DRAFT DOCUMENT

REGULATORY IMPACT ANALYSIS

FOR

PROPOSED

PARTICULATE MATTER

NATIONAL AMBIENT AIR QUALITY STANDARD

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LIST OF ACRONYMS

ACT	Alternative Control Techniques
AIRS	Aerometric Information Retrieval System
AIRCOST	utility SO_2 control cost model (E.H.Pechan & Associates)
AF	air/fuel adjustment
AP-42	compilation of air pollutant emissions factors
BARCT	best available retrofit control technology
BEA	Bureau of Economic Analysis
BOOS	burners out-of-service
CAA	Clean Air Act
CAAAC	Clean Air Act Advisory Committee
CASAC	Clean Air Scientific Advisory Committee
CRDM	Climatological Regional Dispersion Model
CARB	California Air Resources Board
CO	carbon monoxide
CS-C	control strategy-cost
CTG	control technique guidelines
DOE	Department of Energy
EPA	Environmental Protection Agency
EIA	Energy Information Administration
ERCAM	Emission Reductions and Cost Analysis Models
ERCAM No_x	Enhancements to the Emission Reduction and Cost Analysis Models for No_x
ERCAM VOC	Enhancements to the Emission Reduction and Cost Analysis Models for VOC
ESP	electrostatic precipitator
FAC	aerosol coefficients
FACA	Federal Advisory Committee Act
FGD	flue gas desulfurization
FGR	flue gas recirculation
FIP	Federal implementation plan
FMVCP	Federal Motor Vehicle Control Program
GCVTC	Grand Canyon Visibility Transport Commission
GDP	gross domestic product
GSP	Gross State Product
ICI	industrial, commercial, and institutional
ISCST	Industrial Source Complex Short Term
I/M	inspection/maintenance
IR	ignition timing retardation
LAER	lowest achievable emission rate
LEA	low excess air
LEV	low emission vehicle

LIST OF ACROYNMS (continued)

LNB	low-NO_x burner
MACT	maximum achievable control technologyxi
MSA	metropolitan statistical area
NW	megawatts
NAAQS	national ambient air quality standards
NAMS	National Air Monitoring Stations
NAPAP	National Acid Precipitation Assessent Program
NEI	National Emissions Inventory
NH_3	ammonia
NSR	New Source Review
NGR	natural gas recirculation
NO_X	oxides of nitrogen
NPI	National Particulate Inventory
NSCR	non-selective catalytic reduction
NSPS	New Source Performance Standard
OMB	Office of Management and Budget
OMTG	open market trading guidelines
O&M	operating and maintenance
OAQPS	Office of Air Quality Planning and Standards
OFA	overfire air
OMS	Office of Mobile Sources
OXYFIRING	firing of glass furnaces with oxygen-enriched combustion air
PAMS	Photochemical Assessment Monitoring Stations
PM	Particulate Matter
P-V valves	pressure-vacuum valves
RACT	reasonably available control technology
RADM	RegionalAcid Deposition Model
RFA	Regulatory Flexibility Analysis
RIA	Regulatory Impact Analysis
RIS	Regulatory Impact Statement
ROM	Regional Oxidant Modeling
RVP	Reid Vapor Pressure
S-R	source-receptor
SBREFA	Small Business Regulatory Enforcement Fairness Act
SCAQMD	South Coast Air Quality Management District
SCC	Surce Classification Code
SCR	selective catalytic reduction
SIC	Standard Industrial Classification
SIP	State implementation plan

LIST OF ACROYNMS (continued)

SLAMS	State and Local Air Monitoring Stations
SNCR	selective non-catalytic reduction
SOA	secondary organic aerosols
SOCMI	Synthetic Organic Chemical Manufacturing Industry
SO_2	sulfur dioxide
SBA	Small Business Administration
SPMS	special purpose monitors
TAC	total annual costs
TCI	total capital investment
TSP	total suspended particulate
ULNB	ultra low-NO_x burner
UMRA	Unfunded Mandates Reform Act
USDA	U.S. Department of Agriculture
VOC	volatile organic compound
VMT	vehicle miles traveled

EXECUTIVE SUMMARY FOR PM REGULATORY IMPACTS ANALYSIS

The Clean Air Act directs the Environmental Protection Agency (EPA) to identify and set national standards for pollutants which cause adverse effects to public health and the environment. EPA is also required to review the health and welfare-based standards at least once every five years to determine whether, based on new research, revisions to the standards are necessary to continue to protect public health and the environment. A growing list of studies on particulate matter (PM) health effects report associations between fine particles (which are those smaller than 2.5μm in diameter, termed $PM_{2.5}$), and serious effects. These effects include increased mortality in the tens of thousands, particularly among the elderly and people with respiratory and cardiovascular disease, and aggravation of respiratory and cardiovascular disease such as more frequent or serious attacks of asthma in children. As a result of the most recent review process, EPA is proposing to revise the primary (health-based) and secondary (welfare-based) National Ambient Air Quality Standards (NAAQS) for particulate matter. Pursuant to Executive Order 12866, this draft Regulatory Impact Analysis (RIA) assesses the costs, economic impacts, and benefits associated with the *implementation* of these and alternative NAAQS for particulate matter.

In setting the primary air quality standards, EPA's first responsibility under the law is to select standards that protect public health. In the words of the Clean Air Act, for each criteria pollutant EPA is required to set a standard that protects public health with "an adequate margin of safety." As interpreted by the Agency and the courts, this decision is a *health-based* decision that specifically is *not* to be based on cost or other economic considerations. This reliance on science and prohibition against the consideration of cost does not mean that cost or other economic considerations are not important or can be ignored. In fact, the Agency believes that consideration of cost is an essential decision making tool. However, under the health-based approach required by the Clean Air Act, the appropriate place for cost and efficiency considerations is during the development of implementation strategies, strategies that will allow communities, over time, to meet the health-based standards.

Through the development of national emissions standards for cars, trucks, fuels, large industrial sources and power plants, for example, and through the development of appropriately tailored state and local implementation plans, the implementation process is where decisions are made -- both nationally and within each community -- affecting how much progress can be made, and what time lines, strategies and polices make the most sense.

In summary, this draft RIA and associated analyses are intended to generally inform the public about the potential costs and benefits that may result when the proposed revisions to the PM NAAQS are implemented by the States, but are not relevant to establishing the standards themselves.

General Limitations of this Analysis

The consideration of cost and, to be more specific, the use of cost-benefit analyses, provides a structured means of evaluating and comparing various implementation policies, as well as a means of comparing the variety of tools and technologies available for air pollution control efforts. The Agency has found the use of such analyses to be of significant value in developing regulatory options over the years.

General limitations, however, continue to affect the accuracy of cost-benefit analyses. For example, wide ranges of uncertainties often exist within an analysis, especially within studies of national scope involving forecasts over extended periods of time. Analyses, and therefore results, continue to be limited by the inability to monetize certain health or welfare benefits - such as protection against loss of lung function, or ecosystem damage. Comparisons of such incomplete benefits to the more quantifiable and often more complete control costs can be misleading. In addition, though pollution control costs are generally more quantifiable, those costs may be overstated for many reasons: regulated entities concerned about such costs often overstate their cost projections to support their position; a belief by some analysts that conservative planning requires over-estimation; or an inability to forecast significant improvements in the cost-effectiveness of pollution control that generally occur over analytical periods of five to ten years.

Cost-benefit analyses also often fail to deal with distributional issues, (i.e. to provide for the consideration of equity among those who would receive benefits and those on whom the costs would fall). For example, while the direct costs of proposed controls would fall mainly on large industrial sources, control costs are often passed on to a large customer base, or to a broader community base. Therefore, the costs per family may be small, but the benefits to those who avoid respiratory problems or death are large.

The limitations notwithstanding, the process of developing such analyses can still provide useful insights for these working to develop implementation strategies because the analytical framework provides a measurement, however rough, of strategies and tools against a common yardstick. For example, this economic analysis provides estimates concerning possible cost impacts for certain industrial categories. Tailored regional strategies would likely serve to mitigate negative impacts on local industries. Finally, these analyses can help to identify existing data gaps, additional information needs, tools and limitations inherent in certain strategies.

Within these kinds of practical problems lies the general difficulty associated with cost- benefit analyses. By their nature, cost-benefit studies must be full of caveats and warnings about the value of their conclusions. Even the most narrowly focused and rigorous should therefore clearly not be the sole determinative test, but should instead serve as useful analytical tools. Unfortunately, the tendency is for such analyses to be referred to in more definitive terms, and for the conclusions, as uncertain as they may be, to take on lives of their own. Such should clearly not be the case here.

Specific Limitations of this Analysis

EPA is proposing decisions on the PM and ozone NAAQSs simultaneously. Because these NAAQSs are separate regulatory decisions, separate RIAs were prepared. However, significant overlap may exist in both the costs and benefits associated with reducing ozone and PM concentrations. This overlap is due to important commonalities between ozone and PM (primarily $PM_{2.5}$) such as 1) similar atmospheric residence times leading to long-range transport; 2) similar combustion-related source categories that emit gaseous precursors that lead to ozone and PM formation; and 3) similar atmospheric chemistry driven by the same chemical reactions and intermediate chemical species which often favor both high ozone and fine particle levels (see 61 F.R. 29719, June 12, 1996 - Advance Notice of Proposed Rulemaking). This RIA employed existing non-integrated technical models and implementation strategies that were not able to adequately account for these commonalities.

As a consequence of having prepared separate RIAs for the PM and Ozone NAAQSs, the sum of the estimated impacts presented in these analyses is likely to overstate the control cost impacts resulting from joint attainment of both proposed standards. Controls designed to reduce one pollutant frequently also achieve reductions of the other. Such co-control can be direct or indirect via air chemistry interactions. Thus, for example, if control measures designed to reduce PM also achieve ozone reductions, the benefits of attaining the proposed PM standard presented in this analysis may be understated. Similarly, if control measures designed to reduce ozone precursors also achieve PM reductions, the benefits of attaining the ozone standard may be understated.

Another major limitation which affects the results of this RIA is the assumption of the particular implementation approach from which to measure the cost of obtaining the new standards. The strategies used are limited in part because of our inability to predict the breadth and depth of the creative approaches to implementing these new NAAQS, and in part by technical limitations in modeling capabilities. These limitations, in effect, force costs to be developed based on compliance strategies that may reflect suboptimal approaches to implementation, and therefore, those that likely reflect higher potential costs for attaining the new standard. This approach renders the result specifically useful as an incentive to pursue lower cost options, but not as a helpful indicator of likely costs.

It is important to recognize here that if new ozone or particulate matter standards are finalized under the Clean Air Act, the Act allows for substantial new flexibility in the development of implementation strategies, both for control strategies as well as schedules. To the extent that it is warranted, the Act allows for an extension of attainment deadlines as well. This new flexibility may also mean the development of different patterns of designations and moving away from the traditional attainment-nonattainment delineations. The CAAA would require, however, that states eventually achieve the standards.

Even under the current standards, the Agency has begun to put an emphasis on strategies that use the marketplace to reduce costs, that utilize national strategies where they make sense, and that can look to regional and other cooperative approaches -- so that we maximize efficiencies and minimize costs throughout the air quality management system. For example, in implementing the current ozone standard, EPA and a large number of States are already working in this direction through the Ozone Transport Assessment Group, through the Ozone Transport Commission in the Northeast, and through efforts to encourage market approaches for ozone precursors. EPA also is working with Western States through the Grand Canyon Visibility Transport Commission, which is addressing the visibility impacts of both ozone and particles.

Specific to new standards, EPA has established a formal advisory committee under the Federal Advisory Committee Act. The specific purpose of the broad-based stakeholder group is to advise EPA on ways to develop innovative, flexible, practical and cost-effective implementation strategies, and to advise the Agency directly on transitional strategies as well. This group has specifically been tasked with consideration of strategies that would allow the future integration of ozone, PM, and regional haze control programs. This approach is intended to develop control strategies that recognize the significant overlap and similarities that exist among these pollutants as mentioned above.

Among the innovative strategies that FACA may consider are programs such as "Cool Cities", "Green Lights", and "Climate Wise" programs, as well as clean fuel fleets and economic incentive programs (such as California's RECLAIM and EPA's Acid Rain program) to harness market forces to reduce pollution in the most cost-effective manner possible. FACA also may consider an integrated control strategy that analyzes control measures, such as reformulated gasoline, low-emission vehicles, and selective catalytic reduction, jointly. An integrated control strategy is expected to result in control cost savings. At the present moment, however, the potential extent of the impact on ambient PM concentrations resulting from programs such as these is unclear.

Similarities between ozone and PM clearly provide management opportunities for optimizing and coordinating monitoring networks, emission inventories and air quality models, and for creating opportunities for coordinating and minimizing the regulatory burden for sources that would otherwise be required to comply with separate controls for each of these pollutants.

Significant shortcomings also exist as to the data and analytical tools available for these analyses. Existing emissions inventories and air quality modeling to date, either on a national scale, or on an aggregated basis, simply do not provide a sufficient analytical foundation from which to draw accurate results. For instance, national estimates of primary PM fugitive emissions, such as those from paved and unpaved roads, are highly uncertain. Additionally, sufficient current monitoring data for $PM_{2.5}$ exists in only a few cities -- including Los Angeles and Philadelphia. Therefore, projections concerning which areas may violate the PM standard can only be developed through extrapolation from existing PM_{10} data -- an imprecise exercise at best -- and through the use of very uncertain air quality modeling exercises. The combination of these uncertainties must inevitably provide uncertain results. The Agency will examine further the uncertainty issues surrounding projections of nonattainment counties and estimates of costs and benefits.

And finally, the nature of these kinds of analyses is that of a snapshot in time. The cost of implementing these standard revisions in the first few years will mainly be related to monitoring, strategy development and creating State implementation plans. The year 2007 was chosen because most of the mandatory Clean Air Act Amendment requirements that have an impact on ambient particle concentrations (e.g. Title IV SO_2 controls) will have fully taken effect by that time. Therefore, results are based on air quality modeling performed for this single "representative" year. Multi-year air quality modeling was not feasible because of resource constraints. The limitations imposed by this snapshot approach are particularly troublesome in this case, primarily because of two reasons.

First of all, in terms of developing strategies or technologies, a decade can see many changes. For example, relative to air pollution control policy, since 1987 we have seen large scale revisions of the Clean Air Act - including complete rewrites of nonattainment, acid rain and air toxics policies - the Intermodal Surface Transportation and Efficiency Act, and the Energy Policy Act. We have also seen the introduction at the State and national level of utility deregulation. All of these actions, both together and individually, are having important and, in some cases, dramatic effects on air pollution control policy.

In terms of technology, in the last decade we have seen the introduction of three generations of cleaner gasoline (i.e. low RVP, oxygenated and reformulated fuels), cleaner diesel fuels, the introduction of cleaner vehicles, such as electric vehicles, dramatic improvements in scrubber technology for sulfur dioxide controls, the development of replacements for phased-out CFC's, far more cost-effective ways to control auto tail-pipe emissions and the development of on-board diagnostic equipment to assure those cleaner standards continue to be met over time.

Relative to attainment of national ambient air quality standards, since 1990 alone we have seen more than half of the areas in violation of the standards for ozone and carbon monoxide begin to meet the standards, many actually ahead of schedule. Moreover, the costs associated with many of these efforts are less than was estimated, even as late as 1990.

Therefore, in the case of air pollution control, ten years is a very long time over which to carry assumptions. Furthermore, a 2007 snapshot does not allow sufficient time for all areas to reach attainment, even under the current standard. To the extent that new standards will result in additional time for some areas, it is clear that some areas will not be required to be in attainment by 2007. This analysis recognizes this by not arbitrarily forcing all areas to reach attainment in 2007 by the use of extreme control measures since such extreme measures are unlikely ever to be put in place.

While qualitative discussions of the above uncertainties and limitations were included in the analysis, quantitative characterizations of these and other uncertainties generally could not be performed at this time because of insufficient information. Nevertheless, the reader should keep all of these uncertainties and limitations in mind when reviewing and interpreting the results presented below.

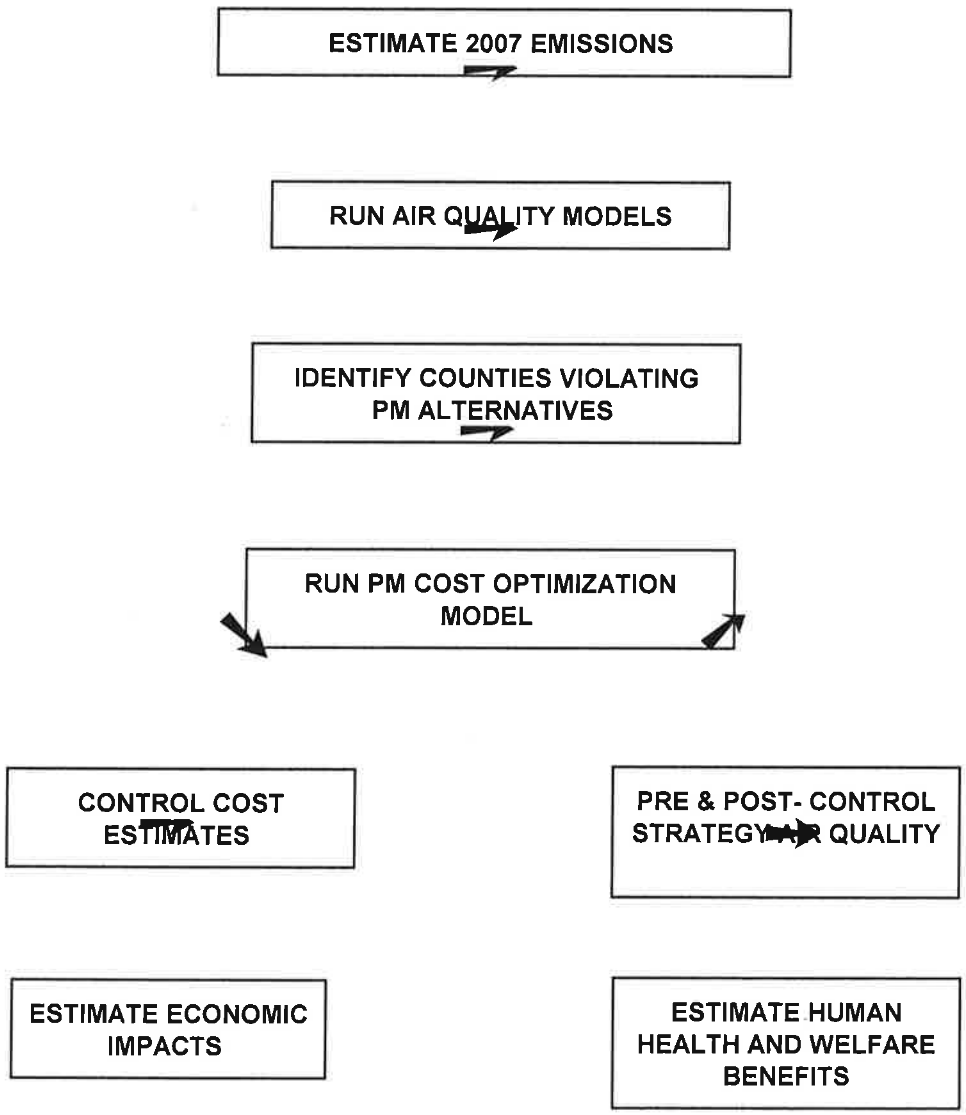
Nature and Sources of Particulate Matter

PM represents a broad class of chemically and physically diverse substances. The current standards regulate particles smaller than 10μm in diameter (PM_{10}). PM_{10} is composed of two major subfractions, known as fine ($PM_{2.5}$) and coarse (PM_{10}) fractions. In most locations, a variety of diverse activities contribute significantly to PM concentrations. Sources of $PM_{2.5}$ typically include fuel combustion (from vehicles, power generation, and industrial facilities), residential fireplaces, agricultural and silvicultural burning, and atmospheric formation from gaseous precursors such as sulfur, nitrogen oxides and volatile organic chemicals (largely produced from fuel combustion). Sources of coarse fraction particles typically include construction and demolition activities, industrial operations, wind blown dust, and road dust. The difference in chemical and physical composition and sources between these two fractions of PM_{10} have significant implications for the relative health risk posed by each fraction and for control strategies to reduce such risk. Based on the review of the scientific criteria and the recommendations of the external science advisors, the EPA is proposing to revise the PM standards by adding separate standards for $PM_{2.5}$ and retaining PM_{10} standards with some revisions.

Overview of PM RIA Methodology: Inputs and Assumptions

The potential costs, economic impacts and benefits have been estimated for proposed revisions to the PM NAAQS. The alternatives analyzed include the proposed standards ($PM_{2.5}$ standard set at 15$\mu g/m^3$, spatially averaged annual mean, and 50 $\mu g/m^3$, 98th percentile 24-hour average) and two alternatives: 1) an annual standard set at a level up to 20$\mu g/m^3$, in combination with a 24-hour standard set at a level up to 65$\mu g/m^3$; and 2) an annual standard set at a level as low as 12.5$\mu g/m^3$, in combination with a 24-hour standard set at a level up to about 50$\mu g/m^3$. The flow chart below summarizes the analytical steps taken in developing the results presented in this RIA.

FIGURE ES-1: Flowchart of Analytical Steps



As noted earlier, the year 2007 was chosen to provide an appropriate baseline for a period in which the new standards are being implemented. The $PM_{2.5}$ analyses have been constructed such that benefits and costs are estimated incremental to those derived from the combined effects of implementing both the 1990 Clean Air Act Amendments (CAAA) and the current PM_{10} NAAQS as of the year 2007. Thus, these analyses provide a "snapshot" of potential benefits and costs associated with the implementation of the proposed $PM_{2.5}$ alternative from a baseline of future CAAA implementation and attainment of the current PM_{10} NAAQS. While the proposal also includes a provision for revising the PM_{10} NAAQS, we did not perform a separate analysis of that alternative because such revisions are proposed only in the context of adding a $PM_{2.5}$ standards. Any impacts that would result from revising the PM_{10} standard are assumed to be captured in the results of the analysis for the $PM_{2.5}$ alternatives. These changes are thought to be small compared to the uncertainties in estimating the costs and benefits.

Control strategy analyses were conducted for 470 counties nationwide currently monitored for PM_{10} and for which sufficient PM_{10} data exist. Approximately 60% of the U.S. population resides in these monitored counties (145 million people, 1990 Census). These analyses assume future PM control strategies will be applied to this set of counties. PM is currently the most extensively monitored criteria pollutant. Significant increases in the number of monitoring sites in the future is not expected. Thus focusing the analysis on the attainment of standards in currently monitored counties was considered most realistic. Nevertheless, because of transport, controls in monitored counties also create costs and benefits in non-monitored counties. These costs and benefits are also estimated.

The national results were derived by dividing the continental U.S. into 7 regions. For any given region, control costs and economic impacts were estimated for the subset of monitored counties predicted to exceed a given $PM_{2.5}$ alternative. Because $PM_{2.5}$ can be transported great distances, the benefits of these emission reductions were estimated for unmonitored as well as monitored counties. However, the benefits of inter-regional transport have not been captured in this analysis.

The assessment of costs, economic impacts and benefits consists of multiple analytical components, dependent upon emissions and air quality modeling. In order to predict baseline air quality in the year 2007, emission inventories were developed for 1990 and then projected to 2007 based upon estimated national growth in industry earnings and other factors. Clean Air Act-mandated controls (e.g., Title I PM Reasonably Available Control Measures, Title II mobile source controls, Title III air toxics control, Title IV Acid Rain SO_2 control) were applied to these emissions to take account of emission reductions that would be achieved in 2007 as a result of CAA implementation. These 2007 CAA emissions in turn were input to an air quality model that relates emission sources to county-level PM concentrations. This 2007 modeled baseline air quality was used to identify counties that exceed the alternative PM concentration levels[a]. A cost optimization model was then employed to determine the least cost control strategies to achieve the alternatives in violating counties. Given the estimated costs of attaining alternatives, the economic impacts of these potential costs on affected industry sectors was subsequently analyzed. Potential health and welfare benefits were estimated from predicted changes in PM air quality in monitored as well as unmonitored counties as a result of control strategies applied in the cost analysis. Finally, benefits and costs were compared to examine questions of economic efficiency.

We applied what we considered a reasonable set of control measures for controlling PM under the Clean Air Act. For some counties, the control measures identified in the cost analysis are predicted to not sufficiently reduce emissions to achieve attainment. This incomplete attainment situation is believed to be in part a byproduct of the uncertainties in the analysis itself. However, there may be cases in which currently identifiable controls may not be enough to reach attainment by 2007, or as could be inferred from a more extensive set of measures referenced in a recent publication from state and local pollution control officials, our control set was not extensive enough. Control strategies

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[a] For the purposes of this RIA, the term "attain" or "attainment" is used to indicate that PM air quality level specified by the standard alternative is achieved. Because the analyses in this RIA are based on one-year of air quality data, they are only estimates of actual attainment; all PM standard alternatives are specified as 3-year averages.

necessary to achieve full attainment of the proposed $PM_{2.5}$ and PM_{10} standards by 2007 may be identified in the future. For example, an initial strategy of additional cost-effective, large-scale regional reductions in PM precursors may reduce the need for local controls of stationary sources in many areas. As noted above, EPA has convened a large group of stakeholders to develop new PM and ozone NAAQS implementation strategies that may offer States innovative and more effective approaches to full attainment of the PM NAAQS.

This analysis focuses on the costs, economic impacts, and benefits associated with partial attainment of PM alternatives. Although there is no unequivocal approach for estimating full-attainment costs, the incremental air quality improvements necessary to achieve full attainment is presented in conjunction with an average marginal cost per regional $PM_{2.5}$ $\mu g/m^3$ reduction. This information is presented for the purpose of completeness.

Cost and Economic Impact Analyses

Annual control costs (in 1990 dollars) were estimated for attainment of each of three $PM_{2.5}$ alternatives in the 470 counties currently monitored for PM_{10}. These costs were estimated, via a cost optimization model, for controls installed in 2007 at sources within the seven regions. In each region, candidate sources for control included both those sited within and outside of monitored counties. Additionally, for the Eastern U.S. where the PM problem is driven largely by regional transport of sulfate, a supplemental analysis of a region-wide SO_2 reduction strategy was assessed. The costs of revising the PM_{10} monitoring network and the costs of a new $PM_{2.5}$ monitoring network have also been estimated. The administrative costs of implementing the PM NAAQS have not been estimated in this analysis; however, they will be assessed for the RIA for the PM NAAQS implementation plan to be proposed in June 1997.

Economic impacts based on these control costs were estimated for the same $PM_{2.5}$ alternatives.

These impacts include a screening analysis providing estimated annual average cost-to-sales ratios for all potentially affected industries and small entities. Finally, a sensitivity analysis of impacts on governmental entities was performed for a sample of potentially affected entities.

Key Results and Conclusions

- Annual identifiable control costs for partial attainment corresponding to the least and most stringent $PM_{2.5}$ alternatives range from approximately \$2 to \$14 billion incremental to the current PM standard. Under the control strategies analyzed, 18 to 104 counties would not be able to attain these alternative concentration levels by 2007.

- For the proposed $PM_{2.5}$ alternative (15 $\mu g/m^3$ annual; 50 $\mu g/m^3$ 24-hour) the estimated annual cost for partial attainment is approximately \$6 billion incremental to the current PM_{10} standard. Under the control strategies analyzed, 57 counties would not be able to attain this alternative.

- Of the partial attainment costs, 60% is incurred east of the Mississippi River.
  Based on partial attainment costs, the estimated per household cost of partially achieving the proposed alternative is \$69 per year; the estimated per capita cost of partially achieving the proposed alternative is \$25 per year.

- Although there are considerable uncertainties in the approach, a sensitivity analysis has been conducted to assess the nature of costs that might be associated with full attainment of the proposed annual $PM_{2.5}$ standard (15$\mu g/m^3$). Based upon the air quality modeling used for this analysis, incremental regionwide average annual $PM_{2.5}$ $\mu g/m^3$ needed to bring residual nonattainment counties into attainment has been estimated. Table ES-1 presents this additional regionwide average $PM_{2.5}$ $\mu g/m^3$ shortfall per modeling region, as well as average annual $PM_{2.5}$ air quality associated with the baseline PM_{10} standard and average annual $PM_{2.5}$ air quality achieved by control measures applied in the cost analysis to attain the proposed $PM_{2.5}$ alternative. The national sum of the regional estimates of average annual $PM_{2.5}$ $\mu g/m^3$ shortfall is approximately 13 $\mu g/m^3$. This is what is needed beyond the average annual $PM_{2.5}$ concentrations achieved in the partial attainment scenario to achieve full attainment of the proposed standard.

There is no unequivocal approach to costing out full attainment given significant data limitations. In the modeling used to develop the cost analysis of partial attainment, a $1 billion per $\mu g/m^3$ marginal cost cutoff for average improvements in air quality to nonattainment areas across a region was used. Thus, relying on the identified control measures in the model, attempts to move beyond the currently projected level of partial attainment would cost significantly more than this. To the extent that more cost-effective measures were left out of the model (as for example the regional SO_2 strategy) or that more cost-effective measures are developed in the future, as historical precedent suggests might well happen, the cost of further progress would be correspondingly reduced.

- As a supplemental analysis, a regional SO_2 strategy in the East implemented incremental to Title IV and in combination with the county-level regional control strategy would increase total costs for the proposed $PM_{2.5}$ alternative in the two eastern regions by $2.5 billion, but also increases the number of counties that are projected to attain the standard by 2007.
- The PM_{10} monitoring network cost is estimated to be approximately $6 million annually for the range of monitoring designs being considered. The $PM_{2.5}$ monitoring network cost is estimated to be approximately $22 million annually for the monitoring design being considered.

- Under the control scenario selected, at least one or more establishments (e.g. industrial plant) in up to 40 to 50 percent of U.S. industries (as defined by 3-digit SIC codes) may be affected by one of the $PM_{2.5}$ alternatives as estimated in a screening analysis that calculated cost-to-sales ratios for each affected industry. Approximately one half of these are estimated to have cost-to-sales ratios exceeding 3 percent, and therefore may experience potentially significant impacts. At least one or more small establishments in up to 30 to 40 percent of affected U.S. industries are estimated to have cost-to-sales ratios exceeding 3 percent, and therefore these small establishments may experience potentially significant impacts. These results are highly sensitive to the choice of control scenario.

Because of the previously discussed limitations of the implementation assumption made in the analysis, the results may only be useful as guidance in the design of approaches to controlling PM.

Table ES-1

<u>Proposed Annual $PM_{2.5}$ Standard</u>: Initial Average Baseline $PM_{2.5}$ Air Quality, Average Annual $PM_{2.5}$ μg/m³ Achieved, Average Annual $PM_{2.5}$ μg/m³ Needed for Full Attainment in Residual Nonattainment Counties by Modeling Region

Region	Average Baseline Air Quality (Annual $PM_{2.5}$ μg/m³)	Average Annual $PM_{2.5}$ μg/m³ Achieved Under Partial Attainment Scenario	Average Annual $PM_{2.5}$ μg/m³ Needed for Full Attainment
MW/NE	20.2 (16.7-23.6)	17.8 (15.1-21.8)	2.8 (0.1-6.8)
RM[a]	23.2 (17.5-25.9)	17.9 (16.3-22.6)	2.9 (1.3-7.6)
SC	16.8	15.1	0.1
SE	19.0	15.1	0.1
NW[a]	17.5 (16.1-19.3)	16.9 (15.6-19.0)	1.9 (0.6-4.0)
W[a]	16.6 (15.8-17.4)	16.2 (15.2-17.1)	1.2 (0.2-2.1)
CA[b]	20.2 (15.9-24.7)	19.4 (15.2-24.0)	4.4 (0.2-9.0)

<u>Key:</u>

MW/NE= Midwest/Northeast; SE= Southeast; RM= Rocky Mountain; SC= South Central; W= West; NW= Northwest; CA= California. (For map, see Figure 7-1.)

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[a] Baseline annual μg/m³ achieved for $PM_{2.5}$ are adjusted to standard reference conditions (i.e., temperature and pressure) and therefore overestimate air quality in high altitude areas.

[b] The entire state of California is included in this particular aggregation, rather than dividing the state between two regions.

Range of values presented in parentheses.

Benefit Analysis

Table ES-2 lists the health and welfare benefit categories that are reasonably associated with reducing PM in the atmosphere, specifying those for which sufficient quantitative information exists to permit benefit calculations. As discussed in the PM proposal, there are a number of uncertainties inherent in the underlying functions used to produce quantitative estimates. For example, while the available epidemiologic evidence provides solid support for a relationship between PM and health endpoints such as mortality and hospital admissions, the underlying concentration-response functions are more uncertain; these uncertainties increase at lower concentrations where the possibility of effects thresholds cannot be clearly excluded. On the other hand, because of the inability to monetize some benefit categories, such as changes in pulmonary function, altered host defense mechanisms and cancer, these categories were not included in the analysis.

TABLE ES-2: HEALTH AND WELFARE EFFECTS OF PARTICULATE MATTER

Type of Endpoint	Quantified Effects	Unquantified Effects

Human Health	Mortality
	  Acute
	  Long-term
	Hospital admissions
	Chronic bronchitis
	Lower respiratory symptoms
	Upper respiratory symptoms
	Acute respiratory symptoms
	Acute bronchitis
	Shortness of breath
	Moderate or worse asthma
	Restricted activity days
	Minor restricted activity days
	Work loss days
		Changes in pulmonary function
		Morphological changes
		Altered host defense mechanisms
		Cancer
		Other chronic respiratory disease

Type of Endpoint	Quantified Effects	Unquantified Effects
Welfare	Household soiling damage Visibility impairment	Other materials damage Visibility impairment in Class 1 areas (e.g. National Parks) Ecosystem effects (e.g. acid sulfate and nitrate deposition)

Another major uncertainty concerns the valuation of mortality risk. Epidemiological evidence suggests that the majority of risk from PM exposure accrues to those over 65 years of age. However, the valuation approach employed was based on estimates derived from average- aged populations. Controversy exists as to whether and how the valuation of mortality risk should be discounted for elderly populations. The RIA performed a sensitivity assessment to examine the impact of discounting the mortality risk valuation measure employed in this study.

The health and welfare benefits were estimated for attainment of alternative $PM_{2.5}$ standards in monitored counties. Given that $PM_{2.5}$ can be transported large distances, the benefits of air quality improvements in nonmonitored counties due to control for attainment in monitored counties has also been assessed. First, the change in incidence of health and welfare effects was estimated for each air quality change as defined by the 2007 baseline and post-control air quality distributions. Secondly, these changes in incidence were monetized by multiplying the estimated change in incidence of each endpoint by its associated dollar value of avoiding an occurrence of an adverse effect. These endpoint-specific benefits were then summed across all counties to derive an estimate of total benefit. Benefits of regional transport between the 7 regions have not been assessed.

Monetized benefits for full attainment of each $PM_{2.5}$ alternatives as well as the current baseline PM_{10} standard have been estimated. Implicit within this analysis is the assumption that all counties reach attainment of each of the standard alternatives. However, the control strategy-cost analysis indicates that some counties would not reach attainment of the alternative standards in 2007 given that insufficient control measures were identified in the cost analysis. Therefore, benefit results for partial attainment are presented to assure that benefits and costs can be appropriately compared. Estimates of benefits for hypothetical full attainment in 2007 are also presented to allow an understanding of the scope of benefits that would be attributable to alternative standards in the event that control strategies to reach complete attainment are identified and implemented by that date.

Key Results and Conclusions

- Estimated total monetized benefits associated with attainment of the $PM_{2.5}$ alternatives incremental to the baseline PM_{10} NAAQS are substantial.

  - Full attainment of the least stringent $PM_{2.5}$ alternative (20/65) results in estimated benefits of between $20 and $40 billion per year, including 1,000 - 6,000 incidences of premature mortality avoided (corresponding to short-term and long-term mortality, respectively) and 22,000 new cases of chronic bronchitis avoided. Full attainment annual benefits range between an estimated $130 and $260 billion for the most stringent alternative (12.5/50), including 9,000 to 36,000 incidences of premature mortality avoided (corresponding to short-term and long-term mortality, respectively), 134,000 new cases of chronic bronchitis avoided and $3 billion in visibility improvement.

  - Partial attainment of the least stringent $PM_{2.5}$ alternative (20/65) results in estimated annual benefits of between $20 and $40 billion, including 1,000 - 6,000 incidences of premature mortality avoided (corresponding to short-term and long-term mortality, respectively) and 24,000 new cases of chronic bronchitis avoided. Partial attainment of the most stringent alternative (12.5/50) results in estimated benefits of between $90 billion and $190 billion per year, including 7,000 - 27,000 incidences of premature mortality avoided (corresponding to short-term and long-term mortality respectively) and 99,000 new cases of chronic bronchitis avoided and $2 billion in visibility improvements.

  - Full attainment of the proposed $PM_{2.5}$ alternative (15/50) results in estimated health benefits of $70 billion or $265 per capita (including short-term mortality) and $140 billion or $565 per capita (including long-term mortality) including 5,000 - 20,000 incidences of premature mortality avoided (corresponding to short-term and long-term mortality respectively) and 74,000 new cases of chronic bronchitis avoided. Welfare benefits, including visibility improvements, are $2 billion and $8 per capita.

- Partial attainment of the proposed $PM_{2.5}$ alternative (15/50) results in estimated health benefits of $60 billion or $225 per capita (including short-term mortality) and $120 billion or $470 per capita (including long-term mortality), including 4,000 - 17,000 incidences of premature mortality avoided (corresponding to short-term and long-term mortality respectively) and 63,000 new cases of chronic bronchitis avoided. Welfare benefits, including visibility improvements, are $2 billion and $8 per capita.

- As a supplemental analysis, a regional SO_2 strategy in the East implemented incremental to Title IV and in combination with the county-level regional control strategy would increase benefits for the proposed $PM_{2.5}$ alternative by between $2 and $13 billion.

Benefit-Cost Comparison

Comparing the benefits versus the costs provides one framework for comparing PM alternatives in the RIA. In this context, the economically efficient alternative maximizes net social benefits (i.e., social benefits minus social costs). As noted above, both the Agency and the courts have defined the NAAQS standard setting decisions, both the initial standard setting and each subsequent review, as *health-based* decisions that specifically are *not* to be based on cost or other economic considerations. This draft benefit-cost comparison is intended to generally inform the public about the potential costs and benefits that may result when the proposed revisions to the PM NAAQS are implemented by the States. Benefit-cost comparisons are presented for both the full and partial attainment scenarios.

Key Conclusions and Limitations

- Benefit-cost comparisons for alternative $PM_{2.5}$ standards for the partial attainment scenario is presented in Table ES-3. A full attainment benefit-cost comparison is not possible given that the Agency has not been able to estimate the cost of full attainment based on currently available technology.

- Quantified net benefit estimates are positive and substantial for all three $PM_{2.5}$ alternatives for the partial attainment scenario. For the proposed standard, estimated net annual benefits range from \$50 billion to \$110 billion for partial attainment, depending on the mortality risk reduction measure employed.

- Estimated net annual benefits for partial attainment control approaches identified in this analysis are greatest under the $PM_{2.5}$ 12.5 $\mu g/m^3$ annual/50 $\mu g/m^3$ 24-hour average alternative. However, this result is affected by the uncertainties in the underlying benefit functions. Therefore, firm conclusions cannot be drawn regarding maximal net benefits.

- Estimating the cost associated with additional air quality improvements needed to eliminate residual nonattainment is a difficult task, given that this analysis is not able to identify specific controls to achieve these reductions by 2007. As explained in the cost analysis, the Agency presents an analysis of the regional, annual average $PM_{2.5}$ $\mu g/m^3$ reductions necessary to achieve full attainment in residual nonattainment counties.

- The scope of this analysis did not allow consideration of flexibility in PM air quality management. The Agency expects the implementation portion of this PM NAAQS review to result in more flexible control strategies and lower costs. This is a second major reason why the cost estimates presented may overstate actual costs and the net benefit estimates presented may understate actual net benefits.

- Some identified benefit categories associated with PM reductions could not be monetized. Unquantified, and hence unmonetized, benefit categories include changes in pulmonary function, altered host defense mechanisms, and potential cancers. Thus, the results allow a comparison of estimated *monetized* benefits versus estimated costs. Those benefits which could not be monetized are not included in this comparison.

- The uncertainties associated with the benefit estimates are substantial. In particular, benefit estimates vary greatly depending on the mortality risk reduction measure employed and the values assigned to different health endpoints.

- Comparisons across alternatives examined should be made with caution because the control strategies identified do not result in full attainment of the alternatives. As the stringency of the standard increases, areas showing residual nonattainment may have a more difficult time to meet a more stringent standard. The cost of this increasing difficulty is not included in these estimates.

- This analysis only considers the control measure costs. The administrative costs to the States of activities such as changing their State Implementation Plans are not included in this analysis. These costs will be included in the analysis for the implementation phase of these standards.

- The cost and benefit estimates presented in the results do not account for market reactions to the new alternatives. The cost and benefit estimates represent the direct costs and benefits but not the true social costs (calculated after market adjustments to price and output changes, etc.) associated with implementation of the alternatives examined. Social costs are typically somewhat smaller than direct costs, while social benefits may be greater or less than direct benefits depending on the specific market adjustments and substitutions that occur. Because the effect of market reactions was not assessed, indirect costs and benefits to consumers and producers could not be quantified. It is anticipated that some of the costs associated with control measures will be borne indirectly by consumers instead of producers.

Table ES-3. Comparison of Annual Benefits and Costs of $PM_{2.5}$ Alternatives in 2007[a] (1990$)

PM2.5 Alternative (μg/m³)	Annual Quantified Benefits[b] (billion $)		Annual Costs of Partial Attainment (billion $) (B)	Net Benefits of Partial Attainment (billion $) (A - B)	Residual Nonattainment (RNA)		
	Full Attainment[c]	Partial Attainment[d] (A)			Number of RNA Counties	National Sum of Regional Average Annual $PM_{2.5}$ μg/m³ Shortfall Needed for Full Attainment	Population in RNA Counties
20/65*	20 - 42	22 - 44	2	20 - 42	18	6.7	6 million
15/50	69 - 144	58 - 119	6	52 - 113	57	13.4	29 million
12.5/50	125 - 257	94 - 192	14	80 - 178	104	18.0	84 million

*** Does not include the reductions in costs and benefits associated with revised PM_{10} standards as they require less reductions than current PM_{10} standard.**

Caveats:

Significant analytical uncertainties

Cost analysis limited to basically add-on control measures

Many nonquantified costs and benefits

Does not consider PM and ozone integration issues

[a] All estimates are measured incremental to the baseline PM_{10} alternative (PM_{10} μg/m³ annual/150 μg/m³ daily, 1 expected exceedance per year).

[b] Lower and upper end of benefit range reflects benefits of including the short-term and long-term mortality risk reduction measure, respectively.

[c] Full attainment benefits based upon rollback of residual nonattainment counties to baseline PM_{10} alternative and then to $PM_{2.5}$ alternative.

[d] Partial attainment benefits based upon post-control air quality as defined in the control cost analysis.

1.0 INTRODUCTION

This draft report, entitled The Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard, was prepared in fulfillment of the requirements in Executive Order 12866. This report was completed according to the guidelines established in the Economic Analysis of Federal Regulations under Executive Order (E.O) 12866 (1/11/96) by the Office of Management and Budget (OMB).

This report also considered the requirements of the Unfunded Mandates Reform Act of 1995 (P.L. 104-4), and E.O. 12898 (2/16/94). The Regulatory Flexibility Act and the Small Business Regulatory Fairness Enforcement Act were taken into consideration in the development of this Regulatory Impact Analysis (RIA). Summarized in this RIA is information on the potential impacts of a new particulate matter (PM) standard on small entities. This information is an input into efforts by the Subcommittee of the Clean Air Act Advisory Committee under the authority of the Federal Advisory Committee Act (FACA) to investigate new implementation strategies for joint control of ozone and PM emissions. The statutory requirements of this RIA are discussed further in Chapter 5..

The Clean Air Act (CAA) directs the Environmental Protection Agency (EPA) to identify and set national standards for pollutants which cause adverse effects to public health and the environment. EPA is also required to review the health- and welfare-based standards at least once every 5 years to determine whether, based on new research, revisions to the standards are necessary to continue to protect public health and the environment. A growing list of studies on PM health effects report associations between fine particles (which is PM smaller than $PM_{2.5}$ μm), and serious effects. These effects include increased mortality in the tens of thousands, particularly among the elderly and people with respiratory and cardiovascular disease, and aggravation of respiratory and cardiovascular disease such as more frequent or serious attacks of asthma in children. As a result of the most recent review process, EPA is proposing to revise the primary (health-based) and secondary (welfare-based)

NAAQS form. Pursuant to
E.O. 12866, this draft RIA assesses the costs, economic impacts, and benefits associated with the *implementation* of these and alternative NAAQS for PM.

In setting the primary air quality standards, EPA's first responsibility under the law is to select standards that protect public health. In the words of the CAA, for each criteria pollutant, EPA is required to set a standard that protects public health with "an adequate margin of safety." As interpreted by the Agency and the courts, this decision is a *health-based* decision that specifically is *not* to be based on cost or other economic considerations. This reliance on science and prohibition against the consideration of cost does not mean that cost or other economic considerations are not important or can be ignored. In fact, the Agency believes that consideration of cost is an essential decision making tool. However, under the health-based approach required by the CAA, the appropriate place for cost and efficiency considerations is during the development of implementation strategies -- strategies that will allow communities, over time, to meet the health-based standards. This is accomplished through the development of national standards (e.g., emissions standards for cars, trucks, fuels, large industrial sources, and power plants) and through the development of appropriately tailored State and local implementation plans. The implementation process is where decisions are made -- both nationally and within each community -- affecting how much progress can be made, and what schedules, strategies, and policies make the most sense.

In summary, this draft RIA and associated analyses are intended to generally inform the public about the potential costs and benefits that may result when the proposed revisions to the PM NAAQS are implemented by the States, but are not relevant to establishing the standards themselves.

1.1 CHARACTERIZATION OF AMBIENT PM

PM represents a broad class of chemically and physically diverse substances. It can be principally characterized as discrete particles that exist in the condensed (liquid or solid) phase spanning several orders of magnitude in size. For regulatory purposes, fine particles can be generally defined as those particles with an aerodynamic diameter of 2.5 m. or less, while coarse fraction particles are those particles with an aerodynamic diameter greater than 2.5 m., but equal to or less than a nominal 10 μm. The health and environmental effects of PM are strongly related to the size of the particles.

The emission sources, formation processes, chemical composition, atmospheric residence times, transport distances and other parameters of fine and coarse particles are distinct. Fine particles are generally formed secondarily from gaseous precursors such as sulfur dioxide ($_{SO)}$, nitrogen oxides ($_{NO}$), or organic compounds and are composed of sulfate, nitrate, and ammonium compounds; elemental carbon; and metals. Fine particles can also be directly emitted. Combustion of coal, oil, diesel, gasoline, and wood, as well as high temperature process sources such as smelters and steel mills, produce emissions that contribute to fine particle formation. In contrast, coarse particles are typically mechanically generated by crushing or grinding and are often dominated by resuspended dusts and crustal material from paved or unpaved roads or from construction, farming, and mining activities. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometers, while coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source. Table 1.1 summarizes the key differences between fine and coarse particles.

Geographic differences (i.e., rural vs. urban locations, East vs. West) also exist between ambient levels of fine and coarse particles and their related characteristics. For instance, total concentrations of coarse fraction particles are generally higher and the crustal material contribution relatively larger in arid areas of the Western and Southwestern U.S. In the Eastern U.S., fine particle sulfate is a significant component of ambient $PM_{2.5}$ concentrations. These geographic differences between ambient level of fine and coarse particles and their related characteristics are summarized in Figure 1-1. The differences in fine and coarse particle characteristics and their geographic variability are significant considerations in the design of control strategies to reduce levels of ambient PM concentrations.

TABLE 1-1.
COMPARISON OF AMBIENT FINE AND COARSE MODE PARTICLES

	Fine Mode	Coarse Mode
Formed from:	Gases	Large solids/droplets
Formed by:	Chemical reaction; Nucleation; Condensation; Coagulation; Evaporation of fog and cloud droplets in which gases have dissolved and reacted.	Mechanical disruption (e.g., crushing, grinding, abrasion of surfaces); Evaporation of sprays; Suspension of dusts.
Composed of:	Sulfate, $SO_4^=$; Nitrate, NO_3^-; Ammonium, NH_4^+; Hydrogen ion, H^+; Elemental carbon Organic compounds (e.g., PAHs, PNAs); Metals (e.g., Pb, Cd, V, Ni, Cu, Zn, Mn, Fe); Particle-bound water.	Resuspended dusts (e.g., soil dust, street dust); Coal and oil fly ash; Metal oxides of crustal elements (Si, Al, Ti, Fe); $CaCO_3$, NaCl, sea salt; Pollen, mold spores; Plant/animal fragments; Tire wear debris.
Solubility:	Largely soluble, hygroscopic and deliquescent.	Largely insoluble and non-hygroscopic.
Sources:	Combustion of coal, oil, gasoline, diesel, wood; Atmospheric transformation products of $_{NO}$, $_{SO}$, and organic compounds including biogenic species (e.g., terpenes); High temperature processes, smelters, steel mills, etc.	Resuspension of industrial dust and soil tracked onto roads; Suspension from disturbed soil (e.g., farming, mining, unpaved roads); Biological sources; Construction and demolition; Coal and oil combustion; Ocean spray.

Lifetimes:	Days to weeks	Minutes to hours
Travel Distance:	100s to 1000s of kilometers	< 1 to 10s of kilometers

Source: Office of Air Quality Planning and Standards Staff Paper, July 1996.

FIGURE 1-1.

1.2 ADVERSE HEALTH AND WELFARE EFFECTS OF ELEVATED AMBIENT CONCENTRATIONS OF PM

Since the last review of the PM criteria and standards, there has been significant new evidence from community epidemiological studies that serious health effects are associated with exposures to ambient concentrations of PM found in the urban U.S. even at levels below current PM standards. The PM Criteria Document (CD) and Staff Paper discuss and evaluate scientific information that suggest that the key health effects associated with PM include: premature mortality, increased hospital admissions and emergency room visits (primarily in the elderly and individuals with cardiopulmonary disease); increased respiratory symptoms and disease (in children, e.g., asthma, and individuals with cardiopulmonary disease); decreased lung function (particularly in children and individuals with asthma); and alterations in lung tissue and structure and in respiratory tract defense mechanisms. Elevated concentrations of fine particles also contribute to visibility impairment, and materials damage and soiling effects.

The PM CD indicates that risk of serious health effects is likely significant from an overall public health perspective given the large number of individuals in sensitive population groups that are exposed to ambient PM. Given this fact and that evidence suggests that effects may occur at levels below the current standards as well as the need to consider the fine and coarse fractions as distinct classes of particles, the Administrator has proposed that the current PM_{10} standards should be revised to protect public health with an adequate margin of safety. Significant reductions in premature mortality, hospital admissions, and other morbidity effects can be expected from attainment of the proposed suite of PM standards. Additionally, perceptible improvements in visibility are expected in many urban areas as a result of attainment of the proposed annual and 24-hour $PM_{2.5}$ standards.

1.3 LIMITATIONS OF SEGREGATED ANALYSES FOR THE OZONE AND PM NAAQS

General Limitations of this Analysis

The consideration of cost and, to be more specific, the use of cost-benefit analyses, provides a structured means of evaluating and comparing various implementation policies, as well as a means of comparing the variety of tools and technologies available for air pollution control efforts. The Agency has found the use of such analyses to be of significant value in developing regulatory options over the years.

General limitations, however, continue to affect the accuracy of cost-benefit analyses. For example, wide ranges of uncertainties often exist within an analysis, especially within studies of national scope involving forecasts over extended periods of time. Analyses, and therefore results, continue to be limited by inabilities to monetize certain health or welfare benefits -- such as protection against loss of lung function, or ecosystem damage. Comparisons of such incomplete benefits to the more quantifiable and usually more complete control costs can be misleading. In addition, though pollution control costs are generally more quantifiable, those costs have historically almost always been overstated for one of several reasons: entities concerned about such costs may overstate their position to emphasize their point; a belief by some analysts that conservative planning requires overestimation; or an inability to forecast significant improvements in the cost-effectiveness of pollution control that generally occur over analytical periods of 5 to 10 years.

Cost-benefit analyses also often notably lack the ability to deal with distributional issues, i.e. to provide for the consideration of equity among those who would receive benefits and those on whom the costs would fall. For example, under a typical stationary source air pollution control scenario, the costs of proposed controls would fall on large industrial sources, whereas the benefits would likely be distributed across a range of individuals throughout the community. Viewed from another perspective, if control costs are passed through to a large customer base, or to a broader community base, then the costs per family may be small, but the benefits to those who avoid respiratory problems or death are large.

These limitations notwithstanding, the process of developing such analyses can still provide useful insights as to existing data gaps, additional needs for information and tools, and limitations inherent in certain options. These insights can be especially useful to those working to develop implementation strategies because the analytical framework provides a mechanism for measuring, however roughly, strategies or tools against a common framework.

For example, this economic analysis provides estimates concerning possible negative cost impacts for certain industrial categories. As is noted in the relevant sections, these estimates are uncertain for two reasons: 1) They do not take into account the variety of localized or regional implementation strategies that may follow the setting of new standards. Such tailored strategies will likely serve to mitigate negative impacts on local industries; and 2) They do not account for growth in revenue and employment that also may result from additional pollution control equipment sales, or from substitutions that will transfer revenue from one industry to another (e.g., oil to natural gas). Regardless of these uncertainties, however, these estimates will be useful in guiding implementation activities, for they serve to pinpoint efforts to mitigate potential negative economic impacts.

Within these kinds of practical problems lie the general difficulty associated with cost-benefit analyses. By their nature, cost-benefit studies must be full of caveats and warnings about the value of their conclusions. Even the most narrowly focused and rigorous studies should, therefore, clearly not be the sole determinative test, but should instead serve as useful analytical tools. Unfortunately, the tendency is for such analyses to be referred to in more definitive terms, and for the conclusions, as uncertain as they may be, to take on lives of their own. This should clearly not be the case here.

Specific Limitations of this Analysis

Concurrent with the review of the ozone NAAQS, the Agency is reviewing the NAAQS for PM. There are many similarities between these two pollutants. Ideally, the RIA would have conducted its economic analysis taking this jointness into account. However, since each NAAQS review is a separate regulatory decision, the health effects and scientific information for each pollutant need to be judged separately and on their own merits. Furthermore, the Agency is in the process of developing the scientific tools and models needed to assess the interactions of these pollutants.

Concurrent with the review of these two NAAQS, EPA has requested the assistance of a broad range of stakeholder groups to help design a new implementation approach to controlling PM and ozone. This stakeholder group has been charged to evaluate new approaches to controlling these pollutants, focusing on the interaction of these pollutants in the atmosphere. As part of this process, EPA will strive to perform an integrated analysis for the proposal of the implementation package in June 1997. A more fully integrated analysis will be available in subsequent stages of the implementation process. The reasons for doing an integrated analysis follow.

While not all attributes of ozone and PM are linked, important commonalities exist between them which provide the technical and scientific rationale for integrated analysis. Similarities in pollutant sources, formation, and control exist between ozone and PM, in particular with respect to the fine fraction of particles addressed by the current PM NAAQS. These similarities include:

(1) atmospheric residence times of several days, leading to regional-scale transport of the pollutants;

(2) similar gaseous precursors, including NO and volatile organic compounds (VOC), which contribute to the formation of both ozone and PM in the atmosphere;

(3) similar combustion-related source categories, such as utilities, industrial boilers, and mobile sources, which emit particles directly as well as gaseous precursors of particles (e.g., $_{SO}$, NO, VOC) and ozone (e.g., NO, VOC); and

(4) similar atmospheric chemistry driven by the same chemical reactions and intermediate chemical species which often favor both high ozone and fine particle levels.

These similarities provide opportunities for optimizing technical analysis tools (i.e., monitoring networks, emission inventories, air quality models) and integrated emission reduction strategies to yield important co-benefits across various air quality management programs. Integration could result in a net reduction of the regulatory burden on some source category sectors that would otherwise be impacted separately by ozone, PM, and visibility protection control strategies. However, it is not possible at this time to perform a fully-integrated benefit-cost analysis. Among the difficulties in performing such an integrated analysis are: the significant differences in methodologies used for the two pollutants (e.g., air quality models); data are not currently available to assess the atmospheric interactions of these pollutants; and the control cost estimates presented in each RIA were developed from different bases and, therefore, cannot be directly compared, attributed to one pollutant or the other, or aggregated. Moreover, efforts to develop integrated implementation strategies have not been completed.

Separate analyses of the ozone and PM RIA's may cause misinterpretation of the total benefits, costs, and economic impact estimates from each RIA. For example, control of ozone precursors (VOC and NO) could result in reduced PM concentrations via reductions in organic and nitrate aerosols. Thus, the total benefits associated with ozone precursor controls may include an indirect component associated with the benefits of reducing adverse effects caused by PM and the cost savings associated with not having to impose as stringent PM controls as would otherwise be necessary to meet the PM NAAQS. To the extent that such indirect benefits exist, the benefit estimates presented in the separate ozone RIA may understate the actual total benefits accruing from ozone precursor controls. Additionally, the PM RIA may overstate benefits and costs if PM reductions are achieved through controls intended to reduce ozone. Similarly, ozone and PM nonattainment areas and air quality management practices overlap, making it difficult to attribute costs when controls reduce both ozone and PM concentrations. Ozone and PM co-control may result in duplication of control cost estimates used in the separate RIA's, resulting in over- or underestimation of costs depending on the types and numbers of control measures selected. Table 1-2 lists some common control measures and source categories.

One of the other major limitations which affects the results of this RIA is the assumption of a particular implementation approach in calculating the cost of obtaining the new standards. The strategies used are limited in part because of our inability to predict the breadth and depth of the creative approaches to implementing these new NAAQS, and in part by technical limitations in modeling capabilities. This limitation, in effect, forces costs to be developed based on compliance strategies that reflect suboptimal approaches to implementation and, therefore, those that likely reflect higher potential costs for attaining the new standard. This required approach renders the result specifically useful as an incentive to pursue lower cost options, but not as a helpful indicator of likely costs.

It is important to recognize here that if new ozone or particulate standards are finalized under the CAA, the Act allows for substantial new flexibility in the development of implementation strategies, both for control strategies as well as schedules. To the extent that it is warranted, the Act allows for an extension of attainment deadlines as well. This new flexibility may also mean the development of different patterns of designations, and movement away from the traditional attainment-nonattainment delineations.

