Regulatory Impact Analysis of the Proposed Revisions to the National Ambient Air Quality Standards for Ground-Level Ozone

(This page intentionally left blank)

EPA-452/R-07-008
July 2007

Regulatory Impact Analysis of the Proposed Revisions to the National Ambient Air Quality Standards

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Health and Environmental Impact Division
Air Benefit-Cost Group
Research Triangle Park, North Carolina

(This page intentionally left blank)

Table of Contents

Appendix Chapter 3

Appendix Chapter 5

6 Incremental Benefits of Attaining Alternative Ozone Standards Relative to the Current 8-hour Standard (0.08 ppm)

Appendix Chapter 6

List of Tables

Number | Page

List of Figures

Number | Page

Acronyms

AHRQ	Agency for Healthcare Research and Quality
AQS	Air Quality System
BenMAP	Benefits Mapping and Analysis Program
BWC	Best workplaces for commuters
CAAA	Clean Air Act Amendments
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CAPMS	Criteria Air Pollutant Modeling System
CAVR	Clean Air Visibility Rule
CDC	Centers for Disease Control
CDC WONDER	Centers for Disease Control Wide-Ranging Online Data for Epidemiological Research
CFR	Code of Federal Regulations
CI	Confidence interval
CMAQ	Community Multi-Scale Air Quality
COI	Cost of illness
COPD	Chronic obstructive pulmonary disease
CPI-U	Consumer price index – urban
C-R	concentration-response
DOE	Department of Energy
DOI	Department of the Interior
DPF	Diesel Particulate Filters
EGU	electric generating unit
EIA	Economic Impact Analysis
EO	Executive Order
EPA	Environmental Protection Agency
ER	Emergency room
HIS	National Health Interview Survey
ICD	International Classification of Disease
IPM	Integrated Planning Model
km	kilometer
kWh	kilowatt hour
MACT	Maximum Achievable Control Technology
MRAD	Minor restricted activity days
MWRPO	Mid-West Regional Planning Organization
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NCHS	National Center for Health Statistics
NEI	National Emissions Inventory

NHAMCS	National Hospital Ambulatory Medical Care Survey
NHANES	National Health and Nutrition Examination Survey
NHDS	National Hospital Discharge Survey
NMMAPS	National Morbidity, Mortality and Air Pollution Study
Non-EGU	Non-Electricity Generating Unit
NOx	nitrogen oxides
O&M	operation and maintenance
OAQPS	Office of Air Quality Planning and Standards (EPA)
OH	Hydroxide
OMB	Office of Management and Budget
ORD	Office of Research and Development (EPA)
OTAQ	Office of Transportation and Air Quality (EPA)
OTC	Ozone Transport Commission
PM	particulate matter
PM_{10}	Particulate matter less than or equal to 10 microns
$PM_{2.5}$	Particulate matter less than or equal to 2.5 microns
POC	Parameter occurrence code
ppb	parts per billion
ppm	parts per million
RIA	Regulatory Impact Analysis
RVP	Reid vapor pressure
SCR	selective catalytic reduction
SIP	state implementation plan
SMR	standard mortality rate
SNCR	selective non-catalytic reduction
SO_2	Sulfur dioxide
US	United States
USC	US code
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UV-B	ultraviolet light, type B
VNA	Voronoi neighbor averaging
VOC	Volatile Organic Compounds
VSL	Value of statistical life
WHO	World Health Organization
WTP	Willingness to pay

Executive Summary

Overview

EPA has performed an illustrative analysis of the potential costs and human health benefits of nationally attaining alternative ozone standards. Per Executive Order 12866 and the guidelines of OMB Circular A-4, this Regulatory Impact Analysis (RIA) presents analyses of the range of standards proposed by the Administrator in the Notice of Proposed Rulemaking (0.070 – 0.075 ppm), as well as one more stringent option (0.065 ppm). The less stringent option is the baseline, or the current primary standard for ozone (0.08 ppm, effectively 0.084 ppm due to current rounding conventions). The benefit and cost estimates below are calculated incremental to a 2020 baseline that incorporates air quality improvements achieved through the projected implementation of existing regulations and full attainment of the existing ozone and particulate matter (PM) National Ambient Air Quality Standards (NAAQS). The baseline includes the Clean Air Interstate Rule and mobile source programs, which will help many areas move toward attainment of the current standard.

We present two sets of results. The first reflects full attainment of the alternative ozone standards in all locations of the U.S. except two areas of California in 2020. These two areas of California are not planning to meet the current standard by 2020, so the estimated costs and benefits for these areas are based on reaching an estimated attainment point in 2020 (their "glidepath" targets). The second set of results, for California only, estimate the costs and benefits from California fully attaining the alternative standards in a year beyond 2020 (glidepath estimates, plus the increment needed to reach full attainment beyond 2020, added together for a California total). Further explanation about these unique circumstances is provided in Chapter 4.

In addition, EPA designed a two-stage approach to estimating costs and benefits because we recognized from the outset that known and reasonably anticipated emissions controls would likely be insufficient to bring many areas into attainment with either the current, or alternative, more stringent ozone standards. The individual chapters of the RIA present more detail regarding estimated costs and benefits based on both partial attainment (manageable with current technologies) and full attainment (manageable in some locations only with hypothetical technologies). The post-2020 estimates for California are entirely based on hypothetical technologies.

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

The prohibition against the consideration of cost in the setting of the primary air quality standards, however, does not mean that costs, benefits or other economic considerations are unimportant or should be ignored. The Agency believes that consideration of costs and benefits is an essential decision making tool for the efficient implementation of these standards. The impacts of cost, benefits, and efficiency are considered by the States when they make decisions regarding what timelines, strategies, and policies make the most sense.

This RIA is focused on development and analyses of illustrative control strategies to meet these alternative standards in 2020. This analysis does not prejudge the attainment dates that will ultimately be assigned to individual areas under the Clean Air Act, which contains a variety of potential dates and flexibility. For purposes of this analysis, though, we assume attainment by 2020 for all areas except for two areas in California

Because States are ultimately responsible for implementing strategies to meet revised standards, this RIA provides insights and analysis of a limited number of illustrative control strategies that states might adopt to meet any revised standard. These illustrative strategies are subject to a number of important assumptions, uncertainties and limitations, which we document in the relevant portions of the analysis.

ES.1 Approach to the Analysis

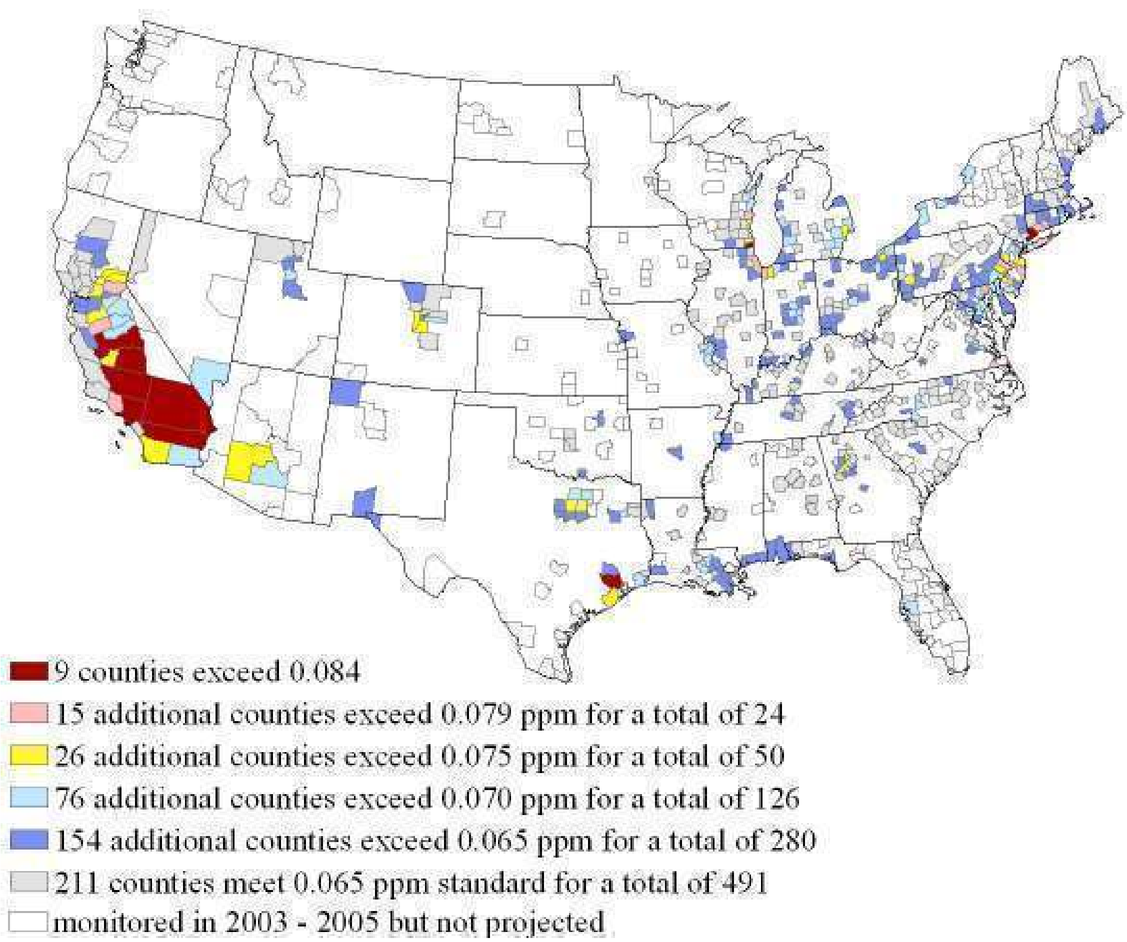
This RIA consists of multiple analyses including an assessment of the nature and sources of ambient ozone; estimates of current and future emissions of relevant precursors that contribute to the problem; air quality analyses of baseline and alternative strategies; development of illustrative control strategies to attain the standard alternatives in future years; estimates of the incremental costs and benefits of attaining the alternative standards, together with an examination of key uncertainties and limitations; and a series of conclusions and insights gained from the analysis.

The air quality modeling results for the *regulatory baseline* (explained in Chapter 3) provide the starting point for developing illustrative control strategies to attain the alternative standards that are the focus of this RIA. The baseline shows that by 2020, while ozone air quality would be significantly better than today under current requirements, several eastern and western states would need to develop and adopt additional controls to attain the alternative standards.

In selecting controls, we focused more on ozone cost-effectiveness (measured as $/ ppb) than on the NOx or VOC cost-effectiveness (measured as $/ton). Most of the overall reductions in NOx achieved our illustrative control strategy were from non-EGU point sources. The NOx based illustrative control strategies we analyzed are also expected to reduce ambient PM 2.5 levels in many locations. The total benefits estimates described here include the co-benefits of reductions in fine particulate levels (PM) associated with year-round application of NOx control strategies beyond those in the regulatory baseline.

Estimated reductions in premature mortality from reductions in ambient ozone and PM dominate the benefits estimates. For this reason, our assessment provides a range of estimates for both PM and ozone premature mortality. Although we note that there are uncertainties that are not fully captured by this range of estimates, and that additional research is needed to more fully establish underlying mechanisms by which such effects occur, such ranges are illustrative of the extent of uncertainly associated with some different modeling assumptions.

Fig ES.1 Projected Ozone Air Quality in 2020 After Application of Known Controls



1 Modeled emissions reflect the expected reductions from federal programs including the Clean Air Interstate Rule, the Clean Air Mercury Rule, the Clean Air Visibility Rule, the Clean Air Nonroad Diesel Rule, the Light-Duty Vehicle Tier 2 Rule, the Heavy Duty Diesel Rule, proposed rules for Locomotive and Marine Vessels and for Small Spark-Ignition Engines, and state and local level mobile and stationary source controls identified for additional reductions in emissions for the purpose of attaining the current PM 2.5 and Ozone standards.

2 Controls applied are illustrative. States may choose to apply different control strategies for implementation.

3 The current standard of 0.08 ppm is effectively expressed as 0.084 ppm when rounding conventions are applied.

4 Modeled design values in ppm are only interpreted up to 3 decimal places.

5 Map shows results from a total of 491 counties with projected design values. Consistent with current modeling guidance, EPA did not project 2020 concentrations for counties where 2001 base year concentrations were less than recommended criterion. Such projections may not represent expected future levels.

ES-2. Results of Benefit-Cost Analysis

There are two sets of results presented below. The first set of national results assumes attainment of revised standards by 2020 in all areas, except for two areas in Southern California. It is expected that benefits and costs will begin occurring earlier, as states begin implementing control measures to show progress towards attainment. Some areas with high ozone levels, such as the two areas in Southern California, are not planning to attain even the current standard until after 2020. In these locations, our national 2020 estimate includes the cost and benefits of reaching an estimated progress point in 2020 (known as a "glidepath" target). The 2020 results will thus not represent a true "full attainment" scenario for the entire nation. In order to gain an understanding of the possible additional costs and benefits of fully attaining in California in a year beyond 2020, we provide an additional set of results for California only. Tables ES-1 to ES-3 present national benefits and costs in 2020, including the "glidepath" targets for California; companion Table ES-4 provides the national estimated reductions in premature mortality and morbidity in 2020, including the "glidepath" targets for California.

Tables ES-5 to ES-7 present the costs and benefits of full attainment for California ("glidepath" in 2020 plus the additional increment achieved between 2020 and a future year added together into one California total); Table ES-8 is the companion table showing estimated reductions in premature mortality and morbidity for California. Because various mobile source rules, such as the onroad and nonroad diesel rule, among others, would be expected to be implemented between 2020 and a future year, the tons of emission reduction expected to occur as a result of those rules has been taken out of the calculated costs and benefits for the estimates of additional tons of emission reduction needed in California between 2020 and a future year. EPA did the analysis this way because to force full attainment in an earlier year than would be required under the Clean Air Act would likely lead to an overstatement of costs because those areas might benefit from these existing federal or state programs that would be implemented between 2020 and the attainment year; because additional new technologies may become available between 2020 and the attainment year; and because the cost of existing technologies might fall over time. As such, we use the best available data to estimate costs and benefits of full attainment for California in a future year, while recognizing that the estimates of costs and benefits for California in a year between 2020 and a future year are likely to be relatively more uncertain than the national attainment estimates for 2020. It is not appropriate to add together the 2020 national attainment, California glidepath estimate and the estimate of California full attainment as an estimate of national full attainment in 2020. The extra increment of attainment that is estimated for California will not occur in 2020, so it is not accurate to add it to our nationwide estimate of the "glidepath" benefits and costs to arrive at a "full attainment" estimate for 2020[1]. It is also not accurate to add the two estimates together to arrive at an estimate of future, post-2020 full attainment benefits and costs, because our nationwide full attainment estimates do not

[1] The California full attainment costs calculated using the offset in NOx emissions from mobile programs would understate the costs of fully attaining in 2020, however, California will not be required to attain in 2020.

allow other areas of the nation to take credit for the reductions in NOx from the mobile source rules that will occur after 2020.[2]

In these tables, the individual row estimates reflect the different studies available to describe the ozone premature mortality relationship. Ranges within the total benefits column reflect variability in the studies upon which the estimates associated with premature mortality were derived. PM co-benefits account for between 13 and 99 percent of co-benefits, depending on the standard analyzed and on the choice of ozone and PM mortality functions used.

Ranges in the total costs column reflect different assumptions about the extrapolation of costs. The low end of the range of net benefits is constructed by subtracting the highest cost from the lowest benefit, while the high end of the range is constructed by subtracting the lowest cost from the highest benefit. The presentation of the net benefit estimates represents the widest possible range from this analysis.

Table ES-1 National Annual Costs and Benefits: 0.079 ppm Standard in 2020 (including California glidepath)

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits*	Total Costs**	Net Benefits
NMMAPS	Bell et al. 2004	$1.2 to $11	$3 to $3.3	-$2.1 to $8.5
Meta-analysis	Bell et al. 2005	$1.6 to $12	$3 to $3.3	-$1.7 to $8.9
	Ito et al. 2005	$1.7 to $12	$3 to $3.3	-$1.7 to $8.9
	Levy et al. 2005	$1.6 to $12	$3 to $3.3	-$1.7 to $8.9
Assumption that association is not causal***		$1.1 to $11	$3 to $3.3	-$2.2 to $8.4

[2] This approach would be an overestimate of national full attainment costs in a future year after 2020 because it would not take into account that other states (not just California) could replace more expensive NOx reductions from other sources with the post-2020 reductions obtained from implementation of mobile source rules that are included in the regulatory baseline.

Table ES-2 National Annual Costs and Benefits: 0.075 ppm Standard in 2020 (including California glidepath)

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits*	Total Costs**	Net Benefits
NMMAPS	Bell et al. 2004	$3 to $16	$5.5 to $8.8	-$5.8 to $10.5
Meta-analysis	Bell et al. 2005	$7.3 to $20	$5.5 to $8.8	-$1.5 to $15
	Ito et al. 2005	$7.8 to $21	$5.5 to $8.8	-$1. to $15
	Levy et al. 2005	$8.7 to $22	$5.5 to $8.8	-$0.1 to $16
Assumption that association is not causal***		$1.5 to $15	$5.5 to $8.8	-$7.3 to $9

Table ES-3 National Annual Costs and Benefits: 0.070 ppm Standard in 2020 (including California glidepath)

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits*	Total Costs**	Net Benefits
NMMAPS	Bell et al. 2004	$4.3 to $26	$10 to $22	-$17 to $16
Meta-analysis	Bell et al. 2005	$9.7 to $31	$10 to $22	-$12 to $21
	Ito et al. 2005	$10 to $32	$10 to $22	-$11 to $22
	Levy et al. 2005	$11 to $33	$10 to $22	-$10 to $23
Assumption that association is not causal***		$2.5 to $24	$10 to $22	-$20 to $14

Table ES-4 National Annual Costs and Benefits : 0.065 ppm Standard in 2020 (including California glidepath)

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits*	Total Costs**	Net Benefits
NMMAPS	Bell et al. 2004	$7.7 to $45	$17 to $46	-$38 to $28
Meta-analysis	Bell et al. 2005	$18 to $55	$17 to $46	-$28 to $38
	Ito et al. 2005	$19 to $56	$17 to $46	-$27 to $39
	Levy et al. 2005	$20 to $57	$17 to $46	-$27 to $40
Assumption that association is not causal***		$4.3 to $42	$17 to $46	-$42 to $25

*Includes ozone benefits, and PM 2.5 co-benefits. Range was developed by adding the estimate from the ozone premature mortality function to both the lower and upper ends of the range of the PM2.5 premature mortality functions characterized in the expert elicitation
**Range reflects lower and upper bound cost estimates
***Total includes ozone morbidity benefits only

Table ES-5: Summary of Total Number of Annual Ozone and $PM_{2.5}$-Related Premature Mortalities and Premature Morbidity Avoided: 2020 National Benefits

Combined Estimate of Mortality

Standard Alternative and Model or Assumption		*Combined Range of Ozone Benefits and $PM_{2.5}$ Co-Benefits*			
		0.079 ppm	0.075 ppm	0.070 ppm	0.065 ppm
NMMAPS	Bell (2004)	200 to 1,900	430 to 2,600	670 to 4,300	1,200 to 7,400
Meta-Analysis	Bell (2005)	260 to 2,000	1,100 to 3,300	1,500 to 5,100	2,800 to 9,000
	Ito (2005)	270 to 2,000	1,200 to 3,300	1,600 to 5,200	3,000 to 9,200
	Levy (2005)	260 to 2,000	1,300 to 3,500	1,800 to 5,400	3,000 to 9,200
No Causality		180 to 1,900	230 to 2,400	390 to 4,000	660 to 6,900

Combined Estimate of Morbidity

Acute Myocardial Infarction	1,100	1,400	2,300	4,000
Hospital and ER Visits	1,300	5,600	7,600	13,000
Chronic Bronchitis	370	470	780	1,300
Acute Bronchitis	950	1,200	2,000	3,500
Asthma Exacerbation	7,300	9,400	16,000	27,000
Lower Respiratory Symptoms	8,100	10,000	17,000	29,000
Upper Respiratory Symptoms	5,900	7,500	13,000	22,000
School Loss Days	50,000	610,000	780,000	1,300,000
Work Loss Days	51,000	65,000	110,000	190,000
Minor Restricted Activity Days	430,000	2,000,000	2,700,000	4,700,000

Table ES-6 California: Annual Costs and Benefits of Attaining 0.079 ppm Standard (beyond 2020)*

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits**	Total Costs***	Net Benefits
NMMAPS	Bell et al. 2004	$0.1 to $0.6	$0.3 to $1.7	-$1.6 to $0.2
Meta-analysis	Bell et al. 2005	$0.2 to $0.7	$0.3 to $1.7	-$1.5 to $0.4
	Ito et al. 2005	$0.3 to $0.7	$0.3 to $1.7	-$1.4 to $0.4
	Levy et al. 2005	$0.2 to $0.7	$0.3 to $1.7	-$1.5 to $0.4
Assumption that association is not causal****		$0.05 to $0.5	$0.3 to $1.7	-$1.6 to $0.2

Table ES-7 California: Annual Costs and Benefits of Attaining 0.070 ppm Standard (beyond 2020)*

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits**	Total Costs***	Net Benefits
NMMAPS	Bell et al. 2004	$0.7 to $3.5	$2 to $13	-$12 to $1.5
Meta-analysis	Bell et al. 2005	$1.9 to $4.7	$2 to $13	-$11 to $2.7
	Ito et al. 2005	$2.1 to $4.8	$2 to $13	-$11 to $2.9
	Levy et al. 2005	$2.1 to $4.8	$2 to $13	-$11 to $2.9
Assumption that association is not causal****		$0.4 to $3.1	$2 to $13	-$13 to $1.2

Table ES-8 California: Annual Costs and Benefits of Attaining 0.075 ppm Standard (beyond 2020)*

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits**	Total Costs***	Net Benefits
NMMAPS	Bell et al. 2004	$0.4 to $1.9	$1.1 to $6.2	-$5.8 to $0.8
Meta-analysis	Bell et al. 2005	$1.1 to $2.6	$1.1 to $6.2	-$5.1 to $1.5
	Ito et al. 2005	$1.2 to $2.7	$1.1 to $6.2	-$5.1 to $1.6
	Levy et al. 2005	$1.2 to $2.7	$1.1 to $6.2	-$5 to $1.6
Assumption that association is not causal****		$0.2 to $1.7	$1.1 to $6.2	-$6 to $0.6

Table ES-9 California: Annual Costs and Benefits of Attaining 0.065 ppm Standard (beyond 2020)*

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits**	Total Costs***	Net Benefits
NMMAPS	Bell et al. 2004	$1.1 to $5.2	$2.9 to $21	-$19 to $2.3
Meta-analysis	Bell et al. 2005	$3.1 to $7.2	$2.9 to $21	-$17 to $4.3
	Ito et al. 2005	$3.4 to $7.4	$2.9 to $21	-$17 to $4.5
	Levy et al. 2005	$3.3 to $7.4	$2.9 to $21	-$17 to $4.5
Assumption that association is not causal****		$0.5 to $4.6	$2.9 to $21	-$20 to $1.7

* Tables present the total of CA glidepath in 2020, plus the additional increment needed to reach full attainment in a year beyond 2020
** Includes ozone benefits and PM 2.5 co-benefits. Range was developed by adding the estimate from the ozone premature mortality function to both the lower and upper ends of the range of the PM2.5 premature mortality functions characterized in the expert elicitation
***Range reflects lower and upper bound cost estimates
****Total includes ozone morbidity benefits only

Table ES-10: Summary of Total Number of Annual Ozone and $PM_{2.5}$-Related Premature Mortalities and Premature Morbidity Avoided: California Post 2020 Attainment

Combined Estimate of Mortality

Standard Alternative and Model or Assumption		*Combined Range of Ozone Benefits and $PM_{2.5}$ Co-Benefits*			
		0.079 ppm	0.075 ppm	0.070 ppm	0.065 ppm
NMMAPS	Bell (2004)	17 to 93	61 to 310	110 to 570	180 to 840
Meta-Analysis	Bell (2005)	42 to 120	170 to 410	300 to 760	490 to 1,200
	Ito (2005)	45 to 120	180 to 430	320 to 780	530 to 1,200
	Levy (2005)	46 to 120	180 to 430	320 to 780	520 to 1,200
No Causality		8.2 to 84	26 to 270	49 to 500	72 to 740

Combined Estimate of Morbidity

	0.079 ppm	0.075 ppm	0.070 ppm	0.065 ppm
Acute Myocardial Infarction	49	160	290	430
Hospital and ER Visits	200	790	1,400	2,200
Chronic Bronchitis	17	53	99	150
Acute Bronchitis	43	140	260	380
Asthma Exacerbation	330	1,100	2,000	2,900
Lower Respiratory Symptoms	360	1,200	2,200	3,200
Upper Respiratory Symptoms	270	850	1,600	2,300
School Loss Days	30,000	120,000	210,000	340,000
Work Loss Days	2,300	7,400	14,000	20,000
Minor Restricted Activity Days	87,000	340,000	600,000	960,000

***Range was developed by adding the estimate from the ozone premature mortality function to both the lower and upper ends of the range of the $PM_{2.5}$ premature mortality functions characterized in the expert elicitation

ES-3. Caveats and Conclusions

Of critical importance to understanding these estimates of future costs and benefits is that they not intended to be forecasts of the actual costs and benefits of implementing revised standards. There are many challenges in estimating the costs and benefits of attaining a tighter ozone standard, which are fully discussed in Chapter 8. Analytically, the characterization of ozone mortality benefits and the estimation of the costs and benefits of the nation fully attaining a tighter standard are being subject to further review by science advisory boards.

There are significant uncertainties in both cost and benefit estimates. Below we summarize some of the more significant sources of uncertainty.

- Benefits estimates are influenced by our ability to correctly model relationships between ozone and PM and their associated health effects (e.g., premature mortality).
- Benefits estimates are also heavily dependent upon the choice of statistical estimates for values associated with each of the health benefits.
- EPA has requested advice from the National Academy of Sciences on how best to quantify uncertainty in the relationship between ozone exposure and premature mortality in the context of quantifying benefits associated with alternative ozone control strategies.
- PM co-benefits are derived primarily from reductions in nitrates (associated with NOx controls). As such, these estimates are strongly influenced by the assumption that all PM components are equally toxic. Co-benefit estimates are also influenced by the extent to which a particular area chooses to use NOx controls rather than VOC controls.
- EPA employed a monitor rollback approach to estimate the benefits of attaining an alternative standard of 0.079 ppm nationwide. This approach likely understates the benefits that would occur due to implementation of actual controls because controls implemented to reduce ozone concentrations at the highest monitor would likely result in some reductions in ozone concentrations at attaining monitors down-wind (i.e. the controls would lead to concentrations below the standard in down-wind locations). The estimated benefits of attaining a standard of 0.075 ppm, however, are likely overstated. EPA will develop and present consistent approaches for the alternative standards for the final RIA.
- There are several nonquantified benefits (e.g. effects of reduced ozone on forest health and agricultural crop production) and disbenefits (e.g. decreases in tropospheric ozone lead to reduced screening of UV-B rays and reduced nitrogen fertilization of forests and cropland) discussed in this analysis in chapter 6.
- Changes in air quality as a result of controls are not expected to be uniform over the country. In our hypothetical control scenario some increases in ozone levels occur in areas already in attainment, though not enough to push the areas into nonattainment
- As explained in chapter 5, there are several uncertainties in our cost estimates. For example, the states are likely to use different approaches for reducing NOx and VOCs in their state implementation plans to reach a tighter standard. In addition, since we are unable to use known controls to get all areas into attainment, we needed to use simple $/ton costs to estimate the overall national cost of meeting the tighter alternatives.
- As discussed in chapter 5, recent advice from EPA's Science Advisory Board has questioned the appropriateness of an approach similar to that used here for estimating

extrapolated costs. EPA will consider this advice and other guidance as it develops the methodology for analyzing the final rule.

- Both extrapolated costs and benefits have additional uncertainty relative to modeled costs and benefits. The extrapolated costs and benefits will only be realized to the extent that unknown extrapolated controls are economically feasible and are implemented.
- Technological advances over time will tend to increase the economic feasibility of reducing emissions, and will tend to reduce the costs of reducing emissions.

- These sources of uncertainty are discussed in more detail in subsequent chapters of the RIA. In addition to considering any advice which comes from advisory bodies prior to the publication of the final ozone NAAQS, EPA will undertake an updated approach with improvements to emissions inventories, models and control strategies for the RIA which will accompany that rulemaking.

Chapter 1: Introduction and Background

Synopsis

This document estimates the incremental costs and monetized human health and welfare benefits of attaining possible revised primary ozone National Ambient Air Quality Standards (NAAQS) nationwide. This document contains illustrative analyses that consider limited emission control scenarios that states, tribes and regional planning organizations might implement to achieve a revised ozone NAAQS. In some cases, EPA weighed the available empirical data to make judgments regarding the proposed attainment status of certain urban areas in the future. According to the Clean Air Act, EPA must use health-based criteria in setting the NAAQS and cannot consider estimates of compliance cost. This Regulatory Impact Analysis (RIA) is intended to provide the public a sense of the benefits and costs of meeting new alternative ozone NAAQS, and to meet the requirements of Executive Order 12866 and OMB Circular A-4 (described below in Section 1.2.2).

