REGULATORY IMPACT ANALYSIS

FOR THE

FINAL REGIONAL HAZE RULE

PREPARED BY THE

INNOVATIVE STRATEGIES & ECONOMICS GROUP
AIR QUALITY STRATEGIES & STANDARDS DIVISION
OFFICE OF AIR QUALITY PLANNING & STANDARDS
OFFICE OF AIR & RADIATION
U.S. ENVIRONMENTAL PROTECTION AGENCY

APRIL 22, 1999

Table of Contents

Chapter 1. INTRODUCTION AND OVERVIEW

Chapter 2. STATEMENT OF NEED FOR PROPOSED REGULATION

Chapter 3. ALTERNATIVE ILLUSTRATIVE PROGRESS GOALS AND CONTROL STRATEGIES

CHAPTER 4. BENCHMARK AND BASELINE EMISSIONS AND AIR QUALITY

Chapter 5. CONTROL MEASURES

Chapter 6. EMISSIONS REDUCTIONS, AIR QUALITY, VISIBILITY, AND COST IMPACTS

Chapter 7. ESTIMATED ADMINISTRATIVE BURDEN AND COSTS ASSOCIATED WITH THE FINAL REGIONAL HAZE RULE

Chapter 8. ECONOMIC IMPACT ANALYSIS

Chapter 9. BENEFITS OF REGIONAL HAZE REDUCTIONS

Chapter 10. BENEFIT-COST COMPARISONS

List of Figures

List of Tables

Select List of Acronyms and Abbreviations

AFS - AIRS Facility System
AIM - Architectural and Industrial Maintenance
AIRS - Aerometric Information Retrieval System
ANPR - Advanced Notice of Proposed Rulemaking
b_{ext} - Total Atmospheric Light Extinction Coefficient
BACT - Best Available Control Technology
BEA - Bureau of Economic Analysis
BEIS - Biogenic Emissions Inventory System
CAA - Clean Air Act
CAAA - Clean Air Act Amendments of 1990
CAPMS - Criteria Air Pollutant Modeling System
CASAC - Clean Air Scientific Advisory Committee
CASTNet - Clean Air Status and Trends Network
CB - Chronic Bronchitis
CEM - Continuous Emissions Monitoring
CME - Control Measure Effectiveness
CO - Carbon Dioxide
COI - Cost of Illness
COPD - Chronic Obstructive Pulmonary Disease
C-R - Concentration-Response
CRDM - Climatalogical Regional Dispersion Model
CV - Contingent Valuation
dv - Deciview
EC - Elemental Carbon
ECOS - Environmental Council of States
EGUs - Electricity Generating Units
EO - Executive Order
EPA - Environmental Protection Agency
ERCAM - Emission Reduction and Cost Analysis Model
FAC - Fractional Aerosol Coefficient
FIP - Federal Implementation Plan
FMVCP - Federal Motor Vehicle Control Program
GCVTC - Grand Canyon Visibility Transport Commision
GSP - Gross State Product
H^+ - Hydrogen Ion
H_2O_2- Hydrogen Peroxide
HNO_3 - Nitric Acid
hr - Hour
IMPROVE - Interagency Monitoring for Protection of Visual Environments
IPM - Integrated Planning Model
ISCST - Industrial Source Complex Short Term

Acronyms and Abbreviations (continued)

Kg/ha - Kilograms Per Hectare
km^2 - Square Kilometer
kWh - Kilowatt Hour
LAER - Lowest Achievable Emissions Rates
lb - Pound
LDs - Loss Days
LEV - Low Emission Vehicle
LRM - Lagrangian Regional Model
LRS - Lower Respiratory Symptoms
MACT - Maximum Achievable Control Technology
MCL - Maximum Contaminant Level
mills/kWh - Mills Per Kilowatt Hour
MM4 - Mesoscale Model, version 4
mmBtu - Millions of British Thermal Units
Mm- Megameter
MOU - Memorandum of Understanding
MRAD - Minor Restricted Activity Days
MRRAD - Minor Respiratory Restricted Activity Days
MW - Megawatts
MWh - Megawatt Hours
MWTP - Marginal Willingness to Pay
NAA - Nonattainment Area
NAAQS - National Ambient Air Quality Standards
NAPAP - National Acid Precipitation Assessment Program
NERC - National Electric Reliability Council
NCLAN - National Crop Loss Assessment Network
NET - National Emission Trends
NH_3 - Ammonia
NLEV - National Low Emission Vehicle
NMSCs - Nonmelanoma Skin Cancers
NOAA - National Oceanic and Atmospheric Administration
NOx - Oxides of Nitrogen
NO_3 - Nitrate
NPI - National Particulate Inventory
NPR - Notice of Proposed Rulemaking
NPS - Non-Point Source
NSA - Nitrate, Sulfate, and Ammonium Components
NSPS - New Source Performance Standards
NSR - New Source Review
O_3 - Ozone
OC - Organic Carbon
OMB - Office of Management and Budget

Acronyms and Abbreviations (continued)

OMS - Office of Mobile Sources
O&M - Operation and Maintenance
OTAG - Ozone Transport Assessment Group
OTC - Ozone Transport Commission
OTR - Ozone Transport Region
PM - Particulate Matter
ppm - Parts Per Million
PRA - Paperwork Reduction Act of 1995
PSD - Prevention of Significant Deterioration
RACT- Reasonably Available Control Technology
RADM - Regional Acid Deposition Model
RFA - Regulatory Flexibility Act
RFP - Reasonable Further Progress
RIA - Regulatory Impact Analysis
RMF - Regional Model Farm
ROP - Rate of Progress
RPM - Regional Particulate Model
SAB - Science Advisory Board
SBA - Small Business Administration
SBREFA - Small Business Regulatory Enforcement Fairness Act of 1996
SCC - Source Classification Code
SIP - State Implementation Plan
SNPR - Supplemental Notice of Proposed Rulemaking
SO_2 - Sulfur Dioxide
SO_4^{2-} - Sulfate Ion
SOA - Secondary Organic Aerosols
S-R - Source-Receptor
TAMM - Timber Assessment Market Model
tpd - Tons Per Day
tpy - Tons Per Year
TSP - Total Suspended Particulates
$\mu g/m^3$ - Micrograms Per Meter Cubed
UAM-V - Urban Airshed Model - Variable Scale
UMRA - Unfunded Mandates Reform Act
URS - Upper Respiratory Symptoms
USDA - United States Department of Agriculture
UV-B - Ultraviolet-B Radiation
VMT - Vehicle Miles Traveled
VOCs - Volatile Organic Compounds
WLDs - Work Loss Days
WTP - Willingness to Pay

EXECUTIVE SUMMARY

Purpose

Section 169A of the Clean Air Act (CAA) calls for the U.S. Environmental Protection Agency (EPA) to establish rules to remedy any existing visibility impairment and prevent any future impairment in mandatory Class I federal areas resulting from manmade air pollution. The mandatory Class I federal areas include 156 national parks and wilderness areas. In the continental United States, there are 147 mandatory Class I federal areas located in 121 counties. The EPA is promulgating the regional haze (RH) rule to address visibility impairment caused by numerous sources located across a broad region. The RH program provides a regulatory framework within which States must establish Class I area visibility improvement goals and emission management strategies needed to achieve these goals. The States have flexibility in developing these goals and associated strategies, taking into account a number of statutory and regulatory factors.

The final regulatory impact analysis (RIA) for the RH rule is prepared in response to Executive Order 12866. To fulfill the requirements of the Order, the analysis includes an assessment of illustrative visibility goals evaluated from a national and a regional perspective. The assessment is based on estimated changes in air quality, monetized benefits, costs, and impacts from two types of emissions control strategies.

Methodology

The final RIA methodology has eight elements: scope, time frame, benchmark emissions and air quality levels, baseline emissions and air quality levels, control strategy Cases A and B, cost and economic impact assessment, benefit analysis, and benefit-cost analysis.

Scope. The analysis examines the Midwest/Northeast, Southeast, South Central, Rocky Mountain, West, and Northwest regions of the continental United States. This encompasses 147 mandatory Class I federal areas in 121 counties in the continental United States.

The scope also includes four illustrative visibility progress goals in addition to the visibility improvement due to baseline conditions (the concept of baseline is explained below). The word "illustrative" is important because the final rule provides for the States to establish reasonable progress goals. The illustrative progress goals use a visibility metric called a "deciview." The deciview is related to changes in visual range and contrast and corresponds to uniform changes in haziness. According to the illustrative progress goals, deciview improvements are to occur on the average of the 20 percent worst visibility days of the year. The illustrative progress goals are as follows:

1. 1.0 deciview improvement in 10 years
2. 1.0 deciview improvement in 15 years, which is equivalent to a 0.67 deciview improvement in 10 years.
3. 5% deciview improvement in 10 years
4. 10% deciview improvement in 10 years

Time frame. According to the final RH rule, visibility progress goals are established and progress measured in achieving those goals over a particular period. The time frame for this analysis is a representative year (i.e. 2015) near the end of what the rule describes as the first long- term strategy period (2018).

Benchmark Emissions and Air Quality Levels. Under the RH rule, visibility progress goals are established relative to a set of emission and air quality conditions. When the rule is actually implemented, monitored air quality values and current emissions inventories will be used to characterize benchmark conditions. To simulate that process, the benchmark for this RIA includes emissions and air quality modeling which reflect increases in economic activity to a future year and emission levels for a future year. Also, reflected in the emission projections are the emission reductions associated with certain federal stationary source emission and mobile emissions control programs.

However, the benchmark emissions and air quality levels do not include emission reductions resulting from implementation plans aimed at the ozone and particulate matter National Ambient Air Quality Standards (NAAQS) which were promulgated in 1997 including associated federal control measures such as the Tier II Mobile Source program.

Baseline Emissions and Air Quality Levels. With the implementation plans for the new ozone and particulate matter NAAQS and the Tier II mobile sources program, many counties with Class I areas will realize improvements in visibility. As noted in the final RH rule, these anticipated deciview improvements are creditable as progress toward achieving established progress goals (visibility improvements due to other CAA programs which are implemented after the States submit their visibility progress improvement plans are also creditable). If a Class I area achieved or surpassed all the illustrative progress goals in going from benchmark to baseline conditions, there would be no incremental air quality, benefit, cost, or impacts associated with the RH rule for that area in the first long- term strategy period.

The RIA attempts to simulate this creditable progress by modeling benchmark and baseline air quality levels and their differences relative to the illustrative progress goals.

Controls Strategy Cases A and B. For Class I areas not achieving an illustrative progress goal under baseline conditions**,** further emission reductions from sources which impair visibility in those Class I areas may be appropriate. The RIA simulates this possibility by the use of a least cost optimization and air quality model to generate control strategies. The model is designed to minimize the cost of achieving an illustrative progress goal.

To reflect the uncertainty inherent in the fugitive dust emissions inventory and the role of fugitive dust in impairing visibility, two control strategy cases are run for each of the four illustrative progress goals. Case A provides for the use of fugitive dust control measures. Case B precludes the use of fugitive dust control measures.

One output of the control strategies simulation is air quality information. In particular, information on where and by how much particulate matter and visibility level change is provided. Another output of the control strategies simulation is cost. Cost estimates are developed at the source, region, and national levels.

Cost and Economic Impact Analysis. The cost of achieving the four illustrative progress goals under Case A or Case B conditions is measured incremental to baseline control levels using the optimization model mentioned above. Costs are produced on a source, region, and national level.

Economic impact is evaluated by assessing control cost relative to sales or revenues for affected sources and economic sectors.

Benefit Analysis. The air quality levels which are an output of the control strategies element is an input to the benefit analysis. That air quality information is combined with air quality effects (e.g. visibility, human health, soiling) models and valuation (e.g. willingness to pay for improved visibility, reduced health risk, etc.) functions to generate estimates of the monetized benefits relative to baseline conditions.

Two sets of assumptions about air quality effects models and valuation functions are used to generate a range of benefit estimates for the four illustrative progress goals under Case A and B.

Benefit-Cost Analysis. The benefit-cost analysis calculates net benefits (i.e. benefits minus costs) for each of the illustrative progress goals relative to baseline conditions. According to economic theory, with positive net benefits and the potential for the gainers to compensate the losers (of a control strategy) society is better-off relative to baseline conditions. With negative, net benefits, society is worse off.

However, incomplete measures of monetized benefits coupled with the flexibility the RH rule provides the States in considering other reasonable progress goals and more cost-effective control strategies, limit the precision of the benefit-cost analysis. Consequently, the analysis is best view as a qualified assessment of the potential costs and benefits of achieving certain illustrative progress goals.

A benefit-cost analysis is conducted under conditions of a uniform national progress goal. There, each region must adopt the same illustrative progress goal. There are sixteen net benefit estimates (benefits minus costs) for the uniform national progress goal assessment. This is due to four illustrative progress goals times two control strategy cases time two estimates of benefits.

A benefit-cost analysis is also conducted for the situation where each region identifies and adopts the optimal goal from an economic perspective. This situation provides for differences in illustrative progress goals across the regions in the first long- term strategy period. This portion of the analysis compares the net benefits from adopting the optimal uniform national goal with the optimal set of regional goals. Two estimates of economic efficiency gains are developed to reflect the range in the benefit estimates. Only control strategy Case A (with fugitive dust controls) costs are used in this portion of the assessment.

Findings of the RIA for the RH Rule

Four major findings emerge from the RIA for the RH Rule

1. Other Environmental Programs Foster Achievement of Illustrative Visibility Progress Goals. The proposed Tier II Mobile Source Rule and Implementation Programs for the Ozone and Particulate Matter NAAQS could lead to significant improvements in visibility in many parts of the country. If States find those improvements are sufficient to achieve visibility progress objectives in the first long- term strategy period, the incremental benefits, costs, and economic impacts of the goal and emission management strategy elements of the Regional Haze rule could be zero. However, under such conditions, there would still be $72 million (1990 dollars) in cost for the administrative (e.g. planning, analysis, etc.) and Best Available Retrofit Technology (BART) requirement (for some establishments in certain source categories) parts of the Regional Haze rule.

2. For 12 of 16 Uniform National Goal Conditions, Net Benefits of the RH Rule Are Positive for the First Long- Term Strategy Period. With four alternative illustrative progress goals, two sets of assumptions about benefits, and two emission control strategies cases, net benefits are calculated for sixteen conditions. Positive net benefits mean that the monetized benefits resulting from strategies aimed at an illustrative goal exceed the costs.

In these calculations, visibility benefits for Class I areas account for between 12 percent and 79 percent of total benefits depending on the set of benefit assumptions applied. Benefits related to reduced particulate matter concentrations in the human health and soiling effects categories account for the remainder of monetized benefits. Some categories of benefits could not be monetized due to the lack of concentration-response and/or valuation functions. Other categories could not be monetized due to the lack of available air quality modeling (e.g., ozone concentration levels and changes).

3. A RH Program Allowing Visibility Progress Goals to Vary Among Regions Is Likely to Yield Higher Net Benefits. The estimated net benefits when all regions adopted the same goal were compared to conditions where each region selected a reasonable progress goal which maximized net benefits associated with air quality improvements and control costs in that region. Estimated net benefits were higher when regions could select the progress goal.

4. The RIA Provides Support for the Flexible Approach Adopted in the RH Rule. The final RH Rule provides for better integration of the Tier II Mobile Source, NAAQS, and RH implementation. The RH Rule provides States with flexibility in the designing RH goals and emission management strategies. And, the final RH Rule facilitates development of better information as inputs to the goal and emission management strategies process.

The RIA demonstrates the importance of addressing the visibility progress gains due to other environmental programs. The RIA illustrates the economic efficiency gains of regional and State flexibility. The RIA reveals the importance of better information in the emission control strategy area. Hence, the RIA provides additional support for the RH Rule.

Refinements to the Previous Economic Analysis

In response to public comment and other factors, the final RIA has an expanded scope, better data, and improved analytical procedures relative to the analysis done for rule proposal.

Expanded Scope. The final RIA expands the number of illustrative reasonable progress goals from two to four. The illustrative goals are expressed in terms of the deciview. This visibility index expresses incremental changes in perception on a common scale over the range of possible conditions. The illustrative goals are directed toward improving visibility on the average of the 20 percent worst visibility days of the year. Two of the goals are expressed in absolute terms. They are a 1.0 deciview improvement in 10 years and a 1.0 deciview improvement in 15 years. These are the same goals assessed in the proposal package economic analysis. Two “relative” progress goals have been added to the analysis. The relative illustrative progress goals are a 5 percent deciview improvement in 10 years and a 10 percent deciview improvement in 10 years (e.g., 5 percent and a 10 of average 20 percent worst day deciview values). The latter goal approximates the rate of progress that, if sustained, would result in attaining natural visibility conditions in 60 years for an area with a 30 deciviews baseline and a natural visibility level of 12 deciviews.

In addition, the final RIA now looks at the economic efficiency consequences of these illustrative progress goals from both a regional and a national perspective. The final RIA also assesses the potential economic impacts from implementing the illustrative visibility progress goals. Finally, this RIA considers two emission control strategies; both of which employ a least-cost optimization methodology for selecting cost-effective controls within the relevant region. Case A considers the use of fugitive dust emissions controls while Case B which precludes the use of fugitive dust emissions control.

Better Data. The final RIA includes refinements to the control cost data file to reflect information gained on N0x controls during the N0x SIP Call rulemaking. In addition, the air quality modeling in the final RIA is enhanced to capture visibility improvements from reductions in volatile organic compounds and directly emitted particulate matter emissions. The RIA also contains additional air quality data which enables expanded geographic coverage of the benefit analysis.

Improved Analytical Procedures. The final RIA estimates and portrays the visibility improvements which result from related environmental objectives such as Tier II Mobile Source and the particulate matter and ozone NAAQS implementation programs. The final RIA also provides for more complete coverage of the visibility benefits. In particular, the final RIA calculates benefits from improved visibility accruing to the 147 Class I areas in 121 Counties in the continental United States. The proposal analysis only accounted for the visibility benefits accruing to a subset of these areas.

Results

The range of estimated incremental benefits is $1 billion to $19 billion (1990 dollars). The corresponding range for costs is $1 billion to $4 billion (1990 dollars). Because the States have the potential flexibility to develop reasonable progress goals that rely exclusively on visibility progress resulting from implementation of the Tier II Mobile Sources rule, NAAQS programs for ozone and particulate matter and other creditable programs, the incremental effects of the Regional Haze rule could be less. Under such circumstances, there would still be administrative activities as well as emissions reduction requirements for some establishments in BART source categories. The corresponding costs are estimated to be $72 million (1990 dollars).

The results summarized in the paragraphs which follow pertain to an assessment of the four illustrative progress goals.

Many of the 121 Counties with Class I Areas Achieve or Surpass Illustrative Progress Goals for the First Long- Term Strategy Period Due to Related Environmental Programs. Even with the most stringent illustrative goal (10 percent deciview improvement in 10 years), 27 counties with Class I areas achieve or surpass the goal without adopting an emission control strategy to address RH. For the least stringent illustrative goal (1.0 deciview improvement in 15 years), 55 counties with Class I areas achieve or surpass the goal. This projected improvement in visibility is due to emission reductions from a modest (relative to what the EPA recently proposed) Tier II Mobile Source Program as well as emission reductions which provide for partial (as opposed to full) attainment of the ozone and particulate matter NAAQS. Hence, the visibility progress attributable to these related programs is probably understated.

Simulated Control Strategies are Effective in Helping More Areas Achieve the Illustrative Goals and Reducing the Deciview Improvement Shortfall. With emission control strategy Case A (with fugitive dust controls), an additional 25 Counties with Class I areas meet the 10 percent deciview improvement in 10 years goal. With Case A, an additional 46 counties with Class I areas meet the 1.0 deciview improvement in 15 years illustrative progress goal. The corresponding totals for emissions control strategy Case B (no fugitive dust controls) are an additional 11 and 39 counties with Class I areas.

Counties with Class I areas which have estimated deciview shortfalls after imposition of Case A or Case B control strategies are often very close to achieving the progress goal. For example, with the 1.0 deciview improvement in 10 years goal, 50 percent to 58 percent of the counties achieve progress of 0.8 deciviews or greater. With the same illustrative goal, over 70 percent of such counties achieve visibility progress of 0.7 deciviews or greater under Case A and B conditions. See Table ES-1.

Table ES-1
The Number of Counties with Class I Areas with Deciview (dv) Shortfalls after Imposition of Simulated Control Strategies
(1.0 dv Improvement in 10 Years Illustrative Goal)

Emission Control Strategy Case	Class I Area Counties with dv Shortfalls	Counties with dv Shortfall Less Than 0.2 dv	Counties with dv Shortfalls Greater than 0.2 dv but less than 0.3dv
Case A	**19**	**11**	**3**
Case B	**32**	**16**	**7**

The Remedy for Highly Uncertain Fugitive Dust Emissions and Control Measure Effectiveness is Improved Emissions Data, Air Quality Monitoring, and Air Quality Modeling. Emission control strategy Case B looked at the consequences of removing fugitive dust controls from the set of possible control measures. If visibility progress was nearly the same under Case B and compliance costs were markedly less, Case B might represent a superior control strategy. However, the analytical simulations did not support that hypothesis. First, relative to Case A, compliance costs went down in some regions and up in others. Second, visibility progress was less under Case B. In particular, there was an increase in the number of Class I area counties with deciview improvement shortfalls.

A comparison of Case A and Case B shows different air quality and cost results. In the face of uncertainty regarding fugitive dust emission and ambient impacts and no close second best control strategy, one recommendation emerges. That is acquisition, development and use of better emissions data, air quality monitoring data, and air quality modeling in the establishment of goals and development of emission management strategies.

The Projected Potential Economic Impact Associated with Achieving the Illustrative Progress Goals is Generally Small, Despite the Fact that Control Strategies Affect Parts of Many Sectors of the Economy. There are nearly 16 million private and non-profit establishments in the United States. The number of establishments is much greater than the number of firms because of the multi-establishment nature of many businesses. About 7 million of these 16 million establishments are in regions which would require further emission reductions to meet the illustrative progress goals. According to emission control strategy Case B estimates, between 0.4 and 1.2 million of the establishments could potentially experience some compliance costs in meeting the illustrative goals. However, the estimated magnitude of such costs for these establishments is relatively small. Specifically, between 0.3 and 1.0 million of these establishments have compliance costs relative to sales ratios of <u>less than</u> 0.01 percent. The number of establishments with compliance cost to sales ratios of 1 percent or greater ranges from 440 to 3360. The results are similar for Case A and the governmental sector.

Where Projected Potential Economic Impact May Be Significant, the Flexible Features of the RH Rule Allow States to Establish Goals and Design Control Strategies Which Avert or Mitigate Such Impacts. As indicated above, there is a relatively small number of estimated establishments with compliance cost as a percent high enough to warrant closer examination. With opportunities for purchasing equivalent visibility improvement emission reductions from other sources, State and local governments and other potentially affected entities may be able to markedly reduce control costs and hence, mitigate adverse impacts. With opportunities for States to establish other progress goals, such impacts may be averted altogether. The flexibility to design and implement improved control strategies and establish other goals is a major feature of the RH rule.

The Estimated Net Benefits of Achieving Nationally Uniform Progress Goals are Often Positive. However, the Results are Sometimes Sensitive to the Stringency of the Goal, the Emission Control Strategy Case, and the Benefits Methodology. With the set of assumptions leading higher benefit estimates, net benefits are substantially positive with benefit to cost ratios ranging from four to eight for all illustrative visibility progress goals.

With the set of assumptions leading to lower benefit estimates, the coverage of potential benefits is less complete and the resulting estimates substantially less. Under such conditions, net benefits are never positive if the illustrative goal of 10 percent deciview improvement over 10 years is imposed throughout the nation. However, that does not mean that goal is not appropriate for some Class I areas. But, despite the more conservative set of benefit estimation assumptions, net benefits remain substantially positive for the 1.0 deciview improvement in 15 years illustrative goal. For the other two illustrative goals, net benefits are slightly positive (benefit to cost ratios of 1.05 to 1.07) under Case A conditions and slightly negative (benefit to cost ratios of 0.82 to 0.92) under Case B conditions. The net benefit estimates for the uniform national goals, control strategy cases and range of benefit assumptions are summarized in Table ES-2.

Table ES-2
Estimated Annual Net Benefits in 2015
for Illustrative Progress Goals

Illustrative National Goal	Annual Quantified Net Benefits (millions of 1990 $) Case A	Annual Quantified Net Benefits (millions of 1990 $) Case B
Baseline Visibility	$0	$0
1.0 dv/15 years	$280 to $4,490	$60 to $3,530
1.0 dv/10 years	$80 to $5,370	($260) to $8,300
5% dv/10 years	$100 to $5,290	($100) to $8,170
10% dv/10 years	($1,820) to $14,360	($1,770) to $15,740

Allowing States to Establish Progress Goals to Address the Unique Characteristics of their Region Can Boost the Net Benefits Relative to a Scenario Which Mandates a Uniform National Visibility Progress Goal. Using the Case A emission reduction strategy as an example, the estimated net benefits from establishing the optimal (net benefit maximizing) uniform national goal were compared to estimated net benefits from adopting the set of goals which maximized net benefits for each region. Economic efficiency gains were realized (net benefits increased) when regions were given the flexibility to establish the optimal goal for air quality improvements accruing to the region. For example, the estimated net benefits for the nation were increased from $15 million to $671 million depending on the set of benefit estimation assumptions used.

Remaining Limitations and Caveats

Although improved from the proposed rule analysis, several limitations remain in the final RIA. As noted by public commenters and others, we do not assess nor do we know the incremental benefits, costs, and impacts in getting to natural visibility conditions. Such an assessment would involve the use of assumptions having a high degree of uncertainty because of having to distant forecasts of emissions, control possibilities, costs, benefits, etc. Without valid forecasts, examination of the 2015 snapshot year understates the visibility progress between baseline and natural visibility conditions. Hence, the RIA approach may understate the associated benefits, costs, and economic impacts in getting to natural visibility conditions.

Within the context of the analytical time frame adopted in this RIA, there are also other limitations. The major remaining limitations are discussed below.

Limitations Due to Abstraction from the Program to Implement the Grand Canyon Visibility Transport Commission Recommendations. The final RIA abstracts from the ongoing successful partnership, goals establishment, and emission management strategies process undertaken by the western States that participated in the Grand Canyon Visibility Transport Commission (GCVTC). The predictions of this RIA regarding the effects of illustrative goals for the Class I areas affected by the GCVTC's emission management strategies are not an attempt to second guess the rigorous analytical process of the GCVTC effort. The RH RIA assessment is merely illustrative.

Limitations Which Result in an Overstatement of the Incremental Effects of the Rule for the First Long- Term Strategy Period. Visibility improvements at Class I areas resulting from the particulate matter and ozone NAAQS and Tier II programs are creditable in achieving visibility progress goals. Visibility progress at Class I areas achieved by those programs reduces the need for further regulations directed at the progress goals during the first (and often subsequent) long- term strategy period(s).

The final RIA for RH does not address the Class I area visibility gains from full attainment of the particulate matter and ozone NAAQS. Furthermore, the Tier II program which was analyzed in the final RIA for RH included less than 10 percent of the emission reduction in the Tier II proposal package. Consequently, the incremental effects of the RH rule are overstated.

If full implementation of these other environmental programs results in achievement of the visibility progress goals or if the States demonstrate the adequacy of goals requiring no additional measures beyond CAA programs, the incremental air quality improvements, benefits, costs, and economic impacts of the RH rule are less for the first long-term strategy period. Under such conditions, the incremental costs of the Regional Haze rule may be associated with administrative activities (e.g. planning, analysis, etc.) and BART controls for some establishments in certain source categories. The corresponding cost is estimated at $72 million (1990 dollars).

Limitations Which Cause the Costs to be Overstated for the First Long- Term Strategy Period. The final RIA uses a least cost/optimal strategy algorithm to simulate achievement of alternative visibility progress goals. The approach has many desirable features. However, the approach does not consider technological progress, Class I area visibility impairment due to emissions from other nations, nor the use of cap and trade systems and other innovative control strategies. Failure to incorporate these factors into the analysis makes the job of achieving visibility progress goals more costly than it needs to be. For example, with a technological progress rate of 2 percent, emission reductions for a given expenditure would be nearly 40 percent greater by 2015 and nearly 50 percent greater by 2018 than they are today.

Limitations Which Cause the Benefits to be Understated for the First Long- Term Strategy Period. The benefits of emission reductions aimed at achieving progress goals in Class I areas often spill over into other geographic areas (e.g. visibility in residential areas) and other categories of effects (e.g. ecological). However, while conceptually appropriate, inclusion of these benefits often requires a foundation of applied research methodologies and results which are not currently available. Incomplete coverage of benefits for other geographic areas, effects categories, and pollutants (e.g. ozone) causes the monetized benefits to be understated. Some of the unquantified benefit categories are summarized in Table ES-3. The table does not include unquantified benefits due to reductions in ambient concentrations of ozone, carbon (a pollutant associated with global climate change), or mercury (a toxic pollutant). Although in some instances, the health endpoints may be similar.

Table ES-3
Unquantified Benefit Categories

Effects Categories	Unquantified Benefits from Reduced Risks Due to Lowered PM Concentrations
Human Health	Changes in Pulmonary Function Morphological Changes Altered Host Defense Mechanisms Cancer Other Chronic Respiratory Disease
Welfare	Materials Damage exclusive of Household Cleaning Damage to Ecosystems (e.g. acidic deposition) Nitrates in Drinking Water Brown Clouds

Limitations Which May Cause the Benefits to be Overstated for the First Long-Term Strategy Period. The benefit methodology used in this analysis is to transfer and extend previous applied research methods and results. Those results are often based on small reductions in environmental risk leading to anticipated improvements in visibility and other benefit categories.

However, the foundation or baseline for the RH RIA is the yet to be realized (or ex ante) benefits from the N0x SIP call, ozone and particulate matter NAAQS, and Tier II programs. Furthermore, the total environmental changes associated with those programs is more than a marginal change for many areas. If there is diminishing marginal utility for environmental improvement, the estimated benefits could be overstated.

In addition, some have argued that emission reductions to meet illustrative progress goals may exacerbate other environmental problems when certain atmospheric and chemical conditions are present. The specific allegations are that attainment of visibility progress goals may also mean intermittent increases in particulate matter, tropospheric ozone levels, UVB radiation and reduced soil quality for some areas.

To the extent these hypotheses are true and not compensated for in the incomplete coverage of benefits limitation mentioned earlier, the estimated benefits of achieving the illustrative progress goals could be overstated.

Limitations With an Unknown Effect on Incremental Benefits, Costs, and Economic Impacts. Uncertainties regarding emission projections, air quality modeling and control strategy design have an indeterminant effect on the incremental effects of the RH rule.

Furthermore, there remain some uncertainties surrounding causal mechanism and other factors for some of the health effects categories. There is some possibility that this could lead to an overestimate of the benefits for these categories.

In addition, the final RIA assumed a 37-State as opposed to a 22-State reduction in nitrogen oxides emissions associated with the final N0x SIP call rule-making of September 1998. The consequences of that differential are a change in the amount of visibility progress associated with illustrative goals and an understatement of partial attainment requirements for the ozone and particulate matter NAAQS. The impact of not accounting for that differential will likely be confined to the Midwest/Northeast and Southeastern Regions. However, whether that impact is positive, negative, or insignificant is indeterminant without further analysis.

Conclusion

The final RIA, although highly caveated and illustrative, represents an improvement over the analysis prepared for the proposed rule due to comments from the public and improvements initiated by the EPA staff.

The RIA demonstrates significant visibility progress in 121 counties with 147 Mandatory Class I federal areas in the continental United States. These improvements result from other CAA programs as well as those targeted directly at illustrative progress goals. Despite incomplete coverage of effects and pollutants, the monetized benefits of strategies aimed at illustrative nationally uniform goals are substantial, outweighing the control strategy costs under

most conditions for the first long- term strategy period. However, higher net benefits may result from a RH program which provides for reasonable progress goals to vary among regions.

These and other aspects of the RIA provide additional support for the RH rule, a rule which recognizes the value of planning, better information, coordination with stakeholders and other environmental programs, and de-centralized, reasoned decision-making.

Chapter 1. INTRODUCTION AND OVERVIEW

1.1 Regional Haze (RH) Rule

As noted in the regulatory impact analysis issued with the final rule, under Section 169A and 169B of the Clean Air Act (CAA), 156 Class I Federal Areas are identified for visibility protection. One hundred and forty-seven of these areas are located in 121 counties in 32 States in the continental United States. The CAA requires that "reasonable progress" be made toward achieving a visibility goals of essentially no manmade visibility impairment in areas of concern. Impairment is often due to transport since there are few emission sources within Class I areas.

The final rule provides a planning and implementation timetable which enables integration of the 03/PM National Ambient Air Quality Standards (NAAQS) and RH Programs. This change was fostered by the Presidential Directive issued upon promulgation of the O3 and PM NAAQS and amendments to the Transportation Efficiency Act-21 (TEA-21). The consequences of integrating those programs are revealed in this final RIA. The final rule also recognizes the importance of regionally customized goals. This featured was fostered by the success of the Grand Canyon Visibility Transport Commission and Wester Governors' Association analytical and planning efforts and further supported by analyses contained in this final RIA.

1.2 Overview of the Final RIA

Chapter 2 of the final RIA addresses the need for the regulation as well as compliance with other statutory authorities and Executive Orders related to this rulemaking. This section is expanded from the previous analysis to address Executive Orders issued and Congressional Mandates enacted since the July 17, 1997 RIA. Chapter 3 describes 4 alternative illustrative visibility improvement goals analyzed in this RIA. Chapter 4 explains the concepts of benchmark visibility conditions and the gains toward achievement of illustrative progress goals as a result of O3/PM NAAQS state implementation plans. Chapter 5 refers to the control measures considered in the previous analysis and notes refinements made since the RIA for the proposal package. Chapter 6 presents the emissions, air quality, visibility and incremental control cost impacts for 4 illustrative visibility progress goals for 2015, a year near the end of the first visibility progress period. Chapter 6 also presents an estimate of costs for the Best Available Control Technology (BART) element of the Regional Haze rule. Chapter 7 assesses the administrative burden hour and dollar cost of the rule for the first planning and implementation cycle. Chapter 8 includes the economic impact, governmental entities, and small entity analyses. Chapter 9 encompasses the incremental benefits of progress toward and/or achievement of illustrative progress goals. Chapter 10 evaluates the net benefits of illustrative goals which are nationally uniform as well as goals which are designed to be optimal from a regional perspective.

1.2.1 Methodological Refinements

The methodology for the RIA which accompanied the proposed rule has been refined in response to public comment and other factors. These refinements are summarized in Table 1-1 and described in the salient chapters.

Table 1-1
Methodological Refinements

ASPECT OF THE ANALYSIS	PROPOSAL ANALYSIS APPROACH	APPROACH USED IN THE FINAL RIA
Number of Illustrative Goals	Two	Four
Visibility Improvement Credits for Partial Attainment of the ozone and particulate matter NAAQS	Limited to improvements from reductions in nitrogen oxides and sulfur dioxide	Also included improvements due to reductions in emissions of particulate matter and volatile organic compounds
Control Measure & Cost Data File	Same as that used in the ozone and particulate matter NAAQS RIA	Modified to reflect improved information on nitrogen oxides emission controls developed during the N0x SIP Call rule-making
Control Strategies	One: all available measures; cost-effectiveness cap	Also included a strategy which precluded the use of fugitive dust controls
Economic Impact Analysis	None	Identify cost relative to revenues for affected entities and economic sectors
Visibility Benefits for Class I Areas	Limited to 3 regions where Class I area visibility benefit studies were conducted	Estimates also generated for Class I areas in other regions using methodology reviewed by economics expert
Application of Illustrative Progress Goals in the benefit-cost analysis	The same goal applied to all regions: national uniform goal	Also considered adoption different goals among regions

1.2.2 Analytical Approach

The analytical approach for the final RIA is similar to that identified in the July 16, 1997 RIA for the proposed RH Rule. Illustrative visibility progress goals are first specified. These visibility progress goals are measured from environmental benchmark conditions. These benchmark conditions are estimated using a 1990 emissions inventory and projecting that inventory to a future year. Some factors such as increases in the level of economic activity may foster increases in emissions; other factors such as ongoing implementation of the CAA requirements to meet acidic deposition precursor emission reductions, Maximum Achievable Control Technology Standards for source categories of air toxics, and the N0x SIP Call objectives result in decreases in emissions over time. The projected emissions inventory is combined with the Source Receptor Matrix air quality model to determine benchmark levels of particulate matter and RH.

Although emissions are only projected to 2010, the future year presumed for the final RIA is 2015. Two thousand fifteen is before the end of the first long term strategy period of 2018. But, the year 2015 does simulate the baseline conditions of partial attainment of the 03/PM NAAQS. Emission reductions and concomitant improvements in visibility as a result of partial attainment of the O3/PM NAAQS serve as mechanisms for creditable progress toward achievement of the illustrative visibility progress objectives. The source receptor matrix model is run using these baseline conditions.

By comparing the bench mark and baseline visibility conditions with the illustrative goals, the amount of progress toward achieving or surpassing the goals is determined. Class I areas predicted to achieve or surpass progress goals are identified and counted. For them, there is no incremental cost, impact, or benefit due to the illustrative progress goals. The complementary nature of the 03/PM NAAQS implementation plan and RH program has resulted in a “windfall” achievement of the illustrative progress goals for those Class I areas.

In many instances, predicted visibility improvement is sufficient to achieve or surpass the illustrative goals. For Class I area/illustrative goal situations where this is not the case, a control strategy model is applied to develop a least cost command and control implementation plan to achieve the illustrative visibility progress goal. For some of these areas, available control measures and cost-effectiveness constraints preclude full achievement of the illustrative target. These areas are noted and counted in the analysis.

To address potential economic impact, the control costs associated with a control strategy aimed at an illustrative goal are compared to sales or revenue on an affected entity and sector basis. These sectors include the profit, not-for-profit, and governmental segments. The higher cost to sales or revenue ratios are used as indicators of where further examination of potential impacts may be warranted. Where the potential impact appears to be relatively large, ways of averting and mitigating these potential impacts are noted.

An upper bound estimate of the administrative costs to governments from implementing the rule in the first long term progress period are estimated independent of the stringency of the illustrative progress goals. These costs are not included in the economic impact or benefit-cost analyses. Because of the small relative size of the upper bound administrative cost estimate, the omission will not affect the results of those analyses.

The beginning and ending particulate matter concentrations as well as visual range improvements are outputs of the baseline and control strategy runs of the source receptor matrix air quality model. The benefit analysis combines that information together with concentration response and valuation functions for various effects categories to generate monetized benefit estimates.

The monetized benefit estimates are compared with the estimated control costs for the illustrative national uniform goals as well as regionally customized goals.

1.3 Remaining Limitations and Caveats

Despite improvements in the final RIA, many limitations remain. Some of these limitations are identified in Table 1-2. These and other limitations are addressed more completely in RIA chapters 3 through 10. Some of the limitations described in Table 1-2 result in an overstatement of costs and economic impact. Other things remaining the same, the net effect of these limitations is to understate the net benefits of achieving the illustrative goals.

The limitations pertaining to estimated benefits have an unknown effect on net benefits. Some limitations result in an overestimate of benefits; other limitations result in an underestimate of benefits.

Table 1-2
Consequences of Key Limitations

ANALYTICAL COMPONENT: LIMITATION	AFFECT ON CONTROL STRATEGY COST ESTIMATES	AFFECT ON ECONOMIC IMPACT ASSESSMENT	AFFECT ON MONETIZED BENEFIT ESTIMATES
Air Quality Modeling: Overstated Impact of Fugitive Dust; Understated Potential Tier II Effect	Estimates are too high	Impacts overstated	Incremental benefits overstated
Control Strategy Design & Costing: Omitted Technological Change; Superior Innovative Strategies	Estimates are too high	Impacts overstated	Effect Uncertain
Did Not Identify Superior Progress Goals-- More Progress for the Same Cost	Estimates may be too high	Impacts may be overstated	Visibility benefits may be understated

ANALYTICAL COMPONENT: LIMITATION	AFFECT ON CONTROL STRATEGY COST ESTIMATES	AFFECT ON ECONOMIC IMPACT ASSESSMENT	AFFECT ON MONETIZED BENEFIT ESTIMATES
Benefit Estimation: Incomplete Coverage of Pollutants & Effects Categories; No Adjustment for Population & Income Increases	No effect	No effect	Benefits Understated
Did not monetize diminishing marginal utility effects or pollutant trade-offs	No effect	No effect	Benefits Overstated

Recognize that states have the flexibility under the final RH Rule to develop better visibility goals from an economic perspective with improved data bases, emission projection algorithms and models. But, perhaps more importantly, recognize that the States have the discretion to select reasonable visibility progress goals which best suit their objectives. The objectives may consider factors in addition to the cost-effectiveness, economic impact, or allocative efficiency aspects of alternative reasonable progress goals.

Chapter 2. STATEMENT OF NEED FOR THE REGULATIONS

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 statutory requirements affecting the development of the RH rule, briefly describes the health and welfare effects associated with controls to reduce RH, and States the need for regulatory action at this time.

2.2 Statutory Authority and Legislative Requirements

The Environmental Protection Agency (EPA) is promulgating the RH rule to achieve reasonable progress towards the national visibility protection goal. In 1977, Congress set forth a national visibility goal in section 169A of the CAA that calls for "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from manmade air pollution." In 1980, EPA adopted rules designed to be the first phase in EPA's overall program to protect visibility. The EPA's 1980 visibility regulations address visibility impairment that is "reasonably attributable" to a single source or small group of sources. The EPA explicitly deferred action addressing RH impairment until some future date "when improvement in monitoring techniques provides more data on source-specific levels of visibility impairment, regional scale models become refined, and our scientific knowledge about the relationships between emitted air pollutants and visibility impairment improves." (U.S. EPA, 1997a).

Congress added section 169B as part of the 1990 CAA Amendments to focus attention on RH issues. Section 169B(f) calls for EPA to establish a visibility transport commission to assess scientific and technical information pertaining to RH in the Grand Canyon National Park. The final report from the Grand Canyon Visibility Transport Commission, "Recommendations for Improving Western Vistas," was completed in June 1996. Section 169B(e) calls for the Administrator, within 18 months of receipt of the Commission's report, to carry out her "regulatory responsibilities under section [169A], including criteria for measuring 'reasonable progress' toward the national goal." (U.S. EPA, 1997a)

2.3 Authority for this RIA

Pursuant to Executive Order (E.O.) 12866, this Regulatory Impact Analysis (RIA) assesses the costs, economic impacts, and benefits associated with the implementation of the final RH rule. E.O. 12866 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."

The Unfunded Mandates Reform Act of 1995 (UMRA) (PL 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. Section 205 requires that the least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule be selected or that the Agency provide an explanation of why such an alternative was not selected. This section applies only when a written statement is required under section 202. Section 204 requires each Agency to develop a process to permit State, local and tribal officials to provide meaningful and timely input in the development of regulatory proposals containing significant Federal intergovernmental mandates.

The RH rule sets forth a program to provide for visibility improvements in mandatory Class I Federal areas, but provides considerable discretion to the States in establishing reasonable progress goals. This RIA fulfills the UMRA section 202 requirement by analyzing the costs and benefits of illustrative progress goals and emission management strategies in 2015, a year near the end of the first long term progress period. In view of the discretion the rule would provide the States in setting reasonable progress goals, the RIA analyzes visibility progress in going from benchmark to baseline conditions, control strategies for four nationally uniform illustrative goals, as well as a control strategy for a set of goals which vary among regions.

The benchmark represents the visibility levels from which progress is measured. Baseline represents the resulting visibility levels from creditable CAA programs such as those to implement the ozone and particulate matter National Ambient Air Quality Standards (which were promulgated in 1997) and the Tier II Mobile Sources Rule. These programs result in substantial emission reductions and air quality improvements, including improved visibility at Mandatory Class I federal areas.

The four illustrative goals are described more fully in Chapter 3. However, they are as follows:

- 1.0 deciview improvement in 15 years (0.67 deciview improvement in 10 years)
- 1.0 deciview improvement in 10 years
- 5% deciview improvement in 10 years
- 10% deciview improvement in 10 years

The RIA considers establishment of these goals at a national level. The RIA also considers establishment of one of those goals or baseline conditions at a regional level (e.g. Midwest/Northeast, Southeast, South Central, Rocky Mountain, West, and Northwest). With the potential flexibility to establish reasonable goals, including progress reflecting baseline conditions, the incremental costs, benefits, and economic impacts of the regional haze (RH) rule could be zero during the first long term strategy period. This may result if there is substantial progress due to implementation of other CAA programs. Hence, a lower bound estimate of the incremental effects of the RH rule is zero. In this situation, all the benefits (including visibility improvements at Mandatory Class I areas), costs, and impacts would be charged to the other CAA programs.

Adoption of the other illustrative goals could mean further emission reductions of RH precursors in some Class I areas. These emission reduction requirements could result in estimated costs and benefits, incremental to baseline conditions, which could exceed $100 million annually in 2015, a year near the end of the first long term progress period. Of course, with potential flexibility to establish other reasonable goals and design more cost-effective emission management strategies, the cost could be less than estimated in the RIA.

The UMRA section 204 consultation requirement was met by providing numerous opportunities for State, local and tribal governments to provide input during development of the RH rule as described in the preamble to the final rule.

The Regulatory Flexibility Act as amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA) provides that, whenever an agency is required to publish a general notice of rulemaking for a rule, the Agency must prepare regulatory flexibility analyses for the proposed and final rules unless the Agency certifies that it will not have a significant economic impact on a substantial number of small entities. The EPA explained in the preamble to the proposed RH rule that the rule would not have a significant adverse economic impact on a substantial number of small entities. In fact, the RH rule applies to the States and does not itself establish any requirements applicable to small entities. **The Agency has thus certified that the RH rule will not have a significant economic impact on a substantial number of small entities.**

To provide additional information to the States and small entities, the Agency has conducted general analyses of the potential cost impacts on small entities of different control measures. These measures may be among those which the States consider in developing an emission management strategy to achieve the reasonable progress goals established by the States. These general analyses also identify ways to mitigate or avert potentially significant impacts and are included in this RIA. It is important to recognize that these general analyses are speculative. Moreover, the EPA expects the States may take steps to minimize significant impacts as part of their goal establishment and emission management strategy development process.

Under Executive Order 12875, Enhancing the Intergovernmental Partnership, EPA may not issue a regulation that is not required by statute and that creates a mandate upon a State, local or tribal government, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by those governments, or EPA consults with those governments. The RH rule does not create a mandate on State, local or tribal governments. The States determine the direct compliance requirements on State, local or tribal governments as the States design and implement emission management strategies to achieve reasonable progress goals.

This final rule is not subject to E.O. 13045, entitled Protection of Children from Environmental Health Risks and Safety Risks, because is does not involve decisions on environmental health risks or safety risks that may disproportionately affect children.

Under E.O. 13084, Consultation and Coordination with Indian Tribal Governments, EPA may not issue a regulation that is not required by statute, that significantly or uniquely affects the communities of Indian tribal governments, and that imposes substantial direct compliance costs on those communities, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by the tribal governments, or EPA consults with those governments. The RH rule does not significantly or uniquely affect the communities of Indian tribal governments. Accordingly, the requirements of section 3(b) of Executive Order 13084 do not apply to this rule.

The Information Collection Request (ICR) for the proposed rule relating to State requirements for the protection of visibility in Mandated Class I national parts and wilderness areas were submitted to the Office of Management and Budget (OMB) for review under the Paperwork Reduction Act, 44 U.S.C. 3501, et seq. This ICR was denied. A new ICR has been prepared by EPA and will be submitted to OMB for approval. [A copy of ICR No. 1813.02 may be obtained from Sandy Farmer, Information Policy Branch; EPA; 401 M St., SW (Mailcode 2137); Washington DC 20460; by calling (202) 260-2740; or from the internet at www.epa.gov/icr. The reporting burden and administrative costs resulting from this action in the first reporting period (1999-2002) are summarized in Chapter 7 of this RIA.

Executive Order 12898 (Environmental Justice) 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. The RH rule does not establish visibility progress goals or emission management strategies. The rule does, however, establishes a framework in which the States accomplish those objectives.

Regardless, in the benefit analysis of the RIA, the available information on visibility, human health, soiling, and other effects categories for all susceptible populations is used to develop monetized estimates. Where monetization is not possible, omitted benefit categories are identified. Furthermore, the scope of the benefit analysis includes air quality improvements within as well as outside the Class I areas.

For air quality improvements at Mandatory Class I national parks and wilderness areas, the benefit analysis includes direct use as well non-use values. Not all Americans have the time and income to visit these national parks and wilderness areas. By taking into account, the preferences of those who visited the parks as well as others, the RIA illustrates the importance of ensuring that the preferences of all stakeholders are reflected in the monetized benefit estimates. The details of the benefit analysis are described in Chapter 9 of this RIA.

Section 12(d) of the National Technology Transfer and Advancement Act of 1995 (NTTAA), Pub L. No. 104-113, 12(d) (15 U.S.C. 272 note) directs EPA to use voluntary consensus standards in its regulatory activities unless to do so would be inconsistent with applicable law or otherwise impracticable. Voluntary consensus standards are technical standards (e.g. materials specifications, test methods, sampling procedures, and business practices) that are developed or adopted by voluntary consensus standards bodies. The NTTAA directs EPA to provide Congress, through OMB, explanations when the Agency decides not to use available and voluntary consensus standards. This rule does not involve technical standards. Therefore, EPA did not consider the use of any voluntary consensus standards.

2.4 **Key Health and Welfare Effects**

The RH is produced from a multitude of sources and can impair visibility in every direction over a large area, possibly over several states. The RH masks objects on the horizon and reduces the contrast of nearby objects. The formation, extent, and intensity of RH is a function of meteorological and chemical processes, which sometimes cause fine particle loadings to remain suspended in the atmosphere for several days and to be transported hundreds of kilometers from their sources. It is this type of visibility degradation that is principally responsible for impairment in national parks and wilderness areas across the country. Visibility in urban areas may be dominated by local sources, but may be significantly affected by long-range transport of haze as well. Fine particles transported from urban areas in turn may be significant contributors to regional-scale visibility impairment.

Visibility has direct significance to people's enjoyment of daily activities in all parts of the country. Individuals value good visibility for the well-being it provides them directly, both in the places where they live and work, and in the places where they enjoy recreational opportunities. Visibility is also highly valued because of the importance people place on protecting nationally-significant natural areas.

Twenty years ago, when initially adopting the visibility protection provisions of the CAA, Congress specifically recognized that the "visibility problem is caused primarily by emission into the atmosphere of sulfur dioxide, oxides of nitrogen and particulate matter, especially fine particulate matter from inadequately controlled sources."[H.R. Rep. No. 95-294 at 204 (1977)] The fine PM (e.g., sulfates, nitrates, organic and elemental carbon, and soil dust) that impair visibility by scattering and absorbing light are among the same particles related to serious health effects and mortality in humans, as well as to environmental effects such as materials damage, soiling, and acid deposition. The health and other welfare effects of fine PM have been extensively discussed in previous EPA RIA's (U.S. EPA 1997d).

2.6 References

U.S. Environmental Protection Agency (1989), Review of the National Ambient Air Quality Standards for Ozone: Assessment of Scientific and Technical Information. Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; EPA report no. EPA-450/2-92/001.

U.S. Environmental Protection Agency (1996a), Air Quality Criteria for Ozone and Related Photochemical Oxidants. Office of Research and Development; Office of Health and Environmental Assessment; Research Triangle Park, N.C.; EPA report nos. EPA/600/P-93/004aF-cF.

U.S. Environmental Protection Agency (1996b), Air Quality Criteria for Particulate Matter. Office of Research and Development, Office of Health and Environmental Assessment; Research Triangle Park, N.C.; EPA report no. EPA/600/P-95/001aF; April.

U.S. Environmental Protection Agency (1996c), Review of the National Ambient Air Quality Standards for Ozone: Assessment of Scientific and Technical Information. Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; EPA report no. EPA/4521R-96-007.

U.S. Environmental Protection Agency (1996d), Review of the National Ambient Air Quality Standards for Particulate Matter: Assessment of Scientific and Technical Information. Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; EPA report no. EPA/4521R-96-013.

U.S. Environmental Protection Agency (1997a), **Draft** Notice of Proposed Rulemaking for Revisions to Existing Visibility Protection Regulations (40 CFR 51.300-307) to Address

RH (RH Preamble). Office of Air Quality Planning and Standards; Research Triangle Park, N.C.**; June**.

U.S. Environmental Protection Agency (1997b), **Draft** National Ambient Air Quality Standards for Ozone--Final Decision (Ozone Preamble). Office of Air Quality Planning and Standards; Research Triangle Park, N.C.**; May.**

U.S. Environmental Protection Agency (1997c). **Draft** National Ambient Air Quality Standards for Particulate Matter--Final Decision (PM Preamble). Office of Air Quality Planning and Standards; Research Triangle Park, N.C.**; May.**

Chapter 3. ALTERNATIVE ILLUSTRATIVE PROGRESS GOALS AND CONTROL STRATEGIES

3.1 Alternative Illustrative Progress Goals

The establishment of alternative illustrative progress goals in an ideal setting is a multi-step process. The first step is the specification and evaluation of alternative visibility progress indexes and progress levels. The next step is an assessment of costs to achieve the various indexes and progress levels. The following step is a “mapping” out of the set of least-cost progress goals. It is from this set of goals that the cost-benefit analysis should be developed.

In the case of the regional haze (RH) rule, one visibility index, the deciview, was selected for analysis. The deciview metric expresses uniform changes in haziness in terms of common increments across a range of visibility conditions. These conditions range from pristine to extremely hazy conditions. Measuring changes for other aesthetic effects use analogous scales. In the case of sound, the decibel scale is used. Like the decibel scale, the deciview provides a useful means of expressing changes in visibility due to changes in air quality while providing a scale that relates the aesthetic effect, visibility, to perception.

There is also an averaging time dimension associated with the deciview index as applied in this analysis. For any Class I area, visibility levels are not constant throughout the year. In fact, there are times when natural background visibility conditions may be observed. And, there are other times when anthropogenic visibility impairment is quite pronounced. The averaging time dimension of the index accounts for this variability in visibility levels.

All of the progress goals analyzed in the Regulatory Impact Analysis (RIA) are expressed in terms of improving long-term visibility on the average of the 20-percent worst visibility days each year. However, the air quality modeling used in this RIA provide estimates of annual deciview changes. But, knowing the distribution of visibility levels over the year, one can predict what an annual average deciview improvement will mean in terms of the average of the 20-percent worst visibility days of the year. Such relationships are considered in designing control strategies to improve visibility on the average of the 20-percent worst visibility days each year.

The deciview index and averaging time are only two of the three factors which make up an alternative illustrative goal for this final RIA. The other factor which is determined by a State is when the goal should be achieved.

The four illustrative goals assessed in this analysis are described in terms of those factors. Two of the illustrative goals specify deciview changes in absolute terms. The other two specify deciview changes in relative terms.

3.1 The Two Absolute Illustrative Goals

3.1.1 Goal 1: 1.0 Deciview Improvement in 15 Years.

This illustrative goal is the least stringent of the four analyzed in the final RIA. The goal calls for a one deciview improvement on the average of the 20-percent worst days of the year. Furthermore, that progress to be achieved in 15 years. However, the end of the first long-term strategy period in the rule is 10 years from the date the EPA expects the visibility progress goals to be established. Furthermore, the RIA uses a year, 2015, which is near the end of that 10-year period, as a basis for comparing all of the illustrative goals. To account for that fact, a deciview improvement of 0.67 (i.e. 10 years/15 years x 1.0 deciviews) is assumed to be an appropriate portrayal of the expected progress from this illustrative goal near the end of the first long-term strategy period.

The shorthand description of this illustrative goal is "**1.0 dv/ 15 years**."

3.1.2 Goal 2: 1.0 Deciview Improvement in 10 Years

For some regions of the country, this is the next to the least stringent illustrative goal. This goal also calls for a 1.0 deciview improvement on the average of the 20-percent worst days of the year. However, the goal is achieved more quickly than the goal 1. Specifically, goal 2 should be achieved by the end of the first long-term strategy period. As noted previously, this is 10 years from establishment of the progress goal and development of implementation plans to meet the goal.

The shorthand description of this illustrative goal is "**1.0 dv/10 years**."

3.2 The Two Relative Illustrative Goals

In response to public comment, the scope of the RIA was expanded to include two relative progress goals.

3.2.1 Goal 3: 5% Deciview Improvement in 10 Years

Goal 3 is also focused on the average of the 20-percent worst days. The goal should be achieved by the end of the first long-term strategy period.

For some regions of the country, the 5% deciview improvement in 10 year goal is the next to the least stringent illustrative goal. For other regions of the country, it is the next to the most stringent. This difference in relative stringency results because of the varying baseline visibility conditions throughout the country. For instance, if the benchmark visibility condition for one region were 18 deciviews, a
5% improvement would be 0.9 deciviews. But, if the benchmark condition for another region were 25 deciviews, a 5% improvement would be 1.25 deciviews. In the first example, the 5% deciview improvement in 10 years is less stringent than goal 2. In the second example, the 5% deciview improvement in 10 years is more stringent than goal 2.

The shorthand description of this goal is "**5% dv/10 years**."

3.2.2 Goal 4: 10% Deciview Improvement in 10 Years

Goal 4 is also focused on the average of the 20-percent worst visibility days. The 10% improvement in benchmark visibility conditions is to be achieved by the end of the first long term strategy period. According to the RH rule, this goal is to be evaluated as part of the goal establishment and emissions management plan development process.

This is the most stringent goal for all regions of the country. In regions with benchmark visibility conditions of 30 deciviews, achieving goal 4 would result in a 3 deciview improvement at the end of the first long-term strategy period. If such regions had natural visibility levels of 12 deciviews, achieving natural visibility conditions would result in 18 deciview improvements. With a 3 deciview improvement for each of 6, 10-year progress periods, such regions would achieve natural visibility conditions in 60 years.

The shorthand description of this goal is "**10% dv/10 years**."

3.3 Emissions Control Strategy Cases

Emissions control strategies are highly dependent on underlying emissions inventories, projection methodologies, air quality monitoring, and air quality modeling. The RIA uses an optimization methodology for selecting cost-effective control measures within a particular geographic region. Despite improvements in the underlying air quality monitoring and modeling information and adjustments for the limited transport of fugitive emissions, the control strategy selected an implausible amount of fugitive dust control. Without the time to further improve the emissions inventory, projections, and air quality modeling, another emissions control strategy case was developed. Hence, there are two emissions control strategies: Case A and Case B. Both use the same optimization methodology.

3.3.1 Emissions Control Strategy Case A.

Emissions control strategy Case A is similar to that used in the economic analysis for the proposed RH rule. There is a cost-effectiveness cap of $1 billion per microgram per cubic meter reduction in fine particulate levels. However, the structure of the optimization model was improved to account for the visibility progress due to reductions in emissions of volatile organic compounds and directly emitted particulate matter. Data inputs to control strategy development were modified to include improved nitrogen oxides (N0x) control cost information acquired during the N0x State implementation plan (SIP) call rulemaking.

Like the analysis for the proposal package, the contribution of fugitive dust emissions to visibility impairment was adjusted to account for limited transport of such emissions.

3.3.2 Emissions Control Strategy Case B.

Emission control strategy Case B was developed to address the uncertainties related to fugitive dust emissions control measures. In emissions control strategy Case B, fugitive dust control measures are not considered in the application of the strategy optimization model.

Chapter 4 BENCHMARK AND BASELINE EMISSIONS, AND AIR QUALITY

4.1 Results in Brief

The foundation for this analysis is a 1990 emissions inventory which is projected to a future year. In actuality, that year is 2010. However, for purposes of this analysis and to comport with legislative changes regarding implementation of the Regional Haze and $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS) rules, the year is 2015. That year, 2015, is near the end of the first long-term strategy, 2018. For that projection, we find that emissions of VOC, NOx, SO_2, and secondary organic aerosols (SOA) are estimated to decrease relative to 1990 levels. This is due in part to other Clean Air Act (CAA) programs such as the Maximum Achievable Control Technology (MACT), Federal Motor Vehicle Control Program (FMVCP), New Source Performance Standards (NSPS), and the final NOx State Implementation Plan (SIP) which are not part of the implementation program for the $PM_{2.5}$ and Ozone NAAQS that were promulgated in 1997. Other emissions are projected to increase over this period due to increases in economic activity despite the emission reduction requirements in the CAA.

The air quality modeling associated with this projected emission inventory leads to air quality projections that are used to determine the amount of air quality improvement to meet the illustrative progress goals explained in Chapter 3. The projected emissions and air quality levels serve as the benchmark for this analysis.

With implementation of the $PM_{2.5}$ and Ozone NAAQS and the Tier II program, there will be emission reductions and improved air quality, including visibility. The particulate matter concentration reductions and visibility improvements associated with partial attainment of the NAAQS and implementation of a Tier II program are estimated using the Phase II Climatological Regional Dispersion Model (CRDM). The resulting air quality improvement will bring several counties with Class I areas into achieving with the illustrative visibility progress goals. In particular, between 27 and 55 counties with Class I areas will achieve the progress goals incidental to partial attainment of the new NAAQS and a Tier II program.

