the] pollutant in the ambient air." Welfare effects as defined in section 302(h) [42 U.S.C. 7602(h)] include, but are not limited to, "effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being."

Section 109(d) of the Act directs the Administrator to review existing criteria and standards at 5-year intervals. When warranted by such review, the Administrator is to revise NAAQS. After promulgation or revision of the NAAQS, the standards are implemented by the States.

From an economic perspective, market failures arising from an "externality" represent one such reason for government intervention. An externality occurs when one party's actions impose uncompensated benefits or costs on another party. For example, the emissions from a factory may adversely affect the health of the surrounding pollution and result in soiling the property in local neighborhoods.

1.4 Changes in the Analysis and Methods between the Interim and Final RIA

This final RIA reflects four key changes in analytical scope and methodology from the interim RIA. First, we have incorporated new data into our emissions inventories. Second, this RIA broadens the geographic scope from the 5-city analysis of the interim RIA to the entire nation. Third, we have augmented our analysis of control strategies with updated information that facilitates the selection of least-cost controls. Finally, we have updated the uncertainty characterization of our benefits results using a recently completed expert elicitation study. We discuss details of each improvement in further chapters of this RIA.

1.4.1 Emissions Inventory Data

An "emissions inventory platform" is composed of the collection of emissions data and emissions processing assumptions used to create inputs to the air quality models. The emissions inventory platform used for this RIA is a modified version of the emissions inventory EPA used in the Clean Air Interstate Rule (CAIR) RIA released in March, 2005.[5] Since the development of the CAIR platform used for the Final CAIR in 2005, EPA updated the platform to improve the technical basis for the modeling work done for this RIA. We summarize these revisions here; Section 2.3 describes these updates in detail.

<u>Changes to the Baseline Emissions Inventory</u>

The inventory revisions (since CAIR) apply to both the baseline and projected inventories; we revised the 2001 base emissions, which we used to project non-EGU emissions to the 2015 and 2020 baseline years modeled. We changed the baseline inventory to incorporate new information not previously available and included revisions to PM emission factors from natural gas combustion, facility-specific inventory revisions, inclusion of newly available year-2000

[5] The documentation for this inventory is available at the EPA docket (number EPA-HQ-OAR-2003-0053-2047) and on the web at http://www.epa.gov/air/interstateairquality/pdfs/finaltech01.pdf.

Canadian inventory data, revised residential wood combustion emissions, and other more minor changes.[6]

Changes to the Projected Emissions Inventory

We also revised future baseline emissions for 2015 and 2020 for this RIA, for both the power sector and other sectors based upon more recent information. For example, several new consent decrees and pollution controls were included on a limited set of power sector sources in the post-CAIR modeling runs of the Integrated Planning Model (IPM).[7] These changes to IPM were small on a national scale, but important at a local scale in certain projected nonattainment areas. Details of these updates are provided in Section 2.3.

As compare to the data used for CAIR, the updates to all sectors resulted in a nationwide decrease of projected baseline emissions of NO_X by approximately 8,300 tons/yr and SO_2 by approximately 18,400 tons/yr with increases in $PM_{2.5}$ of ~5,900 tons/yr for all sources of emissions in 2020. In addition, we increased the reduction achieved for $PM_{2.5}$ emissions of the Heavy Duty Diesel rule for on-road mobile emissions based on corrected modeling input data; the emissions we used are 6% less in 2015 for all on-road mobile and 11% less in 2020 than the $PM_{2.5}$ on-road emissions used during CAIR. We changed our approach for future-year projection of non-EGU stationary sources by adjusting our assumption that emissions growth has a linear relationship with economic growth. For the stationary non-EGU parts of the inventory nationally, this change reduced 2020 emissions of VOC by 26%, NO_X by 23%, CO by 26%, SO_2 by 18%, NH_3 by 23%, and $PM_{2.5}$ by 28%.

Due to the significance of this emissions inventory forecasting assumption, EPA consulted with the Advisory Council on Clean Air Compliance Analysis and the Air Quality Modeling Subcommittee (Council) of the Science Advisory Board (SAB) on August 31, 2006 by public teleconference. In the consultation, EPA requested advice as to proper characterization of the interim emissions forecasting approach and the uncertainties involved. The review of this methodological assumption was completed on an expedited basis by the Council. On September 15, 2006, the Council members issued a letter to the EPA Administrator Stephen L. Johnson reporting their findings. In this letter, the Council recommended an alternative forecasting methodology for the stationary non-EGU source categories as preferred to the method used in this RIA. The Council members suggested the alternative would capture "the underlying technological change that is likely driving the historical decline in emissions, i.e., the efficiency gains in production processes and improvements in air pollution control technologies that can be expected over time." Specifically, the Council suggested using the National Emission Inventory in the 1990s to establish a declining emissions intensity as it relates to changes in the output by sector. As a default, the Council recommended assuming this historical rate of decline would continue to be constant in future years. In the letter to Administrator Johnson, the Council members did recognize that the time constraints involved with the PM NAAQS review and the limitations that might result in the EPA's ability to accomplish their recommendations.

[6] Chapter two discusses each of these changes in depth.
[7] A further discussion of the Integrated Planning Model may be found in chapter 2.

In response to the Council's recommendations, the EPA did endeavor to conduct a limited analysis using the Council's recommended approach for three important non-EGU stationary source sectors including Pulp and Paper Manufacturing, Petroleum Refining, and Chemicals and Allied Products for SO_2 emissions only. The court-ordered schedule for the PM NAAQS review did not allow for further investigation of this method for all non-EGU stationary source categories or relevant pollutants. We found that the Council's suggested approach resulted in essentially a downward trend in future year SO_2 emissions for these source categories implying negative emissions growth in the future for these source categories. Using an approach similar to the Counsel's suggested approach, future-year emissions would decline significantly from 2002 to 2020 for these industries. This result occurs because historical emissions reductions used in this analysis could not be directly attributed to Clean Air Act mandated controls and therefore the entire declining SO_2 emission trend for these three sectors was assumed to continue into the future. We recognize the limitations of this analysis since some historical emission reductions may have been due to Clean Air Act mandated controls (e.g., SIPs, NSPS) that are applied to individual facilities (rather than mandated controls that would be applicable to the entire sector), but given the limited time and quality of the control information in the emission inventory an accurate attribution of these historical emission reductions to the Clean Air Act was not possible. The EPA recognizes the need to find an improved growth forecasting methodology for the stationary non-EGU sectors and is committed to developing the necessary methods and models to achieve this goal in the near future. More information on this issue and copies of the background paper presented to the Council members are included in Appendix E of this document.

Additionally, Table 1-1 provides the impact of this change separately for non-EGU point and stationary area source of this change. The table shows that for these sectors, the emissions used for the RIA are significantly lower (14 –34%) than they would have been had emissions growth been assumed to track economic growth. The basis for this change is described in more detail at the end of Section 2.3.3. As further supporting material, Appendix D describes the impact of this changed assumption on air quality modeling results. Appendix D also explores the impact on future emissions for these sectors of an alternative approach for projecting emissions trends.

Table 1-1: National impact of changed growth assumption for nonEGU point and stationary area source emissions

		VOC	*NO_X*	*CO*	*SO_2*	*NH3*	*PMC*	*$PM_{2.5}$*
NonEGU Point	2020 RIA	1,276,263	2,659,652	3,907,508	2,623,357	78,784	197,462	574,820
	2020 with growth	1,936,662	3,537,339	5,475,138	3,244,133	106,607	296,438	841,942
	% Diff	34.10%	24.80%	28.60%	19.10%	26.10%	33.40%	31.70%
Stationary Area	2020 RIA	7,145,451	1,466,029	3,974,421	1,295,305	149,581	123,719	703,277
	2020 with growth	9,369,403	1,814,842	5,220,186	1,517,562	190,005	152,590	926,242
	% Diff	23.70%	19.20%	23.90%	14.60%	21.30%	18.90%	24.10%

Based on newly-collected data, we also improved projection approaches for pulp and paper facilities, refineries, and cement manufacturing by including the latest information about plant closures, consent decrees, and other planned emissions reductions. We made a number of other changes to our control approaches, assumptions about splitting $PM_{2.5}$ emissions into organic carbon, elemental carbon, and crustal material, and temporal allocation of annual emissions to months.

Impacts of Emission Inventory Changes

The impact of the revised base-year and future-year assumptions as compared to the CAIR platform for emissions in the continental U.S. is shown in Table 1-2. The table shows total and sector-specific changes in both 2001 and 2020 emissions estimates across the emissions platforms. The largest changes in the 2001 estimates are for VOC (4.6% increase) and $PM_{2.5}$ emissions (2.2% decrease). The 2020 emissions have significant changes for all pollutants shown: NO_X (10.5% decrease), SO_2 (14% decrease), VOC (4.9% decrease), $PM_{2.5}$ (19.9% increase), and NH_3 (7.3% decrease). These changes are also shown for NO_X, SO_2, VOC and $PM_{2.5}$ as charts in Figure 1-1.