1.1 Background

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

Section 109 (42 U.S.C. 7409) directs the Administrator to propose and promulgate "primary" and "secondary" NAAQS for pollutants identified under section 108. Section 109(b)(1) defines a primary standard as "the attainment and maintenance of which in the judgment of the Administrator, based on [the] criteria and allowing an adequate margin of safety, [are] requisite to protect the public health." A secondary standard, as defined in section 109(b)(2), must "specify a level of air quality the attainment and maintenance of which in the judgment of the Administrator, based on [the] criteria, [are] requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of [the] pollutant in the ambient air." Welfare effects as defined in section 302(h) [42 U.S.C 7602(h)] include but are not limited to "effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being."

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

1.2 Role of the Regulatory Impact Analysis in the NAAQS Setting Process

1.2.1 Legislative Roles

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

The prohibition against the consideration of cost in the setting of the primary air quality standard, however, does not mean that costs or other economic considerations are unimportant or should be ignored. The Agency believes that consideration of costs and benefits are essential to making efficient, cost effective decisions for implementation of these standards. The impact of cost and efficiency are considered by states during this process, as they decide what timelines, strategies, and policies make the most sense. This RIA is intended to inform the public about the potential costs and benefits that may result when a new ozone standard is implemented, but is not relevant to establishing the standards themselves.

1.2.2 Role of Statutory and Executive Orders

There are several statutory and executive orders that dictate the manner in which EPA considers rulemaking and public documents. This document is separate from the NAAQS decision making process, but there are several statutes and executive orders that still apply to any public documentation. A summary of the pertinent orders is included in Appendix 1. The analysis required by these statutes and executive orders is presented in Chapter 9.

EPA presents this RIA pursuant to Executive Order 12866 and the guidelines of OMB Circular A-4. [1] These documents present guidelines for EPA to assess the benefits and costs of the selected regulatory option, as well as one less stringent and one more stringent option. OMB circular A-4 also requires both a cost-benefit, and a cost-effectiveness analysis for rules where health is the primary effect. Within this RIA we provide a cost benefit analysis. We also provide a cost-effectiveness analysis for that portion of the benefits which occur from concurrent reductions in particulate matter as a result of controls on NOx emissions to reduce ozone levels (see Appendix 6b). We are investigating options for conducting a cost-effectiveness analysis for the ozone portion of the benefits and expect to provide estimates based on that analysis in the final RIA.

---

[1] U.S. Office of Management and Budget. Circular A-4, September 17, 2003. Found on the Internet at <http://www.whitehouse.gov/omb/circulars/a004/a-4.pdf>.

1.2.3 Market Failure or Other Social Purpose

OMB Circular A-4 indicates that one of the reasons a regulation such as the NAAQS may one may be issued is to address market failure. The major types of market failure include: externality, market power, and inadequate or asymmetric information. Correcting market failures is one reason for regulation, but it is not the only reason. Other possible justifications include improving the function of government, removing distributional unfairness, or promoting privacy and personal freedom.

An externality occurs when one party's actions impose uncompensated benefits or costs on another party. Environmental problems are a classic case of externality. For example, the smoke from a factory may adversely affect the health of local residents while soiling the property in nearby neighborhoods. If bargaining was costless and all property rights were well defined, people would eliminate externalities through bargaining without the need for government regulation. From this perspective, externalities arise from high transaction costs and/or poorly defined property rights that prevent people from reaching efficient outcomes through market transactions.

Firms exercise market power when they reduce output below what would be offered in a competitive industry in order to obtain higher prices. They may exercise market power collectively or unilaterally. Government action can be a source of market power, such as when regulatory actions exclude low-cost imports. Generally, regulations that increase market power for selected entities should be avoided. However, there are some circumstances in which government may choose to validate a monopoly. If a market can be served at lowest cost only when production is limited to a single producer of local gas and electricity distribution services, a natural monopoly is said to exist. In such cases, the government may choose to approve the monopoly and to regulate its prices and/or production decisions. Nevertheless, it should be noted that technological advances often affect economies of scale. This can, in turn, transform what was once considered a natural monopoly into a market where competition can flourish.

Market failures may also result from inadequate or asymmetric information. Because information, like other goods, is costly to produce and disseminate, an evaluation will need to do more than demonstrate the possible existence of incomplete or asymmetric information. Even though the market may supply less than the full amount of information, the amount it does supply may be reasonably adequate and therefore not require government regulation. Sellers have an incentive to provide information through advertising that can increase sales by highlighting distinctive characteristics of their products. Buyers may also obtain reasonably adequate information about product characteristics through other channels, such as a seller offering a warranty or a third party providing information.

There are justifications for regulations in addition to correcting market failures. A regulation may be appropriate when there are clearly identified measures that can make government operate more efficiently. In addition, Congress establishes some regulatory programs to redistribute resources to select groups. Such regulations should be examined to ensure that they are both effective and cost-effective. Congress also authorizes some regulations to prohibit discrimination that conflicts with generally accepted norms within our society. Rulemaking may also be appropriate to protect privacy, permit more personal freedom or promote other democratic aspirations.

From an economics perspective, setting an air quality standard is a straightforward case of addressing an externality, in this case where firms are emitting pollutants, which cause health and environmental problems without compensation for those suffering the problems. Although this economics perspective is reflected in Clean Air Act legislative history, there is also legislative history in which members of Congress stated that the purpose of setting national air quality standards solely based on health considerations (without considering costs) is to protect a fundamental right of Americans to be protected from air pollution levels that adversely affect their health. Setting a standard with a reasonable margin of safety attempts to place the cost of control on those who emit the pollutants and lessens the impact on those who suffer the health and environmental problems from higher levels of pollution.

1.2.4 Illustrative Nature of the Analysis

This ozone NAAQS RIA is an illustrative analysis that provides useful insights into a limited number of emissions control scenarios that states might implement to achieve a revised ozone NAAQS. Because states are ultimately responsible for implementing strategies to meet any revised standard, the control scenarios in this RIA are necessarily hypothetical in nature. They are not forecasts of expected future outcomes. Important uncertainties and limitations, are documented in the relevant portions of the analysis.

The illustrative goals of this RIA are somewhat different from other EPA analyses of national rules, or the implementation plans states develop, and the distinctions are worth brief mention. This RIA does not assess the regulatory impact of an EPA-prescribed national or regional rule such as the Clean Air Interstate Rule, nor does it attempt to model the specific actions that any state would take to implement a revised ozone standard. This analysis attempts to estimate the costs and human and welfare benefits of cost-effective implementation strategies which might be undertaken to achieve national attainment of new standards. These hypothetical strategies represent a scenario where states use one set of cost-effective controls to attain a revised ozone NAAQS. Because states—not EPA—will implement any revised NAAQS, they will ultimately determine appropriate emissions control scenarios. State implementation plans would likely vary from EPA's estimates due to differences in the data and assumptions that states use to develop these plans.

The illustrative attainment scenarios presented in this RIA were constructed with the understanding that there are inherent uncertainties in projecting emissions and controls. Furthermore, certain emissions inventory, control, modeling and monitoring limitations and uncertainties inhibit EPA's ability to model full attainment in all areas. An additional limitation is that this analysis is carried out for the year 2020, before some areas are required to reach the current ozone standard. Section 1.3.1 below explains why EPA selected the analysis year of 2020. Despite these limitations, EPA has used the best available data and methods to produce this RIA.

1.3 Overview and Design of the RIA

This Regulatory Impact Analysis evaluates the costs and benefits of hypothetical national strategies to attain several potential revised primary ozone standards. The document is intended to be straightforward and written for the lay person with a minimal background in chemistry, economics, and/or epidemiology. Figure 1.1 provides an illustration of the framework of this RIA.

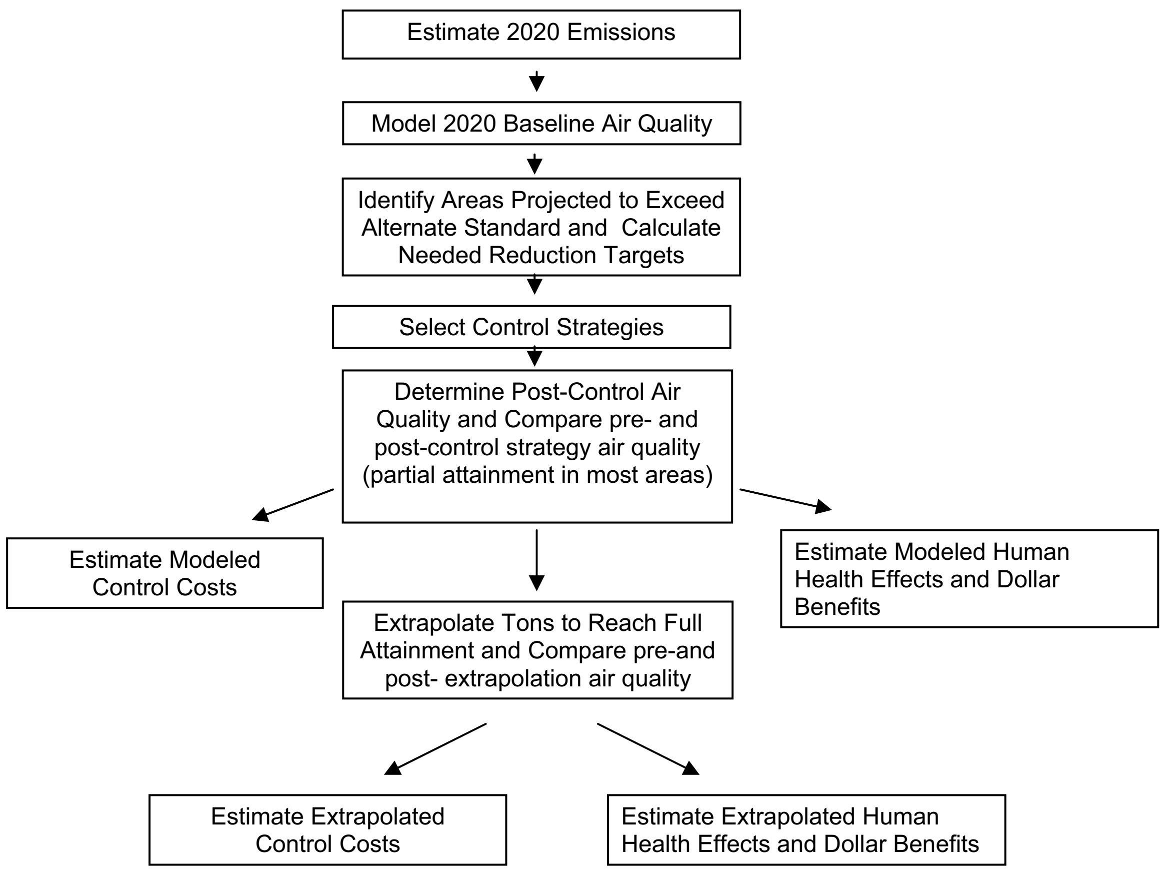


Figure 1.1: the process used to create this RIA

1.3.1 Baseline and Years of Analysis

The analysis year for this regulatory impact analysis is 2020, which allows EPA to build the ozone RIA analysis on the previously completed PM NAAQS RIA analysis. Many areas will reach attainment of the current ozone standard or any alternative standard by 2020. For purposes of this analysis, we assume attainment by 2020 for all areas except for two areas in California with unique circumstances described in chapter 4. Some areas for which we assume 2020 attainment may in fact need more time to meet one or more of the analyzed standards, while others will need less time. This analysis does not prejudge the attainment dates that will ultimately be assigned to individual areas under the Clean Air Act, which contains a variety of potential dates and flexibility to move to later dates (up to 20 years), provided that the date is as expeditious as practicable.

The methodology first estimates what baseline ozone levels might look like in 2020 with existing Clean Air Act programs, including application of controls to meet the current ozone standard and the newly revised PM NAAQS standard. and then models how ozone levels would be predicted to change following the application of additional controls to reach a tighter standard. This allows for an analysis of the incremental change between the current standard and an alternative standard. This timeline is also consistent with expected attainment in 2020 of the revised Particulate Matter (PM) NAAQS covered in the PM NAAQS RIA issued in September 2006. As explained in Chapter 2, since one of the principal precursors for ozone, NOx, is also a precursor for PM, it is important that we account for the impact on ozone concentrations of NOx controls used in the hypothetical control scenario used in the PM NAAQS RIA, so as to avoid double counting the benefits and costs of these controls.

1.3.2 Control Scenarios Considered in this RIA

A hypothetical control strategy was developed for an alternative 8-hr ozone standard of 0.070 ppm, in order to illustrate one national scenario for how such a tighter standard might be met. First, EPA modeled the predicted air quality changes that would result from the application of emissions control options that are known to be available to different types of sources in portions of the country that were predicted to be in non-attainment with 0.070 ppm in 2020. However, given the limitations of current technology and the amount of improvement in air quality needed to reach a standard of 0.070 ppm in some areas, it was also expected that modeling these known controls would not reduce ozone concentrations sufficiently to allow all areas to reach the more stringent standard. This required a second step to calculate the number of tons of emission reductions that would be needed to reach full attainment. This required calculating a conversion factor to quantify the estimated tons of emissions that needed to be reduced to generate a particular change in air quality concentrations of ozone (in ppm). This factor, coupled with the estimated remaining increment (in ppm) of ozone necessary to reach the alternative standard in each area, allowed for an extrapolation of how many tons of additional emissions reductions were estimated to be needed to reach the alternate standard.

1.3.3 Evaluating Costs and Benefits

Applying a two step methodology for estimating emission reductions needed to reach full attainment enabled EPA to evaluate nationwide costs and benefits of attaining a tighter ozone standard, albeit with substantial additional uncertainty regarding the second step estimates. Costs and benefits are presented in this RIA in the same two steps that emissions reductions were estimated. First, the costs associated with applying known controls were quantified, and presented along with an estimate of their economic impact. Second, EPA estimated costs of the additional tons of extrapolated emission reductions estimated which were needed to reach full attainment. The analysis of the benefits of setting an alternative standard included both mortality and morbidity calculations matching the costs of applying known controls and then the benefits of reaching full attainment. The costs and monetized benefits were then compared to provide an estimate of net benefits nationwide.

The RIA presents two sets of results for estimated costs and benefits. The first reflects full attainment in 2020 in all locations of the U.S. except two areas of California. These two areas are not planning to meet the current standard by 2020, so the estimated costs and benefits for these areas are based on reaching an estimated progress point in 2020 (their "glidepath" targets). The second set of results for California only, estimate the costs and benefits from California fully attaining the alternative standards in a year beyond 2020 (glidepath estimates for 2020, plus further increments needed to reach full attainment beyond 2020, added together for California total).

To streamline this RIA, it refers to several previously published documents, including two technical documents EPA produced to prepare for the ozone NAAQS proposal. The first was a Criteria Document created by EPA's Office of Research and Development (published in 2006), which presented the latest available pertinent information on atmospheric science, air quality, exposure, dosimetry, health effects, and environmental effects of ozone. The second was a "Staff Paper" (published in 2007) that evaluated the policy implications of the key studies and scientific information contained in the Criteria Document, as well as presented a risk assessment for various standard levels. The Staff Paper also includes staff conclusions and recommendations to the Administrator regarding potential revisions to the standards. In addition to the Criteria Document and Staff Paper, this ozone RIA relies heavily on the 2006 RIA for particulate matter (PM). Many of the models and methodology used here are the same as in the PM NAAQS RIA. This RIA identifies methodologies used to generate data, but refers readers to the PM NAAQS RIA for many technical details. The focus of this RIA is to explain in detail how the approach or methodologies have changed from the PM NAAQS RIA analysis, and to present the results of the methodologies employed in this analysis, which compares attainment of tighter levels of the ozone standard to the baseline of the current standard.

1.4 Ozone Standard Alternatives Considered

Per Executive Order 12866 and the guidelines of OMB Circular A-4, this RIA presents analyses of the range of standards proposed by the Administrator in the Notice of Proposed Rulemaking (0.070 – 0.075 ppm), as well as one more stringent option (0.065 ppm), and one less stringent option (0.079 ppm). EPA will also model a baseline as the current primary standard for ozone (0.08 parts per million (ppm), calculated as the 3-year average of the annual fourth-highest daily maximum 8-hour average ozone concentration measured at each monitor within an area -- effectively 0.084 ppm using current data rounding conventions).

The EPA Administrator received recommendations to revise the current primary ozone standard from both the Clean Air Act Scientific Advisory Council (CASAC) and EPA staff. Both CASAC and staff expressed the view that the current standard was not adequately protective of human health and should be tightened to provide additional public health protection. Specifically, CASAC recommended that "*…the current primary ozone NAAQS [should] be revised and that the level that should be considered for the revised standard be from 0.060 to 0.070 ppm*."[2] In the Staff Paper, EPA staff suggested a slightly broader range, recommending *"that consideration be given to a standard level within the range of somewhat below 0.080 ppm to 0.060 ppm.*"[3] Both of these recommendations encourage maintaining the same averaging time and form as the current standard. Additionally, both recommendations suggested it was appropriate to specify the level of the standard out to three significant digits.

In the concurrent ozone NAAQS proposal, EPA proposes to revise the 8-hour standard to a level within the range of 0.070 to 0.075 ppm, and to request comment on a wider range of an 8-hour standard from 0.060 ppm to 0.084 ppm, to provide increased protection for children and other sensitive populations against an array of ozone-related adverse health effects that range from decreased lung function and increased respiratory symptoms to serious indicators of respiratory morbidity including emergency department visits and hospital admissions for respiratory causes, and possibly cardiovascular-related morbidity as well as total nonaccidental and cardiopulmonary mortality. The EPA also proposes to specify the level of the primary standard to the nearest thousandth ppm.

This RIA presents benefit and cost estimates for both ends of the proposal range of 0.070 to 0.075 ppm. It also assesses the costs and benefits of attaining one more stringent standard option (0.065 ppm), and will include a less stringent option of 0.079 ppm.. Since EPA is not considering loosening the standard, the less stringent option to the proposed range is the current standard itself. Since this RIA presents an analysis of the costs and benefits incremental to the current standard, retaining the current standard is assumed to have no additional incremental costs or benefits.

For the secondary standard, EPA proposes to revise the current 8-hour standard with one of two options to provide increased protection against ozone-related adverse impacts on vegetation and forested ecosystems. One option is to replace the current standard with a cumulative, seasonal standard expressed as an index (called the W126) of the annual sum of weighted hourly concentrations, cumulated over 12 hours per day (8:00 am to 8:00 pm) during the consecutive 3-month period within the ozone season with the maximum index value, set at a level within the range of 7 to 21 ppm-hours. The other option is to make the secondary standard identical to the proposed primary 8-hour standard in all respects. This RIA provides a limited discussion of an alternative secondary standard showing the number of additional counties with monitors that may violate the standards,

---

[2] (Henderson, 2006c, p. 5). Henderson, R. (2006c) Letter from CASAC Chairman Rogene Henderson to EPA Administrator Stephen Johnson, October 24, 2006, EPA-CASAC-07-001.
[3] U.S EPA. 2007. Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information. OAQPS Staff Paper. North Carolina. EPA-452/R-07-003

depending on the level of the secondary standard. Costs and benefits of attaining the different levels of the secondary were not estimated in this RIA; this analysis focused on the health benefits of the primary standard. An analysis of a separate secondary will be included in the final RIA as appropriate. Hereafter, any reference to the ozone standard will be assumed to be the primary standard, unless otherwise noted.

1.5 References:

Henderson, R. 2006. October 24, 2006. Letter from CASAC Chairman Rogene Henderson to EPA Administrator Stephen Johnson, , EPA-CASAC-07-001.

U.S. EPA. 1970. Clean Air Act. 40CFR50.

U.S. EPA. 2006 .Air Quality Criteria for Ozone and Related Photochemical Oxidants (Final). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/004aF-cF,

U.S EPA. 2007. Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information. OAQPS Staff Paper. North Carolina. EPA-452/R-07-003

Pertinent Statutory and Executive Orders

1. Executive Order 12866: Regulatory Planning and Review
http://www.archives.gov/federal-register/executive-orders/pdf/12866.pdf

2. Paperwork Reduction Act, 44 U.S.C. 3501 et seq
http://www.archives.gov/federal-register/laws/paperwork-reduction/

3. Regulatory Flexibility Act, 5 U.S.C. 601 et seq.
http://www.archives.gov/federal-register/laws/regulatory-flexibility/

4. Unfunded Mandates Reform Act, Public Law 104-4
http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=104_cong_public_laws&docid=f:publ4.104.pdf

5. Executive Order 13132: Federalism, Executive Order 13132
http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1999_register&docid=fr10au99-133.pdf

6. Executive Order 13175: Consultation and Coordination with Indian Tribal Governments
http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2000_register&docid=fr09no00-167.pdf

7. **Executive Order 13045: Protection of Children from Environmental Health & Safety Risks**
http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1997_register&docid=fr23ap97-130.pdf

8. **Executive Order 13211: Actions that Significantly Affect Energy Supply, Distribution or Use**
http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2001_register&docid=fr22my01-133.pdf

9. National Technology Transfer Advancement Act, Public Law No. 104-113, §12(d)
http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=104_cong_public_laws&docid=f:publ113.104.pdf

10. Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
http://www.archives.gov/federal-register/executive-orders/pdf/12898.pdf

Chapter 2: Characterizing Ozone and Modeling Tools Used in This Analysis

Synopsis

This chapter describes the chemical and physical properties of ozone, general ozone air quality patterns, key health and environmental impacts associated with exposure to ozone, and key sources of ozone precursor emissions. In order to evaluate the health and environmental impacts of trying to reach a tighter ozone standard in the year 2020, it was necessary to use models to predict concentrations in the future. The tools and methodology used for the air quality modeling are described in this chapter. Subsequent chapters of this RIA rely heavily on the results of this modeling.

2.1 Ozone Chemistry

Ozone occurs both naturally in the stratosphere to provide a protective layer high above the earth, and at ground-level (troposphere) as the prime ingredient of smog. Tropospheric ozone, which is regulated by the NAAQS, is formed by both naturally occurring and anthropogenic sources. Ozone is not emitted directly into the air, but is created when its two primary components, volatile organic compounds (VOC) and oxides of nitrogen (NOx), combine in the presence of sunlight. VOC and NOx are often referred to as ozone precursors, which are, for the most part, emitted directly into the atmosphere. Ambient ozone concentrations are directly affected by temperature, solar radiation, wind speed and other meteorological factors. Ultraviolet radiation from the sun plays a key role in initiating the processes leading to ozone formation. However, there is little empirical evidence directly linking day-to-day variations in observed surface ultraviolet radiation levels with variations in tropospheric ozone levels.

The rate of ozone production can be limited by either VOCs or NO_x. In general, ozone formation using these two precursors is reliant upon the relative sources of hydroxide (OH) and NOx. When the rate of OH production is greater than the rate of production of NO_x, indicating that NO_x is in short supply, the rate of ozone production is NO_x-limited. In this situation, ozone concentrations are most effectively reduced by lowering current and future NO_x emissions, rather than lowering emissions of VOCs. When the rate of OH production is less than the rate of production of NO_x, ozone production is VOC-limited. Here, ozone is most effectively reduced by lowering VOCs. Between the NOx- and VOC- limited extremes there is a transitional region where ozone is nearly equally sensitive to each species. However ozone is relatively insensitive to marginal changes in both NOx and VOC in this situation. In urban areas with a high population concentration, ozone is often VOC-limited. Ozone is generally NOx-limited in rural areas and downwind suburban areas.

Due to the complex photochemistry of ozone production, NOx emissions lead to both the formation and destruction of ozone, depending on the local quantities of NOx, VOC, and ozone catalysts such as the OH and HO2 radicals. In areas dominated by fresh emissions of NOx, ozone catalysts are removed via the production of nitric acid, which slows the ozone formation rate. Because NOx is generally depleted more rapidly than VOC, this effect is usually short-lived and the emitted NOx can lead to ozone formation later and further downwind. The terms "NOx disbenefits" or "ozone disbenefits" refer to the ozone increases that can result from NOx emission reductions in these localized areas.[1]

2.1.1 Temporal Scale

Ground-level ozone forms readily in the atmosphere, usually during hot weather. The effects of sunlight on ozone formation depend on its intensity and its spectral distribution. Ozone levels tend to be highest during the daytime, during the summer or warm season. Changing weather patterns contribute to day to day and interannual differences in ozone concentrations. Differences in climatic regime, amount and mixture of emissions, and the extent of transport contribute to variations in ozone from city to city.

2.1.2 Geographic Scale and Transport

In many urban areas, ozone nonattainment is not caused by emissions from the local area alone. Due to atmospheric transport, contributions of precursors from the surrounding region can also be important. Thus, in designing control strategies to reduce ozone concentrations in a local area, it is often necessary to account for regional transport within the U.S.

In some areas, such as California, global transport of ozone from beyond North America can contribute to nonattainment areas. In a very limited number of areas, including areas such as Buffalo, Detroit and El Paso, which are located near borders, emissions from Canada or Mexico may contribute to nonattainment. In these areas, our illustrative implementation strategies may have included more controls on domestic sources than would be required if cross-border transport did not occur. However, we have not conducted formal analysis, and as such cannot determine the contribution of non-U.S. sources to ozone design values. The transport of ozone is determined by meteorological and chemical processes which typically extend over spatial scales of several hundred kilometers. Additionally, convection is capable of transporting ozone and its precursors vertically through the troposphere, with resulting mixing of stratospheric ozone for periods of a month or more with tropospheric ozone.

The Technical Support Document (TSD) for the Clean Air Interstate Rule (CAIR) suggests that ozone transport constitutes a sizable portion of projected nonattainment in most eastern areas based on a 2010 analysis. A listing of Eastern states and the extent of transported ozone they receive in the CAIR analysis is located in the CAIR TSD.[2] We used this information to help guide the design of emissions control strategies in this analysis.

---

[1] U.S. EPA. Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines. EPA420-R-04-007. May 2004.

[2] http://www.epa.gov/interstateairquality/pdfs/finaltech02.pdf, table VI-2

2.1.3 Effects of Ozone

Exposure to ground-level ozone is associated with a wide array of human health effects. Short-term exposure to ozone can cause acute respiratory problems; aggravate asthma; cause significant temporary decreases in lung capacity; cause inflammation of lung tissue; lead to hospital admissions and emergency room visits; and impair the body's immune system defenses, making people more susceptible to respiratory illnesses, including bronchitis and pneumonia. In addition, recent studies also provide evidence of additional health impacts associated with exposure to ozone, including premature mortality and possibly cardiac-related effects. (For a complete discussion of these effects, see Chapter 3 of the Staff Paper.)

Ground-level ozone is also associated with numerous environmental impacts. For example, ozone interferes with the ability of plants to produce and store food, so that growth, reproduction and overall plant health are compromised. By weakening sensitive vegetation, ozone makes plants more susceptible to disease, pests, and environmental stresses. Ground-level ozone has been shown to reduce agricultural yields for many economically important crops (e.g., soybeans, kidney beans, wheat, cotton). The effects of ground-level ozone on long-lived species such as trees are believed to add up over many years so that whole forests or ecosystems can be affected. For example, ozone can adversely impact ecological functions such as water movement, mineral nutrient cycling, and habitats for various animal and plant species. Furthermore, one of the key components of ozone, nitrogen oxides, contributes to fish kills and algae blooms in sensitive waterways, such as the Chesapeake Bay. (For a complete discussion of these effects, see Chapter 7 of the Staff Paper.)

2.2 Sources of Ozone

The anthropogenic precursors of ozone originate from a wide variety of stationary and mobile sources. In urban areas, both biogenic (natural) and anthropogenic VOCs are important for ozone formation. Hundreds of VOCs are emitted by evaporation and combustion processes from a large number of anthropogenic sources. Current data show that solvent use and highway vehicles are the two main sources of VOCs, with roughly equal contributions to total emissions. Emissions of VOCs from highway vehicles account for roughly two-thirds of the transportation-related emissions[3] By 2020, EPA emission projections show that VOC emissions from highway vehicles decrease significantly. Solvent use VOC decreases as well, but by 2020 solvent use VOC is projected to be a slightly more significant VOC contributor than mobile VOC. On the regional and global scales, emissions of VOCs from vegetation are much larger than those from anthropogenic sources.

Anthropogenic NOx emissions are associated with combustion processes. The two largest sources of NOx are electric power generation plants (EGUs) and motor vehicles.

---

[3] U.S EPA. 2007. Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information. OAQPS Staff Paper. North Carolina. EPA-452/R-07-003

EGU NOx is approximately 40% less than onroad mobile NOx in 2001. Both decrease between 2001 and 2020, with onroad mobile NOx decreasing more, so that their emissions are similar in 2020. It is not possible to make an overall statement about their relative impacts on ozone in all local areas because EGUs are more sparse than mobile sources, particularly in the west and south (See chapter 3 for a discussion of emission reductions projected in 2020 for the 8-hr ozone current standard baseline and the more stringent alternative control scenario). Natural NOx sources include stratospheric intrusions, lightning, soils, and wildfires. Lightning, fertilized soils, and wildfires are the major natural sources of NOx in the United States. Uncertainties in natural NOx inventories are much larger than for anthropogenic NOx emissions.