The air quality levels after partial attainment of the new $PM_{2.5}$ and Ozone NAAQS and the Tier II program serve as the baseline for the incremental benefit, cost, and economic impact analyses contained in this regulatory impact analysis (RIA). In particular, any deciview goals not met in the baseline are addressed with additional or incremental control measures and strategies. The control measures applied in this RIA will result in an additional 26 to 60 counties having Class I areas meeting the illustrative progress goals under the emissions control case in which fugitive dust emissions controls are allowed (Case A), and 11 to 53 counties having Class I areas meeting the illustrative progress goals under the emissions control case in which fugitive dust emissions controls are not allowed (Case B). The range is due to differences in illustrative progress goals as well as differences in control strategies.

4.2 Introduction

This chapter describes the methods used to estimate baseline emissions and air quality in 2015 in order to assess the incremental costs, benefits and economic impacts of the illustrative RH progress goals.[1] The assessments are conducted from a consistent analytical baseline that is benchmarked to available 2010 CAA projections for emissions growth, levels of controls, and their contribution towards visibility improvement. A single emissions inventory employing consistent methods is used as the basis for the RH analyses. The year 2015 is selected as the year of analysis to provide an appropriate period in which 1) major programs of the CAA of 1990 should be reaching full implementation, and 2) the Ozone and PM standards promulgated in 1997 are to be achieved. Considerable progress is expected in attaining the new criteria air pollutant standards. The year 2015 is best understood for purposes of this report as a nominal "snapshot" year for presenting estimated visibility, costs, economic impacts and benefits; it should be noted that these impacts are based on 2010 emission projections, projections that serve as a proxy for projections for the year 2015.

The RH analyses have been constructed such that benefits, economic impacts, and costs are estimated incremental to those derived from the combined effects of implementing both the CAA of 1990 and the 8-hour Ozone and $PM_{2.5}$ 15/65 standards as of the year 2015. The effects of implementing the CAA of 1990 are called the benchmark for determining the starting point for analyzing the potential visibility improvements associated with the RH rule. The effects of implementing the 8-hour Ozone and $PM_{2.5}$ 15/65 standards promulgated in 1997 including a modest version of the Tier II program are called the baseline from which the incremental effects of meeting these illustrative RH progress goals under both emission control cases (Cases A and B) are measured. These analyses provide a "snapshot" of air quality impacts, costs, economic impacts, and benefits associated with implementation of these illustrative RH progress goals from a baseline of partial attainment of the Ozone and $PM_{2.5}$ 15/65 standards that is benchmarked to future CAA implementation.

Some Class I area counties are not expected to reach the illustrative progress goals as a result of controls put in place to achieve the Ozone and PM standards. Once these Class I area counties have been identified within the set of PM monitored areas, the analysis assumes additional control strategies on a local, regional, and national basis for the purpose of allowing these Class I area counties to meet the goals. It should be noted that while these areas are identified from within monitored areas only, control requirements, costs, benefits, and other economic impacts are estimated for both PM monitored <u>and</u> unmonitored areas. This results

---

[1] 2018 is the end of the period for the first long-term strategy. The term "long-term strategy" refers to the set of emission reduction measures the State includes in its SIP in order to meet the reasonable progress goal it has set. 2015 is a nominal "snapshot" year that reflects the partial attainment control cases for the Ozone and $PM_{2.5}$ NAAQS included in the baseline, and is near the end of the period for the first long-term strategy.

from the fact that controls are expected to be applied to emission sources outside of Class I area counties so that these counties can meet the illustrative progress goals.

The EPA believes that the monitored counties' analytic approach for identifying Class I area counties that cannot meet the illustrative progress goals is most appropriate because 1) the likelihood of significant inability to comply with visibility progress goals in unmonitored areas after modeled emission controls are assumed is small; 2) serious modeling difficulties exist that prevent reliable prediction of visibility progress in unmonitored areas; and 3) any such inability to meet RH progress goals in unmonitored areas may not be detected (U.S. EPA, 1997c). It is possible, however, that the placement of new PM monitors in the future may affect the estimates of counties' ability to meet these illustrative progress goals.

Figure 4-1 illustrates the analytical approach employed for this assessment. Base year emissions for 1990 are projected to 2010 by applying sector-specific growth factors. The CAA-mandated controls (i.e., control efficiencies or control-specific emission factors) then are applied to these future emissions to capture implementation of the 1990 CAA (our "benchmark"). The 2010 post-CAA control emissions are input to air quality models to predict baseline visibility levels from which Class I areas that cannot meet the progress goals subsequently are identified. Control measures to bring these areas to the point of meeting these progress goals are evaluated and applied in the cost analyses. Emission reductions achieved by these control measures determine the "post-control" visibility in these areas. The methodologies used to estimate visibility for assessing the RH progress goals are discussed in Chapter 6.

4.3 Estimation of 1990 Emissions and 2010 Emissions Projections

The initial step in the assessment of RH illustrative progress goals is the development of the 2010 CAA emission estimates. These emissions and associated air quality modeling serve as the benchmark for determining the starting point for analyzing creditable visibility improvements associated with the new NAAQS. The emissions estimation and projection methodologies build upon work conducted for the July 1997 Ozone, PM, and proposed RH rule Regulatory Impact Analysis (RIA) (U.S. EPA, 1997).

The major data sources and estimates for these RH analyses are as follows:

! Version 3 of the 1990 National Particulates Inventory (NPI v.3)(Pechan, 1996c)

! Bureau of Economic Analysis (BEA) projections of Gross State Product (GSP) (BEA, 1995) are used to estimate 2010 emissions.

! Utility sector CAA-control emission projections incorporate future utility deregulation and a 0.15 lb/MMBtu nitrogen oxides (NOx) cap with trading and banking;

- The following CAA-mandated control assumptions are updated in the 2010 benchmark emissions estimates:
    - OTAG Level 2 NOx controls on industrial point sources in 37 OTAG States are applied (it should be noted that the methodology for this analysis was completed before the final NOx SIP call of September 1998 was completed so the analysis in this RIA assumed the OTAG Level 2 NOx controls across the OTAG States as a surrogate for the NOx controls in the actual NOx SIP call);
    - Estimated emission reductions from 7/10 year Maximum Achievable Control Technology (MACT) standards are included;
    - Proposed control requirements for Architectural and Industrial Maintenance (AIM) coatings and consumer and commercial products rules are incorporated.

Figure 4-1 Overview of Emissions and Air Quality Analytical Approach

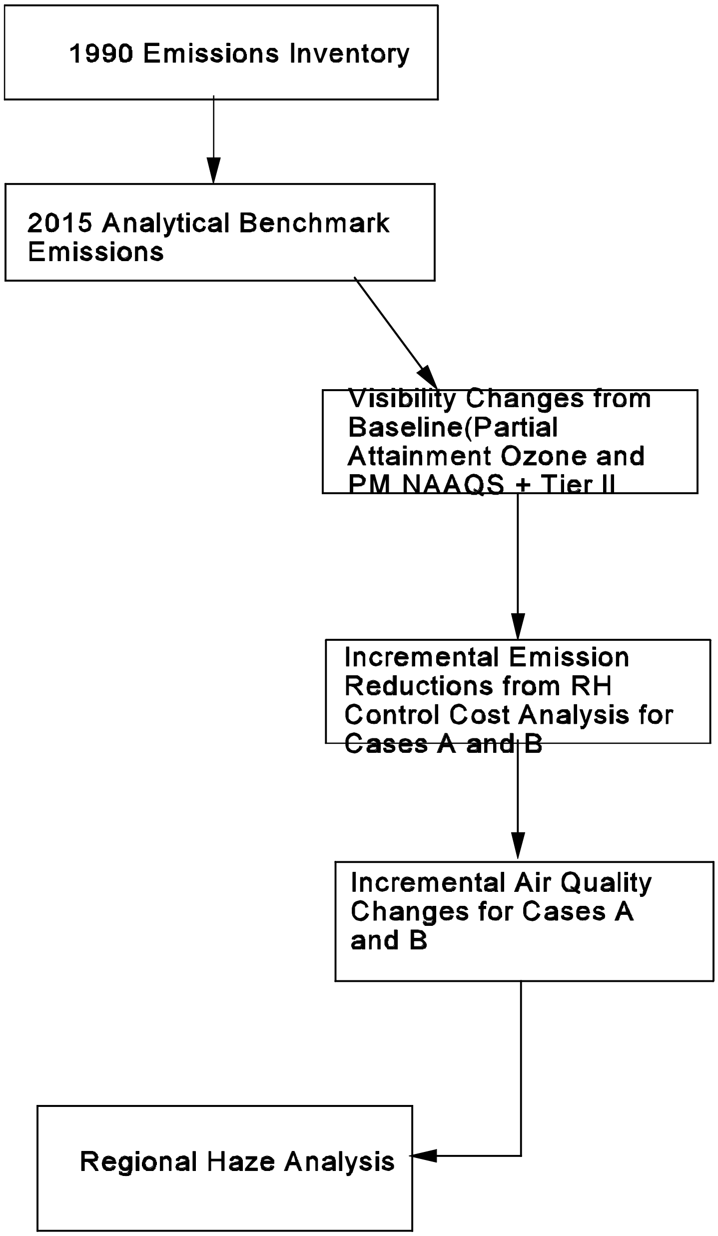
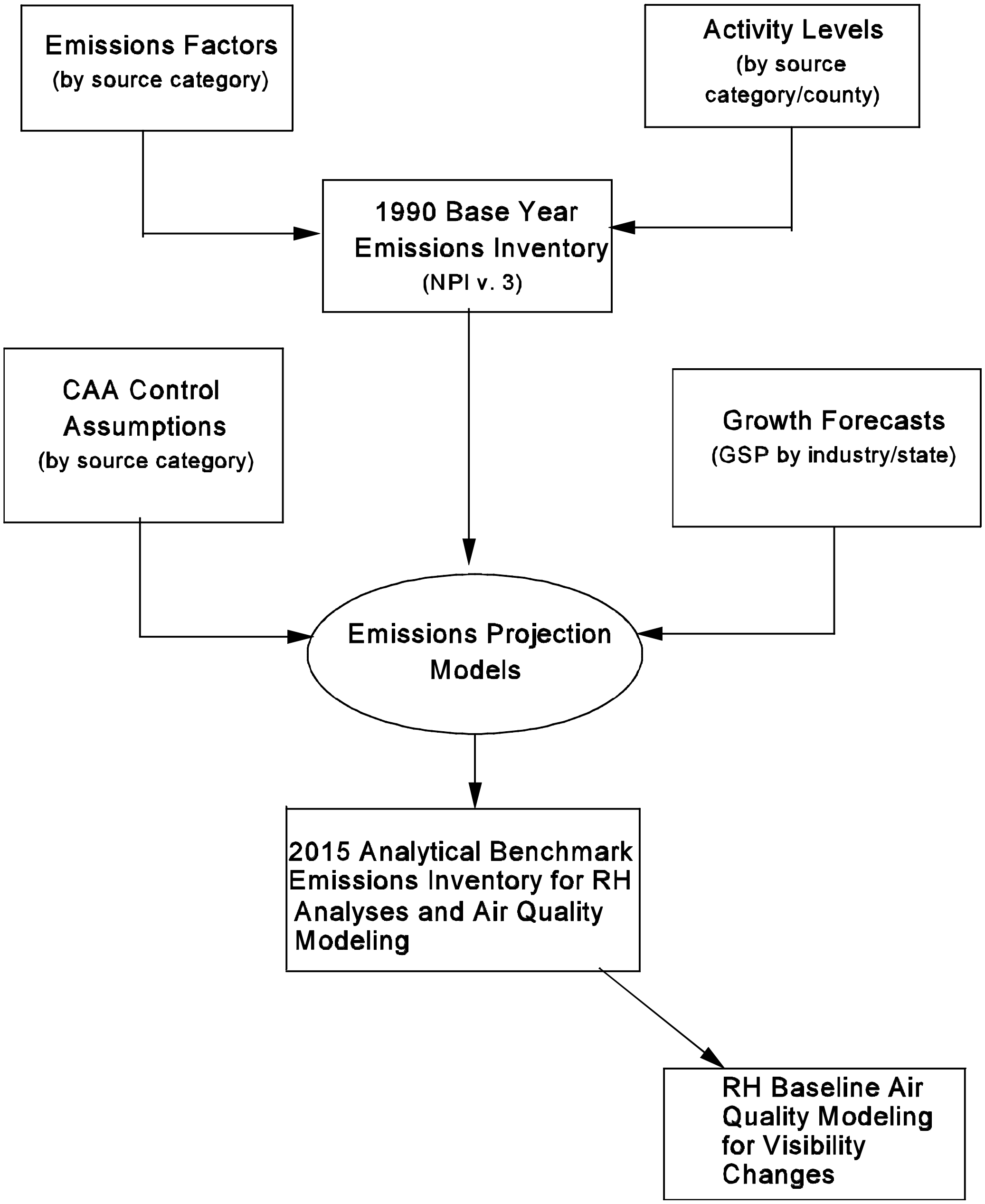


Figure 4-2 illustrates the steps followed in the development of 2010 benchmark emissions. First, source category-specific activity levels and emissions factors are used to estimate emissions for the base year 1990. Any pollution controls in place prior to 1990 are reflected in these base year values. Emissions are estimated for VOC, NOx, sulfur dioxide (SO_2), primary PM_{10} and $PM_{2.5}$, SOA, organic carbon (OC), elemental carbon (EC) and ammonia. As described in the introduction, certain VOC species, based on the reactivity of these organic compounds with atmospheric oxidants, form SOA (Grosjean and Seinfeld, 1989). To estimate SOA emissions, fractional aerosol coefficients (FACs) based on VOC species profiles for each Source Classification Code (SCC) are applied to 1990 VOC emissions (Pechan, 1997a). Biogenic VOC emissions are involved in ozone and SOA formation and are estimated for the base year inventory.

Additionally, ammonia plays a role in the formation of particulate ammonium sulfate and ammonium nitrate. However, anthropogenic emissions of ammonia are a small component of total ammonia emissions. The majority of the ammonia that enters the atmosphere is produced by the biological decomposition of organic material in soils, plant residues, and wastes from animals and humans (NAPAP, 1991). Given that ammonia is not a limiting factor in the formation of secondary particles, ammonia emissions are not considered in the RH control strategy analyses.

Because air quality modeling is conducted on the county level, emissions are estimated for all counties in the contiguous 48 States. The 1990 emissions are then input to an emissions projection model (e.g., Emission Reduction and Cost Analysis Model (ERCAM) for VOC and NOx) that predicts emissions in 2010 based on State-level growth forecasts and control assumptions reflective of implementation of CAA-mandated programs. The resultant 2010 emissions, which serve as a proxy for emissions in 2015, then serve as inputs to the air quality modeling.

Figure 4-2 Development of 2010 Benchmark Emissions



4.3.1 Development of 1990 Benchmark Emissions Inventory

The 1990 emissions inventory that is the benchmark emissions inventory for the analyses of incremental effects contained in this RIA based on Version 3 of the National Particulate Inventory (NPI) (Pechan, 1996c; Pechan, 1997a).

The NPI is developed using a “top-down” approach to estimate national emissions at the county level. Top-down methods rely on existing data sources and use estimation techniques that are comprehensive but with less area-specific detail. In general, emissions factors for individual source types are applied to activity levels for source categories within the major emitting sectors (i.e., utility, industrial point, area, nonroad engines/vehicles, mobile sources and biogenics/natural sources). Emissions factors are expressed in terms of amount of a pollutant emitted for a given activity level (e.g., per ton of fuel consumed, per vehicle mile travelled). Emission factors developed by EPA are available for VOC, NOx, SO_2, and PM_{10}. Because there are no emission factors for $PM_{2.5}$, a PM calculator program containing particle size distribution data for various source categories is used to develop these estimates (Pechan, 1994). The program estimates the fraction of PM emissions from both controlled and uncontrolled sources that are within the fine particle fraction (i.e., < 2.5 microns in diameter) and coarse particle fraction (i.e., between 2.5 and 10 microns in diameter). Finally, anthropogenic ammonia emission factors are a compilation of estimates based primarily on recent European studies (Asman, 1992; Battye et al., 1994).

For the States of California and Oregon and for prescribed burning and wildfire emissions in the 11 western States, emissions estimates based on a bottom-up assessment conducted by the Grand Canyon Visibility Transport Commission (GCVTC) are used (Radian, 1995). These emission estimates are derived from more recent and detailed surveys of emissions from various source categories.

Biogenic VOC emissions are developed based on EPA’s Biogenic Emissions Inventory System (BEIS) (Pierce et al., 1990). Biogenic SOA is estimated from application of VOC species-specific FACs to biogenic VOC emissions (Pechan, 1997a). Natural sources of PM emissions (i.e., wind erosion) are taken from the National Emission Trends Inventory (U.S. EPA, 1996h).

Table 4-1 summarizes the approaches used in development of the benchmark inventory.

4.3.2 1990 Benchmark Emissions Inventory Results and Discussion

Table 4-2 presents a summary of 1990 emissions by pollutant and major sector. Area sources are the largest contributor to anthropogenic VOC emissions in 1990 (45 percent of total national anthropogenic VOC emissions). Biogenic and natural sources of VOC emissions are estimated to be roughly equivalent in magnitude to the anthropogenic total. Motor vehicles account for 33 percent of total national NO_x emissions with 46 percent of the motor vehicle emissions contributed by cars (i.e., light-duty gasoline vehicles). With regard to national SO_2 emissions, the utility sector is the largest emitter (71 percent). Area sources account for the bulk of PM_{10} and $PM_{2.5}$ emissions. Anthropogenic fugitive dust sources contribute the majority of primary PM_{10} and $PM_{2.5}$ emissions. More recent emission inventory efforts indicate that these estimates are overstated. Refer to Section 4.3.3 for a discussion of the potential biases in these estimates.

It should be noted that the ambient air quality impacts of emissions on visibility levels from any individual sector may not be proportional to their contribution to national emissions. The reader is referred to the RH air quality modeling sections (Chapter 4) and the cost chapter (Chapter 6) to understand how emissions from various source categories impact visibility levels.

Table 4-1
Benchmark Emission Inventory - Summary of Approach

Major Source Type	Modeling Approach/Data Sources
Industrial Point Sources	1985 National Acid Precipitation Assessment Program (U.S. EPA, 1989) emissions inventory grown to 1990 based on historical BEA earnings data (BEA, 1990). PM_{10} and $PM_{2.5}$ emissions based on total suspended particulate (TSP) emissions and particle-size multipliers (U.S. EPA, 1994b). California and Oregon State data substituted (Radian, 1995).
Electric Utilities	Based on EIA-767 fuel use for 1990 and unit-specific emission limits (DOE, 1991b) and AP-42 emission rates (U.S. EPA, 1995a)
Nonroad	Internal Combustion Engines/Vehicles (VOC, NO_x, $PM_{2.5}$, PM_{10}): 1991 Office of Mobile Sources (OMS) Nonroad Inventory (U.S. EPA, 1991b) Internal Combustion Engines/Vehicles (SO_2) and Aircraft, Commercial Marine Vessels, Railroads: 1985 NAPAP (U.S. EPA, 1989) grown to 1990 based on historical BEA earnings data (BEA, 1990).
Motor Vehicles	Federal Highway Administration travel data (FHWA, 1992), MOBILE5a/PART5 emission factors (U.S. EPA, 1993a).
Area Sources	1985 NAPAP inventory grown to 1990 based on historical BEA earnings data (BEA, 1990) and State Energy Data System (SEDS) fuel use data (DOE, 1991a); emission factor changes for selected categories (U.S. EPA, 1995a). California and Oregon State data substituted (Radian, 1995).
Solvents	National solvent usage estimates by end-use category from U.S. Paint Industry Data Base and industrial solvent marketing reports (Connolly et al., 1990). Allocated to county level based on industry employment and population (BOC, 1987, 1988a, 1988b).
Fugitive Dust (PM_{10}, $PM_{2.5}$)	
Agricultural Tilling	U.S. Department of Agriculture data (USDA,1991), U.S.EPA PM_{10} emission factors (U.S. EPA ,1995a).
Construction	Census Bureau Construction Expenditures (BOC, 1992), EPA PM_{10} emission factors (U.S. EPA, 1995a).
Unpaved and Paved Roads	EPA PART5 emission factors (U.S. EPA, 1994c), FHWA travel data (FWHA, 1992).
Livestock	USDA farming activity levels (USDA, 1991), EPA PM_{10} emission factors (U.S. EPA, 1995a).
	Particle size multipliers are applied to PM_{10} emissions to estimate $PM_{2.5}$ emissions (U.S. EPA, 1994b).
Biogenic VOC	Emissions for eight landcover types based on a forest canopy model which was used to account for the effects of solar radiation, temperature, humidity, and wind speed on predicted VOC emission rates (Lamb et al., 1993).
Wind Erosion	PM wind erosion emissions from agricultural lands based on acres of spring- or fall-planted crops in each State from the USDA and the expected dust flux (emission rate) based on a simplified version of the NAPAP method (Gillette, 1991). Emissions were distributed to the county level based on rural land area.
Agricultural Ammonia (NH_3)	NH_3 emissions for livestock feedlots and fertilizers based on Census of Agriculture data (BOC, 1992)and EPA-recommended emission factors (Battye et al., 1994).

4.3.3 Key Uncertainties Associated with 1990 Emissions

Given the on-going nature of emissions research, improvements to emissions estimation methodologies will continue to be made. However, there will be uncertainties associated with top-down approaches that rely on existing data sources and less source-specific data.

Because development of 1990 emissions employs emission factors as primary inputs, more uncertain emission estimates result than if source-specific stack tests, load-curve based factors or continuous emissions monitoring (CEM) data are used. The differences in utility SO_2 and NOx emissions between alternative estimation methodologies, however, are not that large. Comparisons of SO_2 CEM data with estimates based on SO_2 emission factors and fuel consumption for a sample of plants showed that the two techniques produced emission estimates within an average of 8 percent at the State level (Schott, 1996). A comparison of NOx emissions based on CEM data and NOx emissions based on EPA emission factors for a sample of utilities in Louisiana resulted in a difference of 22 percent between the two methods (Schott, 1996). However, for area, non-road and motor vehicle sources where source-specific data are mostly unavailable, emission factors are applied to activity levels for each county. Thus, the potential uncertainties are greater for these sources than the better inventoried utility and industrial point sources (Pechan, 1996a). Finally, any possible biases in national emissions estimates from using emissions factors is unclear.

Use of particle size multipliers to estimate PM_{10} and $PM_{2.5}$ emissions from TSP data yields uncertain results relative to application of PM_{10} or $PM_{2.5}$ emission factors. The degree of uncertainty may vary by source category; however, there is no known bias in these factors.

Table 4-2
Summary of 1990 National Emissions Estimates by Major Sector

Major Sector	VOC (1000 tpy)	NOx (1000 tpy)	SO_2 (1000 tpy)	PM_{10} (1000 tpy)	$PM_{2.5}$ (1000 tpy)	SOA (1000 tpy)	OC (1000 tpy)	EC (1000 tpy)
Utility	37	7,426	15,865	283	109	1	10	25
Industrial Point	3,467	2,850	4,644	926	589	35	58	13
Area	10,098	2,100	1042	35,290	7,639	92	1,066	139
Nonroad	2,054	2,836	242	336	293	23	99	160
Motor Vehicle	6,811	7,446	568	355	291	48	57	59
Anthropogenic Subtotal	**22,466**	**22,656**	**22,359**	**37,190**	**8,921**	**198**	**1,290**	**396**
Biogenics	25,988					3,325		
Natural Sources	248	89	1	5,429	995			
TOTAL	**48,702**	**22,745**	**22,360**	**42,619**	**9,916**	**3,523**	**1,290**	**396**

Note: Emissions estimates may not sum due to rounding.
1990 fugitive dust emissions have not been adjusted here as described in Section 4.4.
Air quality impacts from major emitting sectors are not necessarily proportional to their contribution to national emissions estimates. See Sections 4.4 and 4.5 and Chapter 6 of this RIA.

The more recent biogenic emissions estimates from BEIS2 (Geron et al., 1994) are not incorporated in version 3 of the NPI. VOC emissions estimated using BEIS2 are 28 percent higher nationally than biogenics included in the base year emissions. These higher VOC estimates also lead to higher biogenic SOA nationally. However, given that BEIS2 emission estimates have better spatial resolution, higher or lower biogenic VOC emissions for specific counties may result relative to the NPI estimates. Thus at the national level, the estimates of biogenic VOC and SOA may be understated. However, due to the better spatial resolution in the BEIS2 compared to the resolution of the VOC and SOA emissions in the NPI version 3, the bias is less clear in any particular county (Pechan, 1997a).

The most recent fugitive dust emissions estimates developed for the National Emissions Trends Inventory (U.S. EPA, 1997h) indicate that NPI version 3 PM_{10} fugitive dust emissions may be overestimated by 40 percent and $PM_{2.5}$ fugitive dust emissions may be overestimated by 72 percent relative to the Trends estimates. The Trends fugitive dust information was available after PM air quality modeling had been completed and therefore could not be incorporated into this analysis. See Section 4.4 for a discussion of the implications of this overestimate of fugitive dust emissions on modeled visibility levels. Of particular interest is that the $PM_{2.5}$ emission estimate for agricultural operations (tilling and windblown dust) was decreased by about 50 percent, or 1 million tons per year. The emissions decrease from farming operations is clearly concentrated in the farm belt of the central US. Thus, the RH air quality analysis is likely biased toward overestimating fugitive dust impacts on visibility impairment in farming areas, relative to other areas. While some other categories of fugitive dust emissions were also decreased, the net effect of those changes on the RH air quality analysis is unclear.

Fractional aerosol coefficients are used to estimate the percentage of VOCs that may react in the atmosphere and form secondary organic aerosols. There is considerable uncertainty associated with this estimation approach. This assessment assumes that 100 percent of all photochemically-reactive VOC species released eventually react to form SOA. This assumption may lead to overstated modeled SOA concentrations in areas close to the emission sources of organic species having long reaction times (Pechan, 1997a).

For the nonroad emissions category, the extrapolation of the nonroad inventory for 27 $PM_{2.5}$ nonattainment areas to the rest of the country introduces uncertainty to the nonroad emissions estimates, however, with no known bias.

Because the 1985 National Acid Precipitation Activity Project (NAPAP) inventory serves as the basis for the 1990 base year inventory for some source categories, a number of factors are not accounted for. New plant construction, control equipment installation and retirement of emissions sources between 1985 and 1990 are not incorporated in the 1990 inventory. The magnitude of the uncertainty and direction of potential bias in national 1990 emission estimates as a result of these factors is unclear. Additionally, State-level industry earnings data are used to grow emissions from 1985 to 1990 rather than applying the more recent Bureau of Economic Analysis (BEA) Gross State Product (GSP) estimates. This may result in a small underestimate of 1990 emissions (Pechan, 1997a).[2]

Considering relative uncertainty across emissions of individual pollutants, SO_2 emission estimates are the most certain. The SO_2 is generated during combustion of any sulfur-containing fuel and is emitted by industrial processes that consume sulfur-containing raw materials. Apart from control efforts, sulfur emissions are directly related to the fuel sulfur content. As long as fuel usage and fuel sulfur content are measured, SO_2 emissions can be estimated within a relatively narrow range. For example, as part of the Grand Canyon Visibility Transport Commission (GCVTC) emission inventory, uncertainty estimates were developed for various major SO_2 sources (Balentine and Dickson, 1995). The uncertainty estimate calculated for SO_2 emissions from copper smelting is ± 50 percent. However, associated uncertainty for emissions estimates from diesel and gasoline vehicles are assessed at ± 150 percent. Most of this uncertainty is due to the variability in the sulfur content of the fuels.

The NOx estimates are the next most certain category of emissions. Like SO_2, NOx is a product of fuel combustion. Since NOx formation is somewhat more complicated than SO_2, emission estimates are more variable, and uncertain, as well.

The level of uncertainty in PM_{10} emission estimates varies widely by source category. The largest component of the 1990 PM_{10} emission estimates is fugitive dust including fugitive emissions from paved and unpaved roads, construction activities, agricultural tilling, and windblown dust. The GCVTC study estimated the uncertainty for unpaved road emissions to be ± 400 percent. The estimated uncertainty for $PM_{2.5}$ emissions from paved road dust is ± 180 percent (Ballentine and Dickson, 1995). The PM_{10} emission estimates for large point sources, such as utility boilers, are more certain than the fugitive dust source estimates, because these stacks are typically controlled using baghouses or electrostatic precipitators, the outlets of which are frequently tested to ensure compliance with regulations.

The VOC emissions are uncertain because organics are emitted both as a product of fuel combustion and through evaporation. Evaporative emissions are difficult to quantify due to measurement problems. The GCVTC study estimated VOC emissions uncertainty for motor vehicles to be ± 150 percent (Ballentine and Dickson, 1995).

Table 4-3 summarizes the key uncertainties associated with estimation of 1990 emissions (Pechan, 1997a). For each potential source of uncertainty in the base year emissions, the direction of bias is provided. "Positive bias" indicates that 1990 emissions may be overestimated; "negative bias" indicates that they may be underestimated; and "bias unclear" indicates that the direction of potential bias in the emission estimates is unknown.

---

[2] The State-level industry earnings data provided a slight underestimate of production activity for 1990 compared to the 1990 BEA GSP estimates due to a more precise methodology for estimating production activity.

Table 4-3
Uncertainties and Possible Biases in Estimating 1990 Emissions

Potential Source of Uncertainty	Positive Bias? (Overestimate)	Negative Bias? (Underestimate)	Bias Unclear
Use of emission factors rather than stack test, load-curve, or CEM data			✓
Use of particle-size multipliers to estimate PM_{10} and $PM_{2.5}$ emissions from TSP emissions			✓
Extrapolation of nonroad inventory from 27 $PM_{2.5}$ nonattainment areas to nation			✓
Use BEIS rather than more recent BEIS2 for biogenic VOC		✓ (total biogenic VOC and SOA)	✓ (county-level biogenic VOC and SOA)
Use NPI version 3 for fugitive dust emissions rather than more recent data from National Emissions Trends	✓		
Use FACs to estimate SOA from VOC emissions	✓		
Use of 1985 NAPAP inventory for some source categories: - lack data to incorporate for 1985-1990 new plant construction, control equipment installation, retirement of sources. - used state-level earnings data rather than recent BEA GSP to grow emissions from 1985 to 1990.		✓ (small)	✓

4.3.4 1990 Emissions Inventory Results and Discussion

Table 4-4 presents a summary of 1990 baseline emissions by pollutant and major sector. These emissions estimates reflect the partial attainment of the 8-hour Ozone and $PM_{2.5}$ standards modeled in the 1997 RIA. Area sources are the largest contributor to anthropogenic VOC emissions in 1990 (45 percent of total national anthropogenic VOC emissions). Biogenic and natural sources of VOC emissions are estimated to be roughly equivalent in magnitude to the anthropogenic total. Motor vehicles account for 33 percent of total national NO_x emissions with

46 percent of the motor vehicle emissions contributed by cars (i.e., light-duty gasoline vehicles). With regard to national SO_2 emissions, the utility sector is the largest emitter (71 percent). Area sources account for the bulk of PM_{10} and $PM_{2.5}$ emissions. Anthropogenic fugitive dust sources contribute the majority of primary PM_{10} and $PM_{2.5}$ emissions. More recent emission inventory efforts indicate that these estimates are overestimated. Refer to Section 4.3.3 for a discussion of the potential biases in these estimates.

Although biogenic and anthropogenic VOC are approximately equivalent, biogenic SOA is almost 17 times greater than anthropogenic SOA. This difference is due to the FACs used to estimate SOA. The FAC for terpenes, which account for 15 - 60 percent of biogenic VOCs, is 30 percent, while the average FAC for anthropogenic VOC sources is less than 1 percent.

Anthropogenic ammonia emissions are estimated to be approximately 4 million tons per year in 1990, but are believed to be a small component relative to natural sources of ammonia. Given that ammonia is not a limiting factor in the formation of secondary particles, ammonia emissions are not considered for control in these RH analyses.

It should be noted, as is noted earlier in Section 4.3, that the ambient air quality impacts of emissions from any individual sector may not be proportional to their contribution to national emissions. The reader is referred to the air quality modeling sections later in this chapter and the cost chapter (Chapter 6) to understand how emissions from various source categories impact air quality modeling and estimated visibility levels.

Table 4-4
Summary of National 1990 Baseline Emissions Estimates by Major Sector

Major Sector	**VOC** (1000 tpy)	**NOx** (1000 tpy)	**SO_2** (1000 tpy)	**PM_{10}** (1000 tpy)	**$PM_{2.5}$** (1000 tpy)	**SOA** (1000 tpy)	**OC** (1000 tpy)	**EC** (1000 tpy)
Utility	53	3,548	5,235	246	108	1	2	5
Industrial Point	2,158	1,735	4,668	1,004	651	26	18	4
Area	7,046	2,872	1,518	42,601	9,061	57	374	58
Nonroad	1,888	2,061	237	351	373	24	37	58
Motor Vehicle	3,688	5,331	408	204	142	26	26	27
Anthropogenic Subtotal	**14,833**	**15,547**	**12,066**	**44,406**	**10,335**	**134**	**457**	**152**
Biogenics	25,988					3,325		
Natural Sources	248	89	1	5,429	995			
TOTAL	**41,609**	**15,636**	**12,061**	**49,835**	**11,330**	**3,459**	**457**	**152**

Note: Emissions estimates may not sum due to rounding.
Fugitive dust emissions have been adjusted here as described in Section 4.4.
Air quality impacts from major emitting sectors are not necessarily proportional to their contribution to national emissions estimates. See Sections 4.4 and 4.5 and Chapter 6 of this RIA.

4.3.5 Development of 2015 Analytical Emission Projections

The 1990 emissions are projected to 2010 (as a proxy for emissions in 2015) to develop the emissions baseline from which to evaluate additional control measures needed to meet the illustrative RH progress goals. In general, emissions are projected by applying expected increases in 1990 emissions or activity levels and incorporating the effects of 2010 CAA-mandated controls through application of control efficiencies or emission factors, respectively.

4.3.6 Growth Assumptions by Major Sector

This section describes the sector-specific growth assumptions used to project emissions to 2010, which serves as a proxy for emissions in 2015. Table 4-5 summarizes the emissions projection modeling approach by major sector. Version 3 of the NPI employs 1995 BEA GSP 2010 projections by State/Industry for industrial point sources and, in combination with BEA population projections, for nonroad and area source categories. In the absence of product output projections, value added projections such as GSP are superior than earnings or employment projections for estimating future emissions (U.S. EPA, 1991a). Value added is the difference between the value of industry outputs and inputs. The BEA GSP projections are a fuller measure of growth given that future changes in production processes, efficiency, and technological changes are captured.

For the utility sector, outputs from the Integrated Planning Model (IPM) are used to predict how the electric power industry will operate in the future given deregulation (i.e., movement from cost-of-service pricing to competitive pricing) and consequent industry restructuring (U.S. EPA, 1996j). National Electric Reliability Council (NERC) forecasts of regional electricity demand are used to reflect the assumption that utility deregulation will likely lead to lower electricity prices for many users and therefore increased electricity demand. Additional major assumptions included in the utility modeling are the following: 1) technology will continue to improve for coal and natural gas production so that energy prices for these fuels will not substantially increase between 1990 and 2010; 2) the large steam electric generation stock fueled by coal, oil, and gas will be the source of a large amount of power in the future; 3) improvement of the performance and reduction of the costs of electric generation technologies will continue; and 4) movement of power will be primarily constrained at the 16 NERC regions modeled in the analysis (U.S. EPA, 1997a).

Table 4-5
2015 Analytical Growth Assumptions by Major Sector[a]

Sector	Growth Forecast	Modeling Approach
Industrial Point	BEA Gross State Product (GSP) Projections by State/Industry (BEA, 1995)	VOC, NO_x – Emission Reduction and Cost Analysis Model (ERCAM): applies BEA growth projections to base year emissions and applies future year controls as selected by the user (Pechan, 1994, 1996b). PM_{10}, $PM_{2.5}$, SO_2, NH_3 – While no formal model exists, the same basic approach applied in ERCAM was used for these pollutants (Pechan, 1997a).
Utility	Projections of heat input by unit based on National Electric Reliability Council (NERC) data, price and demand forecasts, and technology assumptions.	SO_2, NO_x - Integrated Planning Model (IPM) (U.S. EPA, 1996i). VOC, PM_{10}, $PM_{2.5}$ – base year emission rates or AP-42 emission factors applied to IPM projected heat input by unit (Pechan, 1997a). NH_3 – NH_3 slippage for units controlling with selective catalytic reduction (SCR) (Pechan, 1997a).
Nonroad	BEA GSP and Population Projections by State/Industry (BEA, 1995)	VOC, NO_x – ERCAM (Pechan, 1994, 1996b). PM_{10}, $PM_{2.5}$, SO_2, NH_3 – ERCAM approach (no formal model)(Pechan, 1997a).
Motor Vehicle	National Vehicle Miles Traveled (VMT) Projections from the EPA OMS MOBILE Fuel Consumption Model (FCM) Scaled to Metropolitan/Rest-of-State Areas by Population (U.S. EPA, 1993)	NO_x, VOC – ERCAM: applies MOBILE5a emission factors to projected VMT by month and county/vehicle type/roadway classification (U.S. EPA, 1991c, 1993a). PM_{10}, $PM_{2.5}$, SO_2 – PART5 emission factors(U.S. EPA, 1994c) applied to projected VMT (U.S. EPA, 1991c). NH_3 – special study emission factors applied to projected VMT (Pechan, 1997a).
Area	BEA GSP and Population Projections by State/Industry (BEA, 1995)	VOC, NO_x – ERCAM (Pechan, 1994, 1996b). PM_{10}, $PM_{2.5}$, SO_2, NH_3 – ERCAM approach (no formal model)(Pechan, 1997a).
Biogenic VOC and PM Wind Erosion	Emissions held at 1990 levels	--

[a] Actual growth in emissions is to 2010. 2015 is the nominal "snapshot" year that reflects the partial attainment costs for the Ozone and $PM_{2.5}$ NAAQS included in the baseline, and is near the end of the period for the first long-term strategy.

Mobile source 1990 emissions are projected to 2010 based on growth in VMT. The EPA's MOBILE4.1 Fuel Consumption Model (FCM) is used as the basis for the VMT projections (U.S. EPA, 1991c).

There is no growth assumed in nationwide biogenic emissions of VOC or SOA. Similarly, 2010 PM emissions from natural sources are assumed equal to 1990 levels.

4.3.7 2010 CAA Control Emissions by Major Sector

In order to capture the effects in 2015 (using 2010 emissions projections) of implementation of the CAA as a benchmark for these analyses, future year control efficiencies or emission factors are applied to projected 2010 emissions or activity levels respectively. Table 4-6 summarizes the major CAA requirements that are modeled for the benchmark case. These control requirements are discussed in Appendix A for each major sector.

For the 2010 CAA-control emissions, refined control measure effectiveness (CME) estimates are employed in combination with control efficiencies. The CME reflects the degree to which individual control measures achieve their intended effect. For this assessment, CME is assumed to be 95 percent for this subset. The refined CME estimate is based upon a recent study of historical EPA monitoring and enforcement data that indicate that, on average, control measures achieve 95 - 100 percent of the intended impact (PQA, 1997). The new CME is applied to the appropriate CMEs in place prior to 1990 and those controls assumed in the 2010 CAA-control emissions projections.

Rate of Progress (ROP) and Reasonable Further Progress (RFP) requirements are not modeled for the emissions benchmark; instead, the emission reductions and costs are assessed for future attainment of the 8-hour ozone standard and are therefore in the baseline. Appendix A discusses the methodology and results of this analysis.

Additionally, updated information regarding proposed Title I Architectural Coatings and Consumer and Commercial Products rules and Title III 7 and 10-year Maximum Achievable Control Technology (MACT) rules are incorporated in the 2010 CAA-control emissions.

Ozone air quality modeling analyses show that NOx emissions must be substantially reduced in broad areas of the country in order for areas that are not meeting the current ozone standard to meet that standard (U.S. EPA, 1996b). Efforts to address long-range ozone transport issues have been undertaken by the Northeast Ozone Transport Commission (OTC, 1994) and the Ozone Transport Assessment Group (OTAG). These efforts will likely result in implementation of regional NOx control measures far in advance of the 2015 air quality assessment undertaken for this RIA. These control measures are included in the benchmark case for this RIA.

Table 4-6
CAA 2015 Projection Scenario Summary by Major Sector

Major Sector	Major CAA Scenario Requirements
Industrial Point	VOC and NO_x RACT for all NAAs (except NO_x waivers). New control technique guidelines (CTGs). 0.15 pounds per million British thermal unit (lb/MMBtu) Ozone Transport Assessment Group (OTAG)-wide NO_x cap on fuel combustors $\geq$ 250 MW. OTAG Level 2 NO_x controls across OTAG States. MACT standards (primarily VOC).
Utility	Title IV Phase I and Phase II limits for all boiler types. 250 ton Prevention of Significant Deterioration (PSD) and New Source Performance Standards (NSPS). RACT and New Source Review (NSR) for all non-waived (NO_x waiver) NAAs. Phase II of the Ozone Transport Commission (OTC) NO_x memorandum of understanding (MOU). 0.15 lb/MMBtu OTAG-wide seasonal NO_x cap utility boilers with banking/trading.
Nonroad	Federal Phase I and II compression ignition (CI) engine standards. Federal Phase I and II spark ignition (SI) engine standards. Federal locomotive standards. Federal commercial marine vessel standards. Federal recreational marine vessel standards.
Motor Vehicles	Tier 1 tailpipe standards. 49-State LEV program. Phase 2 Reid vapor pressure (RVP) limits. I/M programs for O_3 and carbon monoxide (CO) NAAs. Federal reformulated gasoline for O_3 NAAs. California LEV (California only). California reformulated gasoline (California only). Diesel fuel sulfur content limits. Oxygenated fuel in CO NAAs.
Area	VOC and NO_x RACT requirements. New CTGs (VOC). MACT Standards (VOC). PM NAA controls. Onboard vapor recovery (vehicle refueling). Stage II vapor recovery systems. Federal rules (consumer/commercial product limits, architectural and industrial maintenance (AIM) coating limits).

The 2010 benchmark reflects the application of regional NOx reductions that are intended to approximate the reductions EPA would propose based upon OTAG recommendations. The regional NOx controls applied for this analysis include: 1) OTAG-wide 0.15 lb/MMBtu NOx emission limit on utilities and on non-utility boilers ≥ 250 MW; 2) OTAG Level 2 NOx controls on non-utility point sources across OTAG States; National Low Emission Vehicle (LEV) emissions standards on light duty vehicles in 49 States, beginning with the 1999 model year. The OTAG recommendation covers a broader universe of sources and provides for an emissions trading program. In addition, OTAG's recommendation does not include uniform control measures across the entire 37-State region. For purposes of comparison, the final NOx SIP call rulemaking promulgated in September 1998 requires States to implement sufficient levels of control to achieve a 0.15 lb/MMBtu NOx emission limit applied to utility boilers; 60 percent control applied to non-utility boilers and combustion turbines; and additional controls applied to cement kilns and stationary internal combustion engines.[3]

The LEV program is included in the baseline based on negotiations with the automobile industry that were initiated several years ago in order to help meet the current standard. Although no agreement has yet been reached, additional reductions from mobile sources likely will be required, either nationally or on a State-by-State basis, in order to meet the current standard. Therefore, inclusion of reductions from this program in the baseline is appropriate. This analysis, however, does not prejudge the outcome of negotiations with the automobile industry.

A version of the Tier II rule scheduled to be proposed this year is included in the baseline. This version reflects prior expectations as to type of standards that would be included in the proposal. The version in the baseline includes standards applicable to light-duty trucks and other light-duty vehicles, but does not include a sulfur standard applicable to refiners nor additional control of hydrocarbon exhaust and evaporative emissions. Since this rule is currently close to proposal, inclusion of reductions from a Tier II program in the baseline where analytically possible is appropriate. This analysis, however, does not prejudge the eventual form of the Tier II rule.

4.3.8 Benchmark Emissions Results and Discussion

Table 4-7 summarizes national 2010 CAA emissions by major sector. Total emissions of VOC, NOx, SO$_2$, and SOA are estimated to decrease from 1990 levels; however, emissions of PM$_{10}$ and PM$_{2.5}$ are estimated to increase between 1990 and 2010. The increases in PM emissions are due primarily to growth in anthropogenic sources of fugitive dust (i.e., paved roads and construction activity).

Emission reductions in 2010 attributable to individual CAA programs are also estimated

---

[2] The estimated level of emissions reductions from implementation of the final NOx SIP call is 1.16 million tons in 2007. This is roughly two-thirds of the reductions estimated under the NOx control programs presently in the benchmark case.

(U.S. EPA. 1997j). These emission reductions reflect the change in emissions between projected 2010 emissions (i.e., incorporating growth between 1990 and 2010) with and without the application of CAA-mandated controls. National VOC emission reductions estimated to be achieved in 2010 due to Titles I and III point source controls are 1.0 million tons of VOC per year. The 2010 Title I and III area source controls are projected to achieve 5.7 million tons of VOC emission reductions per year.

National NOx emission reductions for Title I industrial point source controls are estimated to total 1.6 million tons per year: the CAA-mandated controls and the NOx cap account for approximately 500,000 tons and 100,000 tons of NOx reductions respectively and OTAG-wide Level 2 NOx controls contribute an additional 1 million tons per year of NOx reductions (U.S. EPA, 1997j). Title I area source NOx controls account for reductions of 1.4 million tons of NOx per year. Title I mandated controls, Title IV Acid Rain NOx requirements, and the OTAG-wide NOx cap result in an estimated 3 million tons of summertime NOx reductions from the utility sector (U.S. EPA, 1997a).

Title II mobile source VOC and NOx controls including a national LEV program are estimated to result in annual reductions of 2.8 million tons of VOC and 3.5 million tons of NOx nationally in 2010 (U.S. EPA, 1997j).

The Title IV Acid Rain Program accounts for an 8 million ton reduction in utility SO_2 emissions from 2010 no-control levels (U.S. EPA, 1997a).

4.3.9 Key Uncertainties Associated with Benchmark Emissions

Table 4-9 summarizes the key uncertainties associated with the 2010 benchmark emissions. Because 1990 emissions and activity levels are the basis from which 2010 emissions are projected, the uncertainties associated with 1990 emissions estimates are carried through to the 2010 emission estimates. These uncertainties are discussed in Section 4.3.4.

There are uncertainties associated with the activity surrogates and projections data used to make 2010 growth forecasts for each source sector. However, there are no known biases in either of these data inputs.

Table 4-7
Summary of National 2010 CAA Emissions Estimates by Major Sector

Major Sector	**VOC (1000 tpy)**	**NOx (1000 tpy)**	**SO$_2$ (1000 tpy)**	**PM$_{10}$ (1000 tpy)**	**(1**
Utility	**50**	**3,755**	**9,746**	**277**	
Industrial Point	2,164	1,958	5,990	1,170	
Area	7,533	2,932	1,518	41,051	
Nonroad	1,888	2,063	236	336	
Motor Vehicle	3,946	5,574	409	204	
Anthropogenic Subtotal	**15,581**	**16,282**	**17,899**	**43,038**	
Biogenics	25,988				
Natural Sources	248	89	1	5,429	
TOTAL	**41,817**	**16,371**	**17,900**	**48,467**	

Note: Emissions estimates may not sum due to rounding.
1990 fugitive dust emissions have not been adjusted.
Air quality impacts from major emitting sectors are not necessarily proportional to their contribution to national emissions estimates. See sections 4.4 and 4.5 and Chapter 6 of this RIA.
Organic carbon and elemental carbon emissions were not estimated for 2010 for the CAA baseline scenario.

The 2010 control assumptions used to incorporate the effects of CAA-mandated controls also have related uncertainties. Potential revisions to existing rules or rules that are currently in draft form but would be implemented in 2010 are not incorporated in the 2010 emissions baseline. It is unclear the net effect of these omissions on baseline emissions. Because RFP and ROP are not incorporated in the baseline, 2010 emissions could be underestimated. There may be an overestimate in baseline emissions given that the co-control emission reductions (e.g., PM, NOx) from MACT standards and off-set requirements in the Ozone Transport Region (OTR) and ozone nonattainment areas have not been estimated. Finally, because the NPI is a top-down inventory, area-specific control measures as outlined in nonattainment State implementation plans (SIPs) have not been incorporated in the baseline emissions. The potential bias is unclear for this potential source of uncertainty.

Table 4-8
Uncertainties and Possible Biases in Estimating 2010 Emissions[a]

Potential Source of Uncertainty	Positive Bias? (Overestimate)	Negative Bias? (Underestimate)	Bias Unclear
1990 Emissions	✓ (fugitive dust)	✓ (total biogenic VOC and SOA)	✓
Growth Forecasts:			
- activity surrogates			✓
- projections data			✓

Potential Source of Uncertainty	Positive Bias? (Overestimate)	Negative Bias? (Underestimate)	Bias Unclear
2010 Control Assumptions:			
- Potential revisions to existing rules or rules in draft form not incorporated;			✓
- RFP/ROP for individual ozone nonattainment areas not estimated;		✓	
- Co-control from MACT standards not estimated;	✓		
- Off-set requirements in OTR and ozone nonattainment areas not estimated;	✓		
- Area-specific reductions as reflected in SIPs not incorporated.			✓

[a] The projection of emissions to 2010 is a proxy for emissions in 2015, the analysis year in this RIA.

4.4 Estimation of Benchmark Visibility Levels

The methodology for estimation of benchmark visibility levels for this assessment builds upon the previous method used in the 1997 RIA. The CRDM is used to estimate ambient PM concentrations in 2010. This model predicts quantitative relationships (i.e., source-receptor relationships) between county-level emissions of primary particles and secondary particle precursors and annual concentrations of PM_{10} and $PM_{2.5}$ at county-level receptors. The following data inputs are implemented for this assessment:

! Phase II CRDM air quality modeling results are employed;

! The source-receptor (S-R) matrix is calibrated using 1993 -1995 Aerometric Information Retrieval System (AIRS) monitoring data for all 711 counties monitored for PM_{10} in the 48 contiguous States during this 3-year period;

The following refinements are employed in this analysis that are not employed in the modeling for the proposed RH rule in 1997:

! Contribution to visibility improvements from reduction of OC and EC emissions is not accounted for;

! Estimates of visibility improvements in non-Class I area counties are now estimated and serve as an input to the benefits analyses in Chapter 9.

4.4.1 Overview of Phase II Air Quality Modeling

This section provides a general overview of the Phase II air quality modeling analysis. More detailed information follows in subsequent sections. For Phase II, the Lagrangian Regional Model is used to guide the refinement of the Climatological Regional Dispersion Model (CRDM) to correct for misestimation of fugitive dust emissions (Latimer, 1996). Using 1990 meteorology, the refined CRDM is applied to 1990 emissions to calculate a transfer matrix of S-R relationships for all relevant primary and precursor emissions to estimate cumulative regional ambient concentrations of $PM_{2.5}$ and PM_{10}, as well as the important chemical constituents of secondary particulates: sulfate, nitrate, secondary organics and ammonium. As described in section 4.4.2, the refined CRDM, when used with adjusted primary PM fugitive dust emissions, provides more representative estimates of the spatial distribution of annual PM concentrations in the United States (Pechan, 1997b).

The S-R matrix next is calibrated using 1993-1995 PM_{10} and $PM_{2.5}$ annual monitoring data to benchmark the modeling to ambient air quality values. Additionally, this calibration provides a way to capture the 3-year and spatial averaging aspects of the $PM_{2.5}$ annual standard alternatives.

In order to predict ambient PM concentrations in 2010, emissions projections as described in Section 4.3 are input to the calibrated S-R matrix to produce annual PM_{10} and $PM_{2.5}$ concentration values at county-level receptors. Finally, 1993-1995 peak-to-mean ratios (i.e., ratio of 24-hour value to annual average value) for each monitored county in the analysis are used to estimate the 24-hour PM concentration (i.e., 4th highest daily maximum for the current PM_{10} daily form and 98th percentile value for the $PM_{2.5}$ daily form alternatives) from the model-predicted annual PM concentration. Nonmonitored counties are calibrated using regional average normalization factors. Additionally, regional peak-to-mean ratios are used to derive the 24-hour PM concentration in the nonmonitored counties.

Once 2010 baseline air quality is developed, monitored counties in class I areas are evaluated to determine if they can meet the illustrative RH progress goals. Figure 4-3 illustrates the development of 2010 baseline visibility levels.

4.4.2 Elements of Visibility Modeling

4.4.2.1 *Lagrangian Regional Model*

The Lagrangian Regional Model (LRM) is used to guide the refinement of the CRDM through the estimation of the transport, diffusion, deposition, and chemical conversion of emissions using a spatially and temporally varying wind field. Because the computer memory and run times are excessive to run the LRM for the entire country with 6,000 sources and 3,000 receptors, the LRM was tested for a single point source for a few days of 1990 meteorological data from the Meteorological Model-4 (MM-4) mesoscale model. The LRM simulates the hourly release of puffs which are transported by the averaged winds appropriate for the time and location of the puff. In general, puff-type air quality models are better than Gaussian dispersion models at handling transport and diffusion of pollutants at low wind speeds and therefore show a greater air quality impact from emissions in the local area. A single uniform concentration of each particulate chemical constituent for each hourly puff is calculated based on standard vertical diffusion coefficients, limited by the mixed layer height, and mesoscale diffusion coefficients. Results from the LRM are subsequently used to refine CRDM assumptions to take into account long-range transport of secondary particles and impacts of a county's primary emissions on its air quality (Latimer, 1996).

4.4.2.2 *Climatological Regional Dispersion Model*

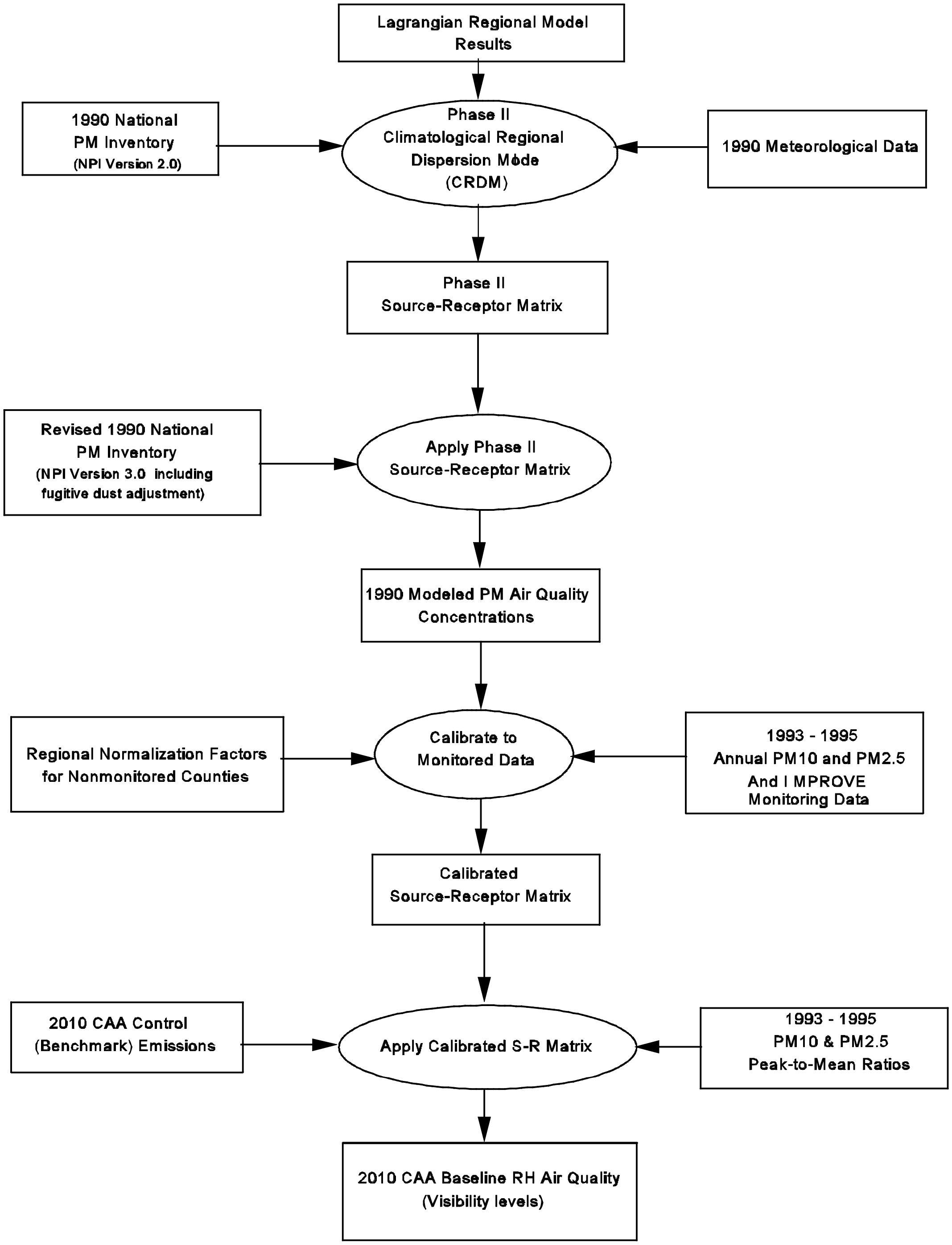
The CRDM is used to generate a matrix of S-R relationships that relate emissions of direct PM_{10} and $PM_{2.5}$ and particle precursors to annual average PM_{10} and $PM_{2.5}$ concentrations (Pechan, 1997b). The S-R matrix reflects the relationship between PM concentration values at a single receptor 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 (ISCST3), an EPA-recommended short range Gaussian dispersion model (U.S. EPA, 1995b). The CRDM incorporates terms for wet and dry deposition and chemical conversion of SO_2 and NOx, 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. For this analysis, meteorological data for 1990 are used.

The CRDM uses Turner's sector-average approach, a probabilistic method in which the frequencies of occurrence of various wind and stability conditions are used to calculate the frequencies of transport of pollutants in various sectors. This method is recommended for estimation of long-term average pollutant concentrations and is discussed more fully in a contractor report (Pechan, 1997b). The assumptions related to chemical conversion of secondary particle precursors, long-range transport of secondary particles and the impact of a county's primary emissions on itself are refined based upon the LRM results. For the Phase II modeling, chemical conversion, transport and deposition equations are updated. Additionally, it was assumed that all primary emissions from the county are evenly distributed over a square with the same area as the county. It is also assumed that primary emissions from the county are always impacting the county. A simple box model is used for each wind speed and stability category. The vertical diffusion coefficient is calculated at a downwind distance corresponding to the length of the side of the square. These assumptions are necessary since spatial variation of emissions within a county cannot be provided for a national scale model.

Emissions data from version 3.0 of the 1990 NPI are 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 NPI. The high number of point sources in the inventory (61,619 point sources) made it impractical to model each point source individually. As a result, elevated point source emissions are aggregated at the county level by plume height. 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 ISCST3. Two aggregated elevated point source groupings are 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. Sources with effective stack heights greater than 500 m are modeled as separate sources. In addition to point sources, the modeled emission sources also include total area/mobile sources for each county and emissions for 10 Canadian provinces and 29 Mexican cities/States. Receptors modeled include all county centroids plus receptors in Canada and Mexico.

Figure 4-3
Development of 2015 Baseline RH Air Quality



A total of 5,944 sources (i.e., industrial point, utility, area, nonroad, and motor vehicle) of primary and precursor emissions are modeled. In addition, secondary organic aerosols formed from anthropogenic and biogenic VOC emissions are modeled. Natural sources of PM_{10} and $PM_{2.5}$ (i.e., wind erosion and wild fires) are also included. Emissions of SO_2, NOx, and ammonia are modeled in order to calculate ammonium sulfate and ammonium nitrate concentrations, the primary particulate forms of sulfate and nitrate. The CRDM produces an S-R matrix of transfer coefficients for each of these primary and particulate precursor pollutants. These coefficients can be applied to the emissions of any unit (area source or individual point source) to calculate a particular source's contribution to a county receptor's total annual PM_{10} or $PM_{2.5}$ concentration. Each individual unit in the inventory is associated with one of the source types (i.e., area, point sources with effective stack height of 0 to 250 m, 250 m to 500 m, and individual point sources with effective stack height above 500 m) for each county.

Once the S-R matrix is developed, the transfer coefficients must be adjusted to reflect concentrations of secondarily-formed particulates (Latimer, 1996). First, the transfer coefficients for SO_2, NOx, and ammonia are multiplied by the ratios of the molecular weights of sulfate/SO_2, nitrate/nitrogen dioxide and ammonium/ammonia to obtain concentrations of sulfate, nitrate and ammonium.[1] The relative concentrations in the atmosphere of ammonium sulfate and ammonium nitrate depend on complex chemical reactions. In the presence of sulfate and nitric acid (the gas phase oxidation product of NOx), ammonia reacts preferentially with sulfate to form particulate ammonium sulfate rather than react with nitric acid to form particulate ammonium nitrate. Under conditions of excess ammonium and low temperatures, ammonium nitrate forms. For each county receptor, the sulfate-nitrate-ammonium equilibrium is estimated based on the following simplifing assumptions:

- All sulfate is neutralized by ammonium;
- Ammonium nitrate forms only when there is excess ammonium;
- Because ammonium nitrate forms only under low temperatures, annual average particle nitrate concentrations are divided by four assuming that sufficiently low temperatures are present only one-quarter of the year.