Table 1-2: Comparison of CAIR and PM NAAQS Emissions in 1000 tons/yr for Key Criteria Pollutants[a]

	Year	*Platform*	*EGU Point*	*Non-EGU Point*	*Stationary Nonpoint*	*Nonroad Mobile*	*On-Road Mobile*	*Total*
NO_X	2001	CAIR	4,937	2,943	1,701	4,051	8,064	21,696
		PM NAAQS	4,936	2,946	1,712	4,057	8,064	21,715
		% Change	0.0%	0.1%	0.6%	0.1%	0.0%	0.1%
	2020	CAIR	2,187	3,457	2,040	2,672	2,438	12,794
		PM NAAQS	1,980	2,662	1,705	2,672	2,432	11,451
		% Change	–9.5%	–23.0%	–16.4%	0.0%	–0.2%	–10.5%
SO_2	2001	CAIR	10,901	2,959	1,344	433	271	15,908
		PM NAAQS	10,849	2,873	1,345	435	271	15,773
		% Change	–0.5%	–2.9%	0.1%	0.3%	0.0%	–0.9%
	2020	CAIR	4,387	3,674	1,565	281	34	9,941
		PM NAAQS	4,259	2,629	1,344	281	34	8,547
		% Change	–2.9%	–28.4%	–14.1%	0.0%	–0.3%	–14.0%
VOC	2001	CAIR	53	1,537	7,981	2,585	4,710	16,865
		PM NAAQS	53	1,538	8,746	2,586	4,710	17,633
		% Change	0.0%	0.0%	9.6%	0.1%	0.0%	4.6%
	2020	CAIR	46	1,745	7,963	1,530	1,768	13,051
		PM NAAQS	45	1,276	7,799	1,530	1,764	12,414
		% Change	–1.5%	–26.9%	–2.1%	0.0%	–0.3%	–4.9%
$PM_{2.5}$	2001	CAIR	599	705	3,480	308	161	5,253
		PM NAAQS	568	607	3,491	308	161	5,136
		% Change	–5.2%	–13.9%	0.3%	0.1%	0.0%	–2.2%
	2020	CAIR	523	934	3,460	193	66	5,176
		PM NAAQS	533	579	3,411	193	61	6,206
		% Change	1.8%	–38.0%	-1.4%	0.0%	–7.5%	19.9%
NH_3	2001	CAIR	8	83	3,320	2	277	3,690
		PM NAAQS	8	80	3,330	2	277	3,697
		% Change	0.0%	–3.4%	0.3%	0.0%	0.0%	0.2%
	2020	CAIR	1	112	3,596	2	418	4,129
		PM NAAQS	1	79	3,328	2	417	3,827
		% Change	–1.9%	–29.6%	–7.5%	0.0%	–0.2%	–7.3%

[a] Estimates in this table are 2001 and 2020 baseline emission estimates.

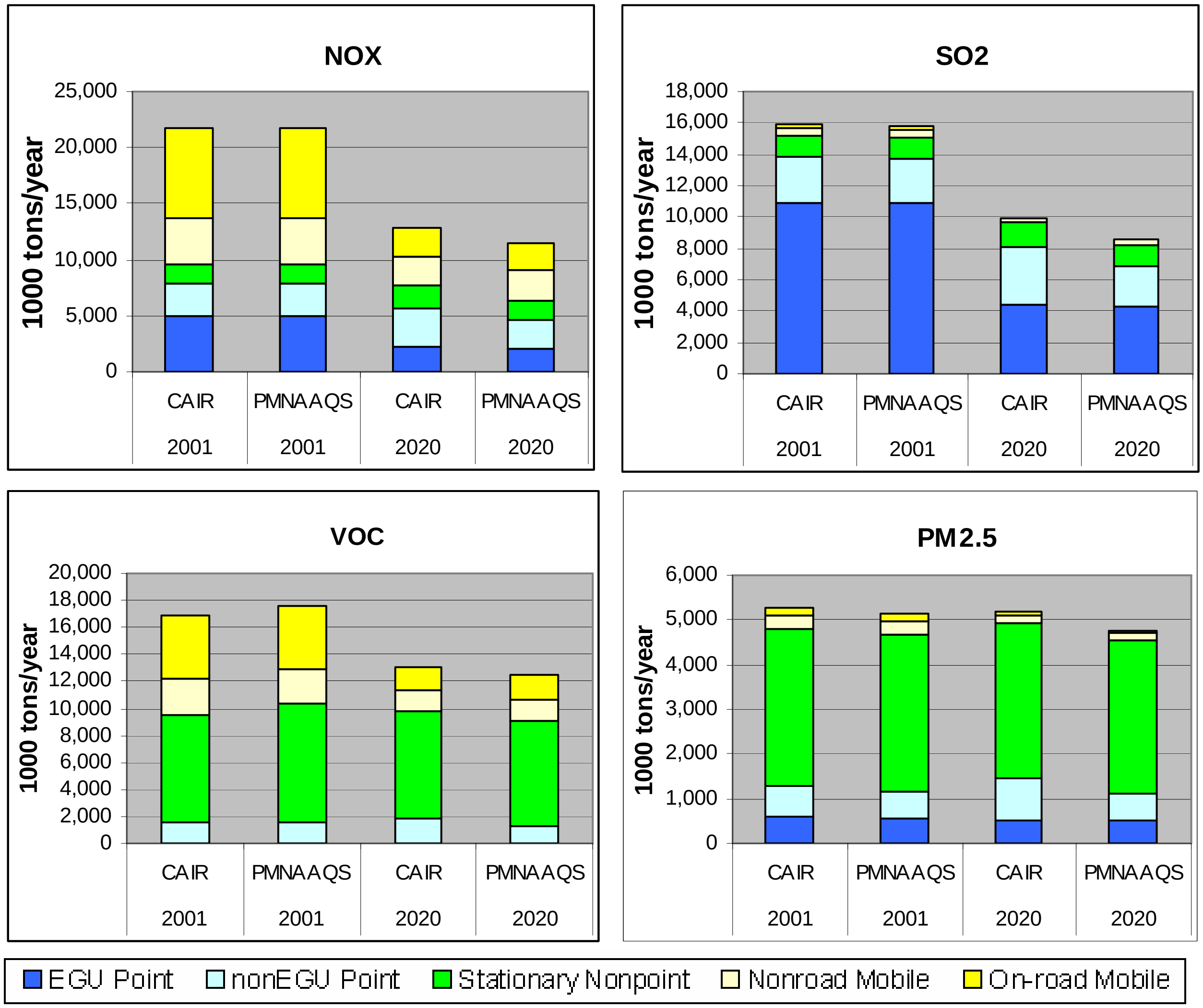

Figure 1-1: Comparison of NO_X, SO_2, VOC, and $PM_{2.5}$ Emissions between CAIR and PM NAAQS Platforms[a]

[a] Estimates in this table are 2001 and 2020 baseline emission estimates that do not reflect our illustrative control strategies.

1.4.2 Air Quality Modeling

This section summarizes the important differences and advances in the air quality modeling of the PM NAAQS Final RIA from the interim RIA, including the technical detail associated with these analyses and technical support documents.

Overview of Interim RIA Air Quality Modeling Approach

For the PM NAAQS Interim RIA, we used a Response Surface Model (RSM)[8] tool to estimate the air quality changes associated with various pollution control strategies. The RSM is a "model of the model" that can provide instantaneous estimates of air quality changes associated with changes in emissions from various source sectors with little bias or error relative to national-scale CMAQ modeling; this quick analysis allows users to quickly evaluate various control scenarios. The interim RIA applied this approach to consider control strategies in five selected urban areas. EPA intended to perform national air quality modeling to estimate national cost and benefit estimates of illustrative control strategies, but determined that the available datasets and tools were inadequate to complete such an analysis within the available timeframe. Most significantly, we concluded that the national-scale analysis based on then-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.[9]

Improvements to Our Air Quality Modeling Approach

For the PM NAAQS Final Rule RIA, we used the RSM as it was originally designed: as a screening tool to investigate cost-effective sector-based control scenarios. We then analyzed these strategies using EPA's Community Multi-Scale Air Quality (CMAQ) Modeling System, which is a national-scale photochemical grid model. These refinements to our air quality modeling approach enabled us to simulate the national air quality changes that occur as a result of our illustrative attainment scenarios. This air quality information, in turn, allows us to provide national-level estimates of the costs and benefits of the nation's ability to attain the proposed revised standard and alternative revised standards.

This final analysis also extends the local-scale dispersion modeling of the interim approach by including additional urban areas. We use local-scale air quality modeling (AERMOD) to (1) examine the spatial variability of direct $PM_{2.5}$ concentrations associated with emissions of primary $PM_{2.5}$ within each urban area, and (2) to quantify the impact of specific emissions source groups on ambient $PM_{2.5}$ concentrations at Federal Reference Method (FRM) monitoring sites. We focused this assessment on five urban areas: Birmingham, Seattle, Detroit, Chicago and Pittsburgh; these latter two urban areas are new for the final RIA. We selected these areas because they provide a mixture of emissions sources, meteorology, and associated $PM_{2.5}$ air quality issues. Because each of the chosen areas are representative of a wide array of conditions that arise across the country in other urban areas, we are able to apply insights learned from the narrow, city-specific analyses to a broader set of areas and circumstances nationally. In this RIA we also model the local-scale impacts of $PM_{2.5}$ controls on selected sources in these urban areas. This analysis complements the CMAQ-based regional-scale modeling analyses through its ability to estimate concentrations at a higher spatial resolution and an estimate of the impact of local sources of primary $PM_{2.5.}$

[8] For additional information regarding the development and application of the RSM, see the Response Surface Modeling Technical Support Document (TSD) for the PM NAAQS Proposal, February 2006, found in the docket.
[9] Some commenters used these city-specific estimates to derive national estimates, which significantly overstate the costs by 1 to 2 orders of magnitude.