A complete list of emissions source categories, for both NOx and VOCs, is compiled in the final ozone Staff Paper (EPA, 2007, pp. 2-3 to 2-6).

2.3 Modeling Ozone Levels in the Future

In order to evaluate the predicted air quality in 2020, it is necessary to use modeling to derive estimated air quality concentrations. The modeling analysis uses an emissions inventory and historical meteorological conditions to simulate pollutant concentrations. The predictions from the modeling are used to (a) project future ozone design values (a representation of the resultant air quality concentration in 2020 equal to the 4th highest maximum 8-hr concentration) and (b) create spatial fields of ozone and $PM_{2.5}$ for characterizing human health impacts from reducing ozone precursors, which in the case of NOx will also affect the formation of $PM_{2.5}$. The air quality model used in this RIA is the Community Multi-Scale Air Quality (CMAQ) model[4]. The modeling to capture the $PM_{2.5}$ was performed for a one year time period. Modeling to calculate ozone-related benefits and the projection of ozone design values was performed for the period June through August. All controls in the illustrative 0.070 scenario were applied similarly to all months. There were no controls applied specifically for PM2.5 co-benefits because the controls developed to reduce summer ozone were applied to all months (see Chapter 3).

2.3.1 Emissions Inventory

The 2020 inventory from the Final PM NAAQS emissions platform was used as the starting point for the baseline and all subsequent analyses[5]. This included emissions from Canada as of 2000[6], and Mexico as of 1999.[7] As first discussed in the PM NAAQS RIA, an examination of the historical data suggests our previous methods have over-predicted future-year emissions for stationary non-EGU point and non-point sources, especially in the longer-forecast periods required for the NAAQS and other programs. To address this issue, we developed an 'interim' emission projection approach that assumes no growth to

[4] See CMAQ references listed at end of this chapter

[5] Final PM NAAQS Inventory is in the public docket EPA-HQ-OAR-2006-0834-0048.3

[6] http://www.epa.gov/ttn/chief/net/canada.html#data

[7] http://www.epa.gov/ttn/chief/net/mexico.html

emissions for many stationary non-EGU sources in estimating future-year emissions. In the future, we intend to pursue improved methods and models that provide more consistency with the historical record and reasonable assumptions regarding future conditions. More information is provided in Appendix D of the PM NAAQS RIA on the interim approach and a sensitivity analysis of the implications of this method relative to our previous forecasting methods. An updated 2020 inventory based on the EPA's 2002 modeling platform is currently being developed and will be used for the final ozone NAAQS RIA In addition, all national and local controls used in the illustrative control scenario for the revised PM NAAQS RIA were included in this 2020 baseline. These controls were included to prevent double counting of costs and benefits, especially in the case of NOx controls which are precursors to both $PM_{2.5}$ and ozone.

2.3.2 CMAQ Model

A national scale air quality modeling analysis was performed to estimate future year attainment/nonattainment of the current and alternative ozone standards. In addition, the model-based projections of ozone and $PM_{2.5}$ were used as inputs to the calculation of expected incremental benefits from the alternative ozone standards considered in this assessment. The 2001-based CMAQ modeling platform (version 4.5) was used as the basis for air quality modeling of future baseline emissions and control scenarios designed to bring areas into attainment with specific standards. This modeling platform was used in the 2006 PM NAAQS RIA. In addition to the CMAQ model, the modeling platform includes the emissions, meteorology, and initial and boundary condition data which are inputs to this model. The model produces spatial fields of gridded air quality concentrations on an hourly basis for the entire modeling domain. The concentrations that are produced can be averaged to produce a number of air quality metrics, including the 8-hr ozone design values, and can be used as inputs for the analysis of costs and benefits.

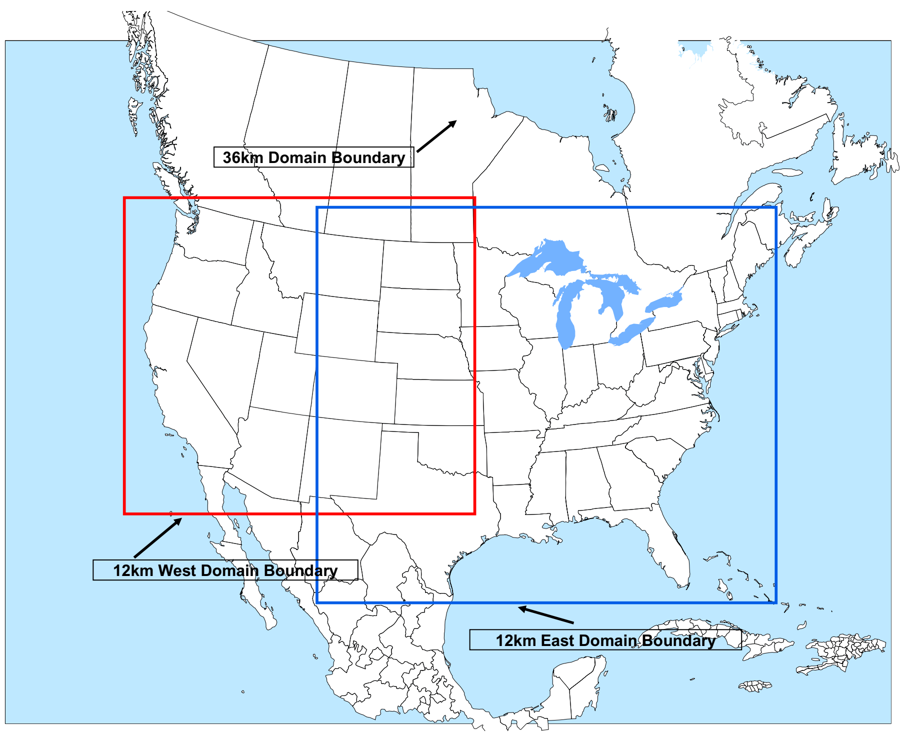
The key inputs to the CMAQ model include emissions from anthropogenic and biogenic sources, meteorological data, and initial and boundary conditions. The CMAQ meteorological input files were derived from simulations of the Pennsylvania State University / National Center for Atmospheric Research Mesoscale Model (Grell, Dudhia, and Stauffer, 1994). This model, commonly referred to as MM5, is a limited-area, nonhydrostatic, terrain-following system that solves for the full set of physical and thermodynamic equations which govern atmospheric motions. The lateral boundary and initial species concentrations were obtained from a three-dimensional global atmospheric chemistry model, the GEOS-CHEM model (Yantosca, 2004). The global GEOS-CHEM model simulates atmospheric chemical and physical processes driven by assimilated meteorological observations from the NASA's Goddard Earth Observing System (GEOS).

EPA performed an extensive evaluation of the 2001-based CMAQ modeling platform as part of the analyses for CAIR and the PM NAAQS RIA. These evaluations have been updated as part of the Locomotive/Marine Proposed Rule to focus on model performance for ozone from the 12 km CMAQ base year simulations in the East. Details of the model performance methodology are described in the Locomotive/Marine Rule Air Quality

Modeling Technical Support Document. For the months of June, July, and August 2001, which were used as the basis for the Ozone NAAQS modeling, the 8-hour daily maximum modeled concentrations underestimate the corresponding observed values by 10 to 15 percent in the East and West. As in the evaluation for previous model applications, the "acceptability" of model performance for the ozone RIA modeling was judged by comparing the results to those found in recent regional ozone model applications for other EPA and non-EPA studies. Overall, the performance for the CMAQ application is generally within the range of these other applications.

Figure 2-1 shows the modeling domains that were used as a part of this analysis. The geographic specifications for these domains are provided in Table 2-1. All three modeling domains contain 14 vertical layers with a top at about 16,200 meters, or 100 mb. Two domains with 12 km horizontal resolution were used for episodic ozone modeling. These domains are labeled as the Eastern and Western 12 km domains in Figure 2-1. Also shown in this figure is the 36 km domain which was used for modeling $PM_{2.5}$ concentrations. For this analysis, predictions from the Eastern domain were used to provide data for all areas east of 100 degrees longitude. Model predictions from the Western domain we used for all areas west of this longitude.

Figure 2.1. Map of the CMAQ Modeling Domains Used for Ozone NAAQS RIA



The selection of 12 km grid resolution for ozone modeling and 36 km resolution for $PM_{2.5}$ modeling is consistent with recommendations on grid resolution for regional analyses in EPA's air quality modeling guidance for ozone and PM. Specifically, the guidance recommends modeling at 12 km or finer resolution, but not greater than 36 km resolution for regional scale modeling. The recommendations in the guidance are based largely on analyses of model performance and model response at various grid resolutions which indicate that results are generally similar at these grid resolutions for secondarily formed pollutants like ozone, nitrate, and sulfate which are components of $PM_{2.5}$. Another factor weighed in the selection of grid resolution is the computation requirement for modeling at 12 km versus 36 km. Specifically, national modeling at 12 km resolution requires roughly 10 times more computer time compared to modeling at 36 km. We were able to minimize the computer burden of modeling at 12 km for ozone because we limited the duration of the ozone model simulations to just the summer months when ozone concentrations are typically at their peak. For $PM_{2.5}$, however, it is useful to model a full year in order to determine annual average $PM_{2.5}$ concentrations in a manner consistent with the annual PM NAAQS. In view of the computer requirements for modeling at 12 km, it would not have been possible to model a full year at 12 km resolution for the Eastern and Western domains as part of the analysis for this proposal RIA.

Table 2.1. Geographic Specifications of Modeling Domains.

36 km Domain (148 x 112 Grid Cells)			12 km Eastern Domain (279 x 240 Grid Cells)			12 km Western Domain (213 x 192 Grid Cells)		
	Lon	lat		lon	lat		lon	lat
SW	-121.77	18.17	SW	-106.79	24.99	SW	-121.65	28.29
NE	-58.54	52.41	NE	-65.32	47.63	NE	-94.94	51.91

2.4 References

Amar, P., R. Bornstein, H. Feldman, H. Jeffries, D. Steyn, R. Yamartino, and Y. Zhang. 2004. Final Report Summary: December 2003 Peer Review of the CMAQ Model. pp. 7.

Byun, D.W., and K.L. Schere. 2006. "Review of the Governing Equations, Computational Algorithms, and Other Components of the Models-3 Community Multiscale Air Quality (CMAQ) Modeling System." *J. Applied Mechanics Reviews* 59(2):51-77.

Dennis, R.L., D.W. Byun, J.H. Novak, K.J. Galluppi, C.J. Coats, and M.A. Vouk. 1996. "The next generation of integrated air quality modeling: EPA's Models-3." *Atmospheric Environment* 30:1925-1938.

Grell, G., J. Dudhia, and D. Stauffer, 1994: A Description of the Fifth-Generation Penn State/NCAR Mesoscale Model (MM5), *NCAR/TN-398+STR*., 138 pp, National Center for Atmospheric Research, Boulder CO.

U.S. Environmental Protection Agency (EPA). 1999. "Science Algorithms of EPA Models-3 Community Multiscale Air Quality." (CMAQ Modeling System D.W. Byun and J.K.S. Ching, Eds. EPA/600/R-99/030, Office of Research and Development).

U.S. Environmental Protection Agency (EPA). March 2005. CMAQ Model Evaluation Report, Office of Air Quality Planning and Standard, Research Triangle Park, NC. (Docket No. OAR-2005-0053-2149).

U.S. Environmental Protection Agency (EPA). 2006 .Air Quality Criteria for Ozone and Related Photochemical Oxidants (Final). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/004aF-cF,

U.S Environmental Protection Agency (EPA). 2007. Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information. OAQPS Staff Paper. North Carolina. EPA-452/R-07-003

U.S. Environmental Protection Agency (EPA). 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze." EPA-454/B-07-002, http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf

U.S. Environmental Protection agency (EPA). "Technical Support Document for the Proposed Locomotive/Marine Rule: Ozone Modeling." EPA-454/R-07-004.

Yantosca, B. 2004. GEOS-CHEMv7-01-02 User's Guide, Atmospheric Chemistry Modeling Group, Harvard University, Cambridge, MA, October 15, 2004.

Chapter 3: Modeled Control Strategy: Design and Analytical Results

Synopsis

In order to estimate the costs and benefits of alternate ozone standards, EPA has analyzed one possible hypothetical scenario to illustrate the control strategies that areas across the country might employ to attain an alternative more stringent primary standard of 0.070 ppm. Specifically, EPA has modeled the impact that additional emissions controls across numerous sectors would have on predicted ambient ozone concentrations, incremental to meeting the current standard (baseline). Thus, the modeled analysis for a revised standard focuses specifically on incremental improvements beyond the current standard, and uses control options that might be available to states for application by 2020. The hypothetical scenario presented in this RIA is one illustrative option for achieving emissions reductions to move towards a national attainment of a tighter standard. It is not a recommendation for how a tighter ozone standard should be implemented, and states will make all final decisions regarding implementation strategies once a final NAAQS has been set.

In order to model a hypothetical control strategy to achieve national attainment of 0.070 ppm incremental to attainment of the current standard, EPA approached the analysis in stages. First, EPA identified controls to be included in the baseline (current state and federal programs plus controls to attain the current ozone and PM standards). Then, EPA applied additional known controls within geographic areas designed to bring areas predicted to exceed 0.070 ppm in 2020 into attainment. This chapter presents the hypothetical control strategy, the geographic areas where controls were applied, and the results of the modeling which predicted ozone concentrations in 2020 after application of the strategy. The strategy to attain a 0.070 ppm level was the only strategy modeled by EPA. EPA did not expect the modeled control strategy to result in attainment at 0.070 ppm everywhere, so the control will result in only partial attainment. Chapter 4 will explain how EPA used the results of the modeled control strategy for 0.070 ppm to estimate total tons of emissions reductions needed to achieve ozone concentrations for the bounds of the range of the proposed more stringent standard (0.075 and 0.070 ppm, and the more stringent option analyzed of 0.065 ppm). Chapters 5 and 6 present the estimated costs and benefits of the modeled costs and benefits for partial attainment.

Because EPA's baseline indicated that some areas were not likely to be in attainment with the current standard by 2020 (0.08 ppm, effectively 0.084 ppm based on current rounding conventions) – (Fig 3.4) EPA expected that known controls would not be enough to bring those areas, and likely others, into attainment with 0.070 ppm in 2020. Modeling results showed that to be the case (see Fig 3.13).

Because it was impossible to meet either the current or any tighter ozone standard nationwide using only known controls, EPA conducted a second step in the analysis, and estimated the number of further tons of emission reductions needed to attain 0.070 ppm (presented in Chapter 4). It is uncertain what controls States would put in place to attain a tighter standard, since additional control measures are not currently recognized as being commercially available. However, existing emissions inventories for the areas that were predicted to be in non-attainment after application of all known controls, do indicate that substantial amounts of ozone precursor emissions (i.e. tons of NOx or VOC) are available for control, pending future technology. Chapter 4 describes the methodology EPA used to estimate the amount of tons available for control to reach attainment, and Chapters 5 and 6 present the extrapolation-based costs and benefits of achieving the reductions in ozone necessary to fully attain the standards, except for a few areas in California, which will be more fully explained in Chapter 4.

3.1 Establishing the Baseline

The regulatory impact analysis (RIA) is intended to evaluate the costs and benefits of reaching attainment with potential alternative ozone standards. In order to develop and evaluate a control strategy for attaining a more stringent (0.070 ppm) primary standard, it is important to first estimate ozone levels in 2020 given the current ozone standard and trends (more information is provided in chapter 1). This scenario is known as the baseline. Establishing this baseline allows us to estimate the incremental costs and benefits of attaining any alternative standard.

This focus on the assessment of the incremental costs and benefits of attaining any alternative standard is an important difference from the focus of the risk assessment used in developing the standard. For purposes of the Staff Paper-risk assessment, risks are estimated associated with just meeting recent air quality and upon just meeting the current and alternative standards as well as incremental reductions in risks in going from the current standard to more stringent alternative standards. When considering risk estimates remaining upon attaining a given standard, EPA is only interested in the risks in excess of policy relevant background (PRB). PRB is defined in the ozone Criteria Document and Staff Paper as including (1) O3 in the U.S. from natural sources of emissions in the U.S., Canada, and Mexico, and (2) O3 in the U.S. from the transport of O3 or the transport of emissions from both natural and man-made sources, from outside of the U.S. and its neighboring countries (Staff Paper, p.2-54). Emissions of ozone precursors from natural sources (e.g. isoprenes emitted from trees) and from sources outside of the U.S. are uncertain, as are the specific impacts those emissions will have on ozone concentrations in areas exceeding alternative standards. Our models use available information on these emissions in generating future projections of baseline ozone concentrations, and our modeled reductions in U.S. emissions of NOx and VOC are based on these baseline levels that include the contribution of natural and non-U.S. emissions. To the extent that these emissions contribute a greater (lesser) proportion of ozone on high ozone days, more (less) reductions in emissions from U.S. sources might be required to reduce ozone levels below the analyzed alternative standards.

In contrast, the RIA only examines the incremental reduction, not the remaining risk, which results from changes in U.S. anthropogenic emissions. The air quality modeling used to establish the baseline for the RIA explicitly includes contributions from natural and anthropogenic emissions in Canada, Mexico, and other countries abroad, as well as the contributions to ozone levels from natural sources in the U.S. Since the RIA does not attempt to estimate the risk remaining upon meeting a given standard, and the alternative standards are clearly above the Staff Paper estimates of PRB, we do not consider PRB a component of the RIA costs and benefits estimates.

In developing the baseline it was important to recognize that there are several areas that are not required to meet the current standard by 2020. The Clean Air Act allows areas with more significant air quality problems to take additional time to reach the current standard. Two areas in Southern California, are not planning to meet the current standard by 2020, so the estimated emission reductions for these areas are based on reaching an estimated progress point in 2020 (their "glidepath" targets). We provide an estimate of the additional amount of tons these areas would need to reduce to meet the standard and the additional costs and benefits of reducing those tons in those few areas.

The baseline includes controls which EPA estimates need to be included to attain the current standard (0.08 ppm, effectively 0.084 ppm based on current rounding conventions) for 2020. Two steps were used to develop the baseline. First, the reductions expected in national ozone concentrations from national rules in effect or proposed today were considered. Because these alone were not predicted to bring all areas into attainment with the tighter standard, EPA used a hypothetical control strategy to apply additional known controls. Additional control measures were used in four sectors to establish the baseline[1]: Non-Electricity Generating Unit Point Sources (Non-EGUs), Non-Point Area Sources (Area), Onroad Mobile Sources and Nonroad Mobile Sources. A fifth sector was used in the subsequent control strategy for a tighter alternative standard: Electricity Generating Unit Point Sources (EGUs). Each of these sectors is defined below for clarity.

- NonEGU point sources are stationary sources that emit at least one criteria pollutant with emissions of 100 tons per year or higher. NonEGU point sources are found across a wide variety of industries, such as chemical manufacturing, cement manufacturing, petroleum refineries, and iron and steel mills.

- Non-Point Area Sources (Area) are stationary sources that are too numerous or whose emissions are too small to be individually included in a stationary source emissions inventory. Area sources are the activities where aggregated source emissions information is maintained for the entire source category instead of each point source, and are reported at the county level.

- Onroad Mobile Sources are mobile sources that travel on roadways. These sources include automobiles, buses, trucks, and motorcycles traveling on roads and highways.

[1] In establishing the baseline, EPA selected a set of cost-effective controls to simulate attainment of the current ozone and $PM_{2.5}$ standards. These control sets are hypothetical as states will ultimately determine controls as part of the SIP process.

- Nonroad Mobile Sources are any portable engine that travels by other means than roadways. These sources include railroad locomotives; marine vessels; aircraft; off-road motorcycles; snowmobiles; pleasure craft; and farm, construction, industrial and lawn/garden equipment.

- Electricity Generating Unit Point Sources (EGUs) are stationary sources producing electricity, such as fossil-fuel-fired boilers and combustion turbines.

3.1.1 National Rules

To reduce ambient ozone concentrations, it was necessary to control emissions of ozone precursors, NOx and VOC. Establishing the baseline required identifying the national rules which were expected to contribute to reductions in NOx and VOCs between now and 2020. Some of these include the Clean Air Interstate Rule (CAIR), Clean Air Mercury Rule (CAMR), and the Clean Air Visibility Rule (CAVR); and the 2007 proposed Locomotive/Marine rule. A complete listing of these rules is provided in table 3.1. In addition, EPA included the control set developed for the hypothetical national attainment strategy presented in the PM NAAQS RIA in the baseline for this ozone analysis.

At the time that EPA established the regulatory baseline -- to capture how existing rules affect the emissions inventory over time even in the absence of this new NAAQS standard -- EPA focused on information that was readily available in the emission inventories and other data sources. Typically, a RIA analysis baseline includes only reductions from final rules and not reductions from regulatory proposals or other actions being contemplated. However, for this analysis, EPA did not include the recently promulgated Renewable Fuel Standard (RFS), due to a lack of readily available quantitative information. In addition, EPA did include reductions from some upcoming rules in an attempt to better characterize reductions that we anticipate to occur in the future (e.g. Ocean Going Vessel Rule). For the analysis to support the Final Rule, EPA will be using an updated emission inventory and improved models and sets of control information. The starting point for the analysis will include only and all promulgated rules, including the Renewable Fuel Standard rule. Any potential reductions resulting from proposed or upcoming rules will be discussed separately.

The RFS RIA provides an analysis of the energy, emissions, air quality, and economic impacts of expanding the use of renewable fuels in comparison to a reference case of 4 billion gallons of renewable fuel use that represents 2004 conditions projected out to 2012. Depending on the anticipated volume of renewable fuel usage in 2012, EPA estimates that this transition to renewable fuels will reduce petroleum consumption between 2.0 and 3.9 billion gallons or roughly 0.8 to 1.6 percent of the petroleum that would otherwise be used by the transportation sector[2].

---

[2] http;//www.epa.gov/otaq/renewablefuels

With regard to emissions impacts, carbon monoxide emissions from gasoline-powered vehicles and equipment will be reduced between 0.9 and 2.5 percent. Emissions of benzene (a mobile source air toxic) will be reduced between 1.8 and 4.0 percent. Further, the use of renewable fuel will reduce carbon dioxide equivalent greenhouse gas emissions between 8.0 and 13.1 million metric tons, about 0.4 to 0.6 percent of the anticipated greenhouse gas emissions from the transportation sector in the United States in 2012.

At the same time, other vehicle emissions may increase as a result of greater renewable fuel use. Nationwide, EPA estimates an increase in total emissions of volatile organic compounds and nitrogen oxides (VOC + NOx) between 41,000 and 83,000 tons. However, the effects will vary significantly by region. Areas that already are using ethanol will experience little or no change in emissions or air quality. In some contexts and situations, however, the use of renewable fuels may impact compliance with a reduced ozone NAAQS standard.

In addition to changes in NOx and VOC emissions resulting from increased use of ethanol in gasoline, fugitive ethanol emissions may also increase peroxacetyl nitrate (PAN) concentrations. Fugitive emissions of ethanol in a photochemical smog polluted environment will generate acetaldehyde, a precursor to PAN. PAN, in turn, can lead to increase ozone levels. As part of the analysis to support the final rule, EPA will examine whether this increase in PAN will affect baseline ozone concentrations in some areas and how this effect can be quantified and incorporated into the baseline.

For the final analysis, EPA will be using an updated emission inventory and improved models and sets of control information. The starting point for the analysis will include all promulgated rules, including the increases in regional VOC and NOx emissions from increased combustion of ethanol.

Table 3.1 National Rules and Control Measures, by Sector, Contributing to the Baseline[3,4]

	Sources of Controls-National	
Sector	NOx	VOC
Non-EGUs	PM 15/35* (west only)	(none used)
Area	PM 15/35* (west only)	(none used)
Onroad Mobile	-Onroad Diesel Particulate Filters and Retirement - Commuter Reduction Strategies -Idling Elimination -Intermodal Transfer from Trucks to Rail	-Onroad Diesel Particulate Filters and Retirement - Commuter Reduction Strategies

[3] References for these rules are provided at the end of this chapter. Controls are explained in Appendix 3.
[4] 0.08 ppm, effectively 0.084 ppm based on current rounding conventions

Nonroad Mobile	-Diesel Marine & Locomotives Rule -Ocean-Going Vessels Rule -Small Spark-Ignition Engine Rule -Nonroad Diesel Particulate Filters & Engine Rebuilds	-Small Spark-Ignition Engine Rule -Nonroad Diesel Particulate Filters & Engine Rebuilds
EGU	-CAIR/CAMR/ CAVR -PM 15/35* (West only)	(none used)

*NOx controls are included as part of the hypothetical control scenario modeled in the 2006 PM NAAQS RIA. These controls included low NOx burners and SNCR for industrial boilers. Further examples can be found in Table 3-5 (page 3-18) of the 2006 PM NAAQS RIA. http://www.epa.gov/ttn/ecas/ria.html

3.1.2 Additional Controls

Additional known controls were also included as needed in the baseline, to simulate attainment with current ozone NAAQS. The applicable controls and their respective sectors are listed in table 3.2 and described below. Details regarding the individual controls are provided in appendix 3. Due to the extensive reductions from EGUs already implemented in CAIR/CAMR/CAVR, no additional EGU controls were included in the baseline. The East was evaluated separately from the West, due to the nature of the controls available in each area and the specific features of the areas needing reductions in ozone, as explained in more detail below.

In the East, controls included in the baseline for Non-EGU and area sources came from a variety of geographic areas and scales. Almost all available controls in Chicago, Houston, and the Northeast Corridor were included in the baseline because these areas contain counties that were projected to be nonattainment of the current ozone NAAQS in 2020 (based on air quality modeling performed as part of the PM NAAQS RIA).