Finally, the total particle mass of ammonium sulfate and ammonium nitrate is calculated.[2]

---

[1] Ratio of molecular weights: Sulfate/SO_2= 1.5; nitrate/nitrogen dioxide = 1.35; ammonium/ammonia = 1.06.

[2] To calculate total particle mass of ammonium sulfate and ammonium nitrate, the anion concentrations of sulfate and nitrate are multiplied by 1.375 and 1.29 respectively.

4.4.2.3 *Comparison of Modeled and Measured PM Concentrations*

In order to evaluate the performance of the Phase II CRDM, model-predicted PM concentrations and measured ambient PM concentrations are compared. Measured annual average PM concentrations by chemical species from the Interagency Monitoring for Protection of Visual Environments (IMPROVE) network are examined for the 3-year period March 1988 - February 1991. This period is chosen because it relates closely to 1990 emissions and meteorological data used in the CRDM. Given that IMPROVE network monitors visibility impairment in predominantly rural Class I areas, these comparisons are incomplete due to the lack of coverage in urban areas. With the exception of the fugitive dust component of $PM_{2.5}$ and PM_{10}, modeled and measured concentrations of sulfate, nitrate and organics are comparable (Latimer, 1996).

This PM air quality modeling effort attempts to model the “background” contribution to ambient PM concentrations. Background PM is defined as the distribution of PM concentrations that would be observed in the U.S. in the absence of anthropogenic emissions of PM and precursor emissions of VOC, NOx and SOx in North America (U.S. EPA, 1996l). Estimating background PM concentrations is important for the cost analysis as it represents that portion of PM mass that is uncontrollable. Background PM levels vary by geographic location and season. The natural component of background arises from physical processes of the atmosphere that entrain small particles of crustal material (i.e., soil from wind erosion), as well as emissions of organic particles and nitrate precursors resulting from natural combustion sources, such as wildfire. In addition, certain vegetation can emit SOA. Biogenic sources and volcanos also emit sulfate precursors. The exact magnitude of this natural portion of PM for a given geographic location cannot be precisely determined because it is difficult to distinguish from the long-range transport of anthropogenic particles and precursors. The PM Criteria Document (U.S. EPA, 1996a) reports that annual average $PM_{2.5}$ concentrations range from 1 - 4 ug/m^3 in the West and from 2 - 5 ug/m^3 in the East.

Given the uncertainties in estimating biogenic VOC and SOA emissions and primary PM emissions from natural sources as well as the uncertainties in the PM air quality model, there is considerable uncertainty in the modeled predictions of the background contribution to PM mass. For some nonattainment counties, apparent overpredictions in the background contribution to PM mass reduces the relative contribution of anthropogenic sources to PM mass. This in turn can significantly diminish the modeled effectiveness of control measures on anthropogenic sources in reducing estimated PM concentration levels.

Although the bulk of primary PM emissions are from anthropogenic and natural fugitive dust sources[1], available speciated monitoring data indicate that fugitive dust contributes substantially less to total $PM_{2.5}$ levels relative to other particle species such as sulfates and

---

[1] Natural and anthropogenic fugitive dust emissions account for 93 percent of PM_{10} emissions and 76 percent of $PM_{2.5}$ emissions in the 1990 base year inventory (NPI version 3).

nitrates. The CRDM-predicted average fugitive dust contribution to $PM_{2.5}$ mass is 31 percent in the East and 32 percent in the West (Pechan, 1997b). Speciated monitoring data show that minerals (i.e., crustal material) comprise approximately 5 percent of $PM_{2.5}$ mass in the East and approximately 15 percent of $PM_{2.5}$ mass in the West (U.S. EPA, 1996a). The 1990 model predictions therefore are not consistent with ambient data. These disparate results may suggest a systematic overbias in the fugitive dust emission estimates. Subsequent PM emission inventory efforts indicate that fugitive dust emissions are overestimated in the baseline emissions inventory. The NPI version 3 fugitive dust PM_{10} and $PM_{2.5}$ emissions used in this analysis are 40 percent and 73 percent greater, respectively, than the most recent NET Inventory estimates[1] (U.S. EPA, 1997h). 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 (U.S. EPA, 1996c).

To address this bias, a multiplicative factor is 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. The multiplicative adjustment of 0.25 is applied under Case A. The 0.25 multiplicative adjustment results in a fugitive dust contribution to modeled ambient $PM_{2.5}$ concentrations of 10 - 17 percent. Given the uncertainties noted in the fugitive dust emissions inventory, however (U.S. EPA, 1998), the multiplicative factor of 0.0 is applied to nationally to these emissions under Case B.

4.4.2.4 *Application of Phase II S-R Matrix to Updated 1990 National Particulate Emissions Inventory*

As described in section 4.3, version 3 of the NPI is used as the base year 1990 inventory. The Phase II S-R matrix next is applied to the revised PM emissions inventory to predict 1990 PM air quality concentrations.

4.4.2.5 *Normalization of S-R Matrix for Annual Estimates of PM_{10} and $PM_{2.5}$*

The resulting 1990 annual PM_{10} and $PM_{2.5}$ values are compared and calibrated to monitored annual PM_{10} and $PM_{2.5}$ concentrations. All predictions are normalized regardless of over prediction or under prediction relative to monitored values. This is 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. Calibration is conducted for county-level modeled PM_{10} and $PM_{2.5}$ estimates falling into one of four air quality data tiers. The tiering scheme reflects increasing relaxation of data completeness criteria and therefore increasing uncertainty for the annual design

---

[2] Natural and anthropogenic fugitive dust emissions account for 86 percent of PM_{10} emissions and 59 percent of $PM_{2.5}$ emissions in the most recent 1990 National Emission Trends Inventory.

value (U.S. EPA, 1997k). Tier 1 monitored counties cover the 504 counties with at least 50 percent data completeness and therefore have the highest level of certainty associated with the annual design value. Tier 2 monitored counties cover 100 additional counties with at least one data point (i.e., one 24-hour value) for each of the 3 years during the period 1993 -1995. Tier 3 monitored counties cover 107 additional counties with missing monitoring data for one or two of the 3 years 1993 - 1995. In total, Tiers 1, 2 and 3 cover 711 counties currently monitored for PM_{10} in the 48 contiguous States.[1] Tier 4 covers the remaining 2369 nonmonitored counties. Normalization factors are calculated and applied to the respective counties for Tiers 1 through 3. Tier 4 nonmonitored counties are calibrated using the appropriate regional normalization factor calculated as the average of Tier 1 normalization factors across a given modeling region[2].

The calibration procedure is conducted employing 1993-1995 PM_{10} ambient monitoring data from the AIRS database following the air quality tier data completeness parameters discussed above. The PM_{10} data represent the annual average of design value monitors averaged over 3 years (U.S. EPA, 1996i). The standardization for temperature and pressure was eliminated from this concentration data based upon proposed revisions to the reference method for PM_{10}.[3]

Because there is little $PM_{2.5}$ monitoring data available, a general linear model is developed to predict $PM_{2.5}$ concentrations directly from the 1993-1995 PM_{10} values (U.S. EPA, 1996e). A SAS™ general linear model (i.e., GLM) procedure is used to predict $PM_{2.5}$ values (dependent variable) as a function of independent variables for season, region, and measured PM_{10} value. These derived $PM_{2.5}$ data are used to calibrate model predictions of annual average $PM_{2.5}$. Given the $PM_{2.5}$ annual standard alternatives allow for spatial averaging, model-predicted annual average $PM_{2.5}$ air quality data are calibrated to the spatially-averaged annual $PM_{2.5}$ value[4] from the derived $PM_{2.5}$ dataset. Additionally, the proposed form of the standard allows for averaging over 3 years of air quality data. These derived, annual $PM_{2.5}$ data represent the annual average value over a 3-year period. These $PM_{2.5}$ concentrations also reflect the elimination of the temperature and pressure standardization, given that they are developed from the previously discussed PM_{10} dataset.

---

[1] The current PM_{10} monitoring network consists of approximately 1600 individual monitors with a coverage of approximately 711 counties in the 48 contiguous States.

[2] As presented in Chapter 6, the contiguous 48 States are divided into six modeling regions for the control strategy-cost analysis. See p. 6-5.

[3] See Proposed Revisions to Appendix J - Reference Method for PM_{10} , Proposed Rule for National Ambient Air Quality Standards for Particulate Matter (<u>Federal Register</u>, Vol. 61, No. 241, p. 65666, December 13, 1996).

[1] County-level spatial averaging is used for this analysis.

4.4.2.6 *Application of Calibrated Phase II S-R Matrix to 2015 CAA Control Emissions*

The calibrated Phase II S-R matrix is next applied to the 2015 CAA control emissions to predict baseline annual air quality and visibility levels at the county level. This baseline air quality reflects the fugitive dust emissions adjustment of 0.25. This is the baseline air quality used in the calculations of results under emissions control case A. Adjusting the fugitive dust emissions by 0 (i.e., zeroing them out) leads to the baseline air quality used in the calculation of results under emissions control case B.

4.4.2.7 *Peak-to-mean Ratios for Calculating 24-hour Average Concentration Value*

Since the CRDM predicts only annual average PM_{10} and $PM_{2.5}$ concentrations, peak-to-mean ratios are employed to derive these values. For each annual PM concentration for the Tier 1 through 3 monitored counties, three sets of peak-to-mean ratios are used to predict 24-hour peak PM_{10} and $PM_{2.5}$ concentrations reflective of the forms of the alternatives being analyzed.[1] The first peak-to-mean ratio is the 3-year average fourth highest 24-hour maximum PM_{10} value to the annual arithmetic mean PM_{10} value. This ratio is applied to the modeled annual average PM_{10} value to predict the fourth highest daily maximum PM_{10} value, the form of the current PM_{10} daily standard. The ratio of annual mean PM_{10} to 99th percentile 24-hour PM_{10} is used to predict the 3-year average 99th percentile PM_{10} value (i.e., form of the selected PM_{10} standard) from the annual mean PM_{10}. The $PM_{2.5}$ peak-to-mean ratio is calculated as the 3-year average 98th percentile 24-hour peak $PM_{2.5}$ value to the spatially averaged annual arithmetic mean $PM_{2.5}$ value. This ratio is applied to the annual mean $PM_{2.5}$ value to predict the 3-year average 98th percentile 24-hour peak $PM_{2.5}$ value (U.S. EPA, 1996e).

4.4.3 Class I Area Counties Meeting each RH Progress Goal

The model-predicted visibility levels reflecting the 2010 CAA-control baseline are used to determine county air quality status. Predicted visibility levels are the most certain for the Tier 1 counties since the estimates are calibrated using 50 percent complete AIRS data as described in Section 4.4.2.5. This set represents approximately 70 percent of the counties within the 48 contiguous States monitored for PM_{10} during 1993-1995, covering approximately 150 million people.

---

[2] Used 1993-1995 AIRS monitoring data following air quality data tiering scheme discussed in section 4.3.2.4.

4.4.4 Uncertainties in Air Quality Modeling for Visibility Improvements

The methodology used to estimate visibility improvements in 2015 from 1990 emissions and ambient concentration data introduces several sources of uncertainty to the control strategy-cost and benefits analyses. Table 4-9 presents potential sources of uncertainty and associated biases in estimating the number of 2015 counties not initially meeting the illustrative progress goals. “Positive bias” indicates that estimated number of 2015 counties not meeting the illustrative progress goals may be overestimated; “negative bias” indicates that estimated number of 2015 counties not meeting the illustrative progress goals may be underestimated; “bias unclear” indicates that the direction of impact from a given potential source of uncertainty on 2015 counties not meeting the illustrative progress goals is unknown. 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.

Because 1990 emissions are an input to the CRDM model, the uncertainties associated with the emissions inventory are carried through to the air quality modeling. As discussed in section 4.3.3, apart from the fugitive dust and biogenic VOC and SOA categories, emissions of primary PM and PM precursors are uncertain although with no known bias. Fugitive dust PM emissions appear to be overestimated by 40 percent for PM_{10} and 73 percent for $PM_{2.5}$ relative to the more recent NET Inventory. The biogenic VOC emissions are underestimated relative to the more recent BEIS2 estimates. Finally, the methodology used to estimate SOA formation from reactive VOCs may overestimate SOA emissions and therefore ambient concentrations of SOA.

There is uncertainty associated with the 1993 - 1995 monitored annual average and 24-hour PM_{10} concentration values that are used to calibrate the ambient concentrations generated by the CRDM at the county-level receptors. These monitoring values are taken from the AIRS data base, which 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 (U.S. EPA, 1996k). However, there is no known bias associated with these values.

Since the $PM_{2.5}$ data are derived from monitored PM_{10} concentrations, they too have associated uncertainty due to instrument measurement error, as described above. Additionally, and more importantly, the $PM_{2.5}$ values are predicted from a regression model (U.S. EPA, 1996e), and therefore are subject to uncertainty associated with this model. Subsequent reanalysis of the model has shown that there is no systematic bias to the $PM_{2.5}$ estimates (U.S. EPA, 1997i).

The CRDM used to generate a matrix of S-R 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 studies of uncertainty associated with CRDM output, Freeman *et al.* (1986) used error propagation and Monte Carlo simulation to study the uncertainty of short range concentration estimates calculated by a similar model, EPA's 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 - 160 percent.

Despite application of the fugitive dust adjustment factor, comparisons of modeled PM predictions to ambient data indicate that the CRDM overpredicts the contribution of fugitive dust to total $PM_{2.5}$ mass and therefore to visibility impairment. The CRDM may overestimate or underestimate other fine particle species when evaluating county-level model predictions relative to $PM_{2.5}$ ambient data. For example, in some PM residual nonattainment counties, the predicted biogenic organic contribution to $PM_{2.5}$ mass appears to be overestimated relative to speciated monitoring data. However, at the national level, there appears to be no systematic bias to the modeled air quality predictions for the non-fugitive dust particle species.

The uncertainties and biases in the 1990 modeled predictions combined with uncertainties in 2010 emission projections bring about similar uncertainties and biases in the 2015 visibility improvement predictions. Table 4-9 lists these uncertainties and biases.

Although the CRDM S-R matrix serves as a useful tool in the design of cost-effective PM control strategies, the modeling approach does not reflect application of state-of-the-art techniques. 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 RADM results are used to complement the CRDM results, particularly with regard to nitrogen deposition. 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.

Table 4-9
Uncertainties and Possible Biases in Estimating the Number of 2015 Counties that Cannot Meet Illustrative RH Progress Goals

Potential Source of Uncertainty	Positive Bias? (Overestimate)	Negative Bias? (Underestimate)	Bias Unclear
Base Year 1990			
- 1990 emissions	✓ (fugitive dust, SOA)	✓(total biogenic VOC and SOA)	✓ (other emissions)
- 1993 - 1995 PM10 ambient data			✓
- 1993 - 1995 PM2.5 derived data			✓
- CRDM 1990 adjusted S-R matrix	✓ (fugitive dust)		✓ (other emissions)
Projection Year 2010 (proxy for 2015 analysis year)			
- Uncertainties from 1990 adjusted S-R matrix	✓ (fugitive dust)		✓
- 2010 emissions projections	✓ (fugitive dust, SOA)	✓ (total biogenic VOC and SOA)	✓ (other emissions)
- 2010 air quality predictions	✓ (fugitive dust)		✓ (other particle species)
2010 Nonattainment Counties			
- Tier 1 geographic scope assumption		✓ (small)	

It should be noted that an air quality adjustment procedure is used to account for CAA-control emissions inventory changes between 2007 and 2010. This adjustment procedure is applied to ozone nonattainment areas that are affected under the cap-and-trade program within the baseline for the final RH rule. For the most part, emissions are projected to decrease between 2007 and 2010. It is therefore reasonable to assume that air quality would improve as a result of these reductions. Because it is not possible to account for the air quality impacts of these changes outside of the nonattainment area, there may be a small overestimate in baseline air quality. Similary, the centroid model used to predict ozone concentrations in nonmonitored counties cannot fully account for ozone transport from nonattainment areas to downwind areas. The centroid model employs geographic interpolation between ozone concentration values in monitored counties to derive ozone concentrations in nonmonitored counties. The centroid model is not an air quality model and therefore any transport impacts from emission changes between 2007 and 2010 cannot be assessed.

4.6 References

Asman, William A.H. (1992), "Ammonia Emissions in Europe: Updated Emission and Emission Variations," National Institute of Public Health and Environmental Protection, Biltoven, The Netherlands, May 1992.

Balentine, Howard W., and Ronald J. Dickson (1995), "Development of Uncertainty Estimates for the Grand Canyon Visibility Transport Commission Emissions Inventory," in The Emission Inventory: Programs & Progress Proceedings of a Specialty Conference sponsored by the Air & Waste Management Association, Research Triangle Park, N.C., October 11-13, 1995.

Battye, R., W. Battye, C. Overcash, and S. Fudge (1994), "Development and Selection of Ammonia Emission Factors," EC/R Inc., Durham, NC, prepared for U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC. August 1994.

Bureau of Economic Analysis (1990), "1990 BEA Regional Projections to 2040: Volume 1: States", U.S. Department of Commerce, Washington, DC. June 1990.

Bureau of Economic Analysis (1995), "Regional State Projections of Economic Activity and Population to 2045", U.S. Department of Commerce, Washington, DC. July 1995.

California Air Resources Board (1991), "Identification of Volatile Organic Compound Species Profiles, ARB Speciation Manual," Second Edition, August 1991.

Connolly et al. (1990), "U.S. Paint Industry Data Base" Prepared by SRI International for the National Paint and Coatings Association, Inc. Washington, DC. 1990.

Cox, W. and S. Chu (1996), "Assessment of Interannual Ozone Variation in Urban Areas from a Climatological Perspective", *Atmospheric Environment 30,* p.2615.

Federal Highway Administration (1992), "Highway Performance Monitoring System: 1990 data files. U.S. Department of Transportation. Washington, DC. February 1992.

Freeman, Daniel L., Richard T. Egami, Norman F. Robinson, John G. Watson (1986), "A Method for Propagating Measurement Uncertainties through Dispersion Models", *JAPCA* 36: 246-253 (1986).

Geron, C., A. Guenther, and T. Pierce (1994), "An Improved Model for Estimating Emissions of Volatile Organic Compounds from Forests in the Eastern United States". *Journal of*

Geophysical Research, 99, pp. 12773-12791.

Gillette, Dale A. and Ranjit Passi (1988): "Modeling Dust Emissions Caused by Wind Erosion", *Journal of Geophysical Research*, Vol. 93, No. D11, Pages 14,233 - 14,242. November 20, 1988.

Grosjean, D. and J. H. Seinfeld (1989), "Parameterization of the Formation Potential of Secondary Organic Aerosols," *Atmospheric Environment*, Volume 23, No. 8, pp. 1733-1747, 1989.

Lamb,B., D. Gay, H. Westberg, and T. Pierce (1993), "A Biogenic Hydrocarbon Emission Inventory for the USA Using a Simple Forest Canopy Model," *Atmospheric Environment*, Volume 27A, pp. 1673-1690, 1993.

Latimer and Associates (1996), "Particulate Matter Source - Receptor Relationships Between All Point and Area Sources in the United States and PSD Class/Area Receptors" Prepared for Bruce Polkowsky, Office of Air Quality Planning and Standards, U.S. EPA. Research Triangle Park, NC. September 1996.

Mathtech, Inc. (1997), "Technical Support Document for Ozone NAAQS Analysis: Air Quality." Prepared for Science Applications International Corporation. July 1997.

National Acid Precipitation Program (1991), "NAPAP 1990 Interim Assessment Report. Volume II. Emissions and Controls." Washington, DC. November 1991.

Ozone Transport Commission (1994), "Memorandum of Understnding Among the States of the Ozone Transport Commission on Development of a Regional Strategy Concerning the Control of Stationary Source Nitrogen Oxide Emissions." September 27, 1994.

E.H. Pechan & Associates, Inc. (1994), "Enhancements to the Emission Reduction and Cost Analysis Model for VOC (ERCAM-VOC) - Draft Final," prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Ambient Standards Branch, March 31, 1994.

E.H. Pechan & Associates, Inc. (1995), "The National Particulates Inventory: Phase II Emission Estimates," prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. June 1995.

E.H. Pechan & Associates, Inc. (1996a), "Evaluation of the National Particulate Inventory (NPI) Using Data Attribute Rating System (DARS)." Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. December 1996.

E.H. Pechan & Associates, Inc. (1996b), "The Emission Reduction and Cost Analysis Model for No_x (ERCAM-NO_x) Revised Documentation," prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Ozone Policy and Strategies Group, Research Triangle Park, NC September 1996.

E.H. Pechan & Associates, Inc. (1996c), "Updates to Fugitive Dust Emission Compoents of the National Particulates Inventory," Memorandum to Bill Kuykendal, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Inventory and Factors Group, Research Triangle Park, NC. January 29, 1996.

E.H. Pechan & Associates, Inc.(1997a), "2010 Clean Air Act Amendment Baseline Emission Projections for the Integrated Ozone, Particulate Matter and Regional Haze Cost Analysis." Prepared for Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, U.S. EPA. Research Triangle Park, NC. July 1997.

E. H. Pechan and Associates (1997b), "Integrated Ozone Particulate Matter and Regional Haze Cost Analysis: Methodology and Results." Prepared for Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, U.S. EPA. Research Triangle Park, NC. July 1997.

Perrin Quarles Associates (1997), "Rule Effectiveness Analysis," Memo to Scott Mathias, Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, U.S. EPA. Research Triangle Park, NC. June 20, 1997.

Pierce, T., B. Lamb, and A. VanMeter (1990), "Development of a Biogenic Emissions Inventory System for Regional Scale Air Pollution Models." Proceedings of the 83rd Air and Waste Mangement Association Annual Meeting, Pittsburgh, PA. 1990.

Radian Corporation (1992), "VOC/PM Speciation Data System, Version 1.5." Prepared for Office of Air Quality Planning and Standards, U.S. EPA. Research Triangle Park, NC. October 1992.

Radian Corporation (1995), "An Emissions Inventory for Assessing Regional Haze in the Colorado Plateau." Prepared for Grand Canyon Visibility Transport Commission. January 23, 1995.

Schott, J. (1996), "Lots of Data, How Do We Use It? Strengths and Inaccuracies of Utility Acid Rain Electronic Data Reports, " Energy Corporation Paper presented at Air and Waste Management Association Conference. New Orleans, LA. September 1996.

U.S. Bureau of the Census (1987), "1987 Census of Agriculture, Volume : Geographical Area Series," Washington, DC, 1987.

U.S. Bureau of the Census (1988a), “County Business Patterns”, Washington, DC, 1988.

U.S. Bureau of the Census (1988b), “City/County Database,” datafiles. Washington, DC, 1988.

U.S. Bureau of the Census (1992), “Census of Population and Housing 1990: Summary Tape File 3A,” New York. August 1992.

U.S. Bureau of the Census (1992), “Statistical Abstract of the United States: 1992,” 112th Edition, Washington, DC, 1992.

U.S. Bureau of the Census (1995), “1992 Census of Agriculture - Geographic Area Series 1A, 1B, and 1C,” (CD-ROM), U.S. Department of Commerce, 1995.

U.S. Department of Agriculture, Forest Service, (1989), “An Inventory of Particulate Matter and Air Toxic Emissions from Prescribed Fires in the United States for 1989,” Seattle, WA, 1989.

U.S. Department of Agriculture (1991), “U.S. Land Use Summary.” Provided by O.T. Overhoe from the Feed Grains and Oil Seeds Section of ASGS-USDA, 1991.

U.S. Department of Energy (1991a), “State Energy Data Report: Consumption Estimates for 1960 - 1989.” DOE/EIA-0214(89). Energy Information Administration. Washington, DC, May 1991.

U.S. Department of Energy (1991b), “Steam-Electric Plant Operation and Design Report,” form EIA-767- data files for 1990. Energy Information Administration. Washington, DC, 1991.

U.S. Environmental Protection Agency (1989), “The 1985 NAPAP Emissions Inventory (Version 2): Development of the Annual Data and Modeler’s Tapes.” Office of Research and Development, Air and Energy Engineering Research Laboratory. Research Triangle Park, NC. November 1989.

U.S. Environmental Protection Agency (1991a), “Procedures for Preparing Emissions Projections,” Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-450/4-91-019, July 1991.

U.S. Environmental Protection Agency (1991b), “Nonroad Engine and Vehicle Emission Study,” Office of Air and Radiation, Washington, DC, November 1991.

U.S. Environmental Protection Agency (1991c), “MOBILE4 Fuel Consumption Model,” Office of Air and Radiation, Washington, DC, August 12, 1991.U.S. Environmental Protection Agency (1993a), “Users Guide to MOBILE5a,” Office of Mobile Sources, Ann Arbor, MI. March 1993.

U.S. Environmental Protection Agency (1993b), "Regional Interim Emissions Inventories 1987-1991), Volume I: Development Methodologies" Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/R-93-021a, May 1993.

U.S. Environmental Protection Agency (1993c), "National Air Pollution Trends, 1990-1992," Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/R-93-032, October 1993.

U.S. Environmental Protection Agency (1994a), "Draft Regulatory Impact Analysis and Regulatory Support Document: Control of Air Pollution; Emission Standards for New Nonroad Spark-Ignition Engines At or Below 19 Kilowatts (25 Horsepower)," Office of Mobile Sources, Ann Arbor, MI. April 1994.

U.S. Environmental Protection Agency (1994b),"PM-10 Controlled Emissions Calculator," Office of Air Quality Planning and Standards, ResearchTriangle Park, NC, January 1994.

U.S. Environmental Protection Agency (1994c), "Draft User's Guide to PART5: A Program for Calculating Particle Emissions From Moter Vehicles." Office of Mobile Sources, Ann Arbor, MI. EPA-AA-AQAB-94-2. July 1994.

U.S. Environmental Protection Agency (1995a), "Compilation of Air Pollutant Emission Factors,Volume I: Stationary Point and Area Sources," Fifth Edition (AP-42), Office of Air Quality Planning and Standards, Research Triangle Park, NC. January 1995.

U.S. Environmental Protection Agency (1995b), "User's Guide for Industrial Source Complex (ISC3) Dispersion Models, Volume 1: User's Instructions." Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA-454/B-95-003a. September 1995.

U.S. Environmental Protection Agency (1996a), "Air Quality Criteria for Particulate Matter," Office of Research and Development, Research Triangle Park, NC. EPA/600/P-95/001aF. April 1996.

U.S. Environmental Protection Agency (1996b), "Air Quality Modeling Analyses to Identify Implications of Some Prospective Ozone NAAQS." Emissions, Monitoring and Analysis Division, Office of Air Quality Planning and Standards, Research Triangle Park, NC. March 1996.

U.S. Environmental Protection Agency (1996c): Memorandum from William B. Kuykendal (U.S. EPA, OAQPS, Emission Inventory and Factors Group) to Allyson Siwik (U.S. EPA, OAQPS, Innovative Strategies and Economics Group). Subject: Review Comments on

E.H. Pechan Economic Analysis Work. July 19, 1996.

U.S. Environmental Protection Agency (1996d), "National Air Quality and Emissions Trends Report, 1995," Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA-454/R-96-005, October 1996.

U.S. Environmental Protection Agency (1996e), "Proposed Methodology for Predicting PM_{25} from PM_{10} Values to Assess the Impact of Alternative Forms and Levels of the PM NAAQS." Prepared by Terence Fitz-Simons, David Mintz and Miki Wayland (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standard, Air Quality Trends Analysis Group), June 26, 1996.

U.S. Environmental Protection Agency (1996f), "Regulatory Impact Analysis for Proposed Ozone National Ambient Air Quality Standard," Office of Air Quality Planning and Standards, Research Triangle Park, NC. Draft Document, December 1996.

U.S. Environmental Protection Agency (1996g), "Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard," Office of Air Quality Planning and Standards, Research Triangle Park, NC. Draft Document, December 1996.

U.S. Environmental Protection Agency (1996h), Memorandum to the Docket from David Mintz (U.S. EPA, OAQPS, Air Quality Trends Analysis Group), Subject: Methodology for Estimating the Number of Counties That May Not Meet Alternative Particulate Matter Standard Options", November 25, 1996.

U.S. Environmental Protection Agency (1996i), "Analyzing Electric Power Generation Under the CAAA," Office of Air and Radiation, Washington, DC. July 1996.

U.S. Environmental Protection Agency (1996j), "Development of a Federal Reference Method for Fine Particles: Current Methodology", Draft Information Statement. Office of Research and Development. Atmospheric Chemistry and Physics Branch. Research Triangle Park, NC. February 9, 1996.

U.S. Environmental Protection Agency (1996k), "Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information, OAQPS Staff Paper." Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA-452\R-96-013. July 1996

U.S. Environmental Protection Agency (1997a), “Air Emissions Estimates from Electric Power Generation for the CAAA Section 812 Prospective Study,” Office of Air and Radiation, Washington, DC. February 1997.

U.S. Environmental Protection Agency (1997b), “The Effects of SOx and NO_x Emission Reductions on Sulfate and Nitrate Particulate Concentrations” Thomas Braverman, Air Quality Modeling Group, Office of Air Quality Planning and Standards. Research Triangle Park, NC. May 1997.

U.S. Environmental Protection Agency (1997c), Memorandum to the Docket from Bruce Madariaga, Innovative Strategies and Economics Group, OAQPS, Research Triangle Park, NC. Subject: Assessing Impacts of Attaining the New NAAQS: Rationale for the Monitored Counties Only Approach. May 19, 1997.

U.S. Environmental Protection Agency (1997d), Memorandum from Dan Mussatti to Scott Mathias. OAQPS, Innovative Strategies & Economics Group, Research Triangle Park, NC. Subject: The identification process for nonattainment areas in the 1996 Ozone RIA. January 28, 1997.

U.S. Environmental Protection Agency (1997e), Memorandum from Warren Freas, Office of Air Quality Planning and Standards, Air Quality Trends Analysis Group to Dan Mussatti, Office of Air Quality Planning and Standards, Innovative Strategies and Economics Group. Subject: Comparison of 1990 Annual 3rd Max 8-hour with 1993 - 1995 Average 3rd Max Design Values. February 6, 1997.

U.S. Environmental Protection Agency (1997f), “Methodology for Estimating Baseline and Post-Control Ozone Air Quality Concentrations for July 1997 Ozone/PM/Regional Haze Regulatory Impact Analysis.” Office of Air Quality Planning and Standards, Innovative Strategies and Economics Group. Research Triangle Park, NC. July 1997.

U.S. Environmental Protection Agency (1997g), “Modeling-related Recommendations for the Revised Regulatory Impact Analysis for the Proposed Revisions to the NAAQS for Ozone” Emissions, Monitoring and Analysis Division, Office of Air Quality Planning and Standards,Research Triangle Park, NC. July, 1997.

U.S. Environmental Protection Agency (1997h), “National Air Pollutant Emission Trends Procedures Document 1990-1996, Section 4:0: National Criteria Pollutant Estimates, 1985-1996.”Office of Air Quality Planning and Standards, Research Triangle Park, NC. Draft Document. June 1997.

U.S. Environmental Protection Agency (1997i), Memorandum to the docket from Terence Fitz-Simons (Office of Air Quality Planning and Standards, Air Quality Trends Analysis Group), "Response to Comments Made by AISI on EPA Methodology for Predicting $PM_{2.5}$ from PM_{10}," February 6, 1997.

U.S. Environmental Protection Agency (1997j), "2010 Non-Utility Point, Area and Mobile Source VOC and NOx Emission Reductions for Title I, II, and II Clean Air Act Programs Assumed in Ozone/PM/Regional Haze RIA 2010 Emissions Baseline: Methodology and Results," Office of Air Quality Planning and Standards, Innovative Strategies and Economics Group, Research Triangle Park, NC. July 1997.

U.S. Environmental Protection Agency (1997k), Memorandum from David Mintz, Air Quality Trends Analysis Group, Office of Air Quality Planning and Standards to Allyson Siwik Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards. Subject: Methodology Used to Create PM10 and PM2.5 Air Quality Databases for RIA Work. July 15, 1997.

U.S. Environmental Protection Agency (1997l), "A Discussion of Uncertainties Inherent in Estimating Future Air Quality for Use in the Ozone RIA:" Emissions, Monitoring and Analysis Division, Office of Air Quality Planning and Standards. Research Triangle Park, NC. July 1997.

U.S. Environmental Protection Agency (1998). An SAB Advisory: The Clean Air Act Section 812 Prospective Study of Costs and Benefits - Air Quality Models and Emissions Estimates Initial Studies. Science Advisory Board, Washington, DC. EPA-SAB- Council-ADV-98-002. September 1998.

Chapter 5 CONTROL MEASURES

5.1 Introduction

This chapter briefly discusses the control measures for improving visibility in order to assess illustrative regional haze (RH) progress goals in this regulatory impact analysis (RIA). The Environmental Protection Agency (EPA) has attempted to identify and develop cost and emission reduction estimates for control measures covering nearly every source category with sources emitting pollutants that contribute to visibility impairment. The measures discussed in the chapter consist primarily of controls already in use, and are intended as illustrative of measures that may be selected to reach progress goals chosen by States or local areas. Generally, the measures involve more conventional control approaches (e.g., "add-on" control devices installed by an air pollution source) that are proven effective at reducing air pollution. Pollution prevention measures such as material substitution, source minimization, and fuel switching are also considered when it is cost effective to do so. Several less conventional measures are also included, such as education and advisory programs, sulfur dioxide (SO_2) emissions trading programs for utilities, and transportation control measures designed to slow growth in vehicle miles traveled (VMT). Technologies emerging now, or to be developed in the future, will likely play a key role in attaining the progress goals 10 to 20 years in the future. These new technologies may be more cost effective than control measures analyzed in this RIA, but have not been included in the analyses presented in Chapter 6 due to lack of control efficiency and cost data for inclusion in the control measure database.

In this analysis, five major emitting sectors are delineated: 1) utility point sources, 2) non-utility stationary point sources, 3) stationary area sources, 4) on-highway mobile sources, and 5) nonroad mobile sources. For each of these source categories, a variety of control measures for primary particulate matter (PM_{10} and $PM_{2.5}$), $PM_{2.5}$ precursors (SO_2, nitrogen oxides (NOx), volatile organic compounds (VOC)), ozone precursors (VOC, NOx), and RH contributors (primary PM, SO_2, NOx, VOC, secondary organic aerosols (SOA), organic carbon (OC), elemental carbon (EC)), have been analyzed[1]. The list of control measures included in this analysis is not exhaustive. Many other control measures may exist, but are not included in this analysis because: 1) the EPA is not able to obtain reliable cost and/or emission reduction estimates; 2) at a specific source, another control measure is identified that achieves equal or greater control efficiency at equal or lower overall cost; or 3) the measure is not currently being implemented for administrative reasons.

---

[1] Controls for ammonia emissions were not included because: 1) ammonia emissions are not a particle-limiting pollutant in the formation of $PM_{2.5}$, and 2) ammonia emissions in the National Particulate Inventory used in this analysis are more uncertain than emissions of VOC, NOx, SO_2, and primary PM.

It should be noted that the contribution of VOC and PM control measures to reducing OC and EC emissions is now considered in the RH optimization routine. The analyses for the proposed RH target program did not account for this contribution. The contribution to control of EC is particularly important since elemental carbon emissions are a major contributor to visibility impairment in some Class I areas (U.S. EPA, 1998b). This adjustment to the RH optimization model renders VOC and PM control measures of greater importance in the choice of control measures for decreasing visibility impairment.

Appendix B contains a table listing the control measures employed in the RH emission reduction and cost analyses. This table indicates the emissions source category that is impacted. For this analysis, all cost and emission reduction estimates for a given control measure are calculated incremental to controls already in place, or incremental to the next less stringent new control measure. As shown in Appendix B, several control measures achieve reductions in more than one pollutant. This is important in that there may be more cost-effective approaches to obtaining progress towards a visibility goal by implementing programs to reduce multiple pollutants than focusing on a single pollutant.

The application of some control measures may result in cost savings (i.e., negative average annual incremental cost per ton values). In these cases, the estimated cost savings are due to the recovery of valuable products or switching to technologies with lower long-run operating costs. One example of this occurring is VOC control measures that limit evaporation of solvents in open-top vapor degreasers. Where these control measures are selected, the estimated savings are credited. Further, some control measures are assigned a zero incremental cost per ton. These measures involve either a long-run transition to a substitute technology with equivalent capital and operating costs, or behavioral change-inducing public information programs for which cost information could not be found or easily developed.

In developing control efficiency estimates, it is assumed that control measures on average achieve 95 to 100 percent of their intended effect. The EPA currently allows States to develop alternate rule effectiveness methods for control measures included in State implementation plans as long as they follow certain basic requirements as described in the 1992 and 1994 guidelines for rule effectiveness (U.S. EPA, 1992b and 1994). The EPA has routinely accepted plan provisions with 95 to 100 percent control measure effectiveness assumptions.[2]

The degree of effectiveness applied to each measure depends on a variety of factors including the extent of monitoring and recordkeeping requirements, difficulty of control

---

[2] There is the possibility that rule effectiveness may not be 100 percent for area and mobile sources. However, it is very likely that RH rule effectiveness will be 100 percent for all sources since capture and collection efficiency and the performance period will be reflected in the design of this rule.

equipment maintenance, extent of over-control achieved by "margin of safety" engineering, and gross noncompliance (PQA, 1997). Generally, stack pollutants like NOx are more easily measured and monitored than, for instance, PM_{10} emissions from wood stoves (residential wood combustion). For that reason, some NOx control measures may be expected to have a higher control measure effectiveness than some VOC control measures. Also, it may be easier to enforce effectively a handful of point sources than a large number of area sources. For that reason, control measures affecting a small group of point sources may have a higher control measure effectiveness than measures affecting a large group of area sources.

In order to derive county-specific cost and control efficiency estimates for mobile and area source control measures, it is necessary to estimate the degree of *rule penetration*. In this context, rule penetration refers to the percentage of the county-level mobile or area source emissions inventory that is affected by the control measure. As used here, rule penetration effectively accounts for applicability constraints, such as size cut-offs. For example, a penetration rate of more than 90 percent indicates that the control measure applies to nearly every major emitting source within the source category. Conversely, a penetration rate of less than 10 percent indicates that only a few emitting sources may be affected. Rule penetration estimates generally are taken from published reports from State and local agencies.

The final emission reduction factor attributable to mobile and area source control measures is a combination of the estimated control efficiency, control measure effectiveness, and rule penetration. For example, an area source control measure with a 50 percent control efficiency, 95 percent control measure effectiveness, and 60 percent rule penetration rate, results in an emission reduction factor of 28.5 percent (0.5 * 0.95 * 0.6).

5.2 Utility Point Source Control Measures

Under the Clean Air Act (CAA), the EPA's primary focus has been further controls on NOx and SO_2. Table 5-1 summarizes the controls in the benchmark for the analysis of the final RH rule. This benchmark, which is estimated for the year 2015[3], assumes that all of the CAA's Title IV requirements are in effect, tighter new source controls are in place than exist in 1999 (based on today's best available control technology (BACT) decisions that have occurred in New

---

[3] 2018 is the end of the period for the first long-term strategy. The term “long-term strategy” refers to the set of emission reduction measures the State includes in its SIP in order to meet the reasonable progress goal it has set. 2015 is a nominal “snapshot” year that reflects the partial attainment control cases for the ozone and $PM_{2.5}$ NAAQS included in the baseline, and is near the end of the period for the first long-term strategy.

Source Review), and a NOx cap-and-trade program has been implemented in the 37 eastern States in the Ozone Transport Assessment Group (OTAG)[4].

The EPA examined a number of additional NOx and SO_2 control measures for the utility sector in the baseline for the final RH rule. These include more stringent NOx reductions for the utility cap-and-trade program in the OTAG States, and more stringent SO_2 reductions than what is called for in the nationwide Title IV utility cap-and-trade program. The EPA is including in the baseline for the final RH rule a cost-effective control strategy using existing technology that reduces the Title IV SO_2 emissions cap for utilities and large industrial boilers.

To meet existing Title IV requirements and the more stringent SO_2 cap (otherwise known as the National $PM_{2.5}$ Strategy) in the baseline, EPA has modeled the following SO_2 control options:

1. Scrubber Installation. New coal-fired units must install scrubbers in accordance with the NSPS, but do have some freedom on how much SO_2 reduction they obtain above the limitations in the NSPS. Existing units can install them. Those operating units that already have scrubbers can choose to increase the scrubber's performance levels to avoid purchasing allowances, or to free up allowances to trade with other operators of other units.

2. Fuel switching. Select coals or fuel oils with sulfur contents that will allow operators to minimize costs. Cost factors include the cost of scrubbers, the cost of allowances that operators may need to purchase if they continue using the same grades of fuel, and the prices of fuels with lower sulfur contents.

3. Repowering. Repower existing coal-fired or oil-fired units to natural gas combined-cycle, or switch to natural gas. (This choice reflects the fact that the units can simultaneously reduce NOx and SO_2 emissions to minimize the total cost of both sets of pollution controls.)

---

[4] This program assumed a 0.15 lb NOx/MMBtu emission cap is applied to all utility sources in the 37-State OTAG region. The emissions cap is achieved through a program of trading NOx emissions allowances (hence, a “cap-and-trade” program). The 15 OTAG States in the fine grid that are not affected by the NOx State Implementation Plan (SIP) call promulgated in September, 1998 are Florida, Mississippi, Louisiana, Texas, Arkansas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Minnesota, Iowa, Vermont, New Hampshire, and Maine.

Table 5-1
Levels of Federal NOx and SO_2 Controls for Electric Power Generation in the Benchmark and the Baseline for the Regional Haze Control Strategy Analyses

Pollutant	Benchmark CAA Requirements and Baseline Measures for the Analysis of RH Control Strategy Analyses
SO_2	Existing units - Benchmark: Comply with the Acid Rain Allowance Trading Program under Title IV of the 1990 CAA with phased-in requirements. Phase I covers the largest 110 coal-fired power plants beginning in 1995. All other units above 25 megawatts are covered in Phase II beginning in 2000. Baseline: Comply with a 60 percent level of control applied beyond Title IV requirements (otherwise known as the National $PM_{2.5}$ Strategy). New units - Benchmark: Comply with the more stringent of New Source Performance Standards (NSPS) set in 1978, BACT/Lowest achievable emission rate (LAER) requirements, and the Acid Rain Allowance Trading Program under Title IV of the CAA 1990. Baseline: Comply with a 60 percent level of control applied beyond Title IV requirements (otherwise known as the National $PM_{2.5}$ Strategy).
NOx	Existing units: Application of Reasonably Available Control Technology (RACT) occurred in 1995 in the Ozone Transport Region and all ozone non-attainment areas. Many States filed for and received waivers from RACT requirements. Compliance by coal-fired units with the Title IV NOx requirements that are phased in over time, or RACT, whichever is more stringent. Group 1/Phase I units comply with the Title IV emission limitations in 1996. Group 1/Phase II units and Group 2 units comply with the Title IV requirements in 2000. Collective action of the 37 Eastern States in OTAG leads to further summer season requirements on NOx emissions throughout the eastern US via a cap-and-trade program. New units: Comply with the more stringent of NSPS, BACT, and the Title IV standards for coal-fired units, whichever is more stringent. Units are also covered by the OTAG requirements of a cap-and-trade program.

4. Natural Gas Replacement. Retire existing coal-fired, or oil-fired units and replace them with combined cycle natural gas units. (This choice also reflects the fact that units can reduce both NOx and SO_2 emissions simultaneously.)

5. Purchase Emission Allowances. Operate units so that they do not exceed allowance levels, or purchase of limited numbers of allowances.

Several types of hybrid actions are also possible. Notably, the modeling framework within IPM allows units to install both NOx and SO_2 pollution controls (under Title IV) together where it would economically make sense for a unit to do so. The costs and performance of scrubbers, repowering, and adding new capacity appear in EPA's Analyzing Electric Power Generation under the CAA (U.S. EPA, 1998a).

For the analysis of the partial attainment $PM_{2.5}$ NAAQS in the baseline for the RH rule, EPA has modeled a trading and banking control strategy that reduces the annual SO_2 emissions cap by 60 percent to 3.58 million tons in 2005. In this report, this control strategy is referred to as the National $PM_{2.5}$ Strategy. The National $PM_{2.5}$ Strategy is a 60 percent reduction beyond Title IV Phase II levels, and is achievable with existing control technology. It is assumed that lowering the SO_2 emissions cap would occur in 2005 and lead to nearly a 50 percent reduction nationwide of annual SO_2 emissions by 2010. Table 5-2 shows the regional emission reductions that EPA expects to occur by the analysis year 2015. Most of the SO_2 reductions occur in the Midwest/Northeast and Southeast control regions.

Table 5-2
Emission Reductions for National $PM_{2.5}$ Strategy: 60% Utility SO_2 Reduction from Title IV Phase II Levels (thousand tons per year)

RH Control Region[a]	**SO_2**	**NOx**	**VOC**	**Primary PM_{10}**	**Primary $PM_{2.5}$**	**SOA (tons per year)**
Midwest/Northeast	2,789.0	108.6	(1.0)	4.4	0.6	18
Southeast	1,290.4	86.7	(3.0)	10.4	(0.1)	11
South Central	354.1	(9.0)	(0.2)	0.9	0.2	5
Rocky Mountain	72.9	8.8	(0.1)	0.1	0.0	3
Northwest	4.5	0.1	0.0	1.6	0.6	0
West	0.0	(0.1)	0.0	0.0	0.0	0
Nation	4,510.9	195.1	(4.3)	17.4	1.2	36

[a] See Chapter 6 for a discussion of RH Control Regions.

Since utilities are predicted to over control emissions initially and bank allowances for later use, the SO_2 emissions level in 2010 is expected to be 5.2 million tons, or a 47 percent reduction from the NAAQS baseline. The additional 13 percent reduction is expected to be realized sometime after 2010. The estimated annual control cost associated with this baseline control measure in 2010 for the electric power industry is \$2.6 billion (1990\$).

It is important to note that regional shifts in power generation due to utility deregulation, and regional shifts in emissions control responsibility due to emissions trading can mean that reductions in NOx and SO_2 emissions are not realized in specific locations. For instance, note that Table 5-2 indicates minor increases in NOx emissions in the South Central and West control regions.

5.3 Non-Utility Stationary Point Source Control Measures

The non-utility stationary point source category contains a diverse group of sources including combustion sources at various manufacturing operations and institutional facilities, larger surface coating operations, and process fugitive dust sources at mineral processing plants. Examples of stationary point source control measures include “add-on” stack controls (such as fabric filters and carbon adsorbers), process fugitive controls (e.g., wet dust suppression), and combustion modifications (low-NOx burners, etc.). Control costs for these measures are estimated at either the point source or source category level. Where sufficient source data are available for point sources, the cost is calculated using control measure and process size-specific cost equations based on a size indicator available in the emissions inventory. Examples of this indicator include stack gas volumetric flowrate and boiler design capacity.

Other point source emission reduction and control cost estimates are developed from information contained in published reports from State and local agencies. Every effort is made to verify that the estimates derived from these published reports are broadly applicable in a nationwide analysis, and that sound engineering cost procedures are used to develop the published estimates.

5.4 Stationary Area Source Control Measures

The stationary area source category also contains a diverse group of sources including smaller combustion sources at various manufacturing operations and institutional facilities, surface coating operations, and fugitive dust sources like paved and unpaved roads. Examples of area source control measures include combustion modifications (low-NOx burners, etc.), fugitive controls (vacuum sweeping and wet dust suppression), public education programs (the public awareness and education (PACE) program for residential wood combustion emissions), add-on stack controls (incineration), and VOC content limits for coatings and various consumer products.

Since the National Particulate Inventory (NPI) does not contain source-specific information on area sources, emission reduction and control cost estimates are developed from information contained in published reports from State and local agencies. In a few cases, the area source categories correspond to point source categories where control efficiency and control cost estimates are already developed. For example, the cost for low-NOx burner controls on industrial coal, oil, and gas combustion is adapted from low-NOx burner controls for industrial point source boilers. In these cases, the point source control efficiency and cost estimates, expressed in dollars per ton of pollutant reduced, are applied to the area source control. An effort is made, if appropriate, to use the point source data associated with the source size expected to be present in the area source category. Also for a few control measures, control efficiency and control cost estimates are transferred from similar, but not identical, applications. For example, the VOC control measure for metal can coating is transferred from industrial surface coating categories.

In this report, the RH illustrative progress goals are examined under two different emissions control cases: Case A, the case in which fugitive dust control measures are considered in the optimization routine; and Case B, the case in which fugitive dust control measures are not considered in the optimization routine. These control cases are described in more detail in Chapter 3. In Case A, the choice of fugitive dust control measures reflects the adjustment to baseline fugitive dust emissions described in Chapter 4. In Case B, the fugitive dust control measures are removed from the control measures database before the optimization routine begins. A list of these control measures is available in the *Addendum to Control Measures for Regional Haze Alternatives* (U.S. Environmental Protection Agency, 1999b).

5.5 Mobile Source Control Measures

The mobile source control measures employed in the benchmark and baseline for the RH rule are classified in two groups: national measures and local measures. Mobile source control measures that are based on changes in vehicle or engine emission standards are best applied at the national level. It would be expensive and difficult for vehicle and engine manufacturers to comply with a patchwork of standards applied at the local level, and, because motor vehicles and engines are mobile, much of the benefit of vehicle or engine emission standards applied at the local level would be lost to immigration of dirtier vehicles or engines into the local area. In contrast, control measures like vehicle inspection and maintenance (I/M) programs, cleaner burning fuels, and VMT management programs are more effectively implemented at the local level.

5.5.1 National Mobile Source Control Measures

Several potential mobile source control measures involving the creation of new emissions standards for on-highway and nonroad mobile sources were examined. Many of these measures, particularly those involving nonroad and heavy duty engines, have the potential to result in significant long-term reductions in NOx, VOC, and/or PM emissions.

The benchmark for the analyses in this report assumes the existence of a voluntary

National Low Emission Vehicle (NLEV) program. The NLEV program in the baseline is based on California emission standards that are more stringent than the standards required in the Clean Air Act (CAA) (“Tier 1" standards).

The baseline for the analyses in this report includes more stringent standards beyond the “Tier 1" standards noted in the benchmark. Referred to as ?Tier 2" standards, they are to begin as early as the 2004 vehicle model year. The CAA requires the EPA to conduct a "Tier 2" study to determine if additional reductions in emissions from light duty gasoline vehicles (LDGV) and light duty gasoline trucks (LDGT), beyond the Tier 1 standard reductions required in the CAA, are necessary to meet the Ozone NAAQS. The required study is now complete, and it is now part of the Tier 2 standards that are scheduled to be proposed this year. Since this rule is still under review, it is uncertain if the standards as currently prepared by the Agency will be those that are promulgated. The version of the Tier 2 standards currently in the baseline for this report is therefore the same version that was applied in the Ozone and PM NAAQS and proposed RH target program RIA in 1997. The assumptions used in the analyses in this report result in significantly fewer emission reductions than those being proposed in the Tier 2 rulemaking. Thus, mobile source controls applied in this analysis are likely to be required by other rulemakings and the costs, benefits, and economic impacts of meeting these illustrative progress goals would be overstated by some degree. Motor vehicle sales statistics indicate that light duty trucks are becoming a greater proportion of the light duty motor vehicle fleet. At the same time, they are subject to less stringent exhaust emissions standards than passenger cars. Further, the heavier categories of light-duty trucks (those with a GVWR of 6,000 to 8,500 pounds) are not included in the NLEV program, while the lighter categories could have emissions standards tightened to more closely match those for passenger cars.

The following limits are assumed in the RH baseline as listed in Table 5-3 for passenger cars and light duty trucks beginning with the 2004 model year:

Table 5-3
Standards for Tier II Version in Regional Haze Baseline

Category	**NMOG (grams/mile)**	**NOx (grams/mile)**
LDGV	0.075	0.20
LDGT1	0.075	0.20
LDGT2	0.100	0.20
LDGT3	0.195	0.40
LDGT4	0.195	0.40

These standards are chosen to maximize the NOx benefits of the potential Tier 2 program. The non-methane organic gases (NMOG) and NOx standards used in this analysis for the LDGV and LDGT1 categories are identical to those in the NLEV program. The standards for the LDGT2 category are the same for NMOG, but a tighter NOx standard is used in this analysis. The heavier categories of light duty trucks, LDGT3 and LDGT4 categories, are not included in the NLEV program. The LDGT3 standard included in this analysis is less stringent than the equivalent California LEV standard for NMOG but more stringent for NOx. The LDGT4 standard is identical to the equivalent California LEV standard for NMOG but more stringent for NOx. Emission reductions associated with these standards are modeled using MOBILE5a with alternate basic emission rate equations.

Costs for these standards in the final RH rule baseline are based on estimates developed by the California Air Resources Board (CARB) for its LEV program. The CARB estimates the incremental per vehicle cost to achieve LEV standards at $120. Because the LDGV and LDGT1 standards are equivalent to the NLEV standards, no incremental cost is assumed for these vehicles. For the LDGT2 category, it is assumed that because only the NOx standard is further tightened, the additional cost will be half of CARB's estimate for achieving the LEV standard, or $60 per vehicle. For the LDGT3 and LDGT4 categories an incremental cost of $120 per vehicle is assumed.

There are six mobile source control measures in the control measure database employed for the analyses of meeting the illustrative RH progress goals. They are: on-highway heavy-duty diesel vehicle program (HDDV), the non-road HDDV, the fleet inherently low emission vehicle program (fleet ILEV), high enhanced inspection and maintenance (I/M) program, and a transportation control program (TCP). The on-highway HDDV program applies to HDDVs with a gross vehicle weight rating (GVWR) of more than 8,500 pounds (lbs), while the nonroad HDDV applies to nonroad HDDVs above the same GVWR. The fleet ILEV, which is applied to light-duty gasoline vehicle with a GVWR under 8,500 lbs. is based on California emissions standards that are more stringent than the standards required in the CAA (referred to as "Tier 1" standards). The high enhanced I/M program is a control measure applied to light-duty gasoline vehicles with a GVWR under 8,500 lbs that tightens the requirements of current I/M programs applied nationally. The transportation control program used in this analysis is based on a set of voluntary measures applied as part of several innovative pilot programs that reduced the vehicle miles traveled (VMT) in a number of locations nationwide.

5.5.2 Local Mobile Source Control Measures

In this analysis, local mobile source control measures include heavy-duty engine retrofit programs, transportation control programs (TCP) designed to reduce VMT, clean engine fleet vehicles, and clean burning fuels. Each of these control measures is discussed in this section.

5.5.2.1 *Heavy Duty Engine Retrofit Programs*

Heavy duty engine retrofit programs can be applied at the local level to target emission reductions where they are most needed. Heavy duty engines for both highway and nonroad vehicles are a significant source of PM emissions. Tighter standards for new engines (Tier 2 or Tier 3 standards depending on engine size classification), which are included in the 2010 CAA baseline (the benchmark for these RH analyses), will help to reduce PM emissions from the heavy duty highway and nonroad fleets. However, because of slow fleet turnover rates for these engines, significant numbers of older engines certified to less stringent emissions standards will still be present in the fleet in 2015. One way to reduce the emissions of these engines is to upgrade or retrofit them with after-treatment devices. Upgrades or retrofits can be done when the engines are being rebuilt, which typically occurs at least once during their lifetimes.

The EPA has experience with these programs through the existing Urban Bus Retrofit Program. However, the costs and emission reductions associated with broader application of these programs is somewhat uncertain, particularly for nonroad engines. It is assumed that both highway and nonroad engines subject to the program can achieve a 25 percent reduction in PM emissions at a cost of $1,000 per engine. These estimates are based on EPA's experience to date with the existing Urban Bus Retrofit Program, which has achieved similar reductions at similar cost. The number of engine retrofit candidates will vary based on the design of the local program. Based on the limited period preceding the analysis year 2015 over which these programs can be phased in, it is assumed that 25 percent of all pre-1994 highway heavy duty engines still in the fleet in 2010 can be retrofitted. For nonroad engines, it is assumed that 25 percent of all pre-2001 engines can be retrofitted by 2010 (Dolce, 1997).

5.5.2.2 *Transportation Control Measures*

It has been shown in several pilot projects, most notably in the Portland, Oregon metropolitan area, that implementing innovative, voluntary transportation measures can directionally influence the growth rate of VMT. Due to the voluntary nature of these programs and the wide variety of transportation measures available to States and localities, it is difficult to estimate specific reductions in the growth rate of VMT, and hence emission reductions attributable to these measures. However, there is general agreement among expert sources that a nationwide 5 percent reduction in the rate of VMT growth over a 10-year period is reasonable. For instance, an area that had 2.0 percent annual VMT growth would instead experience 1.9 percent growth. The cost of transportation control measures (TCMs) is not easily estimated and will vary depending upon the collection of measures employed and many area-specific factors. In this analysis, the cost of an area-specific package of TCMs that reduces the growth rate of VMT by 5 percent is assumed to be $10,000 per ton of NOx reduced. (Dolce, 1997)

5.5.2.3 *Fleet ILEV Program*

The use of cleaner fuels could be a source of additional emission reductions for the light duty vehicle category. However, estimating the amount of additional exhaust reductions associated with burning cleaner fuels when compared to normal gasoline fueled vehicles already meeting the baseline NLEV standards is uncertain. Certain liquid fuels that have relatively low vapor pressures or gaseous fuels that must be contained in pressurized fuel systems provide clear advantages over normal gasoline with respect to evaporative emissions. Vehicles that properly use these fuels and, as a result, have zero evaporative emissions, are referred to as ILEVs.

The analysis in this report assumes that localities could impose requirements that all centrally-fueled light duty fleet vehicles meet ILEV standards by 2015. These ILEVs are assumed to have no evaporative emissions, to comprise 3 percent of the light-duty vehicle and truck VMT, and to have a lifetime incremental cost of $1800 per vehicle. (U.S. EPA, 1992a)

5.5.2.4 *Reformulated Gasoline*

Beginning with the year 2000, more stringent standards will take effect for all reformulated gasoline (RFG) areas. These standards require that VOC emissions be reduced by about 27.5 percent, and that NOx emissions be reduced by 6.8 percent, on average, relative to the emissions of baseline gasoline as defined in the CAA. These more stringent standards, called Phase II standards, also require a 21.5 percent year-round reduction, on average, in air toxics, which is based on mass reductions in benzene, formaldehyde, 1,3-butadiene, acetaldehyde, and polycyclic organic matter (POM). The EPA had previously determined that the overall cost for Phase II RFG, incremental to the cost of the baseline fuel and including the required addition of oxygen and removal of much of the benzene, would be 5.1 cents per gallon (U.S. EPA, 1993).

Based on the subsequently false assumption that most major cities east of the Mississippi River would be out of attainment for the proposed Ozone NAAQS, the EPA assumed RFG would be chosen as a control strategy over most of this region of the country. The estimated incremental cost for implementing the RFG program under this scenario is 6.7 cents per gallon, reflecting the higher costs associated with reformulating a greater fraction of the gasoline pool. However, based on the benchmark projection, the number of areas which ultimately might use the RFG program represent a much smaller portion of U.S. gasoline consumption than originally assumed.

In addition, the manner in which the full costs of the RFG program are allocated to either VOC control or to NOx control results in the program appearing to be less cost effective than previous EPA projections have indicated. When finalizing the RFG program, EPA evaluated the costs of the VOC and NOx standards independently using only the incremental cost associated with meeting each standard (U.S. EPA, 1993). The EPA thus concluded that the Phase II RFG NOx standard employed in the benchmark for this report is cost effective (about $5,000 per ton of NOx controlled), while the VOC standard similarly is determined to be cost effective (about $500 per ton of VOC reduced). The remaining costs of the program were attributed to the toxics reductions achieved. Clearly, in this RIA where the full costs of the program in the benchmark are allocated to either NOx or VOC control, the cost-effectiveness value will be larger than shown in previous work. The EPA does not view these costs to be inconsistent with previous work because the bases for the analyses are so different.

5.6 Analytical Limitations, Uncertainties, and Potential Biases

The cost and emission control effectiveness estimates for the control measures used in this analysis are developed using inputs from several reliable data sources and using best engineering judgement. Cost and effectiveness values may vary significantly among specific applications due to a variety of source-specific variables. Air pollution officials in airshed planning regions will decide exactly how the area-specific control measures are applied. Their actions will ultimately determine the actual costs and effectiveness of these measures, and of the overall air pollution control program.

The NPI characterizes the emission sources that may potentially be affected by control measures. Because of the vast number of emission sources for most pollutants (e.g., VOC emissions from filling gasoline storage tanks), data are not developed for each individual emission source. Control measure cost estimates are developed by applying cost algorithms to the available information in the NPI. The lack of detailed information in the NPI reduces the level of confidence in the cost estimates, but does not necessarily introduce systematic bias.

For some point source categories appearing in the NPI, data are available for a range of model plant sizes. In such cases, cost equations are developed relating size of the emission production activity to costs. For example, costs for flue gas desulfurization (FGD) scrubbers on SO_2 emission sources are based on a spreadsheet model that relates input parameters such as stack gas flowrate and annual operating time to costs for FGD scrubbers. These variables are available for many point sources in the NPI. For other point source categories and all area and mobile source categories, an average incremental cost-effectiveness value (dollar per ton of emission reduction) or other similar average cost value (cents per gallon of gasoline) is used. Costs are developed at the source category level for these sources because the readily available data do not provide enough information to differentiate costs by emission source size or other cost differentiating parameters. Another limitation relates to many of the PM area source control measures. For many of the area source PM control measures it is sometimes necessary to estimate the PM_{10} cost effectiveness from total suspended particulate (TSP) cost-effectiveness data.