1.4.3 Emission Control Data

In this RIA we both modified our process from the interim RIA for selecting cost-effective controls and augmented our emission control information. To select cost-effective emission controls, we extended a method used for the interim RIA that incorporates urban-area specific air quality modeling data into the controls selection decision. For each projected nonattainment area, we used information from the RSM regarding the estimated total reduction in daily and annual $PM_{2.5}$ design values yielded by a given ton of directly-emitted $PM_{2.5}$ and $PM_{2.5}$ precursor (NO_X, SO_2 and NH_3) abated at the nonattaining monitor. We then combined these estimates of air quality impact per ton with estimates of cost per ton for each precursor to derive an estimate of cost per microgram abated. We then ranked controls by cost per microgram to identify the most cost-effective controls for achieving the annual and daily standards. This method allowed us to select those emission controls for each projected nonattainment area that the air quality model estimated to have the greatest air quality impact per ton of precursor reduced. It also allowed us to approximate the amount of controls that would be required to reach attainment in each area. We also constrained our selection of controls with cost per ton caps (ranging from $20,000/ton to $350,000/ton) for each precursor in the projected nonattainment areas to ensure that we did not select controls with an excessively high cost per ton.

Next, we conducted a comprehensive review of the control strategies applied for the interim RIA, the results of which indicated a very high annualized cost per ton estimate (some with costs of more than $1 million/ton of emission reduction). As a result, EPA determined that better information was required regarding: the applicability of certain controls to some sources; the types of emission controls already in place at some sources; new and innovative control measures; and, the credibility of control measures currently in our emission controls database. Based on these results, EPA sought to improve its characterization of control measures in three ways. First, emissions inventory experts and others within EPA researched and identified those control measures that sources in projected nonattainment had either already implemented or were planning to adopt. This effort is described in more detail in Chapter 3 of this RIA.

Second, EPA reviewed and adjusted the applicability of PM control measures to point sources within its emission controls database. Our review, conducted by EPA regulatory project leads and sector experts, led in many cases to improvements in our data; for example, we refined the links that match known control techniques to key source categories. Another recommendation from this review led to the establishment of a ton-per-year threshold for small-emitting sources: our analysis no longer places controls on any sources that emit less than 5 tons per year, because it was determined that these sources were likely to have existing controls in place, and further control was typically not cost-effective and inefficient in reducing area-wide concentrations of PM. Furthermore, our review of mobile source emissions led to a thorough re-analysis of potential mobile source control strategies for use in our attainment scenarios.

Third, EPA reviewed the control measures in our controls database to determine if they were consistent with control measure data collected by Regional Planning Organizations (RPOs), organizations such as the State and Territorial Air Pollution Program Officers and the Association of Local Air Pollution Control Officers (STAPPA/ALAPCO), States such as California (reports prepared by the California Air Resources Board, or CARB) or local agencies such as the South Coast Air Quality Management District (SCAQMD). Our review of the other control measure data sets utilized by these organizations concluded that nearly all of the remaining data was either (a) already incorporated into our controls database, or (b) not sufficiently robust to warrant inclusion in the software tool.

Finally, while our review suggested that our database was mainly complete, EPA identified two additional control measures for various pollutants and source categories for which no measures had been previously available. One of these pollutant and source category combinations is SO_2 emissions from area sources, for which we added a new measure to control SO_2 emissions from home heating oil use based on data from the Clean Air Association of Northeastern States (NESCAUM) study completed in December 2005.[10] We also added a control measure that is intended to reduce area source $PM_{2.5}$ emissions from commercial cooking facilities (mostly restaurants) in response to this review.

The results of this review are available in Appendix I of this RIA. The analyses done for non-EGU sources and included in this final RIA reflect the incorporation of the changes that were recommended.

1.4.4 Benefits Uncertainty Characterization

In response to the recommendations of the National Research Council report on Estimating the Public Health Benefits of Proposed Air Pollution Regulations[11], the benefits assessment in this RIA includes the results of an expert elicitation to characterize uncertainty in the effect estimates used to estimate premature mortality resulting from exposures to PM. The goal of this expert elicitation was to evaluate uncertainty in the underlying causal relationship, the form of the mortality impact function (e.g., likelihood of a threshold, likelihood of a linear function at lower ambient concentration) and the fit of a specific model to the data (e.g., confidence bounds for specific percentiles of the mortality effect estimates). The expert elicitation also addresses issues such as the ability of long-term cohort studies to capture premature mortality resulting from short-term peak PM exposures. To provide a more robust characterization of the uncertainty in the premature mortality function than has been presented in prior RIA's, the analysis for the PM NAAQS was based on EPA's recently completed the full-scale expert elicitation. This elicitation incorporated peer-review comments on the pilot-scale study, which was used in the CAIR RIA.

Chapter 5 of this RIA includes benefits estimates based on the results of the full-scale study, which consist of twelve individual distributions for the coefficient or slope of the C-R function relating changes in annual average $PM_{2.5}$ exposures to annual, adult all-cause mortality. EPA has not combined the individual distributions in order to preserve the breadth and diversity of opinion on the expert panel. In applying these results in a benefits analysis context, EPA incorporated information about each expert's judgments concerning the shape of the C-R function (including the potential for a population threshold $PM_{2.5}$ concentration below which there is no effect on mortality), the distribution of the slope of the C-R function, and the likelihood that the $PM_{2.5}$-mortality relationship is or is not causal (unless the expert incorporated

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[10] NESCAUM. Low Sulfur Heating Oil in the Northeast States: An Overview of Benefits, Costs, and Implementation Issues. December 2005. Found on the Internet at http://www.nescaum.org/documents/report060101heatingoil.pdf.

[11] National Research Council (NRC). 2002. Estimating the Public Health Benefits of Proposed Air Pollution Regulations. Washington, DC: The National Academies Press.

this last element directly in his slope distribution—see Industrial Economics, 2006). Chapter 5 includes estimates of benefits using mortality impact functions derived both from the epidemiology literature and the expert elicitation.

1.5 $PM_{2.5}$ Standard Alternatives Considered

This RIA analyzes the costs and human health and welfare benefits associated with attaining both the selected and one alternative standard; these are expressed in Table 1-3 below as combinations of the annual and daily standard:

Table 1-3: Annual and Daily $PM_{2.5}$ NAAQS Under Consideration

Combination of Annual and Daily Values, in µg/m³	*Notes*
15/65	1997 Standards
15/35	Revised Standards
14/35	Alternative

1.6 Baseline and Pathways to Attainment

1.6.1 Selected Baseline Years

In the RIA, we have chosen 2015 and 2020 as the base years for analysis, which roughly approximate the maximum time period (10 years from designation) under the Clean Air Act for attainment of a NAAQS. Under the Act, States are required to develop plans to attain the standards "as expeditiously as practicable" based on reasonably available measures. In addition, States must attain the standards within five years unless EPA determines that an attainment date extension of an additional one to five years is appropriate, based on the severity of the nonattainment problem and the availability of control measures. For example, current $PM_{2.5}$ area designations became effective in 2005. An area receiving the full five year extension would have an attainment date of 2015 (with attainment based on air quality data for 2012-2014).

For analytical simplicity, we have chosen 2015 as our base year of analysis for attainment with the 1997 $PM_{2.5}$ standards (15 $\mu g/m^3$ annual, 65 $\mu g/m^3$ daily). Although the date of any new designations is uncertain, for the purpose of this analysis we are assuming that new designations would be effective in 2010 and we have chosen 2020 as the year in which to simulate attainment with the revised and alternative revised standards.

From now through 2020, a suite of regionally and nationally-implemented rules already in effect will lead to large emission reductions. These rules include: the Clean Air Interstate Rule (CAIR), the Clean Air Visibility Rule (CAVR) and the Clean Air Mercury Rule (CAMR), the Clean Air Non-Road Diesel Rule, the Heavy Duty Diesel Engines Rule, and the Light-Duty Vehicle Tier 2 vehicle and gasoline standards. These rules—as well as an array of state rules already in place—will produce substantial nation-wide reductions in SO_2, NO_X and directly emitted $PM_{2.5}$, thereby facilitating State attainment of the revised $PM_{2.5}$ NAAQS.

1.6.2 Attainment Pathways

Figures 1-2 and 1-3 below illustrate how a State might factor in the presence of the emission reductions associated with these national, regional and state rules when designing its “attainment pathway”—that is, the sequence and magnitude of emissions reductions necessary to meet the current or revised standards. These figures also describe the positive relationship that reductions in the annual design value have on the daily design value.