NOx controls from Non-EGU/Area sources were included in two ways in the East. First, controls were included in 22 counties with monitors that were projected to violate the current standard in 2020. Second, controls were included in all surrounding counties within the same state that were completely contained within 200 km of the county containing the projected violating monitor. These counties were chosen based upon an examination of previous ozone air quality modeling and emissions inventories as well as existing EPA guidance. VOC controls were applied (for area sources only) in 26 counties where VOC emissions were high (>5,000 tpy), and screening analysis indicated that mean ozone concentrations were predicted to be markedly reduced by local VOC controls (≥ 0.5 ppb) by local VOC controls of 25%. Two additional counties that did not meet these criteria were also included.[5] In the West, Non-EGU and Area Controls were

[5] Porter County, IN, was included, despite being below the emissions threshold, due to its close proximity to Chicago. Harris County, TX, was included because of local

included in the baseline only for California, where they were included state-wide. In California, all controllable tons of NOx and VOC emissions were reduced using known Non-EGU and Area Controls in the baseline. (See Fig 3.1 and Fig 3.2)

Fig. 3.1 Counties Where Controls for Nitrogen Oxides (NOx) Were Included for Non-EGU Point and Area Sources, for the Baseline (Current Standard, 0.08 ppm)

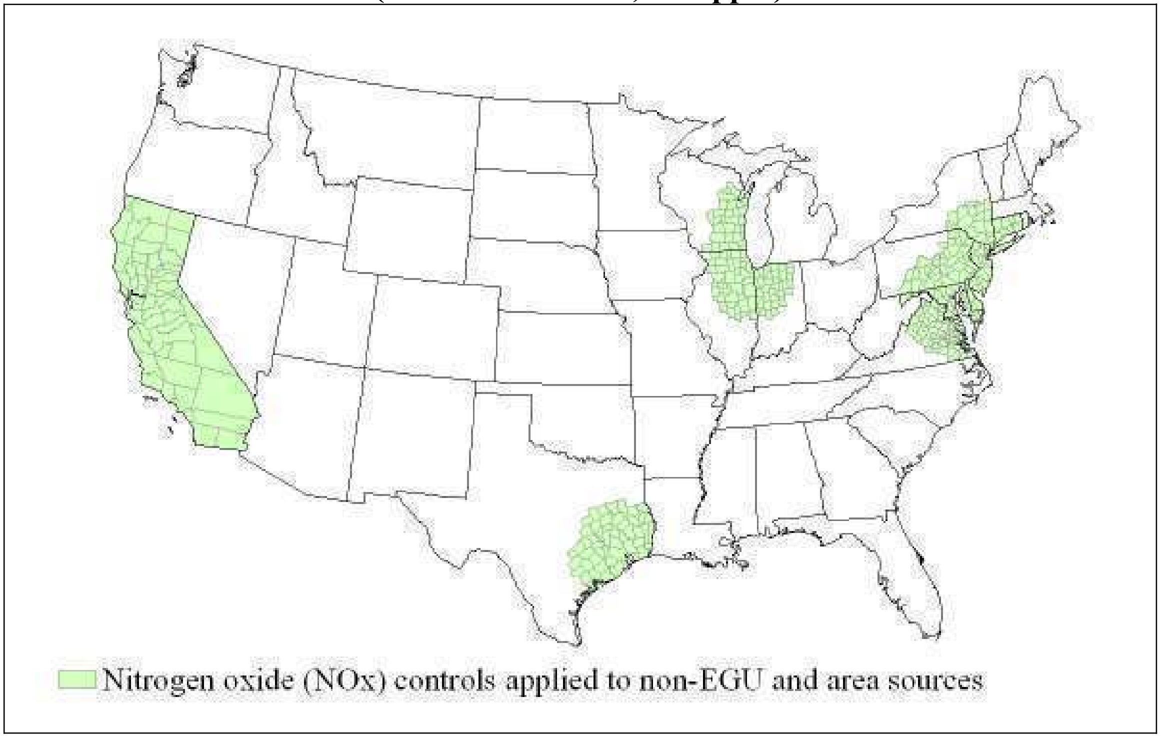
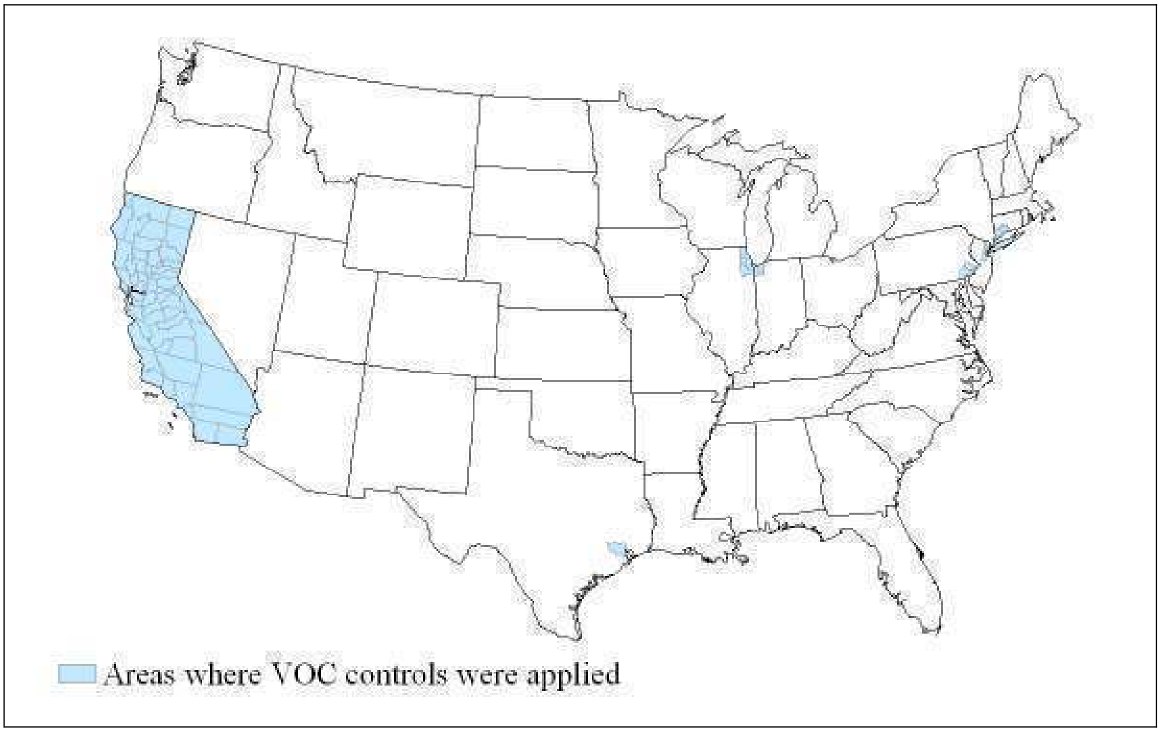


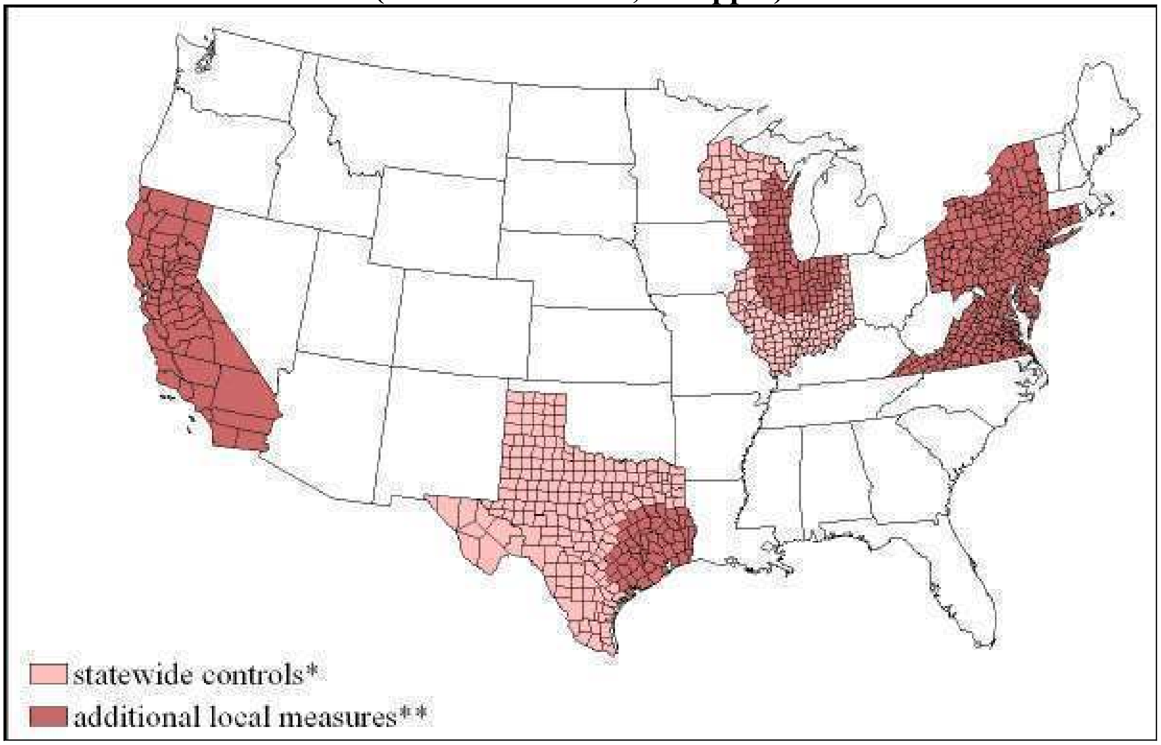
Fig. 3.2 Counties Where Controls for Volatile Organic Chemicals (VOCs) Were Applied to Non-EGU Point and Area Sources in Baseline (Current Standard, 0.08 ppm)

information about the benefits of VOC control, and concerns about the screening tool performance in the 36km region of which Houston is a part.



In the Onroad Mobile sector, local controls were included as necessary in the baseline for both East and West. Counties projected to have a monitor that exceeded the current standard were surrounded by a 200km buffer zone, and controls were included in the counties within this buffer that were within the same state as the exceeding monitor. Where some control measures overlapped for a given county, controls with the lowest costs were included first. This is the only instance in which controls were included in a certain order. For a complete list of the controls and the order in which they were included, see Appendix 3. Both onroad and nonroad diesel retrofits and idling elimination were included statewide in California with an assumed 75% market penetration, and elsewhere in the nation with an assumed 25% market penetration for all states with a county projected to be in nonattainment with the current standard in 2020. EPA determined that 25% would have a significant impact, but was reasonably easy to achieve and was applied for reduction areas outside of California. EPA further determined that for southern California a higher level of reduction was required. 75% was the highest penetration rate that EPA felt could be reasonably accomplished. The remainder of mobile controls were included statewide in Ozone Transport Commission (OTC) states (see section 3.2.2 for more information on OTC states), with the exceptions of Vermont, Maine, New Hampshire, and Massachusetts, which were not projected to have counties in nonattainment with the current standard in 2020. These additional mobile controls were included statewide in California (See Fig. 3.3)

Fig. 3.3 Areas Where NOx and VOC Controls Were Included for Mobile Onroad and Nonroad Sources in Addition to National Mobile Controls in Baseline (Current Standard, 0.08 ppm)



*Onroad retrofits and elimination of long duration idling
**Onroad retrofits, elimination of long duration idling, nonroad retrofits, Commuter Reduction Strategies and Reid Vapor Pressure (RVP)

Table 3.2 Controls by Sector Included in the Baseline Determination for 2020

Sector	*Controls- East*		*Controls- West*	
	NOx	VOC	NOx	VOC
Non-EGUs	-LEC (Low Emission Combustion) -LNB (Low NOx Burner) -LNB + FGR (Flu-Gas Sulfurization) -LNB + SCR (Selective Catalytic Reduction) -Mid-Kiln Firing -NSCR (Non-selective Catalytic Reduction) -OXY-Firing -SCR -SCR + Steam Injection -SCR + Water Injection -SNCR (Selective Non-catalytic Reduction) -SNCR - Urea -SNCR - Urea Based	(none used)	-LNB -Mid-Kiln Firing -NSCR -OXY-Firing -SCR -SCR + Steam Injection -SNCR -SNCR - Urea Based	(none used)
Area	-RACT to 25 tpy (LNB) -Water Heater + LNB Space Heaters	-CARB Long-Term Limits -Catalytic Oxidizer -Equipment and Maintenance -Gas Collection (SCAQMD/ BAAQMD) -Incineration -Incineration >100,000 lbs bread -Low Pressure/Vacuum Relief Valve -OTC Mobile Equipment Repair	-RACT to 25 tpy (LNB) -Switch to Low Sulfur Fuel -Water Heater + LNB Space Heaters	-Add-On Controls -Airtight Degreasing System -Catalytic Oxidizer -Equipment and Maintenance -FIP Rule (VOC content & TE) -Gas Collection (SCAQMD/BAAQMD) -Incineration -Incineration >100,000 lbs bread -Low Pressure/ Vacuum Relief

Table 3.2 Controls by Sector Included in the Baseline Determination for 2020 (continued)

		and Refinishing Rule -OTC Solvent Cleaning Rule -SCAQMD - Low VOC -SCAQMD Limits -SCAQMD Rule 1168 -Switch to Emulsified Asphalts -Use of Low or No VOC Materials		Valve -OTC Solvent Cleaning Rule -Reformulation - FIP Rule -SCAQMD Limits -SCAQMD Rule 1168 -South Coast Phase III -Switch to Emulsified Asphalts -Use of Low or No VOC Materials
Onroad Mobile	-Onroad Selective Catalytic Reduction (SCR) and Diesel Particulate Filters (DPF)[6] -Reduce Gasoline Reid Vapor Pressure (RVP)		-Onroad Selective Catalytic Reduction (SCR) and Diesel Particulate Filters (DPF) [6] -Reduce Gasoline Reid Vapor Pressure (RVP)	
Nonroad Mobile	-Nonroad Selective Catalytic Reduction (SCR) and Diesel Particulate Filters (DPF) [6] -Reduce Gasoline Reid Vapor Pressure (RVP)		-Nonroad Selective Catalytic Reduction (SCR) and Diesel Particulate Filters (DPF) [6] -Reduce Gasoline Reid Vapor Pressure (RVP)	
	-Aircraft NOx Engine Standard -Ocean-Going Vessels – reductions for vessels burning residual fuels[7]	(none used for VOC only)	-Aircraft NOx Engine Standard	(none used for VOC only)
EGU	(none used)	(none used)	(none used)	(none used)

[6] Onroad and Nonroad DPF were applied in the baseline, and SCR retrofit technologies were chosen because of the need to reduce NOx emissions..

[7] Reductions from Ocean-Going Vessels burning residual fuels were applied in the Baseline analysis for the east, but inadvertently omitted for the west. The omission was not identified in time to include it in the initial Baseline analysis for the west.

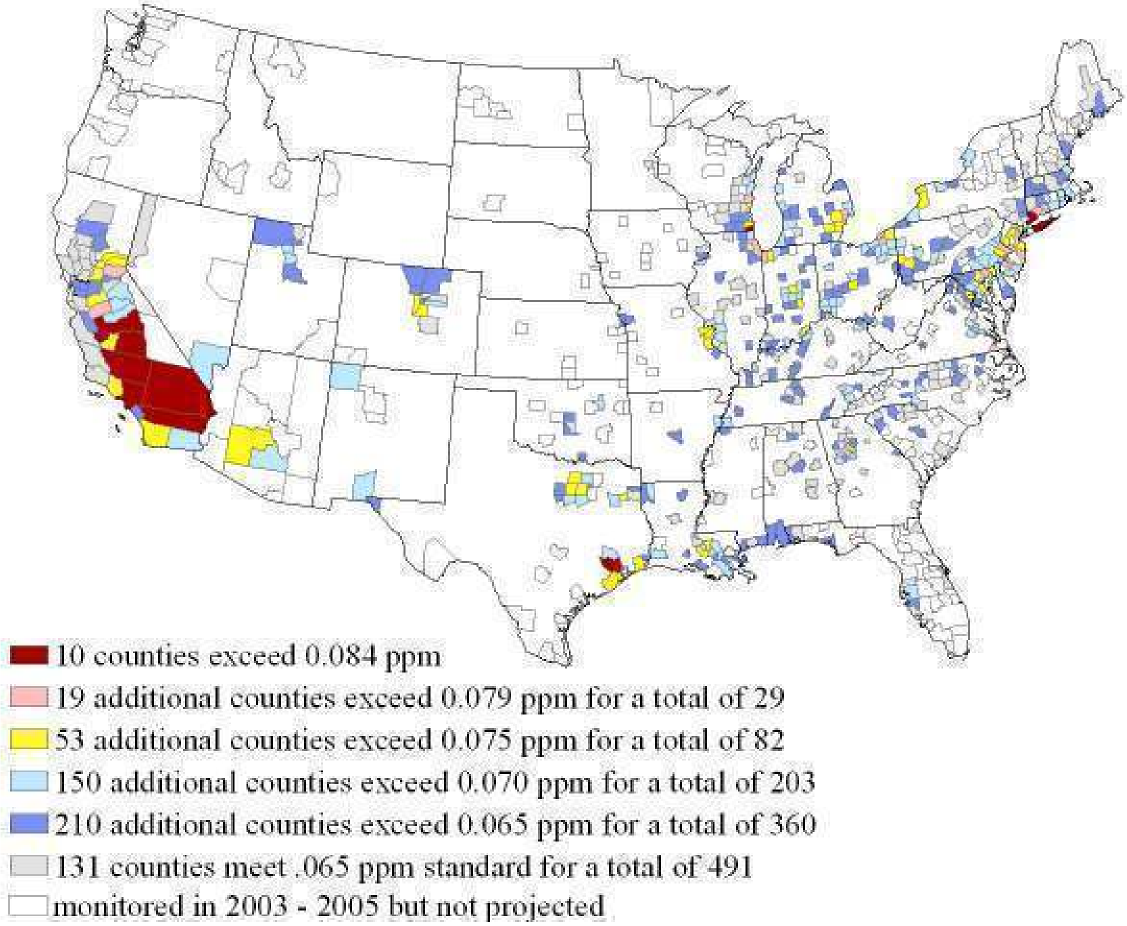
3.1.3 Ozone Levels for Baseline

Establishing the baseline required design values (predicted concentrations) of ozone across the country. Because the intention of this evaluation was to achieve attainment of the current ozone standard, controls were included to reduce ambient ozone concentrations to 0.08 ppm (effectively 0.084 ppm based on current rounding conventions). A map of the country is presented in figure 3.4, which shows predicted concentrations for the 491 counties with ozone monitors that were included in the baseline. Modeling projections were developed for all appropriate counties according to procedures outline in EPA modeling guidance[8].

The baseline shows that 10 counties would not meet the current ozone standard in 2020, even after inclusion of all known controls. After including known controls as described above, the analysis predicted that the remaining 481 counties would attain the current standard by 2020. The baseline forms the foundation for the cost-benefit analysis conducted in this RIA, where EPA compares more stringent primary ozone standard alternatives incrementally to national attainment of the current standard.

[8] Available online at: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf

Fig. 3.4 Baseline Annual Ozone Air Quality in 2020



[a] Modeled emissions reflect the expected reductions from federal programs including the Clean Air Interstate Rule, the Clean Air Mercury Rule, the Clean Air Visibility Rule, the Clean Air Nonroad Diesel Rule, the Light-Duty Vehicle Tier 2 Rule, the Heavy Duty Diesel Rule, proposed rules for Locomotive and Marine Vessels and for Small Spark-Ignition Engines, and state and local level mobile and stationary source controls identified for additional reductions in emissions for the purpose of attaining the current PM 2.5 and Ozone standards.

[b] Controls applied are illustrative. States may choose to apply different control strategies for implementation.

[c] The current standard of 0.08 ppm is effectively expressed as 0.084 ppm when rounding conventions are applied.

[d] Modeled design values in ppm are only interpreted up to 3 decimal places.

[e] Map shows results from a total of 491 counties with projected design values. Consistent with current modeling guidance, EPA did not project 2020 concentrations for counties where 2001 base year concentrations were less than recommended criterion. Such projections may not represent expected future levels.

3.2 Developing the Control Strategy Analysis

After developing the baseline, EPA developed a hypothetical control strategy to illustrate one possible national control strategy that could be adopted to reach an alternative primary standard of 0.070 ppm by 2020. The stricter standard alternative of 0.070 ppm was chosen as being representative of the set of alternatives being considered by EPA in its notice of proposed rulemaking on the ozone NAAQS. Controls for five sectors were used in developing the control analysis, as discussed previously: non-EGU stationary, Area, onroad mobile and nonroad mobile, along with EGU controls only in the East (EGU controls for the West were included in the hypothetical PM NAAQS 15/35 national control strategy, and were therefore already in the ozone baseline). Reductions in both NOx and VOC ozone precursors were needed in all four remaining sectors to meet a tighter standard.

As depicted in the flow diagram in figure 1.1, the control strategy modeled in this RIA first applied and exhausted nearly all known controls (see section 3.2.1 an explanation of which controls were excluded from this analysis). After controls were identified, the expected emissions reductions were input to an air quality model that projected design values for ozone in 2020. Following the control strategy, there were some areas projected not to attain 0.070 ppm in 2020 using all known control measures. EPA was then required to extrapolate the additional emission reductions required to reach attainment. The methodology used to develop those estimates and those calculations are presented in Chapter 4.

As in the analysis for the baseline, parts of the hypothetical national control strategy for 0.070 ppm focused on the Eastern (East) United States (U.S.) separately from the Western U.S. (West). However, this RIA presents estimates of the costs and benefits of attaining alternative ozone standards on a national basis. Table 3.3 presents the specific control technologies that were applied within each sector for the 0.070 ppm control strategy.

Table 3.3: Controls for Emissions Reductions, by Sector, for the 0.070 ppm Control Strategy (Incremental to Baseline)

Sector	*Controls- East*		*Controls- West*	
	NOx	VOC	NOx	VOC
Non-EGUs	-Biosolid Injection Technology -LEC (Low Emission Combustion) -LNB -LNB + FGR -LNB + SCR -LNB+SCR -Mid-Kiln Firing -NGR -NSCR -OXY-Firing -SCR -SCR + Steam Injection -SCR + Water Injection -SNCR -SNCR - Urea -SNCR – Urea Based	-LDAR (Leak Detection and Repair) -Enhanced LDAR -Flares Gas Recovery Monitoring Program -Permanent Total Enclosure (PTE) -Wastewater Drain Control	-Biosolid Injection Technology -LNB -LNB + FGR -LNB + SCR -Mid-Kiln Firing -NSCR -OXY-Firing -SCR -SCR + Steam Injection -SCR + Water Injection -SNCR -SNCR - Urea Based	(none used)
Area	-RACT to 25 tpy (LNB) -Water Heater + LNB Space Heaters	-CARB Long-Term Limits -Catalytic Oxidizer -Equipment and Maintenance -Gas Collection (SCAQMD/BAAQMD) -Incineration -Incineration >100,000 lbs bread -Low Pressure/Vacuum Relief Valve -OTC Mobile Equipment Repair and Refinishing Rule -OTC Portable Gas Container Rule	-RACT to 25 tpy (LNB) -Switch to Low Sulfur Fuel -Water Heater + LNB Space Heaters	(none used)

Table 3.3 (Continued): Controls for Emissions Reductions, by Sector, for the 0.070 ppm Control Strategy (Incremental to Baseline)

		-OTC Solvent Cleaning Rule -SCAQMD - Low VOC -SCAQMD Limits -SCAQMD Rule 1168 -Switch to Emulsified Asphalts -Use of Low or No VOC Materials		
Onroad Mobile[9]	-Increased Penetration of Onroad SCR and DPF from 25% to 75% -Continuous Inspection and Maintenance (OBD)		-Continuous Inspection and Maintenance (OBD)	
Nonroad Mobile[9]	-Increased Penetration of Nonroad SCR and DPF from 25% to 75%		-Ocean-Going Vessels – reductions for vessels burning residual fuels[10]	
EGU	-Lower nested caps in OTC and MWRPO states -Application of SCR and SNCR in coal fired units in NA counties outside of OTC and MWRPO	(none used)	(none used)	(none used)

[9] For Onroad and Nonroad Mobile Source control measures, all measures applied for the Baseline analysis were applied to additional geographic areas in the .070 analysis.

[10] Reductions from Ocean-Going Vessels burning diesel fuel were applied in the Base Case analysis. However, we inadvertently omitted the associated reductions that would occur in vessels burning residual fuels. These additional reductions were applied in the Baseline analysis for the east and in the .070 analyses for the east and west. The omission was not identified in time to include it in the initial Baseline analysis for the west, but was included in the Baseline national PM co-benefits analysis for the east and west.

3.2.1 Controls Applied for a 0.070 ppm Standard: Non-EGU and Area Sectors

Non-EGU and Area control measures were identified using AirControlNET 4.1.[11,12] To reduce NOx and VOC levels, all known control measures, within a given cost-cap, were applied, allowing for the largest emission reduction per source over the widest geographic area. The cost-caps were pollutant specific and applicable only in the East portion of the analysis. For reductions of NOx emissions the cap was $16,000/ton, based upon the approximate benefit per ton of reductions. In some instances, controls were too costly due to the large capital component of installing these controls. A similar process was followed for reductions from VOCs. The marginal cost curve was analyzed, and there was a clear break in the curve at approximately $6,000/ton. Because all available controls up to the cost cap were used in counties needing emission reductions, there was no ordering of which controls were applied first. VOCs were cut at this level because approximately 75% of reductions were coming from controls below that number. Additionally, the relative effectiveness of VOC controls is not high. See Chapter 5 for more information on cost caps

Additionally, controls were added that appeared in preliminary State Implementation Plans (SIPs) from States and Regional Planning Bodies. Supplemental controls that estimated near-term source controls based on similar technology were included in the Non-EGU and Area Source sectors as well. Supplemental controls are described in further detail in Appendix 3.

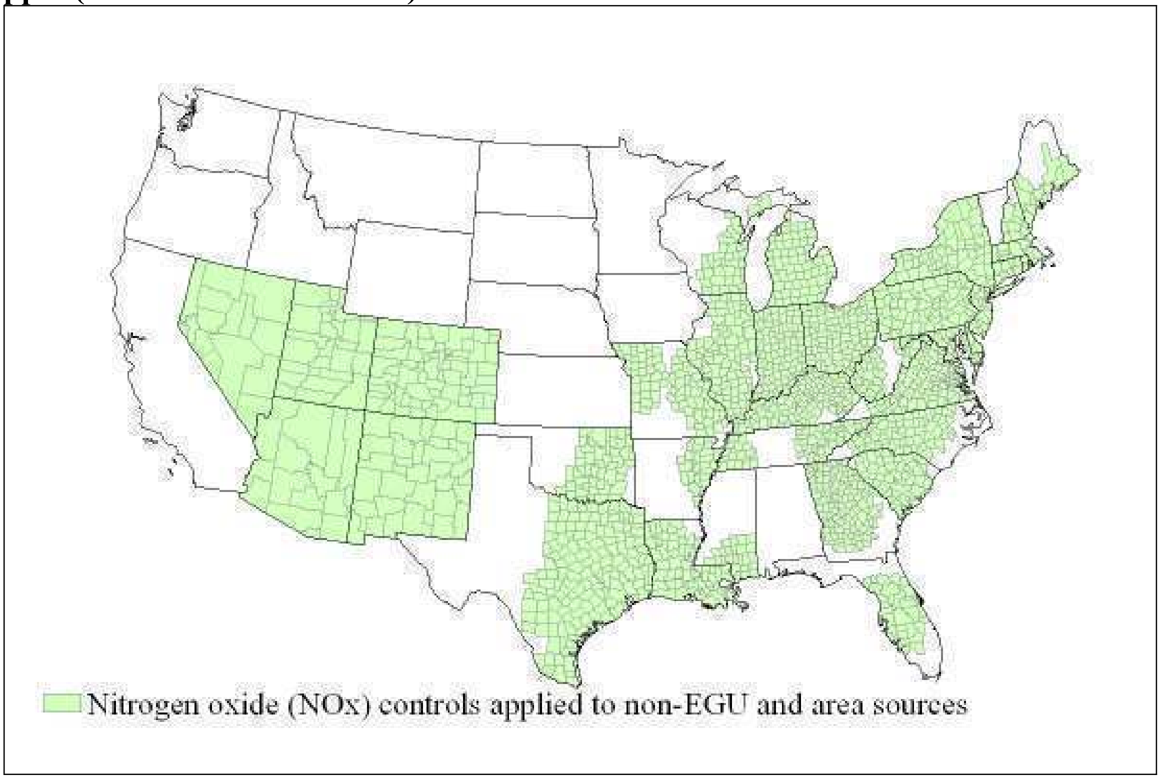
NOx controls were applied in the East for the 233 counties that were projected to have concentrations of greater than 0.070 ppm in the 2020 baseline. Additional controls were applied in surrounding counties within 200 km of the county projected to be out of attainment (at 0.070 ppm), but not crossing state boundaries. In the West, NOx controls were applied statewide, rather than only to counties with violating monitors and their immediate neighbors (See Fig. 3.5). This was due to modeling methodology, in which the 200 km buffer was only validated for the East.

---

[11] See http://www.epa.gov/ttnecas1/AirControlNET.htm for a description of how AirControlNET operates and what data is included in this tool.

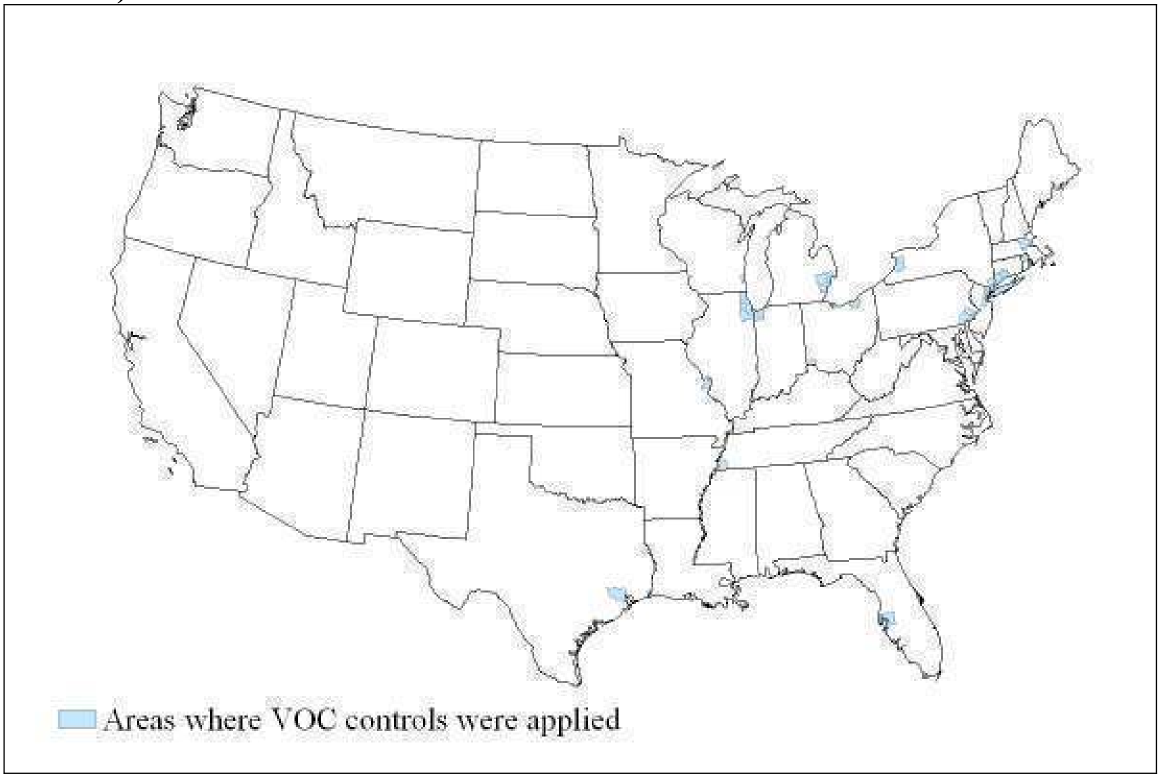
[12] While AirControlNET has not undergone a formal peer review, this software tool has undergone substantial review within EPA's OAR and OAQPS, and by technical staff in EPA's Regional offices. Much of the control measure data has been included in a control measure database that will be distributed to EPA Regional offices for use by States as they prepare their ozone, regional haze, and PM2.5 SIPs over the next 10 months. In addition, the control measure data within AirControlNET has been used by Regional Planning Organizations (RPOs) such as the Lake Michigan Air District Commission (LADCO), the Ozone Transport Commission (OTC), and the Visibility Improvement State and Tribal Assocation of the Southeast (VISTAS) as part of their technical analyses associated with SIP development over the last 3 years. All of their technical reports are available on their web sites.