Another source of uncertainty is associated with the fact that costs are estimated for a projected year of 2015 (in 1990 dollars). The projected level of emissions and level of learning and technological innovation that will occur in emission control industries between now and 2015 are inherently uncertain.

Another limitation associated with the cost estimation procedure involves the transfer of cost information, which was developed for other purposes, to this analysis. The extent of this limitation is largely a function of the available cost data. Given the vast number of control measures and potentially affected sources, it is not possible to develop detailed control cost estimates for each individual emission source or even each source classification code (SCC). Cost information is taken from or developed using EPA costing manuals and guidance documents, State and local agency attainment plans, background documents for NSPS, and other sources. Cost methods, where they are adequately documented, are reviewed to verify that correct procedures are used. However, some potential data sources provide emission reduction and cost estimates with little or no supporting documentation. For this reason, several measures lacking sufficient supporting documentation are excluded from this analysis. The extent to which such measures can achieve genuine reductions at the costs estimated is unknown.

In addition, many of the available cost estimates are based on cost studies that were conducted in the 1980s. For this analysis, these estimates are adjusted to reflect 1990 price levels using an appropriate price index. It would be possible, with a significant additional time commitment, to develop current estimates that would reflect any production-oriented advances that may have affected these costs (e.g., any scale production/cost effects that may have occurred from increased demand for the control technology). As noted above, no attempt is made to account for the potential effects of future technological innovations.

5.7 References

Dolce, G. (1997), Letter regarding ozone/PM/regional haze motor vehicle control modeling and costing. Prepared by U.S. Environmental Protection Agency, Office of Mobile Sources, for E.H. Pechan and Associates, Inc.; April.

Perrin Quarles Associates (1997), Rule Effectiveness Analysis. Memorandum to Scott Mathias, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; June.

U.S. Environmental Protection Agency (1992a), Inherently Low-Emission Vehicle Program, Estimate Emission Benefits and Impact on High-Occupancy Vehicle Lanes. Office of Mobile Sources; Ann Arbor, MI; October.

U.S. Environmental Protection Agency (1992b), Guidelines for Estimating and Applying Rule Effectiveness for Ozone/CO State Implementation Plan Base Year Inventories. Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; EPA-452/R-92-010; November.

U.S. Environmental Protection Agency (1993), Final Regulatory Impact Analysis for Reformulated Gasoline. Office of Mobile Sources; Ann Arbor, MI; December.

U.S. Environmental Protection Agency (1994), Rule Effectiveness Guidance: Integration of Inventory, Compliance, and Assessment Applications. Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; 452/R-94-001; January.

U.S. Environmental Protection Agency (1998a), Analyzing Electric Power Generation Under the CAAA. Office of Air and Radiation; Washington, D.C.; March.

U.S. Environmental Protection Agency (1998b), Control Measures Analysis for Regional Haze Alternatives. Office of Air Quality Planning and Standards; Research Triangle Park, N.C. December.

Chapter 6. EMISSION REDUCTIONS, AIR QUALITY, VISIBILITY AND COST IMPACTS

6.1 Results in Brief

The final regional haze (RH) program is designed to ensure reasonable progress toward visibility goals that States and/or regional planning boards may set. It allows broad discretion on the part of the States in determining control measures to be imposed based on statutory criteria. Under the structure of the final RH rule, the States are able to consider the cost of emission reduction strategies in light of the degree of visibility improvement to be achieved. For this Regulatory Impact Analysis (RIA) the individual decisions on effectiveness of each of the control strategies applied in each region is modeled in a very limited way. With more time and better emissions inventories, better characterization of the emissions, better air quality relationships, technological change, and the ability to consider other visibility progress goals, the actual cost of implementation may be less than what is presented in this RIA. It is expected that the incremental control costs (and also the benefits and economic impacts) of the final RH rule may be less than estimated in this RIA. There may be some positive incremental costs of the RH rule as a result of administrative activities (e.g., planning, analysis, etc.) and Best Available Retrofit Technology (BART) controls for some establishments in certain source categories. The administrative costs are shown in Chapter 7, and a presentation of costs associated with BART controls is available in Section 6.6.3.

It should be noted that there is substantial progress towards these illustrative RH goals in the analysis year 2015[1] resulting from partial attainment of the particulate matter (PM) and Ozone NAAQS promulgated in 1997 including the Tier II version described in Chapter 5 that is in the baseline for the RH rule. There is also additional progress toward these illustrative goals from implementation of the other control measures in the baseline for the RH rule (the 60 percent control of sulfur dioxide (SO_2) beyond Title IV requirements, listed in Chapter 5 of this report). From 46 to 55, or 38 to 45 percent, of the Class I area counties meet the two absolute illustrative RH progress goals considered in this RIA based on implementation of the control strategies in the benchmark case. From 27 to 47, or 22 to 39 percent of the Class I area counties meet the two relative illustrative RH progress goals considered in this RIA based on implementation of the control strategies in the baseline case. It should also be noted that among those Class I area

---

[1] 2018 is the end of the period for the first long-term strategy. The term "long-term strategy" refers to the set of emission reduction measures the State includes in its SIP in order to meet the reasonable progress goal it has set. 2015 is a nominal "snapshot" year that reflects the partial attainment control cases for the Ozone and $PM_{2.5}$ NAAQS included in the baseline, and is near the end of the period for the first long-term strategy.

counties not meeting the illustrative RH progress goals, few of them are expected to be more than 0.2 deciview away from the illustrative goal.

Based on projected emissions levels for the year 2015, and with partial attainment of the Ozone and particulate matter ($PM_{2.5}$) National Ambient Air Quality Standards (NAAQS) as modeled in the 1997 RIA for the final 8-hour Ozone and $PM_{2.5}$ NAAQS and proposed RH target program (henceforth referred to as the "1997 RIA") in the baseline, and for emissions control cases in which fugitive dust controls are considered or not (Cases A and B), this analysis estimates that 19 counties having Class I areas under Case A need additional emission reductions to meet the illustrative progress goal of 1.0 deciview (dv)/10 years for the period of the first long-term strategy. This analysis also estimates that 32 counties having Class I areas under Case B need additional emission reductions to meet the same illustrative progress goal for the period of the first long-term strategy. This analysis also estimates that under Case A 12 counties having Class I areas need additional emission reductions to meet the illustrative progress goal of 1.0 dv/15 years for the period of the first long-term strategy (i.e., an average of a 0.67 deciview improvement from benchmark air quality conditions), and this analysis estimates that under Case B 19 counties having Class I areas need additional emission reductions to meet the same illustrative progress goal for the period for the first long-term strategy.

In response to comments on the proposal RH RIA, this final RH RIA also looks at two relative illustrative progress goals. These goals are defined in Chapter 3 of this RIA. Based on projected emissions levels for the year 2015, and with partial attainment of the ozone and $PM_{2.5}$ NAAQS as modeled in the 1997 RIA in the baseline, and for emissions control Cases A and B, this analysis estimates that 68 mandated Class I areas under Case A need additional reductions to meet the illustrative progress goal of 10% dv/10 years for the period of the first long-term strategy. This analysis also estimates that 83 counties having Class I areas under Case B need additional reductions to meet the same illustrative progress goal for the period of the first long-term strategy. Finally, this analysis also estimates that under Case A that fourteen counties having Class I areas need additional reductions to meet the illustrative progress goal of 5% dv/10 years for the most impaired days from for the period of the first long-term strategy, and this analysis estimates that under Case B 21 counties having Class I areas need additional reductions to meet the same amount of visibility improvement for the period of first long-term strategy.

The additional cost of any implementation of the illustrative RH progress goals will vary depending on the visibility goals submitted and approved as part of State plans. If the goals are adjusted through that process to parallel the implementation programs for the new Ozone and PM standards, the costs for meeting the adjusted goals in those areas will be borne by the Ozone and PM programs. In this analysis, incremental costs are estimated for uniform application of the illustrative progress goals for every mandatory Class I Federal area under either Case A or B.

For the two absolute illustrative progress goals, the additional control cost associated with meeting the progress goal of 1.0 dv/10 years in 56 counties having Class I areas, while partially meeting the progress goal in another 19 counties is estimated to be $1.7 billion (1990 dollars) under Case A. Under Case B, the additional control cost associated with meeting the same progress goal in 43 counties having Class I areas while partially meeting the same progress goal in another 32 counties is estimated to be $1.4 billion (1990 dollars). The additional control cost under Case A associated with meeting the illustrative progress goal of 1.0 dv/15 years in 54 counties having Class I areas while partially meeting the goal in 12 counties is estimated to be $1.1 billion (1990 dollars). Under Case B, the additional control cost associated with meeting the illustrative progress goal of 1.0 dv/15 years in 47 counties having Class I areas, and partially meeting the goal in 19 counties is estimated to be $0.8 billion (1990 dollars).

For the two relative illustrative progress goals, the additional control cost under Case A associated with meeting the goal of 10% dv/10 years in twenty-six counties having Class I areas while partially meeting the goal in 68 counties is estimated to be $4.4 billion (1990 dollars). Under Case B, the additional control cost of meeting this same illustrative progress goal in eleven counties having Class I areas while partially meeting the goal in 83 counties is estimated to be $3.6 billion (1990 dollars). The additional control cost under Case A with meeting the goal of 5% dv/10 years in 60 counties having Class I areas while partially meeting the goal in fourteen counties is estimated to be $1.5 billion (1990 dollars). Under Case B, the additional control cost with meeting this progress goal in 53 counties having Class I areas and partially meeting the goal in twenty-one counties is estimated to be $1.2 billion (1990 dollars).

In summary, the expected annual control cost nationwide in 2015 associated with the RH illustrative progress goals ranges from between $0 to a maximum of $4.4 billion under Case A, and from between $0 to a maximum of $3.6 billion (1990 dollars) under Case B. A comparison to the RH targets (now called absolute illustrative progress goals) analyzed for the proposal RH program shows that the additional control costs are estimated to be about 40 percent less than before under Case A, and more than 50 percent less under Case B. The number of Class I areas that can meet the 1.0 dv/10 years illustrative progress goal increases under Case A (28 v. 19) relative to the estimate given for proposal, but decreases under Case B (28 v. 32). In addition, the number of Class I areas that can meet the 1.0 dv/15 years illustrative progress goal also increases under Case A (17 v. 12) relative to the estimate given for proposal, but decreases under Case B (17 v. 19). The ability of the air quality modeling to account for the contribution of VOC and PM controls to improved visibility (as explained in Chapter 4) is the primary reason for the lower control cost estimates for these goals under either emissions control case. The exclusion of fugitive dust controls from the least-cost optimization for these goals also leads to lower additional control costs but also fewer counties having Class I areas able to meet the illustrative progress goals. This reflects the differences in the post-control air quality profiles that results from removal of the fugitive dust control measures. A list of these control measures is in Chapter

5.

The estimates of the incremental cost of illustrative progress goals are also affected by: 1) an analysis baseline that understates the visibility progress achieved by CAA mandated controls and implementation of a new Ozone standard over the period of the first long-term strategy; 2) the inability to accurately model full attainment of the 8-hour Ozone and $PM_{2.5}$ NAAQS in the baseline; and 3) how close some of the residual Class I area counties are to natural background conditions. These factors suggest that the actual cost of achieving visibility improvements incremental to the baseline for this report could be lower.

It should be noted that direct quantitative comparison of the cost results for Cases A and B is not warranted due to the difference in the number of counties having Class I areas that are not able to meet the illustrative RH progress goals. However, it does suggest the importance of improved emission inventories, air quality modeling, and the concomitant control strategy design.

6.2 Introduction

This chapter presents the air quality and visibility improvements, emission reductions, and cost impacts resulting from additional controls needed by the year 2015 to meet the illustrative RH progress goals under emissions control Cases A and B presented in Chapter 3. Emissions and air quality changes are inputs to the benefits analysis presented in Chapter 9. This analysis also estimates the projected costs (in 1990 dollars) of installing, operating, and maintaining those additional controls needed by the year 2015 to meet the illustrative RH progress goals in our nation's Class I designated areas. These control costs are inputs to the economic impact analysis presented in Chapter 8. The administrative cost associated with these illustrative RH progress goals is addressed in Chapter 7.

The following sections in this chapter cover:

- Methodology for estimating emissions, air quality, and cost impacts associated with the illustrative RH progress goals;

- Emission reduction, air quality improvement, and control cost results associated with the illustrative RH progress goals; and

- Analytical uncertainties, limitations, and potential biases for these results.

6.3 Emissions, Emissions Reduction, Visibility Improvement, and Cost Methodology

This analysis estimates the emission reductions for achieving air quality improvements to meet the illustrative RH progress goals described in Chapter 3 in Class I area counties that are projected to not meet these goals. Since Class I areas rarely contain emissions sources, and because pollutants that degrade visibility can be transported over long distances by prevailing winds, controls must be imposed on sources located outside of Class I areas that contribute to visibility degradation in Class I areas.

The baseline for the RH analysis is the projected emissions inventory from the partial attainment case of the Ozone, PM_{10} and $PM_{2.5}$ 15/65 NAAQS presented in the 1997 RIA, which includes a modest version of the Tier II program described in Chapter 5 of this RIA. The emissions control possibility set includes measures that are not already selected in that analysis.

The projected end of the period of the long-term strategy for achieving and evaluating visibility improvement is 2018. In order to evaluate visibility improvements, visibility monitors must be established in the Class I areas of concern, and it is likely to take a few years to establish these monitors. Ideally, this RIA would evaluate the potential improvements in visibility for the period of the first long-term strategy, and would account for emission reductions achieved from current CAA-mandated controls (e.g., Title IV SO_2 cap on utility sources) and the promulgated $PM_{2.5}$ and Ozone NAAQS (including the modest version of the Tier II program in the RH baseline). However, this requires developing an emissions inventory current as of the first year of the long-term strategy period and a set of control measure impacts incremental to the first year of this period. Instead, the RH analysis takes advantage of the 2010 emissions inventory and incremental control measure database established for the $PM_{2.5}$ and Ozone analyses conducted for the 1997 RIA.

Control costs for attaining the illustrative RH progress goals are evaluated incremental to partial attainment of the current PM_{10} NAAQS, and the current Ozone and $PM_{2.5}$ NAAQS (including the modest version of the Tier II program in the RH baseline). If a Class I area is projected to meet the illustrative progress goals in the year 2015 as a result of ozone and $PM_{2.5}$-related control measures (i.e., baseline control measures), no additional control is needed. However, if the goal is not met, additional control measures are modeled. This baseline provides conservative estimates (i.e., potentially overstates) of the cost of achieving RH progress goals for two reasons. First, the progress achieved by measures related only to $PM_{2.5}$ control through the year 2015 does not include progress achieved due to measures already mandated under the 1990 CAA, or progress achieved due to controls needed to meet the new Ozone standard. These control measures, which are not in the baseline of the RH analysis, may contribute to further visibility improvement over the period of the first long-term strategy. Second, applying the set of control measures included in the $PM_{2.5}$ NAAQS analysis in the 1997 RIA results in residual nonattainment for some areas. To the extent that these areas are actually able to achieve additional reductions to attain the $PM_{2.5}$ standard, further visibility improvements may also be realized.

The 2010 baseline air quality reflective of CAA-mandated controls and additional controls associated with partial attainment of the current 8-hour Ozone and $PM_{2.5}$ NAAQS and the current PM_{10} NAAQS is the primary input to the cost analysis. The 2010 baseline air quality is a proxy for baseline air quality in the 2015 analysis year. Chapter 4 explains the bases of, and assumptions pertaining to, the 2010 emissions and air quality projections. The cost and emission reductions associated with each illustrative RH progress goal are estimated from a "layered" control baseline that incorporates the 2010 baseline air quality *plus* partial attainment of the current PM_{10} NAAQS *plus* the current ozone NAAQS *plus* partial attainment of the current PM_{10} NAAQS. From this baseline, the four illustrative RH progress goals (two for absolute improvement and two for relative improvement) described in Chapter 3 are analyzed. These goals are: 1.0 dv/15 years, 1.0 dv/10 years, 5% dv/10 years, and 10% dv/10 years.

Figure 6-1 shows the analysis steps that make up these baselines for projecting impacts to 2015.

Figure 6-1
Regional Haze Analysis Baselines through 2015

Regional Haze Analysis Baseline

2010 CAA Baseline ------------> Attain Current PM_{10} NAAQS ------------> Attain Current Ozone and $PM_{2.5}$ NAAQS (includes modest Tier II version mentioned in Chapter 5)

For achieving these illustrative RH progress goals under both emission control Cases A (with fugitive dust controls) and Case B (without fugitive dust controls), control measure selection is modeled using a broader *regional* approach that is more appropriate for addressing air quality problems caused by trans-boundary pollution transport. The particles in many of the pollutants and chemical species that contribute to visibility impairment (particularly $PM_{2.5}$) can be transported over long distances by prevailing winds. Since sources outside of Class I area counties projected not to meet an illustrative RH progress goal may significantly contribute to visibility impairment in those counties, controls may be imposed on sources outside the boundaries of Class I area counties projected to be unable to meet an illustrative progress goal. Given the long-range transport of pollutants and chemical species that contribute to visibility impairment, air quality changes will be realized in Class I area counties that meet the illustrative progress and in counties outside nonattainment counties, some of which initially meet the illustrative progress goals. Ultimately, state and local air pollution control authorities, in cooperation with federal efforts, will devise implementation strategies that achieve visibility improvement goals in a manner that minimizes negative impacts.

As discussed in Chapter 4, the modeled PM concentrations that are inputs to the cost optimization model are normalized based on factors from ambient concentrations for 711 counties in the contiguous U.S. where monitoring data meets the Agency PM data completeness criteria. These 711 counties are divided into Tiers 1, 2, and 3, with Tier 1 counties (504 out of the 711) having the most complete PM monitoring data.

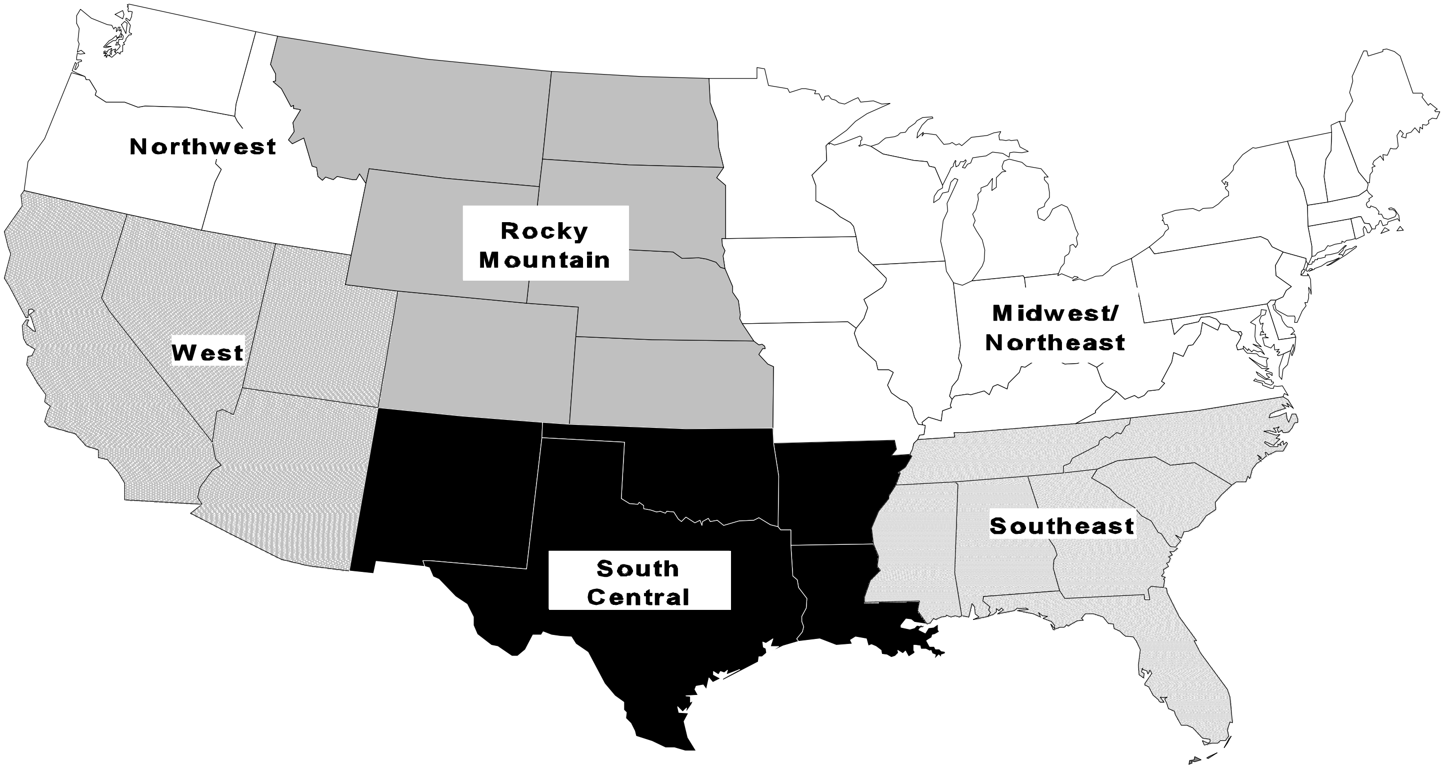
The analysis is confined to analyzing visibility improvements in the 147 Class I areas located in 121 counties in the 48 contiguous States[1]. Further, the set of Class I areas is subdivided into six control regions. The boundaries of these six control regions are depicted in this chapter in Figure 6-2. The boundaries of these regions are delineated to reflect both the meteorological conditions that influence the long-range transport of visibility precursors and the locations of their major sources (e.g., electric utilities). Control measure selection is limited to emission sources in each control region. In addition, selection of some control measures that primarily affect coarse particles (i.e., particles greater than 2.5 microns) is limited to the county containing the Class I area. This limitation prevents control measures that have a minor effect on visibility (e.g., fugitive dust control for unpaved roads) from being selected in counties that are relatively distant from Class I areas. This limitation is pertinent for understanding the results based on Case A (the emissions control case with fugitive dust controls), but not from Case B (the emissions control case without fugitive dust controls).

---

[1] There are 156 Class I areas in the United States, with 9 Class I areas in Alaska and Hawaii. These States are not included in the modeling for the analyses that are in this RIA.

Figure 6-2

Control Regions in RH Optimization Model



6.3.1 Selecting Control Measures Using the RH Optimization Model

The allocation of SO_2 control responsibility and the control measures selected for sources in the utility sector are analyzed using outputs from the Integrated Planning Model (IPM) (U.S. EPA, 1996). Control measures for all other emissions sectors are selected using the RH optimization model. The types of control measures available to both utility and non-utility sources is discussed in Chapter 5 of this RIA.

The RH optimization model works in a manner similar to the PM optimization model discussed in Chapter 6 of the 1997 RIA. However, in this case, the receptor county of interest contains a Class I area, and reductions in $PM_{2.5}$ precursors at the receptor are translated into improvements in visibility (i.e., reductions in light extinction).

The remainder of this section describes the optimization model used for selecting non-utility control measures in each of the RH modeling regions, and also how changes in visibility are estimated. The optimization model uses several inputs to determine which control measures to apply to meet the illustrative RH visibility progress goals. These inputs are the: 1) Incremental Control Measure Data File, 2) Source-Receptor (S-R) Matrix, and 3) Receptor Input File. Each of these inputs will be described below, after which the optimization procedure will be discussed.

6.3.2 Incremental Control Measure Data File

This file contains the incremental precursor pollutant emission reductions and the total annual cost (in 1990 dollars) for each individual control measure-emission source combination. Each of the emission sources is given a "source number" that is indexed to the S-R matrix (described below). The NOx control measure data have been revised since the RIA for the proposed RH target program was published in order to include control measure cost and efficiency data developed for the final NOx State Implementation Plan (SIP) call RIA. Chapter 5 presents and discusses the control measures used in this analysis.

It should be noted that the costs estimated in this report 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 not affect total cost estimates. The year 1990 was selected as the cost reference date to be consistent with the base year for the cost analysis in this report. 1990 is also the base year found in the cost analyses in the 1997 PM and Ozone NAAQS and proposed RH target program RIA and the final NOx SIP call RIA. Finally, to be consistent with the real-dollar analytical basis, a 7 percent real interest rate was used, in accordance with Office of Management and Budget guidance.[1]

The incremental control measure data file is created via optimization on *average annual incremental cost per ton.* For purposes of this analysis, average incremental cost per ton is defined as the *difference* in the annual cost of a control measure and the annual cost of the baseline control (if any), divided by the *difference* in the annual mass of pollutant emissions removed by the control measure and the emissions removed by the baseline control.

The average annual incremental cost per ton is calculated at the source or unit level for point source control measures and at the county level for area and mobile source control measures. For any individual source (e.g., boiler), only the control measures that are most cost-effective at reducing emissions that contribute to visibility impairment are included in the incremental control measure data base. This step eliminates inefficient solutions.

Consider, for example, a furnace that emits 1000 tons per year of primary $PM_{2.5}$. Suppose that this source could be controlled by one of three control devices: 1) fuel gas desulfurization (FGD) scrubber; 2) fabric filter; or 3) electrostatic precipitator (ESP). Further suppose that the associated annual costs, emission reductions, and the average annual incremental cost per ton for these devices is shown in Table 6-1.

Table 6-1
Hypothetical Furnace Control Measures

Control Device	Annual Cost ($/year)	$PM_{2.5}$ Emission Reduction (tons/year)	Average Annual Incremental Cost per Ton ($/ton)
Scrubber	700,000	950	740
Electrostatic Precipitator	600,000	970	620
Fabric filter	800,000	990	810

In this illustration, the ESP is superior to a scrubber from a cost-effectiveness perspective at $620 per ton, as it provides the more emission reduction at a lower annual cost. Because the scrubber provides the lowest emission reduction at a cost greater than that of the ESP, it would never be selected. The fabric filter provides the highest emission reduction (990 tons per year), but its

---

[1] It should be noted that the analyses in this RIA, including the control cost analysis, is a “snapshot” analysis in which results are estimated for a future year (2015). In the case of an analysis in which streams of benefits and costs are brought back to a single net present value, the Agency employs a social discount rate. The discount rate used in this RIA is not the social discount rate. That rate is likely to be well below 7 percent.

annual cost is also the highest of the three options. Because it provides a higher emission reduction than the ESP, even at a higher cost, the fabric filter would be retained in the control measure data base.

6.3.3 Source-Receptor Matrix

The S-R matrix discussed in Chapter 4 provides a link between emission reductions and resulting air quality concentrations. When a control measure from the incremental control measure data file is applied at a source, concentrations for pollutant emissions may be reduced by some amount at *all* associated receptors (i.e., counties) across the multi-state control region.

The S-R matrix was developed from an air quality model that divides sources into two general categories: *elevated point sources* and *area/mobile sources*. In turn, the elevated point sources are aggregated into three categories: 1) sources with effective stack (release) heights less than 250 meters; 2) sources with heights between 250 and 500 meters; and 3) sources with heights above 500 meters. Except for the last category, all sources are assumed to be situated at the population centroid of the county in which they are located. The >500 meter sources are sited according to their individual longitude/latitude coordinates.

The S-R coefficients for a given source and all receptors determine the concentration reductions that occur in proportion to the emission reductions provided by a given control measure. The RH optimization model calculates the light extinction at each Class I area county centroid. If any Class I area county is predicted to fall short of the illustrative progress goal, the optimization model, the control measure selection process is repeated until all Class I area counties meet the illustrative progress goals or a minimum cost per deciview reduced threshold is exceeded by all remaining measures.

Control selection is based on the *cost per average deciview (dv) reduction* rather than average cost per microgram per cubic meter used in the PM NAAQS optimization model. Controls are selected until the modeled dv reduction is achieved in all Class I area counties (in the control region) or until a cost per average deciview of $1 billion is exceeded by all remaining measures. This threshold prevents control measures a great distance from counties not meeting an illustrative progress goal and have little influence on concentrations and visibility in the receptor counties from being applied.

For example, the order of selection on an average incremental cost per ton or average incremental cost per deciview basis for controlling Volatile Organic Compounds (VOC) emissions in a hypothetical county may be: 1) pressure/vacuum vents and vapor balancing for Stage I service station refueling, 2) VOC incineration for metal can coating operations, and 3) VOC content limits and improved transfer efficiency for autobody refinishing operations. However, each of these individual measures has the same S-R coefficient and source number, because all area sources in a county are assumed to release their emissions at the same height and location (the county centroid). Consequently, the cost per microgram per cubic meter reduced, which, within a given aggregation of sources, is directly proportional to the cost per ton reduced, will follow the same order of selection as the *average incremental cost per deciview reduced* of precursor reduced. Table 6-2 provides an indication of the magnitude of the S-R coefficients for a hypothetical receptor (Acme County).

Table 6-2
Simple Illustration of S-R Coefficients For
The Hypothetical Acme County Receptor

Source (all in the county)	Primary $PM_{2.5}$ Coefficient	Nitrate Coefficient	Sulfate Coefficient	Ammonia (NH_3) Coefficient
Point (0-250m)	$0.154x10^{-7}$	$0.191x10^{-8}$	$0.392x10^{-9}$	$0.147x10^{-7}$
Point (250-500m)	$0.258x10^{-8}$	$0.243x10^{-9}$	$0.518x10^{-10}$	$0.277x10^{-8}$
Area Sources	$0.224x10^{-7}$	$0.267x10^{-8}$	$0.546x10^{-9}$	$0.215x10^{-7}$

The units of the coefficients are *seconds per cubic meter*. The S-R matrix coefficients generally decrease with distance, dropping off rapidly beyond a one or two county layer from the receptor county. To illustrate how these coefficients are used to calculate changes in air quality, consider a 1,000 ton per year reduction in primary $PM_{2.5}$ emissions from area sources in Acme County. The change in $PM_{2.5}$ concentration is calculated as follows:

Reduction = (1,000 tons/year)(0.224 x 10^{-7} sec/m^3)(28,767 micrograms-yr/ton-sec)
= 0.644 micrograms per cubic meter,
where 28,767 is the micrograms-yr/ton-sec conversion factor.

6.3.4 Receptor Input File

This file contains the starting total county-level normalized PM_{10} and $PM_{2.5}$ concentrations for the 2010 CAA baseline emissions and partial attainment Ozone and $PM_{2.5}$ NAAQS scenarios. The normalization procedure used to calibrate predicted concentrations to actual monitor data is described in Chapter 4.

6.3.5 Number of Monitored Counties

This analysis selects control measures for meeting RH illustrative progress goals based on a set of $PM_{2.5}$ monitoring data from a subset of counties currently monitored for PM_{10}. There are 711 counties that currently contain monitors capable of measuring PM_{10} air quality; however, only 504 of these monitors meet what is referred to in this analysis as *Tier 1* criteria. Chapter 4 provides a more detailed discussion of the monitoring criteria used to establish tiers.

6.3.6 Scaling Annual Average Deciview Values Relative to Average Peak Values

The illustrative RH progress goals analyzed in this RIA are meant to examine a deciview (or absolute) change or a percentage (relative) change in the average deciview value of the 20 percent worst days over a 10-year period. However, the S-R matrix used to estimate pollution concentrations that contribute to RH formation, outputs annual average values for the pollutants of concern (ammonium sulfate, ammonium nitrate, organic and elemental carbon, and primary PM_{10} and $PM_{2.5}$). This analysis uses the most recent monitoring data from Class I areas to translate a deciview change or a percentage deciview change in the 20 percent worst days to an equivalent change for an annual average day. Appendix C contains the data used to make this calculation.

The average of the 20 percent worst days each year is also be referred to as the 90th percentile value, and can be compared to the annual average or mean value. The ratio of the 90th percentile deciview value to the mean deciview value varies by Class I area. Based on the most recent Interagency Monitoring for Protection of Visual Environments (IMPROVE) data, the average ratio of the 90th percentile deciview value to the mean deciview value for all Class I areas is 1.4. Therefore, a 1.0 deciview change in the 20 percent worst days correlates to a 0.7 deciview change in the annual average day (1.0 divided by 1.4). Similarly, a 0.67 deciview change in the 20 percent worst days correlates to a 0.5 deciview change in the annual average day (0.67 divided by 1.4). These annual average equivalent values are used in this analysis. For the relative progress goal, the same adjustment occurs. A 10 percent deciview change in the 20 percent worst days correlates to a 7 percent deciview change in the annual average day (10 divided by 1.4). Finally, a 5 percent deciview change in the 20 percent worst day days correlates to a 3.5 percent deciview change in the annual average day (5 divided by 1.4).

6.3.7 Estimating Visibility

Decreases in visibility are often directly proportional to decreases in light transmittance in the atmosphere (Trijonis et al., 1990). Light transmittance is attenuated by scattering and absorption by both gases and particles. The light-extinction coefficient is a measure of the total fraction of light that is attenuated per unit distance (Sisler, 1996):

$$b_{ext} = b_{Ray} + b_{sp} + b_{ag} + b_{abs}$$

where:

b_{ext} = total light extinction coefficient (1/Mm),
b_{Ray} = light extinction coefficient due to natural Rayleigh scatter (1/Mm),
b_{sp} = light extinction coefficient due to scattering by particles (1/Mm),
b_{ag} = light extinction coefficient due to absorption by gases (1/Mm), and
b_{abs} = light extinction coefficient due to absorption by particles (1/Mm).

The light extinction coefficient is calculated by multiplying the concentration of an aerosol species by its light-extinction efficiency, and summing over all species.

The term b_{Ray} refers to the natural Rayleigh scatter from air molecules, mainly nitrogen and oxygen. Depending on altitude, this term has a value of 9 to 12 Mm^{-1} (inverse megameters) (Sisler and Malm, 1994).

The term b_{sp} can be broken into the various species of fine and coarse particles that scatter light. Because fine particles are much more efficient at light scattering than coarse particles, several fine particle species are specified, whereas coarse particles are kept as one category. Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon (soot), and soil (Sisler, 1996).

A complicating factor for sulfates, nitrates, and some organic compounds is that these aerosols are hygroscopic, i.e., they absorb water, which greatly enhances their light-scattering abilities. The amount of water absorbed is a function of the relative humidity. A relationship between the relative humidity and scattering efficiency for ammonium sulfate aerosols has been developed, and is also applied to ammonium nitrate aerosols (Sisler, 1996). Recent research indicates that organics are not hygroscopic to weakly hygroscopic (Sisler, 1996) and thus in this analysis, the light scattering efficiency for organics is not assumed to be a function of the relative humidity.

A detailed expression for b_{sp} can thus be written (Sisler, 1996):

$$b_{sp} = 3f(RH) \cdot [SULFATE] + 3f(RH) \cdot [NITRATE] + 4[OMC] + 1[SOIL] + 0.6[CM]$$

where:

3 = dry scattering efficiency of sulfate and nitrates (m^2/g),
$f(RH)$ = function describing scattering characteristics of sulfates and nitrates, based on the relative humidity (unitless),
[*SULFATE*] = concentration of ammonium sulfate aerosols ($\mu g/m^3$),
[*NITRATE*] = concentration of ammonium nitrate aerosols ($\mu g/m^3$),
4 = dry scattering efficiency of organic mass from carbon (m^2/g),
[*OMC*] = concentration of organic aerosols ($\mu g/m^3$),
1 = dry scattering efficiency of soil (m^2/g),
[*SOIL*] = concentration of fine soil ($\mu g/m^3$),
0.6 = dry scattering efficiency of coarse particles (m^2/g), and
[*CM*] = concentration of coarse particles ($\mu g/m^3$).

The function *f(RH)* is calculated as follows:

$$f(RH) = t_0 + t_2(1/(1-RH))^2 + t_3(1/(1-RH))^3 + t_4(1/(1-RH))^4$$

where:

RH = relative humidity, and
t_x = parameters presented in Table 6-3 below.

Table 6-3
Parameter Determining the Effect of Relative Humidity on Visibility

Season	t_0	t_2	t_3	t_4
Spring	0.7554	0.3091	-0.0045	-0.0035
Summer	0.5108	0.4657	-0.0811	0.0043
Autumn	-0.0269	0.8284	-0.1955	0.0141
Winter	1.1886	0.2869	-0.0332	0.0011
Annual	0.5176	0.5259	-0.0947	0.0056

Source: Table 5.1, Sisler, 1996.

The term b_{ag} represents absorption due to gases; NO_2 is the only major light-absorbing gas in the lower atmosphere. This component is assumed to be negligible since concentrations of NO_2 are expected to be negligible in rural areas (Sisler and Malm, 1994), which is generally applicable for Class I areas. However, this may be a poor assumption for locations close to significant NO_x emission sources, such as power plants or urban areas (Sisler, 1996). Under those conditions, the visibility improvement due to reductions in NO_2 could be understated.

The final term of the light-extinction coefficient equation, b_{abs}, represents absorption of light by elemental carbon (EC). Recent research has indicated that direct measurements of absorption by the laser integrated plate method (LIPM) are much more accurate than using absorption estimates based on mass concentrations of light-absorbing carbon. For that reason, this analysis bases b_{abs} on empirical data from monitored sites in the IMPROVE network.

Once the light-extinction coefficient is determined, the visibility index called deciview (*dv*) can be calculated (Sisler, 1996):

$$dv = 10 \cdot \ln(b_{ext} \cdot 10^{-3} / 0.01\, km^{-1})$$

where:

10^{-3} = constant to convert Mm^{-1} to km^{-1}.

A change of one *dv* represents a change of approximately 10 percent in b_{ext}, “which is a small but perceptible scenic change under many circumstances” (Sisler, 1996, p.1-7).

6.3.8 Estimating the Effect of Control Measures on Visibility

Given the available data available from the IMPROVE monitoring network and the changes in sulfate, nitrate, elemental carbon, organic carbon, and primary PM emissions modeled using the S-R matrix described earlier in this chapter and in Chapter 4, light extinction (b_{ext}) is calculated using the following equation:

$$\begin{aligned} b_{ext} = {} & b_{Ray} + 3f(RH) \cdot [SULFATE] + 3f(RH) \cdot [NITRATE] + \\ & 4[OMC] + 1[SOIL] + 0.6[CM] + b_{abs} \end{aligned}$$

The S-R matrix provides concentration estimates of ammonium sulfate (SULFATE), ammonium nitrate (NITRATE), organic and elemental carbon (OMC), fine particle soil (SOIL), and coarse mass (CM= PM_{10} - $PM_{2.5}$). A common assumption for light scattering by background gases (b_{Ray}) is 10 Mm^{-1}. Appendix C provides estimates for f(RH), OMC, SOIL, and b_{abs} based on summary data from 43 relevant IMPROVE monitoring sites between 1992-1995. For Class I areas without monitoring data, values are assigned based on either the closest monitored site or an average of up to three proximate monitored sites. The values are assumed constant in this analysis, even though it is known that certain types of control measures may affect the baseline levels of OMC and b_{abs}. The exact relationship between these factors and specific control measures has not been established, and therefore, these values are held constant. These values then serve as inputs to the RH optimization model.

6.3.9 RH Optimization Model Routine

The optimization routine developed for this analysis employs the following steps:

<u>Step 1</u>. The remaining control measures in the incremental control measure data file are sorted by source number, precursor pollutant controlled, and cost per ton of pollutant reduced.

<u>Step 2</u>. The *incremental* improvement in visibility is calculated *for each Class I area county* for the least costly (on a cost per ton basis) control measure for each individual source/pollutant combination.

<u>Step 3</u>. The measure with the *lowest average cost per increment of visibility improvement* is selected and the deciview levels at each receptor are adjusted to reflect implementation of the selected measure.

<u>Step 4</u>. Steps 2 through 3 are repeated until all input receptors meet the target level *or* all remaining measures are exhausted. A $1 billion per microgram per cubic meter control measure selection threshold (translated into a cost per average deciview threshold) is used in the RH optimization model. The annual cost threshold of $1 billion per microgram per cubic meter is the one used in the PM optimization model.

<u>Step 5</u>. Adjust final post-control visibility predictions in all Class I areas nationwide to account for the trans-boundary effect of control measures selected outside each control region.

Figure 6-3 provides a flowchart for the RH optimization routine.

To illustrate steps 3 and 4, consider the example shown in Table 6-4. This table lists three control measures (A, B, and C) and four receptors (counties 1, 2, 3, and 4). The annual cost (in millions of 1990 dollars per year) is given for each control measure. Also listed for each measure is the deciview improvement at each receptor that result if that measure is applied. For control measure A, these improvements range from 0.1 to 0.3 dv, and average 0.23 dv (column 2). Listed below these reductions are the cost-per-microgram-per-cubic meter ratios for each of the four receptors. These ratios are obtained by dividing the annual cost for control measure A by each of the four $PM_{2.5}$ reductions. The last number in column 2 is the ratio of the annual cost for control measure A divided by the average microgram per cubic meter $PM_{2.5}$ reduction among the four receptors. Similar calculations are made for control measures B and C, in turn.

Table 6-4
Simple Illustration of the Calculation of Cost per Average Deciview Reduced

		Control Measure A	Control Measure B	Control Measure C
Cost (million $/yr)		1.0	1.5	1.5
Deciview reduced (dv)				
	Receptor 1	0.20	0.30	0.80
	Receptor 2	0.30	0.40	0.10
	Receptor 3	0.10	0.50	0.10
	Receptor 4	0.30	0.40	0.25
	Average	0.23	0.40	0.25
Cost per deciview reduced				
	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

The control measure selected in this optimization scheme is the one that gives the lowest cost per average deciview reduced. Based on this decision criterion, control measure B is selected first, followed by measure A and measure C, as needed. But suppose, for instance, that the application of measure B brought receptors 2 through 4 into compliance with the illustrative RH progress goal of interest. If that is the case, the next iteration of the optimization model results in the selection of measure C, in preference to measure A. Why? Since control measure B brought receptors 2 through 4 into compliance, they are no longer included in the calculation of the cost per average deciview reduced. This leaves only receptor 1 under consideration. And, as Table 6-4 shows, control measure C has the lowest annual cost per average deciview reduction ratio for receptor 1. (Note: Because there is only one receptor, this ratio also equals the lowest annual cost per average microgram per cubic meter). Consequently, measure C is selected.

Because the optimization model only includes receptors out of compliance in the calculation of the cost per average microgram reduced, selection of measures that have little or no impact in reducing concentrations in non-complying areas is avoided. Finally, the reader should keep in mind that the scope of this example has been kept small for purposes of illustration. During each iteration of the RH optimization model, the control measure selections are made from literally thousands of measure-receptor combinations.

6.3.10 Baseline Visibility

The visibility baseline in this analysis is represented by the estimated visibility improvement between the benchmark case and the partial attainment of Ozone and $PM_{2.5}$ NAAQS case (which includes a modest version of the Tier II program described in Chapter 5). Table 6-5 summarizes the visibility measurements in terms of deciviews for the two cases. As the table shows, the average visibility improvement in the annual average deciview value for counties containing Class I areas in the Midwest/Northeast and the Southeast control regions is more than the illustrative progress goal of 1.0 dv/10 years. Given the 1.4 to 1 ratio of the deciview measurement for the 20 percent worst days to the case of annual average deciview change (as mentioned in Chapter 4), the visibility improvement is much more pronounced on the worst days, the time of year in which the greatest visibility progress is sought given the form of the illustrative goals described in Chapter 3.

Table 6-5
Projected Annual Average Deciview Values by Control Region[a]

Region	No. of Counties Containing Class I Areas	2010 CAA Baseline (Benchmark)	Partial Attainment of Ozone and $PM_{2.5}$ NAAQS including a version of the Tier II program	Average Annual Deciview Improvement in Baseline for RH Progress Goals
Midwest/Northeast	16	23.1	21.1	2.0
Southeast	13	22.5	21.0	1.5
South Central	14	16.8	16.3	0.5
Rocky Mountain	30	17.6	17.1	0.5
Northwest	18	19.3	19.1	0.2
West	30	17.8	17.1	0.7
Nation	121	19.1	18.3	0.8

[a] The regulatory baseline for analysis of these illustrative RH progress goals is the 2010 CAA benchmark *plus* partial attainment of the 8-hour Ozone and $PM_{2.5}$ NAAQS. This baseline includes a modest version of theTier II program described in Chapter 5 of this RIA.

Table 6-6 indicates the number of Class I area counties for which additional control measures may be needed incremental to the baseline (i.e., incremental to partial attainment of the $PM_{2.5}$ 15/65 standard and the 8-hour Ozone standard). There are substantial visibility improvements due to partial attainment of the $PM_{2.5}$ and Ozone NAAQS that includes a modest version of the Tier II program described in Chapter 5. Specifically,

! Nearly all Class I area counties in the Midwest/Northeast and Southeast regions are projected to meet the illustrative RH progress goals without any additional controls beyond partial attainment of the $PM_{2.5}$ 15/65 standard and the 8-hour Ozone standard.

! There is substantial visibility improvements in the South Central, Rocky Mountain, andwest control regions under all the illustrative progress goals except the 10% dv/10 year. There is a substantial reduction in annual average shortfall for Class I area counties in these control regions resulting from application of baseline control measures.

! The Northwest control region is expected to have the least visibility improvement under any of these illustrative progress goals. This is to be expected since most of the projected nonattainment with the $PM_{2.5}$ and Ozone NAAQS occurs in the Midwest/Northeast, Southeast, and other control regions so that is where the controls are applied. Since the Northwest is installing fewer controls to meet the NAAQS, less progress towards the illustrative RH progress goals would be expected.

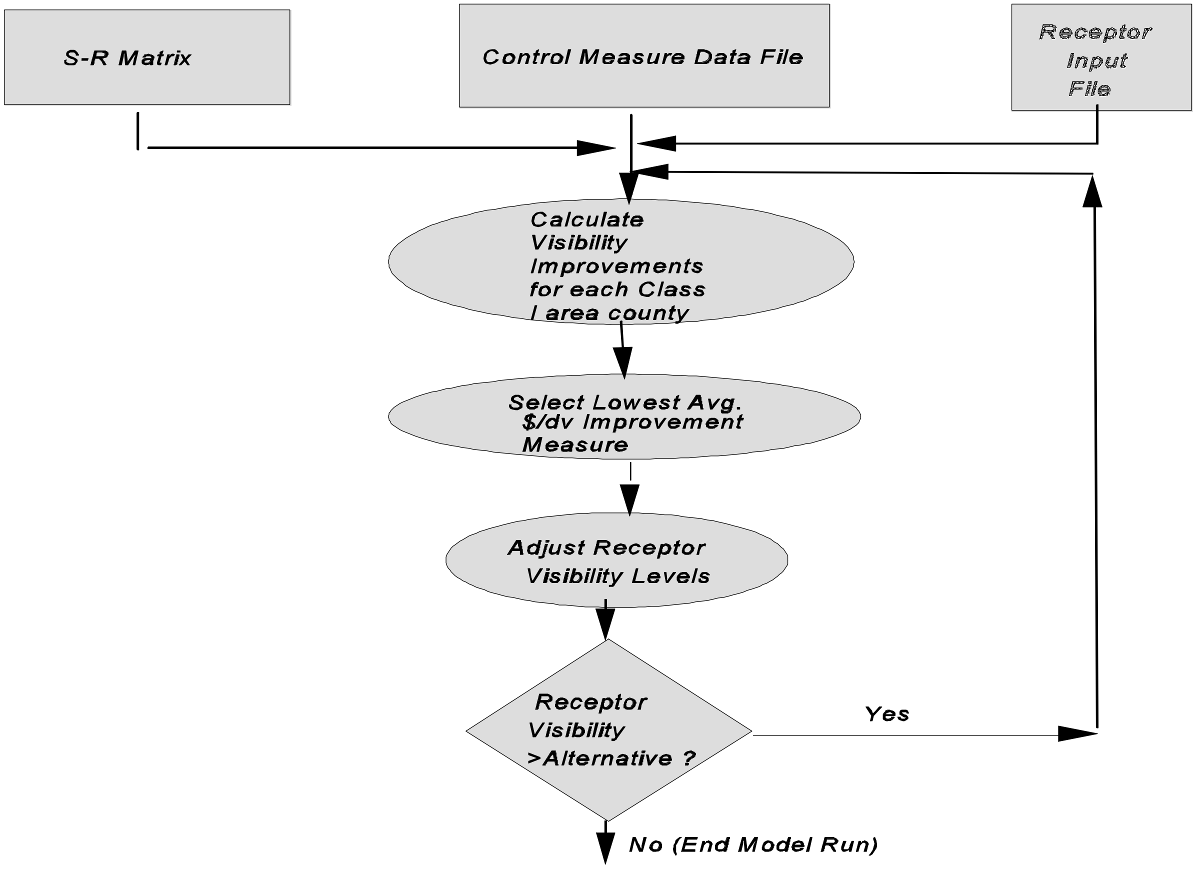
It should also be noted that the control regions in thewest are have the highest proportion of predicted biogenic aerosol emissions, which places them closer to natural conditions than other regions. This would tend to support establishing differing RH progress goals for these areas.

Table 6-6
Number of Class I Area Counties <u>Not</u> Meeting RH Illustrative Progress Goals in the Baseline[a]

Control Region	**Number of Class I Area Counties**	**Number of Class I Area Counties After $PM_{2.5}$ and 8-hour O_3 NAAQS Control**			
		1.0 Deciview Goal Over 15 Years (0.67 Deciview Goal)	**1.0 Deciview Goal Over 10 Years (1.0 Deciview Goal)**	**5% Deciview Goal Over 10 Years**	**10% Deciview Goal Over 10 Years**
Midwest/Northeast	16	0	0	0	1
Southeast	13	0	1	1	7
South Central	14	11	11	11	14
Rocky Mountain	30	14	27	26	30
Northwest	18	17	18	18	18
West	30	16	19	18	24
Nation	121	58	76	74	94

[a] The baseline for the RH rule is the partial attainment control case for the $PM_{2.5}$ and Ozone NAAQS presented in the 1997 RIA.

FIGURE 6-3
RH OPTIMIZATION MODEL STEPS



6.4 Emission Reduction and Air Quality Impacts

This section presents the emission reduction and air quality impact results for the analysis of the illustrative RH progress goals under the emission control Cases A and B. The results presented in this section are incremental to partial attainment of the Ozone and $PM_{2.5}$ NAAQS, which is the baseline for these analyses. Consequently, there are few projected emission reductions from certain control regions, such as the Midwest/Northeast and Southeast, since virtually all Class I area counties in these regions are expected to meet the illustrative progress goals in the baseline. This section includes estimates of the emission reductions and visibility improvements resulting from control measures selected in each control region, and estimates of the change in the status of Class I area counties in meeting the illustrative progress goals for the counties initially projected not to meet the RH progress goals.

Table 6-7 presents the emission reductions, by control region and nationally, associated with the illustrative RH progress goals for the year 2015 for Case A. The emission reductions do not account for potential increases in emissions due to the small additional energy requirements for producing, installing, and operating selected control devices. These reductions also do not reflect the visibility improvement from reduction of NO_2 emissions.

Table 6-7
Emission Reductions by Control Region and Nationally for Illustrative RH Progress Goals in the Year 2015 for Case A[a] (Tons reduced)[b]

RH Progress Goal	Control Region	NOx	SO_2	$PM_{2.5}$	PM_{10}	VOC	SOA	OC	EC
1.0 deciview/15 year	Midwest/Northeast	0	0	0	0	0	0	0	0
	Southeast	0	1	60	60	50	1	20	2
	South Central	101,500	290	12,800	180,700	19,400	300	3,000	600
	Rocky Mountain	84,300	100	6,700	88,000	9,300	100	1,300	200
	Northwest	24,200	1,500	41,200	68,700	43,800	1,500	17,600	3,500
	West	80,100	10	4,100	60,400	800	10	500	100
	Total	**290,100**	**1,900**	**64,860**	**397,800**	**73,350**	**1,910**	**22,420**	**4,400**
1.0 deciview/10 year	Midwest/Northeast	0	0	300	3,300	0	0	10	3
	Southeast	900	6,700	3,200	11,600	7,600	200	1,500	200
	South Central	106,000	41,700	12,900	181,000	21,000	300	3,000	600
	Rocky Mountain	142,000	56,800	12,500	165,800	13,000	100	3,100	400
	Northwest	47,400	14,300	58,400	124,000	72,000	1,700	24,100	4,100
	West	81,600	4,400	5,600	74,500	1,000	10	1,000	200
	Total	**377,900**	**123,900**	**92,900**	**560,200**	**114,600**	**2,300**	**32,700**	**5,500**
5 Percent/10 year	Midwest/Northeast	0	0	200	1,300	0	0	2	2
	Southeast	10	0	800	5,300	3,500	100	300	100
	South Central	105,300	41,200	12,800	180,800	19,500	300	3,000	600
	Rocky Mountain	141,400	41,000	8,100	91,900	12,900	100	1,900	300
	Northwest	74,300	17,300	50,800	94,400	95,300	1,900	20,800	3,900
	West	80,800	4,800	6,200	71,000	900	8	1,300	200
	Total	**401,800**	**104,300**	**78,900**	**444,700**	**132,100**	**2,400**	**27,300**	**5,100**

Table 6-7
Emission Reductions by Control Region and Nationally for Illustrative RH Progress Goals in the Year 2015 for Case A[a] (Tons reduced)[b]
(Continued)

RH Progress Goal	Control Region	NOx	SO_2	$PM_{2.5}$	PM_{10}	VOC	SOA	OC	EC
10 Percent/10-year	Midwest/ Northeast	33,100	130,900	6,200	37,900	29,200	200	400	100
	Southeast	10,800	107,300	80,700	169,500	26,400	700	22,200	3,200
	South Central	135,000	149,900	22,800	214,000	39,100	500	5,000	1,000
	Rocky Mountain	219,700	80,500	13,400	178,800	13,800	100	3,300	400
	Northwest	117,800	46,300	90,400	195,600	107,300	2,000	35,900	5,300
	West	85,400	7,400	8,900	84,700	4,300	100	1,800	300
	Total	**601,800**	**522,300**	**222,400**	**880,500**	**220,100**	**3,600**	**68,600**	**10,300**

[a] Case A represents a control case in which additional control measures beyond baseline are applied including fugitive dust control measures.
[b]Totals may not agree due to rounding.

To provide some perspective on the estimated emissions reductions needed to meet these illustrative progress goals, some substantial emission reductions are projected to occur under Case A for most of the pollutants controlled as shown in Table 6-7. Some substantial emission reductions compared to emission reductions within the National Particulate Inventory (NPI) are projected to occur under Case A for most of the pollutants controlled under the control measures applied. These reductions are roughly 2 to 6 percent based on the most stringent illustrative progress goal (10% dv/10 years) of what is projected under the benchmark case for most of these pollutants (U.S. Environmental Protection Agency, 1997a). For $PM_{2.5}$, the projected emissions reductions under Case A are greater than those for the benchmark case, but less than the emissions reductions projected under the partial attainment of the $PM_{2.5}$ and Ozone NAAQS (up to roughly 50 percent of reductions projected under partial attainment of these NAAQS, based on comparison with the most stringent progress goal). For PM_{10}, the projected emission reductions are as much as 35 percent compared to those in the benchmark case, but only 18 percent of the emission reductions projected in the baseline under partial attainment of the $PM_{2.5}$ and Ozone NAAQS (again, based on comparison to the most stringent progress goal). In addition, these reductions are generally less than 50 percent of the emission reductions obtained in the baseline due to partial attainment of the Ozone and $PM_{2.5}$ NAAQS and PM_{10} NAAQS, except for nitrogen oxides (NOx) emissions. The reductions in NOx emissions under Case A are roughly up to 75 percent of the reductions predicted in the partial attainment case for the Ozone and $PM_{2.5}$

NAAQS and PM_{10} NAAQS (U.S. Environmental Protection Agency, 1999a) based on comparison with the most stringent progress goal. The lack of emission reductions shown for the Midwest/Northeast and Southeast modeling regions under Case A for most of the illustrative progress goals is due to Class I area counties meeting these goals in the baseline.

Emissions reductions by control region and nationally for these illustrative progress goals are shown in Table 6-8.

Table 6-8
Emission Reductions by Control Region and Nationally for Illustrative RH Progress Goals in the Year 2015 for Case B[a] (Tons reduced)[b]

RH Progress Goal	Control Region	NOx	SO_2	$PM_{2.5}$	PM_{10}	VOC	SOA	OC	EC
1.0 deciview/15 year	Midwest/Northeast	0	0	200	1,300	0	0	2	2
	Southeast	0	1	60	60	50	1	20	2
	South Central	105,800	41,700	7,200	9,700	20,400	300	2,800	500
	Rocky Mountain	137,500	41,300	4,400	8,000	12,900	100	1,600	200
	Northwest	30,900	8,400	42,600	46,500	50,400	1,600	18,100	3,600
	West	81,600	3,900	3,800	7,100	900	10	1,300	200
	Total	**355,800**	**95,300**	**58,260**	**72,700**	**84,600**	**2,010**	**23,800**	**4,500**
1.0 deciview/10-year	Midwest/Northeast	0	0	200	1,300	0	0	2	3
	Southeast	6,600	70,900	61,100	85,200	21,200	500	14,800	2,400
	South Central	107,500	42,400	7,300	9,900	21,100	300	2,800	500
	Rocky Mountain	202,200	63,200	7,300	11,900	13,900	100	2,900	400
	Northwest	77,900	15,800	83,000	94,000	86,400	1,800	34,800	5,000
	West	83,400	6,200	5,000	8,500	1,500	10	1,500	300
	Total	**477,600**	**198,500**	**163,900**	**210,800**	**144,100**	**2,700**	**56,800**	**8,600**
5 Percent/10-year	Midwest/Northeast	0	0	200	1,300	0	0	2	2
	Southeast	6,600	70,900	61,100	85,200	21,200	500	14,800	2,400
	South Central	104,000	42,400	7,200	9,800	21,000	300	2,800	500
	Rocky Mountain	142,600	56,800	5,000	8,700	12,900	100	1,800	300
	Northwest	87,000	19,000	80,300	90,800	95,000	1,900	33,400	4,900
	West	81,800	4,800	4,000	7,400	1,000	10	1,400	200
	Total	**422,000**	**193,300**	**157,800**	**203,200**	**151,100**	**2,800**	**54,200**	**8,300**

Table 6-8
Emission Reductions by Control Region and Nationally for Illustrative RH Progress Goals in the Year 2015 for Case B[a] (Tons reduced)[b]

RH Progress Goal	**Control Region**	**NOx**	**SO_2**	**$PM_{2.5}$**	**PM_{10}**	**VOC**	**SOA**	**OC**	**EC**
10 Percent/10-year	Midwest/ Northeast	33,100	137,500	6,400	15,100	30,700	300	900	200
	Southeast	20,700	197,100	123,300	161,600	52,900	1,800	43,400	6,300
	South Central	134,900	149,900	16,500	23,400	39,000	500	5,100	1,000
	Rocky Mountain	220,200	80,500	7,700	12,500	14,500	100	3,000	400
	Northwest	118,100	46,500	86,500	99,200	108,200	2,000	35,300	5,200
	West	85,600	7,800	5,800	9,900	4,700	100	1,500	300
	Total	**612,600**	**619,300**	**246,200**	**321,700**	**250,000**	**4,800**	**89,200**	**13,400**

[a] Case B represents a control case in which additional control measures beyond baseline are applied with no fugitive dust control measures allowed.
[b] Totals may not agree due to rounding.

To provide some perspective on the estimated emissions reductions needed to meet these illustrative progress goals, some substantial emission reductions compared to reductions within the NPI are projected to occur under Case B for most of the pollutants controlled as shown in Table 6-8. These reductions are roughly 2 to 5 percent based on the most stringent illustrative progress goal (10%/10 years) of the emission reductions projected under the benchmark case (2010 CAA baseline) for most of these pollutants (U.S. Environmental Protection Agency, 1997a). For $PM_{2.5}$, the projected emissions reductions under Case A are greater than those for the benchmark case, but less than the emissions reductions projected under the partial attainment of the $PM_{2.5}$ and Ozone NAAQS which includes a modest version of the Tier II program (up to roughly 45 percent of reductions projected under partial attainment of these NAAQS, based on comparison to the most stringent progress goal). For PM_{10}, the projected emissions reductions under Case A are as much as 13 percent compared to the reductions for the benchmark case, but only 7 percent of the emissions reductions projected under the partial attainment of the $PM_{2.5}$ and Ozone NAAQS which includes a modest version of the Tier II program (again, based on comparison to the most stringent progress goal).

In addition, these reductions are generally less than 30 percent of the emission reductions obtained in the baseline due to partial attainment of the Ozone and $PM_{2.5}$ NAAQS and PM_{10} NAAQS, except for NOx emissions. The reductions in NOx emissions under Case B are roughly up to 77 percent of the reductions predicted in the partial attainment case for the Ozone and $PM_{2.5}$ NAAQS and PM_{10} NAAQS (U.S. Environmental Protection Agency, 1999b) based on comparison to the most stringent progress goal. In addition, the lack of emission reductions shown for the Midwest/Northeast and Southeast modeling regions under Case B for most of the illustrative progress goals is due to Class I area counties meeting these goals in the baseline.