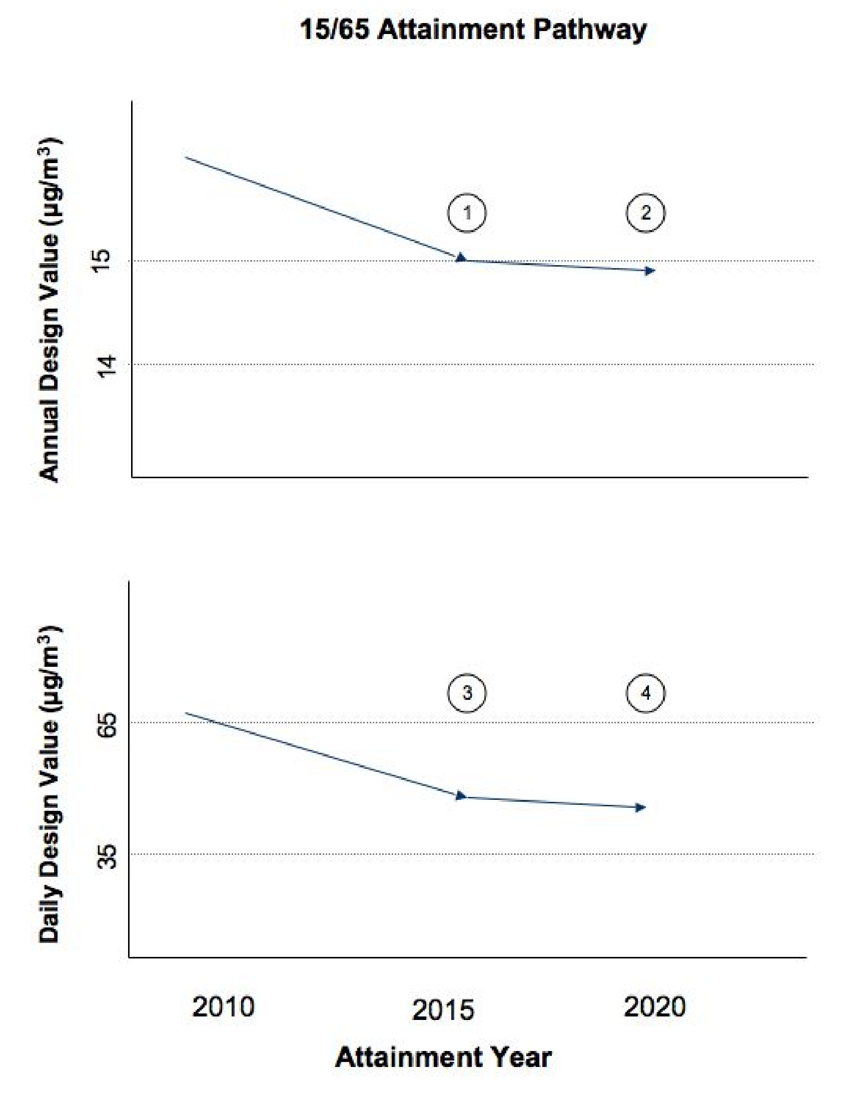
Figure 1-2 below illustrates a plausible attainment pathway that meets only the current $PM_{2.5}$ NAAQS. This pathway assumes that States will design control strategies that just meet the annual standard, which is controlling in most areas, by 2015; this point is identified on the figure as #1. Most states will have already met the existing daily standard of 65 $\mu g/m^3$ by 2015, as reflected by #3. Between 2015 and 2020, the analysis assumes that States may achieve levels cleaner than the annual standard as regional emissions reductions from the national rules continue to lower total emissions and thus reduce the annual and daily design value further below the standards by a small amount.

The attainment pathway for the revised and alternative revised NAAQS of 15/35 or 14/35 may be “steeper.” The analysis assumes that States may achieve levels cleaner than the existing annual or daily standards in 2015 to make progress toward attainment of the revised and more stringent alternative standard in 2020. Figure 1-3 illustrates these more ambitious attainment pathways.

To attain the revised standard of 15/35, States must first attain the current annual standard of 15 $\mu g/m^3$ in 2015 to comply with the statutory deadline (#1). At that time, States may also elect to apply controls to ease attainment of 35 $\mu g/m^3$ in 2020; this establishes an attainment pathway to 15/35 that is identified by #3. As in Figure 1-2 of the previous example, between 2015 and 2020, the suite of national rules will produce additional emission reductions which are likely to reduce the annual design value below the standard, as identified by #2. Finally, between 2015 and 2020 States may implement additional local controls that target the daily standard and attain 35 $\mu g/m^3$ by 2020, as identified by #4.

The attainment pathway for the 14/35 alternative resembles that for 15/35, but accounts for the early progress States might seek to achieve in 2015 toward meeting the 14 $\mu g/m^3$ standard. The analysis assumes States may achieve levels cleaner than the existing 15 $\mu g/m^3$ annual standard between 2015 and 2020 to facilitate their attainment of the 14/35 $\mu g/m^3$ annual standard in 2020, as seen in point #1.[12] Progress toward the tighter 14 $\mu g/m^3$ annual standard in 2015 would also produce improvements in the daily design value beyond those seen for the 15/35 attainment scenario, as identified by point #3.

[12] The control strategy to simulate attainment with the 14/35 alternative includes an illustrative extension to the CAIR program to be implemented between 2015 and 2020. This program would create incentives for banking and trading of SO_2 allowances in 2015, which would produce the air quality improvements observed in the blue line below #1 of Figure 1-3. For further discussion of our control scenarios and this EGU cap, see Chapter 3.



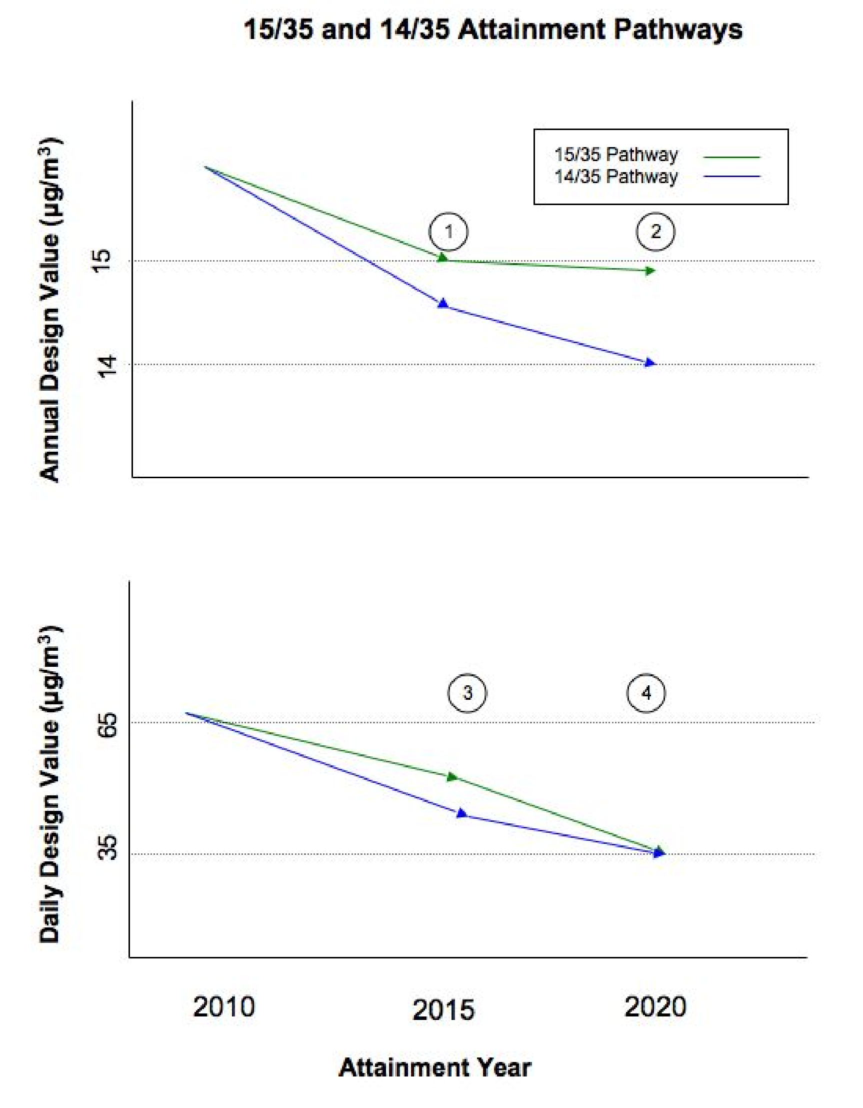


Figure 1-2. Illustrative Attainment Pathway for 1997 Standards	**Figure 1-3. Illustrative Attainment Pathway for Revised and Alternative Standards**

1.7 Control Scenarios Considered in this RIA

In developing control scenarios, EPA accounted for the level of emissions reductions that regional and national-scale rules would generate in each area. Based on this information, EPA developed a "control hierarchy" that expanded in geographic scope and breadth of sources as we simulated attainment with increasingly stringent standard alternatives.