Fig 3.5 Counties Where Controls for Nitrogen Oxides (NOx) Were Applied to Non-EGU Point and Areas Sources for RIA Control Strategy Designed to Meet 0.070 ppm (Incremental to Baseline)



In the East, VOC controls were applied (for area sources only) in 47 counties where the following criteria were met (including the 26 counties which included VOC controls in their baselines): VOC emissions within the county or an adjacent county were high (e.g. >5000 tons per year of area source emissions), and screening analyses indicated that ozone design values would be markedly reduced (> 0.5 ppb) by local VOC controls of 25%, and the county design value was projected to be ≥ 0.070 ppm in the 2020 baseline (See Fig 3.6). No VOC controls were used in the West.

Fig. 3.6 Counties Where VOC Controls Were Applied to Non-EGU Point and Areas Sources for the Control Strategy Designed to Meet 0.070 ppm (Incremental to Baseline)



3.2.2 Controls Applied for a 0.070 ppm Standard: EGU Sector

For the East only, a control strategy was applied for the EGU sector (Fig. 3.7) (EGU controls for the West were already included in the ozone baseline since they were applied for the hypothetical national control strategy in the PM NAAQS RIA.) Annual and ozone season CAIR caps remained unchanged, but coal-fired units were targeted for this shifted strategy within those caps. This strategy was appropriate to consider because transport of NOx pollution is more of a concern in the East, and NOx from EGUs still accounts for a significant portion of emissions in this region. California, while in need of reductions as well, was not included in this strategy because all known controls (including EGU controls) had already been applied in the baseline. The development of an EGU-component to this control strategy was based exclusively on NOx emissions during the ozone season, although the hypothetical controls applied would operate year-round. The EGU sector used the Integrated Planning Model (IPM) to evaluate the reductions that are predicted from a specific control strategy. Details of this tool and subsequent analysis can be found in appendix 3.4.

Reductions in the EGU sector are influenced significantly by the 2003 Clean Air Interstate Rule (CAIR) (see appendix 3.4 for more details on CAIR). CAIR will bring significant emission reductions in NOx, and a result, ambient ozone concentrations in the eastern U.S. by 2020[13]. A map of the CAIR region is presented in appendix 3.4. Emissions and air quality impacts of CAIR are documented in detail in the Regulatory Impact Analysis of the Final Clean Air Interstate Rule[14]

To address nonattainment in the CAIR region (especially the Midwest, Mid-Atlantic, and Northeast), lower nested caps (a limit lower than the current CAIR cap) were applied in these areas for NOx, while holding the CAIR cap unchanged for the entire region. This provides an opportunity to reduce emissions in a cost effective manner in targeted regions. Two geographic regions were targeted for emissions reductions: the Midwest Regional Planning Organization (MWRPO) consisting WI, IL, IN, MI, and OH; and the Ozone Transport Commission (OTC), consisting of DC, MD, PA, DE, NJ, CT, NY, RI, MA, VT, NH, and ME. These areas were chosen because the MWRPO and OTC states are currently investigating ways of reducing EGU emissions further in their states and because most of the potential ozone nonattainment areas are found within these two regions. Considering transport, as well as the local effects, reducing emissions in these areas expected to help bringing the Lake Michigan and Northeast corridor nonattainment areas into attainment.

Lower nested caps were applied in the MWRPO and OTC states, for the ozone season only. The caps that were applied lead to reductions that could be obtained by installing post-combustion controls to all of the coal-fired units that were not projected to have previously installed post-combustion controls in the base-case. Following this, 75% of the reduction that could be obtained from these units was subtracted from the sum of State level ozone control season NOx caps in CAIR[15]. The CAIR cap for the entire region was kept unchanged.

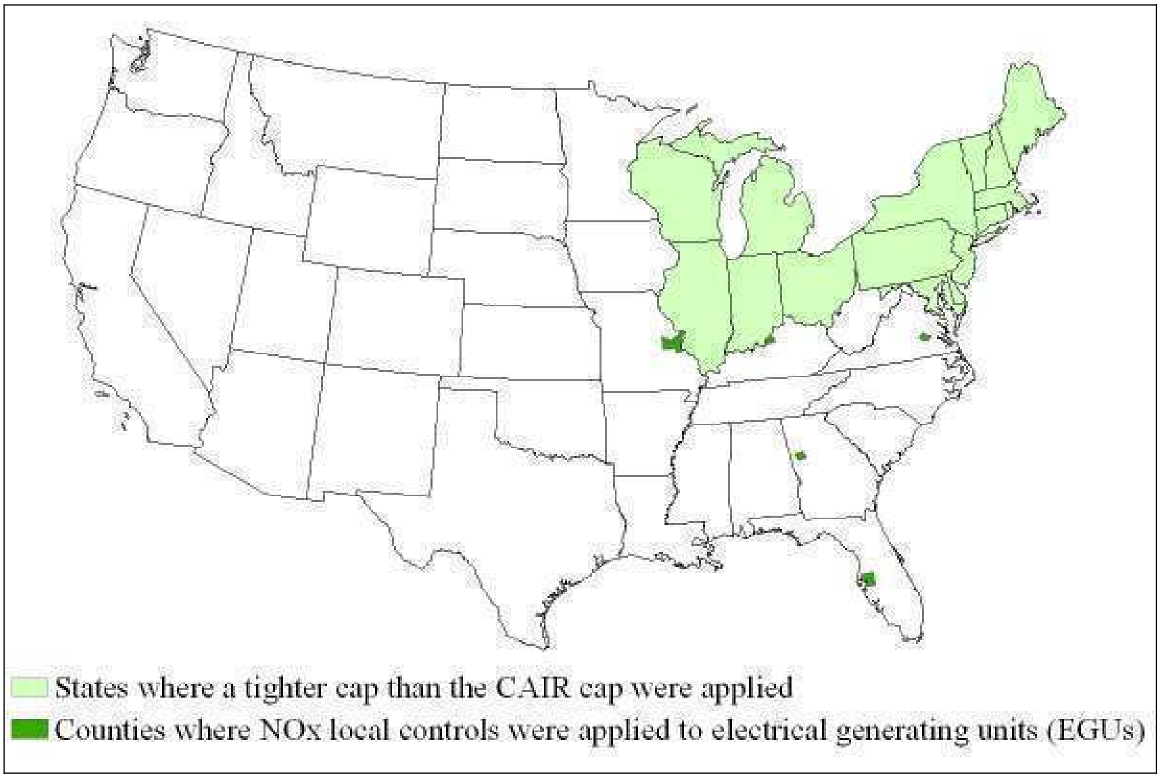
In order to address non-attainment in the CAIR region outside of the MWRPO and OTC, a "command and control" type strategy for coal-fired units has been designed. Annual and ozone season CAIR caps remained unchanged, and coal-fired units were targeted for this reduction. Preliminary analysis showed that most of the needed NOx reductions in the EGU sector can be achieved through application of post-combustion controls (e.g. Selective Catalytic Reductions (SCR) and Selective Non-Catalytic Reductions (SNCR)) on coal units that are projected to remain without controls under the CAIR/CAMR/CAVR cap-and-trade scheme.

[13] See http://www.epa.gov/airmarkets/progress/progress-reports.html for more information

[14] See http://www.epa.gov/CAIR/technical.html

[15] Detailed analysis showed that 75% reduction provides the most cost-effective way of reducing emissions at the targeted non-attainment areas, considering transport, with the most air quality impacts.

Fig 3.7 States Where Nitrogen Oxide (NOx) Controls Were Applied to Electrical Generating Units (EGUs) for the Control Strategy Designed to Meet 0.070 ppm (Incremental to Baseline)



3.2.3 Controls Applied for a 0.070 ppm Standard: Onroad and Nonroad Mobile Sectors

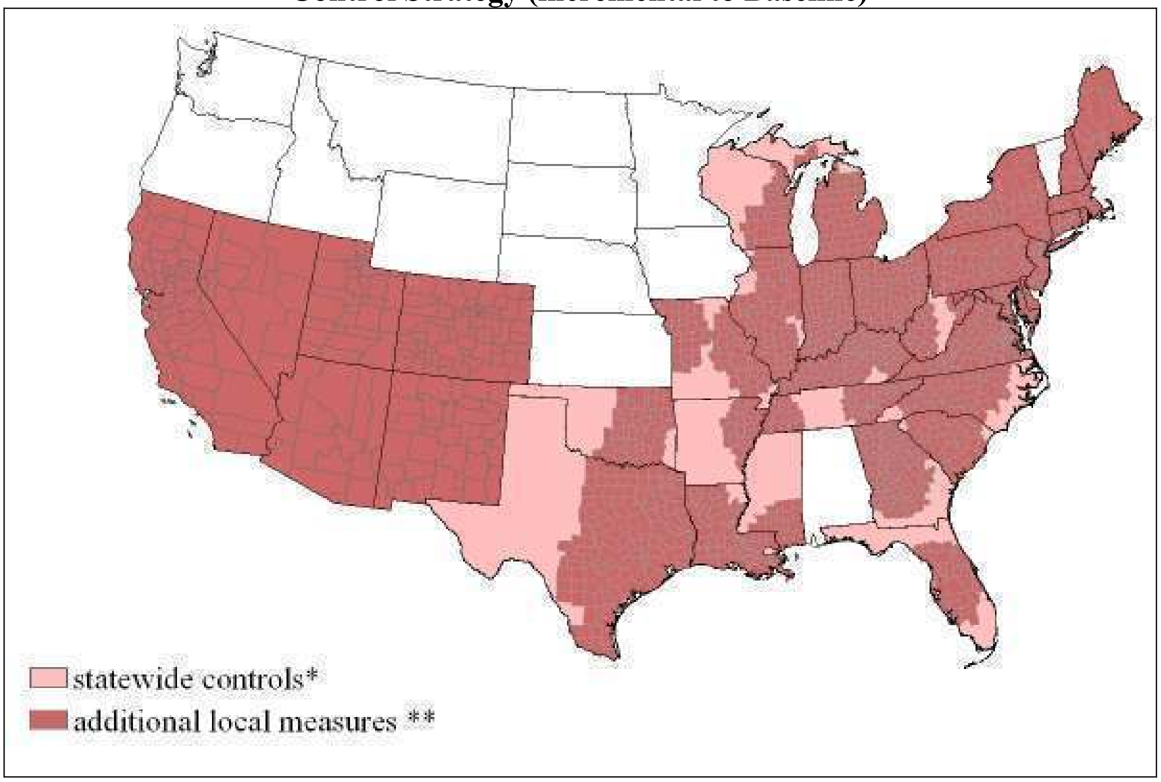
As in other sectors, there are several mobile source control strategies that have been, or are expected to be, implemented through previous national or regional rules. Although many expected reductions from these rules are included in the baseline, additional mobile source controls were required to illustrate attainment of a 0.070 ppm standard (See Fig 3.8). Modeling of the onroad and nonroad mobile sectors was done using MOBILE6. See Appendix 3 for more information.

All of the local mobile source controls included in the ozone baseline were expanded for the hypothetical national control strategy to attain 0.070 ppm standard. In the case of onroad and nonroad Selective Catalytic Reduction (SCR) and Diesel Particulate Filters (DPF), the measure was applied at a greater penetration rate – to 75% of the equipment population. 75% was the highest penetration rate that EPA felt could be reasonably accomplished. All local measures were applied to sources in additional geographic areas. Continuous inspection and maintenance, which allows for much more rapid identification of vehicles failing their emissions standard, was added. Descriptions of the mobile source rules and measures can be found in appendix 3.3.

As in the baseline, onroad SCR and DPF and elimination of idling were applied statewide for all states with a county projected to exceed the 0.070 ppm standard. All other controls were applied to counties within a 200 km buffer from counties projected to exceed the 0.070 ppm alternative standard with the following exceptions:

- counties in neighboring states were omitted from the buffer zone
- controls were applied statewide to Ozone Transport Commission (OTC) states, with the exception of Vermont
- controls were applied statewide in California, Colorado, Utah, New Mexico, Arizona, and Nevada .

Fig. 3.8 Areas Where NOx and VOC Controls Were Applied to Mobile Onroad and Nonroad Sources in Addition to National Mobile Controls for the 0.070 ppm Control Strategy (incremental to Baseline)



*Onroad retrofits and elimination of long duration idling
**Onroad retrofits, elimination of long duration idling, nonroad retrofits, Best Workplace for Commuters programs (BWC), low Reid Vapor Pressure (RVP)

3.2.4 Data Quality for this Analysis

The estimates of emission reductions associated with our control strategies above are subject to important limitations and uncertainties. EPA's analysis is based on its best judgment for various input assumptions that are uncertain. As a general matter, the Agency selects the best available information from available engineering studies of air pollution controls and has set up what it believes is the most reasonable framework for analyzing the cost, emission changes, and other impacts of regulatory controls. EPA is working on approaches to quantify the uncertainties in these areas and will incorporate them in future RIAs as appropriate.

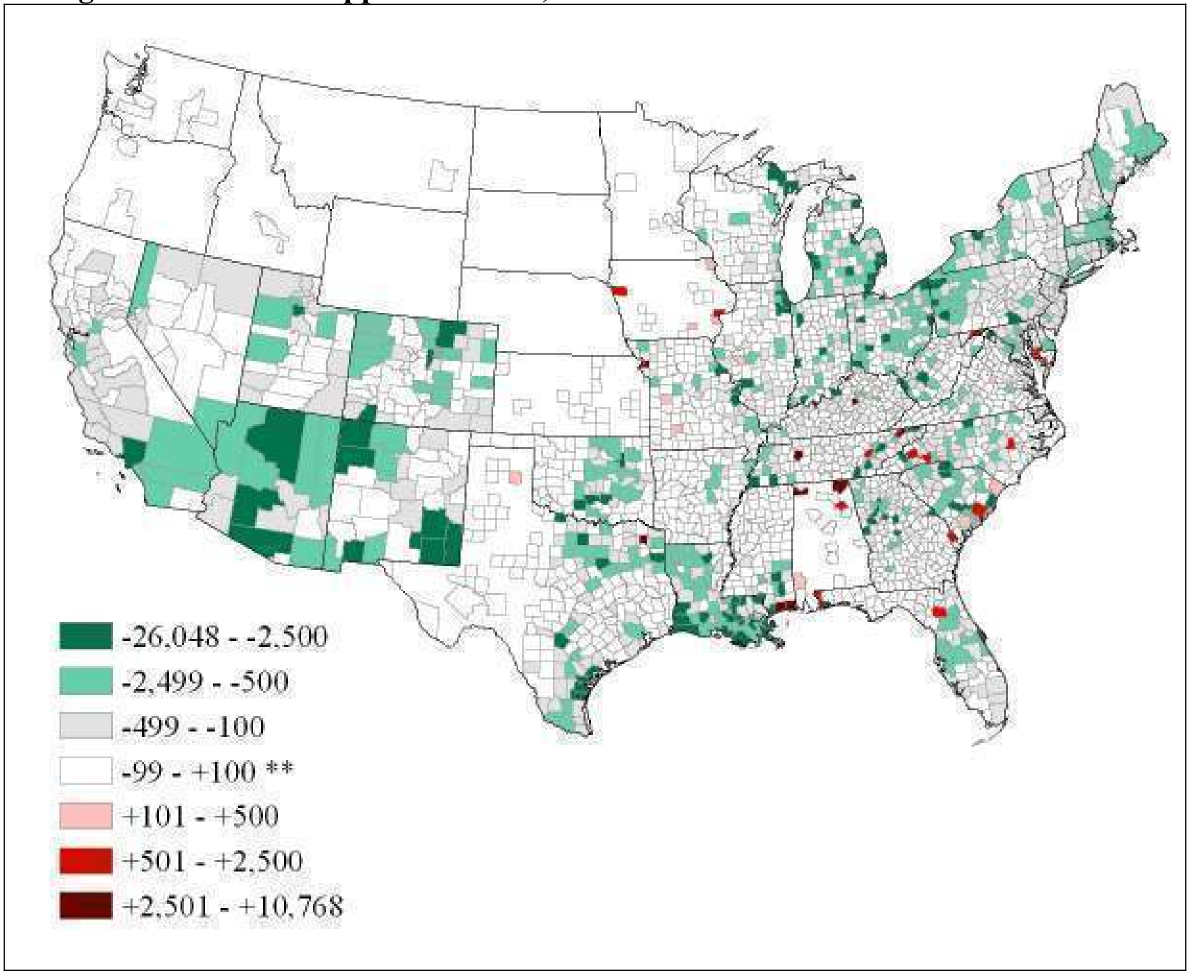
3.3 Geographic Distribution of Emissions Reductions

The following maps break out NOx and VOC reductions into the controlling sectors. The maps for NOx and VOC reductions are presented in Figures 3.9 and 3.11, respectively. Figures 3.10 and 3.12 indicate the emission reductions attributed to each sector. Appendix 3 contains maps of emissions reductions by sector, nationwide.

Prior to reading the maps, there is an important caveat to consider. The control strategy above focuses on reducing emissions of VOCs and NOx, the two precursors to ozone formation. However, in some cases, the application of the control strategy actually increased the level of NOx or VOC emissions. This is due to controls that affect multiple pollutants and complex interactions between air pollutants, as well as trading aspects under the CAIR rule.

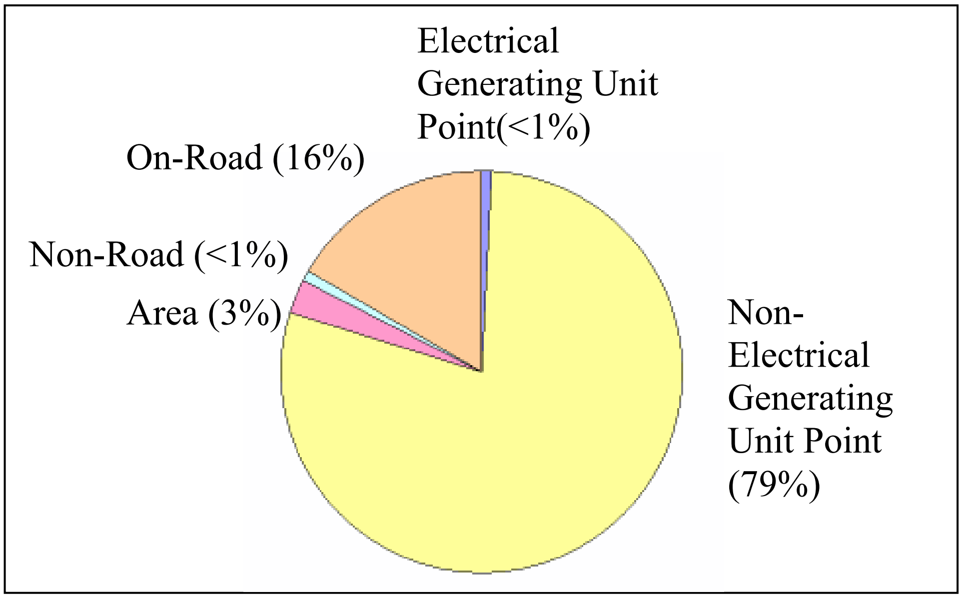
Emissions of NOx do not decrease everywhere within the CAIR region. As explained earlier, the NOx EGU control strategy was designed to achieve emission reductions specifically in the non-attainment areas, while retaining the overall CAIR cap. Application of nested and lower (ozone season) caps for the states in the MWRPO and OTC regions and local controls (SCR and SNCR) on the uncontrolled coal units in the non-attainment counties outside of the OTC and MWRPO within CAIR region result in increase of emissions elsewhere within CAIR region. While there are substantial NOx emission reductions within the OTC and MWRPO expected for the 2020 ozone season (roughly 55,500 tons) as a result of cap-and-trade program with lower caps and local command-and-control reductions in other non-attainment counties where uncontrolled coal units exist, there is the possibility of increased emissions from the remainder of sources within CAIR region. This approach provides a cost effective opportunity for reducing emissions where the reductions are most needed to help reach attainment. It is important to recall that this is a hypothetical control strategy, the states or other authorities may take additional steps to minimize these increases if warranted.

Fig 3.9 Annual Tons of Nitrogen Oxide (NOx) Emission Reductions From Controls Designed to Meet 0.070 ppm Standard,* incremental to the current standard



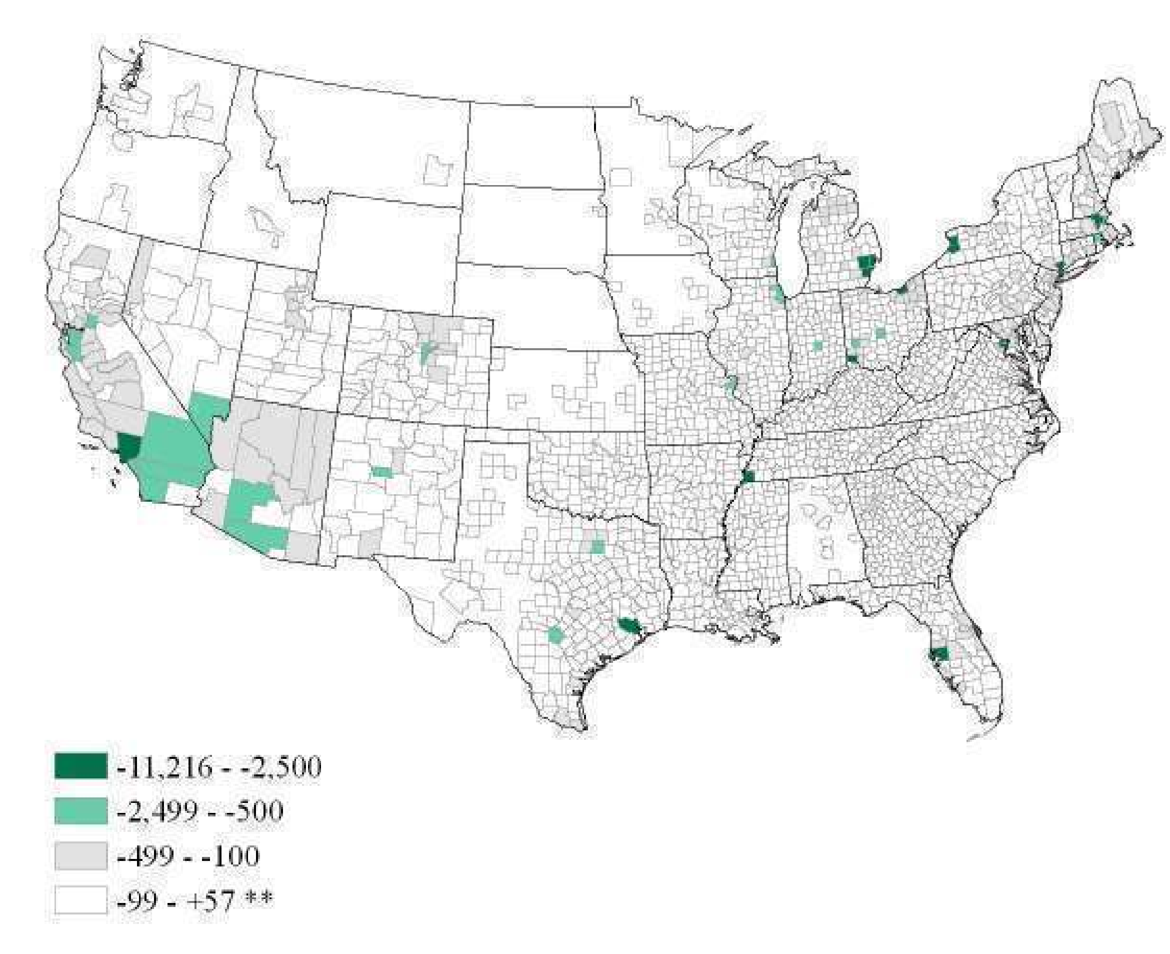
*Reductions are negative and increases are positive
**The -99 - +100 range is shown without color because these are small county-level NOx reductions or increases that likely had little to no impact on ozone estimates. Most counties in this range had NOx differences less than 1 ton.

Fig. 3.10 Percentage of Total Annual NOx Emissions Reduced from Various Sources



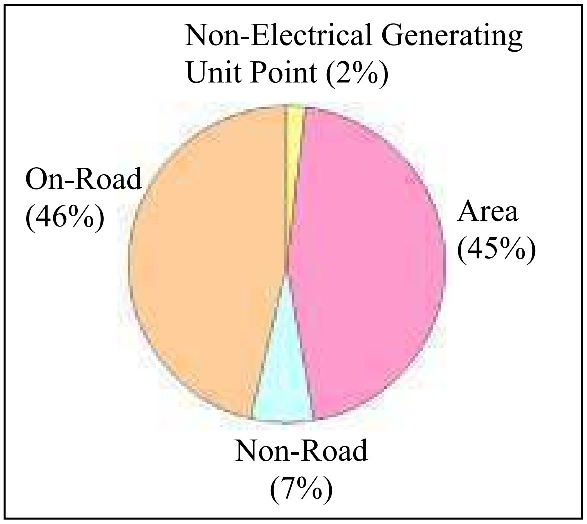
* Note that on a national basis, NOx emissions are reduced by <1%. However, the EGU strategy used in this analysis gains reductions in nonattainment areas, balanced by increases in attainment areas (described in Section 3.3)

Fig. 3.11 Annual Tons of Volatile Organic Compound (VOC) Emission Reductions From Controls Designed to Meet 0.070 ppm Standard*, incremental to the current standard



*Reductions are negative and increases are positive
**The -99 - +57 range is shown without color because these are small county-level VOC reductions or increases that likely had little to no impact on ozone estimates. Most counties in this range had VOC differences less than 1 ton.

Fig. 3.12 Percentage of Total Annual VOC Emissions Reduced from Various Sources*



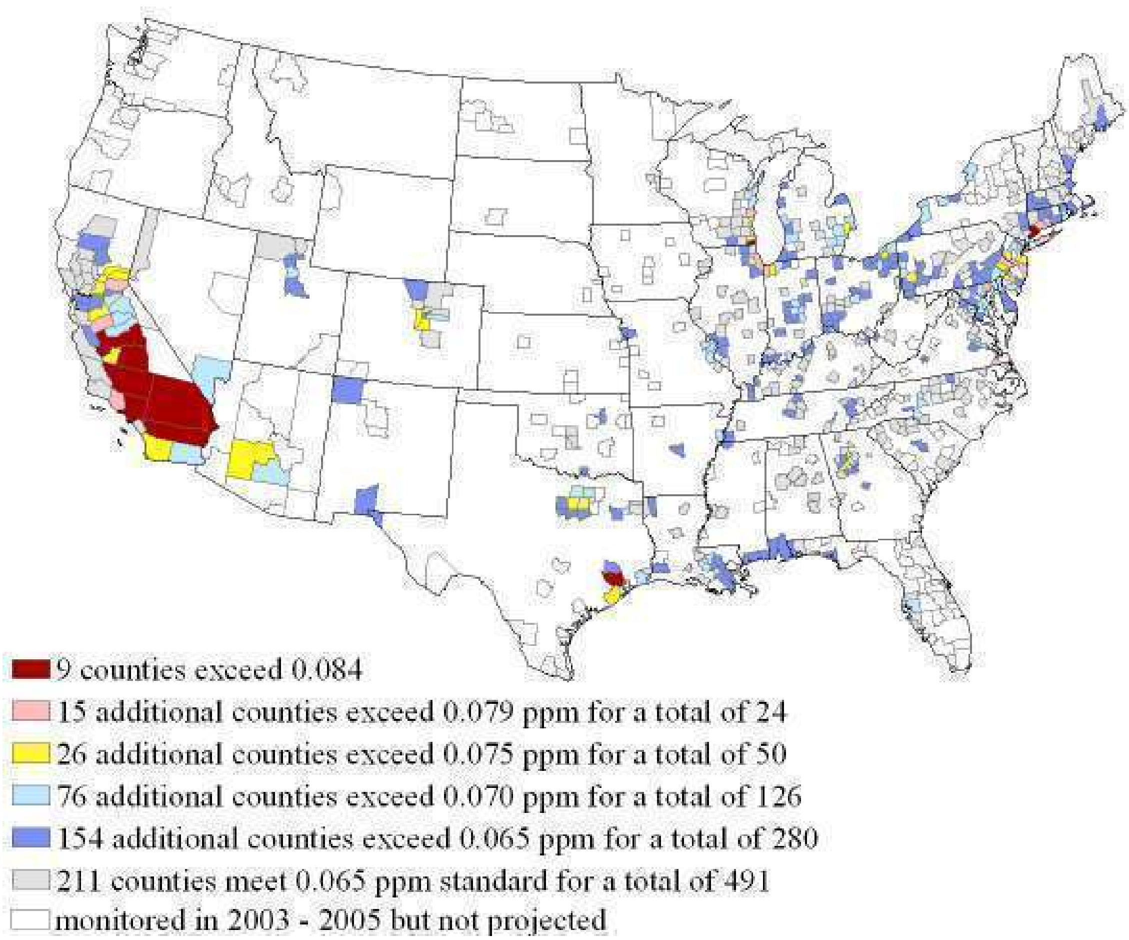
3.4 Ozone Design Values for partial attainment

After determining the emissions reductions from NOx and VOC, we used modeling tools (see section 2.3.2) to determine ozone design values for 2020. Figure 3.13 shows a map of the design values after modeling the control strategy to reach 0.070 ppm. The map legend is broken out to demonstrate under this control strategy, with no adjustments, which counties would reach the targeted standard of 0.070 ppm, the more stringent alternative standard analyzed (0.065 ppm), and the other end of the proposal range (0.075 ppm). It is understood that this illustrative strategy would not be the exact hypothetical strategy used to try to attain either of these alternative standards, due to over- and under-attainment in many counties. (Chapter 4 describes EPA's methodology for estimating tons of reductions needed to hypothetically attain these other two possible alternative standards.) In addition, because ozone formation is dependent on a variety of factors, it is not possible to directly attribute changes in predicted ozone concentrations to emission reductions of a specific precursor from a specific sector.