We would expect the amount of environmental progress and mix of emission reductions to change between emissions control Cases A and B. In the analyses presented in this RIA, these expectations are realized. The variation between Case A and Case B reflects the consequence of uncertainties in emission inventories, air quality modeling, and control measure effectiveness.

6.5 Visibility Improvement Results

This section presents the incremental visibility improvements achieved for each illustrative RH progress goal in Class I area counties that did not achieve the goal in the baseline under both emissions control Case A and Case B. Included are estimates of the additional number of Class I area counties that meet the illustrative RH progress goal, as well as the average improvement realized. As discussed in section 6.3.4, a 1.0 deciview improvement goal for the average 20 percent worst days is roughly equivalent to a 0.7 deciview improvement goal for the annual average day. Similarly, a 0.67 deciview improvement in the average 20 percent worst days is roughly equivalent to a 0.5 deciview improvement in the annual average day. In addition, a 5 percent deciview improvement goal for the average 20 percent worst days is roughly equivalent to a 3.5 percent deciview improvement in the annual average day. Finally, a 10 percent deciview improvement goal for the average 20 percent worst days is roughly equivalent to a 7 percent deciview improvement in the annual average day.

Case A

Table 6-9 presents the number of Class I area counties that initially do not achieve each illustrative RH progress goal and the estimated number of Class I area counties that are not able to achieve the goals after additional control measures are modeled under Case A (with fugitive dust controls included).

Table 6-9
Estimated Number of Class I Area Counties That Do NOT Achieve Illustrative Regional Haze Progress Goals and the Average Deciview Shortfall Under Case A[c]

Region	1.0 Deciview Goal Over 15 Years (0.67 Deciview Goal)			1.0 Deciview Goal Over 10 Years (1.0 Deciview Goal)				5 Percent Deciview Goal Over 10 Years			10 Percent Deciview Goal Over 10 Years	
	Baseline[a]	**Post-Control[b]**	**Average Deciview Shortfall**	**Baseline[a]**	**Post-Control[b]**	**Average Deciview Shortfall**	**Baseline[a]**	**Post-Control[b]**	**Average Deciview Shortfall**	**Baseline[a]**	**Post-Control[b]**	**Average Deciview Shortfall**
Midwest/Northeast	0	0	--	0	0	--	0	0	--	1	1	0.01
Southeast	0	0	--	1	0	--	1	1	0.01	7	1	0.47
South Central	11	2	0.15	11	3	0.23	11	2	0.14	14	12	0.31
Rocky Mountain	21	1	0.06	27	4	0.09	26	1	0.04	30	22	0.25
Northwest	18	2	0.07	18	2	0.10	18	2	0.08	18	12	0.22
West	16	7	0.11	18	10	0.24	18	8	0.27	24	20	0.58
Nation	58	12	0.10	75	19	0.19	74	14	0.19	94	68	0.35

aBaseline represents class I area counties that do not achieve sufficient progress toward the illustrative progress goal after considering partial attainment of the PM$_{2.5}$ 15/65 standard and the 8-hour Ozone standard.

bPost-control represents counties that do not achieve sufficient additional progress toward the visibility goal after considering additional controls not already selected in the PM$_{2.5}$ 15/65 analysis. cCase A represents an emissions control case in which additional control measures beyond baseline are applied including fugitive dust control measures.

This table indicates that 12 of the 66 Class I area counties initially unable to meet the 1.0 dv/15 years goal may not meet the goal with application of additional control measures under Case A, and 19 of the 75 counties initially unable to meet the 1.0 dv/10 years goal may not meet this goal with application of additional control measures under Case A. This table also indicates that 14 of the 74 Class I area counties initially unable to meet the 5% dv/10 years goal cannot meet this goal with application of additional control measures under Case A, and 68 of the 94 Class I area counties initially unable to meet the 10% dv/10 years goal cannot meet this goal with application of additional control measures under Case A.

There are a considerable number of Class I area counties nationwide that are expected to meet the illustrative progress goals under Case A. The only exception is for the 10 % dv/10 years goal. The percentage of Class I area counties nationwide that are expected to meet these illustrative progress goals is listed in Table 6-10. As indicated in that table, the percentage of Class I area counties that meet the illustrative progress goals ranges from 22 to 45 percent from benchmark to baseline, and ranges from 43 to 90 percent with the incremental control measures from baseline included. Consequently, there is a substantial amount of progress towards meeting the visibility goals in the benchmark and baseline as well as with application of incremental control measures.

Table 6-10
Percentage of Class I Area Counties That Meet the RH Illustrative Progress Goals in the Benchmark and Beyond Under Case A[a]

	Percentag e of Class I area counties meeting the 1.0 Dv/ 15 Years Progress Goal	Percentage of Class I area counties meeting the 1.0 Dv/ 10 Years Progress Goal	Percentage of Class I area counties meeting the 5 Percent Dv/10 Years Progress Goal	Percentage of Class I area counties meeting the 10 Percent Dv/10 Years Progress Goal
Benchmark to Baseline	52	38	39	22
Baseline to Incremental Control Strategies	38	46	50	21
Total	90	84	89	43

[a] Case A represents a control case in which additional control measures beyond baseline are applied including fugitive dust control measures.

The average progress in Class I area counties nationally towards meeting these RH goals, measured in average deciview terms, for the two absolute illustrative progress goals is 81 percent for the 1.0 dv/10 years progress goal (1.0 deciview goal) and 90 percent for the 1.0 dv/15 years progress goal (0.67 deciview goal). For the two relative illustrative progress goals, the average progress in Class I area counties nationally is 65 percent for the 10% dv/10 years goal, and 81 percent for the 5 %/10 years goal.

Table 6-9 also shows the average deciview shortfall for the counties that do not reach the goal under Case A. For the 12 counties having Class I areas not achieving the 0.67 deciview goal after controls are applied under Case A, the region wide annual average deciview shortfall ranges from 0.06 to 0.15, meaning that on average these areas achieved from 0.35 to 0.44 (i.e., 70 to 88 percent) of the 0.5 deciview improvement needed to reach the goal. For the 19 counties having Class I areas not achieving the 1.0 deciview goal under Case A, the region wide annual average deciview shortfall ranges from 0.09 to 0.24, meaning that on average these areas achieved from 0.46 to 0.61 (i.e., 63 to 87 percent) of the 0.7 deciview improvement needed to reach the goal. For the 14 counties in Class I areas not achieving the 5% dv/10 years goal under Case A, the region wide annual average deciview shortfall ranges from 0.01 to 0.27, while for the 68 areas not achieving the 10% dv/10 years under Case A, the region-wide annual average deciview shortfall ranges from 0.01 to 0.58.

As mentioned in the preceding paragraph, while there are a number of counties that are not expected to meet the illustrative progress goals, many of these counties experience a substantial degree of visibility improvement. Most counties that are not expected to meet the RH progress goal are within 0.2 deciview of meeting them, indicating that many counties are close to meet these goals according to this report. There are several reasons why these counties are not predicted to meet these progress goals: 1) biogenic overestimation of VOCs in the west; 2) the partial attainment of the Ozone and $PM_{2.5}$ NAAQS is projected for 2015, not 2018, the date at which these goals are likely to be met; 3) technological progress is not considered; 4) the effect of Mexican and Canadian emissions on the control regions is not considered, and 5) superior innovative control strategies (e.g., emissions trading) is not in the control measures database.

Case B

Table 6-11 presents the number of Class I area counties that initially do not meet each illustrative RH progress goal and the estimated number of Class I area counties that are not able to meet the goals after additional control measures are modeled under Case B (with no fugitive dust controls included).

Table 6-11
Estimated Number of Class I Area Counties That Do NOT Achieve Illustrative

Regional Haze Progress Goals and the Average Deciview Shortfall Under Case B[c]

Region	1.0 Deciview Goal Over 15 Years (0.67 Deciview Goal)			1.0 Deciview Goal Over 10 Years (1.0 Deciview Goal)				5 Percent Deciview Goal Over 10 Years			10 Percent Deciview Goal Over 10 Years	
	Baseline[a]	Post-Control[b]	Average Deciview Shortfall	Baseline[a]	Post-Control[b]	Average Deciview Shortfall	Baseline[a]	Post-Control[b]	Average Deciview Shortfall	Baseline[a]	Post-Control[b]	Average Deciview Shortfall
Midwest/NE	0	0	--	0	0	--	0	0	--	1	1	0.09
Southeast	0	0	--	1	1	0.05	1	0	--	7	2	0.35
South Central	11	4	0.14	11	10	0.21	11	5	0.13	14	12	0.51
Rocky Mountain	21	3	0.10	27	6	0.18	26	3	0.18	30	29	0.39
Northwest	18	2	0.08	18	3	0.10	18	2	0.07	18	16	0.35
West	16	10	0.14	18	12	0.28	18	11	0.26	24	23	0.63
Nation	66	19	0.13	75	32	0.22	74	21	0.20	94	83	0.46

aBaseline represents class I area counties that do not achieve sufficient progress toward the illustrative progress goal after considering partial attainment of the PM$_{2.5}$ 15/65 standard and the 8-hour Ozone standard.
bPost-control represents counties that do not achieve sufficient additional progress toward the visibility goal after considering additional controls not already selected in the PM$_{2.5}$ 15/65 analysis.
[C] Case B represents an emissions control case in which additional control measures beyond baseline are applied that do not include fugitive dust control measures.

This table indicates that 19 of the 66 Class I area counties initially unable to meet the 1.0 dv/15 years goal cannot meet the goal with application of additional control measures under Case B, and 32 of the 75 counties initially unable to meet the 1.0 dv/10 years goal cannot meet this goal with application of additional control measures under Case B. This table also indicates that 21 of the 74 Class I area counties initially unable to meet the 5% dv/10 years goal can not meet this goal with application of additional control measures under Case B, and 83 of the 94 Class I area counties initially unable to meet the 10% dv/10 years goal can not meet this goal with application of additional control measures under Case A. The areas not able to meet these goals under Case B, as in Case A, are concentrated primarily in the west control region. Several of these counties are also not able to meet the illustrative progress goals in the baseline based on the results presented earlier in Chapter 6.

There are a considerable number of Class I area counties nationwide that are expected to meet the illustrative progress goals under Case B. The only exception is for the 10% dv/10 years goal. The percentage of Class I area counties nationwide that are expected to meet these illustrative progress goals is listed in Table 6-12. As indicated in that table, the percentage of Class I area counties that meet the illustrative progress goals ranges from 22 to 45 percent from benchmark to baseline, and ranges from 31 to 84 percent with the incremental control measures from baseline included. Consequently, there is a substantial amount of progress towards meeting the visibility goals in the benchmark and baseline as well as with application of incremental control measures.

Table 6-12
Percentage of Class I Area Counties That Meet the RH Illustrative Progress Goals in the Benchmark and Beyond Under Case B[a]

	Percentag e of Class I area counties meeting the 1.0 Dv/ 15 Years Progress Goal	**Percentage of Class I area counties meeting the 1.0 Dv/ 10 Years Progress Goal**	**Percentage of Class I area counties meeting the 5 % Dv/10 Years Progress Goal**	**Percentage of Class I area counties meeting the 10 % Dv/10 Years Progress Goal**
Benchmark to Baseline	45	38	39	22
Baseline to Incremental Control Strategies	39	36	44	9
Total	84	74	83	31

[a] Case B represents a control case in which additional control measures beyond baseline are applied but not including fugitive dust control measures.

The average progress in Class I area counties nationally towards meeting these RH goals, measured in average deciview terms, for the two absolute illustrative progress goals is 78 percent for the 1.0 dv/10 years goal (1.0 deciview goal) and 87 percent for the 1.0 dv/15 years goal (0.67 deciview goal). For the two relative illustrative progress goals, the average progress in Class I area counties nationally is 54 percent for the 10% dv/10 years goal, and 80 percent for the 5% dv/10 years goal.

Table 6-11 also shows the average deciview shortfall for the counties that do not meet the goal under Case B. For the 19 counties having Class I areas not achieving the 0.67 deciview goal after controls are applied under Case B, the region wide annual average deciview shortfall ranges from 0.08 to 0.14, meaning that on average these counties achieved from 0.36 to 0.42 (i.e., 72 to 84 percent) of the 0.5 deciview improvement needed to reach the goal. For the 32 counties having Class I areas not achieving the 1.0 deciview goal under Case B, the region wide annual average deciview shortfall ranges from 0.05 to 0.28, meaning that on average these areas achieved from 0.42 to 0.65 (i.e., 60 to 93 percent) of the 0.7 deciview improvement needed to reach the goal. For the 21 counties in Class I areas not achieving the 5%/10 years goal under Case B, the region wide annual average deciview shortfall ranges from 0.07 to 0.26, while for the 68 areas not achieving the 10% dv/10 years under Case A, the region wide annual average deciview shortfall ranges from 0.09 to 0.63.

As mentioned in the preceding paragraph, while there are a number of counties that are not expected to meet the illustrative progress goals, many of these counties experience a substantial degree of visibility improvement. Most counties that are not expected to meet the RH progress goal are within 0.2 deciview of meeting them, indicating that many counties are close to meet these goals according to this report. There are several reasons why these counties are not predicted to meet these progress goals: 1) biogenic overestimation of VOCs in the west; 2) the partial attainment of the Ozone and $PM_{2.5}$ NAAQS is projected for 2015, not 2018, the date at which these goals are likely to be met; 3) technological progress is not considered; 4) the effect of Mexican and Canadian emissions on the control regions is not considered, and 5) superior innovative control strategies (e.g., emissions trading) is not in the control measures database.

6.6 Cost Analysis Results

This section presents the annual cost of meeting the illustrative RH progress goals incremental to the 8-hour Ozone and $PM_{2.5}$ NAAQS baseline for this analysis under the control Case A (with fugitive dust controls included) and Case B (without fugitive dust controls). Under the structure of the final RH rule, the States are able to take into account costs for emissions reductions strategies in light of the degree of visibility improvement to be achieved. Therefore, high cost-control measures that have only minor effects on visibility can be avoided. For some Class I areas, there may not exist any cost-effective control measures that can be applied in the time period covered by this analysis. In addition, States have the flexibility to establish other reasonable goals and emissions management strategies. In these areas the incremental control costs (and also the benefits) of the final RH rule may be less than estimated in this RIA. Under such conditions, the incremental costs of the RH rule may be associated with administrative activities (e.g., planning, analysis, etc.) and Best Available Retrofit Technology (BART) controls for some establishments in certain source categories. The corresponding cost is estimated at $72 million (1990$). An explanation of this BART cost estimate is presented later in Section 6.6.3. It should be noted that for almost all eastern States a lower bound of zero for potential control costs associated with an illustrative progress goal is reasonable since virtually all Class I area counties are expected to meet these progress goals in the baseline. In addition, based on the control strategies selected by the Grand Canyon Visibility Transport Commission (GCVTC), the control costs may be lower than estimated in this RIA.

The presentation of incremental cost of the illustrative RH progress goals in this RIA is complicated by the residual nonattainment projected to exist for the analysis of the 8-hour Ozone and $PM_{2.5}$ 15/65 NAAQS which includes a modest version of the Tier II program described in

Chapter 5. An analysis that successfully models full attainment of the 8-hour Ozone and $PM_{2.5}$ standard should show reduced incremental costs associated with these illustrative RH progress goals compared to the estimates in this report in areas where there is significant overlap.

6.6.1 Results for Case A

Table 6-13 shows the total annual control cost of the illustrative RH progress goals incremental to the 8-hour Ozone and $PM_{2.5}$ NAAQS for Case A. The largest fraction of the incremental control cost is realized in the Rocky Mountain and Northwest regions. This seems logical since there are relatively few counties projected to be nonattainment for the $PM_{2.5}$ and Ozone NAAQS in the benchmark for these regions. Therefore, less control and accompanying visibility improvement are achieved in these regions in the baseline analysis.

Table 6-13
Regional Haze National Control Cost Summary -- Total Annual Cost for Illustrative Regional Haze Progress Goals[a] under Case A[b,c]
(millions of 1990 dollars)

Control Region	Baseline Visibility	1.0 dv/15 Years (0.67 Deciview Goal)	1.0 dv/ 10 Years (1.0 Deciview Goal)	5 % dv/10 Years	10 % dv/10 Years
Midwest/Northeast	0	0	0	0.3	380
Southeast	0	0.02	30	10	310
South Central	0	450	500	490	980
Rocky Mountain	0	260	620	440	960
Northwest	0	120	300	260	1,150
West	0	240	290	310	600
Nation	0	1,070	1,740	1,510	4,380

[A] Costs are incremental to partial attainment of the 8-hour Ozone and the $PM_{2.5}$ 15/65 standards. Totals may not agree due to rounding.

[b] Case A represents an emissions control case in which additional control measures beyond baseline are applied including fugitive dust control measures.

[C] These costs may be zero for States since they may choose less restrictive progress goals than those analyzed in this report. This is particularly true for States in the Midwest/Northeast and Southeast control regions since virtually all Class I area counties in these regions can meet most of the RH illustrative progress goals in the baseline for the RH rule.

6.6.2 Results for Case B

Table 6-14 shows the total annual control cost of the illustrative RH progress goals incremental to the Ozone 8-hour and $PM_{2.5}$ NAAQS for Case B. The largest fraction of the control cost, as in Case A, is realized in the Rocky Mountain and Northwest regions. This is particularly true for the 10% dv/10 years goal. This seems logical since there are relatively few counties projected to be nonattainment for the $PM_{2.5}$ NAAQS in the baseline in these regions. Therefore, less control and accompanying visibility improvement are achieved in these regions in the baseline analysis.

Table 6-14
Regional Haze National Control Cost Summary -- Total Annual Cost for Illustrative Regional Haze Control Costs[a] for Case B[b]
(million 1990 dollars)

Control Region	Baseline Visibility	1.0 dv/ 15 Years (0.67 Deciview Goal)	1.0 dv/10 Years (1.0 Deciview Goal)	5 % dv/ 10 Years	10 % dv/10 Years
Midwest/Northeast	0	0.3	0.3	0.3	310
Southeast	0	0.3	140	140	530
South Central	0	200	230	230	670
Rocky Mountain	0	270	450	330	640
Northwest	0	120	330	330	960
West	0	160	260	200	500
Nation	0	750	1,430	1,240	3,610

[A] Costs are incremental to partial attainment of the 8-hour Ozone and the $PM_{2.5}$ 15/65 standards. Totals may not agree due to rounding.

[b] Case B represents a control case in which additional control measures beyond baseline are applied without fugitive dust control measures included.

[C] These costs may be zero for States since they may choose less restrictive progress goals than those analyzed in this report. This is particularly true for States in the Midwest/Northeast and Southeast control regions since virtually all Class I area counties in these regions can meet most of the RH illustrative progress goals in the baseline for the RH rule.

The estimated nationwide annual control costs for the two RH alternatives analyzed previously in the 1997 RIA, the 1.0 deciview improvement and 0.67 deciview improvement goals, are now roughly half of the total nationwide annual control costs at proposal for Case A, and slightly more than half the total nationwide annual control costs for Case B. This difference is largely due to the inclusion of OC, EC, and fine particle soils in the RH optimization model. In particular, the optimization model now considers the contribution to visibility impairment from elemental carbon (U.S. EPA, 1999a).

While Case B has lower estimated total annual nationwide costs than Case A, it should be noted that there are more Class I areas that cannot meet the illustrative RH progress goals analyzed in this report. Therefore, quantitative comparison of these two control cases is not warranted due to differences in the number of Class I areas for the post-control air quality profiles are not similar. However, the results from applying Cases A and B do reflect the variability in results due to different assumptions regarding the highly uncertain aspects of the analyses. These differences in the results between the two emission control cases underscore the need for better information regarding emissions inventories, air quality modeling, and control strategy effectiveness.

6.6.3 Estimate of Potential Costs for the BART Element of the Regional Haze Rule

In consideration of compliance cost, performance of technology, existing pollution control at the source, and degree of improvement in visibility from further emission reductions, best available retrofit technology (BART) determinations are separate from yet related to other Clean Air Act programs. For example, if implementation programs designed to meet the NAAQS resulted in adoption of best available technology, there would not be a compliance cost impact from BART for affected establishments in those source categories. Likewise, if participation in the emission allowance trading program of Title IV of the Clean Air Act resulted in adoption of best available technology for SO_2 sources, there would not be a compliance cost impact from BART. For example, there are expected to be minimal compliance costs from controlling SO_2 for BART sources in the electric utility source category in the eastern States.

The BART determinations are developed concurrent with reasonable visibility progress goals and associated emission management strategies. Hence, where one assesses impact is somewhat uncertain. The assessments in this RIA include baseline control levels (from which visibility progress is measured in the first long-term strategy period), the incremental effects of establishing progress goals and emission management strategies independent of the BART process. To the extent, what would have been BART controls are reflected in the controls attributable to other Clean Air Act programs and the progress goal and emission strategy elements of the Regional Haze rule, the incremental control costs of BART are offset. However, there are incremental costs associated with the BART component of the Regional Haze rule. This is because the States have to do modeling and analysis as part of the BART determination process. Those costs are reflected in the total estimates for the administrative costs of the rule that are presented in Chapter 7 of the RIA. The administrative costs are $10 million (1990 dollars) in the 2015 analysis year. As explained in the paragraphs that follow, there may also be instances where there are some control costs for the BART component of the rule.

These candidates for BART-associated control costs are establishments that were built between 1962 and 1977 and that emit more than 250 tons per year of any visibility impairment precursor. Hence, they are a subset of the total number of establishments in the 26 source categories identified in Section 169(a) of the Clean Air Act. An estimate of the number of establishments in these 26 source categories that may incur controls under the 10% dv/10 year goal ranges from 425 (Case A) to 439 (Case B). These are establishments within these 26 source categories with pollutant emissions that are projected to impair visibility under the most stringent illustrative progress goal. The resulting control cost estimate based on the control strategy model employed in this RIA is $1.5 billion in 2015 (1990 dollars) for up to the 439 establishments in those source categories under emission control cases A and B. The estimate of $1.5 billion is not an estimate of the BART element of the Regional Haze rule.

One reasonable way to assess the control costs associated with BART includes adjusting these costs based on looking at the difference between the costs for the most and least stringent illustrative goals (10 % dv/10 year and 1.0 dv/15 year), and making adjustments to account for the limited applicability of the BART for establishments within those 26 source categories. These latter adjustments are necessary to account for the age of process units, existing control technologies, and emissions trading possibilities. This BART cost estimation procedure is as follows:

1) Adjustment for age of establishment. 25 percent of the establishments are presumed in the 1962 to 1977 age category with other establishments being pre-1962 and post-1977. Hence, the control costs for the 425 (Case A) to 439 (Case B) establishments for the 10% dv/10 year goal and 1.0 dv/15 year goal are multiplied by 0.25. Consequently,

	10% dv/10 year	1.0 dv/15 year
Case A	$434 million	$57 million
Case B	487 million	125 million

2) Adjustment for existing controls. If the establishments are controlled for the 1.0 dv/15 year goal, the State is presumed to not come back to the source for a second time. The number of total establishments in these source categories under the 10% dv/10 year goal is again 425 for Case A and 439 for Case B. The number of establishments under 1.0 dv/15 year are 190 and 242, respectively. The associated adjustment factors would be 56 percent (235/425) for Case A and 45 percent (197/439) for Case B. Hence, the cost estimates would be reduced further. Consequently,

Case A	$211 million
Case B	163 million

3) Adjustment for emissions trading. Trading programs are likely to be used to further lower control costs for these large BART establishments. This would lower estimated control costs to 33 percent of the figures arrived at after imposing adjustment 2. This third adjustment is based on the experience of the EPA regarding the estimated costs for the SO_2 emission reduction allowance program prior to the Clean Air Act Amendments (CAAA) of 1990 compared to the realized cost of the program. The estimated cost savings of a trading program was $2 billion before the passage of the CAAA (i.e., $6 billion with command and control compared to $4 billion with

trading). The realized cost of the program, however, was $2 billion ($6 billion with command and control compared to the cost savings resulting from adoption of a trading program of $4 billion). Consequently, drawing on this experience, the command and control costs for BART should be decreased by 67 percent. This final adjustment would result in the following cost for BART sources:

Case A	$70 million
Case B	54 million

The total cost estimate must also include administrative costs. The average control cost estimate in 2015 is $62 million in 1990 dollars (($70 million + 54 million)/2). However, the BART cost estimate must also include administrative costs in 2015 of $10 million (1990 dollars) estimated in Chapter 7. Therefore, under these conditions, the estimated cost of the BART element of the Regional Haze rule is $72 million in 2015 (1990 dollars).

6.7 Analytical Limitations, Uncertainties, and Potential Biases

Because a quantitative uncertainty bound cannot be assigned to every input, the total uncertainty in the emission reduction, air quality, and cost outputs cannot be estimated. Nonetheless, the individual uncertainties can be characterized qualitatively.

Air quality projections to 2015 embody several component uncertainties, such as uncertainties in emission data, emission growth rates, baseline air quality data, and air quality modeling. These uncertainties are addressed in Chapter 4. The application of control measures and their associated costs are affected by the propensity of either the emissions projection methodology or the air quality prediction methodology to overstate or understate initial noncompliance in specific Class I areas.

As noted in Section 6.3, the optimization model annual cost inputs are in the form of average incremental cost per ton reduced. Even if these cost-per-ton estimates are adjusted to account for source size differences (as is done for some point source controls), these adjustments do not account for other important cost-determining variables, such as source status (new versus retrofit), annual operating hours, equipment, materials of construction, and unit prices for utilities, materials, and labor.

The least-cost optimization model also introduces a measure of uncertainty. For instance, when calculating the cost per average deciview reduced, the model does not count any emission reductions that are in excess of those needed to meet a specified visibility goal. This assumption could cause the cost per average deciview—and, in turn, the final control costs—to be overstated or understated, depending upon whether control of the precursor was beneficial.

Because a quantitative uncertainty cannot be assigned to every input, the total uncertainty in the emission reduction, air quality, and cost outputs cannot be estimated. Nonetheless, the individual uncertainties can be characterized qualitatively.

6.8 References

E.H. Pechan and Associates, Inc. (1996), National Complemental 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, N.C.; May.

U.S. Environmental Protection Agency (1996b), Review of the National Ambient Air Quality Standards for Particulate Matter: Assessment of Scientific and Technical Information. Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; EPA report no. EPA/452-R-96-013.

U.S. Environmental Protection Agency (1997a), 2010 Clean Air Act Amendment Baseline Emissions Projections for the Integrated Ozone, Particulate Matter, and Regional Haze Cost Analysis. Prepared for Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; June 13, 1997.

U.S. Environmental Protection Agency (1997b), PM2.5 Composition and Sources, Prepared for FACA National and Regional Strategies Workshop. Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; June 16, 1997.

U.S. Environmental Protection Agency (1998a), Analyzing Electric Power Generation Under the CAAA. Office of Air and Radiation; Washington, D.C.; March.

U.S. Environmental Protection Agency (1999a), Control Measures Analysis of Regional Haze Alternatives. Draft Report. Prepared for Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; December 1998.

U.S. Environmental Protection Agency (1999b), Addendum to Control Measures Analysis of Regional Haze Alternatives. Draft Report. Prepared for Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; February 1999.

Sisler, J.F. (1996), Spatial and Seasonal Patterns and Long Term Variability of the Composition of the Haze in the United States: An Analysis of Data from the IMPROVE Network. Cooperative Institute for Research in the Atmosphere, Colorado State University; Fort Collins, CO; July.

Sisler, J.F.; Malm, W.C. (1994), The Relative Importance of Soluble Aerosols to Spatial and Seasonal Trends of Impaired Visibility in the United States. *Atmos. Environ.* 28(5):851„862.

Trijonis, J.C.; Malm, W.C.; Pitchford, M.;White, W.H. (1990), Visibility: Existing and Historical Conditions, Causes and Effects. NAPAP Report 24; In: Acidic Deposition: State of Science and Technology, Volume III, National Acid Precipitation Assessment Program; Washington, D.C.

Chapter 7 ESTIMATED ADMINISTRATIVE BURDEN AND COSTS ASSOCIATED WITH THE FINAL REGIONAL HAZE RULE

7.1 Introduction

This chapter summarizes the information contained in the Environmental Protection Agency's (EPA) Information Collection Request (ICR) (EPA #1813.02). Under the Paperwork Reduction Act, the EPA is required to assess the burden hours and dollar cost for governments to adminster the Regional Haze (RH) rule as well as the periodic reporting and recording keeping necessary to maintain the rule once it has been approved.

An ICR must be renewed every 3 years and cannot extend more than 3 years into the future without resubmittal for renewal. For the time period mid-1999 to mid-2002 covered by the RH ICR, data items are primarily limited to those of section 309(d)(4) of the Clean Air Act for nine western States. Those States and associated Tribes have created the Western Regional Air Partnership to foster coordination in addressing visibility issues. Those States are ahead of others in the nation in the RH goal establishment and emission strategy development process.

For the other States and Tribes, more of the administrative burden hour and cost burdens will accrue during the first long-term planning and strategy period (e.g., ~2004 to 2018). However, imposition of such burdens cannot be approved, even in part, until future review cycles and subsequent ICR submittals

As explained in Section 7.3, relative to control strategy costs, the estimated administrative burden hour and other costs are small.

7.2 Administrative Burden Hour and Cost Estimates for the First Information Collection Request (ICR) Period (1999 to 2002)

Nine western States are ahead of most other parts of the country in terms of their planning, analysis, and emission management strategy assessment. That fact is reflected in the ICR submittal to the Office of Management and Budget (OMB).[1]

---

[1] The Regional Haze control strategy analysis abstracted from the substantial progress made by the western States in their cooperative venture to address visibility impairment.)

As noted in Section 7.1, the ICR is developed and approved in compliance with the Paperwork Reduction Act. Such requests are approved for a 3-year period and are submitted to OMB with updates and approval requests for future years. Consequently, the EPA does not have an ICR pertinent to 2015, a year near the end of the first long-term strategy period.

Because the ICR which has been prepared for submittal to OMB reflects just the early years of rule implementation, it understates the administrative costs associated with the RH rule during the first long-term strategy period. In the first ICR request period (1999 to 2002), most of the burden hour and cost estimates are related to the activities of nine western States who are further along in the rule implementation process. During that period, it is anticipated the other States will have some costs, these will be related to activities such as familiarizing themselves with the general nature, milestones, and framework of the rule.

According to the ICR submitted with the final RH rule, the first 3 years will result in an estimated total labor burden on the States of from 22,200 to 37,025 hours. The corresponding estimates for the federal government are 1,890 to 3,983 hours. The estimated cost for the States and associated federal government activities is $0.8 to $1.4 million annually. These estimates are in 1990 dollars.

7.3 Bounding of Estimated Administrative Costs for the 2015 Analytical Year

It should be recognized that there is a sequencing regarding the administrative and control cost outlays. Planning, monitoring, analysis, goal establishment, and emission strategy development for the first long-term planning and strategy period come before design, construction, installation, and operation of control measures. But, regardless of that timing difference, there may be an upper bound that one could place on the administrative costs to put them in context relative to the costs associated with control measures and strategies.

The administrative costs are expected to be less than ten times the estimates in the current ICR submittal toward the end of the first long-term strategy period. However, if they are ten times as high as those in the ICR submittal, they would range from $8 million to $11.4 million annually. This is clearly an upper bound estimate, since so many Class I areas can meet a variety of progress goals in the first long-term strategy period without additional control measures mean less planning and administrative activities on the part of the governmental sector. However, were such costs to be incurred, those administrative costs would represent between 0.2 percent and 1.5 percent of estimated control strategy costs. This range reflects the range of control strategy costs resulting from consideration of different control strategy cases and illustrative progress goals. See Chapter 6, Tables 6-13 and 6-14.

Chapter 8. ECONOMIC IMPACT ANALYSIS (EIA)

8.1 Results in Brief

This chapter is not intended to present a full macroeconomic analysis of the impact of the regional haze (RH) illustrative progress goals on the U.S. economy as a whole. Rather, it is intended to portray potential impacts on various industries resulting from the application of control scenarios as part of the illustrative analyses conducted in support of the final RH rule. Given the overall size of the U.S. economy and the estimated benefits and costs associated with this new rule, it is reasonable to expect the impact on the economy as a whole will be minor in the first long-term strategy period. This conclusion is especially true in the case of this rulemaking since the State has the flexibility to set the RH goal instead of meeting an Environmental Protection Agency (EPA) mandated goal.

Results from analyses summarized in this chapter suggest the potential for a variety of economic impacts resulting from the application of the hypothetical control scenarios to attain the illustrative RH progress goals. The potential impacts associated with meeting these illustrative goals by the year 2015 are fairly broad but not deep. While a large number of industries may be potentially affected, few establishments are expected to incur any costs. This is true for these progress goals regardless of how fugitive dust controls are treated in the analyses. Which specific industries or which establishments within these industries will actually be affected depends on the control strategy choices of the State and local level and therefore is difficult to predict with assurances of complete accuracy.

It should be noted that the incremental economic impact from any implementation of RH progress goals will vary depending on the visibility goals submitted and approved as part of State plans. If the goals are adjusted through that process to parallel the implementation programs for the Ozone and particulate matter (PM) standards, the economic impacts for meeting the adjusted goals in those areas will be borne by the Ozone and PM programs. To the extent this occurs, incremental control costs may be less than estimated in this RIA. However, there may be some instances in which there are incremental costs and economic impacts associated with the Best Available Retrofit Technology (BART) element of the RH rule. This is because the States have to conduct modeling and analysis as part of the BART determination process. Those costs are reflected in the total estimates for the administrative costs of the rule that are presented in Chapter 7 of the RIA, and in the estimates of costs of the BART element of the RH rule in Chapter 6. In this analysis, economic impacts are estimated assuming no variation in any of the illustrative progress goals for every mandatory Class I Federal area under either emissions control Case A or B.

In addition, based on the emissions management strategies selected by the Grand Canyon Visibility Transport Commission (GCVTC) as part of their partnership to promote visibility progress, the economic impacts may be lower than estimated in this RIA.

A very small proportion of establishments are potentially affected in 2015[1] for most of the standard industrial classification (SIC) codes affected under these illustrative RH progress goals even for results reflecting the upper end of the cost range. For Case A, the emissions control case with fugitive dust controls included, the estimated proportion of establishments potentially affected ranges from 0.3 percent to 1.3 percent for those establishments having control costs of 0.01 percent of sales or greater. Also, less than 0.1 percent of potentially affected establishments in all SIC codes are expected to have control costs of 1 percent of sales or greater. For Case B, the emissions control case without fugitive dust controls, the estimated proportion of establishments potentially affected ranges from 0.5 percent to 1.8 percent for those establishments having control costs of 0.01 percent of sales or greater. In addition, less than 0.1 percent of potentially affected establishments in all SIC codes are expected to have control costs of 1 percent of sales or greater.

A characterization of small entity impacts predicts some potential for negative impacts on small firms and establishments in a number of industries. However, these impacts will likely be mitigated by cost pass-through to consumers, flexible implementation strategies when designed by the States, and new control technologies.

It should be noted here, as in earlier chapters of this regulatory impact analysis (RIA), that the results associated with emissions control Cases A and B represent two different control case scenarios that yield different post-control air quality profiles. Since the post-control air quality results are different, Case B is not a perfect substitute control strategy for Case A.

---

[1] 2018 is the end of the period for the first long-term strategy. The term “long-term strategy” refers to the set of emission reduction measures the State includes in its SIP in order to meet the reasonable progress goal it has set. 2015 is the nominal “snapshot” year that reflects the partial attainment control cases for the Ozone and $PM_{2.5}$ NAAQS included in the baseline, and is near the end of the period for the first long-term strategy.

8.2 Introduction

This chapter summarizes results of the EIA associated with partial compliance nationwide of the illustrative RH progress goals assessed in this RIA. The level of compliance nationwide with these progress goals, which is nearly complete in the Eastern U.S. but is not in the western U.S., is presented in Chapter 6. The chapter provides information regarding the potential economic impacts associated with the hypothetical control strategy cost estimates[1]. Economic impacts on affected industries and source categories, consumers, and others are assessed.

The different analyses summarized in this chapter include:

- Screening Analysis. This consists of an annual control cost calculated as a percent of sales for establishments in each industry or source category, as classified by 4-digit SIC code.
- Governmental Entities Analysis. This consists of an annual control cost calculated as a percent of revenues for government-owned establishments.
- Small Entity Impacts Analysis. Potential impacts on these entities are characterized using available economic and financial data.

The characterization of small entity impacts in this chapter does not represent a regulatory flexibility analysis (RFA) as defined by the Regulatory Flexibility Act as amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA). No RH progress goal assessed in this RIA imposes requirements applicable to small entities. Refer to Chapter 2 for more details on why an RFA is not required for this rulemaking.

The economic impact estimates presented in this chapter are associated with partial compliance with each of these RH progress goals, the results of which are presented in Chapter 6. Estimates associated with full compliance are not computed in this analysis since these estimates are too speculative as input to economic impact estimation, and would not reflect estimates for selected control measures and potentially affected industries.

This analysis builds upon the EIA included within the July 1997 RIA for the promulgated PM and Ozone standards and the proposed RH target program (henceforth referred as the “1997 RIA”). The major change is that the screening analyses were conducted at the 4-digit SIC code level rather than the 3-digit SIC code level as done in the 1997 RIA. Economic impact analyses for the proposed RH target program alternatives could not be completed in time for inclusion in the 1997 RIA.

---

[1] See Chapter 3 for a description of the regulatory alternatives examined and Chapter 6 for the control strategy cost results.

8.3 Summary of Affected Industries

The purpose of the profile of affected industries is to summarize various market characteristics of economic sectors potentially affected by revisions to the RH progress goals. An industry profile provides information on economic sectors that may be valuable to the States for examining the impact of implementing RH progress goals. This information is background material for the screening and governmental entities analyses.

8.3.1 Industry Profile - Economic and Financial Data

Economic data used in estimating the potential economic impacts of implementing control measures associated with the illustrative RH progress goals follow the categorization established by the SIC Manual 1987 (U.S. Office of Management and Budget, 1987). The data are reported by 4-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.

Additional information on the profile of affected industries is in section 1.0 of Appendix H of the 1997 RIA, and in the Industry Profile for Review of the NAAQS for PM_{10} (U.S. Environmental Protection Agency, 1996a).

8.4 Screening Analysis - Methodology and Results

8.4.1 Introduction

Given the large number of 4-digit SIC codes potentially affected, it is not feasible to develop a detailed economic profile and EIA for each industry potentially affected by one or more control measures employed in the cost analyses. It is possible, however, to conduct a screening analysis which calculates an annual average cost as a percent of sales for each affected SIC code. The purpose of a screening analysis is to provide some signals of potential economic impacts, to show where a more refined or detailed economic analysis may be warranted, and to eliminate the need for a more extensive analysis of certain SIC codes, particularly in cases where the incremental cost impact is likely to be negligible. It does not, however, reflect any assumptions about specific impacts on a given establishment or type of establishment within an SIC code.

Perhaps the most comprehensive source of sales or revenue data is the 1992 Bureau of the Census' Economic Census Report Series (U.S. Department of Commerce, 1997). This publication provides company, establishment, employment, and sales totals by employment size category (e.g., 101-200 employees) down to a 4-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 (U.S. Department of Commerce, 1990).

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 all 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 are provided on an establishment basis, and (2) establishment-level revenue data are available for more SIC codes than firm-level revenue data.

8.4.2 Methodology

An annual cost as a percent of sales screening analysis is conducted to identify those industries or source categories potentially experiencing economic impacts as a result of compliance with the illustrative RH progress goals. Results of the screening analysis provide information regarding the potential severity of impacts on establishments in affected SIC codes.

This calculation, specifically, provides an indication of the magnitude of a price change that would have to occur in order for each industry to fully recover its annual control costs in the year 2015. Taken down to the establishment level, the resulting estimate represents the average price increase necessary for affected establishments in the industry to recover the increased cost of environmental controls. If a price change in affected markets resulting from implementation of the standards is greater than the cost to sales percentage for affected establishments with below average control costs, then those affected establishments will receive revenue in excess of the annual cost of control.

This calculation uses the upper bound of the control costs as inputs. As mentioned in Section 6.1, the results of this calculation may be zero since the States have the flexibility to set RH progress goals rather than meeting an EPA-mandated goal. Therefore, the results shown in this chapter reflect the upper bound of cost impacts.

In order to conduct the screening analysis, it is necessary to:

- Use the cost estimates for control of all visibility precursor emissions associated with the control strategies used in the cost analysis to calculate annual average costs per source category or industry on a SIC code basis;

- Divide the annual average costs by the number of affected establishments in the SIC code to provide an annual average cost per affected establishment for each affected SIC code;

- Divide the average annual cost per establishment by the average sales or revenue per affected establishment in potentially affected industries for each affected SIC code;

The result is the average annual cost as a percent of sales for each affected SIC code. This result is estimated at the establishment level for affected establishments in each SIC code.

The number of establishments are estimated differently depending on the type of emission source. For point sources, the number of affected establishments represents the number of unique plants affected by each control measure. For area and mobile sources, U.S. EPA data are obtained on the number of affected establishments by county and SIC code by projecting from State-level data reported in County Business Patterns (U.S. Department of Commerce, 1991b), since it is not possible to calculate the number of unique establishments affected by each area and mobile source control measure. Generally, the number of establishments in counties reported in County Business Patterns that are affected by control measures is used to estimate the number of affected establishments.

National sales data are available by 4-digit SIC code from the Bureau of the Census' Enterprise Statistics and related publications (U.S. Department of Commerce, 1992). Because of the broad scope of the illustrative progress goals examined in this RIA, average national sales are used. For each potentially affected SIC code, an estimate of national average sales per establishment is prepared and used as the denominator for each average annual cost-to-sales percentage calculated. The annual cost-to-sales percentage estimates reflect the cumulative (total) annual control costs associated with one or more control measures imposed on an industry or source category.

8.4.3 Results

The economic impact results are presented for each emissions control case.

Case A

Table 8-1 presents a summary of the number of industries with potential impacts associated with RH progress goals analyzed at different annual cost as a percent sales thresholds of at least 0.01, 0.1, 1, 3, and 5 percent (U.S. Environmental Protection Agency, 1999b). Under Case A, the four RH illustrative progress goals have the potential to affect some establishments in industries classified in 859 to 896 4-digit SIC codes. This range represents 85 to 89 percent of 1,005 4-digit SIC codes in the 1987 SIC Manual. The number of industries with some establishments potentially affected under these upper bound costs covers a range much lower than that, however. The range of industries with establishments potentially affected is from 49 to 132 4-digit SIC codes with annual costs of 3 percent of sales or greater, and industries in 23 to 63 4-digit SIC codes with some potentially affected establishments may have annual costs of 5 percent of sales or greater. It is important to note that a potential impact on a single establishment is sufficient to result in an industry being considered as potentially affected.

Table 8-1
Summary of Number of 4-digit SICs Having Some Establishments with Potential Economic Impacts for Illustrative Regional Haze Progress Goals[a] in the Year 2015[b,c], for Case A[d] (Expressed as Average Annual Costs as a Percent of Sales; Control Costs and Sales Are in 1990$)

RH Progress Goal	Number of 4-digit SIC codes Potentially Affected	4-digit SIC codes affected - 0.01 Percent or greater	4-digit SIC codes affected - 0.10 Percent or greater	4-digit SIC codes affected - 1 Percent or greater	4-digit SIC codes affected - 3 Percent or greater	4-digit SIC codes affected - 5 Percent or greater
1.0 deciview/15 year	859	185	85	49	30	23
1.0 deciview/10 year	870	232	100	59	39	28
5% deciview/10 year	869	214	100	56	32	24
10% deciview/10 year	896	327	210	132	87	63

a Represents the 4 regional haze progress goals that are being analyzed in this RIA.

b The proportion of establishments that are potentially affected ranges from 2.1 to 6.9 percent as a percentage of establishments nationwide in 2015 across the four RH progress goals analyzed. The number of establishments nationwide is 15,599,647 (U.S. Department of Commerce, 1997).

[c] It is important to note that a potential impact on a single establishment is sufficient to result in a industry classified in a 4-digit SIC code being included as being potentially affected.

[d] These results reflect visibility improvements achieved with application of fugitive dust controls along with other controls, applied as part of a least-cost optimization procedure described in Chapter 6.

It should be noted that a very small proportion of establishments are potentially affected for most of the SIC codes affected under these RH illustrative progress goals. As shown in Table 8-2, the proportion of establishments potentially affected by these progress goals under Case A ranges from 2.1 to 6.9 percent nationwide across the progress goals. However, these proportions fall to 0.3 to 1.3 percent nationwide across the progress goals for industries potentially having annual costs of 0.01 percent of sales or greater, and from 0.02 to 0.04 percent nationwide across these illustrative progress goals for industries potentially having annual costs of 1 percent of sales or greater.

Table 8-2
Summary of Percentage of Establishments Nationwide with Potential Economic Impacts for Illustrative Regional Haze Progress Goals[a] in the Year 2015, for Case A[b]

RH Progress Goal	Percentage of Establishments Nationwide with Potential Economic Impacts	Percentage of Establishments Nationwide with Potential Control Costs of 0.01 Percent or greater of Sales	Percentage of Establishments Nationwide with Control Costs of 1 Percent or greater of Sales
1.0 deciview/15 year	2.1	0.3	0.02
1.0 deciview/10 year	2.9	0.4	0.02
5% deciview/10 year	2.8	0.4	0.02
10% deciview/10 year	6.9	1.3	0.04

[A] Represents the 4 regional haze progress goals that are being analyzed in this RIA.

[b] These results reflect visibility improvements achieved with application of fugitive dust controls along with other controls, applied as part of a least-cost optimization procedure described in Chapter 6.

The screening analysis indicates that many industries in 4-digit SIC codes may be impacted by implementation of these illustrative progress goals, but many of the SIC codes affected may experience annual cost as a percent of sales below 1 percent and have fewer than 1 percent of their establishments potentially affected. This is for the most part due to the complementarity between the control strategies likely to be employed in implementation of the illustrative RH progress goals and the control strategies likely to be employed in implementation of the Ozone and $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS). As shown in Chapter 6, virtually no establishments in the Midwest/Northeast and Southeast control regions (i.e., virtually every State east of the Mississippi River) are expected to incur costs for the period of the first long-term strategy because the anticipated NAAQS implementation programs (in the baseline for these illustrative goals) result in sufficient visibility improvement to achieve progress objectives. The small percentage of establishments expected to incur costs also results from the fact that not all establishments' emissions have a measurable impact on visibility at Class I areas and that not all establishments offer opportunities for cost-effective air quality improvements. Based *only* on these estimates, and given that most establishments in these SIC codes are not potentially affected, impacts from implementation of these RH illustrative progress goals may not be substantial.

Case B

Table 8-3 presents a summary of the number of industries with potential impacts associated with RH progress goal analyzed at different annual cost as a percent sales thresholds of at least 0.01, 0.1, 1, 3, and 5 percent (U.S. Environmental Protection Agency, 1999b). Under Case B, the 4 RH illustrative progress goals have the potential to affect some establishments in industries classified in 861 to 897 4-digit SIC codes. This range represents 86 to 89 percent of 1,005 4-digit SIC codes in the 1987 SIC Manual. The number of industries with some establishments potentially affected under these upper bound costs covers a range much lower than that, however. However, the number of industries with some establishments potentially affected ranges from 27 to 80 4-digit SIC codes with annual costs of 3 percent of sales or greater, and industries in 21 to 60 4-digit SIC codes in which some affected establishments may have annual costs of 5 percent of sales or greater.

Table 8-3
Summary of the Number of 4 digit SIC Codes with Potential Economic Impacts for Illustrative Regional Haze Progress Goals in the Year 2015[b,c], for Case B[d] (Expressed as Average Annual Costs as a Percent of Sales; Control Costs and Sales Are in 1990$)

RH Progress Goal	Total No. of 4 digit SIC Codes Potentially Affected	4 digit SIC codes affected - 0.01 Percent or greater	4 digit SIC codes affected - 0.10 Percent or greater	4 digit SIC codes affected - 1 Percent or greater	4 digit SIC codes affected - 3 Percent or greater	4 digit SIC codes affected - 5 Percent or greater
1.0 deciview/15 year	861	195	68	40	27	21
1.0 deciview/10 year	882	249	123	58	35	26
5% deciview/10 year	871	252	128	58	35	22
10% deciview/10 year	897	330	203	125	80	60

a Represents the 4 regional haze progress goals that are being analyzed in this RIA.

b The proportion of establishments that are potentially affected ranges from 2.7 to 8.1 percent as a percentage of establishments nationwide across the four RH progress goals analyzed. The number of establishments nationwide is 15,599,647 (U.S. Department of Commerce, 1997).

[c] It is important to note that a potential impact on a single establishment is sufficient to result in a industry classified in a 4-digit SIC code being included as being potentially affected.

[d] These results reflect visibility improvements achieved without application of fugitive dust controls along with other controls, applied as part of a least-cost optimization procedure described in Chapter 6.

It should be noted that a very small proportion of establishments are potentially affected for most of the SIC codes affected under these RH illustrative progress goals. As shown in Table 8-4, the proportion of establishments potentially affected by these progress goals under Case A ranges from 2.7 to 8.1 percent nationwide across the progress goals. However, these proportions fall to 0.3 to 1.3 percent nationwide across the progress goals for industries potentially having annual costs of 0.01 percent of sales or greater, and from 0.02 to 0.04 percent nationwide across these illustrative progress goals for industries potentially having annual costs of 1 percent of sales or greater.

Table 8-4
Summary of Percentage of Establishments Nationwide with Potential Economic Impacts for Illustrative Regional Haze Progress Goals[a] in the Year 2015, for Case B[b]

RH Progress Goal	Percentage of Establishments Nationwide with Potential Economic Impacts	Percentage of Establishments Nationwide with Potential Control Costs of 0.01 Percent or greater of Sales	Percentage of Establishments Nationwide with Control Costs of 1 Percent or greater of Sales
1.0 deciview/15 year	2.7	0.5	0.02
1.0 deciview/10 year	4.6	0.9	0.02
5% deciview/10 year	3.8	0.7	0.02
10% deciview/10 year	8.1	1.8	0.04

[A] Represents the 4 regional haze progress goals that are being analyzed in this RIA.

[b] These results reflect visibility improvements achieved without application of fugitive dust controls along with other controls, applied as part of a least-cost optimization procedure described in Chapter 6.

The screening analysis indicates that many industries in 4-digit SIC codes may be impacted by implementation of these illustrative progress goals, but many of the SIC codes affected may experience annual cost as a percent of sales below 1 percent and have fewer than 1 percent of their establishments potentially affected. This is for the most part due to the complementarity between the control strategies likely to be employed in implementation of the illustrative RH progress goals and the control strategies likely to be employed in implementation of the Ozone and $PM_{2.5}$ NAAQS. As shown in Chapter 6, virtually no establishments in the Midwest/Northeast and Southeast control regions (i.e., virtually every State east of the Mississippi River) are expected to incur costs during the first progress period because the anticipated NAAQS implementation programs (in the baseline for these illustrative goals) result in sufficient visibility improvement to achieve progress objectives. The small percentage of establishments expected to incur costs also results from the fact that not all establishments' emissions have a measurable impact on visibility at Class I areas and that not all establishments offer opportunities for cost-effective air quality improvements.

As in Case A, the screening analysis indicates that many industries in 4-digit SIC codes may be impacted by implementation of these illustrative progress goals, but many of the SIC codes affected may experience annual cost as a percent of sales below 1 percent and have fewer than 1 percent of their establishments potentially affected. Based *only* on these estimates, and given that most establishments in these SIC codes are not potentially affected, impacts from implementation of these RH illustrative progress goals under this control case may not be substantial.

A general comparison of the results under each control case shows that a greater percentage of establishments are potentially affected for each RH progress goal in Case B compared to Case A at an impact of 0.01 percent or higher, but the number of establishments potentially affected is roughly equal at an impact of 1.0 percent or higher. The reason for the greater number of establishments being affected under Case B is that a greater number of stationary sources are now affected. In addition, more industries in 4-digit SIC codes are expected to be affected under Case B compared to Case A. The reason for this occurring is that with fewer control possibilities for area sources in Case B compared to Case A, there is a greater concentration on controls for other source types such as stationary and mobile. Therefore, more industries with stationary source emissions may be expected to impose controls to meet these illustrative progress goals in place of government entities (i.e., State and county government agencies) and agricultural entities who are controlled under Case A. Controls are expected to be placed on more stationary sources in industries such as electric utilities, cement manufacturing, and pulp and paper mills. Also, greater application of control strategies such as control of residential wood combustion (wood stove) emissions and on-highway heavy-duty diesel vehicle emission control may occur if fugitive dust controls are not part of a suite of control strategies for improving visibility, particularly in the affected regions. It should be noted that the residential wood combustion program in the control measure database does not consider such practices as switching to gas logs, thus leading to overestimates of the impacts estimated by this model from applying this control strategy. More of these limitations and uncertainties of this analysis is discussed later in this chapter and in Chapters 5 and 6. Thus, there is some potential for creating or exacerbating problems in some industry sectors as a result of alleviating adverse impacts in some other industry sectors by removing certain burdensome control strategies from consideration.

8.4.4 Limitations, Uncertainties, and Potential Biases

There are a number of limitations and uncertainties associated with these screening analyses that may lead to potential biases in the results. Table 8-5 presents these limitations and uncertainties.

Table 8-5
Limitations and Uncertainties of the Screening Analyses

Limitation/Uncertainty	Potential Bias on Screening Analysis Results
The analysis was conducted at the establishment level rather than the firm level because control costs are not available at the firm level.	Unknown
The results given in this chapter represent the highest annual cost as a percent of sales estimated for each SIC code.	Overestimate
The costs of area and mobile source control measures are not summed with the costs for point source control measures for a given establishment.	Underestimated for industries in SIC codes potentially affected by area and mobile source control measures
Inaccuracies with assignment of 4 digit SIC codes for point source establishments for which an SIC code was lacking or inaccurate.	Unknown
For some area and mobile source control measures, difficult to identify the SIC codes that incur control costs because area and mobile source inventories report emissions at county/source category level.	Unknown; total costs allocated to SIC codes identified as potentially affected may be over- or underestimated
Exact number of establishments is unknown because there is no direct relationship between the county-level cost estimates and the number of establishments reported for SIC codes.	Overestimate, since actual number of affected establishments is likely overstated. This is a result of the procedure of identifying affected establishments as part of the procedure allocating costs to individual establishments.
County-level establishment data only available at the 2 and 3-digit SIC code level. 4-digit SIC code establishment counts by county estimated by multiplying 2- and 3-digit SIC code county data by State-level 4-digit SIC code establishment proportions	Unknown; approach adds uncertainty to cost allocation methodology, but the direction of bias is not known
For the dust control plan measure for construction activities (pertains to Case A only), the number of acres of construction work by SIC code and county is the best indicator for economic analysis. This information was not available; number of establishments reported by SIC code and county used instead.	Unknown
The available data for allocating on-highway HDDV retrofit control measure costs to SIC codes do not distinguish between gasoline and diesel vehicles.	Unknown; analysis results will be inaccurate to the extent that heavy-duty diesel trucks are used by different industries than heavy-duty gasoline trucks
Costs for some area source control measures could not be allocated to SIC codes because establishment counts were not available for the SIC codes affected by the measure. In these cases, costs were allocated to potentially affected SIC codes using the sum of establishment counts for all of the counties within the State.	Unknown; costs may be overestimated for some SIC codes and underestimated for others

Lack of methodologies for allocating costs of various mobile source control measures to private/nonprofit entities.	Underestimate
For NO control measures applied to area source fuel combustion categories, average cost per establishment is the same for each SIC code since information was not available to identify specific costs for individual industries.	Unknown
For area and mobile source measures, county-level costs are divided by the number of establishments reported for the county for the potentially affected SIC codes. The average cost per establishment is an underestimate if the number of potentially affected establishments is less than the total number of establishments reported for the SIC codes.	Underestimate
Use of national sales and establishment data to calculate average sales per establishment by SIC code.	Unknown; if high costs are incident on large entities, then the use of average sales per establishment data leads to overestimated impacts

8.5 Environmental Protection Activities

Even though an industry may bear a regulatory burden, the economic impact may be offset if other industries use its product in pollution control activities. For example, the potential direct economic impact associated with implementation of these illustrative RH progress goals on the electric utility industry is likely to be negative. However, electricity is required to operate pollution control equipment used in other industries, and the electric utility industry will receive revenues from additional operation of pollution control equipment associated with the implementation of these illustrative progress goals. Another example is that of the construction industry sector which may experience negative economic impacts from compliance with these RH progress goals. However, the results of the environmental protection (EP) industry model prepared for the 1997 RIA show that the services of the construction industry sector may be in strong demand due to the capital expenditures required in other industries serviced by the construction sector as a result of implementation strategies associated with compliance with these progress goals. Also, an additional source of revenue for the construction industry sector is from increased pollution control spending by governmental agencies associated with implementation of these illustrative progress goals. As a consequence, the net economic impact to the construction industry sector could be positive. Similar comparisons can be made for other industries that these progress goals may potentially affect.

It is important to characterize the relationship of the analysis described above to the other analyses presented in this RIA. The revenues that are projected by this analysis reflect the fact that each purchase for pollution control has a buyer and seller. While a dollar spent by the purchaser of a control device or service is a cost, it is also revenue for the seller. This should not be confused with social cost which enters into a benefit-cost analysis. It is another element of the distributional analysis which focusses on the impacts of the costs incurred in meeting regulatory requirements. Revenue gain to the seller should not be confused with profit. In the long run in a competitive market, revenues for the good or service being sold will be offset by the costs of producing the good or service.

8.6 Small Entity Impacts

8.6.1 Introduction

As explained in the preamble to the final rulemaking and in Chapter 2 of this RIA, these RH progress goals are illustrative and will not impose any regulatory requirements on small entities. Any such requirements would arise from subsequent State regulatory actions. As a result, EPA is not required to conduct a regulatory flexibility analysis under the RFA, as amended by the Small Business Regulatory Enforcement Fairness Act (RFA/SBREFA). Nonetheless, EPA has conducted a more limited analysis of the potential impact on small entities of possible State strategies for implementing any of these illustrative progress goals in order to provide relevant information to the States as they prepare implementation strategies. The results of this analysis are presented below. It should be noted that the results presented below reflect the upper bound of control costs as shown in Chapter 6.

8.6.2 Methodology for Characterization of Potential Impacts

Small entity impacts are characterized as follows (U.S. Environmental Protection Agency, 1997c):

(1) Once the annual cost-to-sales percentages are computed in the screening analysis described above in section 8.3, the results of this analysis are shown in Appendix D. This data, which includes estimates of the percentage of establishments potentially affected, and average annual costs as a percent of sales for potentially affected industries classified by 4-digit SIC codes are presented for each RH progress goal under both emissions control cases.

(2) Strategies to mitigate potentially small entity impacts are then presented. Many of these have been implemented in various areas in the U.S.

8.6.3 Results

Appendix D contains data on the industries classified by 4-digit SIC codes that provide some indication of the proportion of establishments in an affected industry that potentially may be impacted, and the likelihood of significant small business impacts in affected industries. This information may be of value to the States as they develop implementation strategies to meet these illustrative RH progress goals.

These data show that less than 0.05 percent of establishments nationwide are potentially expected to have annual costs of 1 percent of sales or greater for each illustrative progress goal under Case A, and this is also true for Case B. The affected establishments are, in some instances, found in industries classified by 4-digit SIC codes dominated by small businesses. However, the small proportion of establishments affected in almost all potentially affected industries and the low estimates of cost as a percent of sales found in most affected industries indicates little possibility for potentially significant adverse economic impacts to small businesses from these illustrative progress goals nationwide under either Case A or B.

8.6.4 Limitations, Uncertainties, and Potential Biases

The limitations, uncertainties, and potential biases of the small entity characterization include many of those mentioned in Table 8-3 in the screening analysis section. In addition:

- It is not possible to differentiate costs for small establishments from large establishments for those establishments affected by area and mobile source control measures. Therefore, this small entity impact characterization assumes the same percentage magnitude of direct impact from area and mobile source control measures on affected smaller firms in an industry as affected larger firms.

- A small establishment is not necessarily a small entity. Small entities may own more than one establishment, large or small. Therefore, the conclusions drawn from a screening analysis conducted for small entities will not necessarily be the same as those drawn from a screening analysis conducted for small establishments.

8.6.5 Mitigation of Potential Small Entity Impacts

Control measures employed in the cost analyses provide estimates of average incremental costs, not marginal costs. Except in the case of some point source control measures, these average costs do not take into account differences in production capacity (or scale effects). So the same cost of control is applied to each affected entity in a source category, regardless of its size or other important factors. Many sources in the emission inventory may qualify as small entities under the SBA size standards, though this information is not available in the emissions inventory used for this analysis. It is possible that States may require sources to apply traditional pollution control technology or retrofit existing traditional pollution control technology. Since add-on controls can be capital intensive, the capital recovery or the fixed component of the annual cost may be a high percentage of the total annual pollution control cost. Small entities, all other factors being equal, generally have less capital available for purchase of add-on pollution control technology than large entities. In addition, the control cost per unit of production for small entities will likely be higher than for large entities due to economies of scale. Thus, control measures requiring the use of add-on control technology may cause small entities affected by State rules to experience disproportionate economic impacts compared to large entities if no strategies to mitigate potential small entity impacts are available for implementation by States.