1.7.1 Emissions Reductions Associated with National Rules Taking Effect by 2015 and 2020

Figure 1-4 below illustrates the historical downward trend in NO_x and SO_2 emissions due to the implementation of key national programs such as the Acid Rain program, the Clean Air Nonroad Diesel rule, the PM2.5 implementation rule, the Clean Air Interstate Rule and the Regional Haze rule.

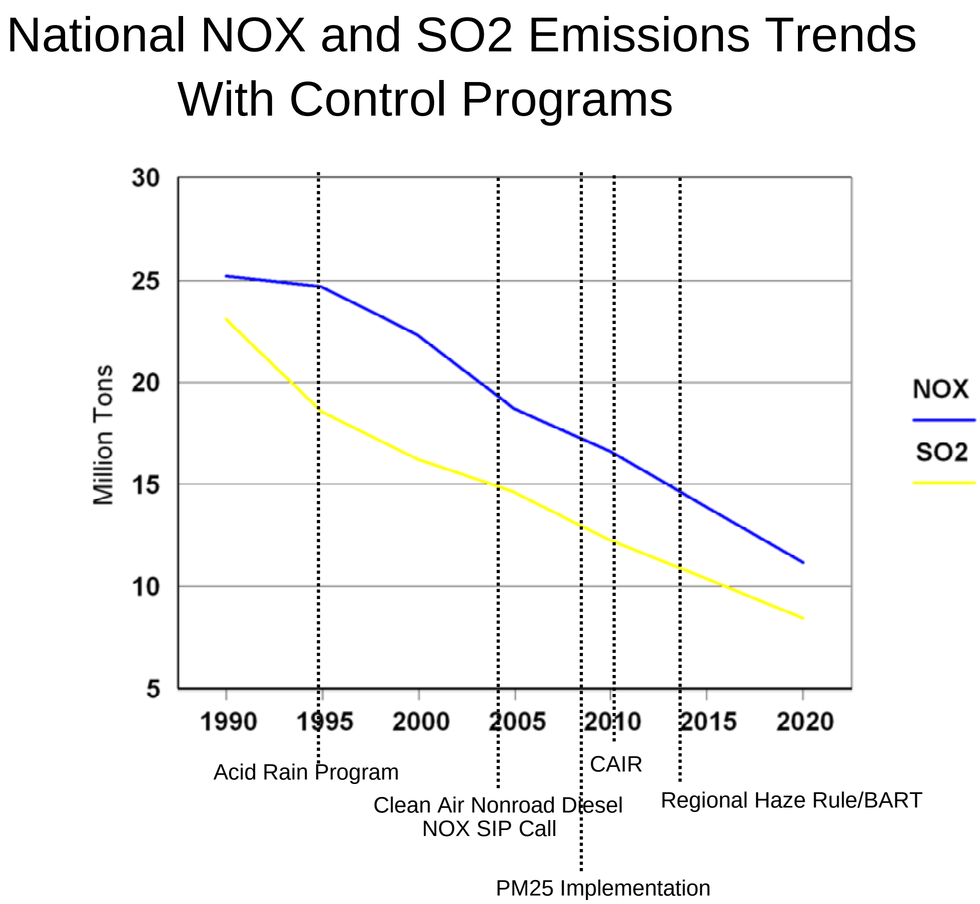


Figure 1-4. Regional and National NO_X and SO_2 Emissions Trends with Control Programs

1.7.2 Control Hierarchy

In examining alternative controls to meet the 1997 standards and the revised and alternative more stringent revised standards, our analyses selected emission controls according to a hierarchy of control strategies. This hierarchy increased the geographical breadth and stringency of controls as we analyzed successively more stringent NAAQS alternatives. Figure 1-5 below illustrates the relationship between the standard alternative and the geographical breadth.

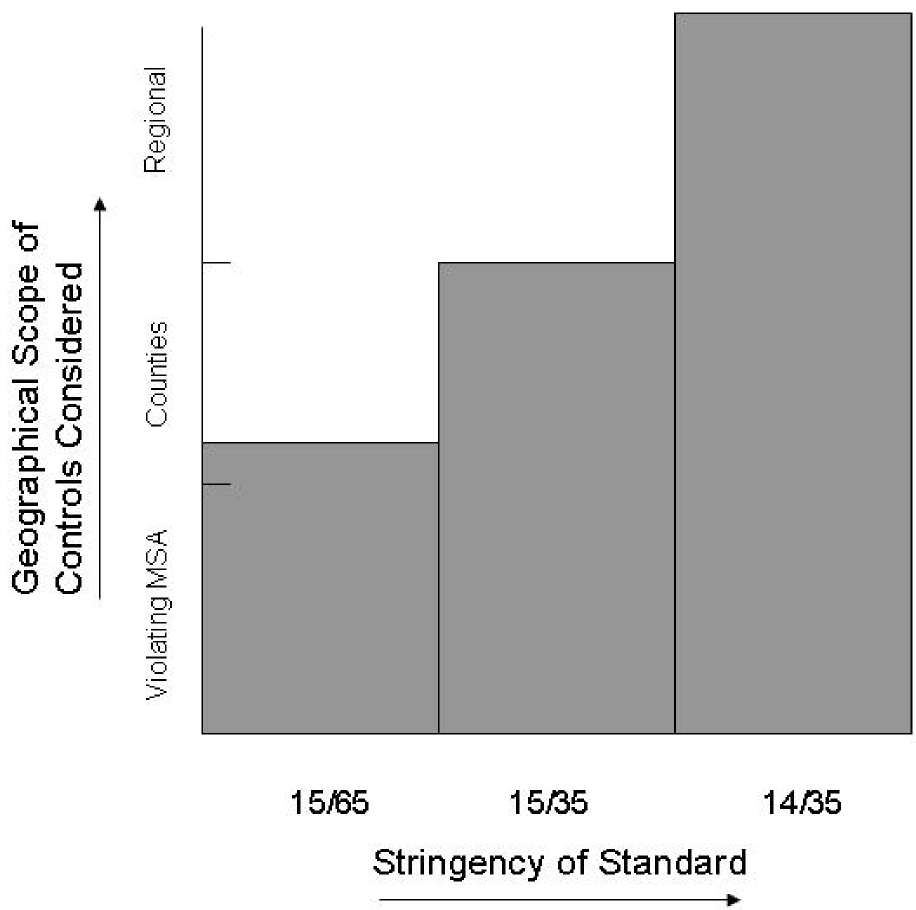


Figure 1-5. Relationship between the Stringency of the Standard and the Geographical Scope of Emission Controls Considered

This figure is an abstraction that is intended to show how we increased the geographical breadth of the control measures as we attempted to simulate attainment with more stringent standards. In general, controls selected to simulate attainment with the existing 15/65 standards were focused in counties within the Metropolitan Statistical Area (MSA) in which a nonattaining monitor was located. In a limited number of locations, controls were extended into counties surrounding these MSA's when sufficient controls were not available within the MSA. In selecting controls to meet the revised 15/35 suite of standards, controls were selected both within the MSA and in surrounding counties expected to contribute to the nonattaining monitor. We selected controls that are local known technologies in use today. If local known controls in the MSA and surrounding area are not enough to bring the area into attainment, then we considered developmental emission controls, which are new and developing control measures that have limited application in 2006, but are likely to be used more widely by 2020. Finally, in selecting controls to meet the alternative more stringent annual standard, a set of regional controls on SO_2 emission sources were considered in addition to controls in the MSAs and surrounding counties. In some areas, it was difficult to model full attainment with the regulatory options. To the extent that we did not simulate full attainment by using known and developmental controls, we applied supplemental carbonaceous particle controls to the modeled air quality results. If we were not able to simulate attainment using these controls, we made a final determination of attainment by weighing the empirical monitoring, modeling and emissions data. Finally, for California and Salt Lake City, due to the magnitude of the projected non-attainment problem, we extrapolated the cost of reaching full attainment. The combination of modeled (local known and developmental controls), supplemental, and extrapolated data form our attainment analysis.

1.7.3 Designation Process

EPA projects certain counties to violate the revised standards in 2020, and our control strategy methodology selects emissions controls both in those violating counties, and in surrounding counties that were identified as being likely to contribute to the violation in the nonattaining county. While this process is intended to provide an illustration of how attainment might be achieved in the nonattainment county using emission reductions in surrounding counties, this is not intended to suggest that these counties would or would not be part of EPA's official designated nonattainment areas.

The process for designating nonattainment areas for the revised PM NAAQS is defined within the Clean Air Act (42 U.S.C. §7407 (d)). EPA plans to complete final designations for areas violating the 24-hour PM2.5 standard by April 2010. The designation process is complex and incorporates information from the States and EPA on a wide range of factors, both for areas with violations and for nearby areas that are potentially contributing to such violations.