A full listing of the counties and their design values is provided in Appendix 3. Figures 3.14 and 3.15 show the tons of emissions reduced by the hypothetical RIA 0.070 ppm control strategy, and the tons of emissions remaining after application of those controls, by sector.

Using this strategy, it is possible to reach attainment in 365 counties. However, there are still an additional 126 counties that will remain out of attainment with an alternative standard of 0.070 ppm using this control strategy. All known controls were applied to this scenario, but attainment was not achieved everywhere. Because of this partial attainment outcome, it will be necessary to identify additional reductions in NOx and VOC in order to assess the costs and benefits of full attainment nationwide. Chapter 4 will address the methodology for determining the additional tons that were needed to reach full attainment.

Fig. 3.13 Projected Ozone Air Quality in 2020 After Application of Known Controls



1 Modeled emissions reflect the expected reductions from federal programs including the Clean Air Interstate Rule, the Clean Air Mercury Rule, the Clean Air Visibility Rule, the Clean Air Nonroad Diesel Rule, the Light-Duty Vehicle Tier 2 Rule, the Heavy Duty Diesel Rule, proposed rules for Locomotive and Marine Vessels and for Small Spark-Ignition Engines, and state and local level mobile and stationary source controls identified for additional reductions in emissions for the purpose of attaining the current PM 2.5 and Ozone standards.
2 Controls applied are illustrative. States may choose to apply different control strategies for implementation.

3 The current standard of 0.08 ppm is effectively expressed as 0.084 ppm when rounding conventions are applied.

4 Modeled design values in ppm are only interpreted up to 3 decimal places.

5 Map shows results from a total of 491 counties with projected design values. Consistent with current modeling guidance, EPA did not project 2020 concentrations for counties where 2001 base year concentrations were less than recommended criterion. Such projections may not represent expected future levels.

Table 3.4 Annual Tons of Emissions Remaining after Application of the 0.070 ppm Control Strategy (35 States + DC Analysis Area)[16]

Pollutant	*Sector*	*2020 Emissions After Controls Applied for PM2.5 15/35 (tons)*	*2020 Emissions After Controls Applied for PM2.5 15/35 and Ozone 0.084 Control Strategy Baseline (tons)*	*0.070 ppm Reductions (tons)*	*2020 Emissions After Controls Applied for PM2.5 15/35 and Ozone 0.070 ppm Control Strategy (tons)*
NOX	**Area**	1,200,000	1,200,000	30,000	1,200,000
	Onroad	1,800,000	1,700,000	170,000	1,600,000
	Nonroad	1,900,000	1,800,000	8,000	1,800,000
	EGU	1,500,000	1,500,000	7,800	1,500,000
	Non-EGU	2,200,000	1,900,000	800,000	1,100,000
VOC	**Area**	5,800,000	5,600,000	84,000	5,500,000
	Onroad	1,500,000	1,500,000	86,000	1,400,000
	Nonroad	1,000,000	1,000,000	12,000	1,000,000
	EGU	39,000	39,000	26	38,000
	Non-EGU	1,100,000	1,100,000	3,400	1,100,000

[16] Numbers may not add up due to rounding

Fig 3.14 Annual NOx Emissions Remaining after PM NAAQS 15/35, Ozone Current Standard, and 0.070 ppm Control Strategies (35 States + DC Analysis Area)

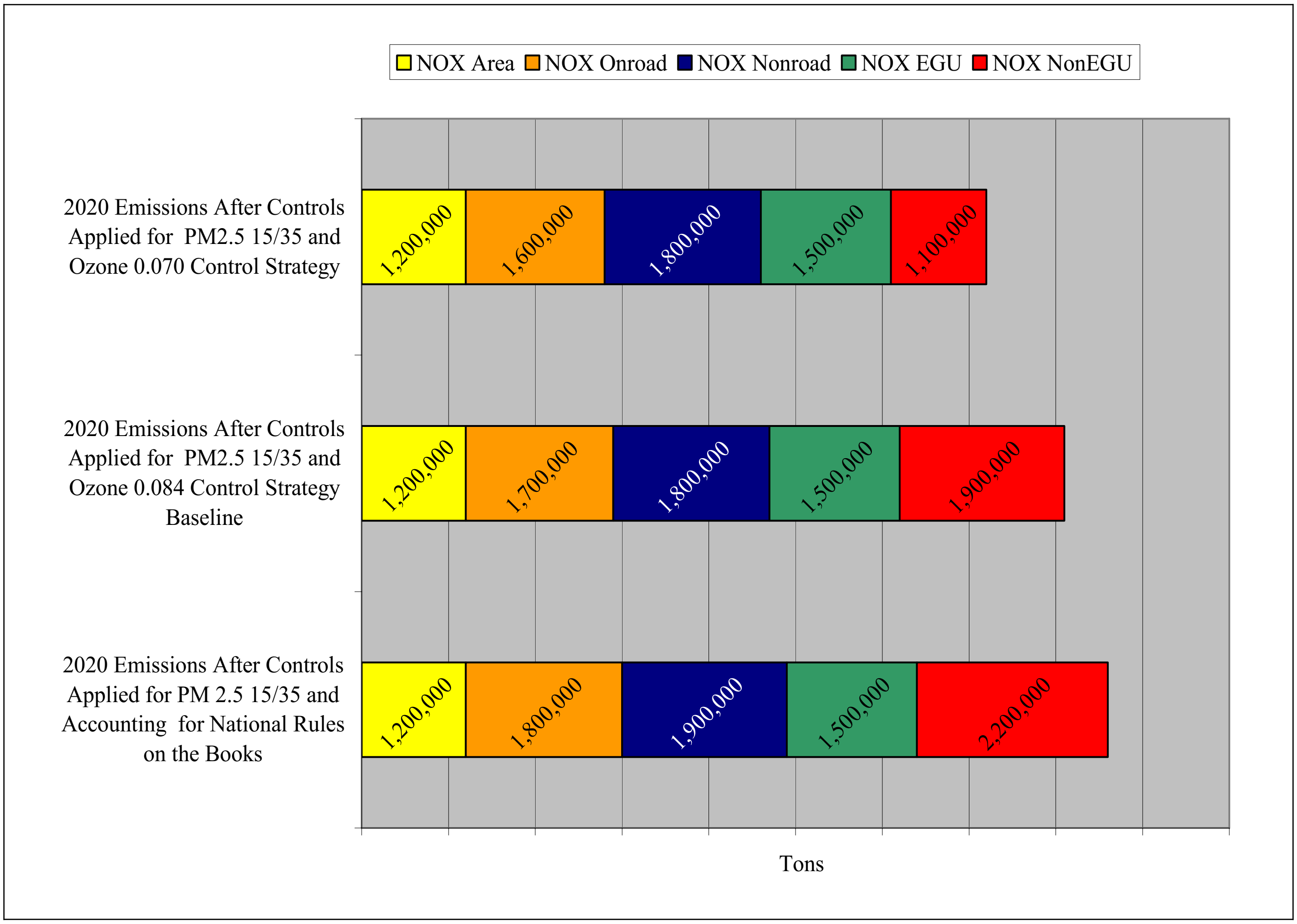
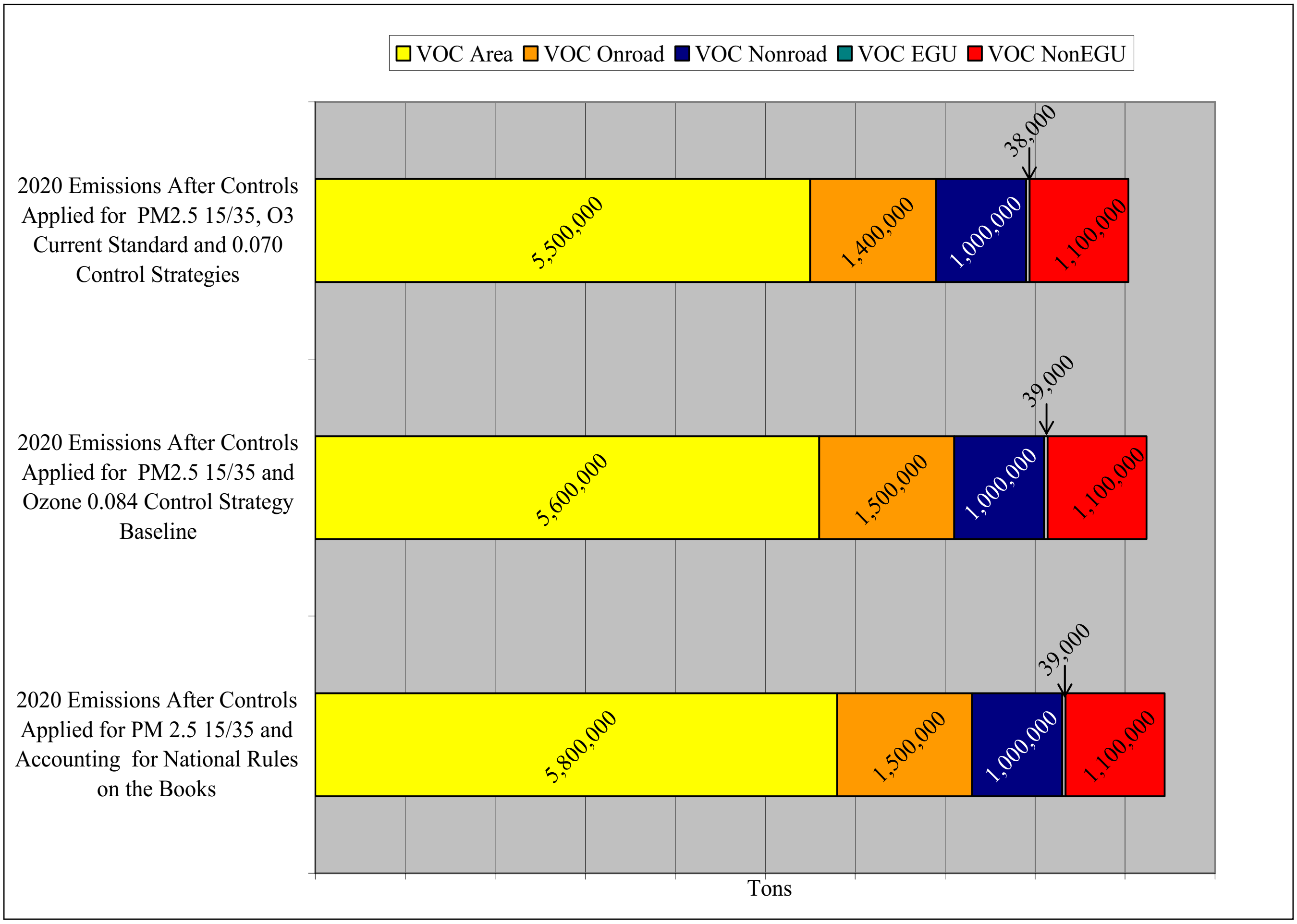


Fig. 3.15 Annual VOC Emissions Remaining after PM NAAQS 15/35, Ozone Current Standard, and 0.070 ppm Control Strategies (35 States + DC Analysis Area)



3.5 References

Michigan Department of Environmental Quality and Southeast Michigan Council of Governments. *Proposed Revision to State of Michigan State Implementation Plan for 7.0 Low Vapor Pressure Gasoline Vapor Request for Southeast Michigan*. May 24, 2006.

National Ambient Air Quality Standards for Particulate Matter, 40 CFR Part 50 (2006)

Rule To Reduce Interstate Transport of Fine Particulate Matter and Ozone (Clean Air Interstate Rule); Revisions to Acid Rain Program; Revisions to the NOX SIP Call; Final Rule, 40 CFR Parts 51, 72, 73, 74, 77, 78 and 96 (2005).

Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units, 40 CFR Parts 60, 63, 72, and 75 (2005)

Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations, 40 CFR Part 51 (2005)

Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder, Proposed rule, 40 CFR Parts 92, 94, 1033, 1039, 1042, 1065 and 1068 (2007)

Control of Emissions from Nonroad Spark-Ignition Engines and Equipment; proposed rule, 40 CFR Parts 60, 63, 85, 89, 90, 91, 1027, 1045, 1048, 1051, 1054, 1060, 1065, 1068, and 1074 (2007)

USEPA. *Guide on Federal and State Summer RVP Standards for Conventional Gasoline Only.* EPA420-B-05-012. November 2005

USEPA. 2007, Regulatory Announcement: EPA Proposal for More Stringent Emissions Standards for Locomotives and Marine Compression-Ignition Engines. EPA420-F-07-015

USEPA. 2007, Proposed Emission Standards for New Nonroad Spark-Ignition Engines, Equipment, and Vessels. EPA420-F-07-032

Appendix- Chapter 3

3a.1 Non-EGU and Area Source Controls Applied in the Baseline and Control Scenarios

3a.1.1 Non-EGU and Area Source Control Strategies for Ozone NAAQS Proposal

In the Non-EGU and Area Sources portion of the control strategy, maximum control scenarios were used from the existing control measure dataset from AirControlNET 4.1 for 2020 (for Geographic Areas defined for each level of the standard being analyzed). This existing control measure dataset reflects changes and updates made as a result of the reviews performed for the final PM2.5 RIA. Following this, an internal review was performed by the OAQPS engineers in the Sector Policies and Programs Division (SPPD) to examine the controls applied by AirControlNET and decide if these controls were sufficient or could be more aggressive in their application, given the 2020 analysis year. This review was performed for non-EGU NOx control measures. The result of this review was an increase in control efficiencies applied for many control measures, and more aggressive control measures for over 80 SCC's. For example, SPPD recommended that we apply SCR to cement kilns to reduce NOx emissions in 2020. Currently, there are no SCRs in operation at cement kilns in the U.S, but there are several SCRs in operation at cement kilns in France now. Based on the SCR experience at cement kilns in France, SPPD believes SCR could be applied at U.S. cement kilns by 2020. Following this, it was recommended that supplemental controls could be applied to 8 additional SCC's from non-EGU NOx sources. We also looked into sources of controls for highly reactive VOC non-EGU sources. Four additional controls were applied for highly reactive VOC non-EGU sources not in AirControlNET.

3a.1.2 NOx Control Measures for Non-EGU Point Sources.

Several types of NOx control technologies exist for non-EGU sources: SCR, selective noncatalytic reduction (SNCR), natural gas reburn (NGR), coal reburn, and low-NOx burners. In some cases, LNB accompanied by flue gas recirculation (FGR) is applicable, such as when fuel-borne NOx emissions are expected to be of greater importance than thermal NOx emissions. When circumstances suggest that combustion controls do not make sense as a control technology (e.g., sintering processes, coke oven batteries, sulfur recovery plants), SNCR or SCR may be an appropriate choice. Finally, SCR can be applied along with a combustion control such as LNB with overfire air (OFA) to further reduce NOx emissions. All of these control measures are available for application on industrial boilers.

Besides industrial boilers, other non-EGU source categories covered in this RIA include petroleum refineries, kraft pulp mills, cement kilns, stationary internal combustion engines, glass manufacturing, combustion turbines, and incinerators. NOx control measures available for petroleum refineries, particularly process heaters at these plants, include LNB, SNCR, FGR, and SCR along with combinations of these technologies.

NOx control measures available for kraft pulp mills include those available to industrial boilers, namely LNB, SCR, SNCR, along with water injection (WI). NOx control measures available for cement kilns include those available to industrial boilers, namely LNB, SCR, and SNCR. Non-selective catalytic reduction (NSCR) can be used on stationary internal combustion engines. OXY-firing, a technique to modify combustion at glass manufacturing plants, can be used to reduce NOx at such plants. LNB, SCR, and SCR + steam injection (SI) are available measures for combustion turbines. Finally, SNCR is an available control technology at incinerators. For more information on these measures, please refer to the AirControlNET 4.1 control measures documentation report.

3a.1.3 VOC Control Measures for Non-EGU Point Sources.

VOC controls were applied to a variety of non-EGU point sources as defined in the emissions inventory in this RIA. These controls are: permanent total enclosure (PTE) applied to paper and web coating operations and fabric operations, and incinerators or thermal oxidizers applied to wood products and marine surface coating operations. A PTE confines VOC emissions to a particular area where can be destroyed or used in a way that limits emissions to the outside atmosphere, and an incinerator or thermal oxidizer destroys VOC emissions through exposure to high temperatures (2,000 degrees Fahrenheit or higher). For more information on these measures, refer to the AirControlNET 4.1 control measures documentation report.

3a.1.4 NOx Control Measures for Area Sources

There were two controls applied for NOx emissions from area sources. The first is RACT (reasonably available control technology) to 25 tpy (LNB). This control is the addition of a low NOx burner to reduce NOx emissions. This control is applied to industrial oil, natural gas, and coal combustion sources. The second control is water heaters plus LNB space heaters. This control is based on the installation of low-NOx space heaters and water heaters in commercial and institutional sources for the reduction of NOx emissions. For additional information regarding these controls please refer to the AirControlNET 4.1 control measures documentation report.

3a.1.5 VOC Control Measures for Area Source.

The most frequently applied control to reduce VOC emissions from area sources was CARB Long-Term Limits. This control, which represents controls available in VOC rules promulgated by the California Air Resources Board, applies to commercial solvents and commercial adhesives, and depends on future technological innovation and market incentive methods to achieve emission reductions. The next most frequently applied controls was the use of low or no VOC materials for graphic art source categories. The South Coast Air District's SCAQMD Rule 1168 control applies to wood furniture and solvent source categories sets limits for adhesive and sealant VOC content. The OTC solvent cleaning rule control establishes hardware and operating requirements for specified vapor cleaning machines, as well as solvent volatility limits and operating practices for cold cleaners. The Low Pressure/Vacuum Relief Valve control measure is the addition of low pressure/vacuum (LP/V) relief valves to gasoline storage tanks at service stations with Stage II control systems. LP/V relief valves prevent breathing emissions from gasoline storage tank vent pipes. SCAQMD Limits control establishes VOC content limits for metal coatings along with application procedures and equipment requirements. Switch to Emulsified Asphalts control is a generic control measure replacing VOC-containing cutback asphalt with VOC-free emulsified asphalt. The equipment and maintenance control measure applies to oil and natural gas production. The Reformulation - FIP Rule control measure intends to reach the VOC limits by switching to and/or encouraging the use of low-VOC pesticides and better Integrated Pest Management (IPM) practices. For additional information regarding these controls please refer to the AirControlNET 4.1 control measures documentation report.

3a.1.6 Supplemental Controls

The table below summarizes the supplemental control measures added to our control measures database by providing the pollutant it controls and its control efficiency. These controls were applied in the baseline scenario to Houston and Chicago, and the Northeast as well as in the incremental control strategy applied to the Eastern U.S. However, these controls are not located in AirControlNET.

Table 3a.1 Supplemental Emission Control Measures Applied in Modeled Attainment Strategies for the Ozone NAAQS RIA – New Control Technologies Added to the Control Measures Database

Pollutant	SCC	SCC Description	Control Technology	Percent Reduction (%)
NOx	20200252	Internal Comb. Engines/Industrial/Natural Gas/2-cycle Lean Burn	LEC (Low Emission Combustion)	87
	20200254	Internal Comb. Engines/Industrial/Natural Gas/4-cycle Lean Burn	LEC (Low Emission Combustion)	87
VOC*	3018001-	Fugitive Leaks	Enhanced LDAR	50
	30600701 and 30600999 -	Flares		98
	3018001 -	Fugitive Leaks	LDAR	80
	30600702 -	Cooling towers	Monitoring Program	No one general estimate

30600503 -	Wastewater Drains and Separators	Inspection and Maintenance Program (Separators) Water Seals (Drains)	65

*Note: the cost of these measures are not included in our incremental annualized cost estimates since these controls are found in the Harris-Galveston-Brazoria Cos. SIP (Texas), and they will be incurred by 2020 in any event. We do quantify the emission reductions since these controls are not accounted for in our baseline inventory for 2020, however.

Low Emission Combustion (LEC)

Overview: LEC technology is defined as the modification of a natural gas fueled, spark ignited, reciprocating internal combustion engine to reduce emissions of NOx by utilizing ultra-lean air-fuel ratios, high energy ignition systems and/or pre-combustion chambers, increased turbocharging or adding a turbocharger, and increased cooling and/or adding an intercooler or aftercooler, resulting in an engine that is designed to achieve a consistent NO_x emission rate of not more than 1.5-3.0 g/bhp-hr at full capacity (usually 100 percent speed and 100 percent load). This type of retrofit technology is fairly widely available for stationary internal combustion engines.

For control efficiency, EPA estimates that it ranges from 82 to 91 percent for LEC technology applications. The EPA believes application of LEC would achieve average NO_x emission levels in the range of 1.5-3.0 g/bhp-hr. This is an 82-91 percent reduction from the average uncontrolled emission levels reported in the ACT document. An EPA memorandum summarizing 269 tests shows that 96 percent of IC engines with installed LEC technology achieved emission rates of less than 2.0 g/bhp-hr.[1] The 2000 EC/R report on IC engines summarizes 476 tests and shows that 97% of the IC engines with installed LEC technology achieve emission rates of 2.0 g/bhp-hr or less.[2]

[1] "Stationary Reciprocating Internal Combustion Engines Technical Support Document for NOx SIP Call Proposal," U.S. Environmental Protection Agency. September 5, 2000. Available on the Internet at http://www.epa.gov/ttn/naaqs/ozone/rto/sip/data/tsd9-00.pdf.

[2] "Stationary Internal Combustion Engines: Updated Information on NOx Emissions and Control Techniques," Ec/R Incorporated, Chapel Hill, NC. September 1, 2000. Available on the Internet at http://www.epa.gov/ttn/naaqs/ozone/ozonetech/ic_engine_nox_update_09012000.pdf.

Major Uncertainties: The EPA acknowledges that specific values will vary from engine to engine. The amount of control desired and number of operating hours will make a difference in terms of the impact had from a LEC retrofit. Also, the use of LEC may yield improved fuel economy and power output, both of which may affect the emissions generated by the device.

Leak Detection and Repair (LDAR) for Fugitive Leaks

Overview: This control measure is a program to reduce leaks of fugitive VOC emissions from chemical plants and refineries. The program includes special "sniffer" equipment to detect leaks, and maintenance schedules that affected facilities are to adhere to. This program is one that is contained within the Houston-Galveston-Brazoria 8-hour Ozone SIP.

Major Uncertainties: The degree of leakage from pipes and processes at chemical plants is always difficult to quantify given the large number of such leaks at a typical chemical manufacturing plant. There are also growing indications based on tests conducted by TCEQ and others in Harris County, Texas that fugitive leaks have been underestimated from chemical plants by a factor of 6 to 20 or greater. [3]

Enhanced LDAR for Fugitive Leaks

Overview: This control measure is a more stringent program to reduce leaks of fugitive VOC emissions from chemical plants and refineries that presumes that an existing LDAR program already is in operation.

Major Uncertainties: The calculations of control efficiency and cost presume use of LDAR at a chemical plant. This should not be an unreasonable assumption, however, given that most chemical plants are under some type of requirement to have an LDAR program. However, as mentioned earlier, there is growing evidence that fugitive leak emissions are underestimated from chemical plants by a factor of 6 to 20 or greater.[4]

[3] VOC Fugitive Losses: New Monitors, Emissions Losses, and Potential Policy Gaps. 2006 International Workshop. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Solid Waste and Emergency Response. October 25-27, 2006.

[4] VOC Fugitive Losses: New Monitors, Emissions Losses, and Potential Policy Gaps. 2006 International Workshop. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Solid Waste and Emergency Response. October 25-27, 2006.

Flare Gas Recovery

Overview: This control measure is a condenser that can recover 98 percent of the VOC emitted by flares that emit 20 tons per year or more of the pollutant.

Major Uncertainties: Flare gas recovery is just gaining commercial acceptance in the US and is only in use at a small number of refineries.

Cooling Towers

Overview: The control measure is continuous monitoring of VOC from the cooling water return to a level of 10 ppb. This monitoring is accomplished by using a continuous flow monitor at the inlet to each cooling tower.

There is not a general estimate of control efficiency for this measure; one is to apply a continuous flow monitor until VOC emissions have reached a level of 1.7 tons/year for a given cooling tower.[5]

Major Uncertainties: The amount of VOC leakage from each cooling tower can greatly affect the overall cost-effectiveness of this control measure.

Wastewater Drains and Separators

Overview: This control measure includes an inspection and maintenance program to reduce VOC emissions from wastewater drains and water seals on drains. This measure is a more stringent version of measures that underlie existing NESHAP requirements for such sources.

Major Uncertainties: The reference for this control measures notes that the VOC emissions inventories for the five San Francisco Bay Area refineries whose data was a centerpiece of this report are incomplete. In addition, not all VOC species from these sources were included in the VOC data that is a basis for these calculations.[6]

In addition to the new supplemental controls presented above, there were a number of changes made to existing AirControlNET controls. These changes were made based upon an internal review performed by EPA engineers to examine the controls applied by AirControlNET and determine if these controls were sufficient or could be more aggressive in their application, given the 2020 analysis year. This review was performed for non-EGU NOx control measures. The result of this review was an increase in control

---

[5] Bay Area Air Quality Management District (BAAQMD). Proposed Revision of Regulation 8, Rule 8: Wastewater Collection Systems. Staff Report, March 17, 2004.
[6] Bay Area Air Quality Management District (BAAQMD). Proposed Revision of Regulation 8, Rule 8: Wastewater Collection Systems. Staff Report, March 17, 2004.

efficiencies applied for many control measures, and more aggressive control measures for over 70 SCCs. The changes apply to the control strategies performed for the Eastern US only. These changes are listed in the table below.

Table 3a.2 Supplemental Emission Control Measures Applied in Modeled Attainment Strategies for the Ozone NAAQS RIA – Changes to Control technologies currently in our Control Measures Database

Pollutant	SCC	AirControlNET Source Description	AirControlNET Control Technology	New Control Technology	New Control Efficiency (%)	Old Control Efficiency (%)
NOX	10200104 10200204 10200205 10300207 10300209 10200217 10300216	ICI Boilers - Coal-Stoker	SNCR	SCR	90.0	40.0
NOX	10200901 10200902 10200903 10200907 10300902 10300903	ICI Boilers - Wood/Bark/ Waste	SNCR	SCR	90.0	55.0
NOX	10200401 10200402 10200404 10200405 10300401	ICI Boilers - Residual Oil	SCR	SCR	90.0	80
NOX	10200501 10200502 10200504	ICI Boilers - Distillate Oil	SCR	SCR	90.0	80
NOX	10200601 10200602 10200603 10200604 10300601 10300602 10300603 10500106 10500206	ICI Boilers - Natural Gas	SCR	SCR	90.0	80
NOX	30500606	Cement Manufacturing - Dry	SCR	SCR	90.0	80

Pollutant	SCC	AirControlNET Source Description	AirControlNET Control Technology	New Control Technology	New Control Efficiency (%)	Old Control Efficiency (%)
NOX	30500706	Cement Manufacturing - Wet	SCR	SCR	90.0	80
NOX	30300934	Iron & Steel Mills - Annealing	SCR	SCR	90.0	85
NOX	10200701 10200704 10200707 10200710 10200799 10201402 10300701 10300799	ICI Boilers - Process Gas	SCR	SCR	90.0	80
NOX	10200802 10200804	ICI Boilers - Coke	SCR	SCR	90.0	70
NOX	10201002	ICI Boilers - LPG	SCR	SCR	90.0	80
NOX	10201301 10201302	ICI Boilers - Liquid Waste	SCR	SCR	90.0	80
NOX	30700110	Sulfate Pulping - Recovery Furnaces	SCR	SCR	90.0	80
NOX	30100306	Ammonia Production – Pri. Reformer, Nat. Gas	SCR	SCR	90.0	80
	30500622 30500623	Cement Kilns	Biosolid Injection	Biosolid Injection	40.0	23
NOX	30590013 30190013 30190014 39990013	Industrial and Manufacturing Incinerators	SNCR	SCR	90.0	45
NOX	30101301 30101302	Nitric Acid Manufacturing	SNCR	SCR	90.0	908
NOX	30600201	Fluid Cat. Cracking Units	LNB + FGR	SCR	90.0	901
NOX	30590003 30600101	Process Heaters - Process Gas	LNB + SCR	LNB + SCR	90.0	88
NOX	30600103 30600111	Process Heaters - Distillate Oil	LNB + SCR	LNB + SCR	90.0	90

Pollutant	SCC	AirControlNET Source Description	AirControlNET Control Technology	New Control Technology	New Control Efficiency (%)	Old Control Efficiency (%)
NOX	30600106 30600199	Process Heaters - Residual Oil	LNB + SCR	LNB + SCR	90.0	80
NOX	30600102 30600105	Process Heaters - Natural Gas	LNB + SCR	LNB + SCR	90.0	80
NOX	30700104	Sulfate Pulping - Recovery Furnaces	SCR	SCR	90.0	80
NOX	30790013	Pulp and Paper - Natural Gas - Incinerators	SNCR	SCR	90.0	45
NOX	39000201	In-Process; Bituminous Coal; Cement Kiln	SNCR - urea based	SCR	90.0	50
NOX	39000203	In-Process; Bituminous Coal; Lime Kiln	SNCR - urea based	SCR	90.0	50
NOX	39000289	In-Process Fuel Use;Bituminous Coal; Gen	SNCR	SCR	90.0	40
NOX	39000489	In-Process Fuel Use; Residual Oil; Gen	LNB	SCR	90.0	37
NOX	39000689	In-Process Fuel Use; Natural Gas; Gen	LNB	SCR	90.0	50
NOX	39000701	In-Proc;Process Gas;Coke Oven/Blast Furn	LNB + FGR	SCR	90.0	55
NOX	39000789	In-Process; Process Gas; Coke Oven Gas	LNB	SCR	90.0	50
NOX	50100101 50100506 50200506 50300101 50300102 50300104 50300506 50100102	Solid Waste Disp;Gov;Other Incin;Sludge	SNCR	SCR	90.0	45

The last category of supplemental controls is control technologies currently in our control measures database being applied to SCCs not controlled currently in AirControlNET.