The analysis of the potential economic impacts of the selected control measures indicates that some small entities may be adversely impacted by implementation associated with meeting these illustrative RH progress goals. Actual impacts will depend on which strategies States decide to use to achieve needed reductions in emissions. However, potential impacts can be lessened and sometimes avoided through the use of flexible implementation strategies. Consequently, EPA is encouraging States to exercise regulatory flexibility for small entities when developing strategies to comply with any RH progress goals the States choose to adopt.

While some States may need to turn to small businesses for emission reductions, small businesses will likely be among the last sources States will choose to control. States may consider controls on small businesses only if such businesses are a significant part of a Class I area’s visibility problem and meeting a progress goal cannot be reached through application of all available cost-effective measures to major sources. To the extent States consider controlling small businesses, EPA believes there are many ways States can mitigate the potential adverse impacts those businesses might experience. For example, States could choose to exempt or apply less stringent requirements to small businesses. Examples of such exemptions can be seen in existing EPA air-toxic standards for the printing, hazardous waste, and pharmaceutical industries. In these rules, EPA exempted small facilities or facilities with relatively low air emissions, or reduced the recordkeeping and monitoring burdens for affected facilities. States could also extend the effective date for control requirements for small businesses to 2015 or later. Reductions needed earlier before the effective date would be obtained from other sources. In addition, applying the most cost-effective control technologies first would tend to exclude small sources which often are not very cost-effective to control. States could also choose to apply control requirements to other businesses before requiring them for small businesses.

The EPA and States also will continue to provide as appropriate compliance assistance to small businesses through compliance assistance centers and issuance of compliance guidelines designed specifically for small businesses.

Some small businesses are likely to benefit from implementation strategies associated with meeting these illustrative RH progress goals. Many suppliers of air pollution control technologies which control ozone and fine particulate precursor emissions are small businesses who will likely benefit from implementation of the progress goals.

Small businesses also may benefit from these implementation strategies if the increase in their product prices resulting from costs associated with implementation strategies exceed the increase in their costs per unit of production.

8.7 Governmental Entities Analysis - Methodology and Results

8.7.1 Introduction

This governmental entities assessment, along with the administrative costs assessment in Chapter 7, is not an unfunded mandates analysis meant to comply with the 1995 Unfunded Mandates Reform Act (UMRA) requirements (see Chapter 2), since these illustrative RH progress goals do not impose requirements upon governmental entities. This section provides an illustration of the potential impacts of the control measures used in the cost analysis on affected government entities.

8.7.2 Methodology

The governmental entities analysis consists of a screening analysis much like that for potentially affected private and nonprofit sector establishments. The calculation is conducted to identify States and counties that may potentially experience impacts as a result of compliance with the illustrative RH progress goals. Results of this analysis provide information regarding the potential severity of impacts on government entities.

Annual control costs (1990$) projected to 2015 are estimated for affected counties and States and then divided by projected revenues for those counties and States in 2015. The result is the annual cost as a percent of revenue for each potentially affected county or State. These results are estimated for annual control costs of 1 percent or greater, and 3 percent or greater.

8.7.3 Results

Federal establishments potentially affected by the control measures modeled in this analysis include military installations, sources in federally managed permit programs on Tribal lands and on the Outer Continental Shelf (OCS), Federal prisons, regional electric power organizations (e.g., the Tennessee Valley Authority (TVA)), and other federally owned or leased buildings and compounds. Federal buildings and compounds generally do not produce the type of emissions which would fall under the scope of the selected standards. As described in Chapter 4, electrical power sources are included in the baseline for the control cost analysis, including some governmental facilities. Few federal prisons may be potentially affected by these illustrative RH progress goals. The number of Tribal and OCS potentially affected are also small. Thus, most of the federal sources potentially affected are military installations.

Non-federal sources or establishments include industrial point source, mobile source, and area source emissions. A number of State-owned establishments are identified in the hypothetical control strategy analysis. These sources are incorporated in the non-federal source category under the assumption they would require similar technical services from contractors as would a privately owned source of pollution.

Control measures identified as affecting federal, State, and county-owned establishments include point, area, and mobile source measures. A list of these control measures is in Appendix E for those measures selected under Case A and Case B. There is some potential for area and mobile source control measures to impact county governments and other governmental entities. The actual number of governmental entities affected by area and mobile source measures is unknown, since area and mobile sources are not identified by individual source in the emissions inventories.

The results of the government entities analysis are presented for each illustrative RH progress goal and by emissions control case.

Case A

The results for Case A are shown in Table 8-6. The results for Case A show that while many States and counties, particularly in the West, may potentially incur control costs associated with meeting a particular RH illustrative goal, relatively few States and counties are likely to experience a substantial cost impact. [1]

---

[1] The analyses in the final RIA abstracts from the ongoing successful partnership, goals establishment, and emission management strategies process undertaken by the western States that participated in the GCVTC.

Table 8-6
Summary of the Potential Impacts to Government Entities for Illustrative Regional Haze Progress Goals[a] in the Year 2015, for Case A[b] (Expressed as Average Annual Costs as a Percent of Revenues; Control Costs and Revenues Are in 1990$)

RH Progress Goals	Number of Affected States	Number of Affected Counties	Number of Counties with Control Costs Greater Than 1 Percent of Revenue (Based on County Revenues Only)[c]	Number of Counties with Control Costs Greater Than 3 Percent of Revenue (Based on County Revenues Only)[c]
1.0 deciview/15 year	16	341	134	55
1.0 deciview/10 year	18	422	168	101
5% deciview/10 year	16	380	145	75
10% deciview/10 year	27	876	224	146

[a] Represents the 4 regional haze progress goals that are being analyzed in this RIA.

[b] These results reflect visibility improvements achieved with application of fugitive dust controls along with other controls, applied as part of a least-cost optimization procedure described in Chapter 6.

[c] These results are based on county revenues being applied to cover the expense associated with potential control measures, and does not assume State funding is available to counties to cover these expenses.

Results comparing control costs for affected States to total States' revenues under emissions control Case A in the *Potential Annual Cost-to-Revenue Percentage Impacts of Regional Haze Alternatives on Government Entities* (EPA, 1999c) show that the States that have the potential for being most significantly affected for these illustrative RH progress goals are in the west. In addition, there are minimal impacts to States and counties east of the Mississippi River. Further detail concerning these impacts is contained in this report. These results are consistent with the results in Chapter 6 showing that virtually all Class I area counties east of the Mississippi River are in compliance with these illustrative progress goals in the baseline.

Case B

Table 8-7 presents the estimates of potential impacts to government entities under Case B. Again, as under Case A, while many States and counties, particularly in the west, may potentially incur control costs associated with meeting a particular RH illustrative goal, relatively few States and counties are likely to experience a substantial cost impact.[1]

Table 8-7
Summary of the Potential Impacts to government Entities for Illustrative Regional Haze Progress Goals[a] in the Year 2015, for Case B[b] (Expressed as Average Annual Costs as a Percent of Revenues; Control Costs and Revenues Are in 1990$)

RH Progress Goals	**Number of Affected States**	**Number of Affected Counties**	**Number of Counties with Control Costs Greater Than 1 Percent of Revenue (Based on County Revenues Only)**	**Number of Counties with Control Costs Greater Than 3 Percent of Revenue (Based on County Revenues Only)**
1.0 deciview/15 year	14	343	117	38
1.0 deciview/10 year	19	631	152	85
5% deciview/10 year	19	572	141	72
10% deciview/10 year	29	1,129	253	106

[a] Represents the 4 regional haze progress goals that are being analyzed in this RIA.
[b] These results reflect visibility improvements achieved without application of fugitive dust controls applied as part of a least-cost optimization procedure described in Chapter 6.

Results comparing control costs for affected States to total States' revenues under emissions control Case A in the *Potential Annual Cost-to-Revenue Percentage Impacts of Regional Haze Alternatives on Government Entities* (EPA, 1999c) show that the States that have the potential for being most significantly affected for these illustrative RH progress goals are in the West. In addition, there are minimal impacts to States and counties east of the Mississippi River. Further detail concerning these impacts is contained in the report mentioned above. These results are consistent with the results for Case B in Chapter 6 showing that virtually all Class I area counties east of the Mississippi River are in compliance with these illustrative progress goals in the baseline.

---

[1] The analyses in this final RIA abstracts from the ongoing successful partnership, goals establishment, and emission management strategies process undertaken by the western States that participated in the GCVTC.

A qualitative comparison of the potential impacts between Case A and Case B shows that more States and counties are affected in Case B compared to Case A. Results from the control strategy analysis also show that more counties may choose to apply additional control to their point and mobile sources, and to provide programs for voluntary reduction in residential wood combustion emissions. Selection of mobile source controls (in particular, the on-highway heavy-duty diesel retrofit program) and programs for voluntary reduction of residential wood combustion emissions occurs in a larger number of counties and States in Case B compared to Case A. It should be noted, however, that direct comparison of results from the two emissions control cases must take into the account their differences in post-control air quality. Results for the two emissions control cases represent findings of potential impacts for different post-control air quality profiles and, as such, direct quantitative comparison is not warranted.

8.7.4 Limitations, Uncertainties, and Potential Biases

The limitations, uncertainties, and potential biases of the governmental entities' assessment include many of the limitations mentioned in Table 8-5 in the screening analysis section. In addition:

- It is difficult to determine the type of government body that provides most of the funding to cover the expense incurred by a county or State associated with implementing many of these control strategies. This makes it difficult to determine in many cases the government body that will experience the potential impact from implementing these control strategies.

8.8 Plausibility Checks

The need for plausibility checks to validate the credibility of these results is important to assure the potentially affected States that these analyses provide a useful picture of potential economic impacts associated with these illustrative progress goals. Review of the data and assumptions for these screening analyses showed that the data used are the best available for input, and the assumptions on how cost allocations are derived for the private and nonprofit establishments are reasonable. Examination of the plausibility of the results from the governmental entities analysis, however, showed that the fugitive dust controls may impose potentially significant impacts upon a number of western States. After review of these results, the assumptions behind the analysis were revised. This review, along with other factors relating to uncertainties in the baseline inventory data, led the EPA to provide analyses including those for the screening for a control case in which no fugitive dust controls are applied.

8.9 References

Nestor, D.V.; Pasurka, C.A. (1995), Environment-Economic Accounting and Indicators of the Economic Importance of Environmental Protection Activities. *The Review of Income and Wealth.* 41: 265-287.

U.S. Department of Commerce (1989), 1987 Census of Agriculture, Volume 1. Geographic Area Series, Part 51: United States Summary and State Data. Bureau of the Census; Washington, D.C., November; Series no. AC-87-A-51.

U.S. Department of Commerce (1990a), 1987 Census of Governments. Bureau of the Census; Washington, D.C.

U.S. Department of Commerce (1990b), BEA Regional Projections to 2040, Volume 1: States. Bureau of Economic Analysis; Washington, DC: U.S. Government Printing Office; June.

U.S. Department of Commerce (1991), Enterprise Statistics: Company Summary (ES87-3). Bureau of the Census; Washington, D.C.

U.S. Department of Commerce (1992), Business Statistics, 1963-1991. Bureau of the Census; Washington, DC: U.S. Government Printing Office; June.

U.S. Environmental Protection Agency (1995), The U.S. Environmental Protection Industry: A Proposed Framework for Assessment. Office of Policy, Planning and Evaluation; Washington, D.C.; EPA report no. 230/R-95-011.

U.S. Environmental Protection Agency (1996a), Industry Profile for Review of the National Ambient Air Quality Standards for PM_{10}. Final Draft. Prepared by E.H. Pechan and Associates, Inc. for the Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; September.

U.S. Environmental Protection Agency (1997a), Control Measure Evaluation for the Integrated Implementation of the Ozone and Particulate Matter National Ambient Air Quality Standards, and Regional Haze Program. Final Review Draft. Prepared by E.H. Pechan and Associates, Inc. for the Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; April.

U.S. Environmental Protection Agency (1999a), Potential Annual Cost to Sales Percentages Impacts of Regional Haze Alternatives on Private and Nonprofit Entities. Final Draft Report. Prepared by the Pechan-Avanti Group for the Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; April.

U.S. Environmental Protection Agency (1999b), Potential Annual Cost to Sales Percentages Impacts of Regional Haze Alternatives on Private and Nonprofit Entities, No Fugitive Dust Controls Allowed. Final Draft Report. Prepared by the Pechan-Avanti Group for the Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; April.

U.S. Environmental Protection Agency (1999c), Potential Annual Cost to Revenue Percentage Impacts of Regional Haze Alternatives on Government Entities. Final Draft Report. Prepared by the Pechan-Avanti Group for the Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; April.

U.S. Environmental Protection Agency (1999d), Potential Annual Cost to Revenue Percentage Impacts of Regional Haze Alternatives on Government Entities, No Fugitive Dust Controls Allowed. Final Draft Report. Prepared by the Pechan-Avanti Group for the Office of Air Quality Planning and Standards; Research Triangle Park, N.C.; April.

U.S. Office of Management and Budget (1987), Standard Industrial Classification Manual 1987. Executive Office of the President; Washington, DC.

CHAPTER 9.
POTENTIAL HEALTH AND WELFARE BENEFITS OF REGIONAL HAZE REDUCTIONS

9.1 Results in Brief

Monetary benefits are calculated for the four illustrative Regional Haze (RH) visibility goals under two emission control cases. Incremental benefits (in 1990$) from progress towards improved visibility goals for the emission control case (Case A) including fugitive dust controls are expected to range from $0 (if all regions choose to set a goal equal to the progress attainable from implementation of the particulate matter (PM) and Ozone National Ambient Air Quality Standards (NAAQS) or if the visibility goal is fully achieved by all regions after implementation of the PM and Ozone NAAQS) to $18.7 billion. For the individual goals, the estimated benefits if all areas adopt the same goal are $3.0 to $7.0 billion for the 1.0 dv/10 years goal, $2.2 to $5.5 billion for the 1.0 dv/15 years goal, $5.1 to $18.6 billion for the 10% dv/10 years goal, and $2.7 to $6.7 billion for the 5% dv/10 years goal. Visibility benefits account for between 12 and 52 percent of total benefits, depending on the visibility goal and the health effects threshold level assumed. The range of benefits for an individual region may differ from the range for the nation as a whole. If a region completely achieves or surpasses a visibility goal through implementation of the PM or Ozone NAAQS, then the incremental benefits from the RH rule will be zero.

Incremental benefits (in 1990$) from progress towards improved visibility goals for the emissions control case (Case B) excluding fugitive dust controls are expected to range from $0 (for the same reasons as above) to $19.4 billion. For the individual goals, the estimated benefits if all areas adopt the same goal are $2.1 to $9.7 billion for the 1.0 dv/10 years goal, $1.2 to $4.3 billion for the 1.0 dv/15 years goal, $3.5 to $19.4 billion for the 10% dv/10 years goal, and $2.0 to $9.4 billion for the 5% dv/10 years goal. Visibility benefits account for between 8 and 58 percent of total benefits, depending on the visibility goal and the health effects threshold level assumed.

This benefits analysis does not quantify all potential benefits or disbenefits. The magnitude of the unquantified benefits associated with omitted categories, such as damage to ecosystems or damage to industrial equipment and national monuments, is not known. However, to the extent that unquantified benefits exceed unquantified disbenefits, the estimated benefits presented above will be an underestimate of actual benefits. The methods for estimating monetized benefits for the RH rule and a more detailed analysis of the results are presented below.

9.2 Introduction

The changes in emissions and associated changes in light extinction and ambient PM concentrations described in Chapter 4 will result in changes in the physical damages associated with elevated ambient concentrations of these pollutants. The damages include changes in both human health and welfare effects categories.

This chapter presents the methods used to estimate the physical and monetary benefits of the modeled emissions changes from implementing illustrative goals for visibility improvements at Federal Class I areas, including national parks and wilderness areas. In addition, the estimates of the avoided physical damages (e.g., incidence reductions), and the results of the benefits analysis for a range of alternative goals are presented. Results are presented for the four potential visibility goals described in Chapter 3. Results are presented twice, once for each emission control case described in Chapter 3. Benefits are calculated for the nation as a whole, assuming that a particular goal is adopted across the nation. Additional estimates of the benefits of regionally determined visibility goals are summarized in this chapter and analyzed further in Chapter 10, Benefit-Cost Comparisons.

The remainder of this chapter is laid out as follows. Section 9.3 provides an overview of the benefits methodology. Section 9.4 discusses methods for estimating the monetary benefits associated with changes in visibility. Section 9.5 discusses methods for estimating avoided incidences and monetary benefits for PM-related health and welfare effects. Section 9.6 provides estimates of visibility and ancillary health and welfare benefits associated with alternative visibility goals using emission control Case A. Section 9.7 provides estimates of visibility and ancillary health and welfare benefits associated with alternative visibility goals using emission control Case B. Section 9.8 summarizes total benefits for the four illustrative goals and the two emission control cases. Section 9.9 provides a set of plausibility checks of the benefits estimates. Finally, Section 9.10 discusses potential benefit categories that are not quantified due to data and/or methodological limitations, and provides a list of analytical uncertainties, limitations, and biases.

9.3 Overview of Benefits Estimation

Most of the specific methods and information used in this benefit analysis are similar to those used in the §812 Retrospective of the Benefits and Costs of the Clean Air Act and forthcoming §812 Prospective Environmental Protection Agency (EPA) Reports to Congress, which were reviewed by EPA's Science Advisory Board (EPA, 1997b), as well as building on the approach used by EPA in the PM and Ozone NAAQS RIA (EPA, 1997a) and in the NOx SIP call and Proposed Tier 2 RIAs (EPA, 1998a and EPA, 1999a), which received extensive review by other Federal agencies.

Prior to describing the details of the approach for the benefits analysis, it is useful to provide an overview of the approach. The overview is intended to help the reader better identify the role of each issue described later in this chapter.

The general term "benefits" refers to any and all outcomes of the regulation that are considered positive, that is, that contribute to an enhanced level of social welfare. The economist's meaning of "benefits" refers to the dollar value associated with all the expected positive impacts of the regulation, that is, all regulatory outcomes that lead to higher social welfare. If the benefits are associated with market goods and services, the monetary value of the benefits is approximated by the sum of the predicted changes in "consumer (and producer) surplus." These "surplus" measures are standard and widely accepted measures in the field of applied welfare economics, and reflect the degree of well being enjoyed by people given different levels of goods and prices. If the benefits are non-market benefits (such as the risk reductions associated with environmental quality improvements), however, other methods of measuring benefits must be used. In contrast to market goods, non-market goods such as environmental quality improvements are public goods, whose benefits are shared by many people. The total value of such a good is the sum of the dollar amounts that all those who benefit are willing to pay.

In addition to benefits, regulatory actions may also lead to potential disbenefits, i.e., outcomes that have a negative impact on social welfare. In general these disbenefits will be incidental to the stated goals of the regulation, otherwise (in an efficient regulatory environment) the regulation would not have been promulgated. Some benefits will also be incidental to the stated goals of the regulation. For example, the goal of the RH rule is improved visibility, however, improvements in visibility will also result in reduced PM related health effects. In order to fully quantify the benefits and costs of a regulatory action, both the benefits and disbenefits should be calculated, so that net benefits (equal to benefits minus disbenefits minus costs) will not be biased upwards. In many cases, however, disbenefits are difficult to quantify, as it is often unclear where and how disbenefits will occur. Benefits may also be difficult to quantify, since many benefits are not measurable using market based measures. The EPA's approach is to present as complete a set of quantified and monetized estimates of benefits and disbenefits as possible, given the current state of science at the time of the analysis.

This conceptual economic foundation raises several relevant issues and potential limitations for the benefits analysis of the regulation. First, the standard economic approach to estimating environmental benefits is anthropocentric -- all benefits values arise from how environmental changes are perceived and valued by people in present-day values. Thus, all near-term as well as temporally distant future physical outcomes associated with reduced pollutant loadings need to be predicted and then translated into the framework of present-day human activities and concerns. Second, as noted below, it is not possible to quantify or to value all of the benefits or disbenefits resulting from environmental quality improvements.

Conducting a benefits analysis for anticipated changes in air emissions is a challenging exercise. Assessing the benefits of a regulatory action requires a chain of events to be specified and understood. As shown in Figure 9-1, illustrating the causality for air quality related benefits, the estimation of benefits requires information about: (1) institutional relationships and policy-making; (2) the technical feasibility of pollution abatement; (3) the physical-chemical properties of air pollutants and their consequent linkages to biological or ecological responses in the environment, and (4) human responses and values associated with these changes.

The first two steps of Figure 9-1 reflect the institutional and technical aspects of implementing the RH regulation (the improved process changes or pollutant abatement). The estimated changes in light extinction or ambient PM are directly linked to the estimated changes in precursor pollutant emission reductions through the use of air quality modeling, as described in Chapter 6. For this analysis, steps 2 through 4 of Figure 9-1 play an important role in determining the total benefits associated with each illustrative goal.

As described in Chapter 4, two sets of emission reductions associated with two sets of available emission controls were developed for input into the source-receptor (S-R) matrix air quality model. In both cases, a number of counties with Class I areas were not able to achieve one or more of the illustrative visibility goals (see Tables 6-9 and 6-11 in Chapter 6). Thus, the benefits estimates will be for partial achievement nationwide of the illustrative visibility goals. If additional cost-effective controls were available such that all counties were able to achieve the illustrative visibility goals, estimated benefits would be higher. The number of counties not achieving the illustrative visibility goals is higher under emission control Case B relative to Case A. The difference ranges from five counties for the least stringent goal to fifteen counties for the most stringent goal. It is thus important to keep the level of compliance in mind when comparing benefits (and costs) both between visibility goals and between the two emission control cases. In essence, the actual goals modeled using the constrained least-cost strategy are different than the desired goals set for the analysis. Given that the actual goals achieved in the two emission control cases (Case A and Case B) differ both from the stated goal and from each other, a quantitative comparison of the benefits between cases is not recommended.

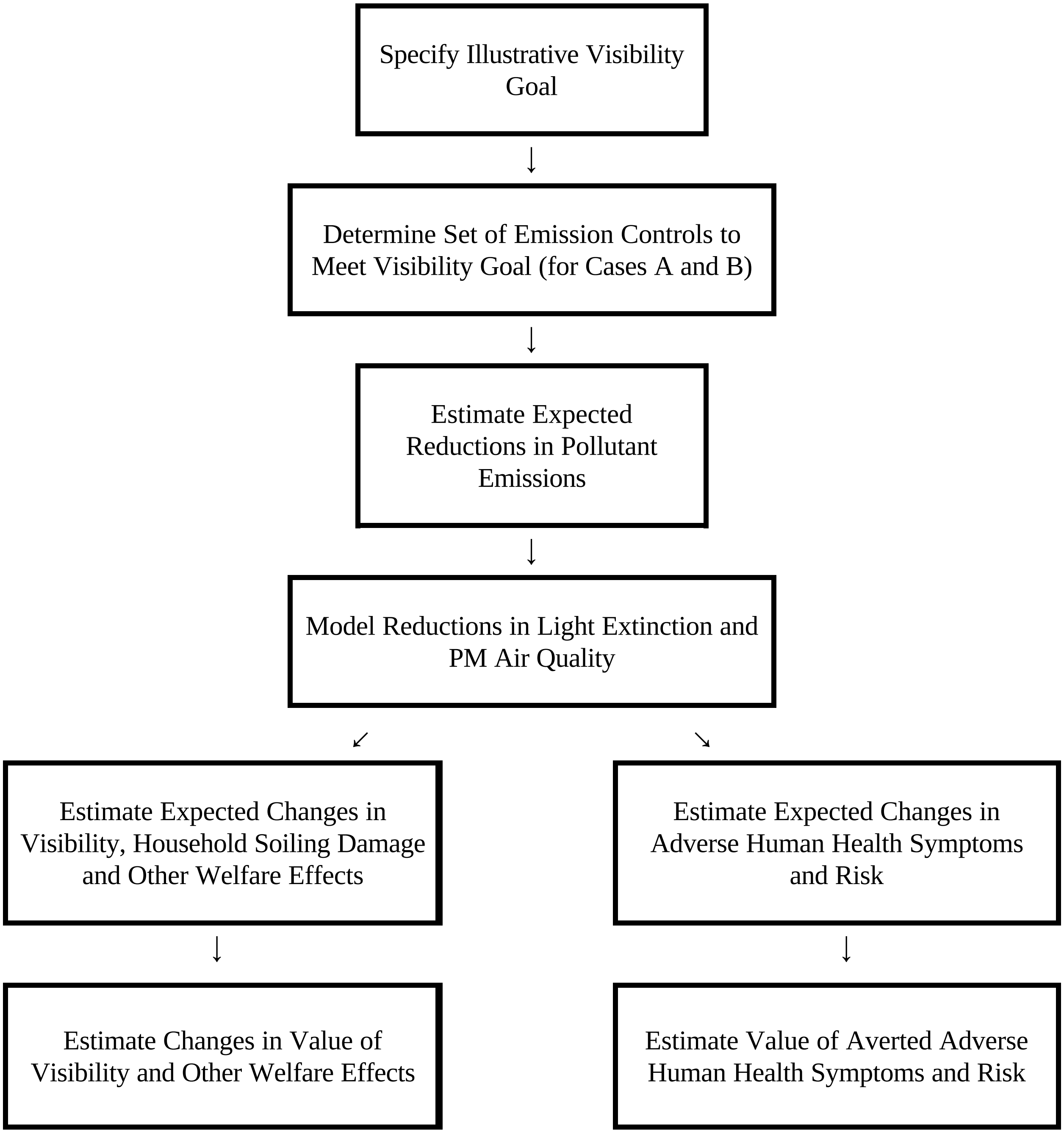
In addition to differences in the number of counties with deciview shortfalls, the types of emissions controlled differs between the two emission control cases. Relative to Case A, Case B (excluding fugitive dust emission controls) results in fewer reductions in PM_{10} and, for some goals, fewer reductions in directly emitted $PM_{2.5}$. Emissions of nitrogen oxides (NOx) and sulfur dioxide (SO_2) are reduced more in Case B relative to Case A. The composition of emissions reductions matters because PM related health benefits are highly dependent on the type of PM concentrations that are reduced, i.e. mortality is dependent on changes in $PM_{2.5}$ concentrations and chronic bronchitis is dependent on changes in PM_{10}. Therefore, given that Case B results in fewer reductions in PM_{10} we would expect to see lower benefits associated with reduced chronic bronchitis. In addition for those goals under Case B that have increased reductions in both directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors, we would expect to see higher benefits associated with reduced mortality. However, for those goals where directly emitted $PM_{2.5}$ increases and $PM_{2.5}$ precursor emissions decrease, the expected impact on mortality related benefits is ambiguous.

This analysis uses a "damage function" approach to estimate the adverse physical effects from air pollution that will be avoided in the United States due to implementation of the emission reductions required to achieve a specified visibility goal. This approach examines individual physical effects that may be affected by reductions in specific pollutants. An "economic unit value" approach is used (for most effect categories, e.g., premature mortality or chronic bronchitis) to estimate society's aggregate demand (i.e., willingness to pay (WTP) for avoiding each type of physical effect on a per-incidence level. Total value for a given physical effect is simply the product of the number of incidences avoided and the value per incidence avoided. The damage function approach assumes that benefits from individual endpoints are additive and independent, i.e., benefits for one endpoint do not depend on benefits for a separate endpoint. Alternative approaches include market-based measures such as hedonic prices, which measure the total value of a reduction in air pollution using a single metric, such as the marginal price of an environmental attribute embedded in the price of a house, or contingent valuation, which asks individuals for their total WTP for a reduction in air pollution. If the single metric approach successfully captures the full WTP for a reduction in air pollution, then the damage function approach should provide an estimate that is less than or equal to the estimate from the single metric approach. All dollar estimates of monetary benefits presented in this chapter are in 1990 dollars.

Some of the estimates of the economic value of avoided health and welfare effects are derived from contingent valuation (CV) studies. Concerns about the reliability of value estimates that come from CV studies have dominated debates about the methodology, since research has shown that bias can be introduced easily into these studies, especially if they are not carefully done. Accurately measuring willingness to pay for avoided health and welfare losses depends on the reliability and validity of the data collected. There are several issues to consider when evaluating study quality, including but not limited to 1) whether the sample estimates of WTP are representative of the population WTP, 2) whether the good to be valued is comprehended and accepted by the respondent, 3) whether the WTP elicitation format is designed to minimize strategic responses, 4) whether WTP is sensitive to respondent familiarity with the good, to the size of the change in the good, and to income, 5) whether the estimates of WTP are broadly consistent with other estimates of WTP for similar goods, and 6) the extent to which WTP responses are consistent with established economic principles. This benefits analysis does not attempt to list the individual strengths and weaknesses of each CV study used, however, in some instances, such as for valuation of chronic bronchitis and residential visibility, when the CV study reliability can be questionable, we adopt alternative estimates as conservative measures of benefits, which are presented in the low-end estimate of the range of monetized benefits.

The valuation of avoided incidences of health effects and avoided degradation of welfare effects relies on benefits transfer. The benefits transfer approach takes values or value functions

Figure 9.1
Methodology for the Regional Haze Benefits Analysis



generated by previous research and transfers them from the study to the policy of interest. For example, the value of reduced mortality is obtained from a distribution of values of statistical life based on 26 wage-risk and contingent valuation studies. None of the values for the health and welfare categories valued in this benefit analysis were generated specifically for the RH rule. The validity of this approach relies on the correlation between the attributes of the policy and the studies from which the values were obtained. Where possible, studies were selected that valued endpoints matching those in the policy analysis. When studies were not available with exact matches between the studied endpoint and the policy endpoint, studies were selected to provide as close a match as possible and differences are noted in the text.

The first step in a benefits analysis using this approach is the identification of the types or categories of benefits associated with the anticipated changes in ambient air quality conditions. The second step is the identification of relevant studies examining the relationships between air quality and these benefit categories and studies estimating the value of avoiding damages. Table 9-1 provides an example of the types of benefits potentially observed as a result of changes in air quality. The types of benefits identified in both the health and welfare categories can generally be classified as use benefits or non-use benefits.

Use benefits are the values associated with an individual’s desire to avoid exposure to an environmental risk. Use benefits include both direct and indirect uses of affected ambient air, and embrace both consumptive and non-consumptive activities. In most applications to air pollution scenarios, the use benefits with the highest monetized value are those related to human health risk reductions, visibility, and materials damage.

Non-use (intrinsic) benefits are values an individual may have for lowering air pollution concentrations or the level of risk unrelated to his or her own exposure. Individuals apart from any past, present, or anticipated future use of the resource in question can value improved environmental quality. Such non-use values may comprise a significant portion of the total monetary benefits. However, the dollar amount to assign to these non-use values often is a matter of considerable debate. While human uses of a resource can be observed directly and valued with a range of technical economic techniques, non-use values often must be ascertained through indirect methods, such as asking survey respondents to reveal their values.

Non-use values may be related to the desire that a clean environment be available for the use of others now and in the future, or may be related to the desire to know that the resource is being preserved for its own sake, regardless of human use. The component of non-use value that is related to the use of the resource by others in the future is referred to as the bequest value. This value is typically thought of as altruistic in nature. For example, the value that an individual places on reducing the general population’s risk of PM exposure either now or in the future is referred to as the bequest value. Another potential component of non-use value is the value that is related to preservation of the resource for its own sake, even if there is no human use of the resource. This component of non-use value is sometimes referred to as existence value. An example of an existence value is the value placed on protecting the habitats of endangered species from the effects of air pollution, even if the species have no direct use to humans.

Table 9-1
Examples of Potential Benefits of Air Quality Improvements

USE BENEFITS	EXAMPLES
Direct	Human Health Improvements (e.g., less incidences of coughing)
Indirect	Non-Consumptive Use (e.g., improved visibility for recreational activities)
Option Value	Risk Premium for Uncertain Future Demand Risk Premium for Uncertain Future Supply (e.g., treating as insurance, the protection of a forest just in case a new use for a forest product will be discovered in the future)
Aesthetic	Residing, working, traveling, and/or owning property in reduced smog locations
NON-USE BENEFITS	
Bequest	Intergenerational Equity (e.g., an older generation wanting a younger generation to inherit a protected environment)
Existence	Stewardship/Preservation/Altruistic Values (e.g., individuals wanting to protect a forest even if they know that they will never use the forest) Ecological Benefits

The majority of health and welfare benefits categories included in this analysis can be classified as direct-use benefits. These benefits are discussed in greater detail than other benefits categories presented in Table 9-1 because more scientific and economic information has been gathered for the direct-use benefits category. Detailed scientific and economic information is not as readily available for the remainder of the potential benefits categories listed in Table 9-1. Information pertaining to indirect use, option value, aesthetic, bequest, and existence benefits is often more difficult to collect.

It is also difficult to identify all the types of benefits that might result from environmental regulation and to value those benefits that are identified. A cost analysis is expected to provide a more comprehensive estimate of the cost of an environmental regulation because technical information is available for identifying the technologies that would be necessary to achieve the desired pollution reduction. In addition, market or economic information is available for the many components of a cost analysis (e.g., energy prices, pollution control equipment, etc.). A similar situation typically does not exist for estimating the benefits of environmental regulation. This problem is due to the non-market nature of many benefit (or disbenefit) categories. Since many pollution effects (e.g., adverse health or ecological effects) traditionally have not been traded as market commodities, economists and analysts cannot look to changes in market prices and quantities to estimate the value of these effects. This lack of observable markets may lead to the omission of significant benefit (or disbenefit) categories from an environmental benefits analysis.

Because of the inability to quantify many of the benefits categories listed in Table 9-1, as well as the omission of unknown but relevant environmental benefits categories, the quantified benefits presented in this report may underestimate total benefits. It is not possible to quantify the magnitude of this underestimation. The more important of these omitted effect categories are shown in Table 9-2. Underestimation of total benefits may be mitigated to some extent if there are also relevant disbenefit categories that are omitted or unquantified.

Within each effect category, there may be several possible estimates of health and welfare effects or monetary benefit values. Each of these possibilities represents a health or welfare "endpoint." The basic structure of the method used to conduct the benefits analysis is to create a set of benefit estimates reflecting different key assumptions concerning environmental conditions and the responsiveness of human health and the environment to changes in air quality, as well as different assumptions about the values people place on changes in health and environmental quality. Total benefits are presented as a range representing the sensitivity of benefits over the set of maintained assumptions. The benefits range does not provide information on the likelihood of any set of assumptions being the correct one. Thus, while the range indicates the sensitivity of benefits to the various assumptions, it requires a subjective determination of which assumption set most closely represents reality.

The primary estimate and upper and lower ends of the range of total benefits are constructed using estimates of non-overlapping endpoints for each effect category, selected to avoid double counting. Double counting occurs when two endpoints contain values for the same thing. For example, an endpoint measuring avoided incidences of all hospital admissions would incorporate avoided incidences of hospital admissions just for heart disease. Thus, including values for avoiding both types of hospital admissions, would double count the value of avoided hospital admissions for heart disease.

Table 9-2
Unquantified Benefit Categories[a]

	Unquantified Benefit Categories Associated with PM
Health Categories	Changes in pulmonary function Morphological changes Altered host defense mechanisms Cancer Other chronic respiratory disease
Welfare Categories	Materials damage (other than consumer cleaning cost savings) Damage to ecosystems (e.g., acid sulfate deposition) Nitrates in drinking water

a Note that there are other pollutants that are reduced in conjunction with strategies implemented to reduce RH. These include ozone, carbon (a pollutant associated with global climate change) and mercury (a toxic pollutant). Co-benefits associated with these pollutant reductions are also not considered in this benefits analysis.

There are defensible alternatives to virtually every decision about the makeup of the plausible range. In order to better inform the reader of important alternative assumptions that could have been made, and to provide an understanding of the impact of each alternative on the overall assessment of the monetary benefits, the benefits analysis includes a number of quantitative sensitivity analyses. Sensitivity analyses for assumptions which affect multiple endpoints, such as the health effects threshold for PM-related health effects, are presented as part of the primary analysis for each affected endpoint. Sensitivity analyses which affect only aggregate benefits, such as calculation of total visibility benefits, will be incorporated into the plausible range and thus included as part of the presentation of total benefits.

Sensitivity analyses for alternative endpoints not included in the plausible range, such as premature mortality related to short-term PM exposures or asthma attacks, are presented in the technical support document for this Regulatory Impact Analysis (RIA) (Abt Associates, 1999).

Table 9-3 lists the specific health and welfare effects that are included in the benefits analysis, indicating the specific effect categories that are included in the plausible range of benefits. Also included in Table 9-3 are the estimates of mean WTP, or “unit values” used to monetize the benefits for each endpoint.

Table 9-3
Quantified and Monetized Health and Welfare Effects

Endpoint	Pollutant	Mean WTP per statistical incident ($1990)	
		Low-end	High-end
Health Risks Valued in the Benefits Analysis			
Mortality, Long-term Exposure - Over age 30	$PM_{2.5}$	$2,200,000	$4,800,000
Chronic Bronchitis - All Ages	PM_{10}	$59,000	$260,000
Hospital Admissions - All Respiratory, All Ages	$PM_{10}/PM_{2.5}$	$6,344	$6,344
Hospital Admissions - Congestive heart failure	PM_{10}	$8,280	$8,280
Hospital Admissions - Ischemic heart disease	PM_{10}	$10,308	$10,308
Acute Bronchitis - Children	$PM_{10}/PM_{2.5}$	$45	$45
Lower Respiratory Symptoms - Children	PM_{10}	$12	$12
Upper Respiratory Symptoms - Children	PM_{10}	$19	$19
Work Loss Days - Adult	$PM_{2.5}$	$83	$83
Minor Restricted Activity Days (MRAD) - Adult	$PM_{2.5}$	$38	$38
Welfare Effects Valued in the Benefits Analysis			
Household Soiling	PM_{10}	$2.52/household/ μg/m^3 change in PM_{10}	$2.52/household/ μg/m^3 change in PM_{10}
Visibility - Residential	Light Extinction[a]	___[b]	variable
Visibility - Select Class I areas	Light Extinction[a]	variable	variable
Nitrogen deposition to selected Eastern U.S. estuaries	NOx	$59 - $238/kg of nitrogen[d]	$59 - $238/kg of nitrogen[d]

[a] Measured in terms of deciview change.

[b] Residential visibility benefits not monetized for the low-end estimate of total benefits.

[c] California and Northwest: $12.89 in-region, $8.96 out-of-region; Southwest and Rocky Mountain: 16.82 in-region, $13.51 out-of-region; Southeast and Northeast/Central: $7.98 in-region, $4.91 out-of-region.

[d] Chesapeake Bay: $59/kg nitrogen, Albemarle-Pamlico Sound: $90/kg nitrogen, Tampa Bay: $238/kg nitrogen, Nine other estuaries: $129/kg nitrogen.

9.4 Valuing Changes in Visibility

Economic benefits may result from two different broad categories of visibility changes: (1) changes in "residential" visibility – including visibility in urban, suburban, and rural areas, as well as in recreational areas not listed as federal Class I areas; and (2) changes in "recreational" visibility – visibility at national parks and wilderness areas listed as federal Class I areas. A key difference in the two types of visibility benefits is that changes in visibility outside of Class I areas (residential visibility changes) are assumed to be valued only by populations in those areas, while changes in visibility in Class I areas (recreational visibility changes) are assumed to be valued by the entire U.S. population. However, within the category of recreational visibility, an individual's WTP for improvements in visibility in a national park may be influenced by whether the park is in the region in which the individual lives, or whether it is somewhere else. In general, people appear to be willing to pay more for visibility improvements at parks that are "in-region" than at parks that are "out-of-region." For additional details regarding the entire visibility analysis, refer to the technical support document for this analysis (Abt Associates, 1999).

The values for changes in residential and recreational visibility are derived from two contingent valuation (CV) studies, a study of residential visibility values conducted by McClelland, et al. in 1993 (based on a 1990 survey), and a study of recreational visibility values conducted by Chestnut and Rowe in 1990 (based on a 1988 survey). Contingent valuation is a rapidly developing field and new methodologies for study design and implementation are continually evolving. As such, studies developed in the late 1980's and early 1990's may differ in some elements of study design from more recent studies. The Chestnut and Rowe study has many properties of a reliable CV study, and EPA's judgement is that these are important enough properties to conclude that the study is useful for providing valuations associated with Class I area visibility improvements. The McClelland et al study has more serious inconsistencies with current best practices for conducting contingent valuation studies. As such, EPA does not conclude that the McClelland study provides a useful value for residential visibility changes in both the low and high ends of the benefits estimates. Instead, residential visibility values are included only in the high end estimate of total benefits. EPA does not quantify the value of residential visibility changes in the low end estimate of total benefits. However, EPA recognizes that residential visibility is likely to have some value, thus the low end estimate of total visibility benefits is likely to be an underestimate.

Visibility effects as described in Chapter 3 are measured in terms of changes in deciview, a unitless measure useful for comparing the effects of air quality on visibility. This measure is directly related to two other common visibility measures: visual range (measured in km) and light extinction (measured in km^{-1}). Modeled changes in visibility are measured in terms of changes in light extinction, which are then transformed into deciviews[1]. A change of one deciview represents a change of approximately 10 percent in the light extinction budget, “which is a small but perceptible scenic change under many circumstances.” (Sisler, 1996) A change of less than 10 percent in the light extinction budget represents a measurable improvement in visibility, but may not be perceptible to the eye in many cases. Some of the average regional changes in visibility are less than one deciview (i.e. less than 10% of the light extinction budget), and thus less than perceptible. However, this does not mean that these changes are not real or significant. Our assumption is then that individuals can place values on changes in visibility that may not be perceptible. This is quite plausible if individuals are aware that many regulations lead to small improvements in visibility which when considered together amount to perceptible changes in visibility.

Visibility is a function of the ability of gases and aerosols to scatter and absorb light. In the 1997 PM and Ozone NAAQS RIA and the NOx State implementation plan (SIP) call RIA, when calculating residential visibility, the S-R matrix estimate included terms for sulfates, nitrates and coarse PM, but did not include organic matter and other variables. By not including these other terms, the resulting estimates of WTP for residential and recreational visibility improvement were initially overestimated and had to be adjusted to obtain correct residential visibility benefit estimates. Advances in modeling have occurred since then, such that the full extinction budget is now modeled for all counties in the U.S., as mentioned in Chapter 4. Thus, no adjustments to the S-R matrix outputs are necessary to obtain correct visibility benefits. For more details, refer to the control measures technical support document (U.S. EPA, 1999b).

The general approach to estimating the benefit of visibility improvements is based on standard microeconomic theory, which holds that the value of an environmental quality improvement is simply the sum of the amounts that individuals would be willing to pay for it. We estimated each household’s WTP for all visibility improvements – both the residential visibility improvement near the household and the visibility improvements at the 156 Federal Class I Areas around the country. The total benefit of all changes in visibility is then calculated as the sum of these household WTPs. The method for developing calibrated WTP functions is based on the approach developed by Smith, et al. (1999).

To estimate a household’s WTP for visibility improvements at federal Class I areas, i.e. national parks and wilderness areas (“recreational visibility”) and in the household’s local area (“residential visibility”), we assumed that both kinds of visibility improvements result in utility for

---

[1] See Chapter 3 for a more complete discussion of the deciview and its relation to light extinction.

the household; both kinds of visibility are therefore arguments in the household's utility function[2], i.e.,

$$U = U\left(X,\ Z,\ Q_{IN},\ Q_{OUT}\right),$$

where X represents all non-visibility consumption goods, Z is the level of visibility in the household's local area (within a county, for example), Q_{IN} is the set of visibility levels at Class I parks in the household's region, and Q_{OUT} is the set of visibility levels at Class I parks outside of the household's region. Once the utility function is specified and the parameters of the utility function are estimated, WTP for any set of improvements in residential and recreational visibility can be calculated.

Changes in visibility due to changes in particulate matter were measured in terms of extinction coefficients, converted into deciviews. The deciview is a measure of the *lack* of visibility, and is therefore an "environmental bad," i.e., higher values result in lower utility. However, under a fixed set of "average" atmospheric conditions, a relationship can be defined between the reduction in deciviews from a baseline level to a lower level and the resulting increase in visibility, measured in terms of visual range. Thus, we can obtain measures of Z, Q_{IN}, and Q_{OUT} as functions of the corresponding deciview levels. By incorporating these functions into the utility function, we can calculate the increase in visibility (and the corresponding increase in utility) that would result from a reduction from a given baseline level to some lower level of the "environmental bad." The chain is as follows: a given reduction in deciview (the "bad") results in a given increase in visual range (the "good"), which in turn results in a given increase in utility. Given a specification for the utility function, we can then calculate the WTP for the increase in visibility.

For this analysis, we selected a Constant Elasticity of Substitution (CES) utility function, in which utility is a function of "all consumption goods," and the three categories of visibility (in-region recreational, out-of-region recreational, and residential visibility)[3]. The CES utility

---

[2] Economists use the utility function as a convenient mathematical representation of a consumer's preferences for consumption goods, environmental quality and other quality of life factors. Economists assume that consumers make choices between consumption goods (and quality of life levels) to maximize the level of utility they can achieve for a given level of income. The value expressed by a utility function (often referred to as the level of "utils") has no intrinsic meaning, merely serving as an index of the level of satisfaction a consumer achieves given a set of consumption and quality of life levels.

[3] The CES utility function for a household in the nth residential area and the ith region of the country is specified as $U_{ni} = (X^{\rho} + \theta Z_n^{\rho} + \sum_{k=1}^{N_i} \gamma_{ik} Q_{ik}^{\rho} + \sum_{j \neq i} \sum_{k=1}^{N_j} \delta_{jk} Q_{jk}^{\rho})^{1/\rho} \quad , \theta > 0, \gamma_{ik} > 0, \forall i, k, \delta_{jk} > 0, \forall j, k,\ \rho \leq 0.$, where Z_n = the level of

function is a very simple utility function, employed here primarily because it yields tractable WTP functions. Alternative assumptions about the form of the utility function may yield different estimates of WTP. Because visibility is not a marketed good, and therefore does not have a market price, the household's maximum achievable utility is a function of household income, each of the two categories of recreational visibility, and residential visibility. The WTP for a change in visibility in any of the three categories can be derived from the CES utility function. Holding all other visibility levels constant, the specification for WTP for a recreational visibility for the kth park in a household's region i is derived from the CES utility function is

$$WTP\left(\Delta Q_{ik}\right) = m - \left[m^{\rho} + \gamma_{ik}\left(Q_{0ik}^{\rho} - Q_{1ik}^{\rho}\right)\right]^{\frac{1}{\rho}}$$

where m is household income, Q_0 is the baseline visibility level and Q_1 is the improved visibility level. The specifications for WTP for changes in visibility in out-of-region parks and in residential visibility are similar, with appropriate substitutions for the Q's.

This formulation allows the household's WTP for visibility improvements to depend on household income. The CES utility function described above has several parameters, one of which (the "shape" parameter, ρ) is closely related to the elasticity of substitution. In addition for applications where the WTP is a small share of income, ρ is approximated by one minus the income elasticity of WTP. There is some evidence, although limited, that the income elasticity of WTP for visibility improvements is about 0.9 (Chestnut, 1997). Because the evidence suggests that the income elasticity is about 0.9, we set the shape parameter to 0.1 (if WTP were not affected by income, the income elasticity of WTP would be zero and the shape parameter would be 1). Thus, the WTP specification we employ is consistent with an income elasticity that is different from zero.

In addition to allowing WTP to depend on income, the above specification of WTP also allows WTP to be a decreasing function of the baseline visibility level. The WTP function thus has commonly observed economic properties, i.e., it is an increasing function of income and a decreasing function of the environmental good, reflecting decreasing marginal utility.

---

visibility in the nth residential area; Q_{ik} = the level of visibility at the kth in-region park (i.e., the kth park in the ith region); Q_{jk} = the level of visibility at the kth park in the jth region (for which the household is out-of-region), $j \neq i$; N_i =the number of parks in the ith region; N_j =the number of parks in the jth region (for which the household is out-of-region), $j \neq i$; and θ, the γ's and δ's are parameters of the utility function corresponding to the visibility levels at residential areas, and at in-region and out-of-region parks, respectively.

The other parameters (θ and the γ's and δ's mentioned in footnote 1) correspond to each of the visibility arguments in the utility function. Each of these parameters can be estimated if we assume that the corresponding visibility category is the first in the set of visibility categories to be valued by the household.[4] To estimate these parameters, we relied on several studies in which household WTPs for visibility improvements were estimated. The basic approach was to calibrate each parameter to the information in the appropriate study. For example, McClelland et al. (1991) estimated household WTP for a specific improvement in residential visibility. Using the mean income and the mean WTP for the specified visibility change reported in the study, and assuming a value of 0.1 for the "shape" parameter (ρ) in the CES utility function, we calibrated the value of the "residential visibility" parameter (θ) to the McClelland et al. study. We calculated the value of the "residential visibility" parameter (θ) that would result in a WTP for a change from the baseline to the improved visibility level in the study equal to the mean WTP reported in the study. The same method was used to estimate each of the recreational visibility category parameters (γ's and δ's).

While the residential visibility parameter was assumed to be the same for households everywhere (due to the limited geographical scope of the McLelland, et al. study), the recreational visibility parameters depend on the household's location. The WTP for improvements in recreational visibility is based on the results of a 1990 Cooperative Agreement project jointly funded by the EPA and the National Park Service (NPS), "Preservation Values For Visibility Protection at the National Parks." Based on the results of this study Chestnut and Rowe, 1990, estimated WTP (per household) for visibility changes at national parks in several areas of the United States – both for households that are in-region (in the same region as the park) and for households that are out-of-region. The areas for which in-region and out-of-region WTP estimates are available, and the sources of benefit transfer-based estimates that we employed in the absence of direct estimates, are summarized in Table 1 below. In all cases, WTP refers to WTP per household.

---

[4] The order in which the household considers its WTP for each of a series of environmental quality improvements will affect its WTP for each improvement, although it will not affect the total WTP for the entire series of improvements. This is because each WTP depends on the household's income, which is diminished by what it has already paid for previous environmental quality improvements. Because household WTP for visibility improvements is generally a very small proportion of total household income, however, the impact of the order of consideration of WTP on the WTP for each individual visibility improvement will be negligible. For more details on this issue see the benefits TSD for this RIA (Abt Associates, 1999).

Table 9-4
Available Information on WTP for Visibility Improvements in National Parks

Region of Park[a]	**Region of Household**	
	In-Region[b]	**Out-of-Region**[c]
1. California	WTP estimate from Chestnut and Rowe, 1990	WTP estimate from Chestnut and Rowe, 1990
2. Colorado Plateau (Southwest)	WTP estimate from Chestnut and Rowe, 1990	WTP estimate from Chestnut and Rowe, 1990
3. Southeast United States	WTP estimate from Chestnut and Rowe, 1990	WTP estimate from Chestnut and Rowe, 1990
4. Northwest United States	(based on benefits transfer from California)	
5. Northern Rockies	(based on benefits transfer from Colorado Plateau)	
6. Rest of United States	(based on benefits transfer from Southeast U.S.)	

[a] Transfer regions are groups of states adjacent to the study region from which WTP values are assigned and which were subjectively determined to have broadly similar park characteristics. Transfer regions include Northwest U.S. (Oregon and Washington), Northern Rockies (Idaho, Montana, and Wyoming), and Rest of U.S.

[b] "In-region" WTP is WTP for a visibility improvement in a park in the same region as that in which the household is located. For example, in-region WTP in the "California" row is the estimate of the average California household's WTP for a visibility improvement in a California park.

[c] "Out-of-region" WTP is WTP for a visibility improvement in a park that is not in the same region in which the household is located. For example, out-of-region WTP in the "California" row is the estimate of WTP for a visibility improvement in a park in California by a household outside of California.

While the CV studies are "park-specific," the utility functions are "household-specific." The values of the parameters in a household's utility function will depend on where the household is located. For households in a region in which a study was conducted (i.e., California, the Colorado Plateau, or the Southeast United States), we directly use the "in-region" WTP estimate from the study to estimate the parameters in the utility function corresponding to visibility at in-region parks. Similarly, we directly use the "out-of-region" WTP estimates from the studies to estimate the corresponding parameters for out-of-region households. For example, the parameters in the utility function of a household in Minnesota corresponding to visibility improvements at California parks are derived using the study estimate of out-of-region WTP for visibility improvements at California parks.

To estimate these parameters for visibility at parks in regions for which no study has been conducted, we relied on benefits transfers, as outlined in Table 9-4. A visibility improvement in parks in one region, however, is not necessarily the same environmental quality good as the same visibility improvement at parks in a different region. This may be due to differences in the scenic vistas at different parks, uniqueness of the parks, or other factors, such as public familiarity with the park resource. To take this potential difference in environmental quality goods being valued into account, we adjusted the WTP being transferred by the ratio of visitor days in the two regions[5]. Suppose, for example, that WTP for a change in visibility at California parks from level Q_0 to level Q_1 was estimated to be $WTP. Suppose, in addition, that California parks are visited twice as often per year as parks in the Northwest. Then the WTP for a visibility change in Northwest parks from level Q_0 to level Q_1 would be calculated as 0.5*$WTP. This WTP estimate would then be used to calculate the parameters for visibility at Northwest parks in the same way that the original WTP estimate for California was used to calculate parameters for visibility at California parks.

The Chestnut and Rowe (1990) study which estimated WTP for recreational visibility improvements at parks in a region did not estimate park-specific WTPs, but only WTP for the improvement at "parks in the region." Region-wide WTPs were therefore apportioned to specific parks within the region. Each park-specific value was calculated as the region-wide WTP times that park's share of total visits per year in the region. However, the WTP function parameters at all parks within a region are determined by the WTP reported for the entire region.

The Preservation Values study examined the demand for visibility in Class I-areas managed by the National Park Service in three broad regions of the country, California, Southwest, and Southeast[6]. For a given region, the Preservation Values study asked respondents in Arizona, California, Missouri, New York and Virginia for their willingness to pay to protect visibility at National Parks (or wilderness areas managed by the NPS) in that region. Table 9-5 lists the parks included in the study. The RH rule is a national program which should have impacts on visibility in Class I areas throughout the entire U.S. and including both National Parks and Federal Wilderness Areas managed by the NPS, Forest Service (FS), and Fish and Wildlife Service (FWS). In the proposed RH Rule (1997), visibility changes outside of the three study

---

[5] This assumes that differences in preferences for visibility at different parks can be proxied for by observed visitation behavior. This is clearly a very crude approximation, since the WTP we are estimating includes both use and non-use values, and a visitation rate is a better measure of use value and is not clearly linked to non-use values. However, short of conducting surveys for individual parks, it is difficult to estimate the relative importance of visibility at each park, so visitation rates may provide a reasonable proxy relative to other types of park information, such as park size.

[6] Chestnut and Rowe classified any national park or wilderness area as a Class I national park if the park or wilderness area was under management by the National Park Service. For the purposes of this discussion and our analysis, a wilderness area is defined as any Class I area under the management of the Forest Service or Fish and Wildlife Services.

regions examined in the Preservation Values study were not assigned any monetary value. In addition, non-NPS Class I areas within study regions were not assigned any monetary value. Given the large changes in visibility occurring in regions outside of the set of Preservation Values study regions, the method used in the proposal severely understated the potential monetary value of visibility changes from the RH rule. To address this deficiency, this analysis uses benefit transfer methods to derive monetary benefits for visibility changes in Class I areas outside of the Preservation Values study regions and for non-NPS Class I areas within the study regions. A full list of the 147 Class I areas and associated park visitation rates is available in Appendix F to this RIA.

Transference of WTP values from the Chestnut and Rowe study regions to non-NPS Class I areas outside the study areas is accomplished in the same manner as for NPS Class I areas outside the study regions. Transference of WTP values to wilderness areas within the study regions can be accomplished in two different ways, depending on the assumed nature of the WTP responses. Recall that respondents were asked their WTP for a visibility changes at all NPS managed Class I areas in a region. Prior to the question, respondents were provided with a map showing the locations of the NPS managed Class I areas in each region. This map did not show the location or number of other Class I areas (managed by the Forest Service or Fish and Wildlife Service) in each region. The first method for transferring WTP to non-NPS Class I areas is to assume that respondents did not include these areas in their WTP for visibility changes in the region. If this is the case, then these areas can be treated the same as other transfer areas. The second method for transferring WTP to non-NPS Class I areas is to assume that respondents did include the non-NPS Class I areas in their WTP for visibility changes in the region, i.e., WTP for visibility changes in non-NPS areas is embedded in the WTP for visibility changes in the entire region. If this is the case, then the WTP for visibility changes in the non-NPS area should be a portion of the WTP for the entire region. If the first method is assumed, then the total WTP for visibility changes at all Class I areas in a study region will exceed the WTP reported in the Chestnut and Rowe study. If the second method is assumed, then the total WTP for visibility changes at all Class I areas in a study region will equal the WTP reported in the Chestnut and Rowe study, but the WTP for a given Class I area in the region will be lower than if the non-NPS areas were excluded. For this analysis, we use the first method to generate the high estimate of visibility benefits for non-NPS Class I areas and the second method to generate the low-end estimate of visibility benefits for non-NPS Class I areas.

Table 9-5

Class I Areas Included in Visibility Study By Region

Visibility Region	National Parks
California	**Yosemite**, Sequoia/Kings Canyon, Redwoods, Pinnacles, Lava Beds, Death Valley, Lassen Volcanic, Joshua Tree, Point Reyes
Southwest	**Grand Canyon**, Mesa Verde, Arches, Bandelier, Capitol Reef, Carlsbad Caverns, Bryce Canyon, Chiricahua, Zion, Saguaro, Canyonlands, Petrified Forest, Rocky Mountain
Southeast	**Shenandoah**, Great Smoky Mountains, Mammoth Cave, Everglades

Note: The "indicator" park is shown in bold for each of these three regions. In each case the indicator park is a well-known park in that region. Source: Chestnut (1997).

Photos from each of the study regions' "indicator parks" were provided as part of the survey instrument. After a number of preparatory questions, respondents reached the WTP section of the survey. Respondents were first instructed that their answer to the WTP question applied only to the region in their survey, and that they did not have to worry about other regions of the country. This makes it less likely that there will be overlap between residential and recreational visibility benefits.

The in-region coefficient estimates the WTP of residents within a given visibility region for visibility improvements at all parks located within that same region. The out-of-region coefficient estimates the WTP of residents living outside a given visibility region for visibility improvements at all parks located within that region. The results of the survey suggest that in-region residents are likely to value visibility improvements at their parks more than out-of-region residents. This is consistent with expectations, as in-region households are more likely to visit, know about, and care for these parks.

Total visibility benefits consist of a combination of residential, in-region and out-of-region recreational visibility benefits. Because of the substantial uncertainty about the reliability of the WTP values estimated in the McLelland, et al. residential visibility study, residential visibility values are not included in the low-end estimate of total visibility benefits. The low-end estimate of total visibility benefits is thus equal to just the in-region and out-of-region recreational visibility values for Class I areas, assuming that the WTP for visibility changes at non-NPS Class I areas is included in the total WTP for visibility changes at NPS Class I areas in a region. In the high-end estimates, total visibility benefits consist of residential visibility benefits, as well as in- and out-of-region recreational visibility benefits for Class I areas, assuming that WTP for non-

NPS Class I areas is in addition to the total WTP for visibility changes at NPS Class I areas in a region.

9.5 Monetized PM-Related Health and Welfare Benefits

Although the primary environmental purpose of the RH rule is to help improve visibility in federal Class I areas, significant monetary benefits will also be associated with changes in ambient levels of PM. While a broad range of adverse health and welfare effects have been associated with exposure to elevated PM levels, only subsets of these effects are selected for inclusion in the quantified benefit analysis. Effects are excluded from the current analysis(1) in order to prevent double counting (such as hospital admissions for specific respiratory diseases); (2) due to uncertainties in applying effect relationships based on clinical studies (where human subjects are exposed to various levels of air pollution in a carefully controlled and monitored laboratory situation) to the population affected by the RH rule; or (3) due to a lack of an established concentration-response relationship. The PM-related effect categories that are included in this analysis are shown in Tables 9-6 and 9-7. For all of the PM-related health endpoints, benefits are estimated under three threshold assumptions: background, lowest observed level in the study from which the concentration-response function is taken, and 15 $\mu g/m^3$, the current PM standard.

The general format for the following sections detailing the benefit assessment methodology for each endpoint is to begin with a presentation of the study used to obtain the concentration-response function for estimation of avoided incidences and then present the method and studies used for economic valuation. For additional information about specific endpoints, see the technical support document for this RIA (Abt Associates, 1999).

Table 9-6
Quantified PM-Related Health Effects Included in the Benefits Analysis

Endpoint	Population to Which Applied	Study
Mortality		
$PM_{2.5}$-related long-term exposure mortality	ages 30+	Pope et al., 1995
Hospital Admissions		
"all respiratory"	all ages	Thurston et al., 1994
Congestive heart failure	age 65+	Schwartz and Morris, 1995
Ischemic heart disease	age 65+	Schwartz and Morris, 1995
Chronic Bronchitis		
Development of chronic bronchitis	all	Schwartz, 1993
Respiratory Symptoms/Illnesses Not Requiring Hospitalization		
Acute bronchitis	ages 10-12	Dockery et al., 1989
$PM_{2.5}$-related lower respiratory symptoms (LRS)	ages 8-12	Schwartz et al., 1994
Upper respiratory symptoms (URS)	asthmatics, age 9-11	Pope et al., 1991
MRADs	ages 18-65	Ostro and Rothschild, 1989
Work loss days (WLDs)	ages 18-65	Ostro, 1987

Table 9-7
Quantified PM-Related Welfare Effects Included in the Benefits Analysis

Endpoint	Population to Which Applied	Study
Household Soiling	all households	Manuel, et al in ESEERCO, 1994
Nitrogen Deposition to Eastern Estuaries[a]	nitrogen sensitive estuaries	EPA, 1999c

[a] Nitrogen deposition is not a PM-related benefit, but rather is a direct result of emissions of NOx. However, for convenience of presentation, it is included in the set of PM-related benefits.