TABLE 1-2

PM-OZONE INTEGRATED CONTROL MEASURES

Control Measure	Examples of Applicable Source Category(ies)
Reformulated Gasoline	Highway and non-road vehicles-gasoline
Reformulated Diesel Fuel	Highway and non-road vehicles-diesel
Enhanced inspection/maintenance	Highway vehicles-gasoline
Air/fuel adjustment + ignition timing retardation	Internal combustion engines (natural gas)
Low emission vehicles	Highway vehicles-gasoline
Vapor balance (Stage I)	Service stations (fuel truck unloading)
Selective/non-selective catalytic reduction	Utility, industrial, & commercial-institutional boilers; gas turbines; nitric acid mfg.; internal combustion engines; process heaters; cogeneration; municipal & medical waste incinerators; iron & steel mills
Low-NO burners	Utility, industrial, & commercial-institutional boilers; process heaters; co-generation; residential natural gas; iron & steel mills; cement mfg.
VOC add-ons (incineration, adsorption, condensation, etc.)	Aircraft/marine/paper/misc. surface coating; web offset lithography; synthetic fiber mfg.; gasoline bulk terminals
Coating reformulation	Wood product/furniture
California Air Resources Board (CARB) best available retrofit control technology (BARCT) limits/Federal implementation plan (FIP) rule	Automobile refinishing
Product reformulation	Aerosols

VOC fugitive controls	Petroleum refineries; synthetic organic chemical mfg.

Even under the current standards, EPA has begun to put an emphasis on strategies that use the marketplace to reduce costs, utilize national strategies where they make sense, and can look to regional and other cooperative approaches -- so that we maximize efficiencies and minimize costs throughout the pollution control system. EPA and a large number of States are already working in this direction through the Ozone Transport Assessment Group, through the Ozone Transport Commission in the Northeast, and through our own efforts to encourage market approaches for ozone precursors. We also are working with Western States through the Grand Canyon Visibility Transport Commission, which is addressing the visibility impacts of both ozone and PM.

Specific to new standards, EPA also has established a formal advisory committee under the FACA. The specific purpose of the broad-based stakeholder group is to advise EPA on ways to develop innovative, flexible, practical and cost-effective implementation strategies, and to advise us directly on transitional strategies as well. Examples of such strategies might include programs such as "Cool Cities", "Green Lights", and "Climate Wise" programs as well as clean fuel fleets and economic incentive programs. This group has specifically been tasked with consideration of strategies that would allow the future integration of ozone, PM, and regional haze programs. This approach is intended to develop control strategies that recognize the significant overlap and similarities that exist among these pollutants as mentioned above.

These similarities clearly provide management opportunities for optimizing and coordinating monitoring networks, emission inventories and air quality models, creating opportunities for coordinating and minimizing the regulatory burden for sources that would otherwise be required to comply with separate controls for each of these pollutants.

Significant shortcomings also exist in the data available for these analyses. Existing emissions inventories and modeling to date, either on a national scale, or on an aggregated basis, simply do not provide a sufficient analytical basis from which to draw accurate results. Sufficient current monitoring data for $PM_{2.5}$ exists in only a few cities -- including Los Angeles and Philadelphia. Projections concerning which areas will be classified as nonattainment can only be developed through extrapolation from existing PM_{10} data -- an imprecise exercise at best -- and through the use of very uncertain modeling exercises. The combination of these uncertainties must inevitably provide uncertain results.

And finally, the nature of these types of analyses is that of a snapshot in time. The cost of implementing these standard revisions in the first few years will mainly be related to monitoring, strategy development and creating state development plans. Therefore, we selected a year more reflective of the implementation of a new standard. The year 2007 was chosen because most of the mandatory CAA requirements will have fully taken effect and most areas currently in violation are expected to achieve attainment with the current NAAQS standard by this year. Analysis results are presented for this single future year because results are based on air quality modeling performed for a single "representative" year. Multi-year air quality modeling was not feasible because of resource constraints. Moreover, the snapshot approach simplifies the presentation and interpretation of results. The limitations imposed by this snapshot approach are particularly troublesome in this case, primarily for two reasons.

First of all, in terms of developing strategies or technologies, a decade can see many changes. For example, relative to air pollution control policy, since 1987 we have seen large scale revisions of the CAA -- including complete rewrites of nonattainment, acid rain, and air toxics policies -- the Intermodal Surface Transportation and Efficiency Act, and the Energy Policy Act. We have also seen the introduction at the State and national level of utility deregulation. All of these actions, both together and individually, are having important and, in some cases, dramatic effects on air quality.

In terms of technology, in the last decade we have seen the introduction of three generations of cleaner gasoline (i.e., low Reid vapor pressure, oxygenated and reformulated fuels), cleaner diesel fuels, the introduction of cleaner vehicles (such as electric vehicles) dramatic improvements in scrubber technology for SO_2 controls, the development of replacements for phased- out chlorofluorocarbons, far more cost-effective ways to control auto tail-pipe emissions, and the development of on-board diagnostic equipment to assure those cleaner standards continue to be met over time.

Relative to attainment of NAAQS, since 1990 alone we have seen more than half of the areas in violation of the standards for ozone and carbon monoxide begin to meet the standards, many actually ahead of schedule. Moreover, the costs associated with many of these efforts are less than was estimated, even as late as 1990.

Therefore, in the case of air pollution control, 10 years is a very long time over which to carry assumptions. Furthermore, a 2007 snapshot does not allow sufficient time for all areas to reach attainment, even under the current standard. Given the likelihood that new standards will result in additional time for some areas, it is clear that some areas will not be required to be in attainment by 2007. This analysis recognizes this by not arbitrarily forcing all areas to reach attainment by 2007 by the use of extreme control measures realizing that such extreme measures are unlikely ever to be put in place.

While qualitative discussions of the uncertainties and limitations discussed above are provided throughout this RIA, lack of information presents a more rigorous quantitative assessment of uncertainties. Nevertheless, the reader should keep all of the above limitations in mind when reviewing and interpreting the results presented below.

1.4 OVERVIEW OF RIA ASSESSMENTS

Potential costs, economic impacts and benefits have been estimated for implementation of the proposed revisions to the PM NAAQS. In order to understand the future impacts of implementation of the CAA in respect to ambient PM concentrations, the year 2007 was chosen for the analytical period. Thus, analyses provide a "snapshot" of the year 2007 and the potential incremental economic impacts of achieving the air quality levels specified in the proposed PM NAAQS in relation to those specified in the current PM_{10} NAAQS.

Given the distinctions between the PM levels and sources in the East versus the West, analyses have been designed to take into consideration these differences both in analytical inputs and in the examination of control strategies. Regional analyses have been conducted at the national level (with the U.S. divided into 7 regions) for the 470 counties which are currently monitored for PM_{10} and which have sufficient data. These monitors are located in high population areas and approximately 60 percent of the U.S. population (1990 Census) resides in these monitored counties. No major geographical expansion in the PM monitoring network is planned. Therefore, these analyses assume that this set of counties will be the basis on which future PM control strategies may be designed. The regional analyses that were performed estimate the costs, economic impacts and benefits of regional control strategies. Additionally, for the Eastern U.S. where the PM problem is driven largely by regional transport of sulfate, a region wide, market-based $_{SO}$ reduction strategy has been assessed.

The assessment of costs, economic impacts and benefits consists of multiple analytical components. In order to predict baseline air quality in the year 2007, emission inventories were developed for 1990 and then projected to 2007. Clean Air Act-mandated controls are applied to these emissions to take account of emission reductions achieved in 2007 as a result of CAA implementation. These emissions in turn are input to an air quality model that relates emission sources to PM concentrations at county-level receptors. This 2007 baseline air quality is used to predict counties that are estimated to have PM levels higher than those specified in alternative PM standards. A cost optimization model is then employed to determine the least cost control strategies to achieve the level of the alternative standards at county receptors. Given the estimated costs of attaining alternative PM standards, the economic impacts of these potential costs on affected industry and governmental sectors is subsequently analyzed. Potential health and welfare benefits are estimated from predicted changes in PM air quality as a result of control strategies applied in the cost analysis. Finally, benefits and costs are compared to examine questions of economic efficiency.

Analyses have been conducted of the impacts of the current PM_{10} NAAQS as well as each of the following PM NAAQS alternatives as outlined in the Proposed Decision:

PM_{10} Standard Alternatives

Current PM NAAQS:

- PM_{10} 50 μg/m^3 annual arithmetic mean and 150 μg/m^3 24-hr, averaged over 3 years with 1 expected exceedance permitted per year.

Proposed revision:

- PM_{10} 50 μg/m^3 annual arithmetic mean and 150 μg/m^3 24-hr average of the 98th percentile concentration over a 3-year period.

Soliciting Comment:

- Revocation of 24-hr PM_{10} standard, retaining the current annual NAAQS.

$PM_{2.5}$ Standard Alternatives

Proposed revision:

- $PM_{2.5}$ 15 μg/m^3 spatially-averaged annual arithmetic mean and 50 μg/m^3 24-hr, average of the 98th percentile concentration over a 3-year period.

Soliciting Comment:

- $PM_{2.5}$ 20 $\mu g/m^3$ spatially- averaged annual arithmetic mean and 65 $\mu g/m^3$24-hr, 98th percentile concentration, averaged over a 3-year period.
- $PM_{2.5}$ 12.5 $\mu g/m^3$ spatially-averaged annual arithmetic mean and 50 $\mu g/m^3$ 24-hr, 98th percentile form, averaged over a 3-year period.

The $PM_{2.5}$ and the proposed PM_{10} alternatives were analyzed incrementally to the current standard. The analyses were performed to get a "snapshot" prediction of baseline air quality in 2007.

The following chapters describe more fully the details of each analytical component. Chapters 2, 3, 4, and 5 outline the need for the proposed rule, the alternative approaches examined, the rationale for choosing the proposed regulatory action, and the statutory authority under which the RIA has been prepared. The analytical inputs and emissions and air quality methodologies are described in Chapter 6. Presented in Chapter 7 are the control strategy design and cost analysis. The economic impacts of the proposed rule and alternative standards on affected industry and governmental sectors are presented in Chapter 8. Discussed in Chapter 9 are the benefits of the proposed PM NAAQS as well as alternative standards. Finally, the benefits and costs of the proposed and alternative PM standards are compared in Chapter 10.

2.0 STATEMENT OF NEED FOR THE PROPOSED RULEMAKING

2.1 INTRODUCTION

Congress passed the Clean Air Act (CAA) to protect public health and the environment from the adverse effects of air pollution. This section summarizes the legislative and judicial requirements affecting the development and revision of the National Ambient Air Quality Standard (NAAQS) and briefly describes the nature of particulate pollution and the need for regulatory action at this time.

2.2 LEGISLATIVE AND JUDICIAL REQUIREMENTS AFFECTING THE DEVELOPMENT AND REVISION OF PARTICULATE MATTER (PM) NAAQS

2.2.1 Legislative Requirements

Two sections of the CAA 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 and 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, [is] requisite to protect the public health."[a] 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 in [the] criteria, is requisite to protect the public welfare from any 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 CAA directs the Administrator to review existing criteria and standards at 5-year intervals. When warranted by such review, the Administrator is to revise NAAQS.
The approved standards will then be implemented by the States.

2.2.2 **Judicial Decisions**

Judicial decisions (Lead Industries Association, Inc. vs. The Environmental Protection Agency (EPA), 1980; American Petroleum Institute vs. EPA, 1981) make clear that the costs and technological feasibility of attainment are not to be considered in setting primary or secondary NAAQS. Such factors can be considered to a limited degree in the development of State plans to implement such standards. Under section 110 of the CAA, the States are to submit to EPA for approval State Implementation Plans (SIP's) that provide for the attainment and maintenance of NAAQS by certain deadlines.

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[a] 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)).

2.3 NATURE OF PM EFFECTS

PM represents a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. Anthropogenic sources of particles include a variety of stationary and mobile sources. Particles may be emitted directly to the atmosphere or may be formed by transformations of gaseous emissions such as sulfur dioxide or nitrogen oxides. The major chemical and physical properties of PM vary greatly with time, region, meteorology, and source category, thus complicating the assessment of health and welfare effects as related to various indicators of particulate pollution. At elevated concentrations, particulate matter can adversely affect human health, visibility, and materials. Components of particulate matter (e.g., sulfuric acid) also contribute to acid deposition.

More specifically, key findings concerning the health effects associated with particulate pollution, as assessed in the Criteria Document for Particulate Matter (CD) and the Office of Air Quality Planning and Standards Staff Paper, can be summarized as follows:

1) Health risks posed by inhaled particles are affected both by the penetration and deposition of particles in the various regions of the respiratory tract, and by the biological responses to these deposited materials.

2) The risks of adverse effects associated with deposition of ambient fine and coarse fraction particles in the thorax (tracheobronchial and alveolar regions of the respiratory tract) are markedly greater than for deposition in the extrathoracic (head) region. Maximum particle penetration to the thoracic regions occurs during oronasal or mouth breathing.

3) As discussed in the CD and Staff Paper, the key health effects categories associated with PM include: 1) premature mortality; 2) aggravation of respiratory and cardiovascular disease (as indicated

by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days); 3) changes in lung function and increased respiratory symptoms; 4) changes to lung tissues and structure; and 5) altered respiratory defense mechanisms. Most of these effects have been consistently associated with ambient PM concentrations, which have been used as a measure of population exposure, in a number of community epidemiological studies. Additional information and insights on these effects are provided by studies of animal toxicology and controlled human exposures to various constituents of PM conducted at higher-than-ambient concentrations. Although, as noted above, mechanisms by which particles cause effects have not been elucidated, there is general agreement that the cardio-respiratory system is the major target of PM effects.

4) Based on a qualitative assessment of the epidemiological evidence of effects associated with PM for subpopulations that appear to be at greatest risk with respect to particular health endpoints, the Proposed Rule draws the following conclusions with respect to sensitive subpopulations:

a) Individuals with respiratory disease (e.g., chronic obstructive pulmonary disease, acute bronchitis) and cardiovascular disease (e.g., ischemic heart disease) are at greater risk of premature mortality and hospitalization due to exposure to ambient PM.

b) Individuals with infectious respiratory disease (e.g., pneumonia) are at greater risk of premature mortality and morbidity (e.g., hospitalization, aggravation of respiratory symptoms) due to exposure to ambient PM. Also, exposure to PM may increase individuals' susceptibility to respiratory infections.

c) Elderly individuals are also at greater risk of premature mortality and hospitalization for cardiopulmonary problems due to exposure to ambient PM.

d) Children are at greater risk of increased respiratory symptoms and decreased lung function due to exposure to ambient PM.

e) Asthmatic individuals are at risk of exacerbation of symptoms associated with asthma, and increased need for medical attention, due to exposure to PM.

5) Review of the available epidemiological studies suggest the need for both short-term (24-hour) and long-term (annual) primary standards in order to prevent sensitive populations from experiencing adverse health effects.

In formulating alternative approaches to establishing adequately protective, effective, and efficient PM standards, it is necessary to specify the fraction of particles found in the ambient air that should be used as the indicator(s) for the standards.

The Proposed Rule concludes that continued use of PM_{10} as the *sole* indicator for the PM standards would not provide the most effective and efficient protection from the health effects of PM. The recent health effects evidence and the fundamental physical and chemical differences between fine and coarse fraction particles have prompted consideration of separate standards for the fine and coarse fractions of PM_{10}. In this regard, the CD concludes that fine and coarse fractions of PM_{10} should be considered separately. Taking into account such information, the Clean Air Scientific Advisory Committee (CASAC) found sufficient scientific and technical bases to support establishment of separate standards relating to these two fractions of PM_{10}. Specifically, CASAC advised the Administrator that "there is a consensus that retaining an annual PM_{10} NAAQS . . . is reasonable at this time" and that there is "also a consensus that a new $PM_{2.5}$ NAAQS be established."

There are significant physical and chemical differences between the two subclasses of PM_{10} and it is reasonable to expect that differences may exist between fine and coarse fraction particles in both the nature of potential effects and the relative concentrations required to produce such effects. The specific components of PM that could be of concern to health include components typically within the fine fraction (e.g., acid aerosols, sulfates, nitrates, transition metals, diesel particles, and ultra fine particles), and other components typically within the coarse fraction (e.g., silica and resuspended dust). While components of both fractions can produce health effects, in general, the fine fraction appears to contain more of the reactive substances potentially linked to the kinds of effects observed in the epidemiological studies. The fine fraction also contains the largest number of particles and a much larger aggregate surface area than the coarse fraction which enables the fine fraction to have a substantially greater potential for absorption and deposition in the thoracic region, as well as for dissolution or absorption of pollutant gases.

With respect to welfare or secondary effects, fine particles have been clearly associated with the impairment of visibility over urban areas and large multi-state regions. Fine particles, or major constituents thereof, also are implicated in materials damage, soiling, and acid deposition. Course fraction particles contribute to soiling and materials damage.

Particulate pollution is a problem affecting localities, both urban and non-urban, in all regions of the United States. Manmade emissions that contribute to airborne particulate matter result principally from stationary point sources (fuel combustion and industrial processes), industrial process fugitive particulate emission sources, non-industrial fugitive sources (roadway dust from paved and unpaved roads, wind erosion from cropland, etc.) and transportation sources. In addition to manmade emissions, consideration must also be given to natural emissions including dust, sea spray, volcanic emissions, biogenic emanation (e.g., from plants), and emissions from wild fires when assessing particulate pollution and devising control strategies.

2.4 NEED FOR REGULATORY ACTION

2.4.1 Market Failure (Externality)

In the absence of government regulation, market systems have failed to deal effectively with air pollution because air sheds have been treated as public goods and because most air polluters do not internalize the full damage caused by their emissions. For an individual firm, pollution is usually an unusable by-product which can be disposed of at no cost by venting it to the atmosphere. However, in the atmosphere, pollution causes real costs to be incurred by others. This is generally referred to in economic theory as a negative externality.

The fact that the producer, or consumer, whose activity results in air pollution, does not bear the full costs of his/her action leads to a divergence between private costs and social costs. This is referred to as "market failure" because it causes a misallocation of society's resources, with more resources being devoted to the polluting activity than would be if the polluter had to bear the full cost.

There are a variety of market and nonmarket mechanisms available to correct this situation. Some of the principal market mechanisms are briefly described in Section 3.0 of this regulatory impact analysis (RIA) ("An Examination of Alternative Approaches"). Other than regulation, nonmarket approaches would include negotiations or litigation under tort law and general common law. In theory, these latter approaches might result in payments to individuals to compensate them for the damages they incur.

Such resolutions may not occur, however, in the absence of government intervention. Two major impediments block the correction of pollution inefficiencies and inequities by the private market. The first is high transaction costs when millions of individuals are affected by thousands of polluters, such as is the case with PM air pollution. The transaction costs of compensating individuals adversely impacted by air pollution include contacting the individuals affected, apportioning injury to each from each pollution source, and executing the appropriate damage suits or negotiations. If left to the private market, each polluter and each affected individual would have to litigate or negotiate on their own or organize into groups for these purposes. The transaction costs involved could be so high as to probably exceed the benefits of the pollution reduction.

The second factor discouraging private sector resolution of the particulate matter pollution problem is that pollution abatement tends to be a public good. That is, after particulate matter has been abated, benefits of the abatement can be enjoyed by additional people at no additional cost. This constitutes the classic "free rider" problem. Any particular individual is reluctant to contribute time or money to reduce particulate emissions expecting that they may be able to "free ride" on others' efforts to mitigate the problem.

In view of the clear legal requirements placed on the EPA by the CAA and the market failure discussed above, the Agency is proposing to revise the NAAQS for PM to provide adequate protection of public health and welfare. As this RIA shows, there are resource costs associated with the implementation of these standards by the States (see Section 7.0, "Control Strategy and Cost Analysis"). However, governmental action is required by the CAA. In addition, EPA believes that the cost of this abatement is less expensive than with any reasonably available private sector alternative. Finally, these standards, when implemented by the States, will mitigate the negative externalities which would otherwise occur due to the failure of the marketplace.

2.5 REFERENCES

U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. EPA-452/R-96-013. July 1996.

U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Draft Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. April 1996.

U.S. Environmental Protection Agency. Office of Research and Development. Final Draft Quality Criteria for Particulate Matter. April 12, 1996.

3.0 AN EXAMINATION OF ALTERNATIVE APPROACHES

This section briefly presents potential alternatives to the proposed revisions of the National Ambient Air Quality Standards (NAAQS) for particulate matter (PM). The outline for the section is adopted from Executive Order 12866 which requires that at a minimum the following alternatives be examined:

a) No regulation
b) Other regulatory approaches
c) Market-oriented alternatives
d) Regulatory alternatives within the scope of present legislation

Although Executive Order 12866 requires that all alternatives be examined, only the most likely ones need to be analyzed in detail.

3.1 NO REGULATION

Abandoning current regulatory requirements for PM would result in a reliance on private efforts to reduce emissions and on the absorptive capacity of the atmosphere. The most likely avenues for private efforts would be either negotiation or litigation under tort and general common law. Generally speaking, there is no incentive for a single company to enter into negotiations with individuals to reduce PM emissions. For an individual firm, the cost of reducing emissions would leave that firm at a competitive disadvantage. Litigation by those damaged could be pursued either to obtain a reduction in emissions or to obtain payment for damages incurred (or both). The costs of such litigation would likely be very high since the individual or classes of individuals bringing suit would have to prove damages. Moreover, there is little incentive for all those affected by air pollution to join together in such a suit since everyone would enjoy the benefits of a successful suit to reduce emissions regardless of the extent of their participation.

Because the Clean Air Act (CAA) requires the Environmental Protection Agency (EPA) to establish standards for criteria pollutants (such as PM) which have adverse effects on public health and because of the impracticality of private efforts, the option of no regulation has not been analyzed in any further detail.

3.2 OTHER REGULATORY APPROACHES

Other regulatory approaches include such options as performance- and technology-based standards and regional or State air quality standards. Performance- and technology-based standards are required by the present law in a variety of forms (e.g., new source performance standards (NSPS) for new and modified sources, lowest achievable emission rate (LAER), and reasonably available control technology (RACT) in non-attainment areas, etc.). They are not based solely on health and welfare criteria but are designed, in part, to augment control strategies for attainment of the NAAQS. These standards generally specify allowable emission rates for specific source categories. The LAER and RACT requirements are intended to allow growth in non-attainment areas while promoting progress towards eventual attainment. NSPS help to reduce the likelihood of future pollution problems by controlling new sources. EPA is required to consider technology and cost in setting NSPS and RACT requirements.

Performance- and technology-based standards serve as useful adjuncts to ambient standards. However, they cannot serve as substitutes for ambient standards since even perfect compliance with them may not produce acceptable air quality levels. Despite the application of such standards, local meteorology, the interaction of multiple sources, and the level of the standard itself (the standards are set on the basis of technology and cost) could produce air quality levels that do not protect public health and welfare.

Regional or State differences in terrain and meteorology as well as economic valuations of clean air have been cited as reasons for adopting regional or State air quality standards. Variations in terrain and meteorology are considered in setting State implementation plans (SIP's) emission limits to achieve a NAAQS. Such variations do not generally change the effect of particular levels of pollution on public health and welfare. However, in the case of PM, the composition of the pollutant and its effects can vary from city to city. On the other hand, transport of pollutants across boundaries would make a system of regional or State air quality standards difficult to enforce. Moreover, the CAA requires national not regional standards.

In summary, the regulatory alternatives outlined above have not been analyzed in detail in this draft because they are beyond the scope of present legislation. However, the performance- and technology-based standards are helpful in augmenting control strategies for meeting ambient standards. These strategies, among others, are being considered as part of the previously- mentioned Agency stakeholder process to develop new implementation strategies.

3.3 MARKET-ORIENTED ALTERNATIVES

There are several market-oriented approaches such as emissions trading, charges, and fees which can be considered by the States in their SIP's to achieve the NAAQS for PM. This regulatory impact analysis (RIA), however, does not assess the impacts of such strategies. The EPA is currently exploring innovative implementation strategies to achieve the proposed PM NAAQS. These strategies will be assessed within the Phase I and/or Phase II implementation economic analyses, which are planned to be completed by June 1997 and June 1998, respectively.

3.4 REGULATORY ALTERNATIVES WITHIN THE SCOPE OF PRESENT LEGISLATION

The assessment of the available quantitative and qualitative health effects data presented in the criteria document and the Office of Air Quality Planning and Standards (OAQPS) Staff Paper, together with recommendations from the Clean Air Scientific Advisory Committee and other public commenters suggest a range of alternatives for both short-term (24-hour) and long-term (annual) particulate matter standards. For a comprehensive discussion of the scientific data that serve as a basis for these alternatives as well as the rationale for the Administrator's approach to this decision, the reader is referred to the OAQPS Staff Paper and Criteria Document, as well as the Federal Register announcing the Administrator's proposed decision. This regulatory impact analysis includes an evaluation of the marginal (incremental) benefits and costs associated with each alternative in relation to the current PM_{10} NAAQS baseline. The current standard is the appropriate baseline to use because it represents the point of comparison for the future if no new standard is implemented. The analysis assists in informing the public on which alternatives return the greatest benefits in relation to the costs incurred when implemented by the States. The alternatives that are put forth in the proposed rule are shown in Tables 3-1 and 3-2.

TABLE 3-1

PRIMARY PM_{10} NAAQS ALTERNATIVES EXAMINED

24-Hour Standard (μg/m^3)	Annual Standard Arithmetic Mean Form (μg/m^3)
150* (current std.)	50
None	50
150**	50

*One-Expected-Exceedance Form
**98th Percentile Form

TABLE 3-2
PRIMARY $PM_{2.5}$ NAAQS ALTERNATIVES EXAMINED

24-Hour Standard 98th Percentile Form ($\mu g/m^3$)	Annual Standard Annual Mean, Spatially Averaged ($\mu g/m^3$)
65	20
50 (proposed std.)	15
50	12.5

3.5 REFERENCES

U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Review of the National Ambient Air Quality Standards for Particulate Matter. Policy Assessment of Scientific and Technical Information. July 1996.

4.0 RATIONALE FOR CHOOSING THE PROPOSED REGULATORY ACTION

The Clean Air Act (CAA) requires that primary National Ambient Air Quality Standards (NAAQS) be set at levels which protect the health of sensitive individuals with an adequate margin of safety. The secondary NAAQS must be adequate to protect public welfare from any known or anticipated adverse effects.

In accordance with sections 108 and 109 of the CAA, the Environmental Protection Agency (EPA) has reviewed and revised the criteria upon which the existing primary and secondary particulate matter (PM) standards are based. The existing primary standards for PM (measured as PM_{10}) are 150 $\mu g/m^3$, averaged over a period of 24 hours with no more than one expected exceedance per year, and 50 $\mu g/m^3$, expected annual arithmetic mean. The secondary standard (also measured as PM_{10}) is identical to primary standards for both the 24-hour and annual averaging periods.

4.1 PROPOSED REVISIONS TO THE PRIMARY PM STANDARDS

In accordance with sections 108 and 109 of the CAA, EPA has reviewed the air quality criteria and NAAQS for PM. Based on this review, EPA proposes to revise the current primary PM_{10} standards by adding two new primary $PM_{2.5}$ standards set at 15 $\mu g/m^3$, annual mean, and 50 $\mu g/m^3$, 24-hour average, to provide increased protection against a wide range of PM-related health effects, including premature mortality and increased hospital admissions and emergency room visits (primarily in the elderly and individuals with cardiopulmonary disease); increased respiratory symptoms and disease (in children and individuals with cardiopulmonary disease such as asthma); decreased lung function (particularly in children and individuals with asthma); and alterations in lung tissue and structure and in respiratory tract defense mechanisms. The proposed annual $PM_{2.5}$ standard would be based on the 3-year average of the annual arithmetic mean $PM_{2.5}$ concentrations, spatially averaged across an area. The proposed 24-hour $PM_{2.5}$ standard would be based on the 3-year average of the 98th percentile of

24-hour $PM_{2.5}$ concentrations at each monitor within an area. The EPA also solicits comment on two alternative approaches for selecting the levels of $PM_{2.5}$ standards. The EPA proposes to revise the current 24-hour primary PM_{10} standard of 150 $\mu g/m^3$ by replacing the 1-expected-exceedance form with a 98^{th} percentile form, averaged over 3 years at each monitor within an area, and solicits comment on an alternative proposal to revoke the 24-hour PM_{10} standard. The EPA also proposes to retain the current annual primary PM_{10} standard of 50 $\mu g/m^3$. Further, EPA proposes new data handling conventions for calculating 98^{th} percentile values and spatial averages, proposes to revise the reference method for monitoring PM as PM_{10}, and proposes a new reference method for monitoring PM as $PM_{2.5}$.

4.2 RECOMMENDED REVISIONS TO THE SECONDARY PM STANDARD

The EPA proposes to revise the current secondary standards by making them identical to the suite of proposed primary standards. In the Administrator's judgment, these standards, in conjunction with the establishment of a regional haze program under section 169A of the CAA, would provide appropriate protection against PM-related public welfare effects including soiling, materials damage, and visibility impairment.

4.3 REFERENCES

U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. EPA-452/R-96-013. July 1996.

U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Draft Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. April 1996.

U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Draft National Ambient Air Quality Standards for Particulate Matter: Proposed Decision. October 28, 1996.

5.0 STATUTORY AUTHORITY

The statutory authority for the proposed revision of the particulate matter (PM) National Ambient Air Quality Standards (NAAQS) is contained in the Clean Air Act (CAA). Two sections of the CAA govern development of the NAAQS. Section 108 (42 U.S.C. 7408) requires the Environmental Protection Agency (EPA) to document the most recent scientific basis (criteria) for setting an ambient standard. Section 109 provides authority for reviewing the criteria and establishing primary (health-based) and secondary (welfare-based) NAAQS.

The CAA specifically requires that ambient standards be based on scientific criteria relating to the level of air quality that should be attained to protect public health and welfare adequately. The CAA also precludes consideration of costs or technological feasibility in determining the levels of ambient standards.

The current development of a new NAAQS for PM has two separate and distinct components: the development of the standard itself, which is codified under 40 CFR Part 50; and the development of cost-effective implementation strategies to achieve the new standard, codified under 40 CFR Part 51. Normally, the process of NAAQS development would be handled as a single entity, with only one regulatory impact analysis (RIA) to determine the combined impacts of Parts 50 and 51. However, resource constraints and the Federal Advisory Committee Act requirements within the Agency resulted in two separate phases. The phase which is assessed in this RIA pertains to the development of a new standard under Part 50. The second phase, which pertains to the implementation of the new standard under Part 51, will be analyzed in a separate RIA.

This RIA is performed under the authority of Executive Order 12866. Executive Order 12866 (9/30/93) states that "Federal agencies should promulgate only such regulations as are required by law, are necessary to interpret the law, or are made necessary or compelling by public need . . . . In deciding whether and how to regulate, agencies should assess all costs and benefits of available regulatory alternatives, including the alternative of not regulating. Costs and benefits shall be understood to include both quantifiable measures . . . and qualitative measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider. Further, in choosing among alternative regulatory approaches, agencies should select those approaches that maximize net benefits . . ., unless a statute requires another regulatory approach." Thus, since the CAA specifically precludes consideration of costs or technological feasibility in determining the ambient standards, the results of this RIA were not taken into account by the Administrator in her decision on whether to change the current NAAQS.

The Unfunded Mandates Reform Act of 1995 (P.L. 104-4), in Title II, section 201, directs agencies "unless otherwise prohibited by law [to] assess the effects of Federal regulatory actions on State, local, and tribal governments, and the private sector . . . ." Section 202 of Title II directs agencies to provide a qualitative and quantitative assessment of the anticipated costs and benefits of a Federal mandate resulting in annual expenditures of $100 million or more, including the costs and benefits to State, local, and tribal governments, or the private sector. Since the NAAQS themselves do not establish any requirements applicable to State, local, and tribal governments, or the private sector, the Unfunded Mandates Reform Act does not apply. However, the Agency has conducted general analyses of the potential impacts of control measures the States might adopt to attain the proposed NAAQS, and has included those analyses in this RIA. Executive Order 12875, "Enhancing the Intergovernmental Partnership"(10/26/93), was also taken into account in the development of this RIA.

The Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA) was developed to assure that Agencies consider the impacts of their rulemakings on small entities. Since the NAAQS themselves do not establish any requirements applicable to small entities, SBREFA does not apply to this rulemaking. However, the Agency has conducted general analyses of the potential cost impacts on small entities of control measures the States might adopt to attain the proposed NAAQS, and has included those analyses in this RIA.

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," (2/16/94) requires that each Federal agency make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minorities and low-income populations. These requirements have been addressed to the extent practicable in the RIA.

This draft RIA and associated analyses are intended only to inform the public about the potential costs and benefits that may result when the proposed revisions to the NAAQS are implemented by the States. The results of the analyses contained in the draft RIA were not considered in the issuance of the proposal. Also, the control strategies examined in the draft RIA do not take into account the ongoing examination by the Clean Air Act Advisory Committee
of new integrated approaches for implementing the proposed revisions to the NAAQS.

5.1 REFERENCES

U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. July 1996.

6.0 EMISSIONS AND AIR QUALITY MODELING

6.1 INTRODUCTION

This chapter describes the several analytical inputs that underlie the control strategy-cost, benefits analysis, and economic impact analyses. These inputs are the: (1) baseline emissions inventory (both primary PM and PM precursors); (2) emission projections; (3) air quality data (measured and modeled); and (4) alternative PM_{10} and $PM_{2.5}$ standards being considered.

These analytical inputs are used to predict certain outputs that are essential to performing these three analyses. First, the 1990 baseline emissions are projected to the year 2007 based upon estimated national growth in industry earnings. The year 2007 was chosen as the analytical year as most of the mandatory CAA requirements that have an impact on ambient particle concentrations (e.g., Title IV SO_2 controls) will have taken effect by this time. These projected emissions are then multiplied by source-receptor coefficients to obtain county predictions of the ambient air quality in 2007. Next, the 2007 air quality predictions are compared to the alternative NAAQS to determine how many counties exceed the level of a given alternative. The 2007 air quality and other data are input to an optimization model that generates regional control costs for those source categories selected for emission reductions. The economic impacts of these control costs on industry sources are also assessed. Once post-control air quality is defined as part of the cost analysis, the economic benefits of the air quality change is assessed.

Finally, associated with each analytical input is an uncertainty, the magnitude of which is often difficult to determine. The major areas of uncertainty in the analytical inputs are presented at the end of the chapter.

6.2 BASELINE EMISSIONS INVENTORY

This section summarizes the 1990 base year emissions inventory that provides one of the foundations of this analysis: the National Particulates Inventory.[1] This inventory represents the most recent estimates of primary PM_{10}, $PM_{2.5}$ and particle precursor emissions available. This inventory was completed for the Office of Air Quality Planning and Standards (OAQPS) as part of a separate EPA study. Although the National Particulates Inventory was not developed as part of this analysis, a summary of its estimation methods is provided to establish an understanding of the sources used to measure base year PM emission levels by source type. This emissions inventory also serves as the basis for the emissions projections for the year 2007 that will be used for comparing control measure impacts of attaining alternative PM standard levels.

6.2.1 Inventory Scope

The National Particulates Inventory was developed based, in part, on two efforts: the 1990 Interim Inventory and the Trends Inventory. Data and methods from these two inventories were updated in June 1995 to form the National Particulates Inventory. The geographic scope of the inventory includes the continental United States, Canada, and Mexico. Given the long-range transport potential of fine particles, emission sources in Canada and Mexico are included in this analysis. The methods used to develop the National Particulates Inventory are listed in Table 6-1, and are summarized by source type in Appendix VI.1.

The baseline 1990 emission inventory used in this analysis contains county-level emissions of primary PM_{10} and $PM_{2.5}$ (particles emitted directly in the particle form), and precursors to secondary particulate formation: sulfur dioxide (SO_2), oxides of nitrogen (NO_x), volatile organic compounds (VOC), and ammonia (NH_3). Emissions of SO_2 and NO_x, assisted by NH_3 that acts as a neutralizing agent, form secondary PM in the atmosphere. Also, certain VOC species, based on reactivity of the organic compound with atmospheric oxidants, form secondary organic aerosols (SOA). Thus, it was necessary to use an inventory of all primary PM and gaseous precursor emissions as the basis for ambient modeling.

For the purposes of this analysis, an adjustment was made to the primary $PM_{2.5}$ fugitive emissions component of the baseline emissions inventory to correct for fugitive dust overestimates uncovered in the inventory. Preliminary results from the air quality modeling for this analysis showed that these fugitive emissions contributed 30 to 46 percent in the East and 28 to 42 percent in the West to the model-predicted 2007 $PM_{2.5}$ nonattainment problem.[2] However, the available monitoring data as discussed in Chapter 1 and summarized in Figure 1.1 indicate that fugitives contribute substantially less to total $PM_{2.5}$ levels relative to other particle species. These data show that minerals comprise approximately 5 percent of $PM_{2.5}$ mass in the East and approximately 15 percent of $PM_{2.5}$ mass in the West.[3] This comparison between the minerals component of fine particle mass from monitoring studies to the estimates of fugitive emission contribution to the model-predicted $PM_{2.5}$ values may suggest a systematic overbias in the fugitive dust emission estimates. Subsequent PM emission inventory efforts have indicated that fugitive dust emissions were overestimated in the baseline emissions inventory.[4] Furthermore, this overestimate in the contribution of fugitive dust to modeled ambient fine particle concentrations relative to speciated monitoring data is likely to be compounded by uncertainties in the air quality modeling.[5]

To correct this problem, a 0.25 multiplicative factor was applied nationally to fugitive dust emissions as a reasonable first-order attempt to reconcile differences between modeled predictions of $PM_{2.5}$ and actual ambient data. This consistent adjustment factor still may lead to an overestimate of the fugitive emissions contribution to modeled $PM_{2.5}$ concentrations in some counties or an underestimate in other counties. On average, this adjustment results in a fugitive dust contribution to modeled ambient $PM_{2.5}$ concentrations of 10 to 25 percent.

TABLE 6-1

SUMMARY OF PRIMARY PM AND PM PRECURSOR EMISSION ESTIMATION APPROACHES BY MAJOR SOURCE TYPE

Major Source Type	Modeling Approach/Data Sources
Electric Utilities	DOE fuel use data.
	U.S. EPA AP-42 Emission factors.
Non-Utility Point Sources	1985 NAPAP and BEA Earnings Projections.
	PM10 and PM2.5 distribution of TSP completed using updated EPA AP-42 Emission Factors, and FIRE data base.
Fugitive Dust:	
Agricultural Tilling	PM10, PM2.5: U.S. Department of Agriculture (USDA) Data.
	NH_3: Commercial Fertilizers Data Base and emission factors from Netherlands study.
Construction	Census Bureau construction Expenditures, and PM10 Emission Factors for Selected Open Air Sources.
Wind Erosion	1985 NAPAP, National Climatological Data Center (NCDC) data, and USDA farming activity levels.
Unpaved and Paved Roads	EPA PART 5 model, NCDC data, Automobile and Truck Fleet data, Federal Highway Administration (FHA) travel data, and silt content data.
Livestock Operations	USDA farming activity levels, EPA PM emission factors, and NH_3 Emissions factors from Netherlands study.
Other Area Sources	NAPAP and appropriate growth factors.
Mobile Sources	FHA travel data, PM emission factors from PART 5, and NH_3 emission factors from Volkswagen study.
Nonroad Sources	Emission Estimates from Emission Inventory Branch (EIB).
Other Combustion:	
Agricultural/Structural Fires	NAPAP and BEA farm income growth factors.
Wildfires	NAPAP. (Grand Canyon Visibility Transport Commission (GCVTC) inventory for 11 western States.)
Prescribed Burning	USDA inventory. (GCVTC inventory for 11 western States.)
Biogenic Sources	1993 study containing emission estimates for 8 land cover types.
SOA	Fractional aerosol coefficients (FAC) from study that estimated potential for certain VOC-emitting source categories to form SOA.
Canadian Sources	NAPAP and Environment Canada growth factors.

TABLE 6-5 (CONT'D)

Mexican Sources	World Bank 1992 emission report and population growth factors. GCVTC inventory for specific point sources.

6.2.2 Inventory Results and Discussion

This section presents summary emissions for base year 1990. This summary includes the adjusted fugitive emissions. Table 6-2 provides 1990 emissions by major source type for each of the following pollutants: PM_{10} and PM_{10}, NH_3, SO_2, NO_x, and SOA. Secondary organic aerosol emissions are presented here rather than VOC emissions as SOA is the estimated particulate transformation product of VOC emissions. This table shows that fugitive dust from unpaved roads is the largest source of PM_{10} emissions on a national basis (30 percent), with fugitive dust emissions from construction sources comprising the second highest PM_{10} component at 19 percent of total PM_{10} emissions.

As with PM_{10}, fugitive emissions including fugitive emissions from agricultural tilling is the largest contributor to primary $PM_{2.5}$ emissions (40 percent). Within the fugitive dust category, unpaved road emissions are the largest source of $PM_{2.5}$ emissions.

Table 6-2 also shows total SO_2 emissions by major source category, as well as the relative contribution of sources composing the two largest (in terms of percent of total SO_2 emissions) source categories. This table shows that fuel combustion by electric utilities is the largest source of SO_2 emissions on a national basis (52 percent), followed by Mexican sources (11 percent), Canadian sources (11 percent), and fuel combustion by industrial sources (11 percent). Most of the utility and industrial fuel combustion emissions are due to coal combustion.

TABLE 6-2

1990 EMISSIONS BY POLLUTANT AND MAJOR SOURCE CATEGORY[a]

Major Source Category	1990 Emissions by Pollutant (thousand tons):					
	PM_{10}	$PM_{2.5}$	NH_3	SO_2	NO_x	SOA
Fuel Combustion Electric Utility - Coal	268.7	99.4	0.0	15,221.9	6,689.5	0.5
Fuel Combustion Electric Utility - Other	14.5	9.6	5.0	642.5	735.1	0.2
Fuel Combustion - Industrial	248.9	176.6	17.3	3,106.1	3,223.5	2.3
Fuel Combustion Other	51.3	28.7	8.0	586.7	669.5	0.5
Fuel Combustion - Residential Wood	459.9	459.9	0.0	6.1	44.3	27.4
Chemical and Allied Products	61.5	41.8	182.6	440.1	275.4	5.6
Metals Processing	138.1	96.4	5.9	909.9	81.8	0.2
Petroleum and Related Industries	29.5	21.0	42.8	439.2	121.8	1.7
Other Industrial Processes	410.0	251.2	37.6	394.8	304.5	6.9
Solvent Utilization	2.1	1.8	0.0	0.8	2.5	61.3
Storage & Transport	64.1	26.4	0.0	5.2	10.5	18.5
Waste Disposal & Recycling	226.1	197.3	81.8	35.7	80.7	1.3
Highway Vehicles - Gasoline	106.1	66.1	198.2	212.2	5,083.8	40.1
Off-Highway - Other	150.7	121.8	2.9	225.3	1,397.4	18.3
Highway Vehicles - Diesel	248.6	224.9	0.3	355.5	2,361.8	7.5
Off-Highway - Nonroad - Diesel	185.6	170.8	0.0	16.7	1,438.4	4.4
Fugitive Dust - Natural Sources	4,181.0	414.4	27.5	0.0	0.0	0.0
Fugitive Dust - Paved Roads	5,936.0	626.2	0.0	0.0	0.0	0.0
Fugitive Dust - Unpaved Roads	13,369.3	880.6	0.0	0.0	0.0	0.0
Fugitive Dust - Construction	8,489.0	43.2	0.0	0.0	0.0	0.0
Agricultural Production - Crops	6,965.4	837.7	419.7	0.2	10.4	0.1
Agricultural Production - Livestock	395.2	192.5	4,185.8	0.0	0.0	0.1
Miscellaneous	17.4	6.4	0.0	0.0	0.0	0.0
Other Combustion - Prescribed Burning	447.1	379.1	0.0	4.7	124.6	0.1
Other Combustion - Wild Fires	243.6	217.0	0.0	1.3	89.1	0.2

[a] "Direct" or "primary" PM_{10} or $PM_{2.5}$ are emitted as particles, whereas NH_3, SO_2, NO_x are precursors that transform in the atmosphere to form secondary PM. SOA is the particulate transformation product of reactive VOCs and atmospheric oxidants.

Mexico	179.4	104.9	0.0	3,302.6	
Canada	1,558.1	1,224.7	233.3	3,194.0	2
Total Emissions	**44,447.4**	**6,920.4**	**5,448.6**	**29,101.6**	**25**

The national NO_x emissions in Table 6-2 reflect that fuel combustion by electric utilities is the largest source of NO_x emissions on a national basis (26 percent), followed by highway vehicles (20 percent), and fuel combustion by industrial sources (13 percent). Most of the utility fuel and industrial fuel combustion NO_x emissions are due to coal combustion and natural gas combustion, respectively.

Table 6-2 also shows the national ammonia emissions results. Livestock feed lots are the largest source of anthropogenic ammonia emissions on a national basis (77 percent), followed by crop production (8 percent). Although only anthropogenic ammonia emissions are presented, it should be noted that biogenic emissions of ammonia, decomposition of plants and animals, forest fires and human breath and perspiration also contribute to ammonia emissions. Man-made sources such as fertilizer application, fossil-fuel combustion and other industrial processes emit relatively smaller quantities of ammonia.[6] As mentioned in Chapter 7, ammonia emissions are not considered for control in this analysis given that ammonia sources are not thoroughly inventoried and ammonia controls are not well developed.

The SOA emissions by major source category in Table 6-2 indicate that solvent utilization is the largest source of SOA emissions on a national basis (28 percent), followed by highway vehicles (18 percent), residential wood combustion (12 percent), and storage and transport, including bulk terminals and plants, petroleum storage, service stations, organic and inorganic chemical storage, and bulk materials storage (8 percent). The biogenic contribution to SOA generally was an order of magnitude greater than anthropogenic SOA.

6.3 EMISSION PROJECTIONS TO 2007

This section summarizes how the primary PM_{10}, primary $PM_{2.5}$, and secondary PM precursor emissions were projected to 2007. Generally, 1990 emissions were grown to 2007 based upon national estimates of growth in industry earnings and other category-specific growth factors. The types and sources for these growth factors are listed in Table 6-1. More detailed descriptions of the projection procedures are given in Appendix VI.2. While the primary interest in this study is in estimating the cost of potential additional controls beyond what the Clean Air Act (CAA) already requires, this section discusses both current (i.e., 1990) control and CAA cases. This may assist some readers in distinguishing how the control effects of the CAA were simulated. The cost analysis, as described in Chapter 7, uses the 2007 CAA case as a baseline from which to evaluate new measures.

6.3.1 Overview of Projection Methods

Emissions of primary PM and PM precursors were projected to 2007 to determine the effects of CAA controls on future year PM concentrations. Emissions were projected under two scenarios:

- *Current Control*——applies expected increases in activity levels with no additional controls implemented beyond those that were in place prior to passage of the 1990 CAA Amendments.

- *CAA Control*——applies expected increases in activity levels and incorporates the effects of controls mandated under the 1990 CAA Amendments. This scenario serves as the emissions baseline for this analysis.

The general procedure used to project emissions is as follows:

(1) Grow 1990 current control emissions or activity levels to 2007 based upon estimated national growth in industry earnings or other growth factors; and

(2) Apply CAA-mandated control efficiencies or emission factors to these projected emissions.

Under the current control scenario, the future year control efficiencies are equivalent to 1990 levels. Motor vehicle emission factors reflect controls that were promulgated prior to the CAA, namely, the Federal Motor Vehicle Control Program (FMVCP). Under the CAA control scenario, future year control efficiencies and motor vehicle emission factors reflect CAA requirements. Specific CAA mandatory measures include such controls as Title I PM RACM, Title III MACT, and Title IV SO_2 control. Table 6- 3 summarizes the CAA control measures modeled in the CAA control scenario. The source category-specific CAA control measures are discussed in more detail in Appendix VI.2.

The Emission Reduction and Cost Analysis Models (ERCAM) were used to perform the emission projections for VOC and NO_x emitters.[7,8] The procedures utilized in these ERCAMs were followed in developing projections for the remaining pollutants. The application of the general procedure described above differs slightly by major emitting sector - motor vehicle, utility, non-utility point, and area/non-road sources. Projection methods by sector are described in Appendix VI.2.

6.3.2 Emission Projection Results

National annual emission projections of PM_{10}, $PM_{2.5}$, SO_2, NO_x, ammonia, and SOA are shown in Tables 6-4 through 6-6. National PM_{10} emissions are shown (Table 6-4) to grow by nearly 13 percent by 2007 in the absence of CAA control initiatives. CAA controls decrease national PM_{10} emissions by 1 percent from the current control case. The small decrease in national emissions is due to the geographic specificity of PM_{10} controls. Currently, 84 counties out of a total of over 3,000 are nonattainment for PM_{10} and therefore subject to controls under existing PM_{10} NAAQS implementation policy. National $PM_{2.5}$ emissions are shown to increase by 12 percent by 2007 under the current control scenario. CAA controls decrease $PM_{2.5}$ emissions by 5 percent from the current control case. Coal-fired electric utilities, gasoline-fueled highway vehicles, and diesel-fueled highway vehicles are the only major source categories showing decreases in PM_{10} and $PM_{2.5}$ emissions in the CAA control case. The majority of the total decrease is attributed to diesel-powered highway vehicles.

TABLE 6-3

SUMMARY OF SELECT CAA MANDATORY MEASURES INCLUDED IN 2007 EMISSIONS CAA-CONTROL BASELINE SCENARIO

Pollutant	Select CAA Mandatory Control
PM_{10}	Title I - PM RACM
SO_2	Title II - Mobile Source Title IV - Acid Rain program - Utility boiler SO_2 cap
NO_x	Title I - Ozone Nonattainment - Stationary sources - NO_x RACT Title II - Mobile Source Title IV - Acid Rain program
SOA (secondary particle form of VOC)	Title I - Ozone Nonattainment - Stationary sources - VOC RACT - Mobile sources - I/M, reformulated gasoline where applicable. Title II - Mobile Source Title III - MACT control - New Source Performance Standards

TABLE 6-4
PM_{10} AND $PM_{2.5}$ EMISSIONS BY MAJOR SOURCE CATEGORY
1990 AND 2007

	PM_{10} Emissions (thousand tons)			$PM_{2.5}$ Emissions (thousand tons)		
Major Source Category	1990	2007 Current*	2007 CAA	1990	2007 Current*	2007 CAA
Fuel Combustion Electric Utility - Coal	268.7	313.3	291.8	99.4	120.5	111.8
Fuel Combustion Electric Utility - Other	14.5	26.6	26.6	9.6	19.0	19.0
Fuel Combustion - Industrial	248.9	291.5	291.5	176.6	205.5	205.5
Fuel Combustion Other	51.3	64.6	64.6	28.7	35.7	35.7
Fuel Combustion - Residential Wood	459.9	507.4	507.4	459.9	507.4	507.4
Chemical and Allied Products	61.5	76.0	76.0	41.8	51.0	51.0
Metals Processing	138.1	148.7	148.7	96.4	103.4	103.4
Petroleum and Related Industries	29.5	31.3	31.3	21.0	22.2	22.2
Other Industrial Processes	410.0	493.5	493.5	251.2	303.3	303.3
Solvent Utilization	2.1	2.6	2.6	1.8	2.2	2.2
Storage & Transport	64.1	72.2	72.2	26.4	29.5	29.5
Waste Disposal & Recycling	226.1	250.9	250.9	197.3	218.4	218.4
Highway Vehicles - Gasoline	106.1	156.8	110.1	66.1	98.1	63.2
Off-Highway - Other	150.7	156.5	156.5	121.8	125.0	125.0
Highway Vehicles - Diesel	248.6	468.7	77.5	224.9	424.5	64.5
Off-Highway - Nonroad - Diesel	185.6	230.9	230.9	170.8	212.5	212.5
Fugitive Dust - Natural Sources	4,181.0	4,181.0	4,181.0	414.4	414.4	414.4
Fugitive Dust - Paved Roads	5,936.0	7,797.4	7,797.4	626.2	822.0	822.0
Fugitive Dust - Unpaved Roads	13,369.3	13,369.2	13,369.3	880.6	880.6	880.6
Fugitive Dust - Construction	8,489.0	10,657.9	10,657.9	43.2	54.2	54.2
Agricultural Production - Crops	6,965.4	8,016.7	8,016.7	837.7	963.1	963.1
Agricultural Production - Livestock	395.2	423.0	423.0	192.5	205.7	205.7
Miscellaneous	17.4	23.2	23.2	6.4	8.6	8.6
Other Combustion - Prescribed Burning	447.1	447.1	447.1	379.1	379.1	379.1
Other Combustion - Wild Fires	243.6	243.6	243.6	217.0	217.0	217.0
Mexico	179.4	179.4	179.4	104.9	104.9	104.9

Canada	1,558.1	1,558.1	1,558.1	1,224.7	1,224.7	1,224.7
Total Emissions	**44,447.4**	**50,188.5**	**49,728.9**	**6920.4**	**7752.5**	**7348.9**

NOTE: *Emission projections in this case are based on the level of controls that existed in 1990.

TABLE 6-5
SO_2 AND NO_X EMISSIONS BY MAJOR SOURCE CATEGORY

Major Source Category	SO_2 Emissions (thousand tons)			NO_x Emissions (thousand tons)		
	1990	2007 Current*	2007 CAA	1990	2007 Current*	2007 CAA
Fuel Combustion Electric Utility - Coal	15,221.9	17,341.3	9,243.1	6,689.5	7,662.3	4,773.2
Fuel Combustion Electric Utility - Other	642.5	841.7	841.5	735.1	1,247.4	1,020.3
Fuel Combustion - Industrial	3,106.1	3,683.2	3,683.2	3,223.5	3,864.5	3,453.5
Fuel Combustion Other	586.7	747.2	747.2	669.5	814.7	784.1
Fuel Combustion - Residential Wood	6.1	6.7	6.7	44.3	49.1	49.1
Chemical and Allied Products	440.1	516.8	516.8	275.4	347.2	338.0
Metals Processing	909.9	1,022.9	1,022.9	81.8	89.9	88.4
Petroleum and Related Industries	439.2	457.6	457.6	121.8	128.0	126.5
Other Industrial Processes	394.8	467.8	467.8	304.5	355.5	346.8
Solvent Utilization	0.8	0.9	0.9	2.5	3.0	2.6
Storage & Transport	5.2	6.3	6.3	10.5	11.0	10.9
Waste Disposal & Recycling	35.7	43.8	43.8	80.7	94.3	91.0
Highway Vehicles - Gasoline	212.2	211.8	211.8	5,083.8	6,322.3	4,683.2
Off-Highway - Other	225.3	224.3	224.3	1,397.4	1,338.8	1,361.8
Highway Vehicles - Diesel	355.5	555.3	111.1	2,361.8	1,965.4	1,696.4
Off-Highway - Nonroad - Diesel	16.7	19.9	19.9	1,438.4	1,799.4	1,313.1
Fugitive Dust - Natural Sources	0.0	0.0	0.0	0.0	0.0	0.0
Fugitive Dust - Paved Roads	0.0	0.0	0.0	0.0	0.0	0.0

Fugitive Dust - Unpaved Roads	0.0	0.0	0.0	0.0	0.0	0.0
Fugitive Dust - Construction	0.0	0.0	0.0	0.0	0.0	0.0
Agricultural Production - Crops	0.2	0.3	0.3	10.4	10.7	10.7
Agricultural Production - Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0
Other Combustion - Prescribed Burning	4.7	4.7	4.7	124.6	124.6	124.6
Other Combustion - Wild Fires	1.3	1.3	1.3	89.1	89.1	89.1
Mexico	3,302.6	3,302.6	3,302.6	709.8	709.8	709.8
Canada	3,194.0	3,194.0	3,194.0	2,127.0	2,127.0	2,127.0
Total Emissions	**29,101.6**	**32,650.3**	**24,107.6**	**25,581.3**	**29,153.8**	**23,200.3**

NOTE: *Emission projections in this case are based on the level of controls that existed in 1990.

TABLE 6-6
AMMONIA AND SOA EMISSIONS BY MAJOR SOURCE CATEGORY

	Ammonia Emissions (thousand tons)			SOA Emissions (thousand tons)		
Major Source Category	1990	2007 Current*	2007 CAA	1990	2007 Current*	2007 CAA
Fuel Combustion Electric Utility - Coal	0.0	0.0	10.4	0.5	0.6	0.6
Fuel Combustion Electric Utility - Other	5.0	7.4	8.1	0.2	0.3	0.3
Fuel Combustion - Industrial	17.3	20.5	20.5	2.3	2.8	2.8
Fuel Combustion Other	8.0	9.7	9.7	0.5	0.6	0.6
Fuel Combustion - Residential Wood	0.0	0.0	0.0	27.4	30.7	30.7
Chemical and Allied Products	182.6	231.7	231.7	5.6	6.5	3.6
Metals Processing	5.9	6.2	6.2	0.2	0.3	0.2
Petroleum and Related Industries	42.8	46.5	46.5	1.7	1.9	1.5
Other Industrial Processes	37.6	44.9	44.9	6.9	8.2	5.6
Solvent Utilization	0.0	0.0	0.0	61.3	74.1	50.9

Storage & Transport	0.0	0.0	0.0	18.5	
Waste Disposal & Recycling	81.8	108.4	108.4	1.3	
Highway Vehicles - Gasoline	198.2	410.4	410.4	40.1	
Off-Highway - Other	2.9	2.7	2.7	18.3	
Highway Vehicles - Diesel	0.3	0.5	0.5	7.5	
Off-Highway - Nonroad - Diesel	0.0	0.0	0.0	4.4	
Fugitive Dust - Natural Sources	27.5	27.5	27.5	0.0	
Fugitive Dust - Paved Roads	0.0	0.0	0.0	0.0	
Fugitive Dust - Unpaved Roads	0.0	0.0	0.0	0.0	
Fugitive Dust - Construction	0.0	0.0	0.0	0.0	
Agricultural Production - Crops	419.7	473.0	473.0	0.1	
Agricultural Production - Livestock	4,185.8	4,664.5	4,664.5	0.1	
Miscellaneous	0.0	0.0	0.0	0.0	
Other Combustion - Prescribed Burning	0.0	0.0	0.0	0.1	
Other Combustion - Wild Fires	0.0	0.0	0.0	0.2	
Mexico	0.0	0.0	0.0	6.6	
Canada	233.3	233.3	233.3	17.0	
Total Emissions	**5,448.6**	**6,287.0**	**6,298.1**	**220.7**	**250**

NOTE: *Emission projections in this case are based on the level of controls that existed in 1990

The SO_2 emissions are shown in Table 6-5 to increase by 12 percent without CAA control initiatives. CAA controls result in a decrease of 26 percent from 2007 current control emissions——a 17 percent decrease from 1990 levels. Coal-fired electric utilities and diesel-fueled highway vehicles are the only categories showing decreases, with electric utilities contributing almost the entire decrease. Coal-fired electric utilities are affected by the Title IV Acid Rain provisions. Diesel fuel sulfur limits produce the highway vehicle emissions decline.