Table 3a.3 Supplemental Emission Control Measures Applied in Modeled Attainment Strategies for the Ozone NAAQS RIA –Control technologies currently in our Control Measures Database Applied to New Source types

Pollutant	SCC	SCC Description	Control Technology	Control Efficiency
NOX	39000602	Cement Manufacturing - Dry	SCR	90.0
NOX	30501401	Glass Manufacturing - General	OXY-Firing	85.0
NOX	30302351 30302352 30302359	Taconite Iron Ore Processing - Induration - Coal or Gas	SCR	90.0
NOX	10100101	External Combustion Boilers;Electric Generation;Anthracite Coal;Pulverized Coal	SNCR	40.0
NOX	10100202	External Combustion Boilers;Electric Generation;Bituminous/Subbituminous Coal;Pulverized Coal: Dry Bottom (Bituminous Coal)	SNCR	40.0
NOX	10100204	External Combustion Boilers;Electric Generation;Bituminous/Subbituminous Coal;Spreader Stoker (Bituminous Coal)	SNCR	40.0
NOX	10100212	External Combustion Boilers;Electric Generation;Bituminous/Subbituminous Coal;Pulverized Coal: Dry Bottom (Tangential) (Bituminous Coal)	SNCR	40.0
NOX	10100401	External Combustion Boilers;Electric Generation;Residual Oil;Grade 6 Oil: Normal Firing	SNCR	50.0
NOX	10100404	External Combustion Boilers;Electric Generation;Residual Oil;Grade 6 Oil: Tangential Firing	SNCR	50.0
NOX	10100501	External Combustion Boilers;Electric Generation;Distillate Oil;Grades 1 and 2 Oil	SNCR	50.0
NOX	10100601	External Combustion Boilers;Electric Generation;Natural Gas;Boilers > 100 Million Btu/hr except Tangential	NGR	50.0
NOX	10100602	External Combustion Boilers;Electric Generation;Natural Gas;Boilers < 100 Million Btu/hr except Tangential	NGR	50.0
NOX	10100604	External Combustion Boilers;Electric Generation;Natural Gas;Tangentially Fired Units	NGR	50.0

NOX	10101202	External Combustion Boilers;Electric Generation;Solid Waste;Refuse Derived Fuel	SNCR	50.0
NOX	20200253	Internal Comb. Engines/Industrial/Natural Gas/4-cycle Rich Burn	NSCR	90

3a.2Mobile Controls/Rules Used in Baseline and Control Scenarios

3a.2.1 Diesel Retrofits and Vehicle Replacement

Retrofitting heavy-duty diesel vehicles and equipment manufactured before stricter standards are in place – in 2007-2010 for highway engines and in 2011-2014 for most nonroad equipment – can provide NO_X and HC benefits. The retrofit strategies included in the RIA retrofit measure are:

- Installation of emissions after-treatment devices called selective catalytic reduction ("SCRs")
- Rebuilding nonroad engines ("rebuild/upgrade kit")

We chose to focus on these strategies due to their high NOx emissions reduction potential and widespread application. Additional retrofit strategies include, but are not limited to, lean NOx catalyst systems – which are another type of after-treatment device – and alternative fuels. Additionally, SCRs are currently the most likely type of control technology to be used to meet EPA's NOx 2007-2010 requirements for HD diesel trucks and 2008-2011 requirements for nonroad equipment. Actual emissions reductions may vary significantly by strategy and by the type and age of the engine and its application.

To estimate the potential emissions reductions from this measure, we applied a mix of two retrofit strategies (SCRs and rebuild/upgrade kits) for the 2020 inventory of:

- Heavy-duty highway trucks class 6 & above, Model Year 1995-2009
- All diesel nonroad engines, Model Year 1991-2007, except for locomotive, marine, pleasure craft, & aircraft engines

Class 6 and above trucks comprise the bulk of the NOx emissions inventory from heavy-duty highway vehicles, so we did not include trucks below class 6. We chose not to include locomotive and marine engines in our analysis since EPA has proposed regulations to address these engines, which will significantly impact the emissions inventory and emission reduction potential from retrofits in 2020. There was also not enough data available to assess retrofit strategies for existing aircraft and pleasure craft engines, so we did not include them in this analysis. In addition, EPA is in the process of negotiating standards for new aircraft engines.

The lower bound in the model year range – 1995 for highway vehicles and 1991 for nonroad engines – reflects the first model year in which emissions after-treatment devices can be reliably applied to the engines. Due to a variety of factors, devices are at a higher risk of failure for earlier model years. We expect the engines manufactured before the lower bound year that are still in existence in 2020 to be retired quickly due to natural turnover, therefore, we have not included strategies for pre-1995/1991 engines because of the strategies' relatively small impact on emissions. The upper bound in the model year range reflects the last year before more stringent emissions standards will be fully phased-in.

We chose the type of strategy to apply to each model year of highway vehicles and nonroad equipment based on our technical assessment of which strategies would achieve reliable results at the lowest cost. After-treatment devices can be more cost-effective than rebuild and vice versa depending on the emissions rate, application, usage rates, and expected life of the engine. The performance of after-treatment devices, for example, depends heavily upon the model year of the engine; some older engines may not be suitable for after-treatment devices and would be better candidates for rebuild/upgrade kit. In certain cases, nonroad engines may not be suitable for either after-treatment devices or rebuild, which is why we estimate that retrofits are not suitable for 5% of the nonroad fleet. The mix of strategies employed in this RIA for highway vehicles and nonroad engines are presented in Table 3a.4 and Table 3a.5, respectively. The groupings of model years for highway vehicles reflect changes in EPA's published emissions standards for new engines.

Table 3a.4 Application of Retrofit Strategy for Highway Vehicles by Percentage of Fleet

Model Year	SCR
<1995	0%
1995-2006	100%
2007-2009	50%
>2009	0%

Table 3a.5 Application of Retrofit Strategy for Nonroad Equipment by Percentage of Fleet

Model Year	Rebuild/Upgrade kit	SCR
1991-2007	50%	50%

The expected emissions reductions from SCR's are based on data derived from EPA regulations (Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-duty Highway Engines and Vehicles published October 2000), interviews with component manufacturers, and EPA's Summary of Potential Retrofit Technologies. This information is available at www.epa.gov/otaq/retrofit/retropotentialtech.htm. The estimates for highway vehicles and nonroad engines are presented in Table 3a.6 and Table 3a.7, respectively.

Table 3a.6: Percentage Emissions Reduction by Highway Vehicle Retrofit Strategy

	PM	CO	HC	NOx
SCR (+DPF)	90%	90%	90%	70%

Table 3a.7: Percentage Emissions Reduction by Nonroad Equipment Retrofit Strategy

Strategy	PM	CO	HC	NOx
SCR (+DPF)	90%	90%	90%	70%
Rebuild/Upgrade Kit	30%	15%	70%	40%

It is important to note that there is a great deal of variability among types of engines (especially nonroad), the applicability of retrofit strategies, and the associated emissions reductions. We applied the retrofit emissions reduction estimates to engines across the board (e.g. retrofits for bulldozers are estimated to produce the same percentage reduction in emissions as for agricultural mowers). We did this in order to simplify model runs, and, in some cases, where we did not have enough data to differentiate emissions reductions for different types of highway vehicles and nonroad equipment. We believe the estimates used in the RIA, however, reflect the best available estimates of emissions reductions that can be expected from retrofitting the heavy-duty diesel fleet.

Using the retrofit module in EPA's National Mobile Inventory Model (NMIM) available at http://www.epa.gov/otaq/nmim.htm, we calculated the total percentage reduction in emissions (PM, NOx, HC, and CO) from the retrofit measure for each relevant engine category (source category code, or SCC) for each county in 2020. To evaluate this change in the emissions inventory, we conducted both a baseline and control analysis. Both analyses were based on NMIM 2005 (version NMIM20060310), NONROAD2005 (February 2006), and MOBILE6.2.03 which included the updated diesel PM file PMDZML.csv dated March 17, 2006.

For the control analysis, we applied the retrofit measure corresponding to the percent reductions of the specified pollutants in Tables 3a.6 and 3a.7 to the specified model years in Tables 1 and 2 of the relevant SCCs. Fleet turnover rates are modeled in the NMIM, so we applied the retrofit measure to the 2007 fleet inventory, and then evaluated the resulting emissions inventory in 2020. The timing of the application of the retrofit measure is not a factor; retrofits only need to take place prior to the attainment date target (2020 for this RIA). For example, if retrofit devices are installed on 1995 model year bulldozers in 2007, the only impact on emissions in 2020 will be from the expected inventory of 1995 model year bulldozer emissions in 2020.

We then compared the baseline and control analyses to determine the percent reduction in emissions we estimate from this measure for the relevant SCC codes in the targeted nonattainment areas.

<u>Pollutants and Source Categories Affected by Measure (SCC)</u>
NOx, and HC

3a.2.2 Implement Continuous Inspection and Maintenance Using Remote Onboard Diagnostics (OBD)

Continuous Inspection and Maintenance (I/M) is a new way to check the status of OBD systems on light-duty OBD-equipped vehicles. It involves equipping subject vehicles with some type of transmitter that attaches to the OBD port. The device transmits the status of the OBD system to receivers distributed around the I/M area. Transmission may be through radio-frequency, cellular or wi-fi means. Radio frequency and cellular technologies are currently being used in the states of Oregon, California and Maryland.

Current I/M programs test light-duty vehicles on a periodic basis – either annually or biennially. Emission reduction credit is assigned based on test frequency. Using Continuous I/M, vehicles are continuously monitored as they are operated throughout the non-attainment area. When a vehicle experiences an OBD failure, the motorist is notified and is required to get repairs within the normal grace period – typically about a month. Thus, Continuous I/M will result in repairs happening essentially whenever a malfunction occurs that would cause the check engine light to illuminate. The continuous I/M program is applied to the same fleet of vehicles as the current periodic I/M programs. Currently, MOBILE6 provides an increment of benefit when going from a biennial program to an annual program. The same increment of credit applies going from an annual program to a continuous program.

Pollutants and Source Categories Affected by Measure (SCC):

- All 1996 and newer light-duty gasoline vehicles and trucks:
- All 1996 and newer 2201001000 Light Duty Gasoline Vehicles (LDGV), Total: All Road Types
- All 1996 and newer 2201020000 Light Duty Gasoline Trucks 1 (LDGT1), Total: All Road Types
- All 1996 and newer 2201040000 Light Duty Gasoline Trucks 2 (LDGT2), Total: All Road Types

OBD systems on light duty vehicles are required to illuminate the malfunction indicator lamp whenever emissions of HC, CO or NOx would exceed 1.5 times the vehicle's certification standard. Thus, the benefits of this measure will affect all three criteria pollutants. MOBILE6 was used to estimate the emission reduction benefits of Continuous I/M, using the methodology discussed above.

3a.2.3 Eliminating Long Duration Truck Idling

Virtually all long duration truck idling – idling that lasts for longer than 15 minutes – from heavy-duty diesel class 8a and 8b trucks can be eliminated with two strategies:

- truck stop & terminal electrification (TSE)
- mobile idle reduction technologies (MIRTs) such as auxiliary power units, generator sets, and direct-fired heaters

TSE can eliminate idling when trucks are resting at truck stops or public rest areas and while trucks are waiting to perform a task at private distribution terminals. When truck spaces are electrified, truck drivers can shut down their engines and use electricity to power equipment which supplies air conditioning, heat, and electrical power for on-board appliances.

MIRTs can eliminate long duration idling from trucks that are stopped away from these central sites. For a more complete list of MIRTs see EPA's Idle Reduction Technology page at http://www.epa.gov/otaq/smartway/idlingtechnologies.htm.

This measure demonstrates the potential emissions reductions if every class 8a and 8b truck is equipped with a MIRT or has dependable access to sites with TSE in 2020.

To estimate the potential emissions reduction from this measure, we applied a reduction equal to the full amount of the emissions attributed to long duration idling in the MOBILE model, which is estimated to be 3.4% of the total NOx emissions from class 8a and 8b heavy duty diesel trucks. Since the MOBILE model does not distinguish between idling and operating emissions, EPA estimates idling emissions in the inventory based on fuel conversion factors. The inventory in the MOBILE model, however, does not fully capture long duration idling emissions. There is evidence that idling may represent a much greater share than 3.4% of the real world inventory, based on engine control module data from long haul trucking companies. As such, we believe the emissions reductions demonstrated from this measure in the RIA represent ambitious but realistic targets. For more information on determining baseline idling activity see EPA's "Guidance for Quantifying and Using Long-Duration Truck Idling Emission Reductions in State Implementation Plans and Transportation Conformity" available at http://www.epa.gov/smartway/idle-guid.htm.

Pollutants and Source Categories Affected by Measure (SCC): NO_x

Table 3a.8 Class 8a and 8b heavy duty diesel trucks (decrease NOx for all SCCs)

SCC	Note: All SCC Descriptions below begin with "Mobile Sources; Highway Vehicles - Diesel;"
2230074110	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Rural Interstate: Total
2230074130	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Rural Other Principal Arterial: Total
2230074150	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Rural Minor Arterial: Total
2230074170	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Rural Major Collector: Total
2230074190	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Rural Minor Collector: Total

2230074210	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Rural Local: Total
2230074230	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Urban Interstate: Total
2230074250	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Urban Other Freeways and Expressways: Total
2230074270	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Urban Other Principal Arterial: Total
2230074290	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Urban Minor Arterial: Total
2230074310	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Urban Collector: Total
2230074330	Heavy Duty Diesel Vehicles (HDDV) Class 8A & 8B;Urban Local: Total

Estimated Emissions Reduction from Measure (%): 3.4 % decrease in NOx for all SCCs affected by measure

3a.2.4 Commuter Programs

Commuter programs recognize and support employers who provide incentives to employees to reduce light-duty vehicle emissions. Employers implement a wide range of incentives to affect change in employee commuting habits including transit subsidies, bike-friendly facilities, telecommuting policies, and preferred parking for vanpools and carpools. The commuter measure in this RIA reflects a mixed package of incentives.

This measure demonstrates the potential emissions reductions from providing commuter incentives to 10% and 25% of the commuter population in 2020.

We used the findings from a recent Best Workplaces for Commuters survey, which was an EPA sponsored employee trip reduction program, to estimate the potential emissions reductions from this measure.[7] The BWC survey found that, on average, employees at workplaces with comprehensive commuter programs emit 15% fewer emissions than employees at workplaces that do not offer a comprehensive commuter program.

We believe that getting 10-25% of the workforce involved in commuter programs is realistic. For modeling purposes, we divided the commuter programs measure into two program penetration rates: 10% and 25%. This was meant to provide flexibility to model a lower penetration rate for areas that need only low levels of emissions reductions to achieve attainment.

According to the 2001 National Household Transportation Survey (NHTS) published by DOT, commute VMT represents 27% of total VMT. Based on this information, we calculated that BWC would reduce light-duty gasoline emissions by 0.4% and 1% with a 10% and 25% program penetration rate, respectively.

Pollutants and Source Categories Affected by Measure (SCC): NO_x, and VOC

[7] Herzog, E., Bricka, S., Audette, L., and Rockwell, J., 2005. *Do Employee Commuter Benefits Reduce Vehicle Emissions and Fuel Consumption? Results of the Fall 2004 Best Workplaces for Commuters Survey*, Transportation Research Record, Journal of the Transportation Research Board: Forthcoming.

Table 3a.9 All light-duty gasoline vehicles and trucks

SCC	Note: All SCC Descriptions below begin with "Mobile Sources; Highway Vehicles - Gasoline;"
2201001110	Light Duty Gasoline Vehicles (LDGV);Rural Interstate: Total
2201001130	Light Duty Gasoline Vehicles (LDGV);Rural Other Principal Arterial: Total
2201001150	Light Duty Gasoline Vehicles (LDGV);Rural Minor Arterial: Total
2201001170	Light Duty Gasoline Vehicles (LDGV);Rural Major Collector: Total
2201001190	Light Duty Gasoline Vehicles (LDGV);Rural Minor Collector: Total
2201001210	Light Duty Gasoline Vehicles (LDGV);Rural Local: Total
2201001230	Light Duty Gasoline Vehicles (LDGV);Urban Interstate: Total
2201001250	Light Duty Gasoline Vehicles (LDGV);Urban Other Freeways and Expressways: Total
2201001270	Light Duty Gasoline Vehicles (LDGV);Urban Other Principal Arterial: Total
2201001290	Light Duty Gasoline Vehicles (LDGV);Urban Minor Arterial: Total
2201001310	Light Duty Gasoline Vehicles (LDGV);Urban Collector: Total
2201001330	Light Duty Gasoline Vehicles (LDGV);Urban Local: Total
2201020110	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Rural Interstate: Total
2201020130	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Rural Other Principal Arterial: Total
2201020150	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Rural Minor Arterial: Total
2201020170	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Rural Major Collector: Total
2201020190	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Rural Minor Collector: Total
2201020210	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Rural Local: Total
2201020230	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Urban Interstate: Total
2201020250	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Urban Other Freeways and Expressways: Total
2201020270	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Urban Other Principal Arterial: Total
2201020290	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Urban Minor Arterial: Total
2201020310	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Urban Collector: Total
2201020330	Light Duty Gasoline Trucks 1 & 2 (M6) = LDGT1 (M5);Urban Local: Total
2201040110	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Rural Interstate: Total
2201040130	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Rural Other Principal Arterial: Total
2201040150	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Rural Minor Arterial: Total
2201040170	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Rural Major Collector: Total
2201040190	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Rural Minor Collector: Total
2201040210	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Rural Local: Total
2201040230	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Urban Interstate: Total
2201040250	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Urban Other Freeways and Expressways: Total
2201040270	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Urban Other Principal Arterial: Total
2201040290	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Urban Minor Arterial: Total
2201040310	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Urban Collector: Total
2201040330	Light Duty Gasoline Trucks 3 & 4 (M6) = LDGT2 (M5);Urban Local: Total

Estimated Emissions Reduction from Measure (%):
With a 10% program penetration rate: 0.4%
With a 25% program penetration rate: 1%

3a.2.5 Reduce Gasoline RVP from 7.8 to 7.0 in Remaining Nonattainment Areas

Volatility is the property of a liquid fuel that defines its evaporation characteristics. RVP is an abbreviation for "Reid vapor pressure," a common measure of gasoline volatility, as well as a generic term for gasoline volatility. EPA regulates the vapor pressure of all gasoline during the summer months (June 1 to September 15 at retail stations). Lower RVP helps to reduce VOCs, which are a precursor to ozone formation. This control measure represents the use of gasoline with a RVP limit of 7.0 psi from May through September in counties with an ozone season RVP value greater than 7.0 psi.

Under section 211(c)(4)(C) of the CAA, EPA may approve a non-identical state fuel control as a SIP provision, if the state demonstrates that the measure is necessary to achieve the national primary or secondary ambient air quality standard (NAAQS) that the plan implements. EPA can approve a state fuel requirement as necessary only if no other measures would bring about timely attainment, or if other measures exist but are unreasonable or impracticable.

Pollutants and Source Categories Affected by Measure (SCC):

- All light-duty gasoline vehicles and trucks: Affected SCC:
- 2201001000 Light Duty Gasoline Vehicles (LDGV), Total: All Road Types
- 2201020000 Light Duty Gasoline Trucks 1 (LDGT1), Total: All Road Types
- 2201040000 Light Duty Gasoline Trucks 2 (LDGT2), Total: All Road Types
- 2201070000 Heavy Duty Gasoline Vehicles (HDGV), Total: All Road Types
- 2201080000 Motorcycles (MC), Total: All Road Types

3a.2.6 Application order for Onroad and Nonroad Mobile Controls

<u>Application order- 0.084 Mobile</u>

- Eliminate Long Duration Idling
- ONRetrofit
- LOWRVP
- Best Workplaces for Commuters

<u>Application order- 0.084 Nonroad</u>

- Diesel C1&C2 Marine/Diesel C3 Marine - 90% Rule (adding controls for SCCs for residual fuel)
- ICAO Engine NOx Standards for Commercial Aircraft
- NRRetrofit
- LOWRVP

<u>Application order- 0.070 Mobile</u>

- Eliminate Long Duration Idling
- Inspection and Maintenance
- ONRetrofit

- LOWRVP
- Best Workplaces for Commuters

<u>Application order – 0.070 Nonroad</u>

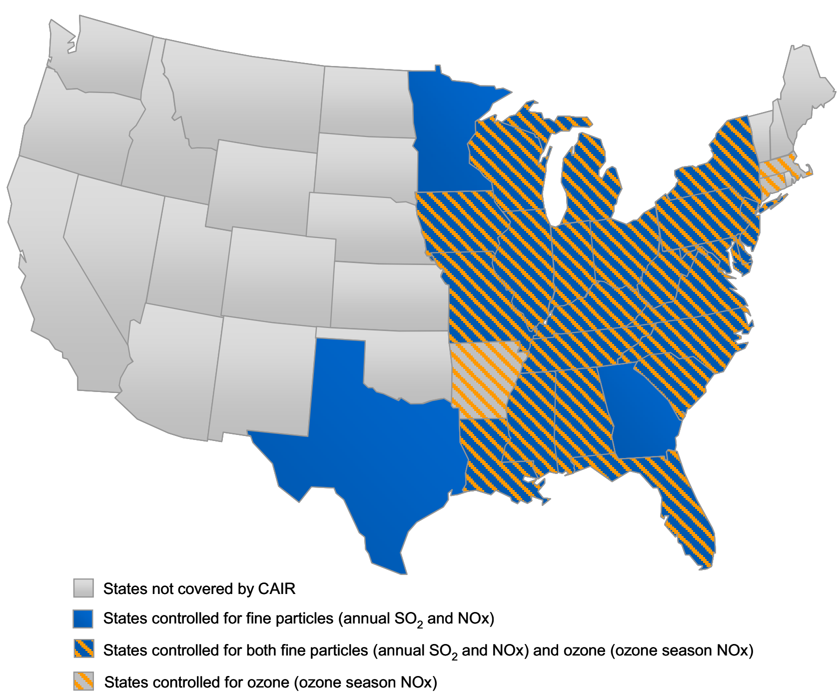
- Diesel C1&C2 Marine/Diesel C3 Marine - 90% Rule (adding controls for SCCs for residual fuel)
- ICAO Engine NOx Standards for Commercial Aircraft
- NRRetrofit
- LOWRVP

3a.3 EGU Controls Used in the Control Strategy

<u>CAIR</u>

The data and projections presented in Section 3.2.2 cover the electric power sector, an industry that will achieve significant emission reductions under the Clean Air Interstate Rule (CAIR) over the next 10 to 15 years. Based on an assessment of the emissions contributing to interstate transport of air pollution and available control measures, EPA determined that achieving required reductions in the identified States by controlling emissions from power plants is highly cost effective. CAIR will permanently cap emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) in the eastern United States. CAIR achieves large reductions of SO_2 and/or NO_x emissions across 28 eastern states and the District of Columbia.

Figure 3a.1 CAIR Affected Region



When fully implemented, CAIR will reduce SO_2 emissions in these states by over 70% and NO_x emissions by over 60% from 2003 levels (some of which are due to NOx SIP Call). This will result in significant environmental and health benefits and will substantially reduce premature mortality in the eastern United States. The benefits will continue to grow each year with further implementation. CAIR was designed with current air quality standard in mind, and requires significant emission reductions in the East, where they are needed most and where transport of pollution is a major concern. CAIR will bring most areas in the Eastern US into attainment with the current ozone and current $PM_{2.5}$ standards. Some areas will need to adopt additional local control measures beyond CAIR. CAIR is a regional solution to address transport, not a solution to all local nonattainment issues. The large reductions anticipated with CAIR, in conjunction with reasonable additional local control measures for SO_2, NO_x, and direct PM, will move States towards attainment in a deliberate and logical manner.

Based on the final State rules that have been submitted and the proposed State rules that EPA has reviewed, EPA believes that all States intend to use the CAIR trading programs as their mechanism for meeting the emission reduction requirements of CAIR.

The analysis in this section reflects these realities and attempts to show, in an illustrative fashion, the costs and impacts of meeting a proposed 8-hr ozone standard of 0.070 for the power sector.

Integrated Planning Model and Background

CAIR was designed to achieve significant emissions reductions in a highly cost-effective manner to reduce the transport of fine particles that have been found to contribute to nonattainment. EPA analysis has found that the most efficient method to achieve the emissions reduction targets is through a cap-and-trade system on the power sector that States have the option of adopting. The modeling done with IPM assumes a region-wide cap and trade system on the power sector for the States covered.

It is important to note that the analysis herein uses the Integrated Planning Model (IPM) v2.1.9 to ensure consistency with the analysis presented in 2006 PM NAAQS RIA and report incremental results. EPA's IPM v2.1.9 incorporates Federal and State rules and regulations adopted before March 2004 and various NSR settlements. A detailed discussion of uncertainties associated with the EGU sector can be found in 2006 PM NAAQS RIA (pg. 3-50). A newer version of the model (IPM v3.0) is available which includes input and model assumption updates in modeling power sector. IPM v3.0 will be used in the Final Ozone NAAQS RIA as part of the updated modeling platform. Additionally, other control strategies are being considered that may be applicable to the EGU sector, which would be presented in the final Ozone RIA.

The economic modeling using IPM presented in this and other chapters has been developed for specific analyses of the power sector. EPA's modeling is based on its best judgment for various input assumptions that are uncertain, particularly assumptions for future fuel prices and electricity demand growth. To some degree, EPA addresses the uncertainty surrounding these two assumptions through sensitivity analyses. More detail on IPM can be found in the model documentation, which provides additional information on the assumptions discussed here as well as all other assumptions and inputs to the model (http://www.epa.gov/airmarkets/progsregs/epa-ipm/past-modeling.html).

EGU NOx Emission Control Technologies

The Integrated Planning Model v2.1.9 (IPM) includes SO_2, NO_x, and mercury (Hg) emission control technology options for meeting existing and future federal, regional, and state, SO_2, NO_x and Hg emission limits. The NOx control technology options include Selective Catalytic Reduction (SCR) system and Selective Non-Catalytic Reduction (SNCR) systems. It is important to note that beyond these emission control options, IPM offers other compliance options for meeting emission limits. These include fuel switching, re-powering, and adjustments in the dispatching of electric generating units.

Table 3a.10 summarizes retrofit NOx emission control performance assumptions.

Table 3a.10. Summary of Retrofit NOx Emission Control Performance Assumptions

	Selective Catalytic Reduction (SCR)		**Selective Non-Catalytic Reduction (SNCR)**	
Unit Type	Coal	Oil/Gas*	Coal	Oil/Gas*
Percent Removal	90% down to 0.06 lb/mmBtu	80%	35%	50%
Size Applicability	Units. 100 MW	Units. 25 MW	Units. 25 MW and Units < 200 MW	Units. 25 MW

* Controls to oil- or gas-fired EGUs are not applied as part of the EGU control strategy included in this RIA.