In past guidance, EPA has stated that it would use the metropolitan area as the presumptive definition of the source area that contributes to an area's PM2.5 nonattainment problem (Holmstead, 2003; Wegman, 2004). However, these presumptive boundaries can be modified based on a number of factors, including air quality, pollutant emissions, population density and the degree of urbanization, traffic and commuting patterns, growth, meteorology, geography/topography, jurisdictional boundaries (including boundaries of previously designated nonattainment areas), and level of control of emission sources. For each area with a violating monitor, the Governor provides to EPA its recommended nonattainment area boundary and related supporting information. The EPA Administrator takes these recommendations into consideration in designating final nonattainment area boundaries.

1.7.4 Summary of Controls Considered for the Current NAAQS and Each Standard Alternative

This analysis considers an array of stationary and mobile source emission controls to simulate attainment with the revised and more stringent alternative standards. To attain the revised standards in the East, our control strategy consisted primarily of controls on directly emitted carbonaceous particles on point and area sources; to achieve these standards in the West, we applied both carbonaceous particle and nitrous oxide controls on stationary sources. The attainment strategy in the East for the alternative more stringent standards included additional SO_2 emission controls on both Electrical Generating Units in the CAIR region and non-EGU SO_2-emitting stationary sources in a multi-state region within the mid-west. Additional information regarding the composition of our control strategy can be found in Chapter 3.

1.7.5 Full Attainment Scenario for California

California poses a unique $PM_{2.5}$ nonattainment challenge in this RIA due both to the magnitude of their existing and projected air quality problem for the revised and more stringent alternative standards, as well as to a number of California-specific limitations in our data and tools. Our analysis suggests that many areas of California are projected to exceed the revised and more stringent alternative standards in 2015 and 2020 by a substantial margin, even after the application of all known cost-effective controls. There are four factors that inhibit our ability to simulate attainment, or near attainment, in California:

1. The magnitude of projected non-attainment is larger than any other state, making the task of simulating attainment much more challenging than elsewhere in the nation.
2. We exhausted our emission controls database, which prevented us from controlling all emission sources that contribute to nonattainment.[13]
3. Key uncertainties exist with regard to both emissions inventories and air quality modeling in the West, which may understate the effectiveness of certain controls.
4. The relatively broad spatial resolution of our air quality modeling (36 km) means that emission reductions from local sources are not accurately "captured" by the relevant nonattaining monitors, resulting in possible understatements of local control efficiencies.[14]

Consequently, providing a credible attainment pathway for California that includes the estimated costs of full attainment entails a specialized treatment in this RIA. While in this analysis we cannot demonstrate full attainment with known controls, in the following chapters we provide information that suggests that there are pathways California can follow to attain the current and alternative NAAQS; we also provide a bounding estimate of attainment cost for each alternative NAAQS. Specifically, we:

1. *Document the uncertainties and limitations of the emissions inventories and CMAQ air quality model in California.* We describe the modeling and emissions uncertainties in California and provide a qualitative characterization of the magnitude that these uncertainties may have on our ability to simulate attainment.
2. *Estimate the costs of achieving the nonattainment increment that is residual after the application of all cost-effective controls*. To derive the cost of achieving this air

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[13] That is to say that there were more emissions of $PM_{2.5}$ precursors than there were control measures available to abate these emissions.
[14] For further discussion of the CMAQ air quality model grid scale and its implications for our controls analysis, see chapter four.

quality increment, we use information regarding the cost of achieving the modeled attainment increment. We document the limitations of this analysis and, because of the high level of uncertainty associated with these cost estimates, present them apart from the estimates for the remainder of the nation.

3. *Characterize the effect that California's emission reduction programs may have on future attainment*. For example, the State has recently developed ambitious emission reduction programs for goods movement that have the potential to substantially improve air quality in nonattainment areas.[15] While this RIA attempts to incorporate the emissions reductions from some of these control measures, differences between EPA and California emissions inventories prevented us from fully capturing the air quality improvements associated with this strategy. Additional information regarding the goods movement plan may be found in Chapter 3.

The cost analysis is found in Chapter 6, while the remainder of the analyses are located in Chapter 4.

1.8 Benefits of Attaining Revised and Alternative Standards in 2020

Tables 1-4 through 1-8 summarize the estimated reductions incidence of mortality and morbidity associated with attaining the revised and more stringent alternative $PM_{2.5}$ standards. These tables also present the valuation estimates associated with these reductions in incidence.

The tables below summarize the estimates of mortality and morbidity that use effect estimates derived from the expert elicitation effort described above in section 1.4.4. In these tables we provide incidence and valuation estimates based on data-derived and expert-elicitation derived mortality functions, for both our modeled and full attainment scenarios. The expert-elicitation derived incidence and valuation estimates include upper and lower-bound estimates based on the two experts who provided the highest and lowest mortality impact functions. Chapter 5 of this RIA complements these summary tables by including the results of the full-scale study.

[15] For additional information regarding the California Goods Movement Initiative, see: "Proposed Emission Reduction Plan for Ports and Goods Movement in California," located at www.arb.ca.gov/planning/gmerp/gmerp.htm

Table 1-4.Estimated Reduction in Incidence of Mortality Effects Associated with Attaining the Revised and More Stringent Alternative Standards

	Reduced incidence of mortality[a]	
	15/35 (µg/m3)	*14/35 (µg/m3)*
Based on Mortality Function from American Cancer Society and Morbidity Functions from Epidemiology Literature[b]		
	2,500	4,400
	Confidence Intervals	*Confidence Intervals*
	(1,000 – 4,100)	(1,700 – 7,100)
Based on Expert Elicitation Derived Mortality Functions and Morbidity Functions from Epidemiology Literature		
	Lower-bound EE: 1,200	Lower-bound EE: 2,200
	Upper-bound EE: 13,000	Upper-bound EE: 24,000
	Confidence Intervals	*Confidence Intervals*
	CI for lower bound EE result: (0 – 5,800)	CI for lower bound EE result: (0 – 11,000)
	CI for upper bound EE result: (6,400 – 19,000)	CI for upper bound EE result: (12,000 – 35,000)

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

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

The estimates in the table below are stratified into modeled partial attainment and full attainment. Modeled partial attainment estimates are derived from modeled air quality improvements from our illustrative control strategies which do not attain the revised or more stringent alternative standards in all areas. For those areas which our air quality models do not project to attain (for reasons explained in Chapter 4) we estimate full attainment by "rolling-back" the violating air quality monitors so that they just attain the revised or more stringent alternative standards. This approach allowed us to develop a nationwide estimate of the monetized human health benefits. For a complete discussion of the monitor roll-back approach, see Chapter 4.

Table 1-5. Estimated Reduction in Incidence of Adverse Health and Welfare Effects Associated with Attaining the Revised and More Stringent Alternative Standards (90 Percent Confidence Intervals Provided in Parentheses)

	Revised Standards (15/35)		**Alternative Revised Standards (14/35)**	
Estimate	*Modeled Partial Attainment*	*Full Attainment (Partial Plus Residual)*	*Modeled Partial Attainment*	*Full Attainment (Partial Plus Residual)*
Chronic bronchitis (age >25 and over)	1,000 (190 – 1,900)	2,600 (490 – 4,800)	2,900 (540—5,300)	4,600 (850—8,300)
Nonfatal myocardial infarction (age >17)	1,900 (1,100 – 2,800)	5,000 (2,700 – 7,200)	5,300 (2,900 – 7,800)	8,700 (4,800 – 13,000)
Hospital admissions—respiratory (all ages)[b]	200 (100 – 310)	530 (260 – 800)	620 (310 – 930)	980 (490 – 1,500)
Hospital admissions—cardiovascular (age >17)[c]	440 (280 – 600)	1,100 (690 – 1,500)	1,300 (830 – 1,800)	2,100 (1,300 – 2,800)
Emergency room visits for asthma (age <19)	530 (310 – 740)	1,200 (730 – 1,700)	2,400 (1,400 – 3,400)	3,200 (1,900 – 4,500)
Acute bronchitis (age 8–12)	2,800 (–90 – 5,600)	7,300 (–260 – 15,000)	7,700 (–260 – 16,000)	13,000 (–440 – 25,000)
Lower respiratory symptoms (age 7–14)	18,000 (8,600 – 27,000)	56,000 (27,000 – 84,000)	46,000 (22,400 – 70,000)	88,000 (43,000 – 130,000)
Upper respiratory symptoms (asthmatic children, age 9–18)	13,000 (4,100 – 22,000)	41,000 (13,000 – 70,000)	34,000 (11,000 – 57,000)	65,000 (20,000 – 110,000)
Asthma exacerbation (asthmatic children, age 6–18)	16,000 (1,800 – 47,000)	51,000 (5,600 – 150,000)	42,000 (4,600 – 120,000)	79,000 (8,900 – 230,000)
Work loss days (age 18–65)	110,000 (100,000 – 130,000)	350,000 (300,000 – 390,000)	300,000 (260,000 – 340,000)	550,000 (480,000 – 620,000)
Minor restricted-activity days (age 18–65)	680,000 (570,000 – 780,000)	2,000,000 (1,700,000 – 2,300,000)	1,800,000 (1,500,000 – 2,000,000)	3,300,000 (2,700,000 – 3,800,000)