In the absence of additional controls, NO_x emissions are shown to increase by 14 percent in 2007. The CAA controls reduce national emissions to levels below 1990 emissions. This represents a 20 percent reduction from current control emissions. Source categories where emission reductions are expected include fuel combustion, highway vehicles, and nonroad/diesel vehicles. NO_x emission reductions result from Title IV Acid Rain provisions, Title I Ozone Nonattainment provisions, and Title II Mobile Source provisions. Control requirements that may result in further NO_x emission decreases include rate-of-progress requirements and attainment demonstrations. The degree to which these further NO_x reductions will occur is unknown at this time.

Anthropogenic ammonia emissions are shown in Table 6-6 to increase 15 percent in 2007, absent CAA controls. The implementation of CAA controls is expected to increase ammonia emissions by 0.2 percent in 2007. This slight increase is attributable to selective catalytic reduction (SCR) controls on utility boilers implemented under CAA New Source Review requirements. National emissions of SOA are shown to increase by 13 percent in 2007 based on 1990 control levels. CAA controls reduce SOA emissions by 23 percent from 2007 current control emissions——a 13 percent decrease from 1990 levels. This decrease is due to point source controls on chemical producers, metals processors, petroleum refineries, and gasoline- and diesel-fueled highway vehicles.

6.3.3 Uncertainties in Emissions Projections

The projections described in this report must be qualified for the following reasons:

1) Point and area source growth is based on 1990 Bureau of Economic Analysis (BEA) national estimates of industry earnings and population projections.[9] Other alternative growth estimates are available and would produce different results. Updated BEA projections were released in July 1995. The BEA now projects Gross State Product (GSP), rather than earnings, on a specific industry level. To determine the effect of BEA's recent projections on emissions, a comparison of BEA's previous projections relative to the recently released GSP projections was made on a regional basis from 1990 to 2007. The differences between GSP growth rates and earnings growth rates indicate that emissions would not likely be significantly affected if BEA's 1995 GSP projections were used. On a national level, the average annual growth rate from a 1988 base year to 2007 is 2.1 percent based on earnings projections, and 2.2 percent based on GSP and a 1992 base year.

2) Many nonattainment controls applied in baseyear PM_{10} nonattainment areas (i.e., PM RACM) are based on generic assumptions on the types of sources to be controlled and the level of associated emission reduction. In many cases, States have flexibility in determining which sources to control and the extent to which each source will be controlled. These State-specific projections would, therefore, provide a better indication of how overall levels might vary than would generic control assumptions.

3) Since these projections were completed, there have been some State-level changes in the implementation of some CAA mandatory measures. For instance, some ozone nonattainment areas that had chosen to require reformulated gasoline for VOC and NO_x control have now withdrawn from the program. No adjustment was made here to account for this change.

4) These projections were made only for source categories situated in the contiguous 48 States. No projections were made for Alaska and Hawaii.

6.4 AMBIENT AIR QUALITY MODELING

This section summarizes the approach that was used in this study to relate emission levels to ambient air quality concentrations. Figure 6-1 presents the steps followed to develop predictions of PM air quality in 2007. The Climatological Regional Dispersion Model (CRDM) was the air quality model selected to estimate ambient PM concentrations. The 1990 baseline emissions inventory and 1990 meteorological data were input to the CRDM to produce a source-receptor (S-R) matrix that relates emissions of primary PM and PM precursors to annual concentrations of PM_{10} and $PM_{2.5}$. This

S-R matrix was applied to the revised 1990 PM emissions inventory that includes the fugitive dust emissions adjustment discussed in section 6.2 to generate 1990 modeled PM concentration estimates.

The 1990 modeled annual PM_{10} concentrations were calibrated using 1991 - 1993 Aerometric Information Retrieval System (AIRS) annual PM_{10} data. Because there is scant $PM_{2.5}$ monitoring data available, a general linear model procedure was used to develop a set of average $PM_{2.5}$ concentration values representative of the 1991 - 1993 period.[a] This derived data was used to calibrate the model-predicted annual $PM_{2.5}$ concentrations. The result of this calibration step is a calibrated source-receptor matrix.

The 2007 CAA baseline air quality was developed by applying the calibrated S-R matrix to the 2007 CAA emissions. For the Eastern U.S., sulfate concentrations were adjusted to account for full implementation of the Title IV Acid Rain Program based on results from the Regional Acid Deposition Model (RADM).[10] County average percentage reductions between RADM 2010 No Control and Title IV scenarios were applied to the 2007 No Control sulfate concentrations to reflect full Title IV implementation. Finally, PM_{10} and $PM_{2.5}$ peak-to-mean ratios were applied to the 2007 CAA baseline PM_{10} and $PM_{2.5}$ annual air quality values to generate daily concentration estimates of PM_{10} and $PM_{2.5}$.

This model-predicted 2007 baseline annual and daily PM_{10} and $PM_{2.5}$ data was used to identify counties that would have PM levels greater than PM standard levels being examined. The alternatives examined are the following:

<u>PM_{10} Alternatives</u>

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[a]Because the forms of the PM standard alternatives allow for averaging over a three year period, this derived $PM_{2.5}$ data reflects three-year average $PM_{2.5}$ concentration values.

- PM_{10} 50 μg/m^3 annual arithmetic mean and 150 μg/m^3 24-hr, 1 expected exceedance permitted per year.
- PM_{10} 50 μg/m^3 annual arithmetic mean and 150 μg/m^3 24-hr, 98th percentile form.
- PM_{10} 50 μg/m^3 annual arithmetic mean and revocation of 24-hr PM_{10} standard.

<u>$PM_{2.5}$ Alternatives</u> - analyzed incremental to current PM_{10} NAAQS

- $PM_{2.5}$ 15 μg/m^3 spatially averaged annual arithmetic mean and 50 μg/m^3 24-hr, 98th percentile form.
- $PM_{2.5}$ 20 μg/m^{3}spatially averaged annual arithmetic mean and 65 μg/m^3 24-hr, 98th percentile form.
- $PM_{2.5}$ 12.5 μg/m^3 spatially averaged annual arithmetic mean and 50 μg/m^3 24-hr, 98th percentile form.

The following section describes in more detail the steps followed in developing 2007 baseline air quality.

6.4.1 Modeling Steps

1) Generate source-receptor matrix using the CRDM

The CRDM, based on a Lagrangian modeling approach, was used to generate a matrix of source-receptor (S-R) relationships that relate emissions of direct PM_{10} and $PM_{2.5}$ and PM precursors to annual average PM_{10} and $PM_{2.5}$ concentrations. The S-R matrix reflects the relationship between PM concentration values at a single receptor in each county (a hypothetical design value monitor sited at the county population centroid) and the contribution by PM species to this concentration from each emission source. The CRDM uses assumptions similar to the Industrial Source Complex Short Term (ISCST2), an EPA-recommended short range Gaussian dispersion model. CRDM incorporates terms for wet and dry deposition of gases and chemical conversion of SO_2 and NO_x, and uses climatological summaries (annual average mixing heights and joint frequency distributions of wind speed and direction) from 100 upper air meteorological sites throughout North America to calculate annual average PM_{10} and $PM_{2.5}$ concentrations. For this analysis, meteorological data for 1990 was used.

The CRDM uses Turner's sector-average approach, which is recommended for long-term average concentrations. This method uses a probabilistic approach in which the frequencies of occurrence of various wind and stability conditions are used to calculate the frequencies of transport in various sectors. Winds are divided into 16 cardinal wind directions.

The high number of point sources in the inventory made it infeasible to model each point source individually. As a result, elevated point source emissions were aggregated at the county level by plume height. In each county, two aggregated categories of elevated point sources were created (and modeled as emitted at the county centroid). In addition to point sources, the modeled emission sources also included total area/mobile sources for each county and emissions for 10 Canadian provinces and 29 Mexican cities/states. Receptors modeled included all county centroids plus receptors in Canada and Mexico.

As mentioned previously, the 1990 emission inventory was input to the CRDM. Stationary and mobile source emissions, as well as ground-level area source emissions for 3,081 counties in the contiguous United States, are contained in the 1990 National Particulates Inventory. Due to the fact that the inventory includes a total of 61,619 point sources – far too many sources to be modeled individually – a scheme was used to aggregate elevated point source emissions to the county level. The effective stack height of each of these sources was calculated for an average wind speed (5 meters/second) using the plume rise algorithm for ISCST2. Two aggregated elevated point source groupings were made: one for sources with effective stack heights less than 250 m, and one for sources with effective stack heights between 250 and 500 m. There were 1,867 counties with aggregated point source emissions in the first category, and 573 counties in the second category. Sources with effective stack heights greater than 500 meters were modeled as separate sources. There were 573 such sources.

In addition to the U.S. emissions, Canadian and Mexican emissions were modeled. Canadian emissions were specified on a province level. It was assumed that the emissions for a given province were released from an area around the largest urban area (e.g., Montreal, Quebec, and Toronto, Ontario). There were 10 Canadian provinces included in the base year inventory; there were 29 Mexican sources, including specific cities and states in northern Mexico.

A total of 5,931 sources of primary $PM_{2.5}$ and PM_{10} emissions were modeled. In addition, secondary organic aerosols formed from anthropogenic and biogenic VOC emissions were modeled. Emissions of SO_2, NO_x, and NH_3 were modeled in order to calculate ammonium sulfate and ammonium nitrate concentrations, the primary particulate forms of sulfate and nitrate.

The S-R matrix of transfer coefficients was developed for each pollutant using CRDM. The resultant S-R matrix consists of coefficients that were calculated separately for direct PM_{10} and $PM_{2.5}$ emissions, as well as SOA, sulfate, nitrate, and NH_3. The matrix of S-R relationships provides a coefficient that can be applied to the emissions of any unit (area source or individual point source) in order to calculate a particular source's contribution to a county receptor's total PM_{10} or $PM_{2.5}$ concentration. Each individual unit in the inventory is associated with one of the source types (area, point 0 to 250, point 250 to 500, and individual points above 500 feet) for each county.

The impact of emissions from a given county decreases rapidly with downwind distance. The relationship depends on whether the emission is a particle or a gaseous precursor and on the precipitation in the area; however, the relationship appears to be inversely related to distance, d.

2) Apply S-R matrix to revised 1990 baseline PM emissions inventory to produce 1990 modeled PM_{10} and $PM_{2.5}$ annual average concentrations

As mentioned in section 6.2, an adjustment was made to the fugitive emission component of the baseline emissions inventory to correct for fugitive dust overestimates uncovered in the inventory. Therefore, the S-R matrix was applied to the revised baseline emissions inventory to predict 1990 annual average concentrations of PM_{10} and $PM_{2.5}$.

3) Calibration of S-R Matrix

The resulting modeled annual PM_{10} and $PM_{2.5}$ values were compared and calibrated to monitored annual PM_{10} concentrations and derived annual $PM_{2.5}$ estimates. This was done by application of a normalization factor, calculated as the monitored value divided by the modeled value. This factor was applied consistently across particle species contributing to the air quality value at a county-level receptor.

This calibration procedure was conducted for 470 counties with PM_{10} monitors and for which monitoring data meeting completeness criteria exist. Given the uncertainties inherent in the CRDM and that sufficient air quality data exists only for these monitored counties, this analysis has been limited to monitored counties. These monitors, however, tend to be sited in high population areas and thus these county-level monitors cover approximately 145 million people (1990 population) or 60 percent of the

U.S. population. These analyses assume that this set of counties will be the basis for which future PM control strategies may be designed.

As mentioned above, 1991 - 1993 annual average PM_{10} data from AIRS that also met data completeness criteria were used in the calibration of modeled annual PM_{10} values. The PM_{10} data represents the annual average of the design value monitors averaged over three years. However, because there is little $PM_{2.5}$ monitoring data available, a general linear model was developed in order to predict $PM_{2.5}$ concentrations from the 1991 - 1993 PM_{10} values.[11] This derived $PM_{2.5}$ data was used to calibrate the model predictions of annual average $PM_{2.5}$. Because the $PM_{2.5}$ annual standard alternatives allow for spatial averaging, model-predicted annual average $PM_{2.5}$ air quality data were calibrated to the spatially-averaged annual $PM_{2.5}$ value from the derived $PM_{2.5}$ dataset. Additionally, the proposed form of the standard allows for averaging over three years of air quality data. This derived, annual $PM_{2.5}$ data represents the annual average value over a three-year period.

4) Apply calibrated S-R matrix to 2007 CAA emissions to estimate 2007 annual average concentrations of PM_{10} and $PM_{2.5}$.

In order to predict what PM air quality might be in 2007, the calibrated S-R matrix is applied to the 2007 CAA control emissions. This is done for emissions of primary PM_{10} and $PM_{2.5}$ and PM precursors except for sulfate in the eastern U.S. As mentioned previously, Eastern sulfate is treated differently in this step. Preliminary air quality modeling results for the 2007 CAA control air quality baseline indicated that contribution of secondary particles, primarily sulfate, to fine particle mass in the East were underestimated relative to speciated monitoring data. The Title IV Acid Rain Program is largely responsible for the sulfate reductions estimated to occur due to CAA-mandated controls in 2007. Therefore, 2010 county-level percentage changes in ambient sulfate concentrations due to the Acid Rain Program as predicted from RADM were applied to the 2007 current control sulfate scenario for the East.[a] This produced 2007 CAA control sulfate concentrations for the East that then were input to the calibrated S-R matrix to generate Eastern sulfate contribution to annual PM concentration estimates.

5) Apply PM_{10} and $PM_{2.5}$ peak-to-mean ratios to estimate daily concentrations of PM_{10} and $PM_{2.5}$.

Because the CRDM predicts only annual average PM_{10} and $PM_{2.5}$ concentrations, peak-to-mean (P/M) ratios were employed to derive these values. Two sets of P/M ratios were used to predict 24-hour peak PM_{10} and $PM_{2.5}$ concentrations reflective of the forms of the alternatives being analyzed.[b] The first P/M ratio is the three-year average 99th percentile 24-hour peak PM_{10} value to the annual arithmetic mean PM_{10} value. This ratio was applied to the modeled annual average PM_{10} value to predict the 99th percentile PM_{10} value. This is roughly equivalent to the current one expected exceedance form (1 expected exceedance per year averaged over three years) of the current PM_{10} NAAQS. The $PM_{2.5}$ P/M ratio was calculated as the three-year average 98th percentile 24-hour peak $PM_{2.5}$ value to the spatially averaged annual arithmetic mean $PM_{2.5}$ value. This P/M ratio was applied to predict the three-year average 98th percentile 24-hour peak $PM_{2.5}$ value (reflective of the proposed form of the $PM_{2.5}$ standard).

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[a] RADM results for 2010 were used as these were readily available at the time of this analysis. It should be noted that the change from the original 2007 CAA baseline sulfate concentration relative to the RADM-based predictions is small.

[b] These peak-to-mean ratios were for the 470 monitored counties with complete monitoring data for the 1991 - 1993 period. $PM_{2.5}$ P/M ratios were calculated based on the derived $PM_{2.5}$ data discussed above. See Fitz-Simons *et al.*, 1996.

6) Identification of counties predicted to have PM levels greater than alternatives.

This complete set of PM_{10} and $PM_{2.5}$ air quality data reflective of the 2007 CAA-control baseline was used to determine model-predicted county air quality status for input into the cost optimization model described in Chapter 7. The rounding convention as is being proposed for the PM NAAQS was used to identify counties predicted in this analysis to have PM levels in 2007 greater than the alternatives examined.[a] Table 6-10 presents tallies of these violating counties.

7) Counties with elevated PM levels are input to cost, economic impact and benefit analyses.

The model-predicted counties with air quality levels greater than the alternatives examined are input to the cost analysis as described in Chapter 7 and the economic impact analysis as discussed in Chapter 8. The analysis has been configured in such a way that control costs and economic impacts are estimated for attainment of alternative levels in monitored counties. However, given that $PM_{2.5}$ transports regionally, control costs and economic impacts may be realized in counties without monitors. Also given that the air quality impacts of attaining the PM alternatives in monitored counties may spill over into nonmonitored counties, the benefit analysis captures benefits of air quality improvements in nonmonitored counties. This is described in futher detail in Chapter 9.

TABLE 6-7

MODEL-PREDICTED COUNTIES WITH PM LEVELS GREATER THAN ALTERNATIVES EXAMINED IN 2007

[a] Rounding convention: $PM_{2.5}$ annual standard - rounded to the nearest 0.1; $PM_{2.5}$ daily standard - rounded to the nearest 1; PM_{10} annual - rounded to the nearest 1; PM_{10} daily - rounded to the nearest 10.

Region[b]	Total Counties in Region[b]	Number of Counties Violating PM Alternative			
		PM_{10} (50/150) current	$PM_{2.5}$[c] (20/65)	$PM_{2.5}$[c] (15/50) proposal	$PM_{2.5}$[c] (12.5/50)
MW/NE	210	7	5	48	120
SE	62	0	0	17	37
RM	68	10	5	23	33
SC	59	0	0	5	18
W	31	18	10	17	20
NW	23	12	4	14	15
CA/C	17	3	0	2	4
Total Counties in Violation		50	24	126	247

6.5 UNCERTAINTY ISSUES

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[a] The regional boundaries are delineated in Chapter 7.

Legend:
MW/NE = Midwest/Northeast
SE = Southeast
RM = Rocky Mountain
SC = South Central
W = West
NW = Northwest
CA/C = California Coastal

[b] Total number of counties modeled in analysis = 470

[c] These alternatives are analyzed incremental to the current PM_{10} alternative.

The methodology used to project PM concentrations in 2007 from 1990 emissions and concentration data introduces several sources of uncertainty to the benefits analysis, control strategy-cost analysis, and, indeed, to any analyses for which the air quality projections are inputs. In this section, the level of uncertainty associated with a particular input variable to the air quality projection procedure has been quantified to the extent possible based on information from published literature or internal EPA studies.

6.5.1 1990 Emissions Inventory

A variety of modeling approaches and data sources were used to develop the 1990 emissions inventory. Emissions from many sources were computed from emission factors in EPA's *Compilation of Air Pollutant Emission Factors* (AP-42). In a study for the Grand Canyon Visibility Transport Commission, Balentine and Dickson used an error propagation technique to estimate the uncertainty of SO_2, VOC, and $PM_{2.5}$ emissions from five source sectors, including combustion, metal smelting, residential wood combustion, motor vehicles, and fugitive dust.[12]

Balentine and Dickson estimated the uncertainty of each of the input values in the AP-42 emission formulas for these sectors from information in the literature or quantitative estimates based on their experience with emissions data. They expressed their results as percentages which represent 90 percent confidence limits. For instance, the 90 percent confidence limit for $PM_{2.5}$ emissions from paved roads is 180 percent. This indicates that 90 percent of the time, the true level of paved road $PM_{2.5}$ emissions falls between *plus* and *minus* 1.8 times the AP-42 formula value.

The uncertainties in fugitive dust estimates were generally the highest (180 percent and 400 percent for paved and unpaved roads, respectively). By contrast, combustion source SO_2 uncertainties ranged from 20 percent to 50 percent, while vehicle $PM_{2.5}$ emission uncertainties were 70 percent.

Along with the other results from the study, these were converted to *coefficent of variation* percentages by dividing the 90 percent confidence limit percentages by 1.65.[a]

6.5.2 Projected 2007 Emissions Inventory

Growth factors based on national estimates of projected industry earnings from sources such as the Bureau of Economic Analysis (BEA) and the Department of Energy (DOE) were used to adjust values in the AP-42 formulas to reflect emission source activity and control levels in the year 2007. However, no source for estimating the uncertainty associated with these factors could be obtained for this study.

6.5.3 Monitored PM_{10} Concentration

There is also uncertainty associated with the monitored annual average PM_{10} concentration values that were used to calibrate the ambient concentrations generated by the CRDM at the county-level receptors. These monitoring values were taken from the AIRS data base, which EPA notes has a performance requirement of 5 $\mu g/m^3$ for concentrations less than 80 $\mu g/m^3$ and $\pm$ 7 percent for concentrations greater than 80 $\mu g/m^3$. However, a comparison of AIRS data obtained from side-by-side samplers of the same and different types indicated measurement differences ranging from 10 to 14 percent for like samplers to 16 to 26 percent for dissimilar samplers.[13]

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[a] The coefficient of variation of a variable equals its standard deviation divided by its mean value. Dividing the 90 percent confidence limits by 1.65 converts them to "68 percent confidence limits"——i.e., the reader may be 68 percent confident that the emission estimate lies within this new range. This range represents plus or minus one standard deviation ("one sigma") of the mean value.

6.5.4 Derived $PM_{2.5}$ Ambient Air Quality Data

Since the PM2.5 data are derived from monitored PM10 concentrations, they too have a small degree of uncertainty due to instrument measurement error, as described in section 6.6.3. Additionally, and more importantly, the PM2.5 values are predicted from a regression model (Fitz-Simons et al.), and therefore are subject to the uncertainty associated with the model. The model yields an R-square of .81. The R-square tells what proportion of the data is "explained" by the model.

6.5.5 PM_{10} and $PM_{2.5}$ Peak-to-mean Ratios

The uncertainty associated with the PM10 peak-to-mean ratios is as stated previously in section 6.6.3. Likewise, the uncertainty associated with the PM2.5 peak-to-mean ratios is as stated previously in section 6.6.4.

6.5.6 Source-Receptor Transfer Coefficients

The CRDM used to generate a matrix of source-receptor transfer coefficients employs a large number of input variables in its calculations, including meteorological data (i.e., wind speed, wind velocity, and stability conditions). While there have been no explicit studies of uncertainty associated with CRDM output, Freeman *et al.* used error propagation and Monte Carlo simulation to study the uncertainty of short range concentration estimates calculated by a similar model, the EPA Industrial Source Complex Short Term (ISCST) Gaussian dispersion model for a single point source. Freeman *et al.* found that for relatively low values of uncertainty assigned to input values (1 to 10 percent), the uncertainty of the concentration at distances from 3 to 15 kilometers downwind of a source averaged 16 percent. When input data uncertainties were increased by a factor of 4, however, the output uncertainty ranged from about 75 percent for stability classes A and B to 100 percent and 160 percent for stability classes C and D, respectively.[a]

The CRDM modeling does not reflect application of state-of-the-art techniques, and serves as a placeholder until more advanced modeling is available. Many of the physical and chemical formulations in the CRDM are crude representations of actual mixing and reaction phenomena required to address aerosol formation, transport and removal phenomena. Where available, more scientifically credible Regional Acid Deposition Model (RADM) results were used to complement the CRDM results. However, even with the anticipated delivery of more comprehensive modeling techniques, the scarcity of speciated ambient data in both urban and rural environments to evaluate model behavior will continue to compromise the certainty of model-derived conclusions.

[a] Each percentage, which is the coefficient of variation of the output concentration, represents the 68 percent confidence interval of the concentration.

6.6 REFERENCES

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APPENDIX VI.1

NATIONAL PARTICULATES INVENTORY ESTIMATION METHODS

This appendix describes the methods used to develop the National Particulates Inventory (NPI). These methods are presented, in turn, for point sources, fugitive dust sources, and other emission sources (miscellaneous area, mobile, other combustion, and biogenic). Other emissions estimation-related topics are included, such as: methods for assessing secondary organic aerosol formation, modifications to regional point and area emission estimates, and the Canadian and Mexican emissions estimated for this analysis.

VI.1.1 Point Source Emissions

Emissions of PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and secondary organic aerosol (SOA) from *electric utilities* are based on data from the Department of Energy (DOE), Energy Information Administration (EIA). The DOE collects monthly boiler-level data on a yearly basis using Form EIA-767 (*Steam-Electric Plant Operation and Design Report*). The steam emission inventory data for 1990 are based on the aggregated monthly electric utility steam boiler-level data from Form EIA-767. All plants with a nameplate rating of at least 10 megawatts (MW) that have at least one operating boiler are required to provide this information to EIA. Emission factors are based on EPA's *Compilation of Air Pollutant Emission Factors* (AP-42).[1]

Emissions of PM_{10}, $PM_{2.5}$, and ammonia (NH_3) from *non-utility point sources* are based on emission estimates from the 1985 National Acid Precipitation Assessment Program (NAPAP) Inventory projected to 1990 using Bureau of Economic Analysis (BEA) industrial earnings data. Because annual PM_{10} and $PM_{2.5}$ emission estimates are not available from the NAPAP files, annual total suspended particulate (TSP) emissions were used as the starting point for estimating PM_{10} and $PM_{2.5}$ emissions. Controlled TSP emissions were projected to 1990 using BEA data and emission estimates from each point source in the 1985 NAPAP Inventory (excluding steam electric utilities).

Each record in the point source inventory was matched to the BEA earnings data based on the State and the 2-digit standard indusrial code (SIC). Zero growth in emissions was assumed for all point sources for which the matching BEA earnings data were not complete. Uncontrolled 1990 PM_{10} emissions were calculated by applying an Source Classification Code (SCC)-specific (uncontrolled) particle size distribution factor to the uncontrolled TSP emissions. The SCC-specific uncontrolled particle size distribution factors were developed based on data in AP-42 and other sources, and on engineering judgment.

Uncontrolled $PM_{2.5}$ emissions from *non-utility point sources* were calculated by applying an SCC-specific particle size distribution factor to the "final" uncontrolled PM_{10} emissions (i.e., after any replacements with TSP). Finally, NH_3 emissions were calculated by growing the 1985 NAPAP NH_3 emissions using the BEA growth factors.[2]

VI.1.2 Fugitive Dust Sources

Fugitive dust emissions occur primarily from the following sources: agricultural tilling, construction, wind erosion, unpaved roads, paved roads, and livestock operations. The methods used to develop emission estimates for these source types in the creation of the NPI are described briefly in the following subsections. After the inventory was created, however, the $PM_{2.5}$ fugitive emission estimates were adjusted downward to bring them in line with PM monitoring data. In this adjustment, $PM_{2.5}$ emissions from *all* fugitive sources (except livestock operations) were multiplied by 0.25.

VI.1.3 Agricultural Tilling

The following AP-42 particulate emission factor equation was used to determine regional PM_{10} emissions from *agricultural tilling* from 1985 to 1990:

where:

$$E = c \cdot k \cdot s^{0.6} \cdot p \cdot a$$

E = PM_{10} emissions (lbs/yr)

c = constant = 4.8 lbs/acre-pass

k = dimensionless particle size multiplier (PM_{10} = 0.21)

s = silt content of surface soil, defined as the mass fraction of particles smaller than 75 μm diameter found in soil to a depth of 10 cm (%)

p = number of passes or tillings in a year (3)

a = acres of land planted

By comparing the U.S. Department of Agriculture (USDA) surface soil map with the USDA county map, soil types were assigned to all counties of the continental United States. Weighted mean State silt values were determined using the number of hectares and silt percentages for each county as the weighting criteria. These silt values were assumed to be constant for the 6-year period examined. It was assumed that crops are tilled three times each year, on average, and this value was used for p. The acres of crops planted in each State were obtained for 1990 from the USDA. $PM_{2.5}$ emissions were calculated from the county-level PM_{10} emissions by applying the AP-42 particle size multiplier of 0.10 (or 0.476 of PM_{10}).

Since NH_3 emissions from fertilizer application may contribute up to 10 percent of total NH_3 emissions nationally, it was important that NH_3 emissions from agricultural tilling be included in the inventory. The activity data used to estimate emissions are from the Commercial Fertilizers Data Base compiled by the Tennessee Valley Authority and now maintained by Association of American Plant Food Control Officials.[3] This data base includes county-level usage of over 100 different types of fertilizers, including those that emit NH_3.

The emission factors used for fertilizer application were taken from a 1992 Netherlands study.[4] This source lists emission factors for 10 different types of fertilizers. (NAPAP only listed an emission factor for one type.) Depending on fertilizer type, then NH_3 emission factors range from 24 to 364 lb NH_3/ton nitrogen applied.

VI.1.4 Construction Activities

The following AP-42 particulate emission factor equation for heavy construction was used to determine regional PM_{10} emissions from *construction activities* for 1990:

$$E = T \cdot \$ \cdot f \cdot m \cdot p$$

where:

E = PM_{10} emissions tons per year (tpy)

T = TSP emission factor (1.2 ton/acre of construction/month of activity)

$\$$ = dollars spent on construction (million $)

f = factor for converting dollars spent on construction to acres of construction (varies by type of construction, acres/million $)

m = months of activity per year (varies by type of construction)

p = dimensionless PM_{10}/TSP ratio (0.22)

Estimates of the dollars spent on the various types of construction by EPA Region for 1987 were obtained from the U.S. Census Bureau. From these estimates, the fraction of total U.S. dollars spent in 1987 for each Region for each construction type was calculated. The EPA determined that for different types of construction, the number of acres was proportional to dollars spent on that construction type. This information (corrected to constant dollars) was utilized along with total construction receipts to determine the total number of acres of each construction type. Estimates of the duration (in months) for each construction type were taken from EPA PM_{10}/TSP ratios for 19 test sites for three different construction activities and were averaged to derive the PM_{10} fraction used in the emission estimates.[5] Regional-level PM_{10} estimates were distributed to the county-level using county estimates of payroll for construction (SIC's 15, 16, 17) from *County Business Patterns*.[6] The following formula was used:

$$\text{County Emissions} = \frac{\text{County Construction Payroll}}{\text{Regional Construction Payroll}} \cdot \text{Regional Emissions}$$

The $PM_{2.5}$ emissions were calculated using the county-level PM_{10} emissions by applying the particle size multiplier of 0.02024.

VI.1.5 Wind Erosion

The PM_{10} wind *erosion emission* estimates for agricultural lands were calculated using a modification of a methodology used by Gillette and Passi to develop wind erosion emission estimates for the 1985 NAPAP Inventory.[7] The NAPAP method and the method used to develop the wind erosion estimates for the NPI are based on the determination of expected dust flux using the probability distribution of wind energy. The methodology uses the mean wind speed coupled with information concerning the threshold friction velocity for the soil and information on precipitation to predict the wind erosion flux potential for soils.

To calculate the flux of emissions from wind erosion, information concerning the average monthly wind speed, total monthly precipitation, and anemometer height used to measure the wind speed was necessary. Values for monthly wind speed, monthly precipitation, and anemometer height were obtained from the local climatological data for several meteorological stations within each State.[8]

Once the emission flux potential for each month for each crop type (fall- or spring-planted) for each State was calculated, then information on the number of acres of spring- or fall-planted crops in each State from the USDA was used to determine the emissions.[9]

State-level PM_{10} estimates were distributed to the county-level using estimates of county rural land area from the Census Burea.[10] The following formula was used:

$$\text{County Emissions} = \frac{\text{County Rural Land}}{\text{State Rural Land}} \cdot \text{State Emissions}$$

The $PM_{2.5}$ emissions were calculated from the county-level PM_{10} emissions by applying the AP-42 particle size multiplier for industrial wind erosion of 0.2 (or 0.40 of PM_{10}), as no other particle size data were available.

VI.1.6 Unpaved Roads

Estimates of PM_{10} emissions from unpaved roads were developed for each county using emission factors from the EPA PART5 emission factor model.[11] PART5 reentrained road dust emission factors depend on the average weight, speed, and number of wheels of the vehicles traveling on the unpaved roadways, the silt content of the roadway surface material, and the percentage of days in the year with minimal (less than 0.01 inches), or no precipitation. Emissions were calculated by month at the State/road-type-level for the average vehicle fleet and then allocated to the county/road-type-level by land area, as shown in the previous equation, using Census Bureau data.[12] The activity factor for calculating reentrained road dust emissions on unpaved roads is the VMT accumulated on these roads. Unpaved road VMT is a function of the average daily traffic volume and the unpaved roadway mileage. The unpaved roadway mileage is estimated, in turn, from the Federal Highway Administration (FHA)[13] (More details on the calculation of the emission estimates for reentrained road dust from unpaved roads are presented in another EPA study.[14])

VI.1.7 Paved Roads

Estimates of PM_{10} emissions from reentrained road dust on paved roads were developed at the county level in a manner similar to that for unpaved roads. PART5 reentrained road dust emission factors for paved roads depend on the road surface silt long and the average weight of all of the vehicles traveling on the paved roadways. The equation used in PART5 to calculate PM_{10} emission factors from reentrained road dust on paved roads is a generic paved road dust calculation formula from AP-42. This equation and its variables are thoroughly described in reference 22. Once computed at the State/road-type-level, paved road emissions were allocated to the county level according to the fraction of total VMT in each county for the specific road type.

VI.1.8 Livestock Operations

County-level PM_{10} emission estimates for cattle feed lots were estimated using activity data from the Census of Agriculture (head of cattle per county) and a PM_{10} emission factor of 17 tons per 1,000 head. $PM_{2.5}$ emissions were calculated from the county-level PM_{10} emissions by applying the AP-42 particle size multiplier for agricultural tilling of 0.476 x PM_{10}.

The NPI also includes NH_3 emissions from cattle feedlots, which were estimated using activity data from the 1992 Census of Agriculture and the emission factors used in the 1985 NAPAP Inventory.[15] The emission factors that were used to calculate emissions are from a study of NH_3 emissions conducted by Asman for the Netherlands National Institute of Public Health and Environmental Protection. Published in 1992, these emission factors range from approximately 0.4 to 50 lb NH_3/head of livestock.

VI.1.8 Other Emission Sources

This subsection discusses *miscellaneous area source (non-fugitive dust)* and *mobile source (highway)* emission estimates. The former category includes emissions from aircraft, railroad locomotives, and marine vessels. Also covered in this "miscellaneous" category are emissions from nonroad sources, other combustion sources, and biogenic sources. For some types of area sources, emissions are based on both 1985 NAPAP and TSP emissions grown to 1990. Particle size multipliers were applied to estimate PM_{10} and $PM_{2.5}$ emissions. In general, NH_3 emissions were estimated by growing NH_3 emissions taken from the 1985 NAPAP Inventory. For other types of area and mobile sources, more recent methods were incorporated.

VI.1.9 Miscellaneous Area Sources

Emission estimates for *miscellaneous (non-fugitive dust) area sources* are based on the 1985 NAPAP Inventory values that were grown to 1990 based on historical BEA earnings data, historical estimates of fuel consumption, or other category-specific growth indicators. Activity levels for *aircraft* are compiled by the FHA on a regional basis. These data were compiled on a regional basis, so the regional trends were applied to each State. Military aircraft landing-takeoff operations totals were not available. As a proxy, BEA data on military sector economic growth were used. *Railroad* data were provided by the Association of American Railroads. National totals of revenue-ton-miles for the years 1985 through 1990 were used to estimate changes in activity during this period. National growth factors were applied to each State and county. *Marine vessel* activity is recorded annually by the U.S. Army Corp of Engineers. Cargo tonnage national totals were used to determine growth in diesel- and residual-fueled vessel use through the year 1989. As *gasoline-powered vessels* are used predominantly for recreation, growth for this category was based on population. *Petroleum refinery fugitive emissions* were grown to 1990 based on refinery capacity by State, as reported in DOE's Petroleum Supply Annual for 1985 through 1990.[16]

Emission factors for *residential wood combustion* (normally inventoried in the "Fuel Combustion Other" category) were updated to reflect recent improvements in AP-42 emission factors. The NAPAP PM_{10} emission factor, which reflects a combination of wood-burning devices, is 39.3 lb/ton wood burned. By contrast, the latest AP-42 device-specific emission factors range from 4.2 lb/ton (pellet stoves) to 30.6 lb/ton (conventional woodstoves). Since no data are available to weight these emission factors (based on stove-type population), and because conventional woodstoves constitute the majority of woodstoves nationwide, the emission factor for conventional wood stoves was used to calculate *all* residential wood combustion emissions. This method provides a conservative (high) emissions estimate because conventional stove emissions are generally higher than those for other wood-burning devices. Usage data were taken from the 1985 NAPAP emission inventory.

VI.1.10 Mobile Sources (Highway)

Mobile source (highway) emissions were estimated using vehicle miles travelled (VMT) data from the FHA's Highway Performance Monitoring System and emission factors from a recent EPA emission factor model. PM (including paved and unpaved road dust) and SO_2 emissions were estimated using emission factors from the PART5 model, recently released by EPA's Office of Mobile Sources (OMS).

Vehicle speeds, which are modeled by vehicle and road types, range from 25 mph (heavy-duty vehicle, local road) to 60 mph (light-duty vehicle, interstate). Emission factors were calculated for each combination of State, inspection and maintenance (I/M) status, month, vehicle type, and speed. The VMT data for each county/month/vehicle type/road type were mapped to the appropriate emission factor.

The PM_{10} emissions consist of those from *highway vehicle exhaust* components and *brake and tire wear*. Exhaust components were calculated by multiplying 1990 monthly county-level, SCC-specific VMT by 1990 State-level, SCC-specific exhaust PM_{10} emission factors generated using PART5. None of the inputs affecting the calculation of the PM_{10} exhaust emission factors vary by month, so only annual PM_{10} exhaust emission factors were calculated. PART5 total exhaust emission factors are the sum of lead, soluble organic fraction, remaining carbon portion, and direct SO_4 (sulfate) emission factors.

The *brake wear* emission factor is 0.013 grams per mile for *all* vehicle types. The *tire wear* emission factor is proportional to the average number of wheels per vehicle: 0.002 grams per mile per wheel.

National annual SO_2 highway vehicle exhaust emission factors from PART5 vary according to fuel density, fuel sulfur content, and speed-dependent vehicle fuel economy. None of these parameters vary by month or State. Monthly/county/SCC-specific SO_2 emissions were then calculated by multiplying each county's monthly VMT at the road- and vehicle-type level by the appropriate SO_2 emission factor.

Little research has been done to date on NH_3 *emission factors from motor vehicles*. The most comprehensive vehicle testing in this area has been done by Volkswagen AG.[17] These tests measured NH_3 emissions for several vehicles, encompassing three engine types. Based on these emission data, MOBILE5a data on the fraction of vehicles with 3-way catalysts, 1990 travel fractions by vehicle type and model year, and corresponding vehicle-specific VMT for each county and road type combination, NH_3 emission factors were calculated. These ranged from approximately 0.002 to 0.1 grams/mile.

VI.1.11 Nonroad Sources

Nonroad sources include motorized vehicles and equipment that are not normally operated on public roadways. The nonroad mobile source emission estimates in the NPI are based on 1990 nonroad emission estimates compiled by EPA's Emission Inventory Branch (EIB).[1] The EIB nonroad data contain a total emission estimate for nonroad sources at the county level. These emission estimates

[1] Now the Emission Inventory and Factors Group, Emission Monitoring and Analysis Division, OAQPS.

include all nonroad sources except aircraft, commercial marine vessels, railroads, and fugitive road dust, which were discussed previously. The nonroad sources not included in the EIB estimates were determined by growing the applicable NAPAP source categories. The EIB nonroad emission estimates were developed from nonroad emission inventories for 27 ozone nonattainment areas (NAA) by EPA's OMS.

VI.1.12 Other Combustion Sources

This category includes agricultural (field) burning, wildfires, structural fires, and prescribed (forest and range management) burning. For most States, emissions for agricultural burning, wildfires, and structural burning were taken from the 1985 NAPAP inventory. For agricultural burning and wildfires, the NAPAP emissions were estimated from the number of acres burned in each county and fuel loading (tons/acre) factors for each crop type. Agricultural burning emissions were grown to a 1990 level using BEA farm income growth statistics; zero growth was assumed for the wildfires category. For prescribed burning, PM_{10}, $PM_{2.5}$, SO_2, NO_x, and VOC emissions are based on a 1989 USDA Forest Service inventory of particulate matter and air toxics from prescribed burning.[18] The Forest Service inventory contained State-level totals for PM_{10}, $PM_{2.5}$, non-methane hydrocarbons (used as a surrogate for VOC), CO, and several air toxics.

For 11 States in the Western United States, more updated estimates for forest wildfires and prescribed burning were available from a 1995 inventory developed by Radian Corporation for the Grand Canyon Visibility Transport Commission (GCVTC).[19] The 11 States include: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The GCVTC Inventory includes newly developed emission estimates for forest wildfires and prescribed burning. The wildfire data in the GCVTC Inventory represents a detailed survey of forest fires in the study area and is clearly more accurate than the wildfire data in the PM Inventory. The prescribed burning data in the GCVTC Inventory is the same as the data in the PM Inventory at the State level, but contains more detailed county-level data.

VI.1.13 Biogenic Emissions

Estimates for biogenic VOC emissions were taken from a national biogenic emissions inventory for eight landcover types: oak forests, other deciduous forests, coniferous forests, grasslands, scrublands, urban vegetation, agricultural crops, and inland waters. This inventory was compiled by Lamb et al.[20] A forest canopy model was used to account for the effects of solar radiation, temperature, humidity, and wind speed on predicted VOC emission rates. The 1990 biogenic emissions presented here assume that there are no emissions from corn crops. This assumption is based on the results of recent field studies that have shown that previous emission factors for corn have been overstated by roughly a factor of 1,000.

VI.1.14 Other Emission Considerations

This subsection presents a potpourri of topics related to emissions estimation. These are: methods for assessing secondary organic aerosol, modifications to regional point and area source emission estimates, and methodologies for inventorying Canadian and Mexican emissions.

VI.1.15 Methods for Assessing Secondary Organic Aerosol Formation

Methods for assessing SOA formation draw heavily from a study in which the researchers assigned fractional aerosol coefficients (FAC) to a wide variety of organic species to express the fraction of emissions that may form SOA.[21] FAC are based on the reactivity of an organic compound with atmospheric oxidants and the vapor pressure of the resulting products. After determining source-specific FAC for all of the VOC source categories, SOA estimates were prepared by multiplying the source-specific FAC (adjusted for methane, if necessary) by the annual VOC emissions for that source category.

Source-specific FAC have been determined for several anthropogenic source categories, such as stationary combustion, mobile sources, and surface coating operations. These FAC range from 0.0001 (natural gas combustion) to 0.3 (pulp and paper industry). Estimates of SOA formation are based primarily on speciation data provided by Lamb et al., and the methods used to determine source-specific FAC. For biogenic sources, Lamb et al., provided data to speciate the emissions for eight landcover types into terpene, olefin, paraffin, and aromatic fractions.

VI.1.16 Modifications to Regional Point and Area Emission Estimates

The emission estimates for the nation described in the previous sections form the NPI used in this analysis. In addition to forest wildfires and prescribed burning emissions, estimates for other source types that were available from the 1995 GCVTC Inventory were also added to the National Particulates Inventory. This inventory was developed by compiling and merging existing inventory data bases. The primary data sources used were State inventories for California and Oregon, AIRS-AFS for point source data for the other nine States, the 1990 Interim Inventory for area and mobile source data for the other nine States, the 1985 NAPAP Inventory for NH_3 and TSP data, and county-level biogenics data from Washington State University.

The following portions of the GCVTC Inventory were incorporated into the National Particulate Inventory:

- Complete point and area source data for California;
- Complete point and area source data for Oregon;
- Forest wildfire data for the entire 11-State region; and
- Prescribed burning data for the entire 11-State region.

State data from California and Oregon were incorporated because they constitute complete inventories developed by the States and are presumably based on more recent and detailed data than the PM Inventory, some of which is still based on the 1985 NAPAP Inventory. No motor vehicle emissions from the GCVTC Inventory were used, with the exception of VOC and NO_x from Oregon and California. VOC and NO_x for California and Oregon were calculated by those States with their specific VMT and emission factor data, and, therefore, are presumed to be the most accurate.

VI.1.17 Canadian and Mexican Emissions

To provide a complete emissions inventory for modeling purposes and to account for the amount of particulate matter transported over the border from Mexico and Canada into the United States, it was necessary to determine the amount of primary and secondary particulate matter emissions emanating from areas of Mexico and Canada near the U.S. border.

Emissions for *Canada* are based on 1985 NAPAP emissions grown to 1990 using emission growth factors. The 1985 NAPAP Inventory contained Canadian TSP emissions for point and area sources. The point source emissions are at the point level and are accounted for by (U.S.) SCC. The area source emissions are at the province-level and are inventoried by Canadian SCC. These Canadian area source SCC were converted to the U.S. area source SCCs, so that the SCC-specific particle size multipliers could be applied.

The growth factors used to grow the 1985 NAPAP emissions to 1990 were provided by Environment Canada.[22] These growth factors were based on growth in 1985 and on 1990 particulate emissions by source category. Growth was assumed to be zero for any category with no data. Each SCC in the point and area source file was assigned to one of the source categories for which there was Canadian growth. The same particle size multipliers used for U.S. emissions were used to estimate Canadian PM_{10} and $PM_{2.5}$ emissions.

For the areas in the Southwest region of the United States, Mexican emissions represent a potentially important influence on ambient PM levels. The primary source of Mexican emissions data in the NPI is a World Bank report that provides estimates of 1985 emissions by State.[23] The World Bank report includes emission estimates for five sectors (motor vehicles, thermo-electricals, manufacturing, services, and oil refining), and does *not* include emissions for residential fuel combustion and fugitive dust.

Potential improvements in Mexican emission estimates were investigated through contacts with EPA Region VI and IX staff. It was found that efforts are underway to produce new motor vehicle emission estimates for Cindad Juarez, Mexico. However, this work is still in progress. Similarly, work on estimating emissions for Mexican States that border Arizona and California is also either in progress, or is just getting underway. One of these efforts is sponsored by the Western Governors' Association.

The emissions data in the National Particulates Inventory for Mexican sources are reported on a State-level for the six Mexican States that border the United States directly to the south. These six Mexican States are Baja California Norte, Coahuila, Chihuahua, Nuevo Leon, Sonora, and Tamaulias. The Mexican data in this inventory reflect 1985 emissions that were projected to 1990 levels using population as a growth indicator. Pechan augmented the data in the inventory by incorporating emissions from Mexican point sources that began operation after 1985 and would not, therefore, be represented in the National Particulates Inventory. Operating data for three Mexican point sources were available from the inventory developed for the GCVTC by Radian. The GCVTC report provided Mexican point source emissions data for two copper smelters (Nacozari and Cananea) and one power plant (Carbon I). Incorporated into the baseline national inventory, the 1990 Mexican emissions from these three sources are shown by pollutant in Table VI.1-1. Radian estimated particulate emissions from the two copper smelters using available operating data for these smelters, and emissions data for two U.S. smelters with comparable emission controls. The GCVTC inventory estimates were provided in tons per day and were converted to tons per year for use in this study

assuming continuous year-round operation. The emissions from the Carbon I electric generating facility were estimated using
AP-42 emission factors and data received from EPA Region VI.[24]

TABLE VI.1-1

1990 EMISSIONS FOR INDIVIDUAL MEXICAN POINT SOURCES

Point Source	1990 Emissions by Pollutant (Tons Per Year):				
	NO_x	SO_2	PM-10	PM-2.5	VOC
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] [illegible]					

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APPENDIX VI-2
EMISSION PROJECTION PROCEDURES

This appendix describes the procedures used to project Particulate Matter (PM) emissions from 1990 to 2007. Procedures are given for projecting emissions from: motor vehicles, electric utilities, and non-utility point sources, and area/nonroad sources, in that order.

VI.2.1 Motor Vehicle Emission Projections

The Emission Reductions and Cost Analysis Models (ERCAM) were used to project motor vehicle emissions for volatile organic compounds (VOC), oxides of nitrogen (NO_{x}), and carbon monoxide (CO) to future years. Emission factors from MOBILE5a were used as a direct input to the ERCAM's. For the other pollutants (PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2), and ammonia (NH_3), future year emission factors were calculated using the Environmental Protection Agency's (EPA) PART5 model. The vehicle miles traveled (VMT) growth procedures used in the ERCAM's were also applied to estimate future year emission levels for these pollutants.

National growth in VMT from the MOBILE 4.1 Fuel Consumption Model is used as the basis for VMT projections.[1] National growth is scaled to the metropolitan statistical area (and rest-of-State) level using population projections.[2] Thus, if an area shows population growth higher than the national average, VMT growth will also be higher than the national average. National VMT projections by vehicle type range from -22.3 percent (light-duty diesel vehicles) to +4.0 percent (heavy-duty diesel vehicles).

After VMT is projected to the future year, MOBILE 5a or PART5 emission factors are applied to calculate the resulting emission levels. The MOBILE 5a emission factors are used by the ERCAM to compute annual, State-level emissions of VOC, NO_x, and CO. These factors are based on monthly average temperatures and also account for different vehicle types, speeds, and roadway classifications.

The ERCAM's match these emission factors with motor vehicle controls at the county level. Under the *Current Control Scenario*, controls modeled included only the Federal Motor Vehicle Control Program (FMVCP), current (as of 1990) inspection and maintenance (I/M) programs, and phase II gasoline Reid Vapor Pressure limits. However, the Clean Air Act (*CAA) Control Scenario* included the following controls mandated under Titles I and II of the Act:
Tier I tailpipe standards (nationally), basic and enhanced I/M, reformulated gasoline, oxygenated fuel, and the California low-emission vehicle program.

The PM_{10}, $PM_{2.5}$, and SO_2 motor vehicle emissions were projected by multiplying 2007 emission factors by 2007 VMT. Using the PART5 model, the emission factors for these three pollutants were calculated nationally by road type (speed), both with and without I/M and reformulated gasoline. The PART5 emission factors were multiplied by VMT at the monthly, county, road type, vehicle type level.

As discussed in Appendix VI-1, the PM emissions consist of three components: exhaust PM, brake wear PM, and tire wear PM. The PM_{10} brake wear emission factor (0.013 grams per mile) is identical for all vehicle types and all conditions, the tire wear emission factor (0.002 grams per mile/wheel) varies by the number of tires per vehicle, and the exhaust PM emission factors vary by vehicle type and depend on the mix of vehicles in the fleet (the registration distribution projected from 1990 to 2007), since different PM tailpipe standards apply to different model years.

The PM emission factors for the *Current Control* Scenario used the same basic inputs to PART5 as the emission factors for the *CAA Control* Scenario. However, for the *Current Control* Scenario, emission factors were modeled using a 1990 calendar year, rather than 2007, to eliminate the effect of CAA tailpipe standards. The effects of reformulated gasoline also were eliminated and I/M factors were applied only to areas with I/M programs existing in 1990.

The SO_2 emission factors were also projected using PART5.

The SO_2 emission factors depend on fuel sulfur content, fuel density, and fuel economy. The differences in fuel sulfur content and fuel density between gasoline and diesel fuel also contribute to the differences in SO_2 emission factors by vehicle type. The *CAA Control* Scenario reflects the effects of the lower fuel sulfur content of diesel fuel required by the CAA beginning in 1993 and the use of reformulated gasoline in certain areas. In the *Current Control* Scenario, emission factors were adjusted to remove the effects of the lower diesel fuel sulfur content and the effects of reformulated gasoline.

The NH_3 emission factors were calculated in a manner consistent with the methodology documented for calculating 1990 NH_3 emission factors from motor vehicles. This methodology is based on applying results of testing performed by Volkswagen AG, as discussed in Appendix VI.1. The differences between the 2007 and 1990 emission factors result from changes in the mix of vehicles equipped with three-way catalysts. The 2007 emission factors range from approximately 0.0019 to 0.14 grams per mile.

VI.2.2 Utility Emission Projections

Utility point source emissions for NO_x, VOC, and CO were projected using the ERCAM's. Particulate matter (PM_{10} and $PM_{2.5}$) and SO_2 emissions were projected using a specialized version of AIRCOST/PC, a Pechan electric utility model.[1] The starting point for utility projections is the Interim 1990 Inventory of utility emissions.[3] Units in the planning stages are added to this inventory.[4] Future year generation projections from the U.S. Department of Energy are used to predict the level of future operation.[5] Generation at existing and planned units is increased where possible (based on historical

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[1] Not to be confused with the *CO$T-AIR* control cost spreadsheets developed by the Innovative Strategies and Economics Group, OAQPS, and which are posted on the OAQPS Technology Transfer Network (Control Technology Center bulletin board).

capacity utilization) to meet this demand. If additional generation is still needed, additional units (generic units) are brought on-line.

The *Current Control* Scenario is a projection of emissions to future years with no new control measures. Control levels for existing utility units remain at 1990 control levels. First of all, Title IV of the CAA specifies that *utility SO_2 emissions* not exceed a specified national cap. Each existing unit is given a number of allowances (a permit to emit a ton of SO_2) based on boiler characteristics and historic operating parameters. Each utility unit can then either reduce its SO_2 emissions to be equivalent to the number of allowances it has been granted, reduce its SO_2 emissions below the level of allowances granted and then bank or sell the excess allowances, or emit more SO_2 than the number of allowances granted, but purchase a sufficient number of allowances or use banked allowances to cover the excess SO_2 emissions.

Utility SO_2 emissions were calculated at the unit (boiler) level for the *CAA Control* Scenario using the AIRCOST/PC model. This model allows SO_2 emission trading to take place at any geographic level, and examines an exhaustive set of boiler control options and calculates the cost of each option. The model then determines the most cost-effective solution for achieving the desired SO_2 emission reduction at the geographic level specified. For the modeling done for the *CAA Control* Scenario, the model was optimized at the national level using the calculated SO_2 allowance total for 2007 with banking.[6] The control options considered were 50 to 90 percent-efficient flue gas desulfurization (FGD), switching to or blending with a lower sulfur coal, and a combination of FGD with fuel blends. This analysis accounts for both trading of allowances and banking. New units were included within the allowance cap (i.e., any new unit would need to purchase a sufficient number of allowances equal to its expected emissions).

Utility PM emissions depend predominantly on the grade and properties of the fuel type used. In coal-fueled units, coal properties, boiler operation, and firing configuration each play an integral part in particulate emission levels. When a unit changes coal types to meet an SO_2 reduction requirement, the coal ash content may change. If the ash content increases, so do the particulate emissions. It is from this reasoning that changes in particulate emissions are calculated using the coal ash content ratio of new coal to old. Oil and gas-fired units in this analysis were not modeled with alternate fuels. For this reason, particulate emissions did not change for these units under the *CAA Control* Scenario.

Planned and generic utility units were assumed to emit PM at the levels specified in applicable New Source Performance Standards (NSPS). The average PM_{10} and $PM_{2.5}$ emission factors for existing oil-fired units are much lower than the NSPS for these units since a majority of existing units currently have highly efficient PM controls, such as electrostatic precipitators. Therefore, the PM_{10} and $PM_{2.5}$ emission rates modeled for gas-fired new units shown in
Table VI-2-1 are more stringent than the actual NSPS rates. Using the capacity, heat and operating rates, and future year capacity utilization factor, PM emissions were calculated.

Regarding *utility NO_x emissions*, Title I of the CAA Amendments of 1990 requires NO_x reasonably available control technology (RACT) on major sources in ozone nonattainment areas. In addition, NO_x RACT is required throughout the (Ozone Transport Region). Major sources are defined by the ozone nonattainment classifications. The corresponding emission rates range from 25 tons/year ("Severe" status) to 100 tons/year ("Marginal/Moderate" and OTR). The RACT control levels are specified individually by each State and, in some States, RACT determinations are made on a case-by-case basis. To model the reductions associated with this requirement, RACT emission rate limits (identical to the Title IV RACT limits for coal-fired utility boilers) were applied by source category. These limits range from 0.2 to 1.0 lb/million BTU, depending on control method and boiler type. Title IV NO_x limits range from 0.45 to 1.0 lb/MMBtu.

TABLE VI-2-1

NEW SOURCE EMISSION RATES FOR FOSSIL FUEL-FIRED BOILERS

Emission Limits (Pounds per MMBtu)					
Fuel	**PM-10**	**PM2.5**	**VOC**	**NOx**	**CO**
Coal	0.028	0.016	0.0027	0.50	0.022
Oil	0.019	0.012	0.0051	0.30	0.033
Gas	0.003	0.003	0.0013	0.20	0.038

Planned and generic electric utility units were assumed to come on line at NSPS NO_x levels. New units expected to be sited in nonattainment areas, or the OTR, were assumed to be subject to New Source Review (NSR). In this case, coal units and oil and gas units were assumed to emit at 0.10 and 0.05 lb/million BTU, respectively. The NO_x emissions from new units located in nonattainment areas or the OTR are required to be offset. To be consistent with the Regional Oxidant Modeling (ROM), offset requirements were calculated by summing NO_x emissions from units that began operation after 1996 at the nonattainment area level (or rest-of-State level for attainment areas in the OTR). Emissions from existing units, within the same area, that retired after 1996, but before 2007, were subtracted from the offset requirement. The remaining emissions from new units were offset at a 1-to-1 ratio by applying selective catalytic reduction (SCR) controls to existing units within the nonattainment area or rest-of-State area.

The *CAA Control* Scenario *VOC and CO utility emissions* were assumed to be equivalent to the *Current Control* Scenario emissions. Ozone nonattainment provisions of the Act do not specify any mandatory VOC or CO controls for utilities, although individual States or nonattainment areas may require them. The VOC and CO emissions for planned and generic units were calculated based on factors provided by the 1985 NAPAP emissions inventory. Using the boiler design capacity, heat rate, operating rate, and future year capacity utilization factor, projected VOC and CO emissions were calculated.

In the *Current Control* Scenario, none of the utility units emits NH_3. In cases where SCR is added as a control, a certain amount of NH_3 slippage occurs resulting in NH_3 emissions under the *CAA Control* Scenario. New units sited in nonattainment areas or the OTR are subject to NSR and are assumed to apply SCR. Also, the utility units assumed to be providing the necessary offsets for new units are also assumed to apply SCR in the *CAA Control* Scenario. In these cases, NH_3 emission factors of 0.062 and 0.002 lb/million BTU are applied to coal-fired and oil- or gas-fired units, respectively. Units without SCR have no NH_3 emissions in the *CAA Control* Scenario.

The 1990 utility data used in this study for California and Oregon were obtained from the GCVTC report. However, the utility data fields provided for these two States included primarily point identifiers (not the same as the ORIS plant identifiers used for the remainder of the utility inventory), SCC's, stack parameters and location, and 1990 emissions. No data on activity, such as fuel consumption or unit capacity, were available. Thus, the data needed to perform emission projections as they were done for the other States was not available for California and Oregon. Therefore, separate procedures were developed for projecting utility emissions from these two States. These procedures are described in reference 22.

VI.2.3 Non-Utility Point Source Emission Projections

Nonutility point source emissions for NO_x and VOC were projected the using ERCAM's. State-level industry earnings projections (per BEA) were used to project future year emission levels. The BEA national growth in earnings by industry (two-digit SIC level) range from -2.0 percent/year (railroad transportation) to +4.7 percent/year (business and miscellaneous repair services) over the

1988 to 2005 period. Emission projections for the remaining pollutants utilized the same approach as in the ERCAM's. The *Current Control* projection applies growth factors and retains 1990 levels of control efficiency. The *CAA Control* Scenario incorporates control efficiencies based on measures mandated by the 1990 Amendments.

Point source emissions of PM_{10} and $PM_{2.5}$ under the *Current Control* Scenario were projected by applying the BEA growth factors to the 1990 emissions. Possible control initiatives for particulates under the CAA would result from the Title I provisions related to PM_{10} nonattainment. Review of the draft State Implementation Plans available indicate the controls are mainly targeting area source emitters, so CAA emissions for point sources were assumed to be equivalent to the *Current Control* emissions.