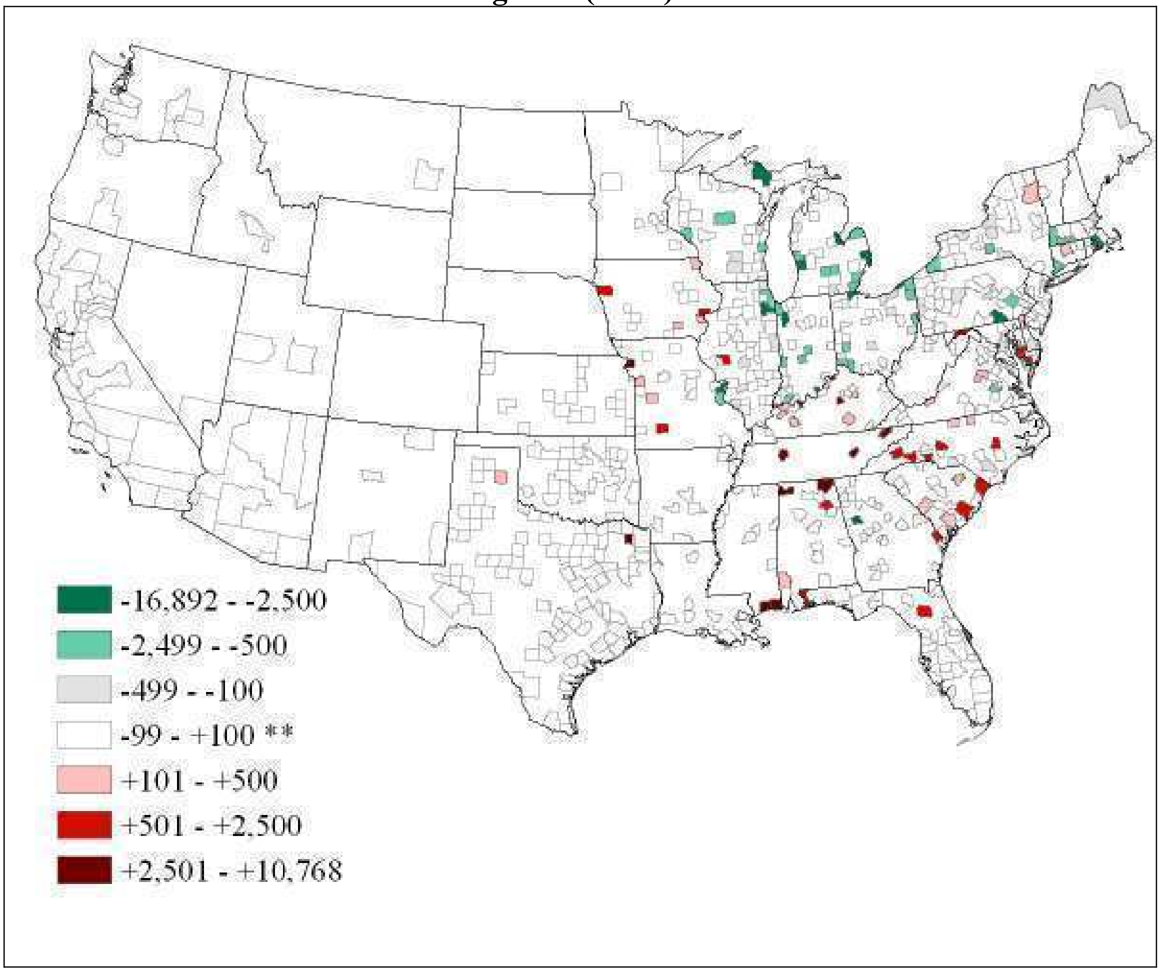
Existing coal-fired units that are retrofit with SCR have a NOx removal efficiency of 90%, with a minimum controlled NOx emission rate of 0.06 lb/mmBtu in IPM v2.1.9.. Potential (new) coal-fired, combined cycle, and IGCC units are modeled to be constructed with SCR systems and designed to have emission rates ranging between 0.02 and 0.06 lb NOx/mmBtu.

Detailed cost and performance derivations for NOx controls are discussed in detail in the EPA's documentation of IPM (http://www.epa.gov/airmarkets/progsregs/epa-ipm/past-modeling.html).

3a.4 Emissions Reductions by Sector

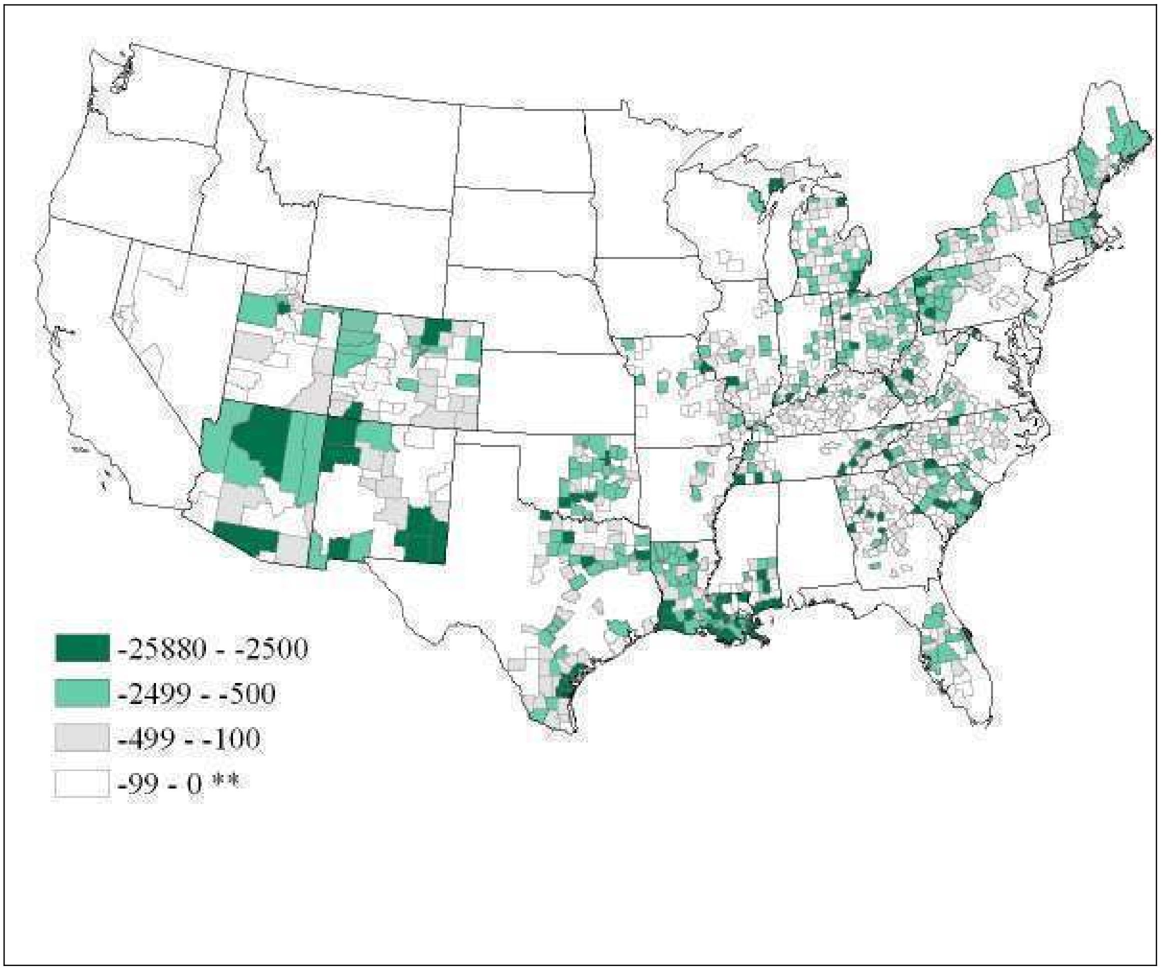
Figures 3a.2- 3a.6 show the NOx reductions for each sector under the 0.070 ppm control strategy.

Figure 3a.2 Tons of Nitrogen Oxide (NOx) Emissions Reduced from Electrical Generating Unit (EGU) Sources*



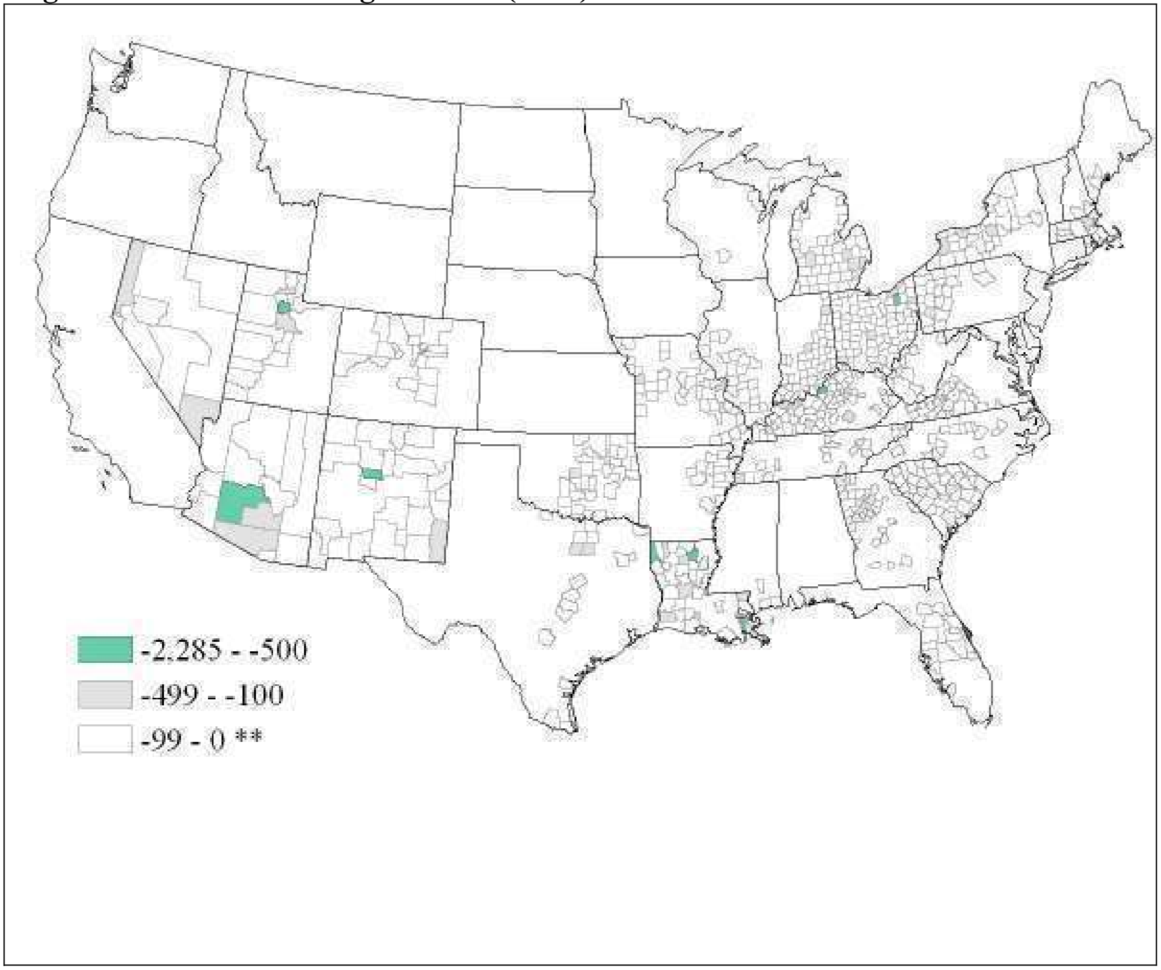
*Reductions are negative and increases are positive
**The -99 - +100 range is not shown because these are small county-level NOx reductions or increases that likely had little to no impact on ozone estimates. Most counties in this range had NOx differences of under 1 ton.

Figure 3a.3 Tons of Nitrogen Oxide (NOx) Emissions Reduced from Non-EGU Point Sources*



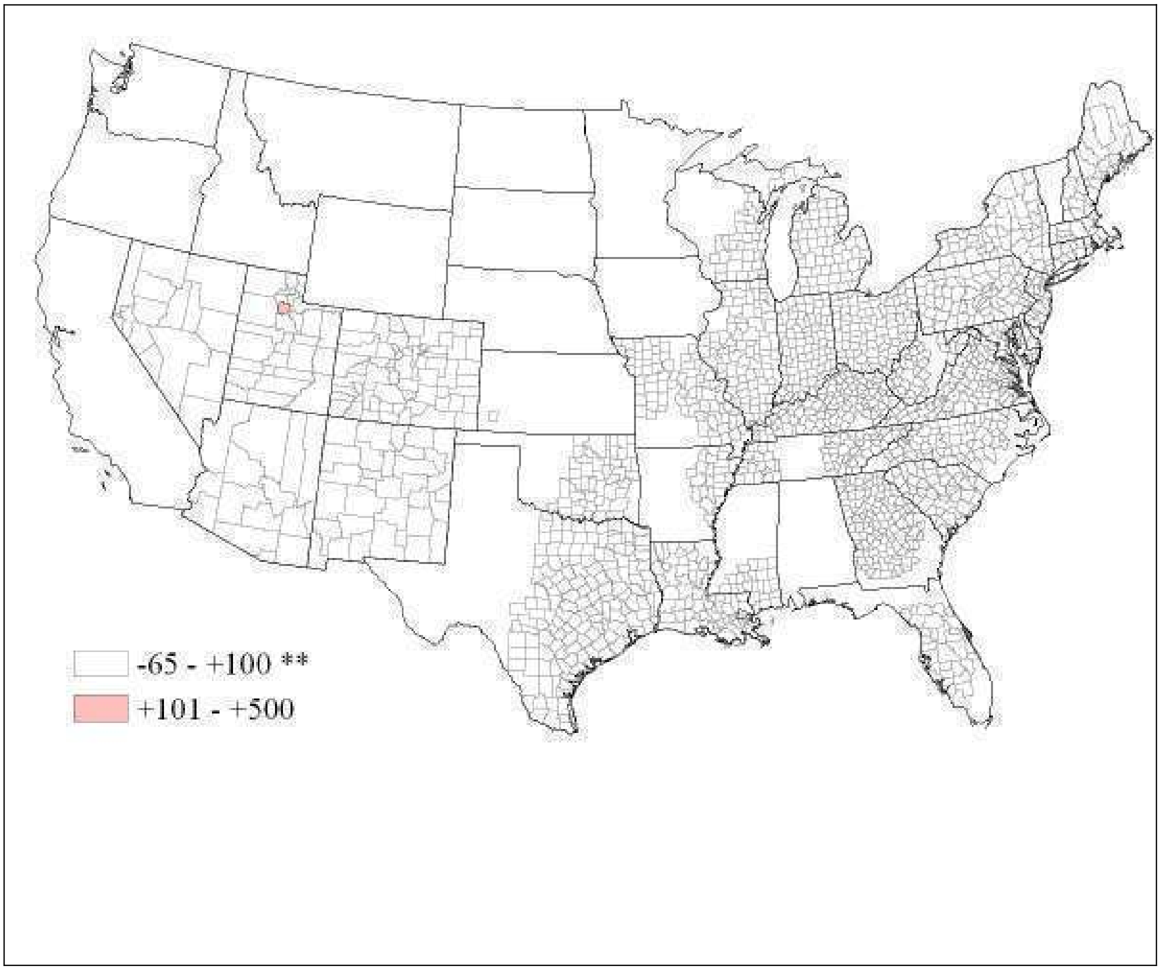
*Reductions are negative and increases are positive
**The -99 - 0 range is not shown because these are small county-level NOx reductions or increases that likely had little to no impact on ozone estimates. Most counties in this range had NOx differences of under 1 ton.

Figure 3a.4 Tons of Nitrogen Oxide (NOx) Emissions Reduced from Area Sources*



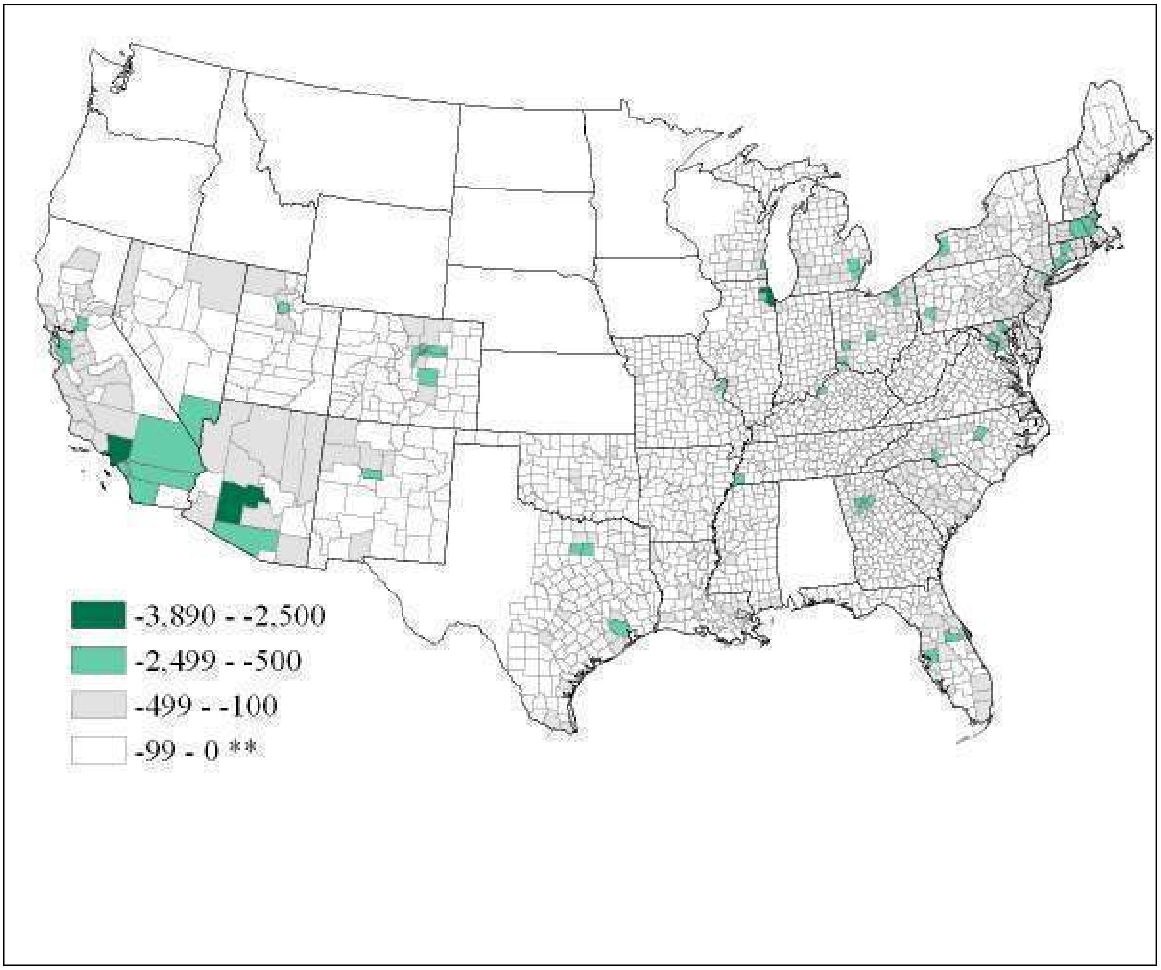
*Reductions are negative and increases are positive
**The -99 – 0 range is not shown because these are small county-level NOx reductions or increases that likely had little to no impact on ozone estimates. Most counties in this range had NOx differences of under 1 ton.

Figure 3a.5 Tons of Nitrogen Oxide (NOx) Emissions Reduced from Nonroad Sources*



*Reductions are negative and increases are positive
**The -99 - 0 range is not shown because these are small county-level NOx reductions or increases that likely had little to no impact on ozone estimates. Most counties in this range had NOx differences of under 1 ton.

Figure 3a.6 Tons of Nitrogen Oxide (NOx) Emissions Reduced from Onroad Sources*



*Reductions are negative and increases are positive
**The -99 - 0 range is not shown because these are small county-level NOx reductions or increases that likely had little to no impact on ozone estimates. Most counties in this range had NOx differences of under 1 ton.

3a.5 Change in Ozone Concentrations Between Baseline and Post-0.070 ppm Control Strategy Modeling

Table 3a.11 Changes in Ozone Concentrations between Baseline and Post-0.070 ppm Control Strategy Modeling

State	County	Baseline 8-hour ozone DV (ppm)	Control Scenario 8-hour ozone DV (ppm)	Change (ppm)
Alabama	Baldwin	0.067	0.066	0.001
Alabama	Clay	0.060	0.056	0.004
Alabama	Elmore	0.062	0.060	0.002
Alabama	Jefferson	0.064	0.063	0.001
Alabama	Madison	0.063	0.061	0.002
Alabama	Mobile	0.068	0.068	0.000
Alabama	Montgomery	0.061	0.060	0.001
Alabama	Morgan	0.066	0.065	0.001
Alabama	Shelby	0.066	0.065	0.001
Alabama	Tuscaloosa	0.057	0.056	0.001
Arizona	Maricopa	0.078	0.077	0.001
Arizona	Pinal	0.072	0.071	0.001
Arkansas	Crittenden	0.075	0.072	0.003
Arkansas	Pulaski	0.069	0.068	0.001
California	Alameda	0.067	0.067	0.000
California	Amador	0.068	0.068	0.000
California	Butte	0.069	0.069	0.000
California	Calaveras	0.073	0.073	0.000
California	Colusa	0.059	0.059	0.000
California	Contra Costa	0.070	0.070	0.000
California	El Dorado	0.080	0.080	0.000
California	Fresno	0.092	0.092	0.000
California	Glenn	0.060	0.060	0.000
California	Imperial	0.072	0.072	0.000
California	Kern	0.096	0.096	0.000
California	Kings	0.079	0.079	0.000
California	Lake	0.053	0.053	0.000
California	Los Angeles	0.105	0.105	0.000
California	Madera	0.075	0.075	0.000
California	Mariposa	0.073	0.073	0.000
California	Merced	0.080	0.080	0.000
California	Monterey	0.054	0.054	0.000

California	Napa	0.051	0.051	0.000
California	Nevada	0.076	0.076	0.000
California	Orange	0.066	0.065	0.001
California	Placer	0.076	0.076	0.000
California	Riverside	0.102	0.102	0.000
California	Sacramento	0.076	0.076	0.000
California	San Benito	0.067	0.067	0.000
California	San Bernardino	0.129	0.129	0.000
California	San Diego	0.077	0.077	0.000
California	San Joaquin	0.067	0.067	0.000
California	San Luis Obispo	0.053	0.053	0.000
California	Santa Barbara	0.065	0.065	0.000
California	Santa Clara	0.065	0.065	0.000
California	Santa Cruz	0.054	0.055	-0.001
California	Shasta	0.058	0.058	0.000
California	Solano	0.057	0.057	0.000
California	Sonoma	0.049	0.049	0.000
California	Stanislaus	0.076	0.076	0.000
California	Sutter	0.065	0.065	0.000
California	Tehama	0.066	0.066	0.000
California	Tulare	0.088	0.088	0.000
California	Tuolumne	0.073	0.073	0.000
California	Ventura	0.079	0.080	-0.001
California	Yolo	0.064	0.064	0.000
Colorado	Adams	0.061	0.060	0.001
Colorado	Arapahoe	0.073	0.072	0.001
Colorado	Boulder	0.066	0.064	0.002
Colorado	Denver	0.068	0.067	0.001
Colorado	Douglas	0.076	0.076	0.000
Colorado	El Paso	0.064	0.063	0.001
Colorado	Jefferson	0.078	0.076	0.002
Colorado	Larimer	0.069	0.067	0.002
Colorado	Weld	0.067	0.065	0.002
Connecticut	Fairfield	0.088	0.087	0.001
Connecticut	Hartford	0.069	0.067	0.002
Connecticut	Litchfield	0.063	0.061	0.002
Connecticut	Middlesex	0.081	0.080	0.001
Connecticut	New Haven	0.084	0.083	0.001
Connecticut	New London	0.072	0.070	0.002
Connecticut	Tolland	0.071	0.069	0.002
D.C.	Washington	0.076	0.073	0.003

Delaware	Kent	0.072	0.070	0.002
Delaware	New Castle	0.075	0.073	0.002
Delaware	Sussex	0.070	0.068	0.002
Florida	Bay	0.067	0.066	0.001
Florida	Brevard	0.055	0.053	0.002
Florida	Duval	0.058	0.057	0.001
Florida	Escambia	0.069	0.069	0.000
Florida	Hillsborough	0.072	0.071	0.001
Florida	Manatee	0.067	0.065	0.002
Florida	Pasco	0.061	0.060	0.001
Florida	Pinellas	0.064	0.063	0.001
Florida	Santa Rosa	0.065	0.064	0.001
Florida	Sarasota	0.063	0.061	0.002
Georgia	Bibb	0.073	0.069	0.004
Georgia	Chatham	0.057	0.056	0.001
Georgia	Cherokee	0.055	0.052	0.003
Georgia	Cobb	0.072	0.068	0.004
Georgia	Coweta	0.072	0.064	0.008
Georgia	Dawson	0.058	0.055	0.003
Georgia	De Kalb	0.076	0.072	0.004
Georgia	Douglas	0.071	0.067	0.004
Georgia	Fayette	0.069	0.066	0.003
Georgia	Fulton	0.080	0.076	0.004
Georgia	Glynn	0.058	0.057	0.001
Georgia	Gwinnett	0.067	0.064	0.003
Georgia	Henry	0.072	0.068	0.004
Georgia	Murray	0.062	0.059	0.003
Georgia	Muscogee	0.065	0.061	0.004
Georgia	Paulding	0.068	0.065	0.003
Georgia	Richmond	0.067	0.063	0.004
Georgia	Rockdale	0.071	0.067	0.004
Illinois	Adams	0.062	0.057	0.005
Illinois	Champaign	0.064	0.062	0.002
Illinois	Clark	0.057	0.056	0.001
Illinois	Cook	0.083	0.083	0.000
Illinois	Du Page	0.065	0.064	0.001
Illinois	Effingham	0.062	0.061	0.001
Illinois	Hamilton	0.066	0.064	0.002
Illinois	Jersey	0.074	0.069	0.005
Illinois	Kane	0.067	0.066	0.001
Illinois	Lake	0.074	0.073	0.001

Illinois	Macon	0.060	0.059	0.001
Illinois	Macoupin	0.064	0.060	0.004
Illinois	Madison	0.071	0.066	0.005
Illinois	McHenry	0.070	0.068	0.002
Illinois	McLean	0.063	0.061	0.002
Illinois	Peoria	0.066	0.064	0.002
Illinois	Randolph	0.065	0.062	0.003
Illinois	Rock Island	0.058	0.057	0.001
Illinois	Sangamon	0.060	0.058	0.002
Illinois	St Clair	0.072	0.069	0.003
Illinois	Will	0.068	0.067	0.001
Illinois	Winnebago	0.061	0.060	0.001
Indiana	Allen	0.070	0.068	0.002
Indiana	Boone	0.072	0.069	0.003
Indiana	Carroll	0.066	0.064	0.002
Indiana	Clark	0.076	0.074	0.002
Indiana	Delaware	0.069	0.067	0.002
Indiana	Floyd	0.071	0.070	0.001
Indiana	Gibson	0.056	0.054	0.002
Indiana	Greene	0.069	0.067	0.002
Indiana	Hamilton	0.076	0.073	0.003
Indiana	Hancock	0.074	0.071	0.003
Indiana	Hendricks	0.071	0.069	0.002
Indiana	Huntington	0.067	0.065	0.002
Indiana	Jackson	0.068	0.065	0.003
Indiana	Johnson	0.070	0.068	0.002
Indiana	La Porte	0.075	0.073	0.002
Indiana	Lake	0.084	0.083	0.001
Indiana	Madison	0.071	0.068	0.003
Indiana	Marion	0.075	0.072	0.003
Indiana	Morgan	0.070	0.066	0.004
Indiana	Perry	0.071	0.071	0.000
Indiana	Porter	0.078	0.077	0.001
Indiana	Posey	0.071	0.070	0.001
Indiana	Shelby	0.077	0.074	0.003
Indiana	St Joseph	0.069	0.067	0.002
Indiana	Vanderburgh	0.068	0.066	0.002
Indiana	Vigo	0.070	0.065	0.005
Indiana	Warrick	0.068	0.067	0.001
Iowa	Clinton	0.063	0.062	0.001
Iowa	Scott	0.066	0.065	0.001

Kansas	Wyandotte	0.070	0.069	0.001
Kentucky	Bell	0.063	0.062	0.001
Kentucky	Boone	0.067	0.066	0.001
Kentucky	Boyd	0.072	0.067	0.005
Kentucky	Bullitt	0.067	0.064	0.003
Kentucky	Campbell	0.077	0.073	0.004
Kentucky	Carter	0.064	0.061	0.003
Kentucky	Christian	0.066	0.065	0.001
Kentucky	Daviess	0.062	0.062	0.000
Kentucky	Edmonson	0.067	0.066	0.001
Kentucky	Fayette	0.063	0.061	0.002
Kentucky	Graves	0.068	0.066	0.002
Kentucky	Greenup	0.068	0.064	0.004
Kentucky	Hancock	0.067	0.067	0.000
Kentucky	Hardin	0.068	0.065	0.003
Kentucky	Henderson	0.066	0.065	0.001
Kentucky	Jefferson	0.072	0.070	0.002
Kentucky	Jessamine	0.062	0.063	-0.001
Kentucky	Kenton	0.073	0.069	0.004
Kentucky	Livingston	0.071	0.069	0.002
Kentucky	McCracken	0.069	0.067	0.002
Kentucky	McLean	0.065	0.064	0.001
Kentucky	Oldham	0.072	0.070	0.002
Kentucky	Pulaski	0.065	0.064	0.001
Kentucky	Scott	0.056	0.055	0.001
Kentucky	Simpson	0.066	0.065	0.001
Kentucky	Trigg	0.060	0.058	0.002
Kentucky	Warren	0.066	0.065	0.001
Louisiana	Ascension	0.071	0.066	0.005
Louisiana	Bossier	0.073	0.070	0.003
Louisiana	Caddo