9.5.1 Issues in Estimating Changes in Health Effects

This benefits analysis relies on concentration-response (C-R) functions estimated in published epidemiological studies relating adverse health and welfare effects to ambient air quality. The specific C-R functions used are included in Table 9-8.

When a single published study is selected as the basis of the C-R relationship between a pollutant and a given health endpoint, applying the C-R function is straightforward. This is the case for the endpoints selected for inclusion in the benefits analysis. A single C-R function may be chosen over other potential functions because the underlying epidemiological study used superior methods, data or techniques, or because the C-R function is more generalized and comprehensive. For example, the study that estimated the effects of PM on hospital admissions for all ages and all respiratory diseases is selected over studies limited to the over 65 year old population or specific categories of respiratory diseases.

The same concentration-response relationship is applied everywhere in the benefits analysis. Although the concentration-response relationship may in fact vary somewhat from one location to another (for example, due to differences in population susceptibilities or differences in the composition of PM), location-specific concentration-response functions are generally not available. While a single function applied everywhere may result in overestimates of incidence changes in some locations and underestimates of incidence changes in other locations, these location-specific biases will to some extent cancel each other out when the total incidence change is calculated. It is not possible to know the extent or direction of the bias in the total incidence change based on application of a single C-R function everywhere.

The remainder of this section discusses two key issues involving the use of C-R functions to estimate the benefits of the RH rule: baseline incidences and health effect thresholds, i.e., levels of pollution below which changes in air quality have no impacts on health.

9.5.1.1 Baseline Incidences

The epidemiological studies of the association between pollution levels and adverse health effects generally provide a direct estimate of the relationship of air quality changes to the relative risk of a health effect, rather than an estimate of the absolute number of avoided cases. For example, a typical result might be that a 10 $\mu g/m^3$ decrease in daily $PM_{2.5}$ levels might decrease hospital admissions by 3 percent. The baseline incidence of the health effect is necessary to convert this relative change into a number of cases.

United States county-level baseline mortality rates for 1990 were obtained from the National Center for Health Statistics (US Department of Health and Human Services, 1994). Because most PM studies that estimate C-R functions for mortality considered only non-accidental mortality, county-specific baseline mortality rates used in the estimation of PM-related mortality were adjusted to provide a better estimate of county-specific non-accidental mortality. Each county-specific mortality rate was multiplied by the ratio of national non-accidental mortality to national total mortality (0.93).

Although total mortality incidences (over all ages) are available for counties, age-specific mortality incidences is not generally available at the county level. Therefore, county-specific baseline mortality incidences among individuals aged 30 and over (necessary for $PM_{2.5}$-related long-term exposure mortality, estimated by Pope et al., 1995) are estimated by applying national age-specific death rates to county-specific age distributions, and adjusting the resulting estimated age-specific incidences so that the estimated total incidences (including all ages) equals the actual county-specific total incidences.

Unlike mortality, county-specific baseline incidence rates for morbidity endpoints are not available. When available, national baseline incidences of these endpoints are used to estimate the county-specific rates. If the C-R function for the health effect is limited to a certain age group (such as ages 65 and older), the county-specific baseline incidence rate is estimated by multiplying the national all-age baseline incidence rate by the ratio of the county-specific proportion of the population in the relevant age group to the national proportion of the population in the relevant age group.

Baseline incidence rates for all respiratory symptoms and illnesses included in the benefit analysis and for restricted activity days are obtained from the studies reporting C-R functions for those health endpoints. No baseline incidence rates are available from other sources for these endpoints.

Table 9-8

PM Health and Welfare Concentration-Response Function Summary Data

Endpoint	Pollutant	Concentration-Response Function		Averaging Time		Population[a]	Pollutant Coefficient[b]
		Source	Functional Form	Studied	Applied		
Mortality							
Mortality (long-term exposure) -$PM_{2.5}$	$PM_{2.5}$	Pope et al., 1995	log-linear	annual median	annual median[c]	ages 30+	0.006408
Hospital Admissions							
All respiratory illnesses	$PM_{2.5}$/ PM_{10}	Thurston et al., 1994	linear	1-day average	1-day average	all	3.45 X 10^{-8}
Congestive heart failure	PM_{10}	Schwartz & Morris, 1995	log-linear	2-day average	1-day average	age 65+	0.00098
Ischemic heart disease	PM_{10}	Schwartz & Morris, 1995	log-linear	1-day average	1-day average	age 65+	0.00056
Respiratory Symptoms/Illnesses not requiring hospitalization							
Development of chronic bronchitis	PM_{10}	Schwartz, 1993		annual mean	annual mean	all	0.012
Acute bronchitis	$PM_{2.5}$/ PM_{10}	Dockery et al., 1989	logistic	annual mean	annual mean[d]	ages 10-12	0.0298
Upper respiratory symptoms (URS)	PM_{10}	Pope et al., 1991	log-linear	1-day average	1-day average	asthmatics, ages 9-11	0.0036
Lower respiratory symptoms (LRS)	PM_{10}	Schwartz et al., 1994	logistic	1-day average	1-day average	ages 8-12	0.01823

Endpoint	Pollutant	Concentration-Response Function		Averaging Time		Population[a]	Pollutant Coefficient[b]
		Source	Functional Form	Studied	Applied		
Minor Restricted Activity Days (MRADs)	$PM_{2.5}$	Ostro and Rothschild, 1989	log-linear	2-week average	1-day average	ages 18-65	0.00741
Work loss days (WLDs)	$PM_{2.5}$	Ostro, 1987	log-linear	2-week average	1-day average	ages 18-65	0.0046
Welfare Endpoints							
Household soiling and damage	PM_{10}	ESEERCO, 1994	linear	annual mean	annual mean	all households	2.52 (dollars per µg/ m^3 PM10 per household)

[a] The population examined in the study and to which this analysis applies the reported concentration-response relationship. In general, epidemiological studies analyzed the concentration-response relationship for a specific age group (e.g., ages 65+) in a specific geographical area. This analysis applies the reported pollutant coefficient to all individuals in the age group nationwide.

[b] A single pollutant coefficient reported for several studies indicates a pooled analysis; see text for discussion of pooling concentration-response relationships across studies.

[c] All 1-day averages are 24-hour averages, 2-day averages are 48-hour averages, etc.

9.5.1.2 Thresholds

A very important issue in applied modeling of changes in PM is whether to apply the concentration-response functions to all predicted changes in ambient concentrations, even small changes occurring at levels approaching “anthropogenic background”. Different assumptions about how to model thresholds can have a major effect on the resulting benefits estimates.

The underlying epidemiological functions used in most of this analysis are in fact continuous down to zero levels. However, in order to remain consistent with the available scientific information, the health benefits estimates for the analysis do not model effects below certain levels. The approach used in the analysis is to provide estimates of benefits under two assumptions, 1) individual concentration-response functions will not be applied to ambient concentrations occurring below the current PM2.5 standard of 15 15 $\mu g/m^3$ and 2) individual concentration-response functions will be applied to ambient concentrations occurring down to the “anthropogenic background” level.

Theoretically, C-R functions should be reestimated when a threshold is assumed to insure consistency with the observed correlation between mortality incidences and the pollutant. If no threshold is assumed in the epidemiological study, then the slope of the C-R function will be flatter than for a function with a threshold. This reflects the fact that all of the observed changes in mortality would have to be associated with changes above the threshold, rather than being associated with changes along the full spectrum of pollutant concentrations. Unadjusted C-R functions are used in this benefits analysis due to a lack of availability of the underlying data used to estimate the C-R functions. These data are necessary to develop threshold adjusted C-R functions. Use of an unadjusted C-R function will result in an underestimate of total avoided incidences when a threshold is assumed.

9.5.2 Premature Mortality

Particulate matter has been associated with increased risk of premature mortality in adult populations (Pope, et al., 1995). Avoided mortality is a very important health endpoint in this economic analysis due to the high monetary value associated with risks to life.

9.5.2.1 *Measuring Reductions in Premature Mortality Risk*

The PM-related premature mortality in the benefits analysis is estimated using the $PM_{2.5}$ relationship from Pope et al., 1995. This decision reflects the Science Advisory Board’s explicit recommendation for modeling the mortality effects of PM in both the completed §812

Retrospective Report to Congress and the ongoing §812 Prospective Study. The Pope study estimates the association between long-term (chronic) exposure to $PM_{2.5}$ and the survival of members of a large study population. This relationship is selected for use in the benefits analysis instead of short-term (daily pollution) studies for a number of reasons outlined below.

There are two types of exposure to elevated levels of PM that may result in premature mortality. Acute (short-term) exposure (e.g., exposure on a given day) to peak PM concentrations may result in excess mortality on the same day or within a few days of the elevated PM exposure. Chronic (long-term) exposure (e.g., exposure over a period of a year or more) to levels of PM that are generally higher may result in mortality in excess of what it would be if PM levels were generally lower. The excess mortality that occurs will not necessarily be associated with any particular episode of elevated air pollution levels. Both types of effects are biologically plausible, and there is an increasing body of consistent corroborating evidence from animal toxicity studies indicating that both types of effects exist.

There are, similarly, two basic types of epidemiological studies of the relationship between mortality and exposure to PM. Long-term studies (e.g., Pope et al., 1995) estimate the association between long-term (chronic) exposure to PM and the survival of members of a large study population over an extended period of time. Such studies examine the health endpoint of concern in relation to the general long-term level of the pollutant of concern -- for example, relating annual mortality to some measure of annual pollutant level. Daily peak concentrations would impact the results only insofar as they affect the measure of long-term (e.g., annual) pollutant concentration. In contrast, short-term studies relate daily levels of the pollutant to daily mortality. By their basic design, daily studies can detect acute effects but cannot detect the effects of long-term exposures. A chronic exposure study design (a prospective cohort study, such as the Pope study) is best able to identify the long-term exposure effects, and will likely detect some of the short-term exposure effects as well. Because a long-term exposure study may detect some of the same short-term exposure effects detected by short-term studies, including both types of study in a benefit analysis would likely result in some degree of double counting of benefits.

Another major advantage of the long-term study design concerns the issue of the degree of prematurity of mortality associated with PM. It is possible that the short-term studies are detecting an association between PM and mortality that is primarily occurring among terminally ill people. Critics of the use of short-term studies for policy analysis purposes correctly point out that an added risk factor that results in a terminally ill person dying a few days or weeks earlier than they otherwise would have (known as "short-term harvesting") is potentially included in the measured PM mortality "signal" detected in such a study. As the short-term study design does not examine individual people (it examines daily mortality rates in large populations, typically a large city population), it is impossible to know anything about the overall health status of the specific population that is detected as dying early. While some of the detected excess deaths may have resulted in a substantial loss of life (measuring loss of life in terms of lost years of remaining life), others may have lost a relatively short amount of life span.

It is much less likely that the excess mortality reported by Pope et al., 1995, whose study is based on a prospective cohort design, contains any significant amount of this short-term harvesting. First, the health status of each individual tracked in the study is known at the beginning of the study period. Persons with known pre-existing serious illnesses were excluded from the study population. Second, the Cox proportional hazard statistical model used in the Pope study examines the question of survivability throughout the study period (10 years). Deaths that are premature by only a few days or weeks within the 10-year study period (for example, the deaths of terminally ill patients, triggered by a short duration PM episode) are likely to have little impact on the calculation of the average probability of surviving the entire 10 year interval.

The Pope long-term study is selected as providing the best available estimate of the relationship between PM and mortality. It is used alone, rather than considering the total effect to be the sum of estimated short-term and long-term effects, because summing creates the possibility of double-counting a portion of total mortality. The Pope study is selected in preference to other available long-term studies because it uses the best methods (i.e., a prospective cohort method with a Cox proportional hazard model), and has a much larger cohort population, the longest exposure interval, and more locations (51 cities) in the United States, than other studies. In relation to the other prospective cohort study (Dockery, et al., 1992, the "Six-cities" cohort study), the Pope study found a smaller increase in excess mortality for a given PM air quality change.

9.5.2.2 *Valuing Reductions in Premature Mortality Risk*

The benefits analysis uses two approaches to determining the value of an avoided statistical incidence of premature mortality, the value of a statistical life (VSL) and the value of a statistical life year (VSLY). The high-end estimate uses the "statistical lives lost" approach to value avoided premature mortality. The mean value of avoiding one statistical death (VSL) is estimated to be \$4.8 million. This represents an intermediate value from a variety of estimates that appear in the economics literature, and is a value that EPA has frequently used in RIAs for other rules. This estimate is the mean of a fitted Weibull distribution of the estimates from 26 value-of-life studies identified in the §812 study as "applicable to policy analysis." The approach and set of selected studies mirrors that of Viscusi (1992) (with the addition of two studies), 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 contingent valuation (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. The 26 studies used to form the distribution of the VSL are listed in Table 9-9. A full set of references for the 26 studies can be found in Viscusi (1992).

The low-end estimate of the value of an avoided incidence of premature mortality is developed using the "statistical life-years lost" approach. If life-years lost is the measure used, then the value of a statistical life-year lost, rather than the value of a statistical life lost would be needed. Moore and Viscusi (1988) suggest one approach for determining the VSL-year lost. They assume that the willingness to pay to save a statistical life is the value of a single year of life times the expected number of years of life remaining for an individual. They suggest that a typical respondent in a mortal risk study may have a life expectancy of an additional 35 years. Using a mean estimate of $4.8 million to save a statistical life, their approach would yield an estimate of $137,000 per life-year lost or saved. If an individual discounts future additional years using a positive discount rate, the value of each life-year lost must be greater than the value assuming no discounting or a zero rate. Using a 35-year life expectancy, a $4.8 million value of a statistical life, and a 5 percent discount rate, the implied value of each life-year lost is $293,000. The value used in the RH benefits analysis will be calculated using the discount rate assumptions adopted for the entire analysis. A higher discount rate will produce a greater value per life-year, and a lower discount rate will produce a lower value. The Moore and Viscusi procedure is identical to this approach, but uses a zero discount rate. In addition to the VSLY, the expected number of life-years saved is necessary to determine the appropriate value for an avoided incidence of premature mortality. Based on adjustments to reflect age-specific relative risks developed in the §812 study, the average number of life-years lost due to PM related premature mortality is determined to be 9.8 years. Using the $4.8 million value of a statistical life (equivalent to 35 years of life), a 5% discount rate, and average life-years lost equal to 9.8 years, the value of an avoided incidence of PM-related premature mortality is then $2.2 million.

Table 9-9
Summary of Mortality Valuation Estimates from Viscusi (1992)

Study	Type of Estimate	Valuation per Statistical Life (millions of 1990 $)
Kneisner and Leeth (1991) (U.S.)	Labor Market	0.6
Smith and Gilbert (1984)	Labor Market	0.7
Dillingham (1985)	Labor Market	0.9
Butler (1983)	Labor Market	1.1
Miller and Guria (1991)	Contingent Valuation	1.2
Moore and Viscusi (1988a)	Labor Market	2.5
Viscusi, Magat, and Huber (1991b)	Contingent Valuation	2.7
Gegax et al. (1985)	Contingent Valuation	3.3
Marin and Psacharopoulos (1982)	Labor Market	2.8
Kneisner and Leeth (1991) (Australia)	Labor Market	3.3
Gerking, de Haan, and Schulze (1988)	Contingent Valuation	3.4
Cousineau, Lacroix, and Girard (1988)	Labor Market	3.6
Jones-Lee (1989)	Contingent Valuation	3.8
Dillingham (1985)	Labor Market	3.9
Viscusi (1978, 1979)	Labor Market	4.1
R.S Smith (1976)	Labor Market	4.6
V.K. Smith (1976)	Labor Market	4.7
Olson (1981)	Labor Market	5.2
Viscusi (1981)	Labor Market	6.5
R.S. Smith (1974)	Labor Market	7.2
Moore and Viscusi (1988a)	Labor Market	7.3
Kneisner and Leeth (1991) (Japan)	Labor Market	7.6
Herzog and Schlottman (1987)	Labor Market	9.1
Leigh and Folson (1984)	Labor Market	9.7
Leigh (1987)	Labor Market	10.4
Gaten (1988)	Labor Market	13.5

9.5.3 Hospital Admissions

The benefits analysis includes three types of PM-related hospital admissions, due to all respiratory illnesses (Thurston et al., 1994), congestive heart failure (Schwartz and Morris, 1995), and ischemic heart disease (Schwartz and Morris, 1995). The benefits analysis relies on a study of all respiratory hospital admissions for all age groups, rather than studies examining the population over 65.

An individual's WTP to avoid a hospital admission will include, at a minimum, the amount of money they pay for medical expenses (i.e., what they pay towards the hospital charge and the associated physician charge) and the loss in earnings. In addition, however, an individual is likely to be willing to pay some amount to avoid the pain and suffering associated with the illness itself. That is, even if they incurred no medical expenses and no loss in earnings, most individuals would still be willing to pay something to avoid the illness.

Because medical expenditures are to a significant extent shared by society, via medical insurance, Medicare, etc., the medical expenditures actually incurred by the individual are likely to be less than the total medical cost to society. The total value to society of an individual's avoidance of hospital admission, then, might be thought of as having two components: (1) the cost of illness (COI) to society, including the total medical costs plus the value of the lost productivity, as well as (2) the individual's WTP to avoid the disutility of the illness itself (e.g., the pain and suffering associated with the illness).

In the absence of estimates of social WTP to avoid hospital admissions for specific illnesses (components 1 plus 2 above), estimates of total COI (component 1) are typically used as conservative (lower bound) estimates. Because these estimates do not include the value of avoiding the disutility of the illness itself (component 2), they are biased downward. Some analyses adjust COI estimates upward by multiplying by an estimate of the ratio of WTP to COI, to better approximate total WTP. Other analyses have avoided making this adjustment because of the possibility of over adjusting -- that is, possibly replacing a known downward bias with an upward bias. The §812 SAB committee has recommended against adjusting the COI estimates upward. While the previous RIAs for PM and ozone, as well as the revised RIA for ozone and PM NAAQS, did adjust the COI estimate upward, the COI values used in the benefits analysis for the NOx SIP call RIA were not adjusted. Consistent with the §812 SAB committee guidance, the RH benefits analysis will not adjust the COI values upward.

The COI estimates used in this RIA include the estimated hospital and physician charges, based on the average length of a hospital stay for the illness, and the estimated opportunity cost of time spent in the hospital. Total estimated COI for a hospital admission for all respiratory illnesses, congestive heart failure, and ischemic heart disease are $9,106, $11,852, and $14,791, respectively. For a more detailed breakdown of the COI estimates, see the technical support document for this analysis (Abt Associates, 1999).

9.5.4 Chronic and Acute Bronchitis

9.5.4.1 *Measuring Reductions in the Risk of Chronic Bronchitis*

There are a limited number of studies that have estimated the impact of air pollution on chronic bronchitis. An important hindrance is the lack of long-term health data and the associated air pollution levels. Schwartz (1993) and Abbey et al.(1993; 1995) provide the evidence that long-term PM exposure gives rise to the development of chronic bronchitis in the U.S. Following the NO_x SIP call analysis (U.S. EPA, 1998), our analysis uses the Schwartz study to develop a C-R function linking PM to chronic bronchitis.

It should be noted that Schwartz used data on the *prevalence* of chronic bronchitis, not its *incidence*. To use Schwartz's study and still estimate the change in incidence, there are at least two possible approaches. The first is to simply assume that it is appropriate to use the baseline *incidence* of chronic bronchitis in a C-R function with the estimated coefficient from Schwartz's study, to directly estimate the change in incidence. The second is to estimate the percentage change in the prevalence rate for chronic bronchitis using the estimated coefficient from Schwartz's study in a C-R function, and then to assume that this percentage change applies to a baseline incidence rate obtained from another source. (That is, if the prevalence declines by 25 percent with a drop in PM, then baseline incidence drops by 25 percent with the same drop in PM.) Our analysis is using the latter approach, and estimates a percentage change in prevalence which is then applied to a baseline incidence rate.

9.5.4.2 *Valuing Reductions in the Risk of Chronic Bronchitis (CB)*

The PM-related CB is the only measured morbidity endpoint that may be expected to last from the initial onset of the illness throughout the rest of the individual's life. The WTP to avoid CB would therefore be expected to incorporate the present discounted value of a potentially long stream of costs (e.g., medical expenditures and lost earnings) and pain and suffering associated with the illness. Two studies, Viscusi et al. (1991) and Krupnick and Cropper (1992), provide estimates of WTP to avoid a case of CB.

The Viscusi, et al. and Krupnick and Cropper studies were experimental studies intended to examine new methodologies for eliciting values for morbidity endpoints. Although these studies were not specifically designed for policy analysis, the EPA believes the studies provide reasonable estimates of the WTP for chronic bronchitis. As with other contingent valuation studies, the reliability of the WTP estimates depends on the methods used to obtain the WTP values. Because some specific attributes of the studies raise questions about the reliability of the WTP values, we value CB using cost-of-illness (COI) for the low-end estimate of benefits and using WTP for the high-end estimate. However, EPA recognizes that COI estimates of the benefits of reduced chronic bronchitis risk are a lower bound on WTP and thus the low-end estimate of chronic bronchitis related benefits is most likely an underestimate.

The study by Viscusi et al., uses a sample that is larger and more representative of the general population than the study by Krupnick and Cropper (which selects people who have a relative with the disease). The valuation of CB in our analysis is therefore based on the distribution of WTP responses from Viscusi et al. (1991). The WTP to avoid a statistical case of pollution-related CB is derived by starting with the WTP to avoid a severe case of CB, as described by Viscusi et al. (1991), and adjusting it downward to reflect (1) the decrease in severity of a case of pollution-related CB relative to the severe case described in the Viscusi et al. study, and (2) the elasticity of WTP with respect to severity reported in the Krupnick and Cropper (Krupnick et al., 1992) study. The technical support document describes the adjustment procedure in more detail (Abt Associates, 1999). The mean value of the adjusted distribution is \$260,000. This is the WTP for CB we used in our benefits analysis.

This WTP estimate is reasonably consistent with full COI estimates derived for CB, using average annual lost earnings and average annual medical expenditures reported by Cropper and Krupnick (1990). Using a 5 percent discount rate and assuming that (1) lost earnings continue until age 65, (2) medical expenditures are incurred until death, and (3) life expectancy is unchanged by CB, the present discounted value of the stream of medical expenditures and lost earnings associated with an average case of CB is estimated to be about \$77,000 for a 30 year old, about \$58,000 for a 40 year old, about \$60,000 for a 50 year old, and about \$41,000 for a 60 year old. A WTP estimate would be expected to be greater than a full COI estimate, reflecting the willingness to pay to avoid the pain and suffering associated with the illness. The WTP estimate of \$260,000 is from 3.4 times the full COI estimate (for 30 year olds) to 6.3 times the full COI estimate (for 60 year olds). The low-end estimate of benefits from reduced incidences of CB is calculated based on the midpoint of the COI estimates across the range of ages, equal to \$59,000 per case.

9.5.4.2 Measuring Reductions in the Risk of Acute Bronchitis

Dockery et al. (1989) is used to estimate the relationship between PM and acute bronchitis. Dockery et al. examined the effects of PM and other pollutants on the reported rates of chronic cough, bronchitis and chest illness, in a study of 5,422 children aged 10 to 12. Bronchitis and chronic cough were both found to be significantly related to PM concentrations.

9.5.4.2 ***Valuing Reductions in the Risk of Acute Bronchitis***

Estimating WTP to avoid a statistical 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 1 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 (Dockery, et al., 1989) was estimated for children, whereas WTP estimates for those symptoms associated with acute bronchitis were obtained from adults.

With these caveats in mind, a rough estimate of WTP to avoid a case of acute bronchitis was derived as the midpoint of a low and a high estimate. The low estimate ($13.29) is the sum of the midrange values recommended by IEc (IEc, 1994) for two symptoms believed to be associated with acute bronchitis: coughing ($6.29) and chest tightness ($7.00). The high estimate was taken to be twice the value of a minor respiratory restricted activity day ($38.37), or $76.74. The midpoint between the low and high estimates is $45.00. This value was used as the point estimate of Midpoint WTP to avoid a case of acute bronchitis in the benefit analysis.

9.5.5 Acute Respiratory Symptoms

Exposure to PM may result in the occurrence of acute respiratory symptoms in either or both the upper and/or lower respiratory systems. Because the valuation studies used to provide unit values for the two types of respiratory symptoms, both are presented in this section.

9.5.5.1 *Measuring Reductions in the Risk of Upper Respiratory Symptoms (URS)*

The concentration-response function for URS is taken from Pope et al. (1991). Pope et al. describe URS as consisting of one or more of the following symptoms: runny or stuffy nose; wet cough; and burning, aching, or red eyes. The children in the Pope study were asked to record respiratory symptoms in a daily diary, and the daily occurrences of URS and lower respiratory symptoms (LRS), as defined above, were related to daily PM-10 concentrations. Estimates of WTP to avoid a day of symptoms are therefore appropriate measures of benefit.

9.5.5.2 *Valuing Reductions in the Risk of Upper Respiratory Symptoms*

The WTP to avoid a statistical day of URS is based on symptom-specific WTPs to avoid those symptoms identified by Pope et al. as part of the URS complex of symptoms. Three CV studies have estimated WTP to avoid various morbidity symptoms that are either within the URS symptom complex defined by Pope et al. or are similar to those symptoms identified by Pope et al. In each CV study, participants were asked their WTP to avoid a day of each of several symptoms. The three individual symptoms that were identified as most closely matching those listed by Pope et al. for URS are cough, head/sinus congestion, and eye irritation. A day of URS could consist of any one of seven possible “symptom complexes” consisting of at least one of these symptoms. It is assumed that each of the seven types of URS is equally likely. The *ex ante* MWTP to avoid a day of URS is therefore the average of the MWTPs to avoid each type of URS, or $18.70. This is the point estimate for the dollar value for URS used in the benefit analysis. Finally, it is worth emphasizing that what is being valued here is URS *as defined by Pope et al., 1991*. While other definitions of URS are certainly possible, this definition of URS is used in this benefit analysis because it is the incidence of this specific definition of URS that has been related to PM exposure by Pope et al., 1991.

9.5.5.3 Measuring Reductions in the Risk of Lower Respiratory Symptoms

Schwartz et al. (1994) is used to estimate the relationship between LRS and PM-10 concentrations. Schwartz et al. (1994) define LRS as at least two of the following symptoms: cough, chest pain, phlegm, and wheeze. The symptoms for which WTP estimates are available that reasonably match those listed by Schwartz et al. for LRS are cough (C), chest tightness (CT), coughing up phlegm (CP), and wheeze (W). A day of LRS, as defined by Schwartz et al., could consist of any one of the eleven combinations of at least two of these four symptoms.

9.5.5.4 *Valuing Reductions in the Risk of Lower Respiratory Symptoms*

It is assumed that each of the eleven types of LRS is equally likely. The *ex ante* MWTP to avoid a statistical day of LRS as defined by Schwartz is therefore the average of the MWTPs to avoid each type of LRS, or $11.82. This is the point estimate used in the benefit analysis for the dollar value for LRS as defined by Schwartz et al. The WTP estimates are based on studies which considered the value of a *day* of avoided symptoms, whereas the Schwartz study used as its measure a *case* of LRS. Because a case of LRS usually lasts at least 1day, and often more, WTP to avoid a day of LRS should be a conservative estimate of WTP to avoid a case of LRS.

Finally, as with URS, it is worth emphasizing that what is being valued here is LRS *as defined by Schwartz et al., 1994.* While other definitions of LRS are certainly possible, this definition of LRS is used in this benefit analysis because it is the incidence of this specific definition of LRS that has been related to PM exposure by Schwartz et al., 1994.

The point estimates derived for MWTP to avoid a day of URS and a case of LRS are based on the assumption that WTPs 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 being avoided. If this is the case, adding WTPs 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 WTPs would tend to underestimate WTP for avoidance of multiple symptoms. It is also possible that people may experience additional symptoms for which WTPs are not available, again leading to an underestimate of the correct WTP. However, for small numbers of symptoms, the assumption of additivity of WTPs is unlikely to result in substantive bias.

9.5.6 Work loss days

9.5.6.1 *Measuring Reductions in Work Loss Days*

A study by Ostro (1987) provides the relationship between ambient PM concentrations and work loss days. Ostro (1987) estimated the impact of PM on the incidence of work-loss days (WLD) in a national sample of the adult working population, ages 18 to 65, living in metropolitan areas. Separate coefficients were developed for each year in the analysis (1976-1981); we then combined these coefficients for use in this analysis.

9.5.6.2 *Valuing Reductions in Work Loss Days*

Thgr WTP to avoid the loss of 1 day of work was estimated by dividing the median weekly wage for 1990 (U.S. Department of Commerce, 1992) 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. Valuing the loss of a day's work at the wages lost is consistent with economic theory, which assumes that an individual is paid exactly the value of his labor.

The use of the median rather than the mean, however, requires some comment. If all individuals in society were equally likely to be affected by air pollution to the extent that they lose a day of work because of it, then the appropriate measure of the value of a work loss day would be the mean daily wage. It is highly likely, however, that the loss of work days due to pollution exposure does not occur with equal probability among all individuals, but instead is more likely to occur among lower income individuals than among high income individuals. It is probable, for example, that individuals who are vulnerable enough to the negative effects of air pollution to lose a day of work as a result of exposure tend to be those with generally poorer health care. Individuals with poorer health care have, on average, lower incomes. To estimate the average lost wages of individuals who lose a day of work because of exposure to PM pollution, then, would require a weighted average of all daily wages, with higher weights on the low end of the wage scale and lower weights on the high end of the wage scale. Because the appropriate weights are not known, however, the median wage was used rather than the mean wage. The median is more likely to approximate the correct value than the mean because means are highly susceptible to the influence of large values in the tail of a distribution (in this case, the small percentage of very large incomes in the United States), whereas the median is not susceptible to these large values. The median daily wage in 1990 was $83.00.

9.5.7 Minor Restricted Activity Days (MRAD)

9.5.7.1 *Measuring Avoided MRAD*

Ostro and Rothschild (1989) estimated the impact of $PM_{2.5}$ on the incidence of minor restricted activity days (MRAD) in a national sample of the adult working population, ages 18 to 65, living in metropolitan areas. We developed separate coefficients for each year in the analysis (1976-1981), which were then combined for use in this analysis.

9.5.7.2 *Valuing Avoided MRAD*

No studies are reported to have estimated WTP to avoid a MRAD. However, IEc (1993) 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 MRADs, rather than MRRADs (a component of MRADs), it is likely that most of the MRADs associated with exposure to PM-2.5 are in fact MRRADs. For the purpose of valuing this health endpoint, then, it is assumed that MRADs associated with PM exposure may be more specifically defined as MRRADs, and the estimate of MWTP to avoid a MRRAD is used.

Any estimate of MWTP to avoid a MRRAD (or any other type of restricted activity day other than WLD) will be somewhat arbitrary because the endpoint itself is not precisely defined. Many different combinations of symptoms could presumably result in some minor or less minor restriction in activity. It has been argued (Krupnick and Kopp, 1988) that mild symptoms will not be sufficient to result in a MRRAD, so that WTP to avoid a MRRAD should exceed WTP to avoid any single mild symptom. A single severe symptom or a combination of symptoms could, however, be sufficient to restrict activity. Therefore, WTP to avoid a MRRAD should, these authors argue, not necessarily exceed WTP to avoid a single severe symptom or a combination of symptoms. The "severity" of a symptom, however, is similarly not precisely defined; moreover, one level of severity of a symptom could induce restriction of activity for one individual while not doing so for another. The same is true for any particular combination of symptoms.

Given that there is inherently a substantial degree of arbitrariness in any point estimate of WTP to avoid a MRRAD (or other kinds of restricted activity days), the reasonable bounds on such an estimate are considered. By definition, a MRRAD does not result in loss of work. The WTP to avoid a MRRAD should therefore be less than WTP to avoid a WLD. At the other extreme, WTP to avoid a MRRAD should exceed WTP to avoid a single mild symptom. The highest IEc midrange estimate of WTP to avoid a single symptom is $15.72, for eye irritation. The point estimate of WTP to avoid a WLD in the benefit analysis is $83. If all the single symptoms evaluated by the studies listed in Exhibit 4.5 are not severe, then the estimate of WTP to avoid a MRRAD should be somewhere between $15.72 and $83.00. Because the IEc estimate of $38.37 falls within this range (and acknowledging the degree of arbitrariness associated with any estimate within this range), the IEc estimate is used as the point estimate of MWTP to avoid a MRRAD.

9.5.8 Household Soiling Damage

Welfare benefits also accrue from avoided air pollution damage, both aesthetic and structural, to architectural materials and to culturally important articles. At this time, data limitations preclude the ability to quantify benefits for all materials whose deterioration may be promoted and accelerated by air pollution exposure. However, this analysis addresses one small effect in this category, the soiling of households by PM.

Assumptions regarding the air quality indicator are necessary to evaluate the concentration-response function. The PM_{10} and $PM_{2.5}$ are both components of total suspended particulates (TSP). However, it is not clear 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 are conservative.

Several studies have provided estimates of the cost to households of PM soiling. The study that is cited by ESEERCO (1994) as one of the most sophisticated and is relied upon by EPA in its 1988 RIA for SO_2 is Manuel et al. (1982). Using 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, Manuel et al. estimate 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, and Watson and Jaksch, 1982, are about eight times and five times greater, respectively). The ESEERCO report notes, however, that the Manuel estimate is probably downward biased because it does not include the time cost of do-it-yourselfers. Estimating that these costs may comprise at least half the cost of PM-related cleaning costs, they double the Manuel et al. estimate to obtain a point estimate of \$2.52 (reported by ESEERCO in 1992 dollars as \$2.70).

9.5.9 Nitrogen Deposition

Excess nutrient loads, especially that of nitrogen, cause a variety of adverse consequences to the health of estuarine and coastal waters. These effects include toxic and/or noxious algal blooms such as brown and red tides, low (hypoxic) or zero (anoxic) concentrations of dissolved oxygen in bottom waters, the loss of submerged aquatic vegetation due to the light-filtering effect of thick algal mats, and fundamental shifts in phytoplankton community structure. Direct C-R functions relating deposited nitrogen and reductions in estuarine benefits are not available. The preferred WTP based measure of benefits depends on the availability of these C-R functions and on estimates of the value of environmental responses. Because neither appropriate C-R functions nor sufficient information to estimate the marginal value of changes in water quality exist at present, this analysis used an avoided cost approach instead of WTP to generate estuary-related benefits.

The use of the avoided cost approach to establish the value of a reduction in nitrogen deposition is problematic, because there is not a direct link between implementation of the air pollution regulation and the abandonment of a separate costly regulatory program by some other agency, (i.e. a state environmental agency). However, there are currently no readily available alternatives to this approach.[7]

The avoided costs to surrounding communities of reduced nitrogen loadings were calculated for three case study estuaries.[8] These costs are used to estimate the avoided costs for ten East Coast estuaries, and two Gulf Coast case study estuaries for which reduced nitrogen loadings were modeled.[9] The avoided cost estimates for the ten East Coast case study estuaries, which represent approximately half of the estuarine watershed area in square miles along the East Coast, are then used to extrapolate avoided costs to all East Coast estuaries. The three case study estuaries are chosen because they have agreed upon nitrogen reduction goals and the necessary nitrogen control cost data. The remaining estuaries in this analysis are chosen based on their potential representativeness and our ability to estimate the direct and indirect nitrogen load from atmospheric deposition.

Our analysis values atmospheric nitrogen reductions on the basis of avoided costs associated with agreed upon controls of nonpoint water pollution sources. We estimated benefits using a weighted-average, locally-based cost for nitrogen removal from water pollution (U.S. EPA, 1998a). Valuation reflects water pollution control cost avoidance based on the weighted average cost/pound of current non-point source water pollution controls for nitrogen in the three case study estuaries. Taking the weighted cost/pound of these available controls assumes States will combine low cost and high cost controls, which could inflate avoided cost estimates.

---

[7] Avoided cost is only a proxy for benefits, and should be viewed as inferior to willingness-to-pay based measures. Current research is underway to develop other approaches for valuing estuarine benefits, including contingent valuation and hedonic property studies. However, this research is still sparse, and does not contain sufficient information on the marginal willingness-to-pay for changes in concentrations of nitrogen (or changes in water quality or water resources as a result of changes in nitrogen concentrations).

[8] The case study estuaries are Albemarle-Pamlico Sounds, Chesapeake Bay, and Tampa Bay.

[9] The ten East Coast estuaries are Albemarle-Pamlico Sounds, Cape Cod Bay, Chesapeake Bay, Delaware Bay, Delaware Inland Bays, Gardiners Bay, Hudson River/Raritan Bay, Long Island Sound, Massachusetts Bays, and Narragansett Bays. The Gulf Coast estuaries are Sarasota Bay and Tampa Bay.

Reductions in nitrogen deposition from the RH rule should have relatively minor impacts on estuaries along the eastern seaboard and the Gulf Coast. Nitrogen reduction programs are currently targeting many of the estuaries in these areas due to current impairment of estuarine water quality by excess nutrients. Some of the largest of these estuaries, including the Chesapeake Bay, have established goals for nitrogen reduction and target dates by which these goals should be achieved. Using the best and most easily implemented existing technologies, many of the estuaries will not be able to achieve the stated goals by the target dates. Meeting these additional reductions will require development of new technologies, implementation of costly existing technologies (such as stormwater controls), or use of technologies with significant implementation difficulties, such as agricultural best management practices (BMPs). Reductions in nitrogen deposition from the atmosphere will directly reduce the need for these additional costly controls. Thus, while the RH rule does not eliminate the need for nutrient management programs already in place, it may substitute for some of the incremental costs and programs (such as an agricultural BMP program) necessary to meet the nutrient reduction goals for each estuary.

We calculated the total fixed capital cost per pound (weighted on the basis of fractional relationship of nitrogen load controlled for the estuary goal) for each of the case-study estuaries and applied in the valuation of their avoided nitrogen load controlled. The weighted capital costs per pound for the case-study estuaries are $33.35 for Albemarle-Pamlico Sounds, $21.82 for Chesapeake Bay, and $88.24 for Tampa Bay[10]. For the purposes of our analysis, EPA assumes that estuaries that have not yet established nutrient reduction goals will utilize the same types of nutrient management programs as projected for the case study estuaries. For the other nine estuaries, an average capital cost per pound of nitrogen (from the three case-estuaries) of $47.80/lb is calculated and applied; it is unclear whether this cost understates or overstates the costs associated with reductions in these other estuaries. The other nine estuaries generally represent smaller, more urban estuaries (like Tampa Bay), which typically have fewer technical and financial options available to control nitrogen loadings from nonpoint sources. This may result in higher control costs more similar to the Tampa Bay case. On the other hand, these estuaries may have opportunities to achieve additional point source controls at lower costs. Also, increased public awareness of nutrification issues and technological innovation may, in the future, result in States finding lower cost solutions to nitrogen removal.

The benefits analysis assumed that the ten included East Coast estuaries are highly or moderately nutrient sensitive, and they represent approximately 45.46 percent of all estuarine

---

[10] The value for Tampa Bay is not a true weighted cost per pound, but a midpoint of a range of $71.89 to $144.47 developed by Apogee Research for the control possibilities (mostly urban BMPs) in the Tampa Bay estuary.

watershed area along the East Coast.[11] Because the National Oceanic Atmospheric Administration (NOAA) data indicate that approximately 92.6 percent of the watershed and surface area of East Coast estuaries are highly or moderately nutrient sensitive, it is reasonable to expect that East Coast estuaries not included in this analysis would also benefit from reduced deposition of atmospheric nitrogen. Therefore, we scaled-up total benefits from the ten representative East Coast estuaries to include the remainder of the nutrient sensitive estuaries along the East Coast on the basis of estuary watershed plus water surface area. Since the ten estuaries are assumed to be nutrient sensitive and account for 48 percent of total eastern estuarine area, we scaled-up estimates by multiplying the estimate for the ten East Coast estuaries by 2.037 (equal to 92.6 percent divided by 45.46 percent). We then added this figure to the benefits estimated for the two Gulf Coast estuaries for a total benefits estimate for nitrogen deposition. Changes in nitrogen deposition to other Gulf Coast estuaries and estuaries in the western U.S. are not valued in this analysis, due to limitations in data on nutrient sensitivity in these estuaries and differences in estuarine conditions between eastern and western estuaries. Estimated nitrogen deposition benefits for eastern estuaries are thus expected to be an underestimate of national nitrogen deposition benefits.

We then than annualized all capital cost estimates based on a 7 percent discount rate and a typical implementation horizon for control strategies. Based on information from the three case study estuaries, this typically ranges from 5 to 10 years. The EPA has used the midpoint of 7.5 years for annualization, which yields an annualization factor of 0.1759. Non-capital installation costs and annual operating and maintenance costs are not included in these annual cost estimates. Depending upon the control strategy, these costs can be significant. Reports on the Albemarle-Pamlico Sounds indicate, for instance, that planning costs associated with control measures comprises approximately 15 percent of capital costs. Information received from the Association of National Estuary Programs indicates that operating and maintenance costs are about 30 percent of capital costs, and that permitting, monitoring, and inspections costs are about 1 to 2 percent of capital costs. For these reasons, the annual cost estimates may be understated.

9.6 Summary of Benefit Estimates

The dollar benefit from reducing light extinction and PM concentrations resulting from implementing the illustrative RH goals is the sum of dollar benefits from the reductions in incidence of all non-overlapping health and welfare endpoints associated with PM and light extinction for a given set of assumptions.

---

[11] There are 43 East Coast estuaries of which ten were in the sample, and 31 Gulf of Mexico estuaries of which two are in the sample.

There is uncertainty about the magnitude of the total monetized benefits associated with any of the illustrative visibility goals examined in the benefits analysis. The benefits are uncertain because there is uncertainty surrounding each of the factors that affect these benefits: the changes in ambient pollutant concentrations that will result from implementation of controls to achieve the illustrative goal; the relationship between these changes in pollutant concentrations and each of the associated health and welfare endpoints; and the value of each adverse health and welfare effect avoided by the reduction in pollutant concentrations.

Some of this uncertainty derives from uncertainty about the true values of analysis components, such as the value of the PM coefficient in a concentration-response function relating PM to a particular health endpoint, or the true dollar value of an avoided hospital admission for congestive heart failure. The analysis relies on estimates of these parameters, but the true values being estimated are unknown. This type of uncertainty can often be quantified. For example, the uncertainty about pollutant coefficients is typically quantified by reported standard errors of the estimates of the coefficients in the concentration-response functions estimated by epidemiological studies. A formal quantitative analysis of the statistical uncertainty imparted to the benefits estimates by the variability in the underlying concentration-response and valuation functions can be found in the technical support document for this benefits analysis (Abt Associates, 1999).

Some of the uncertainty surrounding the results of the benefits analysis, however, involves basically discrete choices and is less easily quantified. For example, the decision of whether to include both residential and recreational visibility to obtain total visibility benefits is largely subjective. Decisions and assumptions must be made at many points in an analysis in the absence of complete information. The estimate of total benefits is sensitive to the decisions and assumptions made. Five of the most critical of these are the following:

- **$PM_{2.5}$ concentration threshold:** Health effects are measured only down to the assumed ambient concentration threshold. Changes in air quality below the threshold will have no impact on estimated benefits. The EPA's Science Advisory Board has recommended examining alternative thresholds. For this analysis, three threshold assumptions were examined: anthropogenic background, the lowest observed level in the health endpoint study, and 15 $\mu g/m^3$ (or the equivalent of 50 $\mu g/m^3$ for PM10 functions).

- **Value of Avoided Incidences of Premature Mortality:** There are two alternative assumptions concerning the appropriate value for an avoided incidence of PM-related premature mortality: 1) avoided incidences should be valued using a value of a statistical life equal to $4.8 million (1990$), or 2) avoided incidences should be valued based on the number of statistical life years saved. Based on the $4.8 million VSL, a 5% discount rate, and an average of 9.8 statistical life years saved, this yields a value for an avoided incidence of premature mortality of \$2.2 million (1990\$).

- **Value of Avoided Incidences of Chronic Bronchitis (CB):** There are two alternative assumptions concerning the appropriate value for an avoided incidence of PM-related CB: 1) avoided incidences should be valued using the measure of WTP derived from Viscusi, et al (1991) and Krupnick and Cropper (1992), equal to \$260,000 per case, or 2) avoided incidences should be values based on a cost-of-illness approach, which yields a value of \$59,000 per case.

- **Residential Visibility:** The McClelland et al. survey which forms the basis for the WTP estimate for changes in visibility outside of Class I areas (residential visibility) has several weaknesses which call into question the reliability of the estimated WTP values. There are two alternative assumptions about residential visibility: 1) estimates of benefits based on the WTP value from the McClelland et al. study accurately reflect true WTP for changes in residential visibility and should thus be included in an estimate of total visibility benefits, or 2) estimates of benefits based on the WTP value from the McClelland et al. study are biased to the point of seriously under or overstating the benefits of residential visibility changes and should not be included in an estimate of total visibility benefits.

- **Visibility Changes at Forest Service Class I Areas:** The Chestnut and Rowe survey which forms the basis for the WTP estimate for changes in recreational visibility only elicited WTP for changes in visibility at Class I areas managed by the NPS. Two alternative assumptions may be considered for valuing changes in visibility at Class I areas not managed by the NPS: (1) values for visibility resources at non-NPS Class I areas are embedded in the WTP value for visibility changes in a region stated by respondents and thus total WTP for visibility changes in a region will not change, although the apportionment of WTP to individual parks in a region will, or (2) values for visibility resources at non-NPS managed Class I areas are additive to the stated values for visibility changes in the NPS Class I areas and thus WTP for visibility changes for all Class I areas in a region will exceed that for just the visibility changes at NPS Class I areas.

A range of total benefits reflecting sensitivity to the above assumptions can be formed by selecting assumptions to yield a low-end and a high-end estimate. The low end of the benefits range is constructed by assuming 1) the PM health-effects threshold is equal to 15 $\mu g/m^3$, 2) the value of an avoided incidence of PM-related premature mortality is equal to \$2.2 million, 3) the value of an avoided case of CB is equal to \$63,500, 4) the value of residential visibility changes is not included in the estimate of total visibility benefits, and 5) WTP for visibility changes at non-NPS Class I areas are assumed to be included in the stated WTP for visibility changes in a region.

The high end of the benefits range is constructed by assuming 1) the PM health effects threshold is equal to anthropogenic background, 2) the value of an avoided incidence of PM-related premature mortality is equal to $4.8 million, 3) the value of avoided case of CB is equal to $260,000, 4) total visibility benefits is the sum of residential and recreational visibility benefits ,and 5) WTP for visibility changes at non-NPS Class I areas is additive to WTP for NPS Class I areas in a study region.

9.6.1 Total Benefits - Case A

Table 9-20 presents a summary of the monetary values for each broad benefit category (visibility, PM health, and PM welfare) and the estimate of total benefits for each of the four regulatory alternatives under emission control Case A. Aggregate results are presented for the low-end and high-end assumption sets defined above. Monetized benefits are estimated for the 2015 analytical year. Estimates of monetized benefits for 2015 are representative of annual benefits expected from all regions selecting an illustrative goal and are not an estimate of the discounted value of the stream of future benefits in 2015.

Table 9-10

Total Quantified Monetary Benefits in 2015 Associated with the Regional Haze Rule, Incremental to the 2010 Base Case: Case A, Fugitive Dust Controls Considered[a]

Illustrative Goal	Benefit Category	Low-end		High-end	
		Millions 1990$	**% of Total**	**Millions 1990$**	**% of Total**
1.0 dv/15 years	Visibility	$1,043	77.5%	$1,191	21.4%
	PM-Health	$260	19.3%	$4,325	77.8%
	PM-Welfare	$42	3.1%	$42	0.8%
	Total	**$1,345**		**$5,558**	
1.0 dv/10 years	Visibility	$1,426	78.6%	$1,632	23.0%
	PM-Health	$333	18.3%	$5,418	76.2%
	PM-Welfare	$56	3.1%	$56	0.8%
	Total	**$1,815**		**$7,106**	
5% dv/10 years	Visibility	$1,258	78.1%	$1,447	21.3%
	PM-Health	$304	18.9%	$5,307	78.0%
	PM-Welfare	$49	3.0%	$49	0.7%
	Total	**$1,611**		**$6,803**	
10% dv/10 years	Visibility	$1,726	67.3%	$2,269	12.1%
	PM-Health	$729	28.4%	$16,361	87.3%
	PM-Welfare	$109	4.3%	$109	0.6%
	Total	**$2,564**		**$18,739**	

[a] Not all possible benefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2.

Several important results from Table 9-10 should be highlighted. First, note that visibility and PM-related health benefits account for over 95 percent of total benefits in all cases. Second, note that as the PM health threshold is lowered, visibility accounts for a lower percentage of benefits, while PM health benefits account for up to 87 percent of total benefits. This suggests that the threshold assumption is important both in determining total benefits, but also in determining the importance of visibility relative to ancillary benefits in determining overall benefits. Finally, it is important to note that three of the four illustrative goals (1.0 dv/10 years, 1.0 dv/15 years, 5% dv/10 years) lead to total benefits differing by a maximum of 34 percent, while the benefits associated with the 10% dv/10 years goal are between 71 and 164 percent greater than the most stringent of the remaining three goals, depending on the assumed threshold. This is due in large part to the magnitude of mortality-related benefits associated with this goal, although visibility benefits are 39 percent larger under the 10% dv/10 year goal relative to the 1.0 dv/10 year goal.

9.6.2 Total Benefits - Case B

Table 9-11 presents a summary of the monetary values for each broad benefit category (visibility, PM health, and PM welfare) and the estimate of total benefits for each of the four regulatory alternatives under emission control Case B. Aggregate results are presented for the low-end and high-end assumption sets defined above. Monetized benefits are estimated for the 2015 analytical year. Estimates of monetized benefits for 2015 are representative of annual benefits expected from all regions selecting an illustrative goal and are not an estimate of the discounted value of the stream of future benefits in 2015.

Table 9-11

Total Quantified Monetary Benefits in 2015 Associated with the Regional Haze Rule, Incremental to the 2010 Base Case: Case B, Fugitive Dust Controls Not Considered[a]

Illustrative Goal	Benefit Category	Low-end		High-end	
		Millions 1990$	% of Total	Millions 1990$	% of Total
1.0 dv/15 years	Visibility	$642	79.6%	$762	17.8%
	PM-Health	$146	18.1%	$3,494	81.7%
	PM-Welfare	$19	2.3%	$19	0.5%
	Total	**$807**		**$4,275**	
1.0 dv/10 years	Visibility	$829	71.1%	$1,025	10.5%
	PM-Health	$296	25.4%	$8,661	89.1%
	PM-Welfare	$41	3.5%	$41	0.4%
	Total	**$1,166**		**$9,727**	
5% dv/10 years	Visibility	$788	68.9%	$977	10.4%
	PM-Health	$315	27.6%	$8,389	89.2%
	PM-Welfare	$40	3.5%	$40	0.4%
	Total	**$1,143**		**$9,406**	
10% dv/10 years	Visibility	$1,156	62.8%	$1,549	8.0%
	PM-Health	$606	32.9%	$17,726	91.6%
	PM-Welfare	$78	4.3%	$78	0.4%
	Total	**$1,840**		**$19,353**	

[a] Not all possible benefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2.

Several important results from Table 9-11 should be highlighted. First, note that visibility and PM-related health benefits account for over 95 percent of total benefits in all cases. Second, note that as the PM health threshold is lowered, visibility accounts for a lower percentage of benefits, while PM health benefits account for up to 92 percent of total benefits. This suggests that the threshold assumption is important both in determining total benefits, but also in determining the importance of visibility relative to ancillary benefits in determining overall benefits.

9.7 Detailed Estimates of Avoided Incidences and Monetary Benefits -- Case A

Estimates of the monetized value of the changes in incidences of health and welfare endpoints are obtained by application of the concentration-response functions and unit dollar values described above to the changes in air quality described in chapter 4. Results in this section are for the air quality changes associated with emissions reductions obtained from applying the controls available in Case A (fugitive dust controls included). Results are presented for the four illustrative goals outlined in Chapter 3. For simplicity of presentation, the detailed results presented in the tables below are based on using the VSL approach to value premature mortality and the contingent valuation estimates of WTP for avoided incidences of chronic bronchitis. Estimates using the VSLY approach for premature mortality and the cost-of-illness approach for chronic bronchitis will lead to significantly lower estimates of the benefits estimates for these endpoints for all threshold levels. Estimates based on these alternative approaches are used to form the range of aggregate monetized benefits presented in Table 9-10. Because of its large impacts on PM-health benefits, results for PM-related health endpoints are presented for the three alternative PM health effect threshold levels, anthropogenic background, lowest observed level or background (LOL), and 15 $\mu g/m^3$. Monetized benefits are estimated for the 2015 analytical year. Estimates of monetized benefits for 2015 are representative of annual benefits expected from all regions selecting an illustrative goal and are not an estimate of the discounted value of the stream of future benefits in 2015.

Annual baseline incidence rates and baseline incidences for the affected populations for PM-related health endpoints are useful to put avoided incidences resulting from the RH rule in context. Incidence rates are not available for all health endpoints, however, information is available for mortality, hospital admissions, URS, work loss days, and MRAD. Table 9-12 lists the baseline incidence rates and affected populations for the above listed endpoints.

Table 9-12
Baseline Incidence Rates and Incidences for Selected PM-related Health Endpoints

PM Health Endpoint	Affected Population	Baseline Incidence Rate	Baseline Incidence
Mortality from long-term exposure	over 30 years old	759 per 100,000 (non-accidental deaths)	1,330,967 (non-accidental deaths)
Hospital Admissions - All respiratory	general population	504 per 100,000	1,500,488
Hospital Admissions - Congestive Heart Failure	general population	231 per 100,000	687,724
Hospital Admissions - Ischemic Heart Disease	general population	450 per 100,000	1,339,722
Upper Respiratory Symptoms	asthmatics, ages 9 to 11	—	38,187
Work Loss Days	workers, ages 18 to 65	150,750 days per year per 100,000 workers	—
Minor Restricted Activity Days	ages 18 to 65	150,750 days per year per 100,000 population	1,450,000,000

9.7.1 Results

Tables 9-13 through 9-16 present estimates of the avoided incidences of PM-related health effects and monetary benefits associated with visibility changes and avoided PM-related health and welfare effects for the four illustrative visibility goals for emission control Case A.

Table 9-13
Estimated Benefits in 2015 Associated with the Regional Haze Rule: 1.0 dv/15 years Visibility Goal, Case A

Endpoint	Avoided Incidences (cases/year)			Monetary Benefits (millions 1990$)		
	15 μg/m^3	LOL	Back ground	15 μg/m^3	LOL	Back ground
Visibility Endpoints						
Residential	direct economic valuation			$83	$83	$83
National Park Recreational	direct economic valuation			$983	$983	$983
Wilderness Area Recreational	direct economic valuation			$60	$60	$60
Total Visibility[a]				**$1,126**	**$1,126**	**$1,126**
PM-related Health Endpoints						
Mortality	15	280	696	$70	$1,330	$3,300
Chronic Bronchitis	3,333	3,369	3,369	$954	$964	$964
Hospital Admissions - AR[b]	125	265	265	$0.8	$1.7	$1.7
Hospital Admissions - CHF[b]	92	102	102	$0.8	$0.8	$0.8
Hospital Admissions - IHD[b]	102	113	113	$1.0	$1.2	$1.2
Acute Bronchitis	56	443	1,511	$0.0	$0.0	$0.1
LRS	7,281	15,367	15,367	$0.1	$0.2	$0.2
URS	2,917	3,241	3,241	$0.1	$0.1	$0.1
Work Loss Days	67,064	142,145	142,145	$6	$12	$12
MRAD	559,041	1,185,688	1,185,688	$21	$45	$45
Total PM-related Health	—	—	—	**$1,054**	**$2,355**	**$4,325**
PM-related Welfare Endpoints						
Household Soiling	direct economic valuation			$42	$42	$42
Nitrogen Deposition	direct economic valuation			$0.0	$0.0	$0.0
Total PM-related Welfare				**$42**	**$42**	**$42**
Total	—	—	—	**$2,222**	**$3,523**	**$5,493**

[a] Total visibility benefits are presented for the low-end assumption about wilderness areas, i.e., values for wilderness areas are assumed to have been included in the total regional value in the Chestnut and Rowe study. Residential visibility benefits are included in the total visibility benefits estimate.

[b] AR=all respiratory, CHF=congestive heart failure, IHD=ischemic heart disease.

Table 9-14
Estimated Benefits in 2015 Associated with the Regional Haze Rule: 1.0 dv/10 years Visibility Goal, Case A

Endpoint	**Avoided Incidences (cases/year)**			**Monetary Benefits (millions 1990$)**		
	15 μg/m³	**LOL**	**Back ground**	**15 μg/m³**	**LOL**	**Back ground**
Visibility Endpoints						
Residential	direct economic valuation			$117	$117	$117
National Park Recreational	direct economic valuation			$1,337	$1,337	$1,337
Wilderness Area Recreational	direct economic valuation			$88	$88	$88
Total Visibility[a]				**$1,542**	**$1,542**	**$1,542**
PM-related Health Endpoints						
Mortality	15	247	855	$72	$1,171	$4,056
Chronic Bronchitis	4,462	4,507	4,507	$1,277	$1,289	$1,289
Hospital Admissions - AR[b]	150	318	318	$1.0	$2.0	$2.0
Hospital Admissions - CHF[b]	117	132	132	$1.0	$1.1	$1.1
Hospital Admissions - IHD[b]	130	147	147	$1.3	$1.5	$1.5
Acute Bronchitis	64	535	2,021	$0.0	$0.0	$0.1
LRS	8,655	18,244	18,244	$0.1	$0.2	$0.2
URS	3,639	4,080	4,080	$0.1	$0.1	$0.1
Work Loss Days	80,106	169,788	169,788	$7	$14	$14
MRAD	667,701	1,416,360	1,416,360	$26	$54	$54
Total PM-related Health	—	—	—	**$1,386**	**$2,533**	**$5,418**
PM-related Welfare Endpoints						
Household Soiling	direct economic valuation			$56	$56	$56
Nitrogen Deposition	direct economic valuation			$0.1	$0.1	$0.1
Total PM-related Welfare				**$56**	**$56**	**$56**
Total	—	—	—	**$2,984**	**$4,131**	**$7,016**

[a] Total visibility benefits are presented for the low-end assumption about wilderness areas, i.e., values for wilderness areas are assumed to have been included in the total regional value in the Chestnut and Rowe study. Residential visibility benefits are included in the total visibility benefits estimate.

[b] AR=all respiratory, CHF=congestive heart failure, IHD=ischemic heart disease.

Table 9-15
Estimated Benefits in 2015 Associated with the Regional Haze Rule: 5% dv/10 years Visibility Goal, Case A

Endpoint	**Avoided Incidences (cases/year)**			**Monetary Benefits (millions 1990$)**		
	15 μg/m^3	**LOL**	**Back ground**	**15 μg/m^3**	**LOL**	**Back ground**
Visibility Endpoints						
Residential	direct economic valuation			$112	$112	$112
National Park Recreational	direct economic valuation			$1,180	$1,180	$1,180
Wilderness Area Recreational	direct economic valuation			$78	$78	$78
Total Visibility[a]				**$1,370**	**$1,370**	**$1,370**
PM-related Health Endpoints						
Mortality	17	316	865	$82	$1,499	$4,103
Chronic Bronchitis	3,905	3,944	3,944	$1,117	$1,128	$1,128
Hospital Admissions - AR[b]	154	327	327	$1.0	$2.1	$2.1
Hospital Admissions - CHF[b]	101	114	114	$0.8	$0.9	$0.9
Hospital Admissions - IHD[b]	113	126	126	$1.2	$1.3	$1.3
Acute Bronchitis	66	515	1,898	$0.0	$0.0	$0.1
LRS	8,869	18,847	18,847	$0.1	$0.2	$0.2
URS	3,222	3,600	3,600	$0.1	$0.1	$0.1
Work Loss Days	82,245	175,459	175,459	$7	$15	$15
MRAD	685,328	1,463,243	1,463,243	$26	$56	$56
Total PM-related Health	—	—	—	**$1,235**	**$2,703**	**$5,307**
PM-related Welfare Endpoints						
Household Soiling	direct economic valuation			$49	$49	$49
Nitrogen Deposition	direct economic valuation			$0.0	$0.0	$0.0
Total PM-related Welfare				**$49**	**$49**	**$49**
Total	—	—	—	**$2,654**	**$4,122**	**$6,726**

[a] Total visibility benefits are presented for the low-end assumption about wilderness areas, i.e., values for wilderness areas are assumed to have been included in the total regional value in the Chestnut and Rowe study. Residential visibility benefits are included in the total visibility benefits estimate.

[b] AR=all respiratory, CHF=congestive heart failure, IHD=ischemic heart disease.