For *non-utility point source NO_x emissions*, the current control scenario is a projection of emissions to future years with no new control measures. Control levels for stationary sources remain at 1990 control levels. Major stationary source NO_x emitters in marginal and above nonattainment areas and in the Northeast OTR are required to install RACT-level controls under the ozone nonattainment related provisions of Title I. RACT control levels are specified by each State. Representative RACT levels were chosen for each source type to model the reductions associated with this requirement. These control levels were developed based on EPA *Alternative Control Techniques* documents.

Non-utility point source VOC emission projections were completed using the ERCAM. Point source control measures for VOC include RACT, new control technique guidelines (CTG), and Title III MACT controls. Title III MACT controls are generally as, or more, stringent than RACT controls in the 2007 scenario. The VOC controls modeled are based on the ROM base case *CAA Control* Scenario.[7] (Point source controls and caveats for the *CAA Control* Scenario are delineated in reference 22.) The *Current Control* Scenario assumes all sources remain at 1990 control levels.

The *CAA Control* Scenario for *non-utility point source SO_2 emissions* were assumed to be equivalent to the *Current Control* Scenario emissions. The SO_2 nonattainment provisions of the Act do not specify any mandatory controls for SO_2 emitters, although individual States or nonattainment areas may require controls. An emission cap of 5.6 million tons of SO_2 per year was set by the Act for industrial sources. If the cap is exceeded, the Administrator may promulgate new regulations. Because the cap is exceeded by only a small amount under the *Current Control* Scenario, and because it is at the Administrator's discretion to promulgate new regulations, *CAA Control* Scenario emissions were assumed to be equivalent to the *Current Control* emissions for point source SO_2.

VI.2.4 Area/Nonroad Emission Projections

Area and nonroad engine emissions for VOC and NO_x were projected using the ERCAM's; similar modeling techniques were used for the remaining pollutants. Growth to future years was estimated using the BEA industry earnings and population projections as described in the previous section. Area source categories were matched with industry, population, or broader BEA categories. After applying the appropriate growth factor, the ERCAM's applied future year control levels. Under the *Current Control* Scenario, future year levels were assumed to be equivalent to 1990 levels. The *CAA Control* Scenario applied control levels to model the effects of the Title I nonattainment provisions, Federal rules, and, in the case of VOC, Title III MACT standards.

For *PM area source emissions*, the *Current Control* Scenario assumes that future year control levels are equal to those in 1990. Under the *CAA Control* Scenario, the same is assumed, although area source controls are being implemented in many PM nonattainment areas. Because of the diversity in control techniques applied in different areas, no control measures were applied to simulate PM nonattainment requirements. The approach taken was to use the optimization modeling to determine controls necessary in areas to meet current PM_{10} standards.

Area/nonroad emission projections for NO_x were completed using the ERCAM. The *Current Control* projection assumes that future year control remains at 1990 levels. The *CAA* projection incorporates the reduction of industrial fuel combustion emissions to model the effects of lowering the RACT source size cutoff in ozone nonattainment areas. A 50 percent control efficiency (at 80 percent rule effectiveness) is applied to represent RACT. The penetration rates (representing the amount of emissions from sources above the size cutoff) range from 0 to 65 percent, depending upon the fuel type. In addition, federal nonroad engine standards were modeled for compression ignition (diesel) engines and the Phase I spark ignition standards. The 2007 projected emission changes for these are -23 percent and +240 percent, respectively.

Area source VOC emission projections were calculated using the ERCAM. The *Current Control* Scenario assumes all sources remain at 1990 control levels. CAA controls, based on the ROM CAA Scenario, include controls for Title I (RACT, new CTG, Stage II vapor recovery, and Federal consumer solvent controls), Federal nonroad engine standards, Title III MACT standards, and onboard vapor recovery systems. These controls are summarized in reference 22. The provisions not incorporated into the VOC analysis, listed under the point source section, may also affect area source emission levels in ozone nonattainment areas.

Finally, future year control levels for *area source SO_2 emitters* (generally fuel combustion and fires) were assumed to be equivalent to 1990 levels under both the *Current Control* and *CAA Control* Scenario.

VI.2-5 REFERENCES

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7.0 CONTROL STRATEGY—COST ANALYSIS

7.1 INTRODUCTION

This chapter presents the results of the particulate matter (PM) National Ambient Air Quality Standards (NAAQS) control strategy—cost (CS-C) analysis. This analysis estimates the projected costs of installing, operating, and maintaining those additional controls needed in the year 2007 to meet the alternatives presented in Chapter 6. These control costs are inputs to the economic impact analysis presented in Chapter 8. The following sections discuss, in turn: (1) the foundation of the CS-C analysis, (2) the analytical uncertainties, and (3) the results of the analysis. Additionally, cost estimates for projected ambient PM monitoring networks are presented in the final section.

An analysis of administrative costs to individual sources and Federal, State, and local governments associated with the PM NAAQS will be considered during the Part 51 implementation process. The Agency will also consider the issues of Federal conformity and impacts on military readiness during the Part 51 implementation process, and attempt to provide cost estimates associated with Federal conformity.

The Agency did not estimate the cost associated with every known control measure, however. Time and resource constraints, in conjunction with having limited data prevent the Agency from analyzing the potential impacts of the PM NAAQS on regional transportation emissions, implementation of TCM, and localized transportation related effects. At this time, it is not possible to estimate the impact that the NAAQS will have on transportation plans in identified nonattainment areas because uncertainties are associated with these estimates. For example, because mobile sources are not individually inventoried, the actual number of establishments affected by these control measures is unknown. Consequently, any cost analysis using these control measures on mobile sources is highly speculative. Control measures such as these currently not included in the PM control strategy cost analysis will be considered during the PM Part 51 implementation process.

Time and resource constraints, in conjunction with having limited data also prevent the Agency from analyzing the potential impacts of the PM NAAQS on sources that receive Federal funding and are located in identified nonattainment areas. This information is not contained in the estimate of control strategy costs for the Federal Government (SIC 971). For each nonattainment area, the Agency has estimated the cost of controlling stationary sources *only* to achieve the PM NAAQS. Although the level of detail in the data bases the Agency used for this RIA is not sufficient to identify the ownership status associated with these controlled sources, it is reasonable to believe that some of these sources are located on Federal facilities.

7.2 ANALYTICAL FOUNDATION

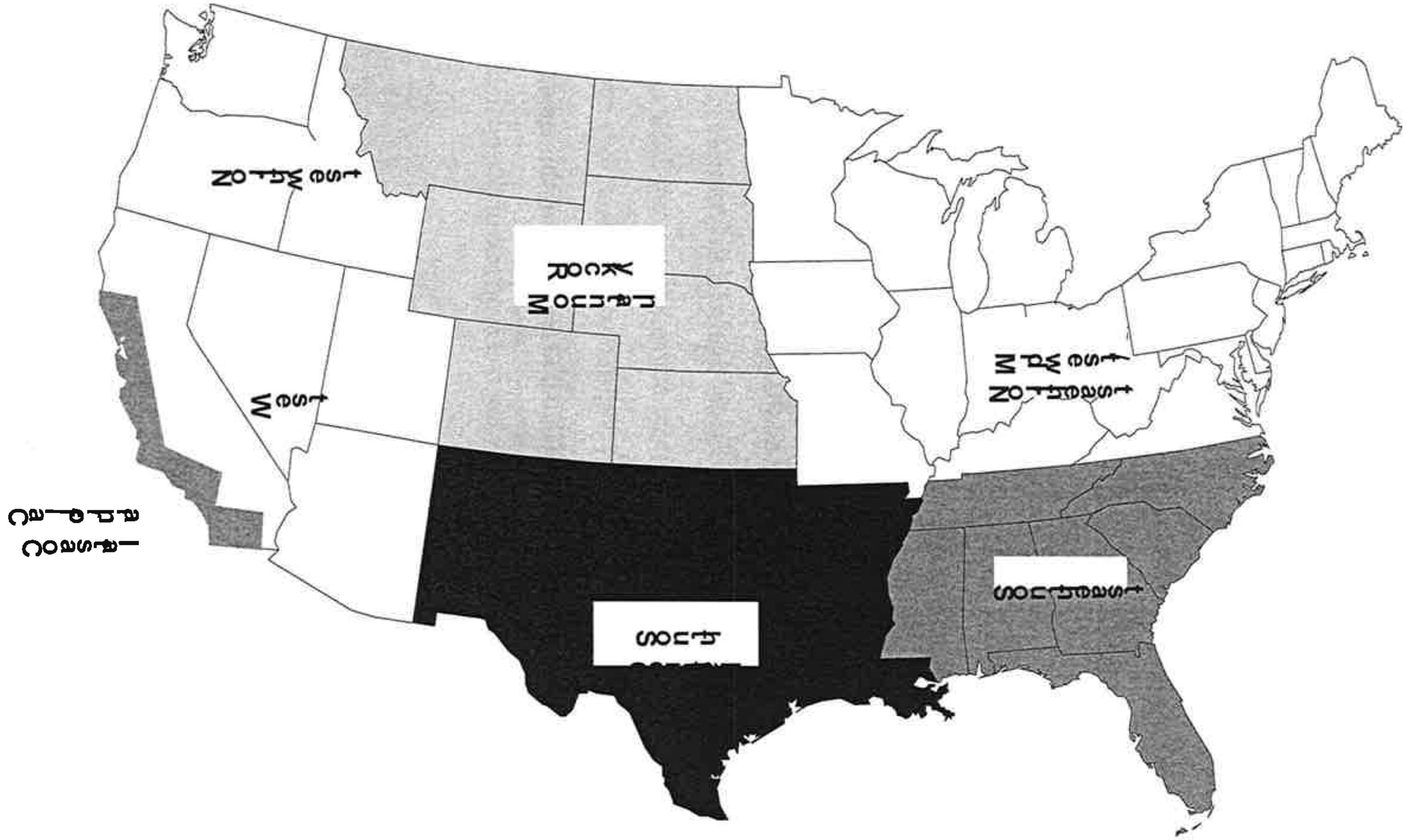
This CS-C analysis rests upon the following bases:

This analysis estimates the control costs for achieving the PM alternatives in counties currently monitored for PM_{10}, as described in Chapter 6. Because sources outside of monitored counties may significantly contribute to elevated PM concentrations in monitored counties, some of these controls may be imposed on sources in *non-monitored* counties. Given long-range transport of $PM_{2.5}$, air quality improvements in non-monitored counties also will be realized.

The analysis is confined to the 48 contiguous States. Further, the set of monitored counties is subdivided into seven regions, the boundaries of which are depicted in Figure 7-1. Only sources and receptors (county-level monitors) situated in a given region are analyzed for that region (*i.e.,* no inter-regional control or air quality impacts are considered). Because fine particle precursors [sulfur dioxide (SO_2), nitrogen oxides (NO_x), and secondary organic

Figure 7-1

PM Modeling Regions Used in Analysis



aerosols (SOA)] can be transported over long distances by prevailing winds, this regional control strategy analysis ("unconstrained analysis") has been performed.

The boundaries of these regions were delineated to reflect both the meteorological conditions that influence the long-range transport of PM precursors and the locations of their major sources (e.g., steam electric utilities). Regional results are presented accordingly.

The 2007 baseline air quality reflective of 1990 Clean Air Act (CAA)-mandated controls is the primary input to the cost analysis. Chapter 6 explains the bases of, and assumptions pertaining to, the 2007 air quality projections.

The cost impacts of attaining the $PM_{2.5}$ alternatives are estimated from a control baseline equivalent to the current PM_{10} alternative (50 $\mu g/m^3$ annual; 150 $\mu g/m^3$ daily [24-hour]—1 expected exceedance form).[a] Thus, all $PM_{2.5}$ costs are *incremental to* this alternative.

The 2007 air quality projections and a set of source-specific emission control measures and associated costs were input to an *optimization model* that selected controls in a least-cost fashion to attain alternative PM levels. These measures were above-and-beyond those controls needed to meet CAA requirements (see Appendix VII-1.) Pollutants considered for control included: direct PM_{10} and $PM_{2.5}$, SO_2, NO_x, and SOA.[b] A more detailed treatment of this model, including an illustration, is given in Appendix VII-2. Following is a synopsis of the modeling steps:

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[a]In this analysis, the daily component of the current standard was computed from the annual component using a ratio based on the 3-year 99th percentile daily concentration, which is assumed to be equivalent to the 1 expected exceedance form of the daily standard.

[b]Sources of anthropogenic emissions, such as feedlots, are not controlled in this analysis. Ammonia sources are not as thoroughly inventoried as other PM precursor emission sources, nor are ammonia controls as well developed and implemented.

1) The Incremental Control Measure Data File sorts the cost inputs (which are in cost/ton form) for each source by source number, pollutant controlled, including $PM_{2.5}$ precursors (i.e., primary PM_{10} and $PM_{2.5}$, No_x, SOA, SO_2), and increasing cost/ton of pollutant reduced. The Incremental Control Measure Data File contains control measures for which sufficient emission reduction and cost information was available at the time of development of the analytical inputs. Most of the control measure information is based directly on EPA documents or State information, although some of the cost information is based on vendor contacts. "Non-convex" measures were excluded from the data base. These are measures for which the cost per ton is higher but the reduction is equal to or less than another measure affecting the same source. For each source category/pollutant combination, any measure which is non-convex on a cost per ton of pollutant emissions reduced would never be selected in determining an optimal solution (i.e., least cost) and was therefore eliminated from the control measure database.

There are also site-specific characteristics which may influence control selection for individual pollution sources (individual plants or jurisdictions). For example, in the PM controls comparison between fabric filters (e.g., shaker, reverse-air, and pulse-jet) and ESP's, cost algorithms are dependent solely on air flow rate. After applying the cost algorithms for the four different options, it was found that the pulse-jet fabric filters were the least costly, so this control technique was the only one used in the control strategy data base. Thus, there are site-specific characteristics which may lead to the selection of a different device than the one applied generically in the cost analysis.

2) The incremental reduction in PM concentration is calculated for each county for the least costly (on a cost/ton basis, equivalent to cost/$\mu g/m^3$) of each individual source/pollutant combination.

3) The cost per average $\mu g/m^3$ reduced across all counties predicted to be at PM levels greater than the alternative examined is calculated for each of these measures.

4) The measure with the *lowest average cost per microgram per cubic meter reduced* is selected, and the PM levels at each county are adjusted to reflect implementation of the selected measure.

5) Steps 2 through 4 are repeated until either all input counties meet the target alternative or the cost/ug/m3-reduced threshold is exceeded by all remaining control measures. The cost/ug/m3-reduced threshold was set equal to $1 billion to eliminate extreme measures that are unrealistically cost-ineffective. A case analysis of two cities (Philadelphia and Denver) was performed to illustrate the cost and air quality impact of cutoffs greater than $1 billion/ug/m3. Results of this analysis indicated that higher cutoffs achieve minimal air quality improvements at an unreasonable high cost. For example, while a $1 billion cutoff for Philadelphia county results in roughly a 20 percent reduction (from the year 2007 CAA baseline) in the annual average PM2.5, a $2 billion cutoff would result in only a 1 percent additional reduction while roughly doubling control costs. Similar results were found for Denver. Since it is highly likely that more cost-effective measures are or will be available by 2007 than those that the model would apply if a greater than $1 billion cutoff were employed, the $1 billion cutoff was maintained.

Appendix VII-2 contains a flowchart that illustrates the optimization modeling steps.

The cost inputs to the optimization model reflect *real, before-tax, 1990 dollars* and a *7 percent real interest (discount) rate.* "Real" dollars are those uninfluenced by inflation; in other words, a "1990 dollar" is assumed to be worth the same today as it was in 1990. "Before-tax" means that the cost analysis does not consider the effects of income taxes (State or federal). Because income taxes are merely transfer payments from one sector of society to another, their inclusion in the cost analysis would bias the results.[1,a] The year 1990 was selected as the cost reference date to be consistent with the CS-C analysis base year. Finally, to be consistent with the real-dollar analytical basis, a 7 percent real interest rate was used, in accordance with Office of

[a]However, these income tax considerations generally would not apply to financial analyses of control cost impacts on firms and other entities.

Management and Budget guidance.[2]

The units of the control cost inputs are *cost per ton*——specifically, the annual cost of the control measure divided by the annual tons of pollutant that it removes. Both the cost and tons removed are measured from the control baseline. Two kinds of cost per ton ($/ton) inputs were used: "constant" and "variable." Constant $/ton inputs were employed with area source control measures (*e.g.*, paved road vacuum sweeping). Cost per ton data for these measures are essentially independent of source size and other cost-determining variables.

Conversely, variable $/ton inputs were applied with point source controls (*e.g.*, fabric filters), as these inputs *do* vary according to source size, as well as emission stream characteristics (pollutant loading, temperature, etc.). For these controls, the $/ton values were computed from these source parameters before being input to the optimization model.

7.3 CONTROL COST RESULTS

This section summarizes the control cost analysis for both partial and full attainment. More details are available from a contractor study.[3]

7.3.1 Partial Attainment Control Costs

The total control costs corresponding to each of the three $PM_{2.5}$ alternatives examined are shown in Table 7-1. Also shown are the numbers of counties predicted to exceed an alternative before ("initial") and after ("residual") the PM Optimization Model was applied. Expressed in billions of 1990 dollars/year, these costs have been computed *incremental to* the baseline PM_{10} alternative.

The cost of attaining a given PM alternative in the monitored counties depends upon the "path" taken to reach it. In achieving this objective, the cost optimization model can apply controls to sources in either two steps or one. It can apply controls so that the monitored counties first meet the current PM_{10} alternative and then apply sufficient additional controls for them to meet the alternative. Alternatively, the model can apply enough controls in one step so that all counties can meet the alternative. The cost of the two-step control strategy could be higher than the one-step approach. Thus, if the incremental-to-current-PM_{10}-alternative costs in Table 7-1 were added to the costs for controlling from the 2007 air quality baseline to the current alternative, the sum could be higher than the costs of controlling directly from the baseline to the $PM_{2.5}$ alternatives.

TABLE 7-1

ESTIMATED 2007 CONTROL COSTS FOR $PM_{2.5}$ ALTERNATIVES INCREMENTAL TO CURRENT PM_{10} ALTERNATIVE

$PM_{2.5}$ Alternative ($\mu g/m^3$)	Number of Counties Violating $PM_{2.5}$ Alternative [a]		Total Cost for Partial Attainment (billion $/yr)[b]
	Initial	Residual	
20/65[c]	24	18	1.7
15/50[d]	126	57	6.3
12.5/50	247	104	14.0

For some counties, the control measures represented by these costs will not reduce emissions sufficiently to achieve the specified level. This situation is referred to as "residual nonattainment". In

[a]"Initial" counties are those with PM levels greater than the alternative before the PM Optimization Model is applied, while the "residual" counties are those that do not achieve the specified level after the model is applied.

[b]All control costs are in real, before-tax 1990 dollars.

[c]The first number is the annual component; the second, the daily component.

[d]Proposed $PM_{2.5}$ standard.

such cases, the cost of full attainment cannot be estimated reliably given the lack of data to develop nonattainment area-specific marginal cost curves. The next section describes an analysis conducted to provide a sense of the potential magnitude of full attainment costs.

Control strategies necessary to achieve attainment of the proposed PM alternatives may be identified in the future. For example, EPA has convened a large group of stakeholders to develop new PM and ozone NAAQS implementation strategies that may offer States innovative and more effective approaches to attainment of the PM NAAQS. For this analysis, the partial attainment scenario results are used to compare the costs, economic impacts, and benefit results.

The Table 7-1 control costs are itemized according to the seven modeling regions in Table 7-2. Although the costs and violating county counts are distributed among the regions, groupings of both occur. From these groupings, certain patterns emerge. Consider the proposed alternative (15 $\mu g/m^3$ annual; 50 $\mu g/m^3$ daily). Here, the two eastern regions (Midwest/Northeast and Southeast) together account for: 50 percent of the initial exceedance of the alternative, 59 percent of the total cost, and 19 percent of the residual exceedance. (PM concentrations in 54 of 65 violating counties were decreased to or below the alternative level.)

Conversely, the Rocky Mountain region contributes 19 percent of the initial nonattainment, 19 percent of the total cost, and 28 percent of the residual nonattainment. (Seven of 23 counties were brought into compliance.) The control strategy in this and some of the other western regions is often driven by fugitive dust sources which are typically more difficult to inventory, and control. Moreover, fugitive dust control measures generally are less efficient in PM removal than are "add-on" stack controls. Consequently, the residual nonattainment may be higher in fugitive dust-dominated violating counties.

Table 7-3 lists the numbers of violating counties by region, along with the nonattainment changes (actual and relative) that occurred after the optimization model was applied. For the proposed alternative, note that the largest nonattainment area reductions occurred in the Midwest/Northeast and Southeast regions: 38 and 16, respectively, corresponding to 79 percent and 94 percent changes. The Midwest/Northeast and Southeast regions also led the others for the 12.5/50 alternative. Here, they contributed 120 of the 143 counties brought into attainment of the $PM_{2.5}$ alternative.

By contrast, for the least stringent 20/65 alternative, the largest violating counties reduction occurred in the West region (3). This success likely is due to the application of fugitive dust controls to sources in this region.

The estimated cost for meeting the current PM_{10} baseline alternative is $1.6 billion/year. This cost was estimated incremental to the 2007 air quality baseline. Twenty-seven of 50 violating counties are predicted to exceed the current PM_{10} baseline alternative after the optimization model has been applied.

TABLE 7-2

ESTIMATED 2007 CONTROL COSTS FOR $PM_{2.5}$ ALTERNATIVES INCREMENTAL TO CURRENT PM_{10} ALTERNATIVE--BY MODELING REGION[a]

$PM_{2..5}$ Alternative (μg/m³)	Modeling Region[b]	Number of Counties		Total Cost for Partial Attainment (billion $/yr)
		Initial	Residual	
20/65	MW/NE	5	3	1.0
	SE	0.00	0.00	0.00
	RM	5	4	0.4
	SC	0.00	0.00	0.00
	W	10	7	0.1
	NW	4	4	0.3
	CC	0.00	0.00	0.00
	TOTAL:	24	18	1.8
15/50	MW/NE	48	10	3.0
	SE	17	1	0.8
	RM	23	16	1.2
	SC	5	1	0.3
	W	17	17	0.3
	NW	14	11	0.6
	CC	2	1	0.2
	TOTAL:	126	57	6.4
12.5/50	MW/NE	120	29	6.8
	SE	37	8	2.8
	RM	33	25	1.7
	SC	18	10	1.6
	W	20	18	0.3
	NW	15	13	0.6
	CC	4	1	0.1
	TOTAL:	247	104	13.9

[a]See footnotes for Table 7-1.

[b]Key: MW/NE = Midwest/Northeast; SE = Southeast; RM = Rocky Mountain; SC = South Central; W = West; NW = Northwest; CC = California Coastal. (For map, see Figure 7-1.)

TABLE 7-3

INITIAL AND RESIDUAL NONATTAINMENT BY MODELING REGION[a]

$PM_{2.5}$ Alternative ($\mu g/m^3$)	Modeling Region[b]	Number of Counties			
		Initial	Residual	Change	Percent Change[c]
20/65	MW/NE	5	3	2	40
	SE	0	0	0	--
	RM	5	4	1	20
	SC	0	0	0	--
	W	10	7	3	30
	NW	4	4	0	0
	CC	0	0	--	--
15/50	MW/NE	48	10	38	79
	SE	17	1	16	94
	RM	23	16	7	30
	SC	5	1	4	80
	W	17	17	0	0
	NW	14	11	3	21
	CC	2	1	1	50
12.5/50	MW/NE	120	29	91	76
	SE	37	8	29	78
	RM	33	25	8	24
	SC	18	10	8	44
	W	20	18	2	10
	NW	15	13	2	13
	CC	4	1	3	75

[a]See footnotes for Table 7-1.

[b]Key: MW/NE = Midwest/Northeast; SE = Southeast; RM = Rocky Mountain; SC = South Central; W = West; NW = Northwest; CC = California Coastal. (For map, see Figure 7-1.)

[c]Percent Change = (Change/Initial) x 100 percent.

7.3.2 Sensitivity Analysis of Full Attainment Control Costs

The incremental control cost estimates presented in 7.3.1 correspond to partial attainment of the three $PM_{2.5}$ alternative standards. Given the available control measures in the Incremental Control Measure Data File and the $1 billion/ug/$m^3$ cost cutoff, the PM Optimization Model could not reduce $PM_{2.5}$ air quality concentrations in all of the monitored counties enough for the alternatives to be met. However, costs of full attainment of $PM_{2.5}$ alternatives would be useful to provide policy makers an estimate of the potential full cost impacts of the alternatives, as well as to provide a consistent basis of comparison with the full attainment benefits. For that reason, based on air quality modeling data and cost optimization model outputs, data useful for gaining a sense of the potential magnitude of the costs of full attainment have been presented. Regionwide average annual $PM_{2.5}$ $\mu g/m^3$ needed to bring residual nonattainment counties into attainment has been estimated. Table 7-4 presents this regionwide average $PM_{2.5}$ $\mu g/m^3$ shortfall per modeling region, as well as annual $PM_{2.5}$ air quality associated with the baseline PM_{10} standard and average annual $PM_{2.5}$ air quality achieved by control measures applied in the cost analysis to attain the proposed $PM_{2.5}$ alternative. The national sum of the regional estimates of average annual $PM_{2.5}$ $\mu g/m^3$ shortfall is approximately 13 $\mu g/m^3$. This is what is needed beyond the average annual $PM_{2.5}$ concentrations achieved in the partial attainment scenario to achieve full attainment of the proposed standard. The national sum of the regional estimates of average annual $PM_{2.5}$ $\mu g/m^3$ shortfall is approximately 7 $\mu g/m^3$ for the least stringent alternative and 18 $\mu g/m^3$ for the most stringent alternative. These average annual $PM_{2.5}$ estimates in shortfall are what would be needed beyond the average annual $PM_{2.5}$ concentrations achieved in the partial attainment scenario to achieve full attainment of the least and most stringent alternatives, respectively.

There is no unequivocal approach to costing out full attainment given significant data limitations. In the modeling used to develop the cost analysis of partial attainment, a $1 billion per $\mu g/m^3$

marginal cost cutoff for average improvements in air quality to nonattainment areas across a region was used. Thus, relying on the identified control measures in the model, attempts to move beyond the currently projected level of partial attainment would cost significantly more than this. To the extent that more cost-effective measures were left out of the model (as for example the regional SO_2 strategy) or that more cost-effective measures are developed in the future, as historical precedent suggests might well happen, the cost of further progress would be correspondingly reduced.

Table 7-4

Proposed Annual $PM_{2.5}$ Standard: Initial Average Baseline $PM_{2.5}$ Air Quality, Average Annual $PM_{2.5}$ µg/m^3 Achieved, Average Annual $PM_{2.5}$ µg/m^3 Needed for Full Attainment in Residual Nonattainment Counties by Modeling Region

Region	Average Baseline Air Quality (Annual $PM_{2.5}$ µg/m^3)	AverageAnnual $PM_{2.5}$ µg/m^3 Achieved Under Partial Attainment Scenario	Average Annual $PM_{2.5}$ µg/m^3 Needed for Full Attainment
MW/NE	20.2 (16.7-23.6)	17.8 (15.1-21.8)	2.8 (0.1-6.8)
RM[a]	23.2 (17.5-25.9)	17.9 (16.3-22.6)	2.9 (1.3-7.6)
SC	16.8	15.1	0.1
SE	19.0	15.1	0.1
NW[a]	17.5 (16.1-19.3)	16.9 (15.6-19.0)	1.9 (0.6-4.0)
W[a]	16.6 (15.8-17.4)	16.2 (15.2-17.1)	1.2 (0.2-2.1)
CA[b]	20.2 (15.9-24.7)	19.4 (15.2-24.0)	4.4 (0.2-9.0)

Key:

MW/NE= Midwest/Northeast; SE= Southeast; RM= Rocky Mountain; SC= South Central; W= West; NW= Northwest; CA= California. (For map, see Figure 7-1.)

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[a] Baseline annual µg/m^3 achieved for PM2.5 are adjusted to standard reference conditions (i.e., temperature and pressure) and therefore overestimate air quality in high altitude areas.

[b] The entire state of California is included in this particular aggregation, rather than dividing the state between two regions.

Range of values presented in parentheses.

7.4 CONTROL COST RESULTS FOR ANALYSIS OF REGIONAL SO_2 STRATEGY IN THE EASTERN U.S.

Finally, a special set of control costs were estimated, via the PM Optimization Model, to assess the potential impact of additional regional SO_2 emission reductions beyond the CAA Title IV requirements in the three eastern regions (Midwest/Northeast, Southeast, and South Central). These costs were estimated for a 50 percent reduction in electric utility SO_2 emissions beyond Title IV SO_2 reduction requirements in the three regions. Based on results from EPA's Regional Acid Deposition Model (RADM), the sulfate components of the PM concentrations in these three Eastern regions were adjusted first to account for full implementation of Title IV. County average percentage reductions between RADM 2010 No Control and Title IV scenarios were applied to the 2007 No Control sulfate concentrations to reflect full Title IV implementation. It should be noted that the change from the original 2007 CAA baseline sulfate concentrations is relatively small. Next, the RADM-predicted post-Title IV sulfate air quality was adjusted to account for the 50% utility SO_2 reduction.

The estimated cost of the 50 percent SO_2 reduction from utilities has been estimated at $4.8 billion (1994$) in the Acid Deposition Standard Feasibility Study Report to Congress.[4] Recognizing that the study used a different methodology for estimating costs, the availability of a cost estimate nevertheless provides an indication of the magnitude of the costs associated with the 50 percent SO_2 reduction. This estimate must be adjusted to 1990 dollars before it can be incorporated into this analysis. Using average Producer Price Indexes[a], the 50 percent SO_2 reduction cost estimate,

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[a]Average producer price index (for Finished Goods) for 1990 = 119.1; for 1994 = 125.5.

expressed in 1990 dollars, is approximately $4.6 billion.[5,6]

The regional control costs, incremental to the 50 percent reduction scenario, are shown in Table 7-4, by alternative and region, along with the initial and residual county counts. The total costs range from $1.3 to $9.8 billion/year, respectively, for the 20/65 and 12.5/50 alternatives. For the proposed alternative (15/50), the total cost of application of the SO_2 strategy in the East is $4.3 billion/year. With all three alternatives, the major portion of the cost is incurred by sources in the Midwest/Northeast region.

Also, the residual nonattainment counts in these regions are lower than those that result when the model is applied to sources without the regional 50 percent reduction. Comparing Table 7-2 with Table 7-4, 12 areas remain in violation of the 15/50 alternative in the three eastern regions without the application of the regional SO_2 strategy, while eight violating counties result when the regional SO_2 strategy is applied (Table 7-4). For the less stringent 20/65 alternative, the violating county counts are much closer: 2 (regional) vs. 3. Finally, the counts for the 12.5/50 alternative are 38 (regional) vs. 47. This regional SO_2 strategy provides for more air quality improvement in the East relative to not having regional SO_2 control. Refer to Chapter 9 for estimated benefits associated with the air quality improvements predicted to result from this strategy.

TABLE 7-5
CONTROL COSTS BY MODELING REGION
INCREMENTAL TO 50 PERCENT SO_2 REDUCTION[a]

$PM_{2.5}$ Altern. ($\mu g/m^3$)	Modeling Region[b]	Violating Counties (No.)[c]		Control Cost for Partial Attainment (billion $/yr)[d]
		Initial	Residual	
20/65[e]	MW/NE	3	2	0.5
	SE	0.00	0.00	0.00
	RM	5	4	0.4
	SC	0.00	0.00	0.00
	W	10	7	0.1
	NW	4	4	0.3
	CC	0.00	0.00	0.00
	Total:	22	17	1.3
15/50	MW/NE	32	8	1.9
	SE	7	0.00	0.00[f]
	RM	23	16	1.2
	SC	2	0.00	0.1
	W	17	17	0.3
	NW	14	11	0.6
	CC	2	1	0.2
	Total:	97	53	4.3
12.5/50	MW/NE	86	27	4.7

[a] These costs are *incremental to* the estimated cost for achieving the electric utilities 50 percent reduction scenario in the East: $4.6 billion (1990 dollars).

[b]Key: MW/NE = Midwest/Northeast; SE = Southeast; SC = South Central; W = West; NW= Northwest; CC = California Coastal. (For map, see Figure 7-1.)

[c]"Initial" counties are those violating an alternative before the PM Optimization Model is applied, while the "residual" counties are those remaining out of compliance after the model is applied.

[d]All control costs are in real, before-tax 1990 dollars.

[e]The first number is the annual component; the second, the daily component.

[f]Less than $0.1 billion/year.

	SE	26	6	1.3
	RM	33	25	1.7
	SC	18	5	1.1
	W	20	18	0.3
	NW	15	13	0.6
	CC	4	1	0.1
	Total:	202	95	9.8

7.5 ANALYTICAL UNCERTAINTIES AND LIMITATIONS

The uncertainty in the inputs to the optimization model are discussed in this section. Because a quantitative uncertainty cannot be ascribed to every input, the total uncertainty in the cost outputs cannot be estimated. Nonetheless, the individual uncertainties can be treated qualitatively.

The air quality projections to 2007 embody several component uncertainties, such as uncertainties in emission data, emission growth rates, baseline air quality data, and air quality model. These uncertainties are addressed in Chapter 6.

In the control strategy analysis, control measures are applied in an "all-or-nothing" fashion. That is, if a measure (such as a fabric filter) is applied to a source, the emission reduction attributed to that fabric filter is the maximum amount it would achieve (typically, > 99 percent over all particle sizes). As the particulate emissions from many sources are already controlled to some extent, the all-or-nothing application of some control measures can result in excess control and, in turn, an overstatement of control costs. In a more rigorous analysis, controls would be applied *incrementally*——that is, the required incremental emission reduction would be exactly matched to the reduction provided by the control measure. However, the numbers of sources and counties that must be optimized in the CS-C analysis are so large (especially in the regional case) that measures must be applied in this "lumpy" fashion to make the analysis tractable.

The control measures applied in this analysis via the optimization model are predominantly add-on (end-of-pipe) controls and other measures normally associated with "command-and-control" abatement policies. Newer measures, such as pollution prevention technologies and emissions trading programs, are not applied.

As noted previously, the optimization model cost inputs are in the form of cost/ton. Even if (as was done for point source controls) these cost/ton figures are adjusted to account for source size differences, these adjustments do not account for other important cost-determining variables, such as source status (new/retrofit), annual operating hours, equipment materials of construction, and unit prices for utilities, materials, and labor.

Most of the cost/ton inputs originally were based upon "study"-level cost estimates, which are nominally accurate to within $\pm$ 30 percent. However, those inputs based on lower-quality estimates (*e.g.*, "order-of-magnitude") are less accurate.

The least-cost optimization model also introduces a measure of uncertainty. The assumptions embedded in such a complex linear programming model are rooted as much in logic as in the data inputs. For instance, when calculating the "cost per average microgram per cubic meter ($\mu g/m^3$)," the model does not count any emission reductions that are in excess of that needed to meet an alternative level. This assumption could cause the cost per average $\mu g/m^3$—and, in turn, the final control costs—to be overstated.

7.6 PM MONITORING COSTS

In anticipation of a revised PM NAAQS, this section presents the costs for reconfiguring the existing PM_{10} monitoring network and for creating a new $PM_{2.5}$ network. These costs, which include recordkeeping and reporting costs, complement the control costs presented in the previous section.

Monitoring (air quality surveillance) networks consist of State and Local Air Monitoring Stations

(SLAMS), National Air Monitoring Stations (NAMS), Photochemical Assessment Monitoring Stations (PAMS), and Special Purpose Monitors (SPMS). The SLAMS are required by EPA to provide ambient concentrations of pollutants for which NAAQS have been established. All SLAMS data must be submitted to EPA. (These networks are further described in an EPA document.[7])

The proposed network for PM_{10} monitors primarily will be derived from the existing network. With a revised standard, the population-oriented NAMS would be maintained and other key sampling locations in existing PM nonattainment areas would be continued. PM_{10} monitoring sites not needed for trends analysis or for monitoring in areas with relatively high PM10 concentrations likely would be discontinued and discouraged in a longer-term network.

A proposed network for $PM_{2.5}$ monitors primarily will consist of a network of population-oriented and other SLAMS monitors, as well as various background and transport sites, NAMS, and SPMS. It is expected that many of the new $PM_{2.5}$ sites will be located at existing PM_{10} monitoring locations, so that better definition of fine and coarse contributions to total PM can be made, for a better understanding of exposure, emission controls, and atmospheric processes.

The following assumptions underlie the development of the PM_{10} and $PM_{2.5}$ monitoring networks:

-- A 3-year period to reach maturity (a complete network)

-- 1997 funding for 1998 network implementation

-- Network phase-in from 1998 to 2000

-- Mature network operation in 2001.

Costs were estimated for PM_{10} and $PM_{2.5}$ monitoring network scenarios. The numbers of monitors and monitoring sites corresponding to these scenarios are:

Pollutant Monitored	Number of Sites	Number of Monitors
PM_{10}	600	760
$PM_{2.5}$	1,200	1,490

Table 7-5 lists the total capital investment (TCI) and total annual costs (TAC) estimated in the year 2001 for implementation of each of these two network scenario. These estimates include costs for labor, electricity, filters, analyses, service, and the like. Each TCI represents the total of all investments in land, instruments, site relocation, and other capital expenditures made through 2001. Each TAC is the sum of the 2001 operating and maintenance costs *plus* the capital charges associated with amortizing the investments made from 1997 through 2001.[a] The TAC's are in 2001 dollars, while the capital costs reflect a range of years.[b] More detailed information on these costs is available.[8,9]

At $22.2 million/year, the TAC of the projected $PM_{2.5}$ monitoring scenario is nearly four times the PM_{10} scenario TAC ($6.0 million/year). This difference is primarily due to the lower PM_{10} TCI. (As most PM_{10} monitors required are already in place, investment requirements would be minimal.) However, even the $PM_{2.5}$ scenario TAC is dwarfed by the control costs estimated to achieve the PM alternative levels. Depending on the alternative, the control costs range from $1.7 to $14.0 *billion*/year (Table 7-1)—nearly 1,000 times higher. The fact that the control and monitoring costs are in different year dollars (1990 vs. 1997-2001), and that they have different year bases (2007 vs. 2001) accounts for little of this contrast.

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[a] The amortizations were made using a 7 percent annual interest (discount) rate and a 15-year equipment life.

[b] Clearly, this is an inconsistency. Each capital cost is expressed in the year dollars that correspond to the year in which the monitoring investments were made. However, as the capital costs were adjusted to the investment years via the Consumer Price Index—which has increased by less than 3 percent annually—the inconsistency is relatively minor.

TABLE 7-6

PM MONITORING COSTS PROJECTED TO 2001

Pollutant Monitored	Total Capital Investment (million $)	Total Annual Cost (million $/yr)[a]
PM_{10}	0.4	6.0
$PM_{2.5}$	18.5	22.2

7.7 SUMMARY AND CONCLUSIONS

As Table 7-1 shows, the estimated costs of attaining the $PM_{2.5}$ alternatives in 2007 in the PM_{10} monitored counties increase with increasing stringency. These costs range from $1.7 to $14.0 billion/year above the current PM_{10} baseline alternative. For the proposed alternative analyzed, 15 $\mu g/m^3$ annual; 50 $\mu g/m^3$ daily, the estimated cost is $6.3 billion/year. This translates to annual costs of $69 per household or $25 per capita. The estimated cost of meeting the current PM_{10} alternative (incremental to the 2007 air quality baseline) is $1.6 billion/year. Both sets of estimates dwarf the costs estimated for the PM_{10} and $PM_{2.5}$ monitoring networks: approximately $6 and $22 million/year, respectively.

Although there are considerable uncertainties in the approach, an analysis was conducted to assess the nature of the costs that might be associated with full attainment of the proposed annual $PM_{2.5}$ standard. Based upon the air quality modeling used for this analysis, the regionwide average annual $PM_{2.5}$ $\mu g/m^3$ needed to bring residual nonattainment counties into attainment of each alternative has been estimated. For the proposed standard, the national sum of the regional estimates of average annual $PM_{2.5}$ $\mu g/m^3$ shortfall is approximately 13 $\mu g/m^3$. This is what is needed beyond

[a]TAC = sum of operating and maintenance costs in 2001 plus capital charges for all investments made between initial year (1997) and maturation year (2001), inclusive.

the average annual $PM_{2.5}$ concentrations achieved in the partial attainment scenario to achieve full attainment of the proposed standard.

Finally, in a supplemental analysis, it was found that applying Eastern regional SO_2 controls beyond those in Title IV prior to running the county-level regional control strategy would increase total costs in the three Eastern regions by $2.5 billion for the proposed $PM_{2.5}$ alternative, but also would increase the number of counties that are projected to attain the proposed standard by 2007.

7.8 REFERENCES

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3. *Complemental National Cost Analysis of Alternative Particulate Matter National Ambient Air Quality Standards: Draft Report*. Prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards (Research Triangle Park, NC) by E.H. Pechan & Associates (Springfield, VA). EPA Contract No. 68-D3-0035, Work Assignment II-79, May 1996 and September 1996 (*Addendum*).

4. *Acid Deposition Standard Feasibility Study Report to Congress,* EPA-430-R-95-001a. U.S. Environmental Protection Agency, Office of Air and Radiation, Acid Rain Division (Washington, DC), October 1995.

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7. *Draft Regulatory Monitoring Strategy for a Revised PM NAAQS: A Blueprint for a New National Monitoring Program for Particulate Matter*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards (Research Triangle Park, NC), April 3, 1996.

8. *Cost of Ambient Air Monitoring for Criteria Pollutants and Selected Toxic Pollutants*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards (Research Triangle Park, NC). EPA-454/R-93-042, October 1993.

9. "Revised Cost Estimates: PM-10/PM Fine Monitoring Networks". U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions Monitoring and Analysis Division, Monitoring and Quality Assurance Group. August 8, 1996.

APPENDIX VII-1

CONTROL STRATEGY-COST ANALYSIS CONTROL MEASURES

The control measures used in the control strategy—cost analysis are tabulated below, along with the applicable source category, pollutant(s) controlled, and data source.
(A legend follows the table.)

Source Category	Control Measure	Pollutants Controlled	Source
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LEGEND

AF — air/fuel adjustment

AIRCOST — utility SO_2 control cost model (E.H. Pechan & Associates)

BARCT — best available retrofit control technology

BOOS — burners out-of-service

CARB — California Air Resources Board

CTG — control technique guideline

ERCAM NO_x — *Emission Reduction and Cost Analysis Model for NO_x - Final Report*, E.H. Pechan & Associates, May 1994

ERCAM VOC - *Enhancements to the Emission Reduction and Cost Analysis Model for VOC - Draft Final*, E.H. Pechan & Associates, March 31, 1994

ESP — electrostatic precipitator

FGD — flue gas desulfurization

FGR — flue gas recirculation

FIP — Federal implementation plan

I/M - inspection/maintenance

IR — ignition timing retardation

LEA — low excess air

LNB — low-NO_x burner

MACT — maximum achievable control technology

NGR — natural gas recirculation

NO_x — oxides of nitrogen

NSCR — non-selective catalytic reduction

OFA — overfire air

OXYFIRING — firing of glass furnaces with oxygen-enriched combustion air

PM — particulate matter

PM Study — *Regional Particulate Strategies*, E.H. Pechan & Associates, September 1995

P-V valves — pressure-vacuum valves

RACT — reasonably available control technology

SCAQMD — South Coast Air Quality Management District

SCR — selective catalytic reduction

SNCR — selective non-catalytic reduction

SO_2 — sulfur dioxide

ULNB — ultra low-NO_x burner

VOC — volatile organic compound

APPENDIX VII-2
PM OPTIMIZATION MODEL

This appendix describes the PM Optimization Model used in the monitored counties cost analysis. An example is also included to illustrate how the model estimates control costs.

The optimization model uses the following inputs to determine which control measures to apply to meet alternative PM_{10} and $PM_{2.5}$ target ambient levels:

Incremental Control Measure Data File: This file contains the incremental precursor pollutant emission reductions and the total annual cost for each individual control measure. There are approximately 230,000 entries in this file representing measures as varied as vacuum sweeping a particular road-type in a county, or installing fabric filters or SO_2 scrubbers on utility boilers. The source number indexed to the S-R matrix is included as a key variable in this file.

Optimization on a cost per ton of pollutant emissions reduced was used to create the incremental control measure data file. Thus, for any individual source (e.g., boiler), only the control measures most cost-effective at reducing the precursor emissions are included in the incremental control measure data base. This step eliminates solutions that would be considered non-convex from a linear programming standpoint. Non-convex measures are those in which the cost per ton is higher but the reduction is equal to or less than another measure affecting the same source. For each source category/pollutant combination, any measure which is non-convex on a cost per ton of precursor emissions basis would never be selected in determining an optimal solution and was, therefore, eliminated from the control measure data base.

Source-Receptor Matrix: This file relates emissions or emission reductions from a source to a receptor (located at a county centroid). It is used to calculate the change in total PM_{10} and

$PM_{2.5}$ concentration resulting from the emission reductions associated with a control measure in the incremental control measure data file.

Receptor Input File: This file contains the starting total PM_{10} and $PM_{2.5}$ concentrations (equivalent to the concentration predicted in 2007 under the CAA scenario) and any calibration factors developed based on the relationship between monitored and modeled values.

The optimization routine developed for this analysis is as follows:

1) The incremental control measure data file is sorted by source number, precursor pollutant controlled, and increasing cost per ton of pollutant reduced.

2) The incremental reduction in PM concentration (either PM_{10} or $PM_{2.5}$ depending on the target standard) is calculated for each receptor for the least costly (on a cost per ton basis) of each individual source/pollutant combination. While selection is on a cost per microgram per cubic meter basis, for a given source/pollutant combination (where source is defined as one of the 5,931 sources such as all area sources for Fairfax County, Virginia), the measure with the least cost per ton will also be least costly on a cost per microgram basis. This is so because the S-R coefficient (i.e., the ratio between emissions at a source and the air quality concentration at a monitor) is the same for that source/receptor combination.

3) The cost per average microgram (per cubic meter) reduced across all receptors out of compliance with the standard is calculated for each of these measures. Thus, for a receptor already meeting the target standard, the impact of a control measure on that receptor would not be counted so that measures which impact receptors already in compliance are not selected. These reductions are carried through in the final analysis of receptor concentration. In addition, any reduction which is in excess of that needed to meet the standard is not counted in the calculation of the cost per average microgram.

4) The measure with the lowest average cost per microgram reduced is selected and the PM levels at each receptor are adjusted to reflect implementation of the selected measure.

5) Steps 2 through 4 are repeated until all input receptors meet the target level or the minimum cost per microgram reduced threshold is exceeded by all remaining measures. The minimum cost per microgram threshold is used to eliminate measures that either (1) have little or no effect at non-complying receptors; or (2) are extremely costly. The minimum cost per microgram is calculated as the cost per microgram reduced for the receptor that achieves the most reduction due to a measure. The current threshold is set at $1 billion per microgram per cubic meter. If the cost per microgram reduced exceeds this value for all receptors currently out of compliance, the measure is not selected. If all remaining measures exceed this value, the simulation ends.

The cost per average microgram of PM reduced—the selection criterion used by the model to choose among measures—is calculated for either PM_{10} or $PM_{2.5}$ on either an annual or 24-hour average basis depending on the alternative being examined. Figure VII-1 depicts the PM Optimization Model steps.

Table VII-1 illustrates the calculation of the cost per average microgram reduced. In this example, control measure 2 would be selected first, followed by measure 1 and measure 3 as needed. Note, however, that if the application of measure 2 brought receptors 2 through 4 into compliance with the NAAQS of interest, measure 3 would be selected in preference to measure 1, since receptors 2 through 4 would no longer be included in the calculation of the cost per average microgram reduced. By only including receptors out of compliance in the calculation of the cost per average microgram reduced, selection of measures which have little or no impact in reducing concentration in non-complying areas is avoided.

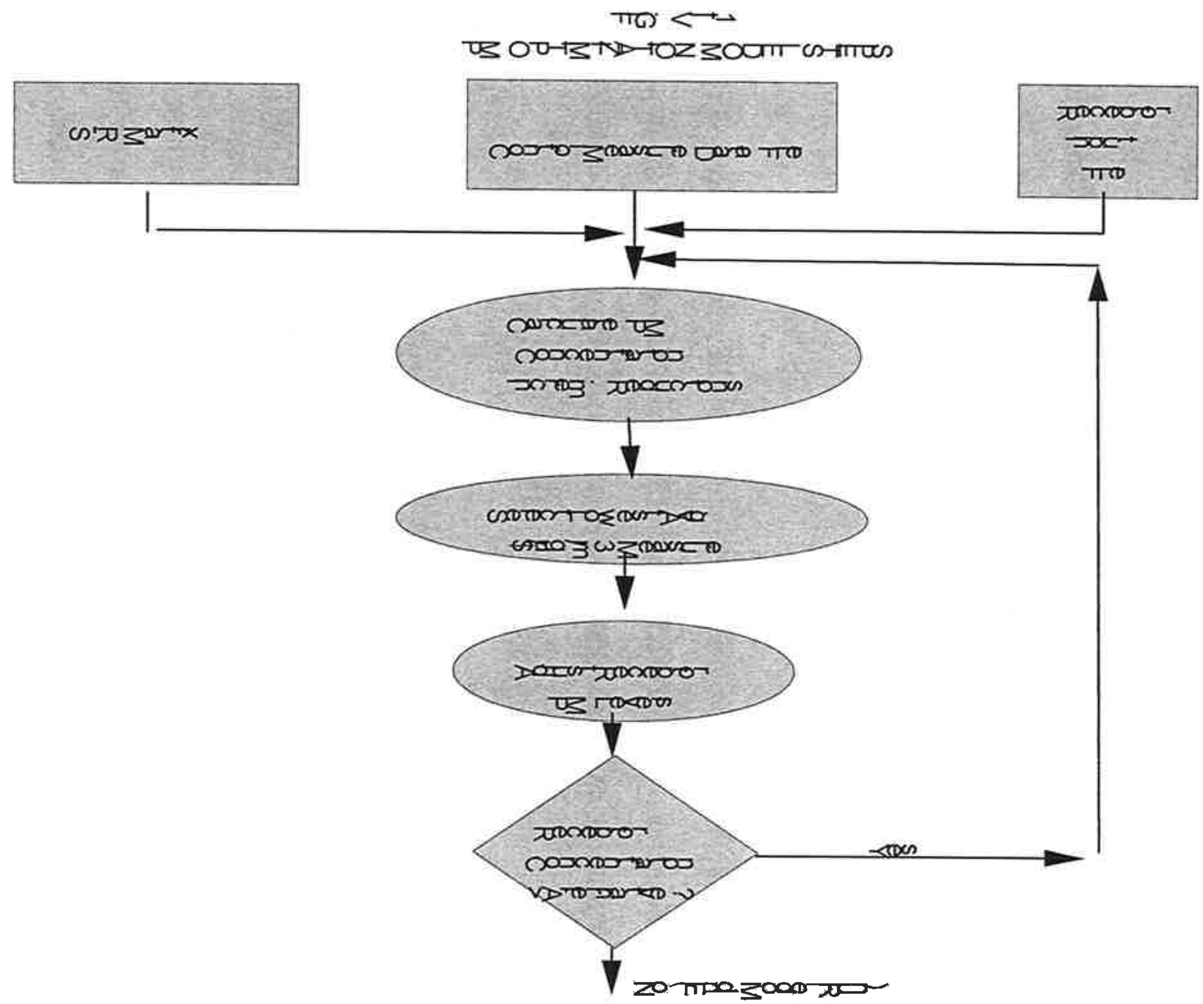

TABLE VII-1

CALCULATION OF COST PER AVERAGE MICROGRAM REDUCED

	Control Measure 1	Control Measure 2	Control Measure 3
Cost (million $/yr)	1.0	1.5	1.5
PM_{10} Reduced ($\mu g/m^3$)			
Receptor 1	0.2	0.3	0.8
Receptor 2	0.3	0.4	0.1
Receptor 3	0.1	0.5	0.1
Receptor 4	0.3	0.4	0.0
Average	0.225	0.400	0.250
Cost per microgram per cubic meter (million $/$\mu g/m^3$)			
Receptor 1	5.0	5.0	1.9
Receptor 2	3.3	3.8	15.0
Receptor 3	10.0	3.0	15.0
Receptor 4	3.3	3.8	--
Average*	4.4	3.8	6.0

[illegible]

8.0 ECONOMIC IMPACT ANALYSIS

8.1 INTRODUCTION

This chapter contains a summary of the results of the economic impact analysis (EIA) associated with attainment of PM alternatives in the year 2007, the year chosen as the period for which all impacts shown in this RIA are estimated as mentioned in Chapter 1. It provides information as to the potential economic impacts that the control strategy costs, as estimated for the three $PM_{2.5}$ alternatives incremental to the current PM_{10} alternative, may have on affected industries and source categories impacted by the control measures selected in the cost analysis and that are described in Chapter 7 of the RIA. The different types of data, methods of analyses, and calculations summarized in this chapter include:

- A summary of economic and financial data on industries potentially impacted by the PM control measures selected in the cost analysis. Among the data presented in the chapter and appendices are sales and employment data per affected industry.

- Two sets of control cost-to-sales ratios: 1) a ratio for all the affected establishments (places of business) in an industry or source category, and 2) another ratio for the small establishments only. Preparing the second set of ratios was done in order to provide estimates of the potential impacts on small entities associated with the PM control measures selected for each of the $PM_{2.5}$ alternatives examined. This part of the analysis is called a screening analysis.

- An estimate of the potential for impacts on affected government entities associated with the PM control measures selected for each $PM_{2.5}$ alternative examined in the cost analysis. Cost-to-budget expenditure ratios are employed to estimate the potential impacts on county-level government agencies due to the potential pollution control cost incurred for the $PM_{2.5}$ alternatives.

- There is also a section on how the issue of environmental justice is handled within the RIA.

The control cost estimates that were estimated in the year 2007 for $PM_{2.5}$ alternatives incremental to the current PM_{10} alternative (shown in Table 7-2) were the cost inputs to the economic impact analysis. The methodologies do not employ any of the monitoring costs nor any administrative costs as inputs.

It should be noted that the economic impacts presented in this chapter were estimated for the implementation of control strategies that do not reflect on the ongoing work of the Subcommittee of the Clean Air Act Advisory Committee that is examining new integrated approaches for implementing the proposed revisions to the ozone and particulate matter NAAQS. As indicated in Chapter 1 of this RIA, the control strategies that emerge from this process may be more efficient and environmentally effective than the ones analyzed here. Further, this RIA does not take into account that significant jointness may exist in the resulting control strategies for both ozone and particulate matter that may have significant bearing on both costs and benefits (and, by implication, economic impacts) associated with the implementation strategies for reducing ozone and particulate matter concentrations. Since this RIA and this economic analysis employed existing non-integrated (i.e., considering ozone and PM control together) technical models and implementation strategies, results from these analyses should be interpreted with these limitations in mind.

It should also be noted that this economic analysis provides estimates concerning possible negative cost and employment impacts for certain industrial categories organized by SIC codes. As is noted in the relevant sections, these estimates are uncertain for two reasons: 1) They do not take into account the variety of localized or regional implementation strategies that may follow the setting of new standards. Such tailored strategies will likely serve to mitigate negative impacts on local industries, and 2) They do not account for growth in revenue and employment that also may result from additional pollution control equipment sales, or from substitutions that will transfer revenue from one industry to another (e.g., oil to natural gas). Regardless of these uncertainties, however, these estimates will be useful in guiding implementation activities, for they serve to pinpoint efforts to mitigate potential negative economic impacts.

The economic impacts presented in this chapter only reflect the direct costs of the application of the control measures selected in the cost analysis summarized in Chapter 7. The Agency recognizes that the economic impacts associated with the control measures, both positive and negative, are distributed beyond the directly affected industries (e.g., the natural gas industry receiving additional revenues due to expanding markets, the effect of pass through regulatory costs on consumer demand, but was unable to prepare estimates of these because of limited data. The EPA will provide market impact estimates using a sample of affected industries for the costs associated with the implementation plans that will be developed during the PM Part 51 implementation process.

No economic impacts associated with the full attainment costs presented in Section 7.3 were estimated in this analysis.

Finally, the economic impacts associated with attainment of the current PM_{10} standard were not estimated in this analysis.

The chapter is organized as follows:

1) a profile of affected industries

2) the methodology and results for the screening analysis, which includes results for all impacted entities and separate results for impacted small entities

3) the methodology for and results from an analysis of governmental entities. Results for impacted small governmental entities are presented here, and

4) a section on how environmental justice is considered in the analyses

8.2 PROFILE OF AFFECTED INDUSTRIES

8.2.1 Purpose of Profile

The purpose of the profile of affected industries is to summarize various market characteristics of economic sectors potentially affected by revisions to the particulate matter (PM_{10}) National Ambient Air Quality Standard (NAAQS) for subsequent consideration in preparing the EIA, and to provide information on economic sectors valuable in examining the impact when the revised NAAQS are implemented by the States. This information is the background material for the screening-level and governmental entities analyses.

8.2.2 Types of Sources

As estimated in the cost analysis, the revised PM_{10} NAAQS when implemented by the States may have an impact on industries in up to 226 3-digit Standard Industrial Classification (SIC) codes, approximately 56 percent of the 427 3-digit SIC codes for the United States as categorized by the Department of Commerce (DOC). The control measures cover stationary (point and area) and mobile (on-highway and nonroad) sources. Most of the sources in the profile came out of the National Particulate Inventory (NPI).

8.2.2.1 Stationary Point Sources

Point sources in the NPI are primarily facilities or establishments that emit 100 tons per year or more of one of the criteria air pollutants. The point source inventory also contains SIC codes for most of the facilities. For each of the incremental control measures, the Emission Reductions and Cost Analysis Model (ERCAM) and the AirCost model (for SO_2 costs) were used to identify all of the potentially affected facilities and their SIC codes. The SIC codes and sectors potentially affected by each incremental PM, SO_2, and NO_x control measure are shown in Appendix VIII-1 for utility, industrial, commercial, and institutional (ICI) boilers. Appendices VIII-2 and VIII-3 show the SIC codes and sectors potentially affected by the control measures for volatile organic compounds (VOC) and non-boiler NO_x sources, respectively.

For more information on stationary point sources, consult the Industry Profile for Review of the NAAQS for PM_{10}.[1]

8.2.2.2 Stationary Area Sources

The area source inventory accounts for stationary source emissions not included in the point source inventory. An area source is defined as a source that emits less than 100 tons per year of a criteria pollutant. In this inventory, the area sources are facilities or establishments that emit less than 100 tons per year of VOC or NO_x. The SIC codes potentially affected by the area source control measures for PM, VOC, and NO_x, and these are shown in Appendices VIII-4 and VIII-5. They were identified either from the SIC Manual 1987 or from the National Emissions Inventory (NEI).