Table 1-6. Estimated Monetary Valuation of Reduction in Incidence of Adverse Health and Welfare Effects Associated with Attaining the Revised and more stringent Alternative Standards (90 Percent Confidence Intervals Provided in Parentheses)

Estimate	Revised Standards (15/35)		Alternative Revised Standards (14/35)	
	Modeled Partial Attainment	*Full Attainment (Partial Plus Residual)*	*Modeled Partial Attainment*	*Full Attainment (Partial Plus Residual)*
Chronic bronchitis (age >25 and over)	$420 ($33 – $1,500)	$1,100 ($83 – $3,700)	$1,200 ($91 – $4,100)	$1,900 ($150 – $6,600)
Nonfatal myocardial infarction (age >17)				
3% Discount Rate	$160 ($43 – $350)	$420 ($110 – $910)	$440 ($120 – $970)	$730 ($200 – $1,600)
7% Discount Rate	$160 ($40 – $350)	$410 ($110 – $890)	$430 ($110 – $950)	$700 ($180 – $1,600)
Hospital admissions—respiratory (all ages)[d]	$3.3 ($1.6 – $4.9)	$8.5 ($4.2 – $13.0)	$10.0 ($4.9 – $15.0)	$16.0 ($7.8 – $23.0)
Hospital admissions—cardiovascular (age >17)[e]	$9.0 ($5.7 – $13.0)	$23.0 ($14.0 – $32.0)	$27.0 ($17.0 – $38.0)	$43.0 ($27.0 – $59.0)
Emergency room visits for asthma (age <19)	$0.14 ($0.08 – $0.22)	$0.34 ($0.19 – $0.51)	$0.66 ($0.36 – $1.00)	$0.88 ($0.48 – $1.30)
Acute bronchitis (age 8–12)	$1.00 (–$0.04 – $2.60)	$2.70 (–$0.10 – $6.70)	$2.80 (–$0.10 – $7.10)	$4.60 (–$0.17 – $12.00)
Lower respiratory symptoms (age 7–14)	$0.29 ($0.11 – $0.54)	$0.90 ($0.34 – $1.70)	$0.75 ($0.28 – $1.40)	$1.40 ($0.54 – $2.70)
Upper respiratory symptoms (asthmatic children, age 9–18)	$0.35 ($0.09 – $0.75)	$1.10 ($0.29 – $2.40)	$0.90 ($0.24 – $1.90)	$1.80 ($0.45 – $3.70)
Asthma exacerbation (asthmatic children, age 6–18)	$0.67 ($0.07 – $2.20)	$2.10 ($0.23 – $7.00)	$1.70 ($0.19 – $5.80)	$3.30 ($0.36 – $11.00)
Work loss days (age 18–65)	$14 ($12 – $15)	$43 ($37 – $48)	$33 ($28 – $37)	$65 ($56 – $73)
Minor restricted-activity days (age 18–65)	$17 ($2 – $33)	$51 ($5 – $99)	$44 ($4 – $86)	$81 ($7 – $160)

Table 1-7: Estimated Annual Monetized Benefits in 2020 of Illustrative Implementation Strategies for the Selected and Alternative $PM_{2.5}$ NAAQS, Incremental to Attainment of the Current Standards

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

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

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

[b] Although the overall range across experts is summarized in this table, the full uncertainty in the estimates is reflected by the results for the full set of 12 experts. The twelve experts' judgments as to the likely mean effect estimate are not evenly distributed across the range illustrated by arraying the highest and lowest expert means. Likewise the 5th and 95th percentiles for these highest and lowest judgments of the effect estimate do not imply any particular distribution within those bounds. The distribution of benefits estimates associated with each of the twelve expert responses can be found in tables 5-13 through 5-16.

[c] Based on Pope et al 2002, used as primary estimate in recent RIAs.

1.9 Cost of Attaining Proposed Revised and Alternative Revised Standards in 2020

Table 1-8 summarizes the total annualized cost of meeting the current standard and the alternative scenarios using 3 and 7 percent discount rates. Total annualized costs are estimated from a baseline inventory in 2020 that reflects controls for CAIR/CAMR/CAVR and other on-the-books rules. Similar to the benefit analysis discussed above, the costs presented below reflect modeled partial attainment (by sector), incremental costs for areas to comply with residual nonattainment, and the total annualized cost of full attainment (summing the costs of partial and residual nonattainment estimates). The incremental cost of the revised standards (15/35) is approximately $5.0 to $5.1 billion using 3 and 7 percent discount rates, respectively. The incremental costs for the more stringent revised alternative standards are $6.8 to $7 billion using 3 and 7 percent discount rates, respectively. These cost numbers are highly uncertain because they include the extrapolated costs of full attainment in California and Salt Lake City. Approximately $4.5 billion of the incremental cost of achieving both 15/35 and 14/35 is attributable to these extrapolated full attainment costs. An analysis of the costs and benefits of attaining the 1997 standards in 2015 is provided in Appendix A.

Table 1-8: Comparison of Total Annualized Engineering Costs Across PM NAAQS Scenarios (millions of 1999 dollars) [a]

Source Category	*Scenario* *Revised Stds: 15/35*	 *Alternative Revised Stds:: 14/35*
I. Modeled Partial Attainment		
A. Electric Generating Units (EGU) Sector		
Local Controls on direct PM	\$340	\$350
Local Controls for NO_X	\$59	\$55
Regional EGU program (equivalent to a Phase III of CAIR)	n/a	\$680
Total	**\$400**	**\$1,100**
B. Mobile Source Sector[b]		
Local Measures - direct PM	\$30	\$30
Local Measures – Nox	\$31	\$31
Total	**\$60**	**\$60**
C. Non-EGU Sector		
Point Sources (Ex: Pulp & Paper, Iron & Steel, Cement, Chemical Manu.)		
SO_2 Regional Program for Industrial Sources	n/a	\$1,000
Local Known Controls	\$300	\$240
Area Sources (Ex: Res. Woodstoves, Agriculture)	\$44	\$46
Developmental Controls (Point & Areas Sources)	\$32	\$36
Total	**\$380**	**\$1,300**
II. Incremental Cost of Residual Nonattainment[c,d]		
East	\$3	\$180
West	\$300	\$300
California	\$4,000	\$4,000
Total	**\$4,300**	**\$4,500**
III. Full Attainment (Partial, plus Residual Nonattainment)		
Total Annualized Costs (using a 7% interest rate)	**\$5,100**	**\$7,000**
Total Annualized Costs (using a 3% interest rate)	**\$5,050**	**\$6,800**

a All estimates provided reflect a baseline of 2020 which include implementation of several national programs (e.g. CAIR, CAMR, CAVR), and compliance with the current standard of 15/65.

b Because we applied all available national mobile source emission controls to simulate attainment with the 1997 standards, there are no incremental costs attributable to these national rules for our 15/35 and 14/35 control strategies. See Appendix A for details regarding the estimated cost of these national rules.

c Upon review of emissions and air quality results of the control strategies applied in this RIA, some areas were indicated with residual nonattainment (requiring additional reductions to meet the standard) as a result of our initial selection of controls. The incremental costs of residual nonattainment reflect supplemental controls and extrapolated costs of additional control measures that would be necessary to bring areas with residual nonattainment into compliance. Chapter 4 provides details of the assessment. Numbers may not sum due to rounding.

d The incremental cost of residual non-attainment for the West and California are extrapolated. The methodology used to derive these estimates is described in Chapter 6. These estimates are derived using a 7 percent discount rate.

1.10 Net Benefits

Table 1-9 below summarizes the net benefits of attaining a revised and more stringent alternative $PM_{2.5}$ NAAQS. The first of these two tables summarize the full attainment benefits, economic costs and net benefits at a 3 and 7% discount rate. In this table we provide benefits estimated using concentration-response (C-R) functions developed from both the expert elicitation and the American Cancer Society cohort reported in Pope et al (2002), which has previously been reported as the primary estimate in recent RIAs**.**

Note that the economic cost estimates derived at a 3 and 7 percent discount rate vary only slightly. This lack of variability is due to three factors. First, many of the control technologies contained no capital equipment. For example, emission controls such as fuel switching do not involve a capital expenditure. Second, for some sources we lacked information regarding the capital life of emission controls. Third, for controls that involved capital equipment, capital expenditures tended to be a small portion of total annualized cost. As a result, the costs were not very sensitive to the use of a different discount rate.