Table 9-16

Estimated Benefits in 2015 Associated with the Regional Haze Rule: 10% dv/10 years Visibility Goal, Case A

Endpoint	Avoided Incidences (cases/year)			Monetary Benefits (millions 1990$)		
	15 $\mu g/m^3$	**LOL**	**Back ground**	**15 $\mu g/m^3$**	**LOL**	**Back ground**
Visibility Endpoints						
Residential	direct economic valuation			$306	$306	$306
National Park Recreational	direct economic valuation			$1,731	$1,731	$1,731
Wilderness Area Recreational	direct economic valuation			$124	$124	$124
Total Visibility[a]				**$2,161**	**$2,161**	**$2,161**
PM-related Health Endpoints						
Mortality	60	1,236	2,877	$284	$5,863	$13,643
Chronic Bronchitis	8,665	8,774	8,774	$2,479	$2,510	$2,510
Hospital Admissions - AR[b]	355	904	904	$2.3	$5.7	$5.7
Hospital Admissions - CHF[b]	237	272	272	$2.0	$2.3	$2.3
Hospital Admissions - IHD[b]	264	303	303	$2.7	$3.1	$3.1
Acute Bronchitis	102	1,245	5,304	$0.0	$0.1	$0.2
LRS	19,568	49,653	49,653	$0.2	$0.6	$0.6
URS	6,718	7,656	7,656	$0.1	$0.2	$0.2
Work Loss Days	191,242	486,681	486,681	$16	$40	$40
MRAD	1,593,098	4,058,430	4,058,430	$61	$156	$156
Total PM-related Health	—	—	—	**$2,847**	**$8,581**	**$16,361**
PM-related Welfare Endpoints						
Household Soiling	direct economic valuation			$108	$108	$108
Nitrogen Deposition	direct economic valuation			$0.9	$0.9	$0.9
Total PM-related Welfare				**$109**	**$109**	**$109**
Total	—	—	—	**$5,117**	**$10,851**	**$18,631**

[a] Total visibility benefits are presented for the low-end assumption about wilderness areas, i.e., values for wilderness areas are assumed to have been included in the total regional value in the Chestnut and Rowe study. Residential visibility benefits are included in the total visibility benefits estimate.

[b] AR=all respiratory, CHF=congestive heart failure, IHD=ischemic heart disease.

9.7.2 Discussion of Results

The results show that the imposition of a health effect threshold has a large impact on the PM2.5 based health functions. For the PM2.5 functions, up to 98 percent of total avoided incidences occur below the 15 µg/m^3 threshold. Health functions based on mean PM2.5 appear to be slightly more sensitive to the threshold level than functions based on the median.

Results also highlight the fact that the magnitude of incidences and the magnitude of monetary benefits for individual endpoints may not be strongly correlated. This is due to relatively large per-unit benefits associated with relatively low risk health endpoints, such as mortality and CB, and the relatively small per unit benefits associated with relatively high risk health endpoints, such as work loss days or MRADs. This highlights the importance of presenting both avoided incidences and monetary benefits to provide a complete picture of the impacts of a given air quality change.

The PM-related health benefits are dominated in all cases by two endpoints: mortality and CB. These two endpoints account for between 97 and 99 percent of all health benefits, depending on the threshold level assumed. The PM-related health benefits also dominate the other two benefit categories, visibility and PM-related welfare effects. Visibility accounts for between 12 and 52 percent of total benefits, depending on the visibility goal and the threshold level assumed.

9.8 Detailed Estimates of Avoided Incidences and Monetary Benefits -- Case B

Estimates of the monetized value of the changes in incidences of health and welfare endpoints are obtained by application of the concentration-response functions and unit dollar values described above to the changes in air quality described in chapter 4. Results in this section are for the air quality changes associated with emissions reductions obtained from applying the controls available in Case B (fugitive dust controls excluded). Results are presented for the four illustrative goals outlined in Chapter 3. For simplicity of presentation, the detailed results presented in the tables below are based on using the VSL approach to value premature mortality and the contingent valuation estimates of WTP for avoided incidences of chronic bronchitis. Estimates using the VSLY approach for premature mortality and the cost-of-illness approach for chronic bronchitis will lead to significantly lower estimates of the benefits estimates for these endpoints for all threshold levels. Estimates based on these alternative approaches are used to form the range of aggregate monetized benefits presented in Table 9-11. Because of its large impacts on PM-health benefits, results for PM-related health endpoints are presented for the three alternative PM health effect threshold levels, anthropogenic background, lowest observed level or background (LOL), and 15 µg/m^3. Monetized benefits are estimated for the 2015 analytical year.

Estimates of monetized benefits for 2015 are represenative of annual benefits expected from all regions selecting an illustrative goal and are not an estimate of the discounted value of the stream of future benefits in 2015.

Annual baseline incidence rates and baseline incidences for the affected populations for PM-related health endpoints are useful to put avoided incidences resulting from the RH rule in context. Incidence rates are not available for all health endpoints, however, information is available for mortality, hospital admissions, URS, WLDs, and MRAD. Table 9-17 lists the baseline incidence rates and affected populations for the above listed endpoints.

Table 9-17

Baseline Incidence Rates and Incidences for Selected PM-related Health Endpoints

PM Health Endpoint	Affected Population	Baseline Incidence Rate	Baseline Incidence
Mortality from long-term exposure	over 30 years old	759 per 100,000 (non-accidental deaths)	1,330,967 (non-accidental deaths)
Hospital Admissions - All respiratory	general population	504 per 100,000	1,500,488
Hospital Admissions - Congestive Heart Failure	general population	231 per 100,000	687,724
Hospital Admissions - Ischemic Heart Disease	general population	450 per 100,000	1,339,722
Upper Respiratory Symptoms	asthmatics, ages 9 to 11	—	38,187
Work Loss Days	workers, ages 18 to 65	150,750 days per year per 100,000 workers	—
Minor Restricted Activity Days	ages 18 to 65	150,750 days per year per 100,000 population	1,450,000,000

9.8.1 Results

Tables 9-18 through 9-21 present estimates of the avoided incidences of PM-related health effects and monetary benefits associated with visibility changes and avoided PM-related health and welfare effects for the four illustrative visibility goals.

Table 9-18
Estimated Benefits in 2015 Associated with the Regional Haze Rule: 1.0 dv/15 years Visibility Goal, Case B

Endpoint	**Avoided Incidences (cases/year)**			**Monetary Benefits (millions 1990$)**		
	15 µg/m^3	**LOL**	**Back ground**	**15 µg/m^3**	**LOL**	**Back ground**
Visibility Endpoints						
Residential	direct economic valuation			$82	$82	$82
National Park Recreational	direct economic valuation			$595	$595	$595
Wilderness Area Recreational	direct economic valuation			$47	$47	$47
Total Visibility[a]				**$724**	**$724**	**$724**
PM-related Health Endpoints						
Mortality	12	177	633	$58	$845	$3,014
Chronic Bronchitis	1,555	1,569	1,569	$419	$423	$423
Hospital Admissions - AR[b]	121	253	253	$0.8	$1.6	$1.6
Hospital Admissions - CHF[b]	40	45	45	$0.3	$0.4	$0.4
Hospital Admissions - IHD[b]	44	49	49	$0.5	$0.5	$0.5
Acute Bronchitis	56	445	1,651	$0.0	$0.0	$0.1
LRS	7,081	14,742	14,742	$0.1	$0.2	$0.2
URS	1,306	1,456	1,456	$0.0	$0.0	$0.0
Work Loss Days	63,826	133,452	133,452	$5	$11	$11
MRAD	531,817	1,112,777	1,112,777	$20	$43	$43
Total PM-related Health	—	—	—	**$504**	**$1,325**	**$3,494**
PM-related Welfare Endpoints						
Household Soiling	direct economic valuation			$19	$19	$19
Nitrogen Deposition	direct economic valuation			$0.0	$0.0	$0.0
Total PM-related Welfare				**$19**	**$19**	**$19**
Total	—	—	—	**$1,247**	**$2,068**	**$4,237**

[a] Total visibility benefits are presented for the low-end assumption about wilderness areas, i.e., values for wilderness areas are assumed to have been included in the total regional value in the Chestnut and Rowe study. Residential visibility benefits are included in the total visibility benefits estimate.

[b] AR=all respiratory, CHF=congestive heart failure, IHD=ischemic heart disease.

Table 9-19
Estimated Benefits in 2015 Associated with the Regional Haze Rule: 1.0 dv/10 years Visibility Goal, Case B

Endpoint	**Avoided Incidences (cases/year)**			**Monetary Benefits (millions 1990$)**		
	15 μg/m^3	**LOL**	**Back ground**	**15 μg/m^3**	**LOL**	**Back ground**
Visibility Endpoints						
Residential	direct economic valuation			$149	$149	$149
National Park Recreational	direct economic valuation			$766	$766	$766
Wilderness Area Recreational	direct economic valuation			$62	$62	$62
Total Visibility[a]				**$977**	**$977**	**$977**
PM-related Health Endpoints						
Mortality	34	589	1,602	$163	$2,802	$7,630
Chronic Bronchitis	3,348	3,374	3,374	$902	$909	$909
Hospital Admissions - AR[b]	226	539	539	$1.4	$3.4	$3.4
Hospital Admissions - CHF[b]	93	105	105	$0.8	$0.9	$0.9
Hospital Admissions - IHD[b]	103	117	117	$1.1	$1.2	$1.2
Acute Bronchitis	73	718	3,331	$0.0	$0.0	$0.1
LRS	12,554	29,719	29,719	$0.1	$0.4	$0.4
URS	2,611	2,941	2,941	$0.1	$0.1	$0.1
Work Loss Days	119,687	285,738	285,738	$10	$24	$24
MRAD	996,433	2,381,446	2,381,446	$38	$92	$92
Total PM-related Health	—	—	—	**$1,117**	**$3,833**	**$8,661**
PM-related Welfare Endpoints						
Household Soiling	direct economic valuation			$41	$41	$41
Nitrogen Deposition	direct economic valuation			$0.4	$0.4	$0.4
Total PM-related Welfare				**$41**	**$41**	**$41**
Total	—	—	—	**$2,135**	**$4,851**	**$9,679**

[a] Total visibility benefits are presented for the low-end assumption about wilderness areas, i.e., values for wilderness areas are assumed to have been included in the total regional value in the Chestnut and Rowe study. Residential visibility benefits are included in the total visibility benefits estimate.

[b] AR=all respiratory, CHF=congestive heart failure, IHD=ischemic heart disease.

Table 9-20
Estimated Benefits in 2015 Associated with the Regional Haze Rule: 5% dv/10 years Visibility Goal, Case B

Endpoint	**Avoided Incidences (cases/year)**			**Monetary Benefits (millions 1990$)**		
	15 μg/m³	**LOL**	**Back ground**	**15 μg/m³**	**LOL**	**Back ground**
Visibility Endpoints						
Residential	direct economic valuation			$144	$144	$144
National Park Recreational	direct economic valuation			$729	$729	$729
Wilderness Area Recreational	direct economic valuation			$59	$59	$59
Total Visibility[a]				**$932**	**$932**	**$932**
PM-related Health Endpoints						
Mortality	33	573	1,552	$158	$2,727	$7,390
Chronic Bronchitis	3,247	3,271	3,271	$875	$881	$881
Hospital Admissions - AR[b]	220	522	522	$1.4	$3.3	$3.3
Hospital Admissions - CHF[b]	90	102	102	$0.7	$0.8	$0.8
Hospital Admissions - IHD[b]	100	113	113	$1.0	$1.2	$1.2
Acute Bronchitis	74	701	3,224	$0.0	$0.0	$0.1
LRS	12,201	28,769	28,769	$0.1	$0.3	$0.3
URS	2,533	2,850	2,850	$0.0	$0.1	$0.1
Work Loss Days	116,493	277,142	277,142	$10	$23	$23
MRAD	969,869	2,309,839	2,309,839	$37	$89	$89
Total PM-related Health	—	—	—	**$1,083**	**$3,726**	**$8,389**
PM-related Welfare Endpoints						
Household Soiling	direct economic valuation			$40	$40	$40
Nitrogen Deposition	direct economic valuation			$0.4	$0.4	$0.4
Total PM-related Welfare				**$40**	**$40**	**$40**
Total	—	—	—	**$2,055**	**$4,698**	**$9,361**

[a] Total visibility benefits are presented for the low-end assumption about wilderness areas, i.e., values for wilderness areas are assumed to have been included in the total regional value in the Chestnut and Rowe study. Residential visibility benefits are included in the total visibility benefits estimate.

[b] AR=all respiratory, CHF=congestive heart failure, IHD=ischemic heart disease.

Table 9-21
Estimated Benefits in 2015 Associated with the Regional Haze Rule: 10% dv/10 years Visibility Goal, Case B

Endpoint	Avoided Incidences (cases/year)			Monetary Benefits (millions 1990$)		
	15 μg/m^3	LOL	Back ground	15 μg/m^3	LOL	Back ground
Visibility Endpoints						
Residential	direct economic valuation			$335	$335	$335
National Park Recreational	direct economic valuation			$1,071	$1,071	$1,071
Wilderness Area Recreational	direct economic valuation			$84	$84	$84
Total Visibility[a]				**$1,490**	**$1,490**	**$1,490**
PM-related Health Endpoints						
Mortality	67	1,467	3,317	$321	$6,983	$15,793
Chronic Bronchitis	6,238	6,310	6,310	$1,681	$1,700	$1,700
Hospital Admissions - AR[b]	386	1,028	1,028	$2.5	$6.5	$6.5
Hospital Admissions - CHF[b]	172	197	197	$1.4	$1.6	$1.6
Hospital Admissions - IHD[b]	190	218	218	$2.0	$2.2	$2.2
Acute Bronchitis	101	1,411	6,287	$0.0	$0.1	$0.3
LRS	21,176	56,216	56,216	$0.3	$0.7	$0.7
URS	4,778	5,439	5,439	$0.1	$0.1	$0.1
Work Loss Days	206,631	549,712	549,712	$17	$46	$46
MRAD	1,720,819	4,582,424	4,582,424	$66	$176	$176
Total PM-related Health	—	—	—	**$2,091**	**$8,916**	**$17,726**
PM-related Welfare Endpoints						
Household Soiling	direct economic valuation			$77	$77	$77
Nitrogen Deposition	direct economic valuation			$1.4	$1.4	$1.4
Total PM-related Welfare				**$78**	**$78**	**$78**
Total	—	—	—	**$3,659**	**$10,484**	**$19,294**

[a] Total visibility benefits are presented for the low-end assumption about wilderness areas, i.e., values for wilderness areas are assumed to have been included in the total regional value in the Chestnut and Rowe study. Residential visibility benefits are included in the total visibility benefits estimate.

[b] AR=all respiratory, CHF=congestive heart failure, IHD=ischemic heart disease.

9.8.2 Discussion of Results

The results show that the imposition of a health effect threshold has a large impact on PM2.5-based health functions. For the PM2.5 functions, up to 98 percent of total avoided incidences occur below the 15 μg/m^3 threshold. Health functions based on mean PM2.5 appear to be slightly more sensitive to the threshold level than functions based on the median.

Results also highlight the fact that the magnitude of incidences and the magnitude of monetary benefits for individual endpoints may not be strongly correlated. This is due to relatively large per unit benefits associated with relatively low risk health endpoints, such as mortality and CB, and the relatively small per unit benefits associated with relatively high risk health endpoints, such as WLDs or MRADs. This highlights the importance of presenting both avoided incidences and monetary benefits to provide a complete picture of the impacts of a given air quality change.

The PM-related health benefits are dominated in all cases by two endpoints: mortality and CB. These two endpoints account for between 95 and 99 percent of all health benefits, depending on the threshold level assumed. For most cases, PM-related health benefits also dominate the other two benefit categories, visibility and PM-related welfare effects. Visibility accounts for between 8 and 58 percent of total benefits, depending on the visibility goal and the threshold level assumed.

9.9 Regional Results

In addition to the national benefits analysis, benefits for emission control Case A were calculated for each of the six control cost regions defined in Chapter 6. This regional analysis was not conducted for emission control Case B. Tables 9-22 and 9-23 present summaries of the total benefits for each of the six control cost regions for the four illustrative visibility goals under the low-end and high-end sets of assumptions. Note that the benefits of visibility improvements are assigned to the region in which the visibility change takes place, rather than to the region in which the population valuing the change reside. Further analysis of the regional results for Case A is presented in Chapter 10., Benefit-Cost Comparisons.

Table 9-22

Summary Results from Regional Benefits Analyses, Low-end Estimates -- Case A[a]

Region	Total Monetized Benefits (million 1990$)			
	1.0 dv/15 years	1.0 dv/10 years	5% dv/10 years	10% dv/10 years
Northwest	$171	$223	$235	$446
West	$345	$465	$453	$560
Rocky Mountain	$680	$935	$754	$1,065
South Central	$68	$76	$72	$130
Midwest/Northeast	$36	$36	$40	$187
Southeast	$19	$45	$28	$239

[a] Total benefit estimates assume 1) residential visibility benefits excluded 2) WTP for visibility at non-NPS Class I areas is included in WTP for NPS Class I areas, 3) mortality is valued using the VSLY based VSL of $2.2 million, 4) chronic bronchitis is valued using cost of illness value of $59,000 per case, 5) Health effects threshold of 15 μg/m^3. Due to rounding, the sum of the regional benefits may not exactly equal the national estimates presented in Tables 9-11 through 9-14.

Table 9-23

Summary Results from Regional Benefits Analyses, High-end Estimates -- Case A[a]

Region	Total Monetized Benefits (million 1990$)			
	1.0 dv/15 years	1.0 dv/10 years	5% dv/10 years	10% dv/10 years
Northwest	$1,455	$1,848	$1,927	$3,285
West	$1,023	$1,275	$1,293	$1,706
Rocky Mountain	$1,183	$1,646	$1,370	$1,993
South Central	$642	$760	$720	$2,135
Midwest/Northeast	$970	$642	$1,059	$4,495
Southeast	$219	$840	$360	$5,030

[a] Total benefit estimates assume 1) both residential and recreational visibility benefits included 2) WTP for visibility at non-NPS Class I areas is addititive to WTP for NPS Class I areas, 3) mortality is valued using the $4.8 million VSL, 4) chronic bronchitis is valued using WTP of $260,000 per case, 5) Health effects threshold equal to anthropogenic background. Due to rounding, the sum of the regional benefits may not exactly equal the national estimates presented in Tables 9-11 through 9-14.

9.10 Plausibility Checks

Given the complexity of the benefits analysis and the damage-function approach to benefits estimation, it is important to check the plausibility of total benefits attributed to implementation of the illustrative visibility goals. One useful plausibility check is to present benefits on a per capita or per household basis for comparison with household income.

The RH rule is expected to impact the entire U.S. population, which is projected to 130 million households in 2010. The 2010 population projections are proxies for the population in the 2015 analysis year. Benefits per household for Case A, based on the projected population, are presented in Table 9-25. Benefits per household for Case B are presented in Table 9-26. Benefits per household are presented both for total benefits and for the health and visibility sub-categories. The per household values appear plausible, as even at the high-end estimate of benefits, benefits per household are small relative to total income.

Table 9-25

Monetized Benefits per Household in 2015 Associated with the Regional Haze Rule: Case A, Fugitive Dust Controls Considered[a]

Illustrative Goal	Benefit Category	1990 $ per Household	
		Low-end	**High-end**
1.0 dv/15 years	Visibility	$8	$9
	PM-Health	$2	$33
	Total	**$10**	**$43**
1.0 dv/10 years	Visibility	$11	$13
	PM-Health	$3	$42
	Total	**$14**	**$55**
5% dv/10 years	Visibility	$10	$11
	PM-Health	$2	$41
	Total	**$12**	**$52**
10% dv/10 years	Visibility	$13	$17
	PM-Health	$6	$126
	Total	**$20**	**$144**

[a] Not all possible benefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2.

Table 9-26
Monetized Benefits per Household in 2015 Associated with the Regional Haze Rule: Case B, Fugitive Dust Controls Not Considered[a]

Illustrative Goal	**Benefit Category**	**1990 $ per Household**	
		Low-end	**High-end**
1.0 dv/15 years	Visibility	$5	$6
	PM-Health	$1	$27
	Total	**$6**	**$33**
1.0 dv/10 years	Visibility	$6	$8
	PM-Health	$2	$67
	Total	**$9**	**$75**
5% dv/10 years	Visibility	$6	$8
	PM-Health	$2	$65
	Total	**$9**	**$73**
10% dv/10 years	Visibility	$9	$12
	PM-Health	$5	$136
	Total	**$14**	**$149**

[a] Not all possible benefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2.

9.11 Limitations and Caveats to the Analysis

Given incomplete information, this national benefits analysis yields approximate results because of the uncertainty associated with any estimate. Potentially important sources of uncertainty exist and many of these are summarized in Table 9-27. These uncertainties can cause the total benefits estimate to be understated or overstated. Where possible, we state the direction of the bias presented by the uncertainty. Howeve,r in most cases, the effect of the uncertainly on total benefits is unknown (i.e., it could increase or decrease benefits depending on specific conditions. 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 direction is noted in the table.

Table 9-27

Sources of Uncertainty in the Benefit Analysis

1. Uncertainties Associated With Concentration-Response Functions
-The value of the ozone- or PM-coefficient in each C-R function. -Application of a single C-R function to pollutant changes and populations in all locations. -Similarity of future year C-R relationships to current C-R relationships. -Correct functional form of each C-R relationship. (e.g., It is uncertain whether there are thresholds and, if so, what they are.) -Extrapolation of C-R relationships beyond the range of ozone or PM concentrations observed in the study.
2. Uncertainties Associated With Ozone and PM Concentrations
-Estimating future-year baseline and hourly ozone and daily PM concentrations. -Estimating the change in ozone and PM resulting from the control policy.
3. Uncertainties Associated with PM Mortality Risk
-No scientific basis supporting a plausible biological mechanism. -Potential causal agents within the complex mixture of PM responsible for the reported adverse health effects have not been identified. -While there were a great number of studies associated with PM_{10}, there were a limited number of studies that directly measured $PM_{2.5}$. -The extent to which adverse health effects are associated with low level exposures that occur many times in the year versus peak exposures. -Estimated health effects levels associated with $PM_{2.5}$ exposure were small. -Possible confounding in the epidemiological studies of $PM_{2.5}$, effects with other factors (e.g., other air pollutants, weather, indoor/outdoor air, etc.). -The extent to which effects reported in the long-term studies are associated with historically higher levels of PM rather than the levels occurring during the period of study. -Reliability of the limited ambient $PM_{2.5}$ monitoring data in reflecting actual $PM_{2.5}$ exposures.
4. Uncertainties Associated With Possible Lagged Effects
-What portion of the PM-related long-term exposure mortality effects associated with changes in annual PM levels would occur in a single year, and what portion might occur in subsequent years. Ignoring lags may lead to an overestimate of benefits.
5. Uncertainties Associated With Baseline Incidence Rates
-Some baseline incidence rates are not location-specific (e.g., those taken from studies) and may therefore not accurately represent the actual location-specific rates. -Current baseline incidence rates may not well approximate what baseline incidence rates will be in the year 2007. -Projected population and demographics -- used to derive incidences – may not well approximate future-year population and demographics.
6. Uncertainties Associated With Economic Valuation
-Unit dollar values associated with health and welfare endpoints are only estimates of mean WTP and therefore have uncertainty surrounding them. -Mean WTP (in constant dollars) for each type of risk reduction may differ from current estimates due to differences in income or other factors.
7. Uncertainties Associated With Aggregation of Monetized Benefits
-Health and welfare benefits estimates are limited to the available C-R functions, there may be components of total benefit omitted. Thus, unquantifiable benefit categories will cause total benefits to be underestimated.

9.11.1 Why Benefits Estimates May Be Understated

9.11.1.1 *Projected Income Growth*

This analysis does not attempt to adjust benefits estimates to reflect expected growth in real income. Economic theory argues, however, that WTP for most goods (such as environmental protection) will increase if real incomes increase. The degree to which WTP may increase for the specific visibility, health and welfare benefits associated with the illustrative RH visibility goals cannot be estimated due to insufficient income elasticity information.

9.11.1.2 Unquantified Benefit Categories

One significant limitation of the health and welfare benefits analyses is the inability to quantify many benefits from reduced emissions of NOx and SO_2. In general, if it were possible to include the unquantified benefits categories in the total monetized benefits, the benefits estimates presented in this RIA would increase. Specific examples of unquantified benefits explored in more detail below include ozone-related benefits, benefits of reduced nitrogen deposition to estuaries, nitrogen in drinking water, other human health effects, and brown clouds.

9.11.1.2.1 Ozone-related Benefits

In addition to reductions in PM, controls employed to meet the illustrative RH visibility goals will also result in reductions in NOx, a precursor in the formation of ozone, which will result in reductions in ambient concentrations of ozone. Due to inadequate modeling resources, ozone reductions are not modeled in this benefits analysis. Possible health benefits associated with reductions in ambient ozone concentrations include avoided incidences of premature mortality, reduced numbers of hospital admissions for respiratory ailments, reductions in incidences of acute respiratory symptoms, and increases in worker productivity for outdoor laborers. Possible ozone-related welfare benefits include increases in yields of commercial crops such as cotton and corn and fruit crops and increases in yields of commercial forests. The magnitude of these omitted benefits is not known. Reductions in ozone may also yield disbenefits, in the form of reduced protection from ultraviolet light, specifically UV-B. The magnitude of this potential disbenefit is not known.

9.11.1.2.2 Nitrates in Drinking Water

Nitrates in drinking water are currently regulated by a maximum contaminant level (MCL) of 10 mg/L on the basis of the risk to infants of methemoglobinemia, a condition which adversely affects the blood's oxygen carrying capacity. In an analysis of pre-1991 data, Raucher, et al. (1993) found that approximately two million people were consuming public drinking water supplies which exceed the MCL. Supplementing these findings, the National Research Council concluded that 42 percent of the public drinking water users in the U.S. (approximately 105 million people) are either not exposed to nitrates or are exposed to concentrations below 1.3 mg/L (National Research Council, 1995).

In a recent epidemiological study by the National Cancer Institute, a statistically significant relationship between nitrates in drinking water and incidence of non-Hodgkin's lymphoma were reported (Ward, et al., 1996). Though it is generally acknowledged that traditional water pollution sources such as agricultural runoff are mostly responsible for violations of the MCL, other more diffuse sources of nitrate to drinking water supplies, such as that from atmospheric deposition, may also become an important health concern should the cancer link to nitrates be found valid upon further study.

9.11.1.2.3 Other Human Health Effects

The benefits of reductions in a number of ozone and PM-induced health effects have not been quantified due to the unavailability of concentration-response and/or economic valuation data. These effects include: reduced pulmonary function, morphological changes, altered host defense mechanisms, cancer, other chronic respiratory diseases, infant mortality, airway responsiveness, increased susceptibility to respiratory infection, pulmonary inflammation, acute inflammation and respiratory cell damage, and premature aging of the lungs and chronic respiratory damage. An improvement in ambient PM and ozone air quality is expected to reduce the number of incidences within each effect category that the U.S. population would experience. Although these health effects are known to be PM or ozone-induced, concentration-response data are not available for quantifying the benefits associated with reducing these effects. The inability to quantify these effects leads to an underestimation of the monetized benefits presented in this analysis.

9.11.1.2.5 Other Unquantifiable Benefits Categories

There are other welfare benefits categories for which there is incomplete information to permit a quantitative assessment for this analysis. For some endpoints, gaps exist in the scientific literature or key analytical components 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. Potentially significant, but unquantified welfare benefits categories include: existence and user values related to the protection of ecosystems, damage to industrial materials or national monuments, and reduced sulfate deposition to aquatic and terrestrial ecosystems. Although scientific and economic data are not available to allow quantification of the effect of PM in these categories, the expectation is that, if quantified, each of these categories would lead to an increase in the monetized benefits presented in this RIA.

9.11.2 Why Benefits Estimates May Be Overstated

9.11.2.1 *PM Mortality Risk*

Table 9-27 summarizes a number of the uncertainties associated with estimating mortality risk associated with particulate matter (PM). Most of these uncertainties can serve to increase or decrease the estimated benefits relative to a hypothetical “true” prediction. Some uncertainties may inflate estimates, while others - such as exclusion of effects categories - can result in understatement. The fundamental concentration-response relationships used to estimate benefits are derived from epidemiological studies of community health. Based on these studies and other available information, the EPA Criteria Document concluded that the observed associations between PM and mortality and other serious health effects were “likely causal.” The Criteria Document also noted that, as yet, the scientific information did not provide a basis for determining what biological mechanisms might account for such effects. To the extent that some chance remains that no causal mechanisms are found for some PM components or for The PM mix taken as a whole, the benefit estimates derived from the epidemiological studies would be overstated.

Similarly, the evaluation of the epidemiological evidence included an extensive assessment of a number of potential pollutant and weather confounders or effects modifiers. The Criteria Document concluded that these factors could not fully account for the observed PM/effects associations, but it is possible that some portion of the quantitative relationships are affected by the presence of other pollutants. While multiple pollutant effects may be additive, it is also possible that the PM-related effects association may be overstated for some studies which might inflate the benefits estimates derived from such studies.

9.11.2.1 *Full Attainment of the PM and Ozone NAAQS*

As indicated above, incremental benefits attributable to the illustrative visibility goals analyzed for this RIA are dependent on the progress towards those goals made through implementation of the PM and Ozone NAAQS. Due to limits on the ability to model future technology to control emissions in a cost-effective manner, the baseline for this analysis assumes partial attainment of the PM and ozone NAAQS, as was presented in the PM and ozone NAAQS RIA. Because of this limitation, progress towards visibility goals that might have occurred if full attainment of the PM and ozone NAAQS was achieved are not credited to the implementation of the PM and ozone NAAQS. Instead, any additional progress past that achieved through partial attainment of the PM and ozone NAAQS is assumed to be creditable to the RH rule. If full attainment of the PM and ozone NAAQS is assumed, then fewer additional emission controls would be necessary to meet the illustrative visibility goals and thus the incremental benefits attributable to the RH rule would be lower.

9.11.2.2 *Unquantified Disbenefits*

In addition to unquantified benefits, a discussion of potential unquantified disbenefits must also be mentioned. The disbenefit categories discussed here are related to nitrogen deposition. There may be other disbenefit categories which we have not been able to identify. Because EPA is not able to quantify these disbenefit categories, total benefits may be overstated.

9.11.2.2.1 Passive Fertilization

Several disbenefit categories are related to nitrogen deposition. Nutrients deposited on crops from atmospheric sources are often referred to as passive fertilization. Nitrogen is a fundamental nutrient for primary production in both managed and unmanaged ecosystems. Most productive agricultural systems require external sources of nitrogen in order to satisfy nutrient requirements. Nitrogen uptake by crops varies, but typical requirements for wheat and corn are approximately 150 kg/ha/yr and 300 kg/ha/yr, respectively (NAPAP, 1990). These rates compare to estimated rates of passive nitrogen fertilization in the range of 0 to 5.5 kg/ha/yr (NAPAP, 1991). So, for these crops, deposited nitrogen could account for as much as 2 to 4 percent of nitrogen needs. Holding all other factors constant, farmers' use of purchased fertilizers or manure may increase as deposited nitrogen is reduced. The EPA has not estimated the potential value of this possible increase in the use of purchased fertilizers, but a qualitative assessment of several factors suggests that the overall value is very small relative to the value of other health and welfare endpoints presented in this analysis. First, reductions in NOx emissions affect only a fraction of total nitrogen deposition. Approximately 70 to 80 percent of nitrogen deposition is in the form of nitrates (and thus can be traced to NOx emissions) while most of the remainder is due to ammonia emissions (personal communication with Robin Dennis, NOAA Atmospheric Research Lab, 1997). Second, some sources of nitrogen, such as animal manure, are available at no cost or at a much lower cost than purchased nitrogen. In addition, in certain areas nitrogen is currently applied at rates which exceed crop uptake rates, usually due to an overabundance of available nutrients from animal waste. Small reductions in passive fertilization in these areas are not likely to have any consequence to fertilizer application. The combination of these factors suggests that the cost associated with compensating for reductions in passive fertilization is relatively minor.

Information on the effects of changes in passive nitrogen deposition on forest lands and other terrestrial ecosystems is very limited. The multiplicity of factors affecting forests, including other potential stressors such as ozone, and limiting factors such as moisture and other nutrients, confound assessments of marginal changes in any one stressor or nutrient in forest ecosystems. However, reductions in deposition of nitrogen could have negative effects on forest and vegetation growth in ecosystems where nitrogen is a limiting factor (EPA, 1993).

On the other hand, there is evidence that forest ecosystems in some areas of the United States are nitrogen saturated (EPA, 1993). Once saturation is reached, adverse effects of additional nitrogen begin to occur such as soil acidification which can lead to leaching of nutrients needed for plant growth and mobilization of harmful elements such as aluminum. Increased soil acidification is also linked to higher amounts of acidic runoff to streams and lakes and leaching of harmful elements into aquatic ecosystems.

9.12 References

Abt Associates, Inc. 1999. *Selected Health and Welfare Benefits Methods for the Regional Haze RIA*, Prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards; Research Triangle Park, N.C., April.

Chestnut, L.G. 1997. Draft Memorandum: *Methodology for Estimating Values for Changes in Visibility at National Parks.;* April 15.

Chestnut, L.G. and R.D. Rowe. 1990. *Preservation Values for Visibility Protection at the National Parks: Draft Final Report.* Prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC and Air Quality Management Division, National Park Service, Denver, CO.

Cropper, M.L. and A.J. Krupnick. 1990. The Social Costs of Chronic Heart and Lung Disease. Resources for the Future Discussion Paper QE 89-16-REV.

Cummings, R., H. Burness and R. Norton. 1981. *Methods Development for Environmental Control Benefits Assessment, Volume V. Measuring Household Soiling Damages from Suspended Air Particulates, A Methodological Inquiry.* Report prepared for the U.S. Environmental Protection Agency, Washington, D.C.

Dennis, R. 1997. Personal communication. NOAA Atmospheric Research Lab; Research Triangle Park, N.C. June.

Dockery, D.W., F.E. Speizer, D.O. Stram, J.H. Ware, J.D. Spengler, and B.G. Ferris, Jr. 1989. Effects of Inhalable Particles on Respiratory Health of Children. *Am. Rev. Respir. Dis.* 139: 587-594.

Empire State Electric Energy Research Corporation (ESEERCO). 1994. *New York State Environmental Externalities Cost Study. Report 2: Methodology.* Prepared by: RCG/Hagler, Bailly, Inc., November.

Industrial Economics, Incorporated (IEc). 1993. Memorandum to Jim DeMocker, Office of Air and Radiation, Office of Policy Analysis and Review, U.S. Environmental Protection Agency, September 30, 1993.

Industrial Economics, Incorporated (IEc). 1994. Memorandum to Jim DeMocker, Office of Air and Radiation, Office of Policy Analysis and Review, U.S. Environmental Protection Agency, March 31.

Krupnick, A.J. and M.L. Cropper. 1992. The Effect of Information on Health Risk Valuations. *Journal of Risk and Uncertainty* 5(2): 29-48.

Manuel, E.H., R.L. Horst, K.M. Brennan, W.N. Lanen, M.C. Duff and J.K. Tapiero. 1982. *Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates, Volumes I-IV.* Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. [Cited in ESEERCO, 1994].

McClelland, G., W. Schulze, D. Waldman, J. Irwin, D. Schenk, T. Stewart, L. Deck, and M. Thayer. 1993. *Valuing Eastern Visibility: A Field Test of the Contingent Valuation Method*. Prepared for Office of Policy, Planning and Evaluation, U.S. Environmental Protection Agency. September.

Moore, M.J., and W.K. Viscusi. 1988. "The Quantity-Adjusted Value of Life". *Economic Inquiry* 26(3): 369-388.

NAPAP. 1990. *Acidic Deposition: State of the Science and Technology, Report 18: Response of Vegetation to Atmospheric Depostion and Air Pollution*. National Acid Precipitation Assessment Program, Office of the Director; Washington, D.C.

NAPAP. 1990. 1990 *Integrated Assessment Report*. National Acid Precipitation Assessment Program, Office of the Director; Washington, D.C.

National Research Council (1995), *Nitrate and Nitrite in Drinking Water.* Subcommittee on Nitrate and Nitrite in Drinking Water, National Academy Press; Washington, DC.

Ostro, B.D. 1987. Air Pollution and Morbidity Revisited: a Specification Test. *J. Environ. Econ. Manage.* 14: 87-98.

Ostro B.D. and S. Rothschild. 1989. Air Pollution and Acute Respiratory Morbidity: An Observational Study of Multiple Pollutants. *Environmental Research* 50:238-247.

Pope, C.A., III, D.W. Dockery, J.D. Spengler, and M.E. Raizenne. 1991. Respiratory Health and PM_{10} Pollution: a Daily Time Series Analysis. *Am. Rev. Respir. Dis.* 144: 668-674.

Pope, C.A., III, M.J. Thun, M.M. Namboodiri, D.W. Dockery, J.S. Evans, F.E. Speizer, and C.W. Heath, Jr. 1995. Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults. *Am. J. Respir. Crit. Care Med.* 151: 669-674.

Raucher, R.S., J.A. Drago, E. Trabka, A. Dixon, A. Patterson, C. Lang, L. Bird, S. Ragland. 1993. An Evaluation of the Federal Drinking Water Regulatory Program Under the Safte Drinkning Water Act as Amended in 1986, Appendix A: Contaminant Specific Summaries. Prepared for the American Waterworks Association.

Schwartz, J. 1993. Particulate Air Pollution and Chronic Respiratory Disease. *Environmental Research* 62: 7-13.

Schwartz, J. and R. Morris. 1995. Air Pollution and Hospital Admissions for Cardiovascular Disease in Detroit, Michigan. *Am. J. Epidemiol.* 142: 23-35.

Schwartz, J., Dockery, D.W., Neas, L.M, Wypij, D., Ware, J.H., Spengler, J.D., Koutrakis, P., Speizer, F.E., and Ferris, Jr., B.G.   1994. Acute Effects of Summer Air Pollution on Respiratory Symptom Reporting in Children. *Am. J. Respir. Crit. Care Med.* 150: 1234-1242.

Smith, V.K., G.Van Houtven, and S. Pattanayak. 1999. Benefit Transfer as Preference Calibration. *Resources for the Future Working Paper*, unnumbered.

Thurston, G. K. Ito, C. Hayes, D. Bates, and M. Lippmann. 1994. Respiratory Hospital Admission and Summertime Haze Air Pollution in Toronto, Ontario: Consideration of the Role of Acid Aerosols. *Environmental Research* 65: 271-290.

U.S. Department of Commerce, Economics and Statistics Administration. 1992. Statistical Abstract of the United States, 1992: The National Data Book. 112th Edition, Washington, D.C.

U.S. Department of Commerce, Bureau of Economic Analysis. BEA Regional Projections to 2045: Vol. 1, States. Washington, D.C. U.S. Govt. Printing Office, July 1995.

U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. 1994. Vital Statistics of the United States, 1990. Volume II-Mortality. Hyattsville, MD.

U.S. Environmental Protection Agency, 1993. *Air Quality Criteria for Oxides of Nitrogen: Volume II.* Prepared by: Office of Research and Development, Washington D.C., EPA report no. EPA/600/8-91/049bF.

U.S. Environmental Protection Agency, 1997a. *Regulatory Impact Analysis for Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed RH Rule.* Prepared by: Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, Research Triangle Park, N.C. July.

U.S. Environmental Protection Agency, 1997b. *The Benefits and Costs of the Clean Air Act, 1970 to 1990*. Prepared for U.S. Congress by U.S. EPA, Office of Air and Radiation/Office of Policy Analysis and Review, Washington, D.C. (April, 1997 - Draft)

U.S. Environmental Protection Agency, 1998a. *Regulatory Impact Analysis for the NOx SIP Call, FIP and Section 126 Petitions, Volume 2: Health and Welfare Benefits*. Prepared by: Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, Research Triangle Park, N.C. December.

U.S. Environmental Protection Agency, 1998b. *The Regional NOx SIP Call & Reduced Atmospheric Deposition of Nitrogen: Benefits to Selected Estuaries,* September, 1998.

U.S. Environmental Protection Agency, 1999. *Regulatory Impact Analysis: Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements*. Prepared by: Office of Mobile Sources, Office of Air and Radiation, April.

Viscusi, W.K., W.A. Magat, and J. Huber. 1991. Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk-Dollar Trade-Offs for Chronic Bronchitis. *Journal of Environmental Economics and Management,* 21: 32-51.

Viscusi, W.K. 1992. *Fatal Tradeoffs: Public and Private Responsibilities for Risk.* (New York: Oxford University Press).

Ward, M. H.; Mark, S. D.; Cantor, K.P.; Weisenburger, D.D.; Correa-Villasenor, A.; Zahm, S.H. (1996), Drinking Water Nitrate and the Risk of Non-Hodgkin's Lymphoma. *Epidemiology* 7:465-471; September.

Watson, W. and J. Jaksch. 1982. Air Pollution: Household Soiling and Consumer Welfare Losses. *Journal of Environmental Economics and Management.* 9: 248-262.

Chapter 10. BENEFIT-COST COMPARISONS

This Regulatory Impact Analysis (RIA) provides cost, economic impact, and benefit estimates that are potentially useful for evaluating alternative illustrative visibility goals for the regional haze (RH) rule. Benefit-cost analysis provides a systematic framework for assessing and comparing such alternatives. According to economic theory, the efficient alternative maximizes net benefits to society (i.e., social benefits minus social costs). However, there are practical limitations for the comparison of benefits to costs in this analysis. This chapter also discusses the key limitations and uncertainties associated with the benefit and cost estimates. Nonetheless, if one is mindful of these limitations, the relative ordering and magnitude of the benefit-cost comparisons presented here can be useful information.

Results of the national analysis of estimated benefits and costs in the 2015 analysis year are presented for the two emission control cases detailed in Chapter 3. These cases, A and B, correspond to cases where additional fugitive dust controls are allowed as a control strategy and where fugitive dust controls are not allowed, respectively. For each case, costs, benefits, and net benefits are presented for the four illustrative visibility goals and the goal of baseline visibility, equivalent to setting the goal equal to visibility conditions at the baseline level of emissions. Note that the costs presented here do not include the monitoring and administrative costs in Chapter 7. In addition, an illustrative regional analysis is presented based on the results for Case A.

10.1 Summary of Cost Estimates: Case A

This section provides a summary of cost results for control-strategy Case A presented in chapter 6 of this RIA. Table 10-1 summarizes the total annual control cost estimates developed in this analysis for the year 2015. These costs reflect illustrative control scenarios applied to point, area, and mobile sources. The majority of the projected total national annual cost for these alternatives is due to control by transportation agencies of emissions from paved and unpaved roads, and control of emissions from utilities. However, as noted in Chapter 6, there is a great deal of uncertainty regarding fugitive dust emissions and their contribution to visibility impairment.

Table 10-1
Estimated Total Annual Cost of Regional Haze Illustrative Goals in 2015: Case A[a]

Illustrative Goal	Total Annual Costs (million 1990$)
Baseline visibility	$0
1.0 dv/15 years	$1,070
1.0 dv/10 years	$1,740
5% dv/10 years	$1,510
10% dv/10 years	$4,380

[a] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.2 Summary of Benefits Estimates: Case A

Table 10-2 summarizes the total annual benefits for control-strategy Case A developed in this analysis for the year 2015 for the low-end and high-end sets of assumptions described in Chapter 9. Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.

Table 10-2
Estimated Range of Annual Quantified Benefits for Illustrative Regional Haze Visibility Goals in 2015: Case A[a,b]

Illustrative Goal	Annual Quantified Benefits (million 1990$) Low-End	Annual Quantified Benefits (million 1990$) High-End
Baseline visibility	$0	$0
1.0 dv/15 years	$1,350	$5,560
1.0 dv/10 years	$1,820	$7,110
5% dv/10 years	$1,610	$6,800
10% dv/10 years	$2,560	$18,740

[a] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.

[b] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.3 Summary of National Net Benefits: Case A

Table 10-3 summarizes the total annual net benefits for emissions control Case A for the four illustrative RH visibility goals for the year 2015. There are several conclusions that can be drawn from Table 10-3.

- For the high-end assumption set, monetized net benefits are positive and substantial for all illustrative visibility goals.

- Although the 10% dv/10 years visibility goal has the largest associated benefits under both the high- and low-end assumption sets, the high cost of meeting this goal makes it the most undesirable option from an economic perspective based on the low-end benefits estimate. Based on the high-end benefits estimates, the 10% dv/10 years goal becomes the preferred goal. However, this depends largely on the increase in PM-related health benefits, rather than increases in visibility benefits (although visibility benefits are also greatest for the 10% dv/10 years goal). For the high-end set of assumptions, the 1.0 dv/15 years is the most undesirable option from an economic efficiency perspective.

- Using the high-end benefits estimates, net benefits are greatest at the most stringent illustrative goal evaluated, i.e., 10% dv/10 years. Using the low-end estimates of benefits, the 1.0 dv/15 years goal yields the highest net benefits. This demonstrates the sensitivity of the goal ordering to the set of assumptions about benefits estimation. At the high end, net benefits for the 10% dv/10 years option are approximately 2.7 times higher than for the next best option (1.0 dv/10 years). At the low end, net benefits for the 1.0 dv/15 years option are approximately 2.7 times higher than the next best option (5% dv/10 years).

- Benefit-cost ratios for the illustrative goals range from 0.6 to 1.3 for the low-end set of assumptions and from 4.1 to 5.2 for the high-end set of assumptions. It should be noted that while the 10% dv/10 years goal has the highest net benefits under the high-end assumption set, the 1.0 dv/15 years goal has the highest benefit-cost ratio under both the low-end and high-end assumption sets. So in terms of dollar benefits per dollar of cost, the 1.0 dv/15 years goal is the dominant goal under both the high and low set of assumptions. This suggests that in terms of robustness of goal ordering to increases in benefits, the 1.0 dv/15 years goal is the most stable.

Table 10-3
Estimated Plausible Range of Annual Quantified Net Benefits[a,b] for Illustrative Regional Haze Visibility Goals 2015: Case A

Illustrative Goal	Annual Quantified Net Benefits (million 1990$) Low-End	Annual Quantified Net Benefits (million 1990$) High-End
Baseline visibility	$0	$0
1.0 dv/15 years	$280	$4,490
1.0 dv/10 years	$80	$5,370
5% dv/10 years	$100	$5,290
10% dv/10 years	($1,820)	$14,360

[a] Calculated as quantified benefits minus costs. Not all possible benefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.

[b] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.4 Summary of Cost Estimates: Case B

This section provides a summary of cost results for emissions control Case B presented in Chapter 7 of this RIA. Table 10-4 summarizes the total annual control cost estimates developed in this analysis for the year 2015. These costs reflect illustrative control scenarios applied to point, area, and mobile sources. A significant portion of the total national annual cost for these alternatives is due to control of utility sources that emit nitrogen oxides (NOx) and sulfur oxide ($SO_{2)}$.

Table 10-4
Estimated Total Annual Cost of Regional Haze Illustrative Goals in 2015: Case B[a]

Illustrative Goal	Total Annual Costs (million 1990$)
Baseline visibility	$0
1.0 dv/15 years	$750
1.0 dv/10 years	$1,430
5% dv/10 years	$1,240
10% dv/10 years	$3,610

[a] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.5 Summary of Benefits Estimates: Case B

Table 10-5 summarizes the total annual benefits for control-strategy Case B developed in this analysis for the year 2015 for the low-end and high-end set of assumptions described in Chapter 9. Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.

Table 10-5
Estimated Plausible Range of Annual Quantified Benefits for Illustrative Regional Haze Visibility Goals 2015: Case B[a,b]

Illustrative Goal	Annual Quantified Benefits (million 1990$) Low-End	Annual Quantified Benefits (million 1990$) High-End
Baseline visibility	$0	$0
1.0 dv/15 years	$810	$4,280
1.0 dv/10 years	$1,170	$9,730
5% dv/10 years	$1,140	$9,410
10% dv/10 years	$1,840	$19,350

[a] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.
[b] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.6 Summary of National Net Benefits: Case B

Table 10-6 summarizes the total annual net benefits for control-strategy Case B for the four illustrative RH visibility goals for the year 2015. There are several conclusions that can be drawn from Table 10-6.

- For the high-end assumption set, monetized net benefits are positive and substantial for all illustrative visibility goals.

- Although the 10% dv/10 years visibility goal has the largest associated benefits, the high estimated cost of meeting this goal makes it the most undesirable option from an economic efficiency perspective based on the low-end benefits estimate. Based on the high-end benefits estimates, the 10% dv/10 year goal becomes the preferred goal. However, this depends largely on the increase in PM-related health benefits, rather than increases in visibility benefits. For the high-end estimates, the 1.0 dv/15 years is the most undesirable option from an economic efficiency perspective.

- Using the high-end benefits estimates, net benefits are greatest at the most stringent illustrative goal evaluated, i.e., 10% dv/10 years. Using the low-end estimates of benefits, the 1.0 dv/15 years goal yields the highest net benefits. This demonstrates the sensitivity of the goal ordering to the set of assumptions about benefits estimation. At the high end, net benefits for the 10% dv/10 years option are approximately 1.9 times higher than for the next best option (1.0 dv/10 years). At the low end, net benefits are positive only for the 1.0 dv/15 years option and $317 million higher than the next best option (5% dv/10 years).

- While net benefits are negative for the low-end set of assumptions for all but the 1.0 dv/15 years goal, it is important to remember that while all of the pollution control costs are included[1], many benefit categories could not be quantified. In addition, the low-end assumption set is designed to yield a very conservative measure of monetized benefits. Relaxing just one of the low-end assumptions, such as using willingness-to-pay as a measure of the value of an avoided case of chronic bronchitis instead of the cost-of-illness, leads to positive net benefits for all but the 10% dv/10 years goal.

- Benefit-cost ratios for the illustrative goals range from 0.5 to 1.1 for the low-end set of assumptions and from 5.4 to 7.6 for the high-end set of assumptions. It should be noted that while the 10% dv/10 years goal has the highest net benefits under the high-end

---

[1] Pollution control costs do include monitoring or administrative costs. Costs are only direct pollution control costs and do not measure social costs such as changes in consumer or producer surplus resulting from implementation of control strategies.

assumption set, the 5% dv/10 years goal has the highest benefit-cost ratio under the high-end assumption set. So in terms of dollar benefits per dollar of cost, the 1.0 dv/15 years goal is the dominant goal under the low set of assumptions and the 5% dv/10 years is the dominant goal under the high-end set of assumptions.

Table 10-6
Estimated Plausible Range of Annual Quantified Net Benefits[a,b]
for Illustrative Regional Haze Visibility Goals 2015: Case B

Illustrative Goal	Annual Quantified Net Benefits (million 1990$) Low-End	Annual Quantified Net Benefits (million 1990$) High-End
Baseline visibility	$0	$0
1.0 dv/15 years	$60	$3,530
1.0 dv/10 years	($260)	$8,300
5% dv/10 years	($100)	$8,170
10% dv/10 years	($1,770)	$15,740

[a] Calculated as quantified benefits minus costs. Not all possible benefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA.
[b] For this chapter, all costs and benefits are rounded to the nearest 10 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier chapters.

10.7 Regional Net Benefit Analysis

Given the flexibility provided by this rule for state determination of visibility goals, a regional analysis of costs and benefits based on the six control cost regions identified in Chapter 6 of this RIA is presented below. This analysis is focused on determining whether selection of visibility goals on a regional basis provides a greater level of total net benefits compared to selection of a single national visibility goal. In addition, the analysis will examine the rank ordering of benefits and costs by region relative to the national rank ordering.

Table 10-7 presents the results of the regional goal selection analysis for emission control Case A. Several important assumptions unique to the regional analysis should be considered when interpreting this analysis. The first assumption is that visibility benefits accrue to the region in which the visibility change occurs, rather than to the region in which the population valuing the visibility change lives. This assumption implies that for a given region the “optimal” choice of a visibility goal should depend on the willingness to pay for visibility improvements of all populations, rather than just the populations in the region. The second assumption is that regions are broadly separable in air quality, i.e., changing the visibility goal for a region has no impacts on benefits in other regions. This allows us to sum the benefits from different regions selecting different visibility goals without having to run new air quality analyses for each permutation of regional visibility goals. To simplify the analysis, we focus only on the air quality generated under emission control Case A in calculating benefits for each region and for the national comparison estimate. Regionality results are presented assuming both residential and recreational visibility benefits are included in the estimate of total visibility benefits. Results are presented for both the low-end and high-end sets of assumptions about PM-related health benefits. Specific assumptions are indicated in the table footnotes.

Table 10-7
Optimal Regional Visibility Goals and Associated Net Benefits: Case A[a]

Region	Low-end[c]		High-end[d]	
	Optimal Goal	Net Benefits (million 1990$)	Optimal Goal	Net Benefits (million 1990$)
West	1.0 dv/15 years	$49	10% dv/10 years	$2,140
Southeast	1.0 dv/10 years	$174	10% dv/10 years	$1,108
South Central[b]	1.0 dv/15 years	$420	10% dv/10 years	$1,036
Rocky Mountain	Baseline visibility	$0	10% dv/ 10 years	$1,152
Northwest	5% dv/10 years	$40	10% dv/10 years	$4,117
Midwest/ Northeast	1.0 dv/15 years	$19	10% dv/10 years	$4,725
Total 6 Control Cost Regions		**$702**		**$14,278**
United States	**1.0 dv/15 years**	**$250**	**10% dv/10 years**	**$14,278**
Efficiency Gain		**$451**		**$0**

[a] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 9-2 in Chapter 9 of this RIA. Optimal goal selected based on maximization of net benefits over all illustrative goals plus the baseline visibility goal.

[b] We did not model all possible efficient goals. Regions can choose an option outside of the modeled set to ensure positive net benefits.

[c] Low-end incorporates the following assumptions: 1) Residential visibility benefits excluded 2) WTP for visibility at non-NPS Class I areas is included in WTP for NPS Class I areas, 3) mortality is valued using the $2.2 million VSL based on the statistical life year approach, 4) chronic bronchitis is valued using a cost of illness value of $59,000 per case, and 5) PM health effects threshold equal to 15 µg/m^3. Due to rounding, the sum of the regional benefits may not exactly equal the national estimates.

[d] High-end incorporates the following assumptions 1) both residential and recreational visibility benefits included 2) WTP for visibility at non-NPS Class I areas is additive to WTP for NPS Class I areas, 3) mortality is valued using the $4.8 million VSL, 4) chronic bronchitis is valued using WTP of $260,000 per case, and 5) PM health effects threshold equal to anthropogenic background . Due to rounding, the sum of the regional benefits may not exactly equal the national estimates.

The next three sections provide a framework for analyzing the results of the regional analysis. The first of these sections discusses what economic theory tells us to expect from a regionally based approach relative to a nationally based approach. The second section examines how the rank ordering of the illustrative goals differs across regions. The third section discusses the optimally selected goals for each region and how the imposition of a threshold on PM-related health effects alters the results of the regionality analysis.

10.7.1 Expectations from Economic Theory

Class I areas are not homogeneous. For example, Class I areas in the west are generally greater in size than those found in the Midwest or northeast. More specific to this illustrative analysis, the Class I areas and the regions in which they are located may vary in terms of the nature of the visibility impairment problem. In particular, the ordering of the alternative illustrative visibility progress goals in terms of relative stringency is not the same for all regions of the country. This is true in terms of estimated benefits and costs (see table 6-11 in Chapter 6 and tables 9-15 through 9-17 in Chapter 9).

Failure to reflect the variability in costs and benefits in goal establishment and implementation plan development can result in inefficiencies. For example, while one of the illustrative goals may maximize positive net benefits on a national basis, that goal may not be the one that maximizes positive net benefits for the Class I areas in each of the regions. Furthermore with a uniform national goal, Class I areas in some regions may accrue zero net benefits, while Class I areas in other regions may have negative net benefits.

We assess the potential gains from recognizing regional differences by incorporating regional variability into this analysis. Specifically, Tables 10-4 and 10-5 identify the set of goals which results when each region chooses from among the four Aillustrative@ goals and the baseline visibility goal and selects the one that maximizes net benefits. Next, we compare the national net benefits from the optimal regional goals set with the net benefits from the optimal uniform national goal. The difference between the net benefits achieved from the optimal uniform national goal and net benefits from optimal regional goals is a measure of the efficiency gains available from regional flexibility.

As with the results from the national analysis, the calculated efficiency gain is conditional and merely illustrative. However, the analysis suggests that there may be efficiency gains from reflecting regional variability in the establishment and implementation of visibility progress goals.

10.7.2 Does the Ordering of Goals by Benefits and Costs Vary Across Regions?

The results presented in Table 6-11 in Chapter 6 and tables 9-15 through 9-17 in Chapter 9 indicate that when considered independently for costs and benefits, the ordering of the four illustrative goals does not vary much across regions for the low-end set of benefits assumptions. However, when costs and benefits are combined to form net benefits, the ordering is not preserved across regions. Table 10-4 demonstrates this by showing that the optimal, net-benefit maximizing goal differs across regions. Four of the five goals are selected by at least one region, suggesting that flexibility in goal establishment may lead to heterogeneity in goals selected across regions. The most stringent relative visibility goal was determined to be the most undesirable options for all regions (and thus was not selected by any region). Three regions selected the 1.0 dv/15 years goal while one region each selected the 1.0 dv/10 years, 5% dv/10 years and the "baseline visibility" goals. The selection of the baseline visibility goal by the Rocky Mountain region indicates that none of the four illustrative goals provided positive net benefits based on the low-end benefits assumptions. The efficiency gains due to the increased flexibility in goal selection equal approximately $451 million, approximately tripling the net benefits relative to a uniform goal for the nation.

Results are very different when the high-end set of assumptions is used to generate the benefits estimates. In this case, the ordering of benefits is not constant across regions, although the 10% dv/10 years goal always yields the highest benefits. The ordering of net benefits is also not constant across goals. However, compared to the low-end assumption set, the high-end estimates leads to no heterogeneity in optimal goals across regions. All six control cost regions select the 10%/10 years goal. As a result, the efficiency gain is from regional goal selection is zero. This suggests that the value of regional flexibility may be dependent on the relative differences between costs and benefits. In addition, it points out the sensitivity of this analysis to the assumptions about the PM health threshold, which tends to drive the large benefits in the high-end estimate.

10.7.3 Is There a Single Goal Which Maximizes Net Benefits Across All Regions?

The results presented in Table 10-4 indicate that there is no one dominant goal across regions, at least based on the low-end benefits estimates. The 1.0 dv/15 years goal is selected for half of the regions, while the other half choose either the 1.0 dv/10 years goal or baseline visibility. When the high-end benefits estimates are used in the net-benefits analysis, the 10% dv/10 years goal appears to be a dominant goal. However, it is important to note that the benefits associated with this goal are largely dominated by ancillary PM-health benefits, composed primarily of PM mortality related benefits. If visibility benefits are used as the primary decision factor in determining visibility progress goals, regions may exhibit greater heterogeneity in goal selection.

10.8 Findings and Qualifications

Cost-benefit analysis provides a valuable framework for organizing and evaluating information on the effects of environmental programs. When used properly, cost-benefit analysis helps illuminate important potential effects of alternative policies and helps set priorities for closing information gaps and reducing uncertainty. However, not all relevant costs and benefits can be captured in any analysis. Executive Order 12866 clearly indicates that unquantifiable or nonmonetizable categories of both costs and benefits should not be ignored. There are many important unquantified and unmonetized costs and benefits associated with the controls to reduce the emissions that lead to impaired visibility, including many health and welfare effects. Potential benefit categories that have not been quantified and monetized are listed in Chapter 9, Table 9-2 of this volume.

Several specific limitations deserve to be mentioned:

- The state of atmospheric modeling is not sufficiently advanced to provide a workable "one atmosphere" model capable of characterizing ground-level pollutant exposure for all pollutants of interest (e.g., ozone, particulate matter, carbon monoxide, nitrogen deposition, etc). Therefore, the Environmental Protection Agency (EPA) must employ several different pollutant models to characterize the effects of alternative policies on relevant pollutants. Also, not all atmospheric models have been widely validated against actual ambient data. In particular, since a broad-scale monitoring network does not yet exist for fine particulate matter ($PM_{2.5}$), atmospheric models designed to capture the effects of alternative policies on $PM_{2.5}$ are not fully validated. Additionally, significant shortcomings exist in the data that are available to perform these analyses. While containing identifiable shortcomings and uncertainties, EPA believes the models and assumptions used in the analysis are reasonable based on the available evidence.

- Another dimension adding to the uncertainty of this analysis is time. In the case of air pollution control, 15 years is a very long time over which to carry assumptions. Pollution control technology has advanced considerably in the last 10 years and can be expected to continue to advance in the future. Yet there is no clear way to model this advance for use in this analysis. In addition, there is no clear way to predict future meteorological conditions, or the growth in source-level emissions over time. Again, EPA believes that the assumptions to capture these elements are reasonable based on the available evidence.

- Qualitative and more detailed discussions of the above and other uncertainties and limitations are included in the analysis. Where information and data exist, quantitative characterizations of these uncertainties are included. However, data limitations prevent an overall quantitative estimate of the uncertainty associated with final estimates. Nevertheless, the reader should keep all of these uncertainties and limitations in mind when reviewing and interpreting the results.