8.2.2.3 Mobile Sources

8.2.2.3.1 On-Highway Sources

Light-duty vehicles, medium-duty vehicles, heavy-duty vehicles, and light-duty trucks are the four types of on-highway sources. The control measures applied to them to control VOC and No_x are a combination of fuel reformulations, new vehicle exhaust emission standards, and an enhanced inspection and maintenance (I/M) program. Appendix VIII-6 shows the SIC codes and industries/source categories that are potentially affected by each of the control measures.

For more information on these sources and control measures, consult the Industry Profile for Review of the NAAQS for PM_{10}.

8.2.2.3.2 Nonroad Mobile Sources

These sources include large nonroad compression ignition (diesel) engines, small recreational vehicle spark-ignition (gasoline) engines, emission fees for commercial marine vessels; and reformulated gasoline and diesel fuel for nonroad vehicles. The reformulated gasoline and diesel fuel control measures for nonroad engines are the same as those applied to on-highway vehicles.[2] Appendix VIII-7 shows the SIC codes and sectors that are potentially affected by each of the control measures.

8.2.3 Industry Profile - Economic and Financial Data

The economic data used in estimating the potential economic impacts of implementing control measures associated with the PM NAAQS alternatives are displayed in this section following the categorization established by the *Standard Industrial Classification Manual 1987* (Office of Management and Budget [OMB], 1987).[3] The data contained in this chapter are reported by 3-digit SIC code, and include: the number of firms and establishments, employment, and sales revenue. The six major sectors are:

- Manufacturing;
- Agriculture, Mining, and Construction;
- Transportation, Communications, and Utilities;

- Wholesale and Retail Trade and Real Estate;
- Services; and
- Public Administration.

The following sections outline the general approach used to develop this economic profile, the definition of terms, and sector-specific data issues that differ from the general approach. The data contained in this section are presented primarily on a 3-digit SIC code level based on the comprehensive list of potentially affected SIC codes presented in the previous chapter. For some industries this data is not available at the 3-digit SIC code level, and the data for these industries is presented at the 2-digit SIC code level.

8.2.3.1 General Approach

Given the large number of SIC codes, it is infeasible with present resources to develop a detailed economic profile and EIA for each industry potentially affected by a control measure. Once the types of data mentioned above are collected, it is possible to conduct a screening analysis. This analysis is an effort to calculate average cost-to-sales ratios for each affected SIC code. The purpose of this task is to provide some estimates of potential economic impacts, and to eliminate the need for more extensive analysis of certain SIC codes, particularly in cases where the incremental cost impact is likely to be negligible. The screening analysis, it should be noted, provides enough information for an initial Regulatory Flexibility Analysis (RFA) if such an analysis were to be done. An initial Regulatory Flexibility Analysis is an analysis of the economic impacts on affected small entities to determine if the impacts meet thresholds of signficance stated in the guidelines to the Regulatory Flexibility Act, the Act that is the legal authority for the RFA, and in draft guidelines to the recently adopted Small Business Regulatory Enforcement Fairness Act (SBREFA). A final RFA is prepared if the thresholds are met.[4]

Perhaps the most comprehensive source of revenue data is the 1987 Bureau of the Census' *Enterprise Statistics* (Department of Commerce [DOC], 1991a).[5] This publication provides company, establishment, employment, and sales totals by employment size category (e.g., 101-200 employees) on a 2- and 3-digit SIC code level. Because the *Enterprise Statistics* data are not available for all potentially affected SIC codes (e.g., agricultural industries), this source was supplemented by other related Census publications.[6,7]

Throughout this chapter, the term *establishment* is defined as a single physical location at which business is conducted or where services or industrial operations are performed. It is not necessarily identical to a *firm*, which may consist of one establishment or more. A *firm* is defined as a business consisting of one or more domestic establishments that the reporting firm specified under its ownership or control during the reporting year. *Employment* is defined as all employees (full-time and part-time) as reported on establishment payrolls. The sales data reported in this chapter are on an establishment, rather than a firm level for two main reasons: (1) the cost input data is provided on an establishment basis, and (2) establishment-level revenue data are available for more SIC codes than firm-level revenue data.

To perform the screening analysis, economic and financial data are needed for the following two size categories: *all* establishments regardless of size, and *small* establishments. The Small Business Administration's (SBA) small business size standards are generally based on the total number of employees in a *firm*, and is usually defined for the majority of potentially affected industries as firms with 500 or less employees.[8] The revenue data in this chapter are presented by employment size category. Other small business cut-offs include various revenue thresholds and higher employment size thresholds. A 100 employee cut-off was selected to conservatively link the SBA's definition of small firms to an establishment basis. A small establishment in this analysis is defined as having less than 100 employees. The average revenue for small establishments in each potentially affected SIC code was calculated as the total sales generated by establishments with less than 100 employees, divided by the total number of establishments with less than 100 employees.

The average revenue at small establishments is compared to each industry's average sales over all employment size categories to provide an assessment of the significance of small businesses in each affected SIC code. High ratios of average sales at small establishments to average sales over all establishments for a given SIC code indicate the potential for an industry to be small business-dominated. To protect the confidentiality of operations at individual establishments, sales data for some employment size categories were not available.

The sales data presented in this chapter were projected to 2007 production levels for consistency with the cost data that will be used in the EIA. Industry-specific growth factors were obtained from the Bureau of Economic Analysis (BEA).[9] Revenue data were also converted to 1990 price levels using the 1987-1990 gross domestic product (GDP) implicit price deflator (DOC, 1992).[10]

8.2.3.2 Industry Sectors

The following sections identify data issues that arose in the preparation of this industry profile. In most cases, the general approach described in the previous section was followed to provide the data contained in this chapter.

8.2.3.2.1 Manufacturing

Appendix VIII-7 presents the number of establishments, firms, and employees in a given SIC code for each manufacturing industry that may incur costs associated with one or more of the control measures listed in Appendix VIII-6. To provide a more detailed characterization of the potentially affected industries, Appendix VIII-7 shows the total number of establishments, firms, and employees for establishments with less than 100 employees and for establishments with less than 500 employees. Also shown is the percentage of total industry establishments, firms, and employment accounted for by establishments with less than 100 employees, and by establishments with less than 500 employees. Generally, the *Enterprise Statistics* data reported for establishments with less than 500 employees is less complete than the data provided for establishments with less than 100 employees. A double asterisk (**) is shown in Appendix VIII-7 for these cases.

Appendix VIII-7 presents average revenue per establishment by SIC code. For each potentially affected SIC code, average sales are presented for a typical establishment regardless of size, and for a typical *small* establishment (with less than 100 employees). For those 3-digit SIC codes for which insufficient data were available to calculate average sales for small establishments, small establishment sales were estimated by applying the proportion of average sales for small establishments to all establishments at the 2-digit SIC code level to the 3-digit SIC code sales data for all establishments. These costs are denoted with a double asterisk (**) in Appendix 8-7.

8.2.3.2.2 Agriculture/Mining/Construction

Establishment and revenue data are not available by employment size category for SIC codes in the agricultural production sector (2-digit SIC codes 01 and 02). The SBA generally uses a $0.5 million revenue threshold to differentiate small farms from large farms. The total number of farms and the total number of farms with less than $500,000 in market value of agricultural products sold are available from the 1987 Census of Agriculture.[11] The Census of Agriculture also reports the average revenue per farm for all farms, and the average revenue per farm for farms with less than $500,000 revenue from agricultural products sold.

Appendix VIII-8 presents these data for the SIC codes associated with agricultural production that are potentially affected by the PM NAAQS alternatives. Data on the number of establishments and employment for these SIC codes are not available.

8.2.3.2.3 Agricultural Services, Forestry, Mining, and Construction Industries

Appendices VIII-9 and VIII-10 present the available establishment, firm, employment, and revenue data for the industries in the agricultural services, forestry, mining, and construction sectors that are potentially affected by the PM implemenation strategies examined. The sources that were used to obtain the data in these tables include *County Business Patterns*, *Census of Mining Industries,* and *Census of Construction Industries.* [12,13,14]

Revenue data are not available for the agricultural service and forestry SIC codes (i.e., 07 and 08). Because of this limitation, payroll data were used as a surrogate for revenue data. However, it should be noted that the use of payroll data as a surrogate for revenue data will likely underestimate revenues.

8.2.3.2.4 Transportation, Communications, and Utilities

Appendices VIII-11 and VIII-12 present the available Census data for the industries in the transportation, communications, and utility sectors potentially affected by the PM implementation strategies examined. The 1992 data were converted to 2007 production levels and 1990 prices using the 1992 to 2007 BEA growth factor for the appropriate SIC code and the GDP implicit price deflator between 1990 and 1992.

8.2.3.2.5 Wholesale and Retail Trade and Real Estate

The data presented in Appendices VIII-13 and VIII-14 for the wholesale trade, retail trade, and real estate sectors were summarized from data published in *Enterprise Statistics*, the *1987 Census of Retail Industries*, and the *1992 Census of Financial, Insurance, and Real Estate Industries.*[15,16,17] The 1992 data were converted to 2007 production levels and 1990 prices using the appropriate 1992-2007 BEA growth factor and the GDP implicit price deflator between 1990 and 1992.

8.2.3.2.6 Services

Appendices VIII-15 and VIII-16 present the establishment, firm, employment, and revenue data that were available from the Bureau of the Census for potentially affected SIC codes in the services sector. Individual publications used in developing the data were: *Enterprise Statistics 1987 Census of Service Industries*, and *1990 County Business Patterns*.[18,19,20]

8.2.3.2.7 Public Administration

The Bureau of the Census publishes annual budget data for States and counties by government function (e.g., highways, public safety).[21] Direct expenditure data are available by State and county; however, the State data do not report the amount of money spent in each county in that State (the direct expenditure data by county only indicate the amount spent by county governments, not the amount of State expenditures by county). Given the amount of effort required to develop methods for allocating the State data to counties for each county in the United States, the data for this section only represent county expenditures.

Appendix VIII-17 displays estimated expenditures in 2007 for affected government agencies. Except for SIC code 962, the list of agencies affected is based on the SIC codes listed with emissions sources in the NPI that are potentially affected by the PM implementation strategies examined. The paved and unpaved road emission source category directly impacts SIC code 962– Regulation and Administration of Transportation Programs. Because this source category is estimated to be affected by control measures for greater than 3,000 counties under the most stringent PM NAAQS alternative, the overall county transportation expenditure average for the nation was used in the analysis. In addition, specific county-level expenditure data are displayed that represent inputs for a cost-to-expenditure analysis of a random sample of 20 U.S. counties in

Appendix VIII-18. This will be part of the governmental entities analysis, which is a sensitivity analysis. For control measures affecting point sources identified with SIC code 971–National Security, expenditure data are presented on a national level only because the Federal government is the entity directly impacted.

8.3 SCREENING ANALYSIS

8.3.1 Introduction

Because of the large number of SIC codes affected, a cost-to-sales ratio screening analysis has been conducted to identify those industries or source categories potentially experiencing impacts. The results of the screening analysis provide information regarding potential impacts on establishments in affected SIC codes. In order to conduct the screening analysis, it is necessary to take the cost estimates for the control strategies used in the cost analysis and calculate average control measure costs per source category on an SIC code basis. These average control measure costs are then divided into the number of establishments in the SIC code to provide an average annual cost per establishment for each affected SIC code. This average annual cost per establishment is then divided into the average revenue of establishments in potentially affected industries for each affected SIC code, and the result is the cost-to-sales ratio for each affected SIC code. The analysis was conducted at a 3-digit SIC code level because financial data are more often available at that level compared to others.

To evaluate small entity impacts, separate cost-to-sales ratios were also developed on a SIC code basis using average revenue data for establishments with 100 or less employees instead of the 500 employees per firm. The lower, conservative threshold of 100 employees per establishment was chosen because: 1) control cost data were not generated at the firm-level, only at the establishment-level; and 2) published sales data typically are not available for a 500-employee threshold due to confidentiality concerns over presenting data for specific establishments.

Control costs for point sources were provided on a facility basis, and the affected SIC code for most sources represents the SIC code reported in the NPI for each potentially affected source. The SIC codes potentially affected by the area source control measures were either identified from the SIC Manual 1987 or the NEI.

8.3.2 Methodology

Each SIC code identified as affected by a control measure was used to link the average control cost per establishment with a measure of the national average sales per establishment for each affected industry. Cost data for each area source control measure were provided by nonattainment area and control measure.

The number of establishments were estimated differently depending on the type of control measure. For stationary point sources, the number of affected establishments represents the number of unique plants affected by each control measure. For stationary area and mobile sources, EPA obtained data on the number of affected establishments by county and SIC code.[22]

National sales data are available by 3-digit SIC code from the Bureau of the Census' Enterprise Statistics and related publications.[23] Because of the broad scope of the PM NAAQS, average national sales were used. For each potentially affected SIC code, the following two values were obtained: 1) a national average sales per establishment over all employee size categories, and 2) a national average sales per establishment for establishments with less than 100 employees.

Nearly 30 percent of the industries impacted (63 SIC codes) may be affected by more than one control measure. The cumulative control costs associated with multiple control measures imposed on an industry or source category are reflected in the cost-to-sales estimates.

The 3 percent threshold for estimating potentially significant economic impacts was chosen to avoid excluding SIC codes with small establishments for which potential impacts may be significant because of uncertainties associated with the cost estimates and sales data, and limitations due to lack of data. This threshold is the same as that used in the California ozone Federal Implementation Plan (FIP) RIA.[24]

8.3.3 Results

Table 8-1 presents a summary of number of industries with potential impacts under the control strategies used for each PM alternative and cost-sales ratio threshold.[25] Under the control strategies for the $PM_{2.5}$ 20 $\mu g/m^3$ annual/65 $\mu g/m^3$ daily alternative, industries in 171 SIC codes have a cost-to-sales ratio greater than zero, with 41 SIC codes meeting a 3 percent threshold analyzed over all establishments within those industries. Under the control strategies for the proposed $PM_{2.5}$ alternative, the $PM_{2.5}$ 15 $\mu g/m^3$ annual/50 $\mu g/m^3$ daily, there are 216 SIC codes impacted having cost-to-sales ratios greater than zero and 51 SIC codes with cost-to-sales ratios exceeding 3 percent. For these two alternatives, most industries' cost-to-sales ratios are estimated to be below 1 percent. The number of SIC codes impacted for the most stringent alternative, the $PM_{2.5}$ 12.5 annual/50 daily, is 226, and the number of SIC codes with establishments having cost-to-sales ratios exceeding 3 percent increases to 74.

For impacts on small establishments only, the number of industries classified by SIC codes with cost-to-sales ratios of at least 3 percent for the $PM_{2.5}$ 20 annual/65 daily alternative is 55, and is 72 for the proposed standard. This number increases to 102 for the most stringent alternative. Lists of these industries classified by SIC code whose cost-to-sales ratios for small establishments only are estimated to be at least 3 percent by each alternative are given in Appendix VIII-18 (for the least stringent alternative - $PM_{2.5}$ 20 annual/65 daily), Appendix VIII-19 (for the proposed $PM_{2.5}$ alternative - $PM_{2.5}$ 15 annual/50 daily), and Appendix VIII-20 (for the most stringent alternative - $PM_{2.5}$ 12.5 annual/50 daily).

TABLE 8-1

SUMMARY OF THE NUMBER OF SIC CODES WITH POTENTIAL ECONOMIC IMPACTS FOR $PM_{2.5}$ ALTERNATIVES IN THE YEAR 2007 (GIVEN BY ANNUAL AVERAGE COST-TO-SALES THRESHOLDS; CONTROL COSTS AND SALES ARE IN 1990$)

Alternative	Total No. of SIC Codes Impacted	10 Percent and above - All *	3 Percent - and above- All*	1 Percent - and above - All*	10 Percent- and above - Small**	3 Percent and above- Small**	1 Percent and above- Small**
$PM_{2.5}$ 20/65	171	22	41	61	40	55	100
$PM_{2.5}$ 15/50	216	27	51	80	53	72	122
$PM_{2.5}$ 12.5/50	226	42	74	117	77	103	145

* Refers to All establishments

** Refers to Small establishments

The reason that the number of SIC codes impacted for small establishments only appear larger than the cost-to-sales ratios for SIC codes for all establishments is that the same average cost of control for a control measure on an industry is imposed on an establishment regardless of its sales, employment, and production levels. Thus, a small establishment in an industry affected by a PM control measure will typically expect in this kind of screening analysis to have a higher cost-to-sales ratio estimated for it compared to a large establishment in the same industry. This is a consequence of the analysis applying the same average cost of control applied to every affected establishment regardless of its production level. This assumption in the analysis does not incorporate economies of scale, which occur when costs per unit of production can be reduced but only at relatively high levels of production. Since the annual cost of pollution control typically becomes a component of the annual cost of production, economies of scale should have the same influence on how pollution control costs behave as production levels increase as for any other component of production costs.

The screening analysis shows that many SIC codes will be impacted by the implementation of the $PM_{2.5}$ alternatives, but many of the SIC codes will experience cost-to-sales ratios below 1 percent. Based only on these ratios, and that there are a number of limitations to any conclusions drawn based on these cost-to-sales ratios, there is some evidence that impacts on most of the affected industries will not be substantial. There is some evidence, however, that there may be potentially significant impacts on 10 to 20 percent of all U.S. industries (represented by SIC codes), and potentially significant impacts on small establishments only in 15 to 25 percent of all U.S. industries.

Based only on these ratios, for both the $PM_{2.5}$ 15 $\mu g/m^3$ annual /50 $\mu g/m^3$ 24-hour and the $PM_{2.5}$ 12.5$\mu g/m^3$ annual/ 50 $\mu g/m^3$ 24-hour average alternatives, the top 5 SIC codes with the greatest potential for impacts associated with the implementation strategies are: **SIC 206** (Sugar and Confectionary Products), **SIC 204** (Grain Mill Products), **SIC 347** (Coating, Engraving, and Allied Services), **SIC 353** (Construction, Mining, and Materials Handling Machinery and Equipment), and **SIC 343** (Heating Equipment, Except Electric and Warm Air, and Plumbing Fixtures).

The top five for potential impacts for the other $PM_{2.5}$ alternative ($PM_{2.5}$ 20 $\mu g/m^3$ annual/ 65 $\mu g/m^3$ 24-hour) differ considerably with only one SIC code in common, **SIC 206**. The other four are: **SIC 371** (Motor Vehicles and Equipment), **SIC 331** (Blast Furnaces and Basic Steel Products), **SIC 651** (Real Estate Operators and Lessors), and **SIC 822** (Colleges and Universities).

8.3.4 Analytical Assumptions and Limitations

There are a number of assumptions and limitations to these analyses. They are:

- The results of the screening analysis reflect the costs estimated from current PM control strategies. It does not reflect the costs from new control strategies emerging from the Federal Advisory Committee Act (FACA) process now underway to prepare implementation plans for the revised PM and Ozone standards.

- There was no differentiation between small and large entities in the application of control strategies in the screening analysis.

- The cost inputs to the analyses have several limitations, namely:

    - detailed cost estimates were not prepared for each emissions source

    - could not conduct the analysis at the firm level, the proper level for the analysis, since control cost data was only available at the establishment level

    - cost estimates were developed using information available through 1994; recent and future developments in control through the 2007 analysis year could results in costs that are significantly lower than those utilized for this analysis. .

- the same average cost per establishment was used for both the EIA and the small entity impact analysis because sufficient data are not reported in the NPI to classify plants as small establishments, and

- the average cost per plant shown for individual SIC codes affected by the area source fuel combustion and surface coating control measures does not differ because information is not available to identify specific costs for individual industries.

- The revenue (sales) data used in these analyses represent national averages by industry. This means that the cost/sales ratios do not predict impacts on specific establishments with a high degree of precision.

- Because area and mobile sources are not individually inventoried, the actual number of establishments affected by these control measures is unknown. Generally, the number of establishments in affected counties that are reported in County Business Patterns was used to estimate the number of affected establishments.

- Since the screening analysis was only performed on entities directly affected by each control measure, the analysis did not estimate impacts of indirectly affected sectors of the economy. Judicial precedent has been set for RFA analyses that such analyses are required only for small entities that are directly regulated [Mid-Tex Electric Cooperative, Inc. v. FERC, 773 F.2d 327 (D.C. Cir. 1985)]. In addition, time and resources precluded use of a general equilibrium model.

- Because of difficulties encountered in attempting to identify SIC codes for approximately 900 facilities in Oregon's point source inventory, these point sources were not included in the analysis.

8.4 GOVERNMENTAL ENTITIES ANALYSIS

8.4.1 Requirements

As mentioned in Chapter 5, the Unfunded Mandates Reform Act of 1995 (UMRA) requires Federal government agencies to assess the effects of Federal regulatory actions on State, local, and tribal governments (Public Law 104-4, signed March 22, 1995). Under Section 202 of UMRA, EPA must prepare a budgetary impact statement to accompany any proposed or final rule that includes a Federal mandate that may result in total estimated costs to State, local, or tribal governments of $100 million or more. Implementation of the control strategies examined may result in an aggregate annual cost of $100 million or more to State and local governments under at least one of the PM alternatives.

This section of the chapter is not an unfunded mandates analysis, but provides estimates of the potential budgetary impact of the control measures used in the control strategy-cost analysis affecting State and local government agencies. This analysis will be useful in guiding future implementation activities, for they can direct efforts to mitigate potential negative economic impacts on government entities. The analysis therefore was conducted for the same reasons as the screening analysis for private sector entities in Section 8.3. No monitoring and administrative costs were used as inputs to calculate the impacts on governmental entities, but will be considered for inclusion in the PM Part 51 RIA.

8.4.2 Methodology

A typical methodology for calculating this type of impact is to use cost-to-annual agency/department expenditure ratios to estimate potentially how much effect there may be on an agency's or department's budget from implementing control strategies. The methodology can provide useful insights into the effects on government entities.

Data on government expenditures by type of government (Federal, State, county, or municipality) and government function (e.g., highways) are available from the Census of Government.[26] The data reported for specific government functions were linked to the corresponding SIC code(s) to provide government expenditures by county for each SIC code and county affected by a point source control measure. Average annual 1987 government expenditures by county were projected to 2007 using BEA growth factors for State and local governments. The average cost of each applicable control measure by county was then divided by average expenditures by county to determine a ratio analogous to the cost-to-sales ratios calculated in the screening analysis. This is the cost-to-(county) budget expenditure ratio.

As a sensitivity analysis, data were also obtained and analyzed for a random sample of 20 counties for each of the three $PM_{2.5}$ alternatives. For this sensitivity analysis, county government expenditure data for highways were compared with the county-level costs for the control measures affecting these source categories. Average annual 1987 government expenditures by county were projected to 2007 using BEA growth factors for State and local governments and then divided into the cost of each applicable control measure by county to determine a ratio analogous to the cost-to-sales ratio developed for private sector industries. Because government entities do not operate in competitive markets, they have more flexibility in trying to offset additional costs. This added flexibility includes reallocating funds from other government functions, and/or raising taxes or user fees. Therefore, a cost-to-expenditure ratio of 5 percent was used to determine potentially significant adverse impacts on government entities.

8.4.3 Results

Impacts for this sensitivity analysis were estimated for entities in SIC 9621 (Regulation and Administration of Transportation Programs). The entities selected for the sensitivity analysis were a random sample of governmental agencies in 20 counties across 15 states, and cost-to-expenditure ratios were computed for each alternative using the sample. As shown in Table 8-2, the number of county government agencies with cost-to-expenditure ratios above zero ranges from 5 for the least stringent alternative ($PM_{2.5}$ 20 annual/ 65 24-hour) to 15 for the most stringent alternative ($PM_{2.5}$ 12.5 annual/50 24-hour). Thus, there are five county government agencies that are estimated to have no impact for any of these alternatives. The number of county goverment agencies with cost-to-expenditure ratios exceeding 3 percent ranged from 2 for the least stringent alternative to 4 for the most stringent alternative. The range of county governmental agencies with cost-to-expenditure ratios exceeding 5 percent ranged from 1 to 4 for those same $PM_{2.5}$ alternatives, and the range for agencies with cost-to-expenditure ratios exceeding 10 percent for the same alternatives was also 1 to 4. For the proposed alternative, the $PM_{2.5}$ 15 $\mu g/m^3$ annual/50 $\mu g/m^3$ 24-hour alternative, 2 county governmental agencies were estimated to have cost-to-expenditure ratios exceeding 3 percent, 2 exceeding 5 percent, and 2 exceeding 10 percent.

TABLE 8-2

SUMMARY OF ANALYSIS OF COUNTY-LEVEL GOVERNMENT AGENCIES WITH POTENTIAL IMPACTS

(Control Costs and Expenditures in 1990$)

$PM_{2.5}$ Alternative	Number of County Government Agencies Potentially Impacted	10 Percent Threshold[a]	5 Percent Threshold[a]	3 Percent Threshold[a]
$PM_{2.5}$ 20/65	5	1	1	1
$PM_{2.5}$ 15/50[b]	10	2	2	2
$PM_{2.5}$ 12.5/50	15	4	4	4

8.4.4 Small Governmental Entities Analysis - Methodology and Results

[a]Represents the number of county-level governmental agencies with cost-to-expenditure ratios at or exceeding the specified threshold.

[b]Represents the proposed standard.

To calculate the potential impacts on small govenmental entities, county-level highway expenditure data were aggregated into two categories: *small* (counties with populations less than 50,000) and *large* (those with populations of 50,000 plus).[27] Using the highway expenditure data collected for the governmental entities analysis for all counties in the sample, cost-to-expenditure ratios were calculated for the small counties in the sample. 13 of the 20 counties in the sample were small by this measure.

TABLE 8-3

SUMMARY OF ANALYSIS OF COUNTY-LEVEL GOVERNMENT ENTITIES WITH POTENTIAL IMPACTS: SMALL COMPARED TO LARGE

(Control Costs and Expenditures in 1990$)

$PM_{2.5}$ Alternatives	Number of Small County Government Agencies Impacted	10 Percent Threshold[a]	5 Percent Threshold[a]	3 Percent Threshold[a]
20 /65	4	2	2	3
15 /50	8	4	4	5
12.5 /50	13	5	5	5

8.4.5 Conclusions and Limitations

The results from Table 8-3 show that the number of small governmental entities impacted by the control measures (paved and unpaved road dust control plans) increase with the stringency of

[a] Represents number of county-level governmental agencies with cost-to-expenditure ratios exceeding the specified threshold.

the alternative standards, not surprisingly. The number of small entities impacted increases from 4 for the least stringent standard to 13 for the most stringent standard, and the number of small entities with cost-to-expenditure ratios estimated to be at least 3 percent ranges from 3 for the least stringent to 5 for the most stringent alternative standard, while the number of small entities with cost-to-expenditure ratios estimated to be at least 10 percent ranges from 2 for the least stringent alternative to 5 for the most stringent.

One major limitation to these results is that the data do not include State government highway expenditures by county.[28] To the extent that State governments spend relatively higher amounts per capita in small counties than in large counties, disproportionate small government entity impacts would be lessened. However, county-level State government highway expenditure data are not readily available. Any conclusions drawn from these results should therefore be taken with considerable caution.

8.5 Environmental Justice

Executive Order 12898 (2/16/94), "Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations," requires that each Federal agency make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minorities and low-income populations.

Since EPA expects the implementation strategies to change considerably as a joint implementation strategy for both ozone and PM NAAQS is prepared and also as a result of the FACA process, an analysis of this type may be misleading because the costs, economic impacts, and benefits of the $PM_{2.5}$ alternatives may be borne by others than those predicted in this analysis. The Agency will provide more detailed information in its RIAs for the Part 51 implementation process. During that process, affected minority and low-income populations will be better identified, which may allow estimation of impacts on these individuals resulting from implementation of the ozone and PM NAAQS.

8.6 REFERENCES

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APPENDIX VIII-1. SIC CODES AND SECTORS POTENTIALLY AFFECTED BY PM, SO_2, AND NO_x CONTROL MEASURES FOR UTILITY AND ICI BOILERS IN THE STATIONARY POINT SOURCE INVENTORY

Source Category	SIC Code	SIC Description	Sector	Pollutants Controlled		
				PM	SO_2	NO_x
Utility Boilers						
	491	Electric Services	Transportation and Public Utilities (T & PU)	√	√	√
ICI Boilers						
	011	Cash Grains	Agricultural			√
	018	Horticultural Specialties	Agricultural			√
	072	Crop Services	Agricultural			√
	101	Iron Ores	Mining		√	√
	102	Copper Ores	Mining			√
	109	Miscellaneous Metal Ores	Mining			√
	122	Bituminous and Lignite Coal	Mining			√
	130	Oil and Gas Extraction	Mining			√
	131	Crude Petroleum and Natural Gas	Mining			√
	132	Natural Gas Liquids	Mining			√
	142	Crushed and Broken Stone, Including Riprap	Mining			√
	144	Sand and Gravel	Mining			√
	147	Chemical and Fertilizer Minerals	Mining	√	√	√
	149	Miscellaneous Nonmetallic Minerals	Mining	√		√
	201	Meat Products	Manufacturing	√	√	√
	202	Dairy Products	Manufacturing			√
	203	Preserved Fruits/Vegetables	Manufacturing	√	√	√
	204	Grain Mill Products	Manufacturing	√	√	√
	205	Bakery Products	Manufacturing			√
	206	Sugar and Confectionery Products	Manufacturing	√	√	√
	207	Fats and Oils	Manufacturing	√	√	√
	208	Beverages	Manufacturing	√	√	√
	209	Misc. Food/Kindred Products	Manufacturing	√	√	√
	211	Cigarettes	Manufacturing	√	√	√
	213	Chewing and Smoking Tobacco and Snuff	Manufacturing			√
	214	Tobacco Stemming and Redrying	Manufacturing			√
	220	Textile Mill Products	Manufacturing			√
	221	Broadwoven Fabric Mills, Cotton	Manufacturing	√	√	√
	222	Broadwoven Fabric Mills, Manmade Fiber and Silk	Manufacturing			√
	223	Broadwoven Fabric Mills, Wool	Manufacturing	√		√
	225	Knitting Mills	Manufacturing			√
	226	Textile Finishing, Except Wool	Manufacturing	√	√	√
	227	Carpets and Rugs	Manufacturing	√		√
	228	Yarn and Thread Mills	Manufacturing	√		√
	229	Miscellaneous Textile Goods	Manufacturing	√	√	√
	232	Men's and Boys' Furnishings	Manufacturing			√
	238	Miscellaneous Apparel and Accessories	Manufacturing	√		√
	242	Sawmills and Planing Mills	Manufacturing			√
	243	Millwork, Plywood & Structural Members	Manufacturing	√	√	√

Source Category	SIC Code	SIC Description	Sector	Pollutants Controlled PM	SO₂	NOₓ
	244	Wood Containers	Manufacturing			√
	249	Miscellaneous Wood Products	Manufacturing	√	√	√
	251	Household Furniture	Manufacturing			√
	252	Office Furniture	Manufacturing			√
	254	Partitions and Fixtures	Manufacturing			√

Source Category	SIC Code	SIC Description	Sector	Pollutants Controlled PM	SO2	NOx
ICI Boilers (cont'd)						
	260	Paper and Allied Products	Manufacturing		√	√
	261	Pulp Mills	Manufacturing	√	√	√
	262	Paper Mills	Manufacturing	√	√	√
	263	Paperboard Mills	Manufacturing	√	√	√
	265	Paperboard Containers	Manufacturing	√	√	√
	267	Miscellaneous Converted Paper Products	Manufacturing	√	√	√
	271	Newspapers: Publishing and/or Printing	Manufacturing			√
	273	Books	Manufacturing			√
	275	Commercial Printing	Manufacturing			√
	277	Greeting Cards	Manufacturing			√
	278	Blankbooks, Looseleaf Binders, and Bookbinding and Related Work	Manufacturing			√
	280	Chemicals and Allied Products	Manufacturing			√
	281	Industrial Inorganic Chemicals	Manufacturing	√	√	√
	282	Plastics Materials and Synthetics	Manufacturing	√	√	√
	283	Drugs	Manufacturing	√	√	√
	284	Soaps, Cleaners, and Toilet Goods	Manufacturing		√	√
	285	Paints and Allied Products	Manufacturing			√
	286	Industrial Organic Chemicals	Manufacturing	√	√	√
	287	Agricultural Chemicals	Manufacturing	√	√	√
	289	Miscellaneous Chemical Products	Manufacturing	√	√	√
	291	Petroleum Refining	Manufacturing	√	√	√
	295	Asphalt Paving and Roofing Materials	Manufacturing		√	√
	299	Miscellaneous Petroleum and Coal Products	Manufacturing			√
	301	Tires and Inner Tubes	Manufacturing	√	√	√
	305	Gaskets, Packing, and Sealing Devices	Manufacturing			√
	306	Fabricated Rubber Products	Manufacturing	√	√	√
	308	Miscellaneous Plastics Products	Manufacturing	√	√	√
	311	Leather Tanning and Finishing	Manufacturing			√
	321	Flat Glass	Manufacturing	√	√	√
	322	Glass and Glassware, Pressed or Blown	Manufacturing			√
	323	Glass Products, made of Purchased Glass	Manufacturing			√
	324	Cement, Hydraulic	Manufacturing		√	√
	325	Structural Clay Products	Manufacturing			√
	326	Pottery and Related Products	Manufacturing			√
	327	Concrete, Gypsum, Plaster Products	Manufacturing	√	√	√
	329	Miscellaneous Nonmetallic Mineral Products	Manufacturing	√	√	√
	330	Primary Metal Industries	Manufacturing		√	√
	331	Blast Furnace and Basic Steel Products	Manufacturing	√	√	√
	332	Iron and Steel Foundries	Manufacturing			√
	333	Primary Nonferrous Metals	Manufacturing	√	√	√
	334	Secondary Nonferrous Metals	Manufacturing			√
	335	Nonferrous Rolling and Drawing	Manufacturing	√	√	√
	336	Nonferrous Foundries (Castings)	Manufacturing			√
	339	Miscellaneous Primary Metal Products	Manufacturing			√
	340	Fabricated Metal Products, Except Machinery and Transportation Equipment	Manufacturing			√
	341	Metal Cans and Shipping Containers	Manufacturing			√
	342	Cutlery, Handtools, and Hardware	Manufacturing		√	√
	343	Heating Equipment, Except Electric and Warm Air; and Plumbing Fixtures	Manufacturing			√

Source Category	SIC Code	SIC Description	Sector	Pollutants Controlled		
				PM	SO_2	NO_x
ICI Boilers (cont'd)						
	344	Fabricated Structural Metal Products	Manufacturing			√
	345	Screw Machine Products, and Bolts, Nuts, Screws, Rivets, and Washers	Manufacturing			√
	346	Metal Forgings and Stampings	Manufacturing	√	√	√
	347	Coating, Engraving, and Allied Services	Manufacturing			√
	348	Ordnance and Accessories, Miscellaneous	Manufacturing		√	√
	349	Miscellaneous Fabricated Metal Products	Manufacturing	√	√	√
	350	Industrial and Commercial Machinery and Computer Equipment	Manufacturing			√
	351	Engines and Turbines	Manufacturing		√	√
	352	Farm and Garden Machinery	Manufacturing		√	√
	353	Construction and Related Machinery	Manufacturing	√	√	√
	354	Metalworking Machinery	Manufacturing			√
	355	Special Industry Machinery	Manufacturing			√
	356	General Industrial Machinery and Equipment	Manufacturing			√
	357	Computer and Office Equipment	Manufacturing			√
	358	Refrigeration and Service Machinery	Manufacturing		√	√
	359	Miscellaneous Industrial and Commercial Machinery and Equipment	Manufacturing			√
	360	Electronic and Other Electrical Equipment and Components, Except Computer Equipment	Manufacturing			√
	361	Electric Distribution Equipment	Manufacturing		√	√
	362	Electrical Industrial Apparatus	Manufacturing			√
	363	Household Appliances	Manufacturing	√	√	√
	364	Electric Lighting and Wiring Equipment	Manufacturing		√	√
	365	Household Audio and Video Equipment	Manufacturing			√
	366	Communications Equipment	Manufacturing			√
	367	Electronic Components and Accessories	Manufacturing			√
	369	Miscellaneous Electrical Equipment	Manufacturing	√	√	√
	370	Transportation Equipment	Manufacturing	√	√	√
	371	Motor Vehicles and Equipment	Manufacturing	√	√	√
	372	Aircraft and Parts	Manufacturing		√	√
	373	Ship and Boat Building and Repairing	Manufacturing		√	√
	374	Railroad Equipment	Manufacturing		√	√
	375	Motorcycles, Bicycles, and Parts	Manufacturing			√
	376	Guided Missiles, Space Vehicles, Parts	Manufacturing		√	√
	379	Miscellaneous Transportation Equipment	Manufacturing			√
	384	Surgical, Medical, and Dental Instruments and Supplies	Manufacturing			√
	386	Photographic Equipment	Manufacturing	√	√	√
	390	Miscellaneous Manufacturing Industries	Manufacturing	√		√
	391	Jewelry, Silverware, and Plated Ware	Manufacturing		√	√
	393	Musical Instruments	Manufacturing			√
	395	Pens, Pencils, and Other Artists' Materials	Manufacturing			√
	399	Manufacturing Industries, Miscellaneous	Manufacturing		√	√
	401	Railroads	T & PU			√
	411	Local and Suburban Passenger Transportation	T & PU			√
	422	Public Warehousing and Storage	T & PU			√
	423	Terminal and Joint Terminal Maintenance Facilities for Motor Freight Transportation	T & PU			√
	449	Services Incidental to Water Transportation	T & PU			√

Source Category	SIC Code	SIC Description	Sector	Pollutants Controlled PM	SO2	NOx
ICI Boilers (cont'd)						
	451	Air Transportation, Scheduled/Air Courier Services	T & PU			√
	458	Airports, Flying Fields & Services	T & PU		√	√
	461	Pipelines, Except Natural Gas	T & PU			√
	481	Telephone Communications	T & PU			√
	490	Electric, Gas, and Sanitary Services	T & PU			√
	491	Electric Services	T & PU	√	√	√
	492	Gas Production and Distribution	T & PU			√
	493	Combination Utility Services	T & PU	√	√	√
	495	Sanitary Services	T & PU	√	√	√
	496	Steam and Air-Conditioning Supply	T & PU	√	√	√
	501	Motor Vehicles, Parts, and Supplies	Wholesale Trade			√
	509	Miscellaneous Durable Goods	Wholesale Trade			√
	515	Farm-Product Raw Materials	Wholesale Trade		√	
	517	Wholesale Trade-Petroleum Products	Wholesale Trade		√	√
	526	Retail Trade-Nurseries and Garden Stores	Retail Trade	√		√
	541	Grocery Stores	Retail Trade			√
	651	Real Estate Operators and Lessors	Finance, Insurance, and Real Estate	√	√	√
	704	Organization Hotels and Lodging Houses, Membership Basis	Services			√
	805	Nursing and Personal Care Facilities	Services			√
	806	Hospitals	Services	√	√	√
	809	Health and Allied Services, Miscellaneous	Services		√	√
	821	Elementary and Secondary Schools	Services	√	√	√
	822	Colleges and Universities	Services	√	√	√
	824	Vocational Schools	Services		√	√
	829	Schools and Educational Services, nec	Services			√
	836	Residential Care	Services			√
	863	Labor Unions and Similar Organizations	Services			√
	871	Engineering, Architectural, Surveying Services	Services			√
	873	Research and Testing Services	Services	√	√	√
	899	Services, Miscellaneous	Services		√	
	910	Executive, Legislative, General Government; Except Finance	Public Administration			√
	922	Public Order and Safety	Public Administration	√	√	√
	931	Public Finance, Taxation, Monetary Policy	Public Administration			√
	940	Administration of Human Resource Programs	Public Administration			√
	943	Administration of Public Health Programs	Public Administration		√	√
	961	Administration of General Economic Programs	Public Administration			√
	963	Regulation, Administration of Utilities	Public Administration		√	√
	971	National Security	Public Administration	√	√	√
	999	Nonclassifiable Establishments	Nonclassifiable Establishments			√

APPENDIX VIII-2. SIC CODES AND SECTORS AFFECTED BY THE CONTROL MEASURES FOR VOC SOURCES IN THE STATIONARY POINT SOURCE INVENTORY

Source Category/SIC Code	SIC Description	Sector
Automobile and Light-Duty Truck Surface Coating (Industrial Surface Coating)		
352	Farm and Garden Machinery	Manufacturing
371	Motor Vehicles and Equipment	Manufacturing
373	Ship and Boat Building and Repairing	Manufacturing
Plastic Parts Surface Coating (Industrial Surface Coating)		
282	Plastics Materials and Synthetics	Manufacturing
306	Fabricated Rubber Products, Miscellaneous	Manufacturing
Surface Coating - General/Unspecified (Industrial Surface Coating)		
229	Miscellaneous Textile Goods	Manufacturing
243	Millwork, Plywood & Structural Members	Manufacturing
245	Wood Buildings and Mobile Homes	Manufacturing
251	Household Furniture	Manufacturing
254	Partitions and Furniture	Manufacturing
265	Paperboard Containers	Manufacturing
267	Converted Paper and Paperboard Products, Except Containers and Boxes	Manufacturing
273	Books	Manufacturing
275	Commercial Printing	Manufacturing
306	Fabricated Rubber Products, Miscellaneous	Manufacturing
308	Miscellaneous Plastics Products	Manufacturing
311	Leather Tanning and Finishing	Manufacturing
336	Nonferrous Foundries (Castings)	Manufacturing
340	Fabricated Metal Products	Manufacturing
341	Metal Cans and Shipping Containers	Manufacturing
347	Metal Services, Miscellaneous	Manufacturing
349	Miscellaneous Fabricated Metal Products	Manufacturing
352	Farm and Garden Machinery	Manufacturing
353	Construction and Related Machinery	Manufacturing
363	Household Appliances	Manufacturing
367	Electronic Components and Accessories	Manufacturing
369	Miscellaneous Electrical Equipment	Manufacturing
371	Motor Vehicles and Equipment	Manufacturing
373	Ship and Boat Building and Repairing	Manufacturing
379	Miscellaneous Transportation Equipment	Manufacturing
390	Miscellaneous Manufacturing Industries	Manufacturing
399	Miscellaneous Manufactures	Manufacturing
495	Sanitary Services	Transportation and Public Utilities
971	National Security	Public Administration
Rule Effectiveness Improvements		
072	Crop Services	Agriculture
204	Grain Mill Products	Manufacturing
205	Bakery Products	Manufacturing
207	Fats and Oils	Manufacturing
226	Textile Finishing, Except Wool	Manufacturing
229	Miscellaneous Textile Goods	Manufacturing
242	Sawmills and Planing Mills	Manufacturing
243	Millwork, Plywood & Structural Members	Manufacturing
249	Miscellaneous Wood Products	Manufacturing
251	Household Furniture	Manufacturing
262	Paper Mills	Manufacturing

Source Category/SIC Code	SIC Description	Sector
Rule Effectiveness Improvements (cont'd)		
263	Paperboard Mills	Manufacturing
265	Paperboard Containers	Manufacturing
267	Converted Paper and Paperboard Products, Except Containers and Boxes	Manufacturing
273	Books	Manufacturing
275	Commercial Printing	Manufacturing
277	Greeting Cards	Manufacturing
281	Industrial Inorganic Chemicals	Manufacturing
282	Plastics Materials and Synthetics	Manufacturing
283	Drugs	Manufacturing
285	Paints and Allied Products	Manufacturing
286	Industrial Organic Chemicals	Manufacturing
287	Agricultural Chemicals	Manufacturing
289	Miscellaneous Chemical Products	Manufacturing
291	Petroleum Refining	Manufacturing
295	Asphalt Paving and Roofing Materials	Manufacturing
299	Miscellaneous Petroleum and Coal Products	Manufacturing
301	Tires and Inner Tubes	Manufacturing
306	Fabricated Rubber Products, nec	Manufacturing
308	Miscellaneous Plastics Products	Manufacturing
311	Leather Tanning and Finishing	Manufacturing
329	Miscellaneous Nonmetallic Mineral Products	Manufacturing
331	Blast Furnace and Basic Steel Products	Manufacturing
332	Iron and Steel Foundries	Manufacturing
334	Secondary Nonferrous Metals	Manufacturing
335	Nonferrous Rolling and Drawing	Manufacturing
341	Metal Cans and Shipping Containers	Manufacturing
342	Cutlery, Handtools, and Hardware	Manufacturing
346	Metal Forgings and Stampings	Manufacturing
347	Metal Services, nec	Manufacturing
348	Ordnance and Accessories, Miscellaneous	Manufacturing
349	Miscellaneous Fabricated Metal Products	Manufacturing
351	Engines and Turbines	Manufacturing
354	Metalworking Machinery	Manufacturing
355	Special Industry Machinery	Manufacturing
357	Computer and Office Equipment	Manufacturing
362	Electrical Industrial Apparatus	Manufacturing
363	Household Appliances	Manufacturing
367	Electronic Components and Accessories	Manufacturing
369	Miscellaneous Electrical Equipment	Manufacturing
371	Motor Vehicles and Equipment	Manufacturing
372	Aircraft and Parts	Manufacturing
386	Photographic Equipment	Manufacturing
399	Manufacturing Industries, Miscellaneous	Manufacturing
422	Public Warehousing and Storage	Transportation and Public Utilities
461	Pipelines, Except Natural Gas	Transportation and Public Utilities
509	Miscellaneous Durable Goods	Wholesale Trade
517	Wholesale Trade-Petroleum Products	Wholesale Trade
971	National Security	Public Administration

APPENDIX VIII-3. SIC CODES AND SECTORS AFFECTED BY CONTROL MEASURES FOR NO_x SOURCES IN THE STATIONARY POINT SOURCE INVENTORY

Source Category/SIC Code	SIC Description	Sector
Cogeneration		
132	Extraction-Natural Gas Liquids	Mining
211	Cigarettes	Manufacturing
262	Paper Mills	Manufacturing
263	Paperboard Mills	Manufacturing
281	Industrial Inorganic Chemicals	Manufacturing
371	Motor Vehicles and Equipment	Manufacturing
Adipic and Nitric Acid Manufacturing Plants		
281	Industrial Inorganic Chemicals	Manufacturing
282	Plastics Materials and Synthetics	Manufacturing
286	Industrial Organic Chemicals	Manufacturing
287	Agricultural Chemicals	Manufacturing
289	Miscellaneous Chemical Products	Manufacturing
Cement Manufacturing		
224	Cement, Hydraulic	
287	Agricultural Chemicals	Manufacturing
324	Cement, Hydraulic	Manufacturing
327	Concrete, Gypsum, Plaster Products	Manufacturing
329	Miscellaneous Nonmetallic Mineral Products	Manufacturing
355	Special Industry Machinery	Manufacturing
Glass Manufacturing - Flat		
321	Flat Glass	Manufacturing
322	Glass -Pressed or Blown	Manufacturing
Glass Manufacturing - Pressed/Blown		
322	Glass -Pressed or Blown	Manufacturing
Glass Manufacturing-Container		
281	Industrial Inorganic Chemicals	Manufacturing
321	Flat Glass	Manufacturing
322	Glass -Pressed or Blown	Manufacturing
332	Iron and Steel Foundries	Manufacturing
Gas Turbines		
102	Copper Ores	Mining
131	Crude Petroleum and Natural Gas Extraction	Mining
132	Extraction-Natural Gas Liquids	Mining
208	Beverages	Manufacturing
262	Paper Mills	Manufacturing
281	Industrial Inorganic Chemicals	Manufacturing
282	Plastics Materials and Synthetics	Manufacturing
286	Industrial Organic Chemicals	Manufacturing
287	Agricultural Chemicals	Manufacturing
291	Petroleum Refining	Manufacturing
299	Miscellaneous Petroleum and Coal Products	Manufacturing
306	Fabricated Rubber Products	Manufacturing
449	Services Incidental to Water Treatment	Transportation and Public Services
491	Electric Services	Transportation and Public Utilities
492	Gas Production and Distribution	Transportation and Public Utilities
493	Combination Utility Services	Transportation and Public Utilities
495	Sanitary Services	Transportation and Public Utilities
Reciprocating IC Engines		
101	Iron Ores	
109	Metal Mining-Miscellaneous	Mining
131	Crude Petroleum and Natural Gas Extraction	Mining
132	Extraction-Natural Gas Liquids	Mining
138	Oil and Gas Field Services	Mining
179	Construction-Miscellaneous Trade Contractors	Construction
201	Meat Products	Manufacturing
262	Paper Mills	Manufacturing

Source Category/SIC Code	SIC Description	Sector
Reciprocating IC Engines (cont'd)		
281	Industrial Inorganic Chemicals	Manufacturing
282	Plastics Materials and Synthetics	Manufacturing
286	Industrial Organic Chemicals	Manufacturing
287	Agricultural Chemicals	Manufacturing
289	Miscellaneous Chemical Products	Manufacturing
291	Petroleum Refining	Manufacturing
299	Miscellaneous Petroleum and Coal Products	Manufacturing
321	Flat Glass	Manufacturing
324	Cement, Hydraulic	Manufacturing
333	Primary Nonferrous Metals	Manufacturing
362	Electrical Industrial Apparatus	Manufacturing
367	Electronic Components and Accessories	Manufacturing
371	Motor Vehicles and Equipment	Manufacturing
449	Services Incidental to Water Treatment	Transportation and Public Services
461	Pipelines, except Natural Gas	Transportation and Public Utilities
490	Electric, Gas, and Sanitary Services	Transportation and Public Utilities
491	Electric Services	Transportation and Public Utilities
492	Gas Production and Distribution	Transportation and Public Utilities
493	Combination Utility Services	Transportation and Public Utilities
496	Steam and Air-Conditioning Supply	Transportation and Public Utilities
517	Wholesale Trade-Petroleum Products	Wholesale Trade
541	Retail Trade-Grocery Stores	Retail Trade
806	Hospitals	Services
931	Finance, Taxation, & Monetary Policy	Public Administration
971	National Security	Public Administration
Process Heaters		
101	Metal Mining-Iron	Mining
131	Crude Petroleum and Natural Gas Extraction	Mining
132	Extraction-Natural Gas Liquids	Mining
142	Crushed and Broken Stone	Mining
179	Construction-Miscellaneous Trade Contractors	Construction
261	Pulp Mills	Manufacturing
263	Paperboard Mills	Manufacturing
267	Converted Paper and Paperboard Products, Except Containers and Boxes	Manufacturing
281	Industrial Inorganic Chemicals	Manufacturing
282	Plastics Materials and Synthetics	Manufacturing
286	Industrial Organic Chemicals	Manufacturing
289	Miscellaneous Chemical Products	Manufacturing
290	Petroleum and Coal Products	Manufacturing
291	Petroleum Refining	Manufacturing
308	Miscellaneous Plastics Products	Manufacturing
329	Miscellaneous Nonmetallic Mineral Products	Manufacturing
331	Blast Furnace and Basic Steel Products	Manufacturing
333	Primary Nonferrous Metals	Manufacturing
335	Nonferrous Rolling and Drawing	Manufacturing
336	Nonferrous Foundries (Castings)	Manufacturing
341	Metal Cans and Shipping Containers	Manufacturing
346	Metal Forgings and Stampings	Manufacturing
349	Miscellaneous Fabricated Metal Products	Manufacturing
363	Household Appliances	Manufacturing
371	Motor Vehicles and Equipment	Manufacturing
492	Gas Production and Distribution	Transportation and Public Utilities
517	Wholesale Trade-Petroleum Products	Wholesale Trade
Iron and Steel Mills		
331	Blast Furnace and Basic Steel Products	Manufacturing

Source Category/SIC Code	SIC Description	Sector
Medical Waste Incinerators		
495	Sanitary Services	Transportation and Public Utilities
806	Hospitals	Services
Municipal Waste Incinerators		
495	Sanitary Services	Transportation and Public Utilities
806	Hospitals	Services
873	Research, Development, and Testing Services	Services
951	Environmental Quality	Public Administration
971	National Security	Public Administration

APPENDIX VIII-4. SIC CODES AND SECTORS AFFECTED BY CONTROL MEASURES FOR PM, VOC, and NO_x SOURCES IN THE STATIONARY AREA SOURCE INVENTORY

Source Category	SIC Code	SIC Description	Sector
PM Emissions			
Paved Roads - Rural and Urban	962	Regulation and Administration of Transportation Programs	Public Administration
Unpaved Roads - Rural and Urban	962	Regulation and Administration of Transportation Programs	Public Administration
Construction Activities[1]	153	Operative Builders	Construction
	161	Highway and Street Construction	Construction
	162	Heavy Construction, Except Highway	Construction
Agricultural Tilling[2]	071	Soil Preparation Services	Agriculture, Forestry, Fishing
	072	Crop Services	Agriculture, Forestry, Fishing
	078	Landscape and Horticultural Services	Agriculture, Forestry, Fishing
Agricultural Burning[2]	071	Soil Preparation Services	Agriculture, Forestry, Fishing
	072	Crop Services	Agriculture, Forestry, Fishing
	078	Landscape and Horticultural Services	Agriculture, Forestry, Fishing
Beef Cattle Feedlots	021	Beef Cattle Feedlots	Agriculture, Forestry, Fishing
Residential Wood Combustion	343	Wood Stoves	Manufacturing
VOC Emissions			
Service Stations: Underground Storage Tanks	554	Gasoline Service Stations	Retail Trade
Service Stations: Stage I - Truck Unloading	517	Petroleum and Petroleum Products	Wholesale Trade
Bulk Terminals	422	Public Warehousing and Storage	Transportation and Public Utilities (T & PU)
	509	Miscellaneous Durable Goods	Wholesale Trade
	517	Petroleum and Petroleum Products	Wholesale Trade
Marine Surface Coating	335	Nonferrous Rolling and Drawing	Manufacturing
	373	Ship and Boat Building and Repairing	Manufacturing
Metal product surface coating	101	Iron Ores	Mining
	102	Copper Ores	Mining
	103	Lead and Zinc Ores	Mining
	104	Gold and Silver Ores	Mining
	106	Ferroalloy Ores, Except Vanadium	Mining
	109	Miscellaneous Metal Ores	Mining
	123	Anthracite Coal	Mining
	138	Oil and Gas Field Services	Mining
	141	Dimension Stone	Mining
	142	Crushed and Broken Stone	Mining
	144	Sand and Gravel	Mining
	145	Clay, Ceramic, and Refractory Minerals	Mining
	147	Chemical and Fertilizer Minerals	Mining
	148	Nonmetallic Minerals Services	Mining
	153	Operative Builders	Construction
	171	Plumbing, Heating, and Air Conditioning	Construction
	173	Electrical Work	Construction
	174	Masonry, Stonework, and Plastering	Construction
	175	Carpentry and Floor Work	Construction
	176	Roofing, Siding, and Sheet Metal Work	Construction
	204	Grain Mill Products	Manufacturing
	209	Miscellaneous Food and Kindred Products	Manufacturing
	234	Women's and Children's Undergarments	Manufacturing

Source Category	SIC Code	SIC Description	Sector
	236	Girls' and Children's Outerwear	Manufacturing
	238	Miscellaneous Apparel and Accessories	Manufacturing
	241	Logging	Manufacturing

Source Category	SIC Code	SIC Description	Sector
VOC Emissions (cont'd)			
Metal product surface coating (cont'd)	252	Office Furniture	Manufacturing
	254	Partitions and Fixtures	Manufacturing
	259	Miscellaneous Furniture and Fixtures	Manufacturing
	272	Periodicals	Manufacturing
	275	Commercial Printing	Manufacturing
	277	Greeting Cards	Manufacturing
	278	Blankbooks and Bookbinding	Manufacturing
	281	Industrial Inorganic Chemicals	Manufacturing
	282	Plastics Materials and Synthetics	Manufacturing
	289	Miscellaneous Chemical Products	Manufacturing
	302	Rubber and Plastics Footwear	Manufacturing
	306	Fabricated Rubber Products, nec	Manufacturing
	308	Miscellaneous Plastics Products, nec	Manufacturing
	313	Footwear Cut Stock	Manufacturing
	317	Handbags and Other Personal Leather Goods	Manufacturing
	322	Glass and Glassware, Pressed and Blown	Manufacturing
	331	Blast Furnace and Basic Steel Products	Manufacturing
	334	Secondary Nonferrous Metals	Manufacturing
	335	Nonferrous Rolling and Drawing	Manufacturing
	341	Metal Cans and Shipping Containers	Manufacturing
	342	Cutlery, Handtools, and Hardware	Manufacturing
	343	Plumbing and Heating, Except Electric	Manufacturing
	344	Fabricated Structural Metal Products	Manufacturing
	346	Metal Forgings and Stampings	Manufacturing
	347	Metal Services, nec	Manufacturing
	349	Miscellaneous Fabricated Metal Products	Manufacturing
	351	Engines and Turbines	Manufacturing
	352	Farm and Garden Machinery	Manufacturing
	353	Construction and Related Machinery	Manufacturing
	354	Metalworking Machinery	Manufacturing
	355	Special Industry Machinery	Manufacturing
	357	Computer and Office Equipment	Manufacturing
	358	Refrigeration and Service Machinery	Manufacturing
	359	Industrial Machinery, nec	Manufacturing
	362	Electrical Industrial Apparatus	Manufacturing
	371	Motor Vehicles and Equipment	Manufacturing
	373	Ship and Boat Building and Repairing	Manufacturing
	374	Railroad Equipment	Manufacturing
	379	Miscellaneous Transportation Equipment	Manufacturing
	399	Miscellaneous Manufacturers	Manufacturing
	443	Freight Transportation on the Great Lakes	T & PU
	508	Lumber and Construction Materials	Wholesale Trade
	531	Department Stores	Retail Trade
	551	New and Used Car Dealers	Retail Trade
	581	Eating and Drinking Places	Retail Trade
	764	Reupholstery and Furniture Repair	Services
Paper Surface Coating	104	Gold and Silver Ores	Mining
	109	Miscellaneous Metal Ores	Mining
	131	Crude Petroleum and Natural Gas	Mining
	212	Cigars	Manufacturing
	262	Paper Mills	Manufacturing
	265	Paperboard Containers and Boxes	Manufacturing