Table 1-9: Comparison of Full Attainment Benefits with Social Costs[f], Incremental to Attainment of 1997 Standards (Billion 1999$)

	Revised standard of 15/35 ($\mu g/m^3$)					Alternative standards of 14/35 ($\mu g/m^3$)				
	Benefits[a]		*Costs[b]*	*Net benefits[c]*		*Benefits[a]*		*Costs[b]*	*Net benefits[c]*	
Benefits Based on Mortality Function from the American Cancer Society Study and Morbidity Functions from the Published Scientific Literature[d]										
3%	$17		$5.4	$12		$30		$7.9	$22	
7%	$15		$5.4	$9		$26		$7.9	$18	
Benefits Range Based on Expert Elicitation Derived Mortality Functions and Morbidity Functions from the Published Scientific Literature[e]										
	Low Mean	High Mean		Low Mean	High Mean	Low Mean	High Mean		Low Mean	High Mean
3%	$9	$76	$5.4	$3.5	$70	$17	$140	$7.9	$8.7	$130
7%	$8	$64	$5.4	$2.4	$59	$15	$120	$7.9	$6.7	$110

[a] Results reflect the use of two different discount rates: 3% and 7%, as recommended in EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b) and OMB Circular A-4 (OMB, 2003). Results are rounded to two significant digits
[b] Includes roughly $180 Million in supplemental engineering costs.
[c] Estimates rounded to two significant digits after calculations.
[d] based on Pope et al 2002, used as primary estimate in previous RIAs.
[e]Although the overall range across experts is summarized in this table, the full uncertainty in the estimates is reflected by the results for the full set of 12 experts. The twelve experts' judgments as to the likely mean effect estimate are not evenly distributed across the range illustrated by arraying the highest and lowest expert means. The distribution of benefits estimates associated with each of the twelve expert responses can be found in Chapter 5.
[f] For the purposes of comparison with the benefits, EPA uses the total social cost estimate which is slightly higher than the engineering cost

A comparison of the benefits and costs of attaining the revised and alternative standards yields two important observations. First, the comparative magnitude and distribution of benefits estimates for the revised and more stringent alternative standards is significantly affected by differences in assumed attainment strategies. As noted above, attainment with the revised standards was simulated using mainly local reductions, while a supplemental eastern regional SO_2 reduction program was used for the more stringent alternative. Under the assumptions in the analyses, the regional strategy resulted in significant additional benefits in attainment areas, making the difference in benefits between the revised and alternative standards larger than can be accounted for by the 1 $\mu g/m^3$ lower annual level for the alternative standards.

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

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

1.11 Uncertainties and Limitations

Air Quality Modeling and Emissions

- Overall, the air quality model performs well in predicting monthly to seasonal concentrations, similar to other state-of-the-science air quality model applications for $PM_{2.5}$. Thus, there is less certainty in analyses involving 24-hour model predictions than those involving longer-term averages concentrations and 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. In both the East and West, secondary carbonaceous aerosols are the most challenging species for the modeling system to predict in terms of evaluation against ambient data.
- A number of uncertainties arise from use of baseline data from EPA's National Emissions Inventory. Of particular concern is the apparent disparity between modeled contributions of mobile source emissions and ambient-based techniques, which suggest

that the mobile source emission inventory of directly emitted $PM_{2.5}$ is biased low by a significant amount.

- Additional uncertainty is introduced as a result of our limited understanding concerning the collective impact on future-year emission estimates from economic growth estimates, increases in technological efficiencies, and limited information on the effectiveness of control programs.
- The regional scale used for air quality modeling can understate the effectiveness of controls on local sources in urban areas as compared to areawide or regional controls.

Controls & Cost

A number of limitations and uncertainties are associated with the analysis of non-EGU point, EGU point and area source emission controls:

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

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

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

- EPA believes that the EGU cost assumptions used in the analysis reflect, as closely as possible, the best information available to the Agency today. Cost estimates for SO_2 reductions from EGUs are based on results from the Integrated Planning Model and assume that the electric utility industry will be able to meet the environmental emission caps at least cost. However, to the extent that transaction and/or search costs, combined with institutional barriers, restrict the ability of utilities to exhaust all the gains from emissions trading, costs are underestimated by the model. Utilities in the IPM model also have "perfect foresight." To the extent that utilities misjudge future conditions affecting the economics of pollution control, costs may be understated as well. However, economic models of the power sector and empirical evidence show that projected compliance costs are typically over-estimated by the EPA; industry takes advantage of cap and trade more effectively than EPA can predict. The EGU analysis using IPM does not take into account the potential for advancements in the capabilities of pollution control technologies for SO_2 and NO_x removal as well as reductions in their costs over time. As configured in this application, IPM does not take into account demand response (i.e., consumer reaction to electricity prices).

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

- The full attainment cost estimates for California and Salt Lake City are extrapolated, and as such are more uncertain than the attainment cost estimates for other areas. As we describe in Chapter 6, this method does not incorporate the impacts of learning-by-doing or technological innovation. The method is also very sensitive to the air quality data used to derive the shape of the curve.

Benefits

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

- This analysis assumes that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because the composition of PM produced via transported precursors emitted from EGUs may differ significantly from direct PM released from automotive engines and other industrial sources . In accordance with advice from the CASAC, EPA has determined that no clear scientific grounds exist for supporting differential effects estimates by particle type, based on information in the most recent Criteria Document. In chapter 5, we provide a decomposition of benefits by PM component species to provide additional insights into the makeup of the benefits associated with reductions in overall PM2.5 mass (See Tables 5-32 and 5-33).

- This analysis assumes that the C R function for fine particles is approximately linear within the range of ambient concentrations under consideration (above the assumed threshold of 10 µg/m3). Thus, we assume that the CR functions are applicable to estimates of health benefits associated with reducing fine particles in areas with varied concentrations of PM, including both regions that are in attainment with PM2.5 standards and those that do not meet the standards. However, we examine the impact of this assumption by looking at alternative thresholds in a sensitivity analysis.

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

1.12 Organization of this Regulatory Impact Analysis

This RIA includes the following eight chapters and twelve appendices:

- *Chapter 2: Defining the $PM_{2.5}$ Air Quality Problem*. This chapter analyzes current and future-year $PM_{2.5}$ speciation, source apportionment and projected nonattainment in 2015 and 2020. This chapter also details the emissions inventories that we use to project future-year air quality

- *Chapter 3: Controls Analysis*. This chapter documents our analysis of various control strategies to simulate attainment with the current standard.

- *Chapter 4*: *Air Quality Impacts*. This chapter details the results of the air quality modeling we performed to simulate attainment with the current, revised and alternative standards.

- *Chapter 5: Benefits Analysis and Results*. This chapter presents our estimates of the incremental health impacts and monetized human health and visibility benefits associated with attainment of the revised and more stringent alternative standards.

- *Chapter 6*: *Cost and Economic Impacts*. This chapter provides the estimated incremental engineering and social cost associated with the revised and more stringent alternative standards.

- *Chapter 7: Comparison of Costs and Benefits*. This chapter compares the estimated costs and benefits of attaining each standard alternative.

- *Chapter 8*: *Statutory and Executive Order Impact Analyses*. This chapter addresses each of the statutory and executive orders.

- *Appendix A*: *2015 Attainment Analysis of 1997 Standards*. This appendix documents the emission controls we applied, and the air quality modeling we performed, to simulate attainment of the 1997 standards in 2015.

- *Appendix B: AERMOD Local-Scale Analysis*. This appendix details the use of the AERMOD dispersion model to characterize the local-scale impacts of emission controls

- *Appendix C: Impact per Ton Estimates*. This appendix summarizes the Response Surface Model-derived estimates of the quantitative relationship between reductions in $PM_{2.5}$ precursors and the formation of $PM_{2.5}$ in various urban areas.

- *Appendix D*: *Emission Inventory Growth Sensitivity Analysis*. This appendix analyzes the effect of recent changes to emissions growth assumptions by comparing the 2015 air quality impacts with and without the new assumption.

- *Appendix E*: *Summary of Non-EGU Stationary Source Controls*. This appendix lists the costs and control efficiencies non-EGU stationary source control measures in AirControlNET.

- *Appendix F*: *Economic Impact Analysis*. This appendix provides additional information regarding the economic impact analysis to assess the incremental social costs of attaining the revised and more stringent alternative standards.

- *Appendix G*: *Health Based Cost Effectiveness Analysis.* This appendix provides the results of the health-based cost effectiveness analysis.

- *Appendix H: Additional Details on Benefits Methodologies*. This appendix provides additional information regarding the benefits methodologies used in chapter 5.

- *Appendix I*: *Visibility Benefits Methodology*. This appendix describes the methods we used in estimating visibility-related benefits.

- *Appendix J*: *Additional Sensitivity Analyses Related to the Benefits Analysis*. This appendix provides additional sensitivity analyses related to valuation and physical effects.

- *Appendix K*: *Supplemental Air Quality Information.* This appendix includes maps of the air quality results as well as pie charts of the model-predicted changes in $PM_{2.5}$ speciation by each projected non-attainment area.

- *Appendix L*: *Changes to AirControlNET Database.* This appendix lists the changes made to the emission controls in AirControlNET as a result of the quality assurance process.

- *Appendix M*: *Projected $PM_{2.5}$ Annual and Daily Design Values*. This appendix contains the projected base case and control case design values for 2015 and 2020.

- *Appendix N: Comparison of Projected $PM_{2.5}$ Using 36 kilometer and 12 kilometer air quality modeling*. This appendix presents the results of an analysis examining the sensitivity of projected $PM_{2.5}$ concentrations to the use of a 36 or 12 kilometer CMAQ grid resolution.

- *Appendix O*: *CMAQ Model Performance Evaluation for 2001*. This sensitivity analysis examines the ability of the CMAQ model to replicate base year $PM_{2.5}$ concentrations.

1.12 References

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