Source Category	SIC Code	SIC Description	Sector
VOC Emissions (cont'd)			
Paper Surface Coating (cont'd)	267	Converted Paper and Paperboard Products, Except Containers and Boxes	Manufacturing
	275	Commercial Printing	Manufacturing
	279	Printing Trade Services	Manufacturing
	285	Paints and Allied Products	Manufacturing
	329	Miscellaneous Nonmetallic Mineral Products	Manufacturing
	344	Fabricated Structural Metal Products	Manufacturing
	616	Mortgage Bankers and Brokers	Finance, insurance, and Real Estate
	791	Dance Studios, Schools, and Halls	Services
	792	Producers, Orchestras, Entertainers	Services
	794	Commercial Sports	Services
	801	Offices and Clinics of Medical Doctors	Services
Wood Furniture Surface Coating	124	Coal Mining Services	Mining
	144	Sand and Gravel	Mining
	172	Painting and Paper Hanging	Construction
	224	Narrow Fabric Mills	Manufacturing
	235	Hats, Caps, and Millinery	Manufacturing
	243	Millwork, Veneer, Plywood, and Structural Wood Members	Manufacturing
	251	Household Furniture	Manufacturing
	252	Office Furniture	Manufacturing
	253	Public Building and Related Furniture	Manufacturing
	254	Partitions, Shelving, Lockers, and Office and Store Fixtures	Manufacturing
	259	Industrial Machinery, nec	Manufacturing
	379	Miscellaneous Transportation Equipment	Manufacturing
	502	Furniture and Homefurnishings	Wholesale Trade
	503	Lumber and Construction Materials	Wholesale Trade
	519	Miscellaneous Nondurable Goods	Wholesale Trade
	753	Automotive Repair shops	Services
	762	Electrical Repair Shops	Services
Adhesives: Industrial	289	Miscellaneous Chemical Products	Manufacturing
Miscellaneous Surface Coating	101	Iron Ores	Mining
	102	Copper Ores	Mining
	103	Lead and Zinc Ores	Mining
	104	Gold and Silver Ores	Mining
	106	Ferroalloy Ores, Except Vanadium	Mining
	108	Metal Mining Services	Mining
	109	Miscellaneous Metal Ores	Mining
	124	Coal Mining Services	Mining
	131	Crude Petroleum and Natural Gas	Mining
	132	Natural Gas Liquids	Mining
	141	Dimension Stone	Mining
	144	Sand and Gravel	Mining
	147	Chemical and Fertilizer Mineral Mining	Mining
	148	Nonmetallic Minerals Services, Except Fuels	Mining
	149	Miscellaneous Nonmetallic Minerals, Except Fuels	Mining
	161	Highway and Street Construction, Except Elevated Highways	Construction
	173	Electrical Work	Construction
	174	Masonry, Stonework, Tile Setting, and Plastering	Construction
	175	Carpentry and Floor Work	Construction

Source Category	SIC Code	SIC Description	Sector
VOC Emissions (cont'd)			
Miscellaneous Surface Coating (cont'd)	204	Grain Mill Products	Manufacturing
	205	Bakery Products	Manufacturing
	208	Beverages	Manufacturing
	221	Broadwoven Fabric Mills, Cotton	Manufacturing
	222	Broadwoven Fabric Mills, Manmade Fiber and Silk	Manufacturing
	223	Broadwoven Fabric Mills, Wool	Manufacturing
	229	Miscellaneous Textile Goods	Manufacturing
	237	Fur Goods	Manufacturing
	238	Miscellaneous Apparel and Accessories	Manufacturing
	239	Miscellaneous Fabricated Textile Products	Manufacturing
	242	Sawmills and Planing Mills	Manufacturing
	243	Millwork, Veneer, Plywood, and Structural Wood Members	Manufacturing
	245	Wood Buildings and Mobile Homes	Manufacturing
	249	Miscellaneous Wood Products	Manufacturing
	251	Household Furniture	Manufacturing
	252	Office Furniture	Manufacturing
	253	Public Building and Related Furniture	Manufacturing
	254	Partitions, Shelving, Lockers, and Office and Store Fixtures	Manufacturing
	259	Miscellaneous Furniture and Fixtures	Manufacturing
	261	Pulp Mills	Manufacturing
	262	Paper Mills	Manufacturing
	263	Paperboard Mills	Manufacturing
	267	Converted Paper and Paperboard Products, Except Containers and Boxes	Manufacturing
	271	Newspapers: Publishing and/or Printing	Manufacturing
	272	Periodicals: Publishing and/or Printing	Manufacturing
	273	Books	Manufacturing
	274	Miscellaneous Publishing	Manufacturing
	275	Commercial Printing	Manufacturing
	276	Manifold Business Forms	Manufacturing
	277	Greeting Cards	Manufacturing
	278	Blankbooks, Looseleaf Binders, and Bookbinding and Related Work	Manufacturing
	279	Service Industries for the Printing Trade	Manufacturing
	281	Industrial Inorganic Chemicals	Manufacturing
	282	Plastics Materials and Synthetics	Manufacturing
	283	Drugs	Manufacturing
	285	Paints, Varnishes, and Allied Products	Manufacturing
	291	Petroleum Refining	Manufacturing
	295	Asphalt Paving and Roofing Materials	Manufacturing
	301	Tires and Inner Tubes	Manufacturing
	306	Fabricated Rubber Products, nec	Manufacturing
	308	Miscellaneous Plastics Products	Manufacturing
	311	Leather Tanning and Finishing	Manufacturing
	317	Handbags and Other Personal Leather Goods	Manufacturing
	323	Glass Products, Made of Purchased Glass	Manufacturing
	326	Pottery and Related Products	Manufacturing
	329	Abrasive, Asbestos, and Miscellaneous Nonmetallic Mineral Products	Manufacturing
	331	Steel Works, Blast Furnaces, and Rolling and Finishing Mills	Manufacturing

Source Category	SIC Code	SIC Description	Sector
VOC Emissions (cont'd)			
Miscellaneous Surface Coating (cont'd)	334	Secondary Smelting and Refining of Nonferrous Metals	Manufacturing
	335	Rolling, Drawing, and Extruding of Nonferrous Metals	Manufacturing
	336	Nonferrous Foundries (Castings)	Manufacturing
	341	Metal Cans and Shipping Containers	Manufacturing
	343	Heating Equipment, Except Electric and Warm Air; and Plumbing Fixtures	Manufacturing
	344	Fabricated Structural Metal Products	Manufacturing
	346	Metal Forgings and Stampings	Manufacturing
	347	Coating, Engraving, and Allied Services	Manufacturing
	348	Ordnance and Accessories, Except Vehicles and Guided Missiles	Manufacturing
	349	Miscellaneous Fabricated Metal Products	Manufacturing
	351	Engines and Turbines	Manufacturing
	352	Farm and Garden Machinery and Equipment	Manufacturing
	353	Construction, Mining, and Materials Handling Machinery and Equipment	Manufacturing
	355	Special Industry Machinery	Manufacturing
	356	General Industrial Machinery	Manufacturing
	357	Computer and Office Equipment	Manufacturing
	358	Refrigeration and Service Machinery	Manufacturing
	361	Electric Transmission and Distribution Equipment	Manufacturing
	362	Electrical Industrial Apparatus	Manufacturing
	363	Household Appliances	Manufacturing
	364	Electric Lighting and Wiring Equipment	Manufacturing
	367	Electronic Components and Accessories	Manufacturing
	371	Motor Vehicles and Motor Vehicle Equipment	Manufacturing
	372	Aircraft and Parts	Manufacturing
	373	Ship and Boat Building and Repairing	Manufacturing
	374	Railroad Equipment	Manufacturing
	375	Motorcycles, Bicycles, and Parts	Manufacturing
	379	Miscellaneous Transportation Equipment	Manufacturing
	384	Surgical, Medical, and Dental Instruments and Supplies	Manufacturing
	393	Musical Instruments	Manufacturing
	399	Miscellaneous Manufacturing Industries	Manufacturing
	417	Terminal and Service Facilities for Motor Vehicle Passenger Transportation	T & PU
	443	Freight Transportation on the Great Lakes	T & PU
	448	Water Transportation of Passengers	T & PU
	474	Rental of Railroad Cars	T & PU
	478	Miscellaneous Services Incidental to Transportation	T & PU
	492	Gas Production and Distribution	T & PU
	502	Furniture and Homefurnishings	Wholesale Trade
	503	Lumber and Other Construction Materials	Wholesale Trade
	504	Professional/Commercial Equipment and Supplies	Wholesale Trade
	506	Electrical Goods	Wholesale Trade
	512	Drugs, Drug Proprietaries, and Druggists' Sundries	Wholesale Trade
	516	Chemicals and Allied Products	Wholesale Trade
	519	Miscellaneous Nondurable Goods	Wholesale Trade
	521	Lumber and Other Building Materials Dealers	Retail Trade

VOC Emissions (cont'd)

Source Category	SIC Code	SIC Description	Sector
Miscellaneous Surface Coating (cont'd)	531	Department Stores	Retail Trade
	551	Motor Vehicle Dealers (New and Used)	Retail Trade
	556	Recreational Vehicle Dealers	Retail Trade
	557	Motorcycle Dealers	Retail Trade
	559	Automotive Dealers, nec	Retail Trade
	563	Women's Accessory and Specialty Stores	Retail Trade
	608	Foreign Banking and Branches and Agencies of Foreign Banks	Finance, Insurance and Real Estate
	609	Functions Related to Depository Banking	Finance, Insurance and Real Estate
	622	Commodity Contracts Brokers and Dealers	Finance, Insurance and Real Estate
	655	Land Subdividers and Developers	Finance, Insurance and Real Estate
	671	Holding Offices	Finance, Insurance and Real Estate
	679	Miscellaneous Investing	Finance, Insurance and Real Estate
	703	Camps and Recreational Vehicle Parks	Services
	704	Organization Hotels and Lodging Houses, Membership Basis	Services
	724	Barber Shops	Services
	726	Funeral Service and Crematories	Services
	729	Miscellaneous Personal Services	Services
	753	Automotive Repair Shops	Services
	762	Electrical Repair Shops	Services
	769	Miscellaneous Repair Shops, Related Services	Services
	799	Miscellaneous Amusement and Recreation Services	Services
	801	Offices and Clinics of Doctors of Medicine	Services
Autobody Refinishing	753	Top & Body Repair & Paint Shops	Services
Aerosol Paints	285	Paints, Varnishes, Lacquers, Enamels, and Allied Products	Manufacturing
Aircraft Surface Coating	223	Broadwoven Fabric Mills, Wool	Manufacturing
	291	Petroleum Refining	Manufacturing
	347	Metal Services, nec	Manufacturing
	366	Communications Equipment	Manufacturing
	372	Aircraft and Parts	Manufacturing
Synthetic Organic Chemical Manufacturing Industry (SOCMII) Batch Reactor Processes	286	Industrial Organic Chemicals	Manufacturing
SOCMI Fugitive Emission Leaks	286	Industrial Organic Chemicals	Manufacturing
Petroleum Refinery Fugitive Emission	291	Petroleum Refining	Manufacturing
Leaks	295	Asphalt Paving and Roofing Materials	Manufacturing
	299	Miscellaneous Petroleum and Coal Products	Manufacturing
Oil and Natural Gas Production Fields	131	Crude Petroleum and Natural Gas	Mining
	132	Natural Gas Liquids	Mining
	138	Oil and Gas Field Services	Mining
Pharmaceutical Manufacturing	283	Drugs	Manufacturing
Synthetic Fiber Manufacturing	282	Plastics Materials and Synthetics	Manufacturing
Pesticides	287	Pesticides and Agricultural Chemicals, n.e.c.	Agriculture, Forestry, Fishing

Source Category	SIC Code	SIC Description	Sector
NO_x Emissions			
Residential Space Heaters	343	Heating Equipment, Except Electric and Warm Air Furnaces	Manufacturing
Residential Water Heaters	363	Household Appliances, Miscellaneous	Manufacturing

[1] Entities classified under SIC codes 152 (Residential Building Construction) and 154 (Nonresidential Building Construction) may also be affected by this control measure. However, the County Business Patterns does not report establishment or employment data needed to prepare the economic assessment and regulatory flexibility analysis.

[2] Entities classified under SIC codes 011 (Cash Grains), 013 (Field Crops, Except Cash Grains), 016 (Vegetables and Melons), 017 (Fruits and Nuts), 018 (Horticultural Specialties), and 019 (General Farms, Primarily Crop) may also be affected by this control measure. However, the County Business Patterns does not report establishment or employment data needed to prepare the economic assessment and regulatory flexibility analysis.

APPENDIX VIII-5. SIC CODES AND SECTORS POTENTIALLY AFFECTED BY NO_x CONTROL MEASURES FOR INDUSTRIAL FUEL COMBUSTION IN THE STATIONARY AREA SOURCE INVENTORY

SIC Code	SIC Description	Sector	Fuel Type: Coal	Fuel Type: Oil	Fuel Type: Natural Gas
101	Metal Mining-Iron	Mining	✓		
131	Crude Petroleum and Natural Gas Extraction	Mining			✓
132	Extraction-Natural Gas Liquids	Mining			✓
144	Sand and Gravel	Mining	✓		
147	Chemical and Fertilizer Minerals	Mining			✓
201	Meat Products	Manufacturing	✓	✓	✓
202	Dairy Products	Manufacturing	✓		✓
203	Preserved Fruits/Vegetables	Manufacturing	✓	✓	✓
204	Grain Mill Products	Manufacturing	✓	✓	✓
205	Bakery Products	Manufacturing		✓	✓
206	Sugar and Confectionery Products	Manufacturing	✓	✓	✓
207	Fats and Oils	Manufacturing	✓	✓	✓
208	Beverages	Manufacturing	✓	✓	✓
209	Misc. Food/Kindred Products	Manufacturing		✓	✓
221	Broadwoven Fabric Mills, Cotton	Manufacturing		✓	
222	Broadwoven Fabric Mills, Manmade Fiber and Silk	Manufacturing			✓
223	Broadwoven Fabric Mills, Wool	Manufacturing		✓	✓
224	Narrow Fabric Mills	Manufacturing		✓	
225	Knitting Mills	Manufacturing	✓		
226	Textile Finishing, Except Wool	Manufacturing	✓	✓	✓
229	Miscellaneous Textile Goods	Manufacturing	✓	✓	✓
233	Women's, Misses', and Juniors' Outware	Manufacturing		✓	
243	Millwork, Plywood & Structural Members	Manufacturing	✓		
249	Misc. Wood Products	Manufacturing		✓	✓
251	Household Furniture	Manufacturing	✓	✓	
261	Pulp Mills	Manufacturing	✓	✓	✓
262	Paper Mills	Manufacturing	✓	✓	✓
263	Paperboard Mills	Manufacturing	✓	✓	✓
265	Paperboard Containers	Manufacturing		✓	✓
267	Miscellaneous Converted Paper Products	Manufacturing	✓	✓	✓
271	Newspapers	Manufacturing		✓	
275	Commercial Printing	Manufacturing		✓	✓
280	Chemicals and Allied Products	Manufacturing			✓
281	Industrial Inorganic Chemicals	Manufacturing	✓	✓	✓
282	Plastics Materials and Synthetics	Manufacturing	✓	✓	✓
283	Drugs	Manufacturing	✓	✓	✓
284	Soaps, Cleaners, and Toilet Goods	Manufacturing	✓	✓	✓
285	Paints and Allied Products	Manufacturing			✓
286	Industrial Organic Chemicals	Manufacturing	✓	✓	✓
287	Agricultural Chemicals	Manufacturing	✓	✓	✓
289	Miscellaneous Chemical Products	Manufacturing	✓	✓	✓
291	Petroleum Refining	Manufacturing		✓	✓
295	Asphalt Paving and Roofing Materials	Manufacturing		✓	✓
299	Miscellaneous Petroleum and Coal Products	Manufacturing	✓		✓
301	Tires and Inner Tubes	Manufacturing	✓	✓	✓

SIC Code	SIC Description	Sector	Fuel Type: Coal	Oil	Natural Gas
305	Gaskets, Packing, and Sealing Devices and Rubber and Plastic Hose and Belting	Manufacturing		✓	
306	Fabricated Rubber Products	Manufacturing	✓	✓	✓
308	Miscellaneous Plastics Products	Manufacturing	✓	✓	✓
311	Leather Tanning and Finishing	Manufacturing	✓	✓	
322	Glass-Pressed or Blown	Manufacturing			✓
323	Products of Purchased Glass	Manufacturing			✓
324	Cement, Hydraulic	Manufacturing	✓		
325	Structural Clay Products	Manufacturing			✓
326	Pottery and Related Products	Manufacturing	✓		✓
327	Concrete, Gypsum, Plaster Products	Manufacturing	✓		✓
329	Miscellaneous Nonmetallic Mineral Products	Manufacturing		✓	✓
331	Blast Furnace and Basic Steel Products	Manufacturing	✓	✓	✓
332	Iron and Steel Foundries	Manufacturing			✓
333	Primary Nonferrous Metals	Manufacturing			✓
334	Secondary Nonferrous Metals	Manufacturing	✓	✓	✓
335	Nonferrous Rolling and Drawing	Manufacturing		✓	✓
339	Miscellaneous Primary Metal Products	Manufacturing		✓	✓
341	Metal Cans and Shipping Containers	Manufacturing			✓
342	Cutlery, Handtools, and Hardware	Manufacturing		✓	
343	Plumbing and Heating, Except Electric	Manufacturing		✓	
344	Fabricated Structural Metal Products	Manufacturing		✓	✓
346	Metal Forgings and Stampings	Manufacturing	✓		✓
348	Ordnance and Accessories, Miscellaneous	Manufacturing		✓	✓
349	Miscellaneous Fabricated Metal Products	Manufacturing			✓
351	Engines and Turbines	Manufacturing	✓	✓	✓
352	Farm and Garden Machinery	Manufacturing			✓
353	Construction and Related Machinery	Manufacturing	✓	✓	✓
354	Metalworking Machinery	Manufacturing	✓		
356	General Industrial Machinery	Manufacturing		✓	
357	Computer and Office Equipment	Manufacturing		✓	✓
358	Refrigeration and Service Machinery	Manufacturing		✓	✓
359	Miscellaneous Industrial and Commercial Machinery and Equipment	Manufacturing		✓	
361	Electric Distribution Equipment	Manufacturing		✓	✓
362	Electrical Industrial Apparatus	Manufacturing	✓	✓	✓
363	Household Appliances	Manufacturing	✓		✓
364	Electric Lighting and Wiring Equipment	Manufacturing			✓
365	Household Audio and Video Equipment	Manufacturing			✓
366	Communications Equipment	Manufacturing		✓	
367	Electronic Components and Accessories	Manufacturing		✓	✓
369	Miscellaneous Electrical Equipment	Manufacturing		✓	
371	Motor Vehicles and Equipment	Manufacturing	✓	✓	✓
372	Aircraft and Parts	Manufacturing		✓	✓
373	Ship and Boat Building and Repairing	Manufacturing		✓	
374	Railroad Equipment	Manufacturing	✓		
376	Guided Missiles, Space Vehicles, Parts	Manufacturing		✓	
384	Medical Instruments and Supplies	Manufacturing		✓	
386	Photographic Equipment	Manufacturing		✓	✓
391	Jewelry, Silverware, and Plated Ware	Manufacturing		✓	✓
393	Musical Instruments	Manufacturing		✓	
399	Manufacturing Industries, Miscellaneous	Manufacturing			✓

APPENDIX VIII-6. SIC CODES AND SECTORS AFFECTED BY CONTROL MEASURES FOR PM, VOC, AND NO_x SOURCES IN THE ON-HIGHWAY AND NONROAD MOBILE SOURCE INVENTORY

Source Category/Control Measure	SIC Code	SIC Description	Sector
On-Highway Motor Vehicles			
California Reformulated Diesel Fuel Program	291	Petroleum Refineries	Manufacturing
Federal and California Reformulated Gasoline Programs	291	Petroleum Refineries	Manufacturing
California Low Emission Vehicle Program	371	Motor Vehicles and Equipment	Manufacturing
	551	New and Used Car Dealers	Retail Trade
Enhanced I/M	554	Gasoline Service Stations	Retail Trade
		Households	
	753	Automotive Repair Shops	Services
Nonroad Motor Vehicles			
California Reformulated Diesel Fuel and Federal Reformulated Gasoline Programs	291	Petroleum Refineries	Manufacturing
California Phase II Exhaust Standards for Nonroad Diesel Engines $\geq$175 bhp	351	Internal Combustion Engines, not elsewhere classified	Manufacturing
Commercial Marine Vessels, Emission Fees	441	Deep Sea Foreign Transportation of Freight	Water Transportation
	442	Deep Sea Domestic Transportation of Freight	Water Transportation
	443	Freight Transportation on the Great Lakes	Water Transportation
	444	Water Transportation of Freight, nec	Water Transportation
Locomotive Engines:			
• Potential Federal NO_x Emission Standards and	374	Railroad Equipment	Manufacturing
• Potential CA NO_x Emission Standards	374	Railroad Equipment	Manufacturing
Recreational Vehicles - Potential California Standards for 2- and 4-stroke engines	375	Motorcycles, Bicycles, and Parts	Manufacturing
	379	Transportation Equipment, Not Elsewhere Classified	Manufacturing

APPENDIX VIII-7. MANUFACTURING: DISTRIBUTION OF ESTABLISHMENTS, FIRMS, AND EMPLOYEES BY EMPLOYMENT SIZE CATEGORY

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
201	Establishments	2,393	2,892	7,635	31%	38%
	Firms	2,315	2,562	2,668	87%	96%
	Employment	40,237	91,972	478,711	8%	19%
202	Establishments	1,516	2,348	4,365	35%	54%
	Firms	1,356	1,525	1,569	86%	97%
	Employment	24,155	60,322	190,383	13%	32%
203	Establishments	1,140	1,482	4,417	26%	34%
	Firms	1,095	1,269	1,324	83%	96%
	Employment	20,995	58,184	279,533	8%	21%
204	Establishments	1,608	2,004	3,431	47%	58%
	Firms	1,443	1,525	1,545	93%	99%
	Employment	19,912	35,955	109,113	18%	33%
205	Establishments	2,165	2,551	4,571	47%	56%
	Firms	2,038	2,169	2,227	92%	97%
	Employment	32,787	61,430	211,366	16%	29%
206	Establishments	826	1,020	3,144	26%	32%
	Firms	732	818	844	87%	97%
	Employment	13,818	32,864	139,634	10%	24%
207	Establishments	509	585	586	87%	100%
	Firms	-	-	358	-	-
	Employment	21,200	29,200	30,100	70%	97%
208	Establishments	1,458	1,929	3,754	39%	51%
	Firms	1,369	1,538	1,597	86%	96%
	Employment	23,238	56,669	228,083	10%	25%
209	Establishments	3,349	3,731	3,764	89%	99%
	Firms	-	-	3,313	-	-
	Employment	59,273	**	161,257	37%	**
211	Establishments	6	6	16	38%	38%
	Firms	-	-	12	-	-
	Employment	**	**	27,494	**	**

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
212	Establishments	18	27	27	67%	100%
	Firms	-	-	-	-	-
	Employment	600	2,600	2,600	23%	100%
213	Establishments	19	29	30	63%	97%
	Firms	-	-	-	-	-
	Employment	500	**	3,200	16%	**
214	Establishments	29	44	47	62%	94%
	Firms	-	-	-	-	-
	Employment	900	5,000	6,900	13%	72%
22	Establishments	4,097	5,219	9,071	45%	58%
	Firms	3,971	4,572	4,764	83%	96%
	Employment	82,446	213,655	761,959	11%	28%
221	Establishments	195	253	301	65%	84%
	Firms	-	-	246	-	-
	Employment	2,700	20,000	72,000	4%	28%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
222	Establishments	237	379	436	54%	87%
	Firms	-	-	-	-	-
	Employment	4,600	41,600	88,300	5%	47%
223	Establishments	89	110	118	75%	93%
	Firms	-	-	106	-	-
	Employment	2,000	7,400	14,000	14%	53%
224	Establishments	213	268	272	78%	99%
	Firms	-	-	247	-	-
	Employment	5,900	16,300	18,500	32%	88%
225	Establishments	1,597	1,963	3,698	43%	53%
	Firms	1,556	1,800	1,850	84%	97%
	Employment	39,145	90,272	242,881	16%	37%
226	Establishments	521	650	669	78%	97%
	Firms	-	-	591	-	-
	Employment	10,700	42,000	56,100	19%	75%
227	Establishments	365	445	475	77%	94%
	Firms	-	-	419	-	-
	Employment	7,200	24,100	53,300	14%	45%
228	Establishments	280	549	612	46%	90%
	Firms	-	-	387	-	-
	Employment	9,500	79,200	113,900	8%	70%
229	Establishments	942	1,062	1,076	88%	99%
	Firms	-	-	984	-	-
	Employment	23,900	48,500	52,500	46%	92%
232	Establishments	1,149	1,842	1,930	60%	95%
	Firms	-	-	-	-	-
	Employment	36,000	193,100	258,300	14%	75%
233	Establishments	9,485	10,228	10,257	92%	100%
	Firms	-	-	-	-	-
	Employment	188,600	299,000	348,900	54%	86%
234	Establishments	349	542	561	62%	97%
	Firms	-	-	-	-	-
	Employment	12,300	53,300	67,500	18%	79%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
235	Establishments	309	352	355	88%	99%
	Firms	-	-	-	-	-
	Employment	6,725	14,553	17,560	38%	83%
236	Establishments	631	817	837	75%	98%
	Firms	-	-	-	-	-
	Employment	21,200	40,800	71,800	30%	57%
237	Establishments	380	380	380	100%	100%
	Firms	-	-	-	-	-
	Employment	2,100	2,100	2,100	100%	100%
238	Establishments	880	976	981	90%	100%
	Firms	-	-	925	-	-
	Employment	18,300	31,600	40,800	45%	78%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
239	Establishments	6,762	7,127	7,160	94%	100%
	Firms	-	-	6,906	-	-
	Employment	91,700	167,600	197,600	46%	85%
241	Establishments	11,889	11,933	11,936	100%	100%
	Firms	-	-	-	-	-
	Employment	76,800	82,000	85,700	90%	96%
242	Establishments	6,255	6,703	6,712	93%	100%
	Firms	-	-	6,135	-	-
	Employment	98,100	175,600	180,100	55%	98%
243	Establishments	7,417	7,901	7,929	93.5%	100%
	Firms	-	-	7,516	-	-
	Employment	112,400	215,600	240,100	47%	90%
244	Establishments	2,175	2,217	2,217	98%	100%
	Firms	-	-	2,169	-	-
	Employment	31,100	37,000	37,000	84%	100%
245	Establishments	833	1,078	1,084	77%	99%
	Firms	-	-	808	-	-
	Employment	20,800	63,200	65,300	32%	97%
249	Establishments	3,902	4,096	4,104	95%	100%
	Firms	-	-	3,827	-	-
	Employment	50,800	86,600	90,100	56%	96%
251	Establishments	4,935	5,132	5,706	86.5%	90%
	Firms	-	-	5,240	-	-
	Employment	83,400	202,102	294,900	28%	69%
252	Establishments	796	962	986	81%	98%
	Firms	-	-	916	-	-
	Employment	15,500	52,700	80,700	19%	65%
253	Establishments	435	488	491	89%	99%
	Firms	-	-	465	-	-
	Employment	8,600	20,100	21,800	39%	92%
254	Establishments	2,293	2,452	2,458	93%	100%
	Firms	-	-	2,399	-	-
	Employment	40,200	70,500	74,000	54%	95%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size: Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
259	Establishments	1,984	2,074	2,086	95%	99%
	Firms	-	-	2,012	-	-
	Employment	25,300	42,500	49,900	51%	85%
26	Establishments	3,516	4,578	9,919	35%	46%
	Firms	3,373	3,846	3,975	85%	97%
	Employment	81,059	177,034	769,709	11%	23%
261	Establishments	11	32	39	28%	82%
	Firms	-	-	26	-	-
	Employment	600	7,700	14,200	4%	54%
262	Establishments	65	192	282	23%	68%
	Firms	-	-	122	-	-
	Employment	3,700	35,300	129,100	3%	27%
263	Establishments	70	174	205	34%	85%
	Firms	-	-	91	-	-
	Employment	4,300	27,100	52,300	8%	52%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
265	Establishments	1,968	2,698	2,711	73%	100%
	Firms	-	-	2,309	-	-
	Employment	65,100	**	197,101	33%	**
267	Establishments	2,132	2,695	2,774	77%	97%
	Firms	-	-	2,489	-	-
	Employment	58,572	170,241	232,323	25%	73%
271	Establishments	7,771	8,438	8,576	91%	98%
	Firms	-	-	7,473	-	-
	Employment	122,722	259,635	443,133	28%	59%
272	Establishments	4,064	4,225	4,255	96%	99%
	Firms	-	-	3,759	-	-
	Employment	46,212	79,055	116,125	40%	68%
273	Establishments	2,002	2,118	2,648	76%	80%
	Firms	-	-	2,459	-	-
	Employment	30,968	71,139	121,483	26%	59%
274	Establishments	2,233	2,348	2,369	94%	99%
	Firms	-	-	-	-	-
	Employment	28,900	52,100	69,400	42%	75%
275	Establishments	31,413	32,286	32,352	97%	100%
	Firms	-	-	31,140	-	-
	Employment	345,766	509,216	566,369	61%	90%
276	Establishments	684	852	853	80%	100%
	Firms	-	-	-	-	-
	Employment	22,900	43,900	53,200	43%	83%
277	Establishments	134	152	162	83%	94%
	Firms	-	-	-	-	-
	Employment	2,000	**	21,300	9%	**
278	Establishments	1,375	1,533	1,546	89%	99%
	Firms	-	-	-	-	-
	Employment	30,600	56,700	68,700	45%	83%
279	Establishments	4,689	4,689	4,778	98%	98%
	Firms	-	-	-	-	-
	Employment	54,300	**	69,400	78%	**

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
28	Establishments	7,674	9,749	21,037	36%	46%
	Firms	7,012	7,486	7,682	91%	97%
	Employment	104,720	201,337	1,196,947	9%	17%
281	Establishments	1,243	1,366	1,393	89%	98%
	Firms	-	-	628	-	-
	Employment	21,100	87,200	93,600	23%	93%
282	Establishments	475	619	685	69%	90%
	Firms	-	-	375	-	-
	Employment	13,919	47,413	130,180	11%	36%
283	Establishments	928	1,107	3,015	31%	37%
	Firms	876	963	1,006	87%	96%
	Employment	15,320	32,317	310,730	5%	10%
284	Establishments	1,938	2,178	4,297	45%	51%
	Firms	1,848	1,961	1,997	93%	98%
	Employment	24,305	46,431	209,616	12%	22%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size: Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
285	Establishments	1,296	1,415	1,418	91%	100%
	Firms	-	-	1,123	-	-
	Employment	29,279	**	54,678	54%	**
286	Establishments	694	909	962	72%	95%
	Firms	-	-	674	-	-
	Employment	1,800	63,300	125,700	1%	50%
287	Establishments	613	843	1,188	52%	71%
	Firms	511	543	552	93%	98%
	Employment	7,723	13,911	28,188	27%	49%
289	Establishments	2,506	2,674	2,685	93%	100%
	Firms	-	-	2,210	-	-
	Employment	46,882	75,881	87,962	53%	86%
29	Establishments	1,118	1,504	15,226	7.3%	10%
	Firms	939	1,012	1,057	89%	96%
	Employment	14,619	22,612	452,770	3%	5%
291	Establishments	137	243	13,828	1%	2%
	Firms	114	133	171	67%	78%
	Employment	2,470	6,575	420,330	1%	2%
295	Establishments	1,253	1,318	1,367	92%	96%
	Firms	521	650	704	74%	92%
	Employment	17,900	24,200	28,100	64%	86%
299	Establishments	535	557	557	96%	100%
	Firms	392	464	464	85%	100%
	Employment	10,000	13,100	13,100	76%	100%
301	Establishments	74	108	145	51%	75%
	Firms	-	-	114	-	-
	Employment	1,494	9,281	68,505	2%	14%
302	Establishments	37	56	61	61%	92%
	Firms	-	-	54	-	-
	Employment	691	**	10,704	7%	**
305	Establishments	540	667	679	80%	98%
	Firms	-	-	658	-	-
	Employment	13,983	41,780	55,085	25%	76%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
306	Establishments	1,354	1,587	1,619	84%	98%
	Firms	-	-	1,379	-	-
	Employment	32,411	80,023	105,809	31%	76%
308	Establishments	8,842	10,609	12,978	68%	82%
	Firms	8,552	9,343	9,473	90%	99%
	Employment	169,589	326,930	513,558	33%	64%
311	Establishments	282	312	316	89%	99%
	Firms	-	-	311	-	-
	Employment	5,942	**	15,462	38%	**
313	Establishments	120	127	127	94%	100%
	Firms	-	-	-	-	-
	Employment	3,100	5,000	5,000	62%	100%
317	Establishments	482	528	530	91%	100%
	Firms	-	-	-	-	-
	Employment	6,600	13,900	16,700	40%	83%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
321	Establishments	95	113	124	77%	91%
	Firms	-	-	65	-	-
	Employment	1,371	**	15,117	9%	**
322	Establishments	358	454	505	71%	90%
	Firms	-	-	394	-	-
	Employment	5,358	32,958	74,350	7%	44%
323	Establishments	1,376	1,482	1,497	92%	99%
	Firms	-	-	1,324	-	-
	Employment	18,739	**	55,347	34%	**
324	Establishments	134	224	225	60%	100%
	Firms	-	-	123	-	-
	Employment	2,743	**	19,085	14%	**
325	Establishments	496	587	592	84%	99%
	Firms	-	-	423	-	-
	Employment	15,047	31,255	34,716	43%	90%
326	Establishments	909	987	1,001	91%	99%
	Firms	-	-	970	-	-
	Employment	9,279	**	38,799	24%	**
327	Establishments	9,183	9,465	9,467	97%	100%
	Firms	-	-	7,388	-	-
	Employment	142,051	**	193,400	73%	**
329	Establishments	1,445	1,579	1,601	90%	99%
	Firms	-	-	1,423	-	-
	Employment	28,357	57,767	76,802	37%	75%
33	Establishments	4,359	5,580	11,471	38%	49%
	Firms	4,159	4,720	4,897	85%	96%
	Employment	84,805	201,219	801,728	11%	25%
331	Establishments	908	1,207	1,299	70%	93%
	Firms	-	-	1,281	-	-
	Employment	22,896	86,591	261,421	9%	33%
332	Establishments	801	1,048	1,691	47%	62%
	Firms	772	924	953	81%	97%
	Employment	19,374	49,126	124,214	16%	40%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
333	Establishments	110	140	174	63%	81%
	Firms	-	-	133	-	-
	Employment	1,874	8,991	36,247	5%	25%
334	Establishments	340	386	387	88%	100%
	Firms	-	-	365	-	-
	Employment	6,686	**	15,503	43%	**
335	Establishments	636	980	1,041	61%	94%
	Firms	-	-	731	-	-
	Employment	20,267	97,627	158,147	13%	63%
336	Establishments	1,361	1,574	1,652	82%	95%
	Firms	1,322	1,453	1,464	90%	99%
	Employment	26,770	52,337	65,686	41%	80%
339	Establishments	867	916	919	94%	100%
	Firms	-	-	909	-	-
	Employment	17,642	**	33,335	53%	**

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size: Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
34	Establishments	30,327	34,181	39,538	77%	87%
	Firms	29,300	30,916	31,181	94%	99%
	Employment	495,501	806,948	1,363,681	36%	59%
341	Establishments	348	512	518	67%	99%
	Firms	-	-	275	-	-
	Employment	11,732	41,617	44,886	26%	93%
342	Establishments	2,083	2,363	2,415	86%	98%
	Firms	-	-	2,089	-	-
	Employment	38,644	97,804	143,043	27%	68%
343	Establishments	660	775	787	84%	99%
	Firms	-	-	782	-	-
	Employment	9,989	**	46,133	22%	**
344	Establishments	11,598	12,426	12,475	93%	100%
	Firms	-	-	11,533	-	-
	Employment	223,317	373,689	415,377	54%	90%
345	Establishments	2,375	2,561	2,572	92%	100%
	Firms	-	-	-	-	-
	Employment	50,300	85,500	94,700	53%	90%
346	Establishments	3,560	4,052	4,101	87%	99%
	Firms	-	-	3,751	-	-
	Employment	82,158	176,018	251,240	33%	70%
347	Establishments	4,946	5,132	5,137	96%	100%
	Firms	-	-	5,030	-	-
	Employment	84,119	113,225	116,322	72%	97%
348	Establishments	256	299	803	32%	37%
	Firms	252	273	291	87%	94%
	Employment	2,879	7,942	71,899	4%	11%
349	Establishments	8,369	9,015	9,063	92%	100%
	Firms	-	-	6,908	-	-
	Employment	130,626	255,942	291,915	45%	88%
35	Establishments	46,766	50,726	61,346	76%	83%
	Firms	45,580	47,105	47,465	96%	99%
	Employment	573,010	869,932	2,101,652	27%	41%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
351	Establishments	215	250	445	48%	56%
	Firms	204	215	226	90%	95%
	Employment	3,090	5,476	49,504	6%	11%
352	Establishments	1,582	1,763	2,037	78%	87%
	Firms	1,533	1,612	1,633	94%	99%
	Employment	21,296	35,424	98,187	22%	36%
353	Establishments	2,828	3,478	5,179	55%	67%
	Firms	2,608	2,826	2,870	91%	99%
	Employment	44,522	88,445	223,383	20%	40%
354	Establishments	10,543	11,144	11,891	89%	94%
	Firms	10,309	10,569	10,612	97%	100%
	Employment	135,761	186,118	253,512	54%	73%
355	Establishments	3,917	4,628	5,329	74%	87%
	Firms	3,755	3,976	4,014	94%	99%
	Employment	60,265	104,028	157,677	38%	66%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
356	Establishments	2,901	3,522	5,085	57%	69%
	Firms	2,753	2,985	3,048	90%	98%
	Employment	53,013	101,323	237,282	22%	43%
357	Establishments	1,538	1,975	6,597	23%	30%
	Firms	1,440	1,615	1,697	85%	95%
	Employment	25,034	57,790	659,871	4%	9%
358	Establishments	1,613	1,961	2,040	79%	96%
	Firms	-	-	1,873	-	-
	Employment	32,493	105,387	189,311	17%	56%
359	Establishments	22,057	22,325	22,346	99%	100%
	Firms	-	-	-	-	-
	Employment	217,900	262,000	291,700	75%	90%
36	Establishments	11,726	13,834	24,055	49%	58%
	Firms	11,381	12,504	12,818	89%	98%
	Employment	201,852	426,129	1,629,951	12%	26%
361	Establishments	545	703	739	74%	95%
	Firms	-	-	602	-	-
	Employment	12,877	48,297	77,499	17%	62%
362	Establishments	1,629	1,952	2,018	81%	97%
	Firms	-	-	1,963	-	-
	Employment	33,798	110,157	168,858	20%	65%
363	Establishments	291	343	1,141	26%	31%
	Firms	283	309	332	85%	91%
	Employment	3,876	11,052	117,840	3%	9%
364	Establishments	1,459	1,801	1,862	78%	97%
	Firms	-	-	1,695	-	-
	Employment	33,556	105,504	162,904	21%	65%
365	Establishments	743	845	1,003	74%	84%
	Firms	734	772	781	94%	99%
	Employment	8,732	16,685	36,115	24%	46%
366	Establishments	960	1,311	4,089	24%	32%
	Firms	923	1,083	1,123	82%	96%
	Employment	20,126	53,205	394,921	5%	14%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
367	Establishments	4,347	5,108	6,361	68%	80%
	Firms	4,251	4,714	4,833	88%	98%
	Employment	81,678	171,140	418,373	20%	41%
369	Establishments	1,700	2,050	2,114	80%	97%
	Firms	-	-	2,104	-	-
	Employment	33,758	110,790	185,499	18%	60%
37	Establishments	8,186	9,335	21,943	37%	43%
	Firms	7,943	8,527	8,727	91%	98%
	Employment	121,863	244,355	3,081,809	4%	8%
371	Establishments	3,200	3,799	8,704	37%	44%
	Firms	3,091	3,369	3,467	89%	97%
	Employment	53,159	112,828	1,263,938	4%	9%
372	Establishments	1,350	1,628	1,767	76%	92%
	Firms	-	-	1,386	-	-
	Employment	27,185	89,047	624,341	4%	14%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size: Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
373	Establishments	2,465	2,669	4,317	57%	62%
	Firms	2,417	2,541	2,572	94%	99%
	Employment	28,910	55,501	204,109	14%	27%
374	Establishments	143	171	185	77%	92%
	Firms	-	-	150	-	-
	Employment	3,973	9,840	28,629	14%	34%
375	Establishments	225	238	241	93%	99%
	Firms	-	-	233	-	-
	Employment	2,934	5,819	9,923	30%	59%
376	Establishments	68	95	143	48%	66%
	Firms	-	-	97	-	-
	Employment	1,850	9,229	201,073	1%	4.6%
379	Establishments	868	952	962	90%	99%
	Firms	-	-	947	-	-
	Employment	14,665	31,321	44,783	33%	70%
384	Establishments	2,888	3,310	3,408	85%	97%
	Firms	-	-	3,023	-	-
	Employment	52,845	147,021	229,404	23%	64%
386	Establishments	638	764	1,587	40%	48%
	Firms	616	651	660	93%	99%
	Employment	8,574	16,299	181,491	5%	9%
39	Establishments	15,490	16,415	17,408	89%	94%
	Firms	15,198	15,658	15,745	97%	99%
	Employment	171,122	260,625	358,935	48%	73%
391	Establishments	2,638	2,722	2,725	97%	100%
	Firms	-	-	-	-	-
	Employment	27,171	43,743	47,239	58%	93%
393	Establishments	372	403	404	92%	100%
	Firms	-	-	-	-	-
	Employment	4,174	**	12,625	33%	**
395	Establishments	894	955	962	93%	99%
	Firms	-	-	-	-	-
	Employment	12,803	25,400	31,130	41%	82%

APPENDIX VIII-7 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
399	Establishments	7,075	7,366	7,382	96%	100%
	Firms	-	-	-	-	-
	Employment	87,741	**	160,839	55%	**

NOTES: * The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (generally less than 500 employees) to an establishment basis.

** Employment data withheld for certain size categories in this employment size range to avoid disclosure of operations at individual establishments.

APPENDIX VIII-8. MANUFACTURING: COMPARISON OF AVERAGE REVENUE FOR ALL ESTABLISHMENTS TO AVERAGE REVENUE FOR SMALL ESTABLISHMENTS

SIC code	Estimated Average Sales Per Establishment in 2007 For All Establishments (in 1000s of 1990$)	Estimated Average Sales Per Establishment in 2007 for Small Establishments* (in 1000s of 1990$)	Ratio of Average Sales For Small Establishments to Average Sales for All Establishments
201	19,290	5,527	29%
202	13,315	5,007	38%
203	11,814	3,495	30%
204	9,583	3,428	36%
205	6,172	1,208	20%
206	7,010	2,669	38%
207	43,948	21,299	48%
208	14,053	3,686	26%
209	10,134	3,348	33%
211	2,920,545	251,916**	9%
212	11,481	2,389	21%
213	58,200	6,053	10%
214	81,745	14,862	18%
22	8,385	2,047	24%
221	25,356	1,197	5%
222	17,327	2,548	15%
223	22,019	2,238	10%
224	6,649	2,231	34%
225	5,310	1,968	37%
226	13,299	2,913	22%
227	29,091	3,739	13%
228	22,721	4,174	18%
229	8,724	2,628	30%
232	10,241	3,128	31%
233	2,387	478	20%
234	8,752	8,179	93%
235	1,856	1,265	68%
236	5,670	2,529	45%
237	1,369	1,265	92%
238	3,058	1,502	49%
239	2,824	1,101	39%
241	2,016	1,281	64%
242	4,830	2,310	48%
243	4,640	1,918	41%
244	1,666	1,298	78%
245	9,840	3,971	40%
249	3,325	1,862	56%
251	5,396	1,773	33%
252	12,698	2,271	18%
253	8,722	2,284	26%
254	3,779	1,958	52%
259	2,997	1,305	44%

APPENDIX VIII-8 (CONTINUED)

SIC code	Estimated Average Sales Per Establishment in 2007 For All Establishments (in 1000s of 1990$)	Estimated Average Sales Per Establishment in 2007 for Small Establishments* (in 1000s of 1990$)	Ratio of Average Sales For Small Establishments to Average Sales for All Establishments
26	16,187	3,526	22%
261	153,545	33,447**	22%
262	145,607	17,287	12%
263	96,730	21,071**	22%
265	13,215	5,965	45%
267	17,201	4,114	24%
271	6,017	1,303	22%
272	7,692	2,324	30%
273	9,958	3,060	31%
274	5,718	2,567	45%
275	2,058	1,120	54%
276	15,102	1,786	12%
277	29,853	2,604	9%
278	4,383	1,776	41%
279	1,445	1,139	79%
28	21,178	4,833	23%
281	22,955	7,204	31%
282	111,791	16,963	15%
283	22,363	3,008	13%
284	12,882	2,980	23%
285	13,724	6,287	46%
286	90,160	13,860	15%
287	9,998	3,481	35%
289	8,863	5,318	60%
29	13,799	4,945	36%
291	553,301	42,456	8%
295	6,445	4,657	72%
299	9,142	6,903	76%
301	99,723	3,747	4%
302	13,970	1,346	10%
305	10,588	3,246	31%
306	9,416	3,076	33%
308	5,716	2,556	45%
311	6,984	3,001	43%
313	2,027	1,044	52%
317	2,027	1,044	52%
321	41,291	2,097	5%
322	22,318	1,275	6%
323	5,523	1,746	32%
324	27,047	8,944	33%
325	6,826	3,735	55%
326	3,426	859	25%
327	3,400	2,338	69%

APPENDIX VIII-8 (CONTINUED)

SIC code	Estimated Average Sales Per Establishment in 2007 For All Establishments (in 1000s of 1990$)	Estimated Average Sales Per Establishment in 2007 for Small Establishments* (in 1000s of 1990$)	Ratio of Average Sales For Small Establishments to Average Sales for All Establishments
329	8,551	2,894	34%
33	12,367	2,365	19%
331	49,452	5,095	10%
332	8,205	1,747	21%
333	74,465	4,050	5%
334	13,040	8,343	64%
335	36,514	6,961	19%
336	3,540	1,553	44%
339	3,490	2,182	63%
34	4,479	1,862	42%
341	30,750	10,316	34%
342	7,887	2,003	25%
343	8,638	2,429	28%
344	4,375	2,469	56%
345	3,649	2,234	61%
346	9,507	2,730	29%
347	2,015	1,371	68%
348	11,888	1,003	8%
349	4,404	1,989	45%
35	5,846	1,597	27%
351	17,804	1,779	10%
352	7,232	1,480	20%
353	6,416	2,160	34%
354	2,260	1,154	51%
355	3,761	1,743	46%
356	5,377	2,069	38%
357	15,064	2,497	17%
358	15,967	2,683	17%
359	1,171	769	66%
36	11,193	2,372	21%
361	15,868	2,716	17%
362	10,107	1,967	19%
363	15,823	1,850	12%
364	13,071	2,463	19%
365	8,303	1,766	21%
366	12,188	2,437	20%
367	7,130	1,627	23%
369	12,090	1,472	12%
37	35,538	2,260	6%
371	38,564	2,267	6%
372	80,938	2,963	4%
373	9,088	1,459	16%
374	23,567	5,656	24%

APPENDIX VIII-8 (CONTINUED)

SIC code	Estimated Average Sales Per Establishment in 2007 For All Establishments (in 1000s of 1990$)	Estimated Average Sales Per Establishment in 2007 for Small Establishments* (in 1000s of 1990$)	Ratio of Average Sales For Small Establishments to Average Sales for All Establishments
375	7,336	2,049	28%
376	316,586	5,142	2%
379	9,164	2,426	26%
384	10,100	2,241	22%
386	18,748	2,271	12%
39	2,244	1,035	46%
391	2,468	1,090	44%
393	2,545	1,225	48%
395	3,227	1,294	40%
399	1,858	1,009	54%

NOTES: *The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (generally less than 500 employees) to an establishment basis.

**Sales data withheld for certain size categories in this employment size range to avoid disclosure of operations at individual establishments. Average sales at small establishments is calculated based on the assumption that sales at small establishments for this 3-digit SIC code represents the same proportion of average sales for all establishments as the ratio of average sales for all establishments to small establishments at the 2-digit SIC code level.

APPENDIX VIII-9. AGRICULTUAL PRODUCTION: DISTRIBUTION OF FARMS BY SALES RANGE

SIC Code	Distribution of Farms by Market Value of Agricultural Products Sold					
	Number of Farms			Average Revenue Per Farm in 2007		
	Total	Farms w/ Sales < $500,000*	% of Total	Total	Farms w/ Sales < $500,000*	% of Total
01	802,245	790,432	99%	$91,000	$66,000	73%
011	407,503	404,421	99%	90,000	81,000	90%
013	211,053	208,644	99%	61,000	43,000	71%
016	25,375	24,101	95%	177,000	63,000	36%
017	89,369	86,660	97%	110,000	55,000	51%
018	21,088	19,214	91%	300,000	94,000	31%
019	47,857	47,392	99%	52,000	42,000	80%
021	843,597	834,337	99%	76,000	39,000	52%

NOTES: Establishment and employment data are not presented because they are not available for these SIC codes; these values do not include revenue from government payments.
* This is generally the designation that the Small Business Administration currently uses to indicate small businesses in these industries.

APPENDIX VIII-10. AGRICULTURAL SERVICES, FORESTRY, MINING, AND CONSTRUCTION: DISTRIBUTION OF ESTABLISHMENTS AND EMPLOYEES BY EMPLOYMENT SIZE CATEGORY

SIC Code	Data	Distribution of Establishments and Employees by Employment Size Category				
		Less Than 100 Employees*	Less Than 500 Employees	Total	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
071	Establishments	521	523	523	100%	100%
	Employment	2,941	2,941	3,658	80%	80%
072	Establishments	3,202	3,264	3,265	98%	100%
	Employment	25,521	33,329	36,603	70%	91%
078	Establishments	46,702	46,884	46,903	100%	100%
	Employment	224,825	247,672	274,112	82%	90%
08	Establishments	1,770	1,797	1,798	98%	100%
	Employment	13,060	16,205	17,981	73%	90%
101	Establishments	41	44	51	80%	86%
	Employment	**	1,200	7,100	**	17%
102	Establishments	38	52	61	62%	85%
	Employment	-	-	13,800	-	-
103	Establishments	31	39	39	79%	100%
	Employment	700	**	2,000	35%	**
104	Establishments	336	370	372	90%	99%
	Employment	4,400	**	13,200	33%	**
106	Establishments	55	57	57	96%	100%
	Employment	-	-	1,300	-	-
108	Establishments	266	268	268	99%	100%
	Employment	**	2,888	2,800	**	100%
109	Establishments	168	179	179	94%	100%
	Employment	**	3,800	3,800	**	100%
122	Establishments	3,125	3,472	3,507	89%	99%
	Employment	54,800	132,500	157,500	35%	84%
123	Establishments	105	107	107	98%	100%
	Employment	**	1,900	1,900	**	100%
124	Establishments	287	291	291	99%	100%
	Employment	3,200	3,900	3,900	82%	100%
13	Establishments	18,934	19,758	21,135	90%	93%
	Firms	17,947	18,141	18,179	99%	100%
	Employment	126,244	161,948	213,141	59%	76%
131	Establishments	9,867	10,128	10,203	97%	99%
	Employment	66,400	123,000	200,400	33%	61%

APPENDIX VIII-10 (CONTINUED)

SIC Code	Data	Distribution of Establishments and Employees by Employment Size Category				
		Less Than 100 Employees*	Less Than 500 Employees	Total	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
132	Establishments	702	714	714	98%	100%
	Employment	11,000	12,800	12,800	86%	100%
138	Establishments	10,558	10,985	11,802	89%	93%
	Firms	10,147	10,273	10,291	99%	100%
	Employment	82,973	106,202	134,377	62%	79%
141	Establishments	148	149	149	99%	100%
	Employment	**	1,200	1,200	**	100%
142	Establishments	1,949	2,002	2,002	97%	100%
	Employment	35,800	43,600	43,600	82%	100%
144	Establishments	2,732	2,749	2,750	99%	100%
	Employment	27,100	28,600	31,300	87%	91%

APPENDIX VIII-10 (CONTINUED)

SIC Code	Data	Distribution of Establishments and Employees by Employment Size Category				
		Less Than 100 Employees*	Less Than 500 Employees	Total	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
145	Establishments	172	196	198	87%	99%
	Employment	3,900	6,700	10,000	39%	67%
147	Establishments	401	437	445	90%	98%
	Employment	1,900	9,900	9,907	19%	100%
148	Establishments	176	177	177	99%	100%
	Employment	**	1,700	1,700	**	100%
149	Establishments	338	352	352	96%	100%
	Employment	4,300	**	6,900	62%	**
152	Establishments	72,927	73,070	73,077	100%	100%
	Employment	435,249	**	435,249	93%	**
153	Establishments	20,568	20,754	20,765	99%	100%
	Employment	125,770	159,982	168,937	74%	95%
154	Establishments	37,531	38,288	38,347	98%	100%
	Employment	191,333	327,373	391,963	49%	84%
161	Establishments	10,426	10,959	10,985	95%	100%
	Employment	161,521	259,999	284,378	57%	91%
162	Establishments	24,887	25,518	25,607	97%	100%
	Employment	279,987	399,886	540,739	52%	74%
171	Establishments	66,211	66,890	69,491	95%	96%
	Firms	68,031	68,459	68,722	99%	100%
	Employment	503,050	581,029	609,740	83%	95%
172	Establishments	9,653	9,735	29,867	32%	33%
	Employment	117,119	130,771	169,968	69%	77%
173	Establishments	48,052	48,727	49,576	97%	98%
	Firms	48,278	48,722	48,760	99%	100%
	Employment	374,713	452,849	502,631	75%	90%
174	Establishments	37,726	38,199	46,182	82%	83%
	Employment	351,087	431,990	456,961	77%	95%
175	Establishments	18,140	18,273	44,183	41%	41%
	Employment	159,085	182,817	235,010	68%	78%
176	Establishments	12,336	12,466	25,673	48%	49%
	Employment	183,639	203,753	231,137	79%	88%
179	Establishments	51,346	51,815	51,830	99%	100%
	Employment	395,528	474,603	485,774	81%	98%

APPENDIX VIII-10 (CONTINUED)

NOTES: Firm-level data are not presented for most of these SIC codes because they are not available.

* The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (generally less than 500 employees) to an establishment basis.

** Employment data withheld for certain size categories in this employment size range to avoid disclosure of operations at individual establishments.

APPENDIX VIII-11. AGRICULTURAL SERVICES, FORESTRY, MINING, AND CONSTRUCTION: COMPARISON OF AVERAGE REVENUE FOR ALL ESTABLISHMENTS TO AVERAGE REVENUE FOR SMALL ESTABLISHMENTS

SIC code	Estimated Average Sales Per Establishment in 2007 For All Establishments (in 1000s of 1990$)	Estimated Average Sales Per Establishment in 2007 for Small Establishments* (in 1000s of 1990$)	Ratio of Average Sales For Small Establishments to Average Sales for All Establishments
071**	228	171	75%
072**	300	234	78%
078**	146	119	82%
08**	245	174	71%
101	31,789	4,989***	16%
102	41,934	8,123***	19%
103	8,179	2,871	35%
104	7,234	1,679	23%
106	2,298	361***	16%
108	1,116	175***	16%
109	2,984	468***	16%
122	8,167	4,051	50%
123	2,178	1,210	56%
124	1,560	1,230	79%
13	1,824	1,030	56%
131	7,430	3,265	44%
132	34,275	33,078	97%
138	820	501	61%
141	876	344***	39%
142	3,620	3,084	85%
144	1,509	1,331	88%
145	9,586	3,535	37%
147	9,468	610	6%
148	1,418	559***	39%
149	2,658	1,766	66%
152	708	657	93%
153	1,990	1,531	77%
154	2,032	1,384	68%
161	3,923	2,283	58%
162	2,409	1,344	56%
171	1,076	890	83%
172	1,245	1,036	83%
173	1,700	1,233	73%
174	1,245	1,036	83%
175	1,245	1,036	83%
176	1,245	1,036	83%
179	836	685	82%

NOTES: * The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (less than 500 employees) to an establishment basis.

** The data presented for these industries represents payroll because revenue data are not available.

*** Average sales at small establishments is calculated based on the assumption that sales at small establishments for this 3-digit SIC code represents the same proportion of average sales for all establishments as the ratio of average sales for all establishments to small establishments at the 2-digit SIC code level.

APPENDIX VIII-12. TRANSPORTATION, COMMUNICATIONS, AND UTILITIES: DISTRIBUTION OF ESTABLISHMENTS, FIRMS, AND EMPLOYEES BY EMPLOYMENT SIZE CATEGORY

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
401	Establishments	-	-	-	-	-
	Firms	516	-	530	97%	-
	Employment	25,835	-	235,543	11%	-
411	Establishments	6,879	**	7,106	97%	**
	Firms	5,928	6,157	6,177	96%	100%
	Employment	99,028	**	148,160	67%	**
417	Establishments	11	11	11	100%	100%
	Firms	5	8	8	63%	100%
	Employment	166	166	166	100%	100%
422	Establishments	5,619	5,920	6,916	81%	86%
	Firms	5,063	5,147	5,162	98%	100%
	Employment	40,579	57,280	72,429	56%	79%
423	Establishments	17	17	17	100%	100%
	Firms	15	15	15	100%	100%
	Employment	289	289	289	100%	100%
441, 2	Establishments	386	**	441	88%	**
	Firms	5,644	**	22,911	25%	**
	Employment	135	**	183	74%	**
443, 4	Establishments	227	**	260	87%	**
	Firms	196	**	226	87%	**
	Employment	4,033	**	11,438	35%	**
448	Establishments	398	**	421	95%	**
	Firms	4,857	**	19,434	25%	**
	Employment	376	394	397	95%	99%
449	Establishments	4,520	**	4,686	96%	**
	Firms	44,142	**	103,367	43%	**
	Employment	4,047	4,143	4,175	97%	99%
451	Establishments	4,555	5,087	5,242	87%	97%
	Firms	94,393	192,414	571,097	17%	34%
	Employment	-	-	-	-	-
458	Establishments	2,694	**	2,846	95%	**
	Firms	34,002	**	78,031	44%	**
	Employment	2,189	2,249	2,273	96%	99%
461	Establishments	804	**	828	97%	**
	Firms	9,687	**	16,740	58%	**
	Employment	66	87	100	66%	87%
474	Establishments	99	**	102	97%	**
	Firms	69	**	73	95%	**
	Employment	509	509	509	100%	100%

APPENDIX VIII-12 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
478	Establishments	1,762	**	1,802	98%	**
	Firms	1,327	**	1,376	96%	**
	Employment	-	-	-	-	-
481	Establishments	21,273	**	23,309	91%	**
	Firms	307,242	**	916,223	34%	**
	Employment	3,323	3,458	3,497	95%	99%
49	Establishments	17,093	**	18,825	91%	**
	Firms	8,092	8,401	8,597	94%	98%
	Employment	280,399	**	908,480	31%	**
491	Establishments	4,495	**	5,288	85%	**
	Firms	105,935	**	424,462	25%	**
	Employment	1,084	1,253	1,324	82%	95%
492	Establishments	3,506	**	3,823	92%	**
	Firms	59,689	**	147,418	40%	**
	Employment	529	570	632	84%	90%
493	Establishments	1,337	**	1,766	76%	**
	Firms	35,173	**	221,192	16%	**
	Employment	167	183	228	73%	80%
495	Establishments	4,197	**	4,357	96%	**
	Firms	59,734	**	88,764	67%	**
	Employment	3,159	3,248	3,265	97%	99%
496	Establishments	53	**	60	88%	**
	Firms	738	**	1,550	48%	**
	Employment	43	49	49	88%	100%

NOTES: * The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (less than 500 employees) to an establishment basis.
** Data withheld for certain size categories in this employment size range to avoid disclosure of operations at individual establishments.

APPENDIX VIII-13. TRANSPORTATION, COMMUNICATIONS, AND UTLITIES: COMPARISON OF AVERAGE REVENUE FOR ALL ESTABLISHMENTS TO AVERAGE REVENUE FOR SMALL ESTABLISHMENTS

SIC code	Estimated Average Sales Per Establishment in 2007 For All Establishments (in 1000s of 1990$)	Estimated Average Sales Per Establishment in 2007 for Small Establishments* (in 1000s of 1990$)	Ratio of Average Sales For Small Establishments to Average Sales for All Establishments
401**	46,474	4,079	9%
411	975	666	68%
417	1,273	1,273	100%
422	1,550	1,132	73%
423	1,941	1,941	100%
441,442	20,087	9,877	49%
443,444	11,446	5,081	44%
448	6,398	1,232	19%
449	1,709	898	53%
451***	5,400	873	16%
458	2,755	1,430	52%
461	8,585	6,546	76%
474	9,518****	6,202	65%
478	1,112****	725	65%
481	8,100	3,437	42%
49	19,911	7,342	37%
491	33,269	10,705	32%
492	23,847	13,894	58%
493	48,314	9,973	21%
495	4,108	2,936	71%
496	9,384	4,545	48%

NOTES: * The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (less than 500 employees) to an establishment basis.

** Data for this SIC code are not available from the Census. Data for regional and local railroads (averaging 386 and 29 employees per firm) are used to represent small establishments; "total" data also include Class I railroads (averaging 15,000 employees per establishment); the SBA small business size standards are 1,500 employees per firm for SIC 4011, and 500 employees per firm for SIC 4013.

*** Data for this SIC code represent payroll because revenue data are unavailable.

**** Average sales per establishment for all establishments are calculated based on the assumption that sales at all establishments for this 3-digit SIC code represent the same proportion of average sales for small establishments as the ratio of average sales for small establishments to all establishments reported as a total for SIC codes 478/474.

APPENDIX VIII-14. WHOLESALE AND RETAIL TRADE AND REAL ESTATE: DISTRIBUTION OF ESTABLISHMENTS, FIRMS, AND EMPLOYEES BY EMPLOYMENT SIZE CATEGORY

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
501	Establishments	38,398	41,362	45,257	85%	91%
	Firms	34,373	34,745	34,772	99%	100%
	Employment	323,874	390,310	435,345	74%	90%
502	Establishments	13,148	13,708	13,749	96%	100%
	Firms	12,050	12,203	12,208	99%	100%
	Employment	103,658	130,223	135,238	77%	96%
503	Establishments	15,258	16,325	16,686	91%	98%
	Firms	13,765	13,974	13,990	98%	100%
	Employment	145,942	184,367	199,209	73%	93%
504	Establishments	34,005	35,821	38,111	89%	94%
	Firms	31,040	31,451	31,511	99%	100%
	Employment	289,002	366,030	475,292	61%	77%
506	Establishments	25,540	27,477	29,750	86%	92%
	Firms	22,580	22,888	22,930	98%	100%
	Employment	211,387	267,976	348,897	61%	77%
508	Establishments	61,052	64,653	66,297	92%	98%
	Firms	54,072	54,608	54,645	99%	100%
	Employment	479,460	578,567	615,216	78%	94%
509	Establishments	30,737	31,619	32,009	96%	99%
	Firms	29,483	29,728	29,745	99%	100%
	Employment	191,144	234,785	252,863	76%	93%
512	Establishments	3,603	4,065	4,780	75%	85%
	Firms	3,338	3,434	3,448	97%	100%
	Employment	30,590	49,758	83,730	37%	59%
515	Establishments	10,861	11,755	12,218	89%	96%
	Firms	8,697	8,769	8,778	99%	100%
	Employment	92,340	105,755	112,246	82%	94%
516	Establishments	9,123	9,606	9,965	92%	96%
	Firms	8,185	8,260	8,266	99%	100%
	Employment	64,544	77,392	83,472	77%	93%
517	Establishments	14,516	15,965	16,351	89%	98%
	Firms	11,123	11,290	11,299	98%	100%

APPENDIX VIII-14 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
	Employment	120,600	148,771	161,675	75%	92%
519	Establishments	36,524	38,667	39,880	92%	97%
	Firms	33,007	33,356	33,388	99%	100%
	Employment	254,432	318,572	362,265	70%	88%

APPENDIX VIII-14 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
521	Establishments	-	-	25,077	-	-
	Firms	18,521	18,774	18,810	98%	100%
	Employment	-	-	371,606	-	-
526	Establishments	9,232	**	9,247	100%	**
	Firms	-	-	-	-	-
	Employment	66,852	**	68,944	97%	**
531	Establishments	66	351	25,718	0%	1%
	Firms	50	141	243	21%	58%
	Employment	3,197	23,667	2,216,508	0%	1%
541	Establishments	93,240	101,443	142,286	66%	71%
	Firms	86,546	87,904	88,238	98%	100%
	Employment	735,143	996,579	2,725,819	27%	37%
551	Establishments	24,506	**	25,971	94%	**
	Firms	23,148	24,693	24,720	94%	100%
	Employment	713,660	**	920,577	78%	**
554	Establishments	83,923	91,805	99,449	84%	92%
	Firms	73,637	74,050	74,099	99%	100%
	Employment	464,891	542,727	607,635	77%	89%
556	Establishments	-	-	2,702	-	-
	Firms	2,502	**	2,511	100%	**
	Employment	-	-	23,462	-	-
557	Establishments	3,728	3,728	3,728	100%	100%
	Firms	3,602	3,619	3,619	100%	100%
	Employment	25,862	25,862	25,862	100%	100%
559	Establishments	-	-	685	-	-
	Firms	**	676	676	**	100%
	Employment	-	-	4,735	-	-
563	Establishments	6,321	**	6,326	100%	**
	Firms	3,863	3,885	3,891	99%	100%
	Employment	32,700	**	33,286	98%	**
58	Establishments	310,743	333,543	398,903	78%	84%
	Firms	297,164	302,174	302,813	98%	100%
	Employment	3,197,863	4,116,768	6,374,480	50%	65%
608,9	Establishments	4,816		5,008	96%	**
	Firms	2,743	2,879	2,918	94%	99%
	Employment	-	-	-	-	-
616	Establishments	13,607	**	13,814	99%	**
	Firms	8,270	8,472	8,534	97%	99%
	Employment	113,534	**	169,029	67%	**

APPENDIX VIII-14 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
622	Establishments	1,251	**	1,272	98%	**
	Firms	1,127	1,143	1,146	98%	100%
	Employment	7,930	**	12,490	63%	**
651	Establishments	93,362	**	93,603	100%	**
	Firms	-	-	-	-	-
	Employment	400,083	**	446,939	90%	**
655	Establishments	12,580	**	12,658	99%	**
	Firms	11,637	11,715	11,723	99%	100%
	Employment	70,304	**	84,438	83%	**
671	Establishments	9,127	**	9,332	98%	**
	Firms	8,093	8,279	8,298	98%	100%
	Employment	54,380	**	102,758	53%	**
679	Establishments	8,014	**	8,061	99%	**
	Firms	7,322	7,369	7,376	99%	100%
	Employment	34,959	**	46,306	75%	**

NOTES: * The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (less than 500 employees) to an establishment basis. ** Data withheld for certain size categories in this employment size range to avoid disclosure of operations at individual establishments.

APPENDIX VIII-15. WHOLESALE AND RETAIL TRADE AND REAL ESTATE: COMPARISON OF AVERAGE REVENUE FOR ALL ESTABLISHMENTS TO AVERAGE REVENUE FOR SMALL ESTABLISHMENTS

SIC code	Estimated Average Sales Per Establishment in 2007 For All Establishments (in 1000s of 1990$)	Estimated Average Sales Per Establishment in 2007 for Small Establishments* (in 1000s of 1990$)	Ratio of Average Sales For Small Establishments to Average Sales for All Establishments
501	3,148**	2,539	81%
502	3,558**	3,261	92%
503	4,462**	4,091	92%
504	2,611	2,312	89%
506	4,734**	4,340	92%
508	2,798**	2,565	92%
509	5,706	2,587	45%
512	8,521	4,685	55%
515	10,469	9,034	86%
516	3,917	3,412	87%
517	9,839	8,410	85%
519	4,452	2,426	54%
521	2,595	1,901***	73%
526	901	887	98%
531	8,866	4,846	55%
541	3,386	1,232	36%
551	17,063	13,928	82%
554	1,458	1,191	82%
556	3,197	2,479***	78%
557	1,445	1,445	100%
559	1,604	1,244***	78%
563	466	458	98%
58	710	415	58%
608,9	24,066	8,001	33%
616	2,116	1,226	58%
622	2,228	1,479	66%
651	991	923	93%
655	1,102	943	86%
671	5,103	4,172	82%
679	2,468	2,149	87%

NOTES: * The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (less than 500 employees) to an establishment basis.

** Average sales at all establishments is calculated based on the assumption that sales at all establishments for this 3-digit SIC code represent the same proportion of average sales for small establishments as the ratio of average sales for small establishments to all establishments for SIC code 50.

*** Average sales at small establishments is calculated based on the assumption that sales at small establishments for this 3-digit SIC code represents the same proportion of average sales for all establishments as the ratio of average sales for all establishments to small establishments at the 2-digit SIC code level.

APPENDIX VIII-16. SERVICES: DISTRIBUTION OF ESTABLISHMENTS, FIRMS, AND EMPLOYEES BY EMPLOYMENT SIZE CATEGORY

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
703	Establishments	3,144	**	3,155	100%	**
	Firms	3,071	**	3,082	100%	**
	Employment	16,027	**	18,197	88%	**
704	Establishments	3,019	**	3,029	100%	**
	Firms	2,904	2,918	2,918	100%	100%
	Employment	13,836	**	15,581	89%	**
724	Establishments	5,646	**	5,646	100%	**
	Firms	-	-	5,377	-	-
	Employment	16,911	16,911	16,911	100%	100%
726	Establishments	14,695	**	14,701	100%	**
	Firms	11,882	11,895	11,899	100%	100%
	Employment	80,405	**	81,199	99%	**
729	Establishments	15,184	**	15,493	98%	**
	Firms	12,662	12,761	12,781	99%	
	Employment	91,006	**	155,510	59%	**
753	Establishments	112,020	112,601	113,121	99%	100%
	Firms	108,863	108,921	108,926	100%	100%
	Employment	460,037	471,198	475,709	97%	99%
762	Establishments	16,530	**	16,579	100%	**
	Firms	14,755	14,810	14,823	100%	100%
	Employment	94,369	**	103,189	91%	**
764	Establishments	-	-	6,144	-	-
	Firms	**	6,129	6,129	**	100%
	Employment	-	-	22,481	-	-
769	Establishments	32,693	**	33,020	99%	**
	Firms	30,953	31,041	31,052	100%	100%
	Employment	172,758	**	200,953	86%	**
791	Establishments	3,401	**	3,405	100%	**
	Firms	-	-	-	-	-
	Employment	17,845	**	18,356	97%	**
792	Establishments	6,206	**	6,281	99%	**
	Firms	-	-	-	-	-
	Employment	37,247	**	50,709	73%	**
794	Establishments	2,291	**	2,443	94%	**
	Firms	2,208	2,324	2,350	94%	99%
	Employment	19,907	**	68,727	29%	**
799	Establishments	33,190	**	33,703	98%	**
	Firms	29,832	30,312	30,372	98%	100%
	Employment	346,553	**	498,099	70%	**
801	Establishments	178,122	**	178,639	100%	**
	Firms	171,063	171,532	171,590	100%	100%
	Employment	974,983	**	1,098,495	89%	**
805	Establishments	5,724	8,902	13,829	41%	64%
	Firms	5,940	7,926	8,088	73%	98%
	Employment	231,061	564,997	926,375	25%	61%

APPENDIX VIII-16 (CONTINUED)

SIC Code	Data	Distribution of Establishments, Firms, and Employees by Employment Size				
		Less Than 100 Employees*	Less Than 500 Employees	TOTAL	Ratio of <100 Employees to Total	Ratio of <500 Employees to Total
806	Establishments	187	454	3,090	6%	15%
	Firms	158	341	415	38%	82%
	Employment	8,343	47,179	447,361	2%	11%
809	Establishments	7,831	**	7,917	99%	**
	Firms	6,028	6,127	6,142	98%	100%
	Employment	78,058	**	95,036	82%	**
821	Establishments	13,599	14,310	14,339	95%	100%
	Firms	-	-	-	-	-
	Employment	308,232	422,477	438,568	70%	96%
822	Establishments	1,678	2,489	2,973	56%	84%
	Firms	-	-	-	-	-
	Employment	42,401	245,709	1,082,042	4%	23%
824	Establishments	3,153	**	3,243	97%	**
	Firms	2,186	2,288	2,304	95%	99%
	Employment	47,220	**	62,247	76%	**
829	Establishments	-	-	5,411	-	-
	Firms	4,906	4,931	4,942	99%	100%
	Employment	-	-	40,003	-	-
836	Establishments	9,498	**	9,991	95%	**
	Firms	5,427	5,966	5,993	91%	100%
	Employment	149,702	**	238,372	63%	**
863	Establishments	19,122	19,237	19,246	99%	100%
	Firms	-	-	-	-	-
	Employment	145,519	167,980	176,220	83%	95%
871	Establishments	52,447	54,788	62,554	84%	88%
	Firms	55,779	56,446	56,555	99%	100%
	Employment	394,312	520,640	713,910	55%	73%
873	Establishments	10,542	11,222	11,998	88%	94%
	Firms	9,971	10,032	10,248	97%	98%
	Employment	82,577	131,246	188,863	44%	69%
899	Establishments	21,833	21,945	22,014	99%	100%
	Firms	21,623	21,647	21,652	100%	100%
	Employment	55,211	59,149	63,711	87%	93%

NOTES: * The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (less than 500 employees) to an establishment basis.
** Data withheld for certain size categories in this employment size range to avoid disclosure of operations at individual establishments.

APPENDIX VIII-17. SERVICES: COMPARISON OF AVERAGE REVENUE FOR ALL ESTABLISHMENTS TO AVERAGE REVENUE FOR SMALL ESTABLISHMENTS

SIC code	Estimated Average Sales Per Establishment in 2007 For All Establishments (in 1000s of 1990$)	Estimated Average Sales Per Establishment in 2007 for Small Establishments* (in 1000s of 1990$)	Ratio of Average Sales For Small Establishments to Average Sales for All Establishments
703	601	555	92%
704***	339	304	90%
724	113	113	100%
726	582	579	99%
729	305	247	81%
753	473	454	96%
762	964	888	92%
764	339	337****	99%
769	956	813	85%
791	190	187	98%
792	1,308	1,070	82%
794	3,459	1,536	44%
799	909	591	65%
801	950	869	91%
805	2,908	1,484	51%
806	15,066	4,150	28%
809	1,257	1,102	88%
821*	599	416	69%
822*	8,662	560	6%
824	1,521	1,197	79%
829	372	237****	64%
836	738	483	66%
863**	573	425	74%
871	1,327	763	57%
873	1,804	969	54%
899	339	279	82%

NOTES: * The 100 employee threshold is used to conservatively convert the SBA's definition of small firms (less than 500 employees) to an establishment basis.

** Data for this SIC code represents payroll because revenue data are not available.

*** Data for this SIC code also includes data for SIC code 7032.

**** Average sales at small establishments is calculated based on the assumption that sales at small establishments for this 3-digit SIC code represents the same proportion of average sales for all establishments as the ratio of average sales for all establishments to small establishments at the 2-digit SIC code level.

APPENDIX VIII-18. PUBLIC ADMINISTRATION: GOVERNMENT AGENCY EXPENDITURES

SIC Code	Description	State	County	Estimated Expenditures in 2007 (in 1,000s of 1990 $)
910	Executive, legislative, and general	South Carolina	Charleston Co	16,582
911	Executive offices	Pennsylvania	York Co	17,327
919	General government, miscellaneous	Massachusetts	Bristol Co	20,309
922	Public order and safety	California	Riverside Co	301,345
		Colorado	Fremont Co	5,158
		Illinois	Johnson Co	368
		Illinois	Logan Co	4,431
		Illinois	Randolph Co	3,066
		Indiana	La Porte Co	13,103
		Indiana	Madison Co	19,531
		Indiana	Putnam Co	1,193
		Maryland	Anne Arundel Co	105,048
		Maryland	Washington Co	15,144
		Massachusetts	Suffolk Co	321,953
		Minnesota	Washington Co	23,687
		New York	Bronx Co	2,044,436
		New York	Columbia Co	6,914
		New York	Dutchess Co	49,104
		New York	Wyoming Co	3,849
		Ohio	Delaware Co	10,513
		Ohio	Madison Co	3,603
		Ohio	Ross Co	11,223
		Ohio	Union Co	4,586
		Ohio	Warren Co	11,059
		Pennsylvania	Centre Co	7,977
		Pennsylvania	Cumberland Co	14,653
		Pennsylvania	Montgomery Co	111,455
		Virginia	Fairfax Co	195,108
		Virginia	Powhatan Co	957
931	Finance, taxation, & monetary policy	Michigan	Branch Co	849
940	Admin. of human resources	Illinois	Vermilion Co	12,072
943	Admin. of public health programs	Maryland	Montgomery Co	58,195
		Ohio	Montgomery Co	63,799
951	Environmental quality	California	Los Angeles Co	382,526
		California	Orange Co	70,937
		New York	Westchester Co	1,275
961	Admin. of general economic programs	Idaho	Butte Co	243
		Tennessee	Roane Co	897
962	Regulation, administration of transportation programs	California	Los Angeles Co	1,504,063
		Arizona	Maricopa Co	464,105
		Delaware	Sussex Co	3,619
		Georgia	Bryan Co	1,007
		Georgia	Newton Co	60,047
		Georgia	Pierce Co	19,370
		Illinois	Bond Co	2,777
		Illinois	Brown Co	1,396
		Illinois	Calhoun Co	1,374
		Illinois	Cass Co	2,843

APPENDIX VIII-18 (CONTINUED)

SIC Code	Description	State	County	Estimated Expenditures in 2007 (in 1,000s of 1990 $)
962	Regulation, administration of transportation programs (continued)	Illinois	Champaign Co	21,021
		Illinois	Christian Co	7,779
		Illinois	Clinton Co	5,671
		Illinois	Effingham Co	5,228
		Illinois	Fayette Co	4,348
		Illinois	Greene Co	2,345
		Illinois	Jersey Co	2,619
		Illinois	Macoupin Co	7,343
		Illinois	Marion Co	6,119
		Illinois	Menard Co	17,433
		Illinois	Monroe Co	2,095
		Illinois	Montgomery Co	6,070
		Illinois	Morgan Co	4,956
		Illinois	Perry Co	2,777
		Illinois	Pike Co	3,694
		Illinois	Randolph Co	4,096
		Illinois	Sangamon Co	21,994
		Illinois	Schuyler Co	2,004
		Illinois	Scott Co	1,135
		Illinois	St. Clair Co	25,865
		Illinois	Washington Co	2,472
		Iowa	Plymouth Co	5,379
		Iowa	Union Co	3,297
		Kansas	Cowley Co	5,702
		Minnesota	Kandiyohi Co	13,303
		Montana	Blaine Co	1,977
		North Dakota	Sioux Co	291
		Ohio	Erie Co	8,292
		Ohio	Geauga Co	14,145
		Ohio	Huron Co	8,249
		Ohio	Lorain Co	23,073
		Ohio	Medina Co	13,209
		Ohio	Portage Co	15,588
		Ohio	Summit Co	70,465
		Rhode Island	Bristol Co	3,817
		Rhode Island	Washington Co	6,860
		Tennessee	Jackson Co	1,818
		Texas	Parmer Co	1,348
		Texas	Upton Co	1,649
		Virginia	Arlington Co	34,206
		Virginia	Augusta Co	654
		Washington	Pend Oreille Co	3,142
		Wyoming	Park Co	4,050
963	Regulation, administration of utilities	Washington	Benton Co	1,675,807
		UNITED STATES		
962	Regulation, administration of transportation programs			4,792
971	National security			475,435,160*

* Expenditures represent national total because the Federal government is the directly impacted entity.

APPENDIX VIII-19. $PM_{2.5}$ 20 μg/m^3 /65 μg/m^3 ANNUAL/65 μg/m^3 24-HOUR AVERAGE ALTERNATIVE: SIC CODES WITH SMALL ESTABLISHMENT COST-TO-SALES RATIOS OF 3 PERCENT OR GREATER

SIC Code	SIC Code Description
071	Soil Preparation Services
072	Crop Services
078	Landscape and Horticultural Services
106	Ferroalloy Ores, Except Vanadium
131	Cotton
138	Oil and Gas Field Services
141	Dimension Stone
149	Miscellaneous Nonmetallic Minerals
153	Operative Builders
154	Nonresidential Building Construction
161	Vegetables and melons
162	Heavy Construction, Except Highway
204	Grain Mill Products
206	Sugar and Confectionery Products
208	Beverages
209	Misc. Food and Kindred Products
251	Broiler, fryer, and roaster chickens
252	Chicken eggs
262	Paper Mills
263	Paperboard Mills
267	Misc. Converted Paper Products
284	Soap, Cleaners, and Toiler Goods
287	Agricultural Chemicals
289	Miscellaneous Chemical Products
291	General farms, primarily animal
321	Flat Glass
322	Glass and Glassware, Pressed or Blown
324	Cement, Hydraulic
331	Blast Furnace and Basic Steel Products
333	Primary Nonferrous Metals

SIC Code	SIC Code Description
342	Cutlery, Handtools, and Hardware
343	Plumbing and Heating, Except Electric
344	Fabricated Structural Metal Products
345	Screw Machine Products, Bolts, Etc.
346	Metal Forgings and Stampings
347	Metal Services, NEC
348	Ordnance and Accessories, NEC
349	Misc. Fabricated Metal Products
351	Engines and Turbines
352	Farm and Garden Machinery
359	Industrial Machinery, NEC
363	Household Appliances
371	Motor Vehicles and Equipment
372	Aircraft and Parts
373	Ship and Boat Building and Repairing
374	Railroad Equipment
375	Motorcycles, Bicycles, and Parts
379	Miscellaneous Transportation Equipment
39	Miscellaneous Manufacturing Industries
411	Local and Suburban Transportation
491	Electric Services
651	Real Estate Operators and Lessors
753	Automotive Repair Shops
799	Misc. Amusement, Recreation Services
822	Colleges and Universities
962	Regulation, Admin. of Transportation

APPENDIX VIII-20. $PM_{2.5}$ 15 $\mu g/m^3$ ANNUAL /50 $\mu g/m^3$ 24-HOUR AVERAGE ALTERNATIVE: SIC CODES WITH SMALL ESTABLISHMENT COST-TO-SALES RATIOS OF 3 PERCENT OR GREATER

SIC Code	SIC Code Description
071	Soil Preparation Services
072	Crop Services
078	Landscape and Horticultural Services
106	Ferroalloy Ores, Except Vanadium
138	Oil and Gas Field Services
141	Dimension Stone
147	Chemical and Fertilizer Minerals
149	Miscellaneous Nonmetallic Minerals
153	Operative Builders
161	Vegetables and melons
162	Heavy Construction, Except Highway
179	Fruits and tree nuts, nec
201	Meat Products
204	Grain Mill Products
205	Bakery Products
206	Sugar and Confectionery Products
208	Beverages
229	Miscellaneous Textile Goods
251	Broiler, fryer, and roaster chickens
252	Chicken eggs
254	Poultry hatcheries
262	Paper Mills
263	Paperboard Mills
267	Misc. Converted Paper Products
275	Commercial printing
281	Industrial Inorganic Chemicals
283	Drugs
286	Industrial Organic Chemicals
287	Agricultural Chemicals
289	Miscellaneous Chemical Products
291	General farms, primarily animal
301	Tires and Inner Tubes
321	Flat Glass
322	Glass and Glassware, Pressed or Blown
324	Cement, Hydraulic

$PM_{2.5}$ 15 $\mu g/m^3$ ANNUAL /50 $\mu g/m^3$ 24-HOUR AVERAGE ALTERNATIVE: SIC CODES WITH SMALL ESTABLISHMENT COST-TO-SALES RATIOS OF 3 PERCENT OR GREATER (CONTINUED)

SIC Code	SIC Code Description
326	Pottery and Related Products
331	Blast Furnace and Basic Steel Products
333	Primary Nonferrous Metals
342	Cutlery, Handtools, and Hardware
343	Plumbing and Heating, Except Electric
344	Fabricated Structural Metal Products
345	Screw Machine Products, Bolts, Etc.
346	Metal Forgings and Stampings
347	Metal Services, NEC
348	Ordnance and Accessories, NEC
349	Misc. Fabricated Metal Products
351	Engines and Turbines
352	Farm and Garden Machinery
353	Construction and Related Machinery
359	Industrial Machinery, NEC
363	Household Appliances
37	Transportation Equipment
371	Motor Vehicles and Equipment
372	Aircraft and Parts
373	Ship and Boat Building and Repairing
374	Railroad Equipment
375	Motorcycles, Bicycles, and Parts
379	Miscellaneous Transportation Equipment
39	Miscellaneous Manufacturing Industries
411	Local and Suburban Transportation
443	Freight Trans. on the Great Lakes
444	Water Transportation of Freight, NEC
458	Airports, Flying Fields, & Services
491	Electric Services
496	Steam and air-conditioning supply
651	Real Estate Operators and Lessors
753	Automotive Repair Shops
799	Misc. Amusement, Recreation Services
809	Health and Allied Services, NEC
821	Elementary and Secondary Schools

$PM_{2.5}$ 15 $\mu g/m^3$ ANNUAL /50 $\mu g/m^3$ 24-HOUR AVERAGE ALTERNATIVE: SIC CODES WITH SMALL ESTABLISHMENT COST-TO-SALES RATIOS OF 3 PERCENT OR GREATER (CONTINUED)

SIC Code	SIC Code Description
822	Colleges and Universities
836	Residential Care
962	Regulation, Admin. of Transportation

APPENDIX VIII-21. $PM_{2.5}$ 12.5 μg/m^3 ANNUAL/50 μg/m^3 24-HOUR AVERAGE ALTERNATIVE: SIC CODES WITH SMALL ESTABLISHMENT COST-TO-SALES RATIOS OF 3 PERCENT OR GREATER

SIC Code	SIC Code Description
011	Cash Grains
071	Soil Preparation Services
072	Crop Services
078	Landscape and Horticultural Services
106	Ferroalloy Ores, Except Vanadium
138	Oil and Gas Field Services
141	Dimension Stone
147	Chemical and Fertilizer Minerals
149	Miscellaneous Nonmetallic Minerals
153	Operative Builders
161	Vegetables and melons
162	Heavy Construction, Except Highway
179	Fruits and tree nuts, nec
201	Meat Products
203	Preserved Fruits and Vegetables
204	Grain Mill Products
205	Bakery Products
206	Sugar and Confectionery Products
208	Beverages
209	Misc. Food and Kindred Products
221	Broadwoven Fabric Mills, Cotton
226	Textile Finishing, Except Wool
229	Miscellaneous Textile Goods
238	Miscellaneous Apparel and Accessories
243	Millwork, Plywood & Structural Members
251	Broiler, fryer, and roaster chickens
252	Chicken eggs
254	Poultry hatcheries
261	Pulp Mills
262	Paper Mills
263	Paperboard Mills
265	Paperboard Containers and Boxes
267	Misc. Converted Paper Products
275	Commercial printing
281	Industrial Inorganic Chemicals

$PM_{2.5}$ 12.5 μg/m^3 ANNUAL/50 μg/m^3 24-HOUR AVERAGE ALTERNATIVE: SIC CODES WITH SMALL ESTABLISHMENT COST-TO-SALES RATIOS OF 3 PERCENT OR GREATER (CONTINUED)

SIC Code	SIC Code Description
282	Plastics Materials and Synthetics
283	Drugs
284	Soap, Cleaners, and Toiler Goods
286	Industrial Organic Chemicals
287	Agricultural Chemicals
289	Miscellaneous Chemical Products
291	General farms, primarily animal
299	Misc. Petroleum and Coal Products
301	Tires and Inner Tubes
306	Fabricated Rubber Products, NEC
321	Flat Glass
322	Glass and Glassware, Pressed or Blown
324	Cement, Hydraulic
326	Pottery and Related Products
327	Concrete, Gypsum, and Plaster Products
331	Blast Furnace and Basic Steel Products
332	Iron and Steel Foundries
333	Primary Nonferrous Metals
34	Fabricated Metal Products
342	Cutlery, Handtools, and Hardware
343	Plumbing and Heating, Except Electric
344	Fabricated Structural Metal Products
345	Screw Machine Products, Bolts, Etc.
346	Metal Forgings and Stampings
347	Metal Services, NEC
348	Ordnance and Accessories, NEC
349	Misc. Fabricated Metal Products
35	Industrial Machinery and Equipment
351	Engines and Turbines
352	Farm and Garden Machinery
353	Construction and Related Machinery
355	Special Industry Machinery
358	Refrigeration and Service Machinery
359	Industrial Machinery, NEC

$PM_{2.5}$ 12.5 μg/m³ ANNUAL/50 μg/m³ 24-HOUR AVERAGE ALTERNATIVE: SIC CODES WITH SMALL ESTABLISHMENT COST-TO-SALES RATIOS OF 3 PERCENT OR GREATER (CONTINUED)

SIC Code	SIC Code Description
36	Electronic & Other Electric Equipment
363	Household Appliances
369	Misc. Electrical Equipment & Supplies
37	Transportation Equipment
371	Motor Vehicles and Equipment
372	Aircraft and Parts
373	Ship and Boat Building and Repairing
374	Railroad Equipment
386	Photographic Equipment and Supplies
39	Miscellaneous Manufacturing Industries
393	Musical Instruments
411	Local and Suburban Transportation
443	Freight Trans. on the Great Lakes
444	Water Transportation of Freight, NEC
458	Airports, Flying Fields, & Services
49	Electric, Gas, and Sanitary Services
491	Electric Services
493	Combination Utility Services
495	Sewerage systems
496	Steam and air-conditioning supply
517	Petroleum and Petroleum Products
526	Retail Nurseries and Garden Stores
651	Real Estate Operators and Lessors
753	Automotive Repair Shops
799	Misc. Amusement, Recreation Services
806	Hospitals
809	Health and Allied Services, NEC
821	Elementary and Secondary Schools
822	Colleges and Universities
824	Vocational Schools
836	Residential Care
863	Labor Organizations
871	Engineering & Architectural Services
873	Research and Testing Services

$PM_{2.5}$ 12.5 $\mu g/m^3$ ANNUAL/50 $\mu g/m^3$ 24-HOUR AVERAGE ALTERNATIVE: SIC CODES WITH SMALL ESTABLISHMENT COST-TO-SALES RATIOS OF 3 PERCENT OR GREATER (CONTINUED)

SIC Code	SIC Code Description
962	Regulation, Admin. of Transportation

9.0 BENEFITS

9.1 INTRODUCTION

This chapter addresses the monetized benefits associated with attainment of alternative particulate matter (PM) standards in the year 2007. Benefits are estimated for a range of $PM_{2.5}$ alternatives incremental to the baseline PM_{10} alternative. Two attainment scenarios have been assumed: 1) full attainment of each of the standard alternatives; 2) partial attainment of standard alternatives based on post-control air quality resulting from the cost analysis. All benefit estimates are expressed in 1990 dollars, consistent with the cost analysis. This chapter describes the benefit analysis methodology and presents point estimates of national benefits for each $PM_{2.5}$ alternative.

9.2 OVERVIEW OF BENEFIT ANALYSIS METHODOLOGY

9.2.1 Summary of Analytical Process

In evaluating the national benefits associated with attainment of alternative PM standards in the year 2007, the basic question considered for each $PM_{2.5}$ alternative scenario is: What is the monetized benefit of attainment of a given suite of $PM_{2.5}$ levels nationwide in excess of the benefit of attainment of the baseline PM_{10} alternative nationwide? To answer this question it is necessary to:

- determine the change in air quality resulting from attainment of $PM_{2.5}$ alternatives incremental to the baseline PM_{10} alternative;

- estimate the changes in national incidence of each health and welfare endpoint associated with PM that would result from attainment of alternative $PM_{2.5}$ standards incremental to attainment of the baseline PM_{10} alternative;

- multiply the estimated change in incidence of each endpoint by the estimated dollar value of avoiding an occurrence of an adverse effect; and

- sum the non-overlapping, endpoint-specific estimated benefits to derive an estimate of total monetized benefit nationwide for each $PM_{2.5}$ alternative.

The first component of the analytical process is determination of the air quality change from predicted 2007 baseline air quality to attainment of the current PM_{10} and alternative $PM_{2.5}$ levels. The benefit analysis uses baseline and post-control 2007 annual average and 98th percentile daily maximum air quality as estimated through the emissions and air quality modeling described in Chapter 6. Because the air quality model cannot predict an annual distribution of daily ambient PM concentrations, a method was developed and employed to derive daily PM concentrations from the annual mean and daily maximum PM concentrations. This method is described further in Section 9.3.1.

The benefit analysis was conducted for two attainment scenarios: full attainment of each of the alternative PM concentration levels and partial attainment of the PM alternatives based on post-control air quality resulting from the cost analysis. Recall from Chapter 7 that the control measures selected in the cost analysis are insufficient to attain the PM alternatives in all counties. Thus, for each PM alternative, there is some degree of residual nonattainment, or in other words, some counties are predicted to still violate the PM alternative even after controls are applied. This partial attainment scenario captures the reduced benefits of residual nonattainment in relation to full attainment. The benefits of full attainment are also assessed to allow an understanding of the scope of benefits that may be attributable to alternative PM standards provided that control strategies to reach complete attainment can be identified in the future.

The second component of the analysis, the risk assessment component, estimates changes in the incidence of health and welfare endpoints resulting from changes in ambient PM concentrations associated with attainment of a given set of PM concentration levels from the baseline PM_{10} level as described above. The basic methods employed in the risk assessment component of the benefit analysis were developed for the PM National Ambient Air Quality Standards (NAAQS) Staff Paper[1] and are described in detail in a contractor report referred to here as the PM Risk Assessment Report.[2]

To the extent possible, the risk assessment component of the benefit analysis is methodologically consistent with analyses conducted for the PM NAAQS Staff Paper; however, the benefit analysis risk assessment differs in three ways. First, some of the health and welfare endpoints considered in the benefit analysis were not included among the endpoints considered in the Staff Paper risk assessment. Second, the benefit analysis considers risk reductions nationwide, rather than for specific locations within the United States. However, the estimate of avoided incidence nationwide is simply the sum of the estimates of avoided incidences in each county in the United States. The methods developed to estimate risk reduction (or avoided incidence of health effects) in a single location (e.g., a single sample city or county) are therefore applicable to the national benefit analysis. Finally, the risk assessment carried out for the PM NAAQS Staff Paper used actual PM monitoring data to estimate risk reductions in relatively current years (1992-1993 for Philadelphia, and 1995 for Los Angeles). As described in Chapter 6, this assessment considers risk reductions in the year 2007 for which ambient concentrations of PM were projected.

The third component of the analysis is the economic valuation component. The monetized value of an avoided occurrence (or, equivalently, of a reduction of risk) of each endpoint is first estimated. Each endpoint-specific monetized benefit is then derived by multiplying the estimated unit value by the incidence change estimated in the risk assessment.

Finally, because there are cases in which health endpoints and population categories evaluated are not mutually exclusive, there is a possibility of double counting benefits. Thus, the fourth component of the analysis is the aggregation component, in which the non-overlapping, endpoint-specific nationwide monetized benefits are summed to derive an estimate of total national monetized benefit.

9.2.2 Benefit Categories Quantified vs. Unquantified

The evidence for the association of health and welfare effects with PM exposure derives from a large body of literature dating back more than 40 years. The key health effects categories associated with PM include premature mortality and increased hospital admissions and emergency room visits (primarily in the elderly and individuals with cardiopulmonary disease); increased respiratory symptoms and disease (in children, e.g., asthma, and individuals with cardiopulmonary disease); decreased lung function (particularly in children and individuals with asthma); and alterations in lung tissue and structure and in respiratory tract defense mechanisms. Most of these health-effects categories have been consistently associated with PM exposure from a number of community epidemiological studies, with supporting insights from animal toxicology and controlled human exposures of various constituents of PM conducted at higher than ambient levels. The PM Criteria Document[3] and Staff Paper review and discuss the findings and conclusions related to the principal health effects associated with PM exposure.

This assessment is consistent with the health endpoints evaluated in the PM Risk Assessment yet also attempts to be comprehensive in estimating the full range of potential benefits that may result from reductions in ambient PM concentrations. Thus, there are additional health endpoints included in the benefit analysis. Similarly, the national benefit analysis estimates benefits associated with visibility improvements and household soiling. Health and welfare endpoints quantitatively estimated in the benefit analysis are summarized in Table 9.1.

There are other benefit categories for which there is incomplete information to permit a quantitative assessment of benefits for this analysis. For some endpoints, gaps exist in the scientific literature or a key analytical component(s) and thus do not support an estimation of incidence. In other cases, there is insufficient economic information to allow estimation of the economic value of adverse effects. Thus, this benefit analysis is incomplete in respect to full coverage of all potential benefits for PM alternatives. Table 9.2 summarizes those health and welfare endpoints quantified versus those that were not quantified for this analysis. Unquantified benefits categories for which benefits may be economically significant include visibility benefits in Class I areas (e.g., Grand Canyon National Park) or the benefits of reduced acid deposition (sulfates and nitrates) to aquatic and terrestrial ecosystems. For example, the National Acid Precipitation Assessment Program (NAPAP) reports that user values for visibility changes at recreation sites in the east and west are in the range of $1 - $10 per visitor per day. Similarly, estimates of the economic effects of acidic deposition damages on recreational fishing in the Adirondack region of New York ranged from $1 million to $13 million annually.[4]

9.2.3 The Basic Model of Total Monetized Benefits

9.2.3.1 Total Monetized Benefits

For a given air quality standard scenario, total monetized benefit in the jth county (TMB_j) may be written as the sum of the monetized benefits associated with all non-overlapping endpoints:

$$TMB_j = \sum_{i=1}^{N} \Delta y_{ij} * MWTP_i \ . \qquad \textbf{(1)}$$

where Δy_{ij} is the change in incidence of the ith health endpoint in the jth county times the mean value of an avoided occurrence of the ith health endpoint, $MWTP_i$.

TABLE 9.1 HEALTH AND WELFARE ENDPOINTS INCLUDED IN THE NATIONAL BENEFITS ANALYSIS

Endpoint	Source of Concentration-Response Function
Mortality ($PM_{2.5}$ short-term exposure)*	pooled analysis (Schwartz et al., 1996)[5]
Mortality ($PM_{2.5}$ long-term exposure)	Pope et al., 1995[6]
Hospital admissions ("all respiratory")	Thurston et al., 1994[7]
Hospital admissions (Ischemic Heart Disease)	Schwartz & Morris, 1995[8]
Hospital admissions (Congestive Heart Failure)	Schwartz & Morris, 1995[9]
Chronic Bronchitis	Schwartz, 1993[10]
Upper Respiratory Symptoms (# of days)	Pope et al., 1991[11]
Lower Respiratory Symptoms (# of cases)	Schwartz et al., 1994[12]
Acute Respiratory Symptoms (any of 19)	Krupnick et al., 1990[13]
Acute Bronchitis	Dockery et al., 1989[14]
Shortness of Breath	Ostro et al., 1995[15]
Moderate or Worse Asthma Status	Ostro et al., 1991[16]
Restricted Activity Days	Ostro, 1987[17]
Minor Restricted Activity Days	Ostro & Rothschild, 1989[18]
Work Loss Days	Ostro, 1987[19]
Visibility Impairment	Damberg and Polkowsky, 1996[20]
Household Soiling Damage	RCG/Hagler Bailly, 1994[21]

*See PM Risk Assessment

TABLE 9.2

HEALTH AND WELFARE EFFECTS OF PARTICULATE MATTER

Type of Endpoint	Quantified Effects	Unquantified Effects
Human Health	Mortality Acute Long-term Hospital admissions Chronic bronchitis Lower respiratory symptoms Upper respiratory symptoms Acute respiratory symptoms Acute bronchitis Shortness of breath Moderate or worse asthma Restricted activity days Minor restricted activity days Work loss days	Changes in pulmonary function Morphological changes Altered host defense mechanisms Cancer Other chronic respiratory disease
Welfare	Household soiling damage Visibility impairment	Other materials damage Visibility impairment in Class 1areas (e.g. National Parks) Ecosystem effects (e.g. acid sulfate and nitrate deposition)

9.2.3.2 Physical Effects Model as a Component of Total Monetized Benefit

As described earlier, the risk assessment component of the benefit analysis estimates the change in incidence of each health and welfare endpoint for each air quality scenario analyzed. The county and health endpoint-specific incidence change, Δy_{ij}, is modeled as the population response to the change in ambient PM concentrations in the jth county, ΔPM_j, that would be associated with attainment of the specified PM standard(s):

$$\Delta y_{ij} = y_{ij}[e^{\beta_{ij} * \Delta PM_j} - 1] \quad . \tag{2}$$

where y_{ij} is the baseline incidence of the ith health endpoint in the jth county, and β_{ij} is the value of β_i, the coefficient of PM in the concentration-response relationship between PM and the ith health endpoint, in the jth county[a].

9.2.3.3 Total National Monetized Benefits

The total national monetized benefit (TNMB) associated with attaining an alternative $PM_{2.5}$ scenario in the United States is the sum of the total monetized benefits achieved in each county. The total national monetized benefit can be written as:

$$TNMB = \sum_{i=1}^{N} \sum_{j=1}^{J} y_{ij}[e^{M\beta_i * \Delta PM_j} - 1] * MWTP_i \quad . \qquad (3)$$

The total national monetized benefit as written above is a function of the mean population PM coefficient in the concentration-response function for a given health or welfare endpoint ($M\beta_i$) and the mean WTP to reduce risk of a given endpoint ($MWTP_i$). Theoretically, the national analysis could use county-specific concentration-response functions to estimate county-specific benefits. There are many counties in the United States, however, and the individual county-specific values of the PM coefficient (the β_{ij}'s) are not known. Additionally, the national analysis is not as concerned with county-specific changes in incidence as with the national change in incidence. Therefore, the mean of the population distribution of the β's is used to obtain the national change in incidence associated with a change in ambient PM concentrations.

Assuming that willingness to pay (WTP) to reduce a given risk varies from one individual to another, there is, for each risk, a distribution of WTP's to reduce that risk. This population distribution has a mean. It is an estimate of this population mean of WTP's to reduce the ith risk, MWTP, that is used in this analysis.

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[a] See the PM Risk Assessment Final Report for derivation of this equation.

9.2.4 Key Uncertainties in Benefit Analysis Results

If all necessary information were complete, the national benefit analysis could predict a total national benefit associated with the attainment of a given PM level or set of PM levels. In the face of incomplete information, however, this national benefit cannot be predicted exactly but can only be estimated. Associated with any estimate there is uncertainty.

Potentially important sources of uncertainty exist and many of these are summarized in Table 9.3. In most cases, there is no apparent bias associated with the uncertainty. For those cases for which the nature of the uncertainty suggests a direction of possible bias, this is noted in the table.

TABLE 9.3 IDENTIFIED SOURCES OF UNCERTAINTY IN THE NATIONAL BENEFIT ANALYSIS
1. Uncertainties Associated With Annual and Daily PM Concentrations
1.1. There is uncertainty surrounding the baseline and projected annual means and the daily maximum PM-10 and PM-2.5 concentrations for each county as predicted by the CRDM air quality model.
1.2. It is uncertain how well the county-specific distributions of 365 daily PM concentrations generated from the county-specific estimated gamma distributions approximate what the actual county-specific distributions of daily PM concentrations will be in the year 2007.
2. Uncertainties Associated With Simulation of Full and Partial Attainment of Standards
2.1. The degree to which linear rollbacks of daily PM concentrations reflect the future air quality distribution of full attainment of alternative PM standards is uncertain.
2.2. There is uncertainty surrounding the CRDM predictions of post-control air quality reflective of partial attainment of alternative PM levels.
3. Uncertainties Associated With Concentration-Response Functions
3.1. There is uncertainty surrounding the mean value of the PM coefficient (β) in the concentration-response function for each combination of health or welfare endpoint and PM indicator.
3.2. There is uncertainty about how well the mean population, Mβ, approximates that value of β, that if used in all counties, would yield the same result as would be obtained if county-specific β's were used.
3.3. It is uncertain how similar future year concentration-response relationships will be to current concentration-response relationships.
3.4. The correct functional form of each concentration-response relationship is uncertain.
3.5. In the few cases for which is was necessary, there is uncertainty associated with extrapolation of concentration-response relationships beyond the range of PM concentrations observed in the study. Moreover, there is uncertainty regarding whether very low PM concentration "cutpoints" or thresholds exist below which benefits from PM reductions accrue at a lesser rate or not at all. To the extent that such cutpoints exist, PM benefit estimates in this study may be overstated. This possibility is greatest for the most stringent alternative examined. However, no clear evidence of the existence of thresholds for alternative endpoints has been identified.

TABLE 9.3 IDENTIFIED SOURCES OF UNCERTAINTY IN THE NATIONAL BENEFIT ANALYSIS
4. Uncertainties Associated With Baseline Incidence Rates
4.1. Some baseline incidence rates are not county-specific (e.g., those taken from studies) and may therefore not accurately represent the actual county-specific rates.
4.2. It is uncertain how well current baseline incidence rates (used in the analysis) approximate what baseline incidence rates will be in the year 2007, given either baseline ambient PM concentrations or any alternative scenario.
4.3. It is uncertain how well the population projections, used to derive incidences, approximate what actual populations will be in the year 2007.
5. Uncertainties Associated With Economic Valuation
5.1. Unit dollar values associated with each health and welfare endpoint are only estimates of MWTP and therefore have uncertainty surrounding them.
5.2. Even using constant dollars (e.g., 1990 dollars), it is uncertain whether MWTP for each type of risk reduction will be the same in the year 2007 as the current MWTP.
6. Uncertainties Associated With Aggregation of Monetized Benefits
6.1 Because benefit estimation is limited to those health and welfare endpoints for which concentration-response functions have been estimated, there may be components of total benefit omitted. This would lead to a downward bias in the estimated total monetized benefit.

9.3 ESTIMATION OF INCIDENCE OF HEALTH AND WELFARE EFFECTS FOR ALTERNATIVE PM NAAQS

This section describes in more detail the methods used to estimate the change in incidence of adverse health and welfare effects due to attainment of alternative PM levels. The model-predicted annual and daily maximum PM_{10} and $PM_{2.5}$ concentrations are used to derive an annual distribution of daily PM concentrations. The air quality change is either defined by post-control air quality for the partial attainment scenario or by rollback for the full attainment scenario. Next, concentration-response functions are evaluated for the predicted air quality change. This procedure results in an estimate of reductions in incidence of health and welfare effects for the air quality improvement predicted for each PM alternative. The details of the methods employed here to evaluate concentration-response functions are found in supporting contractor reports.[22,23]

9.3.1 Derivation of Annual Distribution of Daily PM Concentrations

As described in Chapter 6, baseline air quality predicted by the CRDM model is used as input to the benefit analysis. Because the annual distribution of daily PM concentrations cannot be predicted by the model, they must be derived from other predicted information. A reasonable functional form for county-specific air quality distributions can be assumed, based on an examination of PM distributions in recent years for which actual data exist. Once a functional form is chosen, all that is unknown about a given county-specific distribution are the values of its parameters. The model-predicted statistics, the annual mean and 98th or 99th percentile daily maximum, can then be used to estimate these parameters, for each county-specific distribution, completing the estimate of the county-specific distribution of daily PM concentrations in the year 2007. For the baseline PM_{10} alternative, the 3-year average 99th percentile daily maximum value is used.[a] For the $PM_{2.5}$ alternatives, the 98th percentile daily maximum value is used.[b] Daily PM concentrations from this estimated distribution can then be generated by Monte Carlo methods.

To determine the most reasonable annual distributional form for the daily PM concentrations in each county in the United States for the year 2007, PM data for recent years in each of four locations (Philadelphia, PA; St. Louis, MO; Provo, UT; and El Paso, TX) were fit to a number of distributions (including, but not limited to, the lognormal, the beta and the gamma distributions). Because it generally provided the best fit to the PM data for recent years in the four locations examined, the gamma distribution was chosen. The above procedure was carried out for each county in the national analysis, generating 365 daily PM_{10} and 365 daily $PM_{2.5}$ concentrations for each county in the analysis. The procedure used to estimate the two parameters of the gamma distribution and to then generate a year's worth of daily PM concentrations from the fully specified distribution is described in detail in a contractor report .

9.3.2 Post-control PM Air Quality

For the partial attainment scenarios, post-control air quality as predicted from the air quality and cost modeling is used to define the air quality change for a given PM alternative. However, to obtain the change in air quality between the 2007 baseline air quality and full attainment of the PM alternatives, a rollback procedure is employed. For any given PM alternative, the post-control air quality defines those counties that are predicted to attain alternative PM concentration levels as well as those that are still predicted to exceed an alternative PM concentration level even after control measures are selected. For those residual nonattainment counties, the post-control air quality is rolled back by a particular percentage. The amount of reduction in air quality

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[a] As described in Chapter 6, the three-year average 99th percentile daily maximum value was used to approximate the current one expected exceedance form of the PM_{10} standard.

[b] As described in Chapter 6, the derived three-year average 98th percentile daily maximum value was used to approximate the form of the $PM_{2.5}$ alternative standards being examined.

required to attain the alternative PM levels is determined based upon which concentration level of the PM_{10} and $PM_{2.5}$ combinations, daily or annual, is "controlling" (i.e., requires the larger reduction in ambient concentration).[a]

9.3.3 Concentration-response Functions in the National Benefit Analysis

Table 9.4 presents the health and welfare endpoints evaluated for this assessment. For each endpoint, the table also provides the PM indicator used in the concentration-response function, the study from which the concentration-response function is taken, and the population for which health or welfare effects are estimated. Two contractor reports provide further detail regarding concentration-response evaluation.[24]

As can be seen from the table, the health and welfare effects studies have used different air quality indicators for particles. This analysis assesses benefits for both PM_{10} and $PM_{2.5}$. For functions using PM_{10} as an indicator, PM_{10} data for each standard alternative was used. For functions using $PM_{2.5}$ as an indicator, $PM_{2.5}$ data for each standard alternative was used. However, in the case of household soiling, assumptions regarding the air quality indicator were necessary to evaluate the concentration-response function.

In each alternative scenario, the function for household soiling damage, originally derived using total suspended particulates (TSP) as an indicator of PM, was evaluated using the indicator under consideration for that scenario. PM_{10} and $PM_{2.5}$ are both components of TSP. However, it is not clear exactly which components of TSP cause household soiling damage. The Criteria Document cites some evidence that smaller particles may be primarily responsible, in which case these estimates would be conservative.

Because benefits are assessed for 2007, a population projection for each county is needed to

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[a] See contractor technical memorandum for further details of this procedure (Deck, 1996).

evaluate the concentration-response function. Using 1990 population by block group (a small unit within Census tract), the U.S. Census projects population by block group to the year 2005. For each 10 kilometer by 10 kilometer grid cell in the United States, the population in the year 2007 was projected for the national benefit analysis from the 1990 population and the 2005 projected population for that grid cell by linear extrapolation. The population of the continental United States in the year 2007 is projected to be 273.8 million.

TABLE 9.4

HEALTH AND WELFARE ENDPOINTS INCLUDED IN THE PM BENEFITS ANALYSIS

Endpoint	PM Indicator	Applied Population	Source of Concentration-Response Function
Mortality (short-term exposure)*	$PM_{2.5}$	All	pooled analysis (Schwartz et al., 1996)
Mortality (long-term exposure)	$PM_{2.5}$	All	Pope et al., 1995
Hospital admissions ("all respiratory")	$PM_{2.5}$	All	Thurston et al., 1994
Hospital admissions (Ischemic Heart Disease)	PM_{10}	65 & older	Schwartz & Morris, 1995
Hospital admissions (Congestive Heart Failure)	PM_{10}	65 & older	Schwartz & Morris, 1995
Chronic Bronchitis	PM_{10}	All	Schwartz, 1993
Upper Respiratory Symptoms (# of days)	PM_{10}	9-11 yr. old asthmatics	Pope et al., 1991
Lower Respiratory Symptoms (# of cases)	PM_{10}, $PM_{2.5}$	8-12 yr. olds	Schwartz et al., 1994
Acute Respiratory Symptoms (any of 19)	PM_{10}	18-65 yr. olds	Krupnick et al., 1990
Acute Bronchitis	PM_{10}, $PM_{2.5}$	10-12 yr. olds	Dockery et al., 1989
Shortness of Breath	PM_{10}	7-12 yr. old African-American Asthmatics	Ostro et al., 1995
Moderate or Worse Asthma Status	$PM_{2.5}$	asthmatics	Ostro et al., 1991
Restricted Activity Days	$PM_{2.5}$	18-65 yr. olds	Ostro, 1987
Minor Restricted Activity Days	$PM_{2.5}$	18-65 yr. olds	Ostro & Rothschild, 1989
Work Loss Days	$PM_{2.5}$	18-65 yr. olds	Ostro, 1987
Visibility impairment	light extinction	All counties	Damberg and Polkowsky, 1996
Household Soiling Damage	TSP	all households	RCG/Hagler Bailly, 1994

*See PM Risk Assessment

For most concentration-response functions, baseline incidences of health effects are needed for evaluation of the functions. In the case of mortality, county-specific mortality rates were obtained for each county in the United States from the National Center for Health Statistics (NCHS). Because those studies that estimated concentration-response functions for short-term exposure mortality considered only non-accidental mortality, county-specific baseline mortality rates used in the estimation of PM-related short-term exposure mortality are adjusted to reflect a better estimate of county-specific non-accidental mortality. Each county-specific mortality rate is multiplied by the ratio of national non-accidental mortality to national total mortality (0.93). Because the study estimating a concentration-response function for long-term exposure mortality included all mortality, county-specific baseline mortality rates are left unadjusted when applied to long-term exposure mortality functions.

County-specific hospital admissions baseline incidence rates are obtained by multiplying the national hospital admissions rate for the relevant International Classification of Diseases (ICD) code(s) per 100,000 individuals aged 65 or older by the county-specific population of those aged 65 or older.[a]

Baseline incidence rates for all respiratory symptoms and illnesses included in the benefit analysis and for restricted activity days were obtained from the studies reporting concentration-response functions for those health endpoints. No baseline incidence rates were available from other sources for these endpoints. Finally, the household soiling damage function is a linear function and, therefore, does not require a baseline incidence rate.

Because future incidence rates cannot be known, the baseline incidence rates used for the future year analysis are current baseline incidence rates. The extent to which these current rates correspond to what incidence rates in the year 2007 will be, given either baseline PM

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[a] Except for Thurston et al., 1994, all hospital admissions studies used in the benefit analysis apply only to individuals 65 and older. The Thurston study used a linear concentration-response function, which, unlike an exponential concentration-response function, does not require a baseline incidence rate for calculation of PM-related incidence.

concentrations in 2007 or PM concentrations achieved under any alternative PM standards, is not known.

9.4 ECONOMIC VALUATION OF CHANGES IN INCIDENCE OF HEALTH AND WELFARE EFFECTS

As described previously, changes in incidence of health and welfare effects are valued using mean willingness to pay (MWTP) to avoid an occurrence (or to reduce the risk) of a health or welfare effect. Thus, total benefit is derived by multiplying the estimated change in incidence of a health or welfare effect for a given air quality change by the unit value estimated for MWTP to avoid that adverse effect. This section briefly describes general issues in valuing environmental quality improvements and the derivation of estimates of MWTP for endpoints evaluated in the benefit analysis.

9.4.1 General Issues in Valuing Environmental Quality Improvements

A correct measure of the value an individual places on something, whether it is something that can be purchased in a market or not, is willingness to pay (WTP). The WTP is the maximum amount of money an individual would pay such that the individual would be indifferent between having the good or service and having kept the money.

For both market and nonmarket goods, WTP reflects individuals' preferences. Because preferences are likely to vary from one individual to another, WTP for both market and non-market goods such as improvements in environmental quality is likely to vary from one individual to another. In contrast to market goods, however, non-market goods are public goods whose benefits are shared by many individuals. The individuals who "consume" the environmental quality improvement may have different WTP's for this non-market good. The total social value of the good is the sum of the WTP's of all individuals who consume the good.

In the case of health improvements related to air pollution reduction, the beneficiaries may not be known beforehand. For example, 100 days of cough avoided may be predicted to result from a reduction of PM concentrations to achieve a given standard, but which individuals will be spared those days of coughing is not known earlier. The health benefits conferred on individuals by a reduction in air pollution concentrations are, then, actually *reductions in the probabilities* of having to endure certain health problems. These benefits may not be the same for all individuals and, in fact, could be zero for some individuals. Likewise, the WTP for a given benefit is likely to vary from one individual to another.

The reduction in the probability of each health problem for each individual is not known, nor is it known each individual's WTP for each possible benefit he or she might receive. Therefore, in practice, the value of a *statistical* health problem avoided is estimated. For example, although a reduction in PM concentrations may avoid premature mortality, whose lives will be saved cannot be known beforehand. What is known is that the reduction in ambient PM concentrations results in a reduction in mortality risk. It is this reduction in mortality risk that is valued in a monetized benefit analysis. Individual WTP's for small reductions in mortality risk are summed over enough individuals to infer the value of a *statistical* life saved. This is very different from the value of a particular, identified life saved.

As mentioned previously, WTP for a particular health benefit is unlikely to be the same for all individuals. It is believed to vary with certain factors, most notably with income or wealth, which varies dramatically across the population, with the discrepancy between the lowest and the highest quintiles having become more pronounced during the last 20 years. The WTP for a health-related environmental improvement may therefore also vary dramatically across individuals in the U.S. A wealthy individual might be willing to pay many times what a poor individual would be willing to pay to avoid, for example, a day of coughing or a case of bronchitis. The mean WTP, as a measure of the value of a health problem avoided, would be highly influenced by a few very large WTP's that could result from a highly skewed income distribution.

If the individuals receiving health improvements, however, are a random sample from the population (i.e., if all individuals have the same chance of receiving these benefits), then, it is commonly argued, the mean WTP is the population parameter of interest. Predicted benefits therefore are the mean WTP for the benefit times the number of individuals predicted to receive the benefit.

The individuals actually receiving health improvements, however, may not be a random sample of the population. In the case of PM-induced premature mortality, there is evidence that most of those individuals receiving the benefit of a reduction in the probability of dying in the current year as a result of a reduction in ambient PM concentrations are the elderly. If WTP for mortality risk improvement among the elderly is substantially different from WTP for mortality risk improvement among younger individuals, then using the population mean WTP will give a biased result. This issue is addressed in this assessment through a sensitivity analysis and discussed in Section 9.5.3.

Although the mean WTP may be the appropriate measure for benefit analysis, the sample mean may not be the best estimate of the population mean WTP. In contingent valuation (CV) studies that try to estimate the mean WTP for a non-market good, subjects often report WTP's that are absurdly large (protest bids). Sample means are particularly susceptible to the influence of such protest bids. Even though the population mean WTP is generally considered the appropriate measure of valuation in benefit analysis, the sample *median* WTP was recommended by the National Oceanic and Atmospheric Administration Panel Report on CV's as the preferred estimator of the population mean WTP.[25] Those dollar values that are based on WTP estimates from CV studies are therefore based on median WTPs where possible (e.g., the dollar values for upper respiratory symptoms (URS) and lower respiratory symptoms (LRS) are based largely on median WTPs from one or more CV studies).

While the estimation of WTP for a market good (i.e., the estimation of a demand schedule) is not a simple matter, the estimation of WTP for a nonmarket good, such as a decrease in the risk of having a particular health problem, is substantially more difficult. Estimation of WTP for decreases in very specific health risks (e.g., WTP to avoid 1 day of coughing or WTP to avoid admission to the hospital for respiratory illness) is further limited by a paucity of information. Derivation of the point estimates discussed below is often limited by available information. The WTP to avoid a day of specific morbidity endpoints, such as coughing or shortness of breath, has been estimated by only a small number of studies (two or three studies, for some endpoints; only one study for other endpoints). Point estimates in the benefit analysis for health endpoints involving these morbidity endpoints are therefore similarly based on only a few studies.

If exposure to pollution has any cumulative or lagged effects, then a given reduction in pollution concentrations in 1 year may confer benefits not only in that year, but in future years as well. Because this benefit analysis pertains to a single year only, however, any benefits achieved in other years are not included in the analysis.

Finally, the existence of altruistic or other "non-use" values are not considered in any of the unit value derivations. Individuals' WTP's for reductions in health risks for others are implicitly assumed to be zero.

9.4.2 Derivation of Point Estimates of Mean Willingness to Pay

This benefit analysis draws upon a variety of studies for the economic valuation of incidence reductions estimated to result from alternative PM standards. Tables 9.5 and 9.6 present the unit dollar values of mean willingness to pay (MWTP) that are used in the assessment. The derivation of these unit values are briefly described below.[a]

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[a] See Post et al. (1996) for additional details on the derivation of WTP estimates.

9.4.2.1 Premature Mortality

The dollar value of avoiding one statistical death is estimated to be $4.8 million. This is the mean of the estimates from 26 value-of-life studies identified by Industrial Economics, Inc. (IEc) as "applicable to policy analysis"[26] and for use in the Agency's assessment of the costs and benefits of the Clean Air Act.[a] The IEc's assessment mirrors that of Viscusi (1992)[27] and uses the same criteria used by Viscusi in his review of value-of-life studies. The $4.8 million estimate is consistent with Viscusi's conclusion that "most of the reasonable estimates of the value of life are clustered in the $3 to $7 million range." Five of the 26 studies are CV studies, which directly solicit WTP information from subjects; the rest are wage-risk studies, which base WTP estimates on estimates of the additional compensation demanded in the labor market for riskier jobs. See Table 9-10 for a summary table of the value-of-life studies used for this analysis.

The transferability of estimates of the value of a statistical life from the 26 studies to the PM benefit analysis rests on the assumption that, within a reasonable range, WTP for reductions in mortality risk is linear in risk reduction. In addition, the characteristics of the study subjects and the nature of the mortality risk being valued in the study could affect the transferability of the value of statistical life to this assessment.

[a] See "The Benefits and Costs of the Clean Air Act, 1970 - 1990". Draft Report to Congress. May 3, 1996.

TABLE 9.5

SUMMARY OF HEALTH AND WELFARE INFORMATION FOR CALCULATION OF MONETIZED BENEFITS FROM REDUCING PM_{10} CONCENTRATIONS

Health or Welfare Endpoint	**Applied Population***	**Estimated Unit Dollar Value (1990 $)**	**Derivation of Estimated Dollar Value per Incidence**
A. **Hospital Admissions**:			
1. for congestive heart failure (ICD code 428)	age ≥ 65	$16,600	$ value combines a cost-of-illness estimate,including the hospital charge, based on patients of all ages, and the cost of associated physician care,with the opportunity cost of time spent in the hospital. Source of hospital charge estimate: AHCPR study, Elixhauser et al., 1993. Source of physician charge estimates: Abt Associates Inc., 1992.
2. for ischemic heart disease (ICD code 410-414)	age ≥ 65	$20,600	$ value combines a cost-of-illness estimate,including the hospital charge, based on patients of all ages, and the cost of associated physician care,with the opportunity cost of time spent in the hospital. Source of hospital charge estimate: AHCPR study, Elixhauser et al., 1993. Source of physician charge estimates: Abt Associates Inc., 1992.
B. **Chronic Bronchitis**	all	$587,500	$ value is the mean of estimates from 4 studies of the benefit of avoiding a case of chronic bronchitis: Viscusi et al., 1991 and Krupnick and Cropper, 1992.
C. **Respiratory Problems Not Requiring Hospitalization**			

Health or Welfare Endpoint	Applied Population*	Estimated Unit Dollar Value (1990 $)	Derivation of Estimated Dollar Value per Incidence
1. Upper respiratory symptoms (URS) -- defined as one or more of the following: runny or stuffy nose, wet cough, burning, aching, or red eyes (# of days)	asthmatics age 9-11	$18.70	Using the 3 symptoms for which WTP estimates are available that closely match those listed by Pope et al., 7 different "symptom clusters" defining different "types" of URS were delineated, based on Pope et al.'s definition of URS. A $ value was derived for each type of URS, using IEc midrange estimates of WTP to avoid each symptom in the cluster and assuming additivity of WTPs. The $ value for URS is the average of the $ values for the 7 different types of URS. Note: IEc midrange estimates for each symptom are weighted averages of WTP estimates by Dickie et al. (1987), Tolley et al. (1986), and Loehman et al. (1979). (See IEc, 1993).
2. Lower Respiratory Symptoms (LRS) defined in the study as two or more of the following: cough, chest pain, phlegm, and wheeze. (# of cases)	ages 8-12	$11.82	Using the 4 symptoms for which WTP estimates are available that closely match those listed by Schwartz et al., 11 different "symptom clusters" defining different "types" of LRS were delineated, based on Schwartz et al.'s definition of LRS. A $ value was derived for each type of LRS, using IEc midrange estimates of WTP to avoid each symptom in the cluster and assuming additivity of WTPs. The $ value for LRS is the average of the $ values for the 11 different types of LRS. Note: IEc midrange estimates for each symptom are weighted averages of WTP estimates by Dickie et al. (1987), Tolley et al. (1986), and Loehman et al. (1979). (See IEc, 1993).
3. Presence of any of 19 acute respiratory symptoms	adults age 18-65	$18.31	Assuming that this health endpoint is URS with 40% probability, LRS with 40% probability, and both URS and LRS with 20% probability, the $ value for this endpoint is the weighted average (using the weights 0.40, 0.40, and 0.20) of the $ values derived for URS, LRS, and URS + LRS.
4. Doctor-diagnosed acute bronchitis associated with long-term exposure	ages 10-12	$45.00	Approximate mean of IEc-derived low and high estimates. (See IEc, 1994)
5. Days of shortness of breath	7-12 yr. old African-American asthmatics	$5.29	This is the mean of the median estimates from two studies of WTP to avoid a day of shortness of breath: Dickie et al., 1987 ($0.00), and Loehman et al.,1979 ($10.57).

Health or Welfare Endpoint	Applied Population*	Estimated Unit Dollar Value (1990 $)	Derivation of Estimated Dollar Value per Incidence
D. **Visibility Impairment**	all counties	East = $149 West = $117	Source: IEc, September 1993
E. **Soiling and Materials Damage**	all households	$2.52	Source: RCG/Hagler Bailly, 1994. RCG uses $1.26 as its low estimate of annual cost of soiling and materials damage per household (assuming 2.63 persons per household), taken from Manuel et al., 1982 (Mathtech). The Manuel study measured particulate matter as TSP rather than PM-10 or PM-2.5. Hypothesizing that at least half of the costs of household cleaning are for the time value of do-it-yourselfers, which was not included in the Manuel estimate, RCG multiplied the Manuel estimate by 2 to get a point estimate of $2.52, in 1990 $ (reported by RCG as $2.70 in 1992 dollars).

*Populations to which concentration-response functions were applied in the benefit analysis matched the study populations in characteristics listed.

TABLE 9.6

SUMMARY OF HEALTH AND WELFARE INFORMATION FOR CALCULATION OF MONETIZED BENEFITS FROM REDUCING $PM_{2.5}$ CONCENTRATIONS

Health or Welfare Endpoint	**Applied Population***	**Estimated Unit Dollar Value (1990 $)**	**Derivation of Estimated Dollar Value per Incidence**
A. **Mortality**			
1. Short-term exposure studies **	all ages	$4.8 million	$ value is the mean of value-of-life estimates from 26 studies --5 CV and 21 labor market studies (IEc, 1992). Studies are listed in Appendix IX.1.
2. Long-term exposure study	all ages		
B. **Respiratory Hospital Admissions** (ICD codes 466, 480-482, 485, 490-493)	all ages	$12,700	$ value combines a cost-of-illness estimate,including the mean hospital charge for the ICD codes considered by Thurston, based on patients of all ages, and the cost of associated physician care,with the opportunity cost of time spent in the hospital. Source of hospital charge estimate: Agency for Health Care Policy and Research (AHCPR) study, Elixhauser et al., 1993. Source of physician charge estimates: Abt Associates Inc., 1992. Note: Opportunity cost estimate excludes value of WLD for individuals in the workforce because this is included in RAD category.
C. **Lower Respiratory Symptoms** (LRS) defined in the study as two or more of the following: cough, chest pain, phlegm, and wheeze. (# of cases)	ages 8-12	$11.82	Using the 4 symptoms for which WTP estimates are available that closely match those listed by Schwartz et al., 11 different "symptom clusters" defining different "types" of LRI were delineated, based on Schwartz et al.'s definition of LRI. A $ value was derived for each type of LRI, using IEc midrange estimates of WTP to avoid each symptom in the cluster and assuming additivity of WTPs. The $ value for LRI is the average of the $ values for the 11 different types of LRI. Note: IEc midrange estimates for each symptom are weighted averages of WTP estimates by Dickie et al. (1987), Tolley et al. (1986), and Loehman et al. (1979). (See IEc, 1993).

Health or Welfare Endpoint	Applied Population*	Estimated Unit Dollar Value (1990 $)	Derivation of Estimated Dollar Value per Incidence
D. **"Moderate or Worse" Asthma Status** reflecting the subjective assessments of asthmatic subjects	asthmatics, ages 18-70	$32.48	Mean of average WTP estimates for the four severity definitions of a "bad asthma day." Source: Rowe and Chestnut (1986), a study which surveyed asthmatics to estimate WTP for avoidance of 1" bad asthma day," as defined by the subjects.
E. **Restricted Activity Days**			
1. RAD's	ages 18-65	not available	
2. WLD's	working adults, ages 18-65	$83.00	Median weekly wage for 1990 divided by 5 (U.S. Dept. of Commerce, 1992)
3. MRAD's (MRAD's associated with exposure to PM are assumed to be MRRADs)	working adults , ages 18-65	$38.37	Median WTP estimate to avoid 1 MRRAD -- minor respiratory restricted activity day -- from Tolley et al. (1986) (recommended by IEc as the mid-range estimate -- see IEc, 1993). MRADs associated with exposure to PM are assumed to be MRRADs.
F. **Visibility Impairment**	all counties	East =$149 West = $117	Source: IEc, September 1993
G. **Soiling and Materials Damage**	households	$2.52	Source: RCG/Hagler Bailly, 1994. RCG uses $1.26 as its low estimate of annual cost of soiling and materials damage per household (assuming 2.63 persons per household), taken from Manuel et al., 1982 (Mathtech). The Manuel study measured particulate matter as TSP rather than PM-10 or PM-2.5. Hypothesizing that at least half of the costs of household cleaning are for the time value of do-it-yourselfers, which was not included in the Manuel estimate, RCG multiplied the Manuel estimate by 2 to get a point estimate of $2.52, in 1990 $ (reported by RCG as $2.70 in 1992 dollars).

*Populations to which concentration-response functions were applied in the benefit analysis matched the study populations in characteristics listed.

** See PM Risk Assessment Final Report.

Compared with the subjects in wage-risk studies, the population believed to be most affected by PM (i.e., the population that would receive the greatest mortality risk reduction associated with a given reduction in PM concentrations) is, on average, older and probably more risk averse. Citing Schwartz and Dockery (1992)[28] and Ostro et al. (unpublished), Chestnut (1995)[29] estimates that approximately 85 percent of those who die prematurely from PM-related causes are over 65. The average age of subjects in wage-risk studies, in contrast, would be well under 65.

There is also reason to believe that those over 65 are, in general, more risk averse than the general population while workers in wage-risk studies are likely to be less risk averse than the general population. Although Viscusi's list of recommended studies excludes studies that consider only much-higher-than-average occupational risks, there is nevertheless likely to be some selection bias in the remaining studies -- that is, these studies are likely to be based on samples of workers who are, on average, more willing to accept higher risks than the general population. In contrast, older people as a group exhibit more risk averse behavior.

In addition, it might be argued that because the elderly have greater average wealth than those younger, the affected population is also wealthier, on average, than wage-risk study subjects, who tend to be blue collar workers. It is possible, however, that among the elderly it is largely the poor elderly who are most vulnerable to PM-related mortality risk (e.g., because of generally poorer health care). If this is the case, the average wealth of those affected by a reduction in PM concentrations relative to that of subjects in wage-risk studies is uncertain.

The direction of bias resulting from the age difference is unclear, particularly because age is confounded by risk aversion (relative to the general population). It could be argued that, because an older person has fewer expected years left to lose, his/her WTP to reduce mortality risk would be less than that of a younger person. This hypothesis is supported by one empirical study, Jones-Lee et al. (1985)[30], that found the value of a statistical life at age 65 to be about 90 percent of what it is at age 40. Citing the evidence provided by Jones-Lee et al. (1985), Chestnut (1995) estimates a weighted average value of a statistical life based on the approximate age distribution for the U.S. population age 65 and older. This results in an adjustment to the value of a statistical life for those 65 and over of 75 percent of what it is for those under 65.

The greater risk aversion of older people, however, implies just the opposite. Citing Ehrlich and Chuma (1990)[31], IEc (1992) notes that "older persons, who as a group tend to avoid health risks associated with drinking, smoking, and reckless driving, reveal a greater demand for reducing mortality risks and hence have a greater implicit value of a life year." That is, the more risk averse behavior of older individuals suggests a greater WTP to reduce mortality risk.

There is substantial evidence that the income elasticity of WTP for health risk reductions is positive (see, for example, Alberini et al., 1994[32]; Mitchell and Carson, 1986[33]; Loehman and Vo Hu De, 1982[34]; Gerking et al., 1988[35]; and Jones-Lee et al., 1985), although there is uncertainty about the exact value of this elasticity. Individuals with higher incomes (or greater wealth) should be willing to pay more to reduce risk, all else equal, than individuals with lower incomes or wealth. Whether the average income or level of wealth of the population affected by PM reductions is likely to be significantly different from that of subjects in wage-risk studies, however, is unclear, as discussed above.

Finally, there is some evidence (see, for example, Violette and Chestnut, 1983[36]) that people will pay more to reduce involuntarily incurred risks than risks incurred voluntarily. If this is the case, WTP estimates based on wage-risk studies may be downward-biased estimates of WTP to reduce involuntarily incurred PM-related mortality risks.

Potential sources of bias in an estimate of WTP to reduce the risk of PM-related mortality based on wage-risk studies are presented below in Table 9.7.

TABLE 9.7

POTENTIAL SOURCES OF BIAS IN ESTIMATES OF WTP TO REDUCE THE RISK OF PM-RELATED MORTALITY BASED ON WAGE-RISK STUDIES

Factor	Likely Direction of Bias in MWTP Estimate
Age	Upward (?)
Degree of Risk Aversion	Downward
Income	Downward, if the elderly affected are a random sample of the elderly; Unclear, if the elderly affected are the poor elderly.
Risk Perception: Voluntary vs. Involuntary risk	Downward

The need to adjust wage-risk-based WTP estimates downward because of the likely upward bias introduced by the age discrepancy has received significant attention (see Chestnut, 1995; IEc, 1992). In a similar vein, EPA's Science Advisory Board's Clean Air Act Compliance Analysis Council has highlighted the importance of life expectancy as an issue affecting mortality risk valuation.[a] If the age difference were the only difference between the population affected by PM changes and the subjects in the wage-risk studies, there might be some justification for trying to adjust the point estimate of $4.8 million downward. Even in this case, however, the degree of the

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[a] Dr. Richard Schmalansee, Chair, Science Advisory Board's Clean Air Act Compliance Analysis Council, letter to EPA Administrator Carol M. Browner, Subject: Science Advisory Board's review of the Office of Policy, Planning and Evaluation's (OPPE) and the Office of Air and Radiation's (OAR) progress on the retrospective study of the impacts of the Clean Air Act, March 24, 1993 (EPA-SAB-CAACAC-LTR-90-006).

Dr. Richard Schmalansee, Chair, Science Advisory Board's Advisory Council on Clean Air Compliance Analysis, letter to EPA Administrator Carol M. Browner, Subject: ACCACA Review of Progress on the Retrospective Study of the Clean Air Act (CAA) Benefits and Costs from 1970 through 1990, June 3, 1996. (EPA-SAB-ACCACA-96-003).

adjustment would be unclear. There is good reason to suspect, however, that there are biases in both directions, as shown in the table above. Because in each case the extent of the bias is unknown, the overall direction of bias in the point estimate of $4.8 million is similarly unknown. Adjusting the estimate upward or downward to compensate for any one source of bias could increase the degree of bias. The point estimate of $4.8 million was, therefore, left unadjusted for this assessment; however, Section 9.5.3 presents results of a sensitivity analysis in which the unit value of a reduction in premature mortality among individuals 65 years or older is adjusted.

9.4.2.2 Hospital Admissions

Because WTP estimates for the hospital admissions categories evaluated in this analysis are not available, unit dollar values are derived by combining estimates of two factors: cost of illness (COI) and opportunity cost. The COI estimates include the estimated hospital and physician charges, based on the average length of a hospital stay for the health effect. Hospital charges are based on Agency for Health Care Policy and Research data (Elixhauser, 1993)[37]. Estimation of the opportunity cost of time spent in the hospital is explained below.

Abt Associates Inc. (1992)[38] estimated that physician charges for the first day of hospital care for asthma (in 1988) or chronic obstructive pulmonary disease (COPD) (in 1989) averaged $94 (in 1990 $); physician charges for subsequent days of hospital care averaged $35. Average physician charges associated with hospital care for asthma or COPD were assumed to provide reasonably good estimates of average physician charges associated with hospital stays for the other illness categories considered here.

To estimate the opportunity cost of a day spent in the hospital for an individual aged 65 or older, it is assumed that such an individual is not in the workforce. As an approximation, it was assumed that, for the young, the elderly, and any other unemployed individuals the opportunity cost of a day spent in the hospital is one-half the median daily wage, or $41.50 (see Section 9.5.2.8). Thus, the opportunity cost associated with a hospital admission is simply equal to $41.50 times the average number of days of the hospital stay.

To derive unit dollar values for hospital admissions for respiratory illness based on the Thurston study, which considered individuals of all ages, it is assumed that half of the PM-related hospital admissions are among individuals who are not employed, including the young and the elderly.[a] Because the value of work loss days for those in the labor force is considered as a separate endpoint, only the opportunity cost for those outside of the workforce is included.

Since COI estimates do not measure values associated with pain and suffering, as well as other reductions in well-being from illness, they significantly understate the true WTP to avoid illness. For this reason an adjustment factor is employed to scale the hospital admissions COI estimate upward to estimate WTP. Following the strategy employed by Chestnut (1985), the hospital admissions COI estimate is multiplied by a factor of 2. This factor is based on results from three studies providing evidence on WTP/COI ratios for the same study population addressing the same change in the same health effect. While this adjustment approach is based on limited evidence, the resulting hospital admissions valuation estimate is not clearly biased. This is an area in which further research will be done for the final PM NAAQS RIA.

9.4.2.3 Chronic Bronchitis

The WTP estimate used for avoided chronic bronchitis is based on studies that elicited from respondents a willingness to pay for chronic bronchitis in terms of a willingness to trade the risk of chronic bronchitis for the risk of a fatal automobile accident (a risk-risk tradeoff).[39,40] The

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[a] This is approximately the same as the ratio of employed to total population in the United States. In 1994, for example, this ratio was 123/260, or 47 percent.

valuation of a change in the risk of a fatal automobile accident is then applied to infer a valuation for a case of chronic bronchitis avoided. Using this method, four unit values have been suggested:[a] (1) a mean value of $883,000; (2) a median value of $457,000 which captures the skewness of the response distribution; (3) $210,000, based on the mean value, with an adjustment for the severity of the chronic bronchitis case; and (4) a value of $800,000 derived from the mean risk-risk response, but adjusting the for skewness of automobile mortality valuation by using the *median* value for automobile mortality. For this analysis, the central estimate of the value of avoiding a case of chronic bronchitis is taken to be the mean of the four suggested estimates, which is $587,500.

9.4.2.4 Upper Respiratory Symptoms (URS) and Lower Respiratory Symptoms (LRS)

The complex of symptoms for both upper and lower respiratory symptoms as reported in the underlying epidemiology study are matched with median WTP estimates from three contingent valuation studies (Dickie et al.[41], Tolley et al.[42], Loehman et al.). It is assumed for both URS and LRS that each of the symptom combinations identified in the underlying health study occur with equal probability; therefore, the median WTP is the average of median WTP across all symptom combinations. The median WTP to avoid upper respiratory symptoms is $18.70. The median WTP to avoid lower respiratory symptoms is $11.82.

The point estimates derived for MWTP to avoid a day of URS and a case of LRS are based on the assumption that WTP's are additive. For example, if WTP to avoid a day of cough is $7.00, and WTP to avoid a day of shortness of breath is $5.00, then WTP to avoid a day of both cough and shortness of breath is $12.00. If there are no synergistic effects among symptoms, then it is likely that the marginal utility of avoiding symptoms decreases with the number of symptoms

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[a] *Review of Clean Air Act Section 812 Retrospective Study of Costs and Benefits*, Report of the Advisory Council on Clean Air Compliance Analysis (EPA-SAB-ACCACA-96-003), June 1996.

being avoided. If this is the case, adding WTP's would tend to overestimate WTP for avoidance of multiple symptoms. However, there may be synergistic effects -- that is, the discomfort from two or more simultaneous symptoms may exceed the sum of the discomforts associated with each of the individual symptoms. If this is the case, adding WTP's would tend to underestimate WTP for avoidance of multiple symptoms. It is also possible that people may experience additional symptoms for which WTP's are not available, again leading to an underestimate of the correct WTP. However, for small numbers of symptoms, the assumption of additivity of WTP's is unlikely to result in substantive bias.

9.4.2.5 Presence of Any of 19 Acute Respiratory Symptoms

"Presence of any of 19 acute respiratory symptoms" is a somewhat arbitrary "health endpoint" used by Krupnick et al. (1990)[43]. Because all 19 symptoms are not listed in the Krupnick study, it is not clear exactly what symptoms were included in the study. Acute respiratory symptoms must be either upper respiratory symptoms or lower respiratory symptoms. In the absence of further knowledge about which of the two types of symptoms is more likely to occur among the "any of 19 acute respiratory symptoms," it is assumed that they occur with equal probability. Because this health endpoint may also consist of combinations of symptoms, it is also assumed that there is some (smaller) probability that upper and lower respiratory symptoms occur together.

To value avoidance of a day of "the presence of any of 19 acute respiratory symptoms", it is assumed that this health endpoint consists either of URS, or LRS, or both. It is also assumed that "the presence of any of 19 acute respiratory symptoms" is a day of URS with 40 percent probability, a day of LRS with 40 percent probability, and a day of both URS and LRS with 20 percent probability. Using the point estimates of WTP to avoid a day of URS and LRS derived above, the point estimate of WTP to avoid a day of "the presence of any of 19 acute respiratory symptoms" is $18.31.

Because this health endpoint is only vaguely defined, and because of the lack of information on the relative frequencies of the different combinations of acute respiratory symptoms that might qualify as "any of 19 acute respiratory symptoms," the unit dollar value derived for this health endpoint must be considered only a rough approximation. It is recognized that there are inconsistent valuation methodologies for this endpoint between the ozone and PM NAAQS RIA benefit analyses. The EPA is examining the use of a single method for use in the final RIA's accompanying promulgation of the ozone and PM NAAQS.

9.4.2.6 Acute Bronchitis

Estimating WTP to avoid a case of acute bronchitis is difficult for several reasons. First, WTP to avoid acute bronchitis itself has not been estimated. Estimation of WTP to avoid this health endpoint therefore must be based on estimates of WTP to avoid symptoms that occur with this illness. Second, a case of acute bronchitis may last more than one day, whereas it is a day of avoided symptoms that is typically valued. Finally, the concentration-response function used in the benefit analysis for acute bronchitis is estimated for children, whereas WTP estimates for those symptoms associated with acute bronchitis are obtained from adults.

With these caveats in mind, a rough estimate of WTP to avoid a case of acute bronchitis is derived as the midpoint of a low and a high estimate.[a] The low estimate ($13.29) is the sum of the midrange values recommended by IEc (IEc, 1994)[44] for two symptoms believed to be associated with acute bronchitis: coughing ($6.29) and chest tightness ($7.00). The high estimate is taken to be twice the value of a minor respiratory restricted activity day ($38.37), or $76.74.

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[a] The derivation of the low and high estimates of WTP to avoid a case of acute bronchitis are explained in some detail in IEc (1994).

The midpoint between the low and high estimates is $45.00. This value is used as the point estimate of MWTP to avoid a case of acute bronchitis in the benefit analysis.

9.4.2.7 Shortness of Breath

A point estimate of MWTP to avoid a day of shortness of breath was derived as the mean of the median estimates from two studies that evaluated this symptom. The median estimate from Dickie et al., 1987, was $0.00; the median estimate from Loehman et al., 1979, was $10.57. The mean of these two medians is $5.29.

9.4.2.8 Moderate or Worse Asthma Status

This health endpoint comes from Ostro et al. (1991)[45], a study in which asthmatics were asked to record in a daily diary a subjective rating of their overall asthma status each day (0=none, 1-mild, 2=moderate, 3=severe, and 4=incapacitating).

The unit dollar value used for this endpoint is based on a study which asked asthmatics to estimate their WTP to prevent an increase in "bad-asthma days" (Rowe and Chestnut, 1986).[46] Subjects were left to define for themselves what constitutes a bad-asthma day. Rowe and Chestnut found that WTP estimates depended in part on how the subjects defined a bad asthma day. For example, the mean WTP among subjects defining a bad-asthma day as one with any symptoms was $11.81, whereas the mean WTP among subjects defining a bad-asthma day as one with more than moderate symptoms was $53.80. In general, WTP increased as the definition of a bad asthma day increased in severity.

Although subjects' assessment of what constitutes a "bad-asthma day" varied considerably in the Rowe and Chestnut study, the subjective assessment of an asthma day being bad is very similar to the subjective assessment of an asthma day being "of moderate or worse status" in the Ostro study, in which subjects were also asked their subjective assessments. To estimate WTP to avoid a day of asthma that is of moderate or worse status, the WTP's from the Rowe and Chestnut study for all four severity categories in the study (with corresponding WTP estimates of $11.81, $24.93, $39.37, and $53.80) were therefore averaged. The point estimate of WTP to avoid a day of asthma that is of moderate or worse status is therefore $32.48.

9.4.2.9 Work Loss Days

Willingness to pay to avoid the loss of one day of work was estimated by dividing the median weekly wage for 1990[47] by 5 (to get the median daily wage). This values the loss of a day of work at the median wage for the day lost. The median daily wage in 1990 was $83.00. Valuing the loss of a day's work at the wages lost is consistent with economic theory under competitive conditions which assumes that an individual is paid exactly the value of his labor.

9.4.2.10 Minor Restricted Activity Days

No studies are reported to have estimated WTP to avoid a minor restricted activity day (MRAD). However, IEc (1993)[48] has derived an estimate of WTP to avoid a minor respiratory restricted activity day (MRRAD), using WTP estimates from Tolley et al. (1986) for avoiding a three-symptom combination of coughing, throat congestion, and sinusitis. This estimate of WTP to avoid a MRRAD, so defined, is $38.37. Although Ostro and Rothschild (1989) estimated the relationship between $PM_{2.5}$ and MRAD's, rather than MRRAD's (a component of MRAD's), it is likely that most of the MRAD's associated with exposure to $PM_{2.5}$ are in fact MRRAD's. For the purpose of valuing this health endpoint, then, it is assumed that MRAD's associated with PM exposure may be more specifically defined as MRRAD's, and the estimate of MWTP to avoid a MRRAD ($38.37) is used.

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9.4.2.11 Visibility Impairment

For this analysis, visibility changes have been estimated in units of deciview. A one deciview change in visibility is perceptible by individuals and thus its usefulness as a metric for economic valuation purposes. The value of avoided visibility impairment is derived from various studies of the WTP to improve visibility.[49] These studies estimated WTP values in different cities in the U.S. The values used to monetize the measured reductions in visibility were found to vary between the Eastern and Western United States ($149 and $117 per percent change in visual range, respectively). Visibility benefits here represent the economic value of improved county-level visibility experienced by individuals residing in that county.

9.4.2.12 Household Soiling Damage

Manuel et al. (1982)[50] provides an estimate of the cost to households of PM soiling. The study uses a household production function approach and household expenditure data from the 1972-73 Bureau of Labor Statistics Consumer Expenditure Survey for over twenty cities in the United States. The study estimates the annual cost of cleaning per $\mu g/m^3$ PM per household as $1.26 ($0.48 per person times 2.63 persons per household). This estimate is low compared with others (e.g., estimates provided by Cummings et al., 1981[51], and Watson and Jaksch, 1982[52], are about eight times and five times greater, respectively). RCG/Hagler Bailly (1994)[53] notes, however, that the Manuel estimate is probably downward-biased because it does not include the time cost of do-it-yourselfers. RCG/Hagler Bailly estimates that these costs may comprise at least half the cost of PM-related cleaning costs. Consistent with the RCG/Hagler Bailly method, this analysis doubles the Manuel estimate to obtain a point estimate of $2.52 (reported by RCG/Hagler Bailly in 1992 dollars as $2.70).

The Manuel study measures particulate matter as TSP rather than PM_{10} or $PM_{2.5}$. There is insufficient information on the relative soiling capabilities of the different size fractions of TSP. Therefore, for the purpose of this analysis, it is assumed that particles of all sizes are equally soiling and the same unit dollar value can in turn be used for PM_{10} or $PM_{2.5}$.

9.5 SUMMARY OF RESULTS

This section describes the method used to eliminate the possibility of double counting when adding up national benefits across endpoints. Additionally, the estimates of national benefits for $PM_{2.5}$ alternatives are presented.

9.5.1 Aggregation of Monetized Benefits to Derive Total Monetized Benefits

Aggregation refers to the adding together of the monetized benefits associated with different health or welfare endpoints to derive a total monetized benefit attributable to attainment of a given set of alternative PM standards. Ideally, the effects of PM could be divided into mutually exclusive categories that, combined, account for all the effects. Even if health endpoint categories are overlapping, they are mutually exclusive, and can therefore be aggregated, if the populations for which their concentration-response functions were estimated are mutually exclusive. For example, respiratory illnesses among children and respiratory illnesses among adults are mutually exclusive categories.

In practice, however, the health endpoint-population categories examined in the epidemiological literature are not always mutually exclusive; nor does their sum necessarily make up the total of all PM-related effects. Recall from Section 9.4.2.2, there is some possibility of overlap between hospital admissions for all respiratory illnesses (Thurston et al, 1994) and restricted activity days in that the opportunity cost of time spent in the hospital (a component of the unit dollar value for each type of hospital admissions) for individuals in the workforce is taken to be the value of a lost day of work, which is also a component of the value of a restricted activity day avoided. Double counting is avoided by leaving out of the hospital admission MWTP the opportunity cost of time spent in the hospital for those individuals in the workforce. This component of benefits is accounted for in the benefits of reduced restricted activity days.

Concentration-response functions for both short-term exposure mortality and long-term exposure mortality are estimated. While there is very likely substantial overlap in the incidences of PM-related short-term exposure and long-term exposure mortality (and, therefore, in the benefits associated with them), both are considered important health endpoints. The omission of either from the analysis was therefore considered unwise. Instead, for each PM alternative analysis, two estimates of total monetized benefits are presented: one containing the monetized benefit associated with avoided short-term exposure mortality and the other containing the monetized benefit associated with avoided long-term exposure mortality.

There are a number of short-term exposure mortality studies that were available for use; some employ PM_{10} as an air quality indicator and others $PM_{2.5}$. Because the epidemiological evidence suggests a stronger association between premature mortality and elevated concentrations of $PM_{2.5}$, a $PM_{2.5}$ concentration-response function based on a pooled analysis[54] was used to estimate short-term mortality benefits.

There is also a possibility of some overlap between "the presence of any of 19 acute respiratory symptoms" and MRRAD's. The age ranges of the populations studied are the same in both studies and it is also possible that an acute respiratory symptom could result in a minor respiratory restricted activity day. The degree of overlap, however, is not known, and it is likely that much of the benefit associated with each endpoint is not included within the benefit associated with the other endpoint. Additionally, it is assumed for this analysis that the benefit of avoiding an asthma attack is captured in the "moderate or worse asthma status" endpoint rather than "any of 19 acute respiratory symptoms." The unit value for the "any of 19 acute respiratory symptoms" reflects this assumption. Thus, no adjustments have been made.

Within the category of restricted activity days, a number of aggregation issues arises. Health endpoints within the restricted activity days category for which concentration-response functions have been estimated include: (1) restricted activity days (RAD's), (2) MRAD's, and (3) work loss days (WLD's).

The MRAD's are defined by Ostro and Rothschild (1989) as not including WLD's. MRAD's and WLD's are therefore mutually exclusive; both are proper subsets of RAD's. However, because the concentration-response functions for these endpoints were estimated by different studies, there is no guarantee that the incidence of MRAD's predicted for a given location will be less than the incidence of RAD's predicted for that location (and similarly for WLD's and RAD's).

There are currently available estimates of dollar values only for WLD's ($83) and MRAD's ($38.37). The following possibilities are available to estimate the monetized benefits associated with RAD's:

1. (Incidence of MRAD's)($ value of MRAD's) + (incidence of WLD's)($ value of WLD's);

2. (RAD's - WLD's)($ value of MRAD's) + WLD's($ value of WLD's).

3. An average of the results of the two methods.

In the second approach, the incidence of RAD's is predicted using the concentration-response function for RAD's estimated by Ostro (1987). The incidence of WLD's is also predicted, using the concentration-response function for WLD's estimated by the same study. The incidence of RAD's that are not WLD's (including, for example, MRAD's and RAD's that are not minor, but do not result in the loss of a work day) is then obtained by subtracting incidence of WLD's from the incidence of RAD's.

The first method omits RAD's that are neither WLD's nor MRAD's. The second method doesn't omit any kinds of RAD's but undervalues the RAD's that are not WLD's by valuing them all at the dollar value for MRAD's. If the true concentration-response functions for all the restricted activity day categories and the true dollar values were known, the second approach would be preferable because it omits less monetized benefit. While the first approach omits a class of RAD's (those that are neither WLD's nor MRAD's) and in effect values them at zero dollars, the second approach simply undervalues a portion of the class of RAD's that is completely omitted in the first approach.

However, neither the true concentration-response functions nor the true dollar values are known. It is therefore unclear which method will give a better estimate. Method 3, averaging the results of methods 1 and 2, therefore seems to be reasonable.

Finally, there are no aggregation problems within the category of respiratory illness given that health effects are for non-overlapping populations.

9.5.2 Partial and Full Attainment Incidence Reductions and Benefit Results

Partial and full attainment national incidence reductions incremental to the baseline PM_{10} alternative are presented in Tables 9.8 and 9.9. Point estimates of national benefits associated with partial and full attainment of alternative $PM_{2.5}$ levels incremental to partial attainment of the baseline PM_{10} alternative are given in Tables 9.10 and 9.11. Both the separate monetized benefits for each health and welfare endpoint considered and the total monetized benefits are shown. All monetary values are presented in 1990 dollars.

The estimated benefits associated with partial attainment of all the $PM_{2.5}$ alternatives are substantial. The partial attainment of the baseline PM_{10} alternative in 2007 is estimated to result in undiscounted monetized benefits of $27 billion when the estimate is based on including the benefits from avoided short-term exposure mortality, and $41 billion when the estimate is based on including the benefits from avoided long-term exposure mortality. The *additional* monetized benefits estimated to result from attainment of alternative $PM_{2.5}$ levels range from $22 billion (for attainment of the $PM_{2.5}$ alternative - 20 $\mu g/m^3$ annual/65 $\mu g/m^3$ daily) to $94 billion (for attainment of the $PM_{2.5}$ alternative - 12.5 $\mu g/m^3$ annual, 50 $\mu g/m^3$ daily) when total benefits are based on including the benefits of avoided short-term exposure mortality. When total benefits are based on including the benefits of avoided long-term exposure mortality, they range from $44 billion to $192 billion. The additional benefits of the $PM_{2.5}$ alternative - 15 $\mu g/m^3$ annual/50 $\mu g/m^3$ daily - range from $58 billion to $119 billion.

Estimates of $PM_{2.5}$ benefits for the full-attainment scenario range from $20 billion to $125 billion including short-term mortality and $42 billion to $257 billion including long-term mortality. Full-attainment benefits for the proposed $PM_{2.5}$ alternative are estimated to be $69 billion to $144 billion including short-term mortality and long-term mortality respectively. A summary of these estimates is presented in Table 9.9. The benefits from full attainment of the current PM_{10} standard are estimated to range from $45 billion including short-term mortality and $70 billion including long-term mortality.

As discussed in Chapter 7, the effectiveness of a regional SO_2 control strategy (50 percent reduction in utility SO_2 for the East) in combination with county-level PM controls in achieving alternative $PM_{2.5}$ concentration levels incremental to the current PM_{10} alternative was examined. The benefits of this strategy in attaining the proposed $PM_{2.5}$ alternative in 2007 were also assessed. The partial attainment benefits are estimated to be $60 billion including short-term exposure mortality benefits and $132 billion including the long-term mortality benefits. For the full-attainment scenario, benefits increase to $69 billion to $152 billion with either the inclusion of short-term or long-term mortality benefits, respectively. Thus, within the limitations of this analysis, the regional SO_2 control strategy in combination with county-level PM controls provides comparatively larger benefits than county-level PM controls only.

Because the dollar value associated with saving a statistical life is a major factor contributing to the estimate of benefits for each of the alternative scenarios, and because the long-term exposure study predicts so much more premature mortality avoided than is predicted by the short-term exposure studies, the uncertainties surrounding mortality are of primary importance. Further research is needed to determine why there is such a discrepancy between mortality predicted by the long-term and short-term exposure studies, and which predictions are closer to the truth. It is possible that the long-term exposure study estimate of PM-related mortality is biased upwards. This might be the case, for example, if observed mortality was related to PM levels in years prior to the study and if those levels were higher than levels observed during the study. It is also possible, however, that the long-term exposure study is capturing some PM-related mortality that the short-term exposure studies do not capture. If, for example, some PM-related mortality results from cumulative exposure over a longer period of time than is considered in the short-term exposure studies, these studies may be underestimating the incidence of PM-related mortality. Because it is unclear whether the long-term exposure study or the short-term exposure studies present a more accurate picture of PM-related mortality incidence, total benefit estimates based on both, separately, have been presented.

9.5.3 Sensitivity Analysis of Age-related MWTP to Avoid a Statistical Mortality

As mentioned previously, an as yet unresolved issue of importance to the benefit analysis is the extent to which PM-related premature mortality occurs among individuals who, even in the absence of exposure to PM, would have died within a relatively short period of time -- that is, the extent to which exposure to PM simply hastens already impending deaths (for example, among the sick and/or the elderly). This is a particularly important issue because it illuminates the fact that not all deaths entail the same number of "life-years" lost and calls into question whether avoiding a premature death that is only a week premature, for example, is worth the same as avoiding a premature death that is many years premature.

A related issue arises when estimating the benefits derived from long-term mortality studies. The Criteria Document and Staff Paper conclude that at least some fraction of the deaths in these studies likely reflect cumulative PM impacts above and beyond those seen from acute exposures. If multi-year exposures produce such effects, then the benefits accompanying reductions in PM levels might take some time to achieve maximum effect. The data do not permit any clear determination of any possible "lag" structure. In any event, the risk estimates for the original study accounted for the 7 to 12 year period over which effects data were collected, and so no adjustments were made for this analysis.

The Agency has received comment in the Section 812 process on the valuation of premature mortality from a Science Advisory Board committee of external reviewers.[a] The committee recommended that a quantitative sense of the distribution of mortality effects among age cohorts should be obtained. Secondly, the committee suggested four possible approaches to adjusting the statistical value of life to reflect differences in quality and quantity of life among different cohorts. To date, there is only minimal information regarding the age distribution for the association

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[a] *An SAB Report: Review of Clean Air Act Section 812 Retrospective Study of Costs and Benefits.* Advisory Council on Clean Air Compliance Analysis (ACCACA) Review the Agency's Retrospective Study of the Section 812 Clean Air Act Benefits and Costs from 1970 to 1990. EPA-SAB-ACCACA-96-003. June 1996.

between PM air quality and premature mortality. Similarly, the epidemiological evidence does not presently provide information to derive estimates of remaining life foregone, measured as life-years-lost, for individuals dying at different ages. Moreover, the economic valuation science is limited at this time and thus prevents derivation of a value of each life-year-lost.

However, to provide some idea of how benefits from mortality risk reductions may be sensitive to an age-specific valuation measure, a sensitivity analysis was conducted in which, in contrast to assuming that a single MWTP for a statistical life saved ($4.8 million) applies to all individuals in the population, it is assumed that the elderly (individuals 65 and older) are willing to pay only 75 percent of this, or $3.6 million. This is consistent with the method used by Chestnut (1995). Assuming also that 80 percent of all PM-related premature deaths are among the elderly,[a] the inclusion of age-related MWTP results in a 20 percent decrease in monetized benefits associated with avoided short-term or long-term exposure mortality in all alternative $PM_{2.5}$ scenarios.

[a] The estimate that 80 percent of all PM-related deaths are among individuals aged 65 and over is consistent with other estimates in the literature. See, for example, Schwartz 1994 and Ostro et al., 1996.

Table 9.8
Estimated Partial Attainment Incidence Reductions in the Year 2007 Associated with Attainment of Alternative $PM_{2.5}$ Standards (millions 1990 $)

Benefits estimated incremental to current PM_{10} alternative (50µg/m³ annual; 150µg/m³ daily)

ENDPOINTS — Annual $PM_{2.5}$ level (ug/m³)	20	15	12.5
Daily $PM_{2.5}$ level (ug/m³)	65	50	50
Mortality - short-term exposure	1,000	4,000	7,000
Mortality - long-term exposure	6,000	17,000	27,000
Hospital Admissions			
All Respiratory Admissions	1,000	4,000	7,000
Congestive Heart Failure	1,000	2,000	3,000
Ischemic Heart Disease	1,000	2,000	3,000
Chronic Bronchitis	24,000	63,000	99,000
Upper Respiratory Symptoms (# of days)	16,000	41,000	64,000
Lower Respiratory Symptoms (# of cases)	73,000	215,000	355,000
Acute Respiratory Symptoms (any of 19)	5,500,000	14,315,000	22,527,000
Acute Bronchitis	18,000	46,000	69,000
Shortness of breath	33,000	87,000	148,000
Moderate or Worse Asthma Status	68,000	207,000	369,000
Restricted Activity Days			
RADs	150,000	444,000	742,000
WLDs	55,000	162,000	271,000
MRADs	455,000	1,345,000	2,245,000
Visibility (change in deciview per person)	.3	.8	1.5
Household Soiling Damage	not applicable	not applicable	not applicable

Table 9.9
Estimated Full Attainment Incidence Reductions in the Year 2007 Associated with Attainment of Alternative $PM_{2.5}$ Standards (millions 1990 $)

Benefits estimated incremental to current PM_{10} alternative (50µg/m^3 annual; 150µg/m^3 daily)

Annual $PM_{2.5}$ level (ug/m^3)	20	15	12.5
ENDPOINTS Daily $PM_{2.5}$ level (ug/m^3)	**65**	**50**	**50**
Mortality - short-term exposure	1,000	5,000	9,000
Mortality - long-term exposure	6,000	20,000	36,000
Hospital Admissions			
All Respiratory Admissions	1,000	5,000	9,000
Congestive Heart Failure	1,000	2,000	4,000
Ischemic Heart Disease	1,000	2,000	4,000
Chronic Bronchitis	22,000	74,000	134,000
Upper Respiratory Symptoms (# of days)	14,000	48,000	84,000
Lower Respiratory Symptoms (# of cases)	69,000	258,000	464,000
Acute Respiratory Symptoms (any of 19)	4,995,000	16,694,000	29,761,000
Acute Bronchitis	16,000	54,000	91,000
Shortness of breath	32,000	99,000	193,000
Moderate or Worse Asthma Status	66,000	242,000	468,000
Restricted Activity Days			
RADs	146,000	536,000	976,000
WLDs	53,000	195,000	356,000
MRADs	443,000	1,620,000	2,943,000
Visibility (change in deciview per person)	.3	1.0	1.9

ENDPOINTS — Annual $PM_{2.5}$ level (ug/m³) / Daily $PM_{2.5}$ level (ug/m³)	20 / 65	15 / 50	12.5 / 50
Household Soiling Damage	not applicable	not applicable	not applicable

Table 9.10
Estimated Partial Attainment Benefits in the Year 2007 Associated with Attainment of Alternative $PM_{2.5}$ Standards
(millions 1990 $)

Benefits estimated incremental to current PM_{10} alternative (50µg/m³ annual; 150µg/m³ daily)

ENDPOINTS — Annual $PM_{2.5}$ level (ug/m³) / Daily $PM_{2.5}$ level (ug/m³)	20 / 65	15 / 50	12.5 / 50
Mortality - short-term exposure	$6,617	$18,615	$31,294
Mortality - long-term exposure	$28,953	$80,175	$129,538
Hospital Admissions			
All Respiratory Admissions	$18	$52	$87
Congestive Heart Failure	$12	$30	$48
Ischemic Heart Disease	$17	$42	$67
Chronic Bronchitis	$14,288	$36,856	$58,317

Annual $PM_{2.5}$ level (ug/m^3)	20	15	12.5
ENDPOINTS — Daily $PM_{2.5}$ level (ug/m^3)	**65**	**50**	**50**
Upper Respiratory Symptoms (# of days)	$0	$1	$1
Lower Respiratory Symptoms (# of cases)	$1	$3	$4
Acute Respiratory Symptoms (any of 19)	$102	$262	$412
Acute Bronchitis	$1	$2	$3
Shortness of breath	$0	$0	$1
Moderate or Worse Asthma Status	$2	$7	$12
Restricted Activity Days	$15	$45	$74
Visibility (change in deciview per person)	$406	$1,206	$2,151
Household Soiling Damage	$310	$797	$1,254
Total Benefits			
With Short-term Mortality	$21,792	$57,917	$93,727
With Long-term Mortality	$44,125	$119,477	$191,970

Table 9.11
Estimated Full Attainment Benefits in the Year 2007 Associated with Attainment of Alternative $PM_{2.5}$ Standards (millions 1990 $)

Benefits estimated incremental to current PM_{10} alternative (50μg/m^3 annual; 150μg/m^3 daily)

ENDPOINTS — Annual $PM_{2.5}$ level (ug/m³)	20	15
Daily $PM_{2.5}$ level (ug/m³)	65	50
Mortality - short-term exposure	$6,521	$22,485
Mortality - long-term exposure	$28,470	$97,319
Hospital Admissions		
All Respiratory Admissions	$17	$63
Congestive Heart Failure	$11	$35
Ischemic Heart Disease	$15	$49
Chronic Bronchitis	$12,793	$43,448
Upper Respiratory Symptoms (# of days)	$0	$1
Lower Respiratory Symptoms (# of cases)	$1	$3
Acute Respiratory Symptoms (any of 19)	$91	$306
Acute Bronchitis	$1	$2
Shortness of breath	$0	$1
Moderate or Worse Asthma Status	$2	$8
Restricted Activity Days	$15	$54
Visibility (change in deciview per person)	$399	$1,401
Household Soiling Damage	$278	$931
Total Benefits		
With Short-term Mortality	**$20,145**	**$68,786**
With Long-term Mortality	**$42,094**	**$143,620**

9.6 CONCLUSION

In summary, the monetized benefits estimated to result from the attainment of the alternative $PM_{2.5}$ scenarios considered in this analysis are substantial. They are, however, surrounded by substantial uncertainty from many sources. Because the uncertainty from several sources is not readily quantifiable, but may be very significant, these limitations should be kept in mind. The following is a summary of the principle benefit analysis results.

- Full attainment of the least stringent $PM_{2.5}$ alternative (results in estimated benefits of between $20 and $40 billion per year. Full attainment annual benefits range between an estimated $125 and $260 billion for the most stringent alternative.

- Partial attainment of the least stringent $PM_{2.5}$ alternative results in estimated annual benefits of $20 and $40 billion. Partial attainment of the most stringent alternative results in estimated benefits of between $95 billion and $190 billion per year.

- Full attainment of the proposed $PM_{2.5}$ alternative results in estimated health benefits of $65 billion or $265 per capita (including short-term mortality) and $140 billion or $565 per capita (including long-term mortality). Welfare benefits, including the impact on visibility, are $2 billion or $8 per capita.

- Partial attainment of the proposed $PM_{2.5}$ alternative results in estimated health benefits of $55 billion or $225 per capita (including short-term mortality) and $120 billion or $470 per capita (including long-term mortality). Welfare benefits, including the impact on visibility, are $2 billion or $8 per capita.

- As a supplemental analysis, a regional SO_2 strategy in the East implemented incremental to Title IV and in combination with the county-level regional control strategy would increase benefits for the proposed $PM_{2.5}$ alternative by between $2 and $13 billion.

TABLE 9-12

ESTIMATES USED TO GENERATE PROPOSED DISTRIBUTION OF VALUE OF A STATISTICAL LIFE

Author and Year	Type of Estimate	Mean Risk Level	Worker's Compensation Considered?	Mean Income (1990$)	Value of Life - Best Estimate (million 1990$)
Kneisener and Leeth (1991) (US)	Labor Market	4.00E-04	yes	$26,226	0.6
Smith and Gilbert (1984)	Labor Market	NA	no	NA	0.7
Dillingham (1985)	Labor Market	1.40E-04	no	20,848	0.9
Butler (1983)	Labor Market	5.00E-05	yes	NA	1.1
Miller and Guria (1991)	Contingent Value	NA	NA	NA	1.2
Moore and Viscusi (1988a)	Labor Market	5.00E-05	yes	19,444	2.5
Viscusi, Magat, and Huber (1991b)	Contingent Value	NA	NA	NA	2.7
Gegax et al. (1985)*	Contingent Value	7.00E-04	NA	NA	3.3
Marin and Psbcharopoulos (1982)	Labor Market	1.00E-04	no	11,287	2.8
Kneisener and Leeth (1991) (Australia)	Labor Market	1.00E-04	yes	18,177	3.3
Gerking, de Haan, and Schulze (1988)	Contingent Value	NA	NA	NA	3.4
Cousineau, Lacroix, and Girard (1988)	Labor Market	1.00E-05	no	NA	3.6
Jones-Lee (1989)	Contingent Value	NA	NA	NA	3.8
Dilingham (1985)	Labor Market	8.00E-05	no	20,848	3.9
Viscusi (78, 79)	Labor Market	1.00E-04	no	24,834	4.1
R.S. Smith (1976)	Labor Market	1.00E-04	no	NA	4.6
V.K. Smith (1983)*	Labor Market	3.00E-04	unknown	NA	4.7
Olson (1981)	Labor Market	1.00E-04	no	NA	5.2
Viscusi (1981)	Labor Market	1.00E-04	no	17,640	6.5

R.S. Smith (1974)	Labor Market	NA	no	22,640	7.2
Moore and Viscusi (1988a)	Labor Market	8.00E-05	yes	19,444	7.3
Kneisener and Leeth (1991) (Japan)	Labor Market	3.00E-05	no	34,989	7.6
Herzog and Schlottman (1987)	Labor Market	NA	no	NA	9.1
Leigh and Folson (1984)	Labor Market	1.00E-04	no	27,693	9.7
Leigh (1987)	Labor Market	NA	no	NA	10.4
Gaten (1988)	Labor Market	NA	no	NA	13.5

Source: Viscusi (1992)

* - Added after consultation with Viscusi

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10.0 BENEFIT-COST COMPARISON

10.1 Introduction

This Regulatory Impact Analysis provides cost, economic impact, and benefit estimates useful for evaluating PM alternatives. Benefit-cost analysis is one possible framework that can be employed to assess and compare PM alternatives. According to economic theory, the economically efficient alternative maximizes net benefits to society (i.e., social benefits minus social costs). However, both the Agency and the courts have defined the NAAQS standard setting process as a fundamentally health-based decision that specifically is not to be based on cost or other economic considerations. This benefit-cost comparison, therefore, is intended to generally inform the public about the potential costs and benefits that may result when the proposed revisions to the PM NAAQS are implemented by the States.

10.2 Comparison of Benefits to Costs

Table 10-1 presents the estimated benefits (employing short-term and long-term mortality risk measures, and assuming full and partial attainment), costs, net benefits (full and partial attainment benefits minus control costs), and the number of residual nonattainment counties by $PM_{2.5}$ alternative.

10.3 Key Results and Conclusions

- Quantified net benefit estimates are positive and substantial for all three $PM_{2.5}$ alternatives for the partial attainment scenario. For the proposed $PM_{2.5}$ alternative (15 $\mu g/m^3$ annual/50 $\mu g/m^3$ daily) estimated net annual benefits range from \$50 billion to \$110 billion, depending on the mortality risk reduction measure employed.

- Estimated net annual benefits for partial attainment control approaches identified in this analysis are greatest under the $PM_{2.5}$ 12.5 $\mu g/m^3$ annual/50 $\mu g/m^3$ daily alternative. However, this result may be affected by uncertainties in the underlying benefit functions. Therefore, firm conclusions cannot be drawn regarding maximal net benefits.

- Estimating the cost associated with additional air quality improvements needed to eliminate residual nonattainment is a difficult task, given that this analysis is not able to identify specific controls to achieve these reductions by 2007. However, as explained in the cost analysis, the Agency presents an analysis of the national sum of the regional, annual average $PM_{2.5}$ $\mu g/m^3$ reductions necessary to achieve full attainment in residual nonattainment counties. This shortfall per $PM_{2.5}$ alternative is presented in Table 10-1.

Table 10-1. Comparison of Annual Benefits and Costs of $PM_{2.5}$ Alternatives in 2007[a] (1990$)

$PM_{2.5}$ Alternative ($\mu g/m^3$)	Annual Quantified Benefits[b] (billion $)		Annual Costs of Partial Attainment (billion $) (B)	Net Benefits of Partial Attainment (billion $) (A - B)	Residual Nonattainment (RNA)		
	Full Attainment[c]	Partial Attainment[d] (A)			Number of RNA Counties	National Sum of Regional Average Annual $PM_{2.5}$ $\mu g/m^3$ Shortfall Needed for Full Attainment	Population in RNA Counties
20/65*	20 - 42	22 - 44	2	20 - 42	18	6.7	6 million
15/50	69 - 144	58 - 119	6	52 - 113	57	13.4	29 million
12.5/50	125 - 257	94 - 192	14	80 - 178	104	18.0	84 million

*** Does not include the reductions in costs and benefits associated with revised PM_{10} standards as they require less reductions than current PM_{10} standard.**

Caveats:

Significant analytical uncertainties

Cost analysis limited to basically add-on control measures

Many nonquantified costs and benefits

Does not consider PM and ozone integration issues

[a] All estimates are measured incremental to the baseline PM_{10} alternative (PM_{10} $\mu g/m^3$ annual/150 $\mu g/m^3$ daily, 1 expected exceedance per year).

[b] Lower and upper end of benefit range reflects benefits of including the short-term and long-term mortality risk reduction measure, respectively.

[c] Full attainment benefits based upon rollback of residual nonattainment counties to baseline PM_{10} alternative and then to $PM_{2.5}$ alternative.

[d] Partial attainment benefits based upon post-control air quality as defined in the control cost analysis.

10.4 Limitations to the Benefit-Cost Comparison

As discussed throughout this document, there are significant analytical uncertainties associated with this cost-benefit assessment. Limitations specific to the comparison of estimated benefits and costs for $PM_{2.5}$ alternatives include:

- Some identified benefit categories associated with PM reductions could not be monetized. Unquantified, and hence unmonetized, benefit categories include changes in pulmonary function, altered host defense mechanisms, and cancer. Thus, Table 10-1 presents a comparison of estimated *quantified* benefits versus estimated total costs.

- The uncertainty associated with the benefit estimates are substantial. In particular, benefit estimates vary greatly depending on the mortality risk reduction measure employed.

- Comparisons across alternatives examined should be made with caution because of the existence of residual nonattainment. Costs associated with more stringent standards may not increase at a highly increasing rate because low-cost controls may be employed to attain alternatives in the additional violating counties. Residual nonattainment, however, increases with the stringency of the standard.

- The cost and benefit estimates presented in Table 10-1 do not account for market reactions to the PM alternatives. The cost and benefit estimates represent the direct but not the true social benefits and costs (calculated after market adjustments to price and output changes, etc.) associated with alternative standards. Social costs are typically somewhat smaller than direct control costs while social benefits may be greater or less than direct benefits depending on the specific market adjustments and substitutions that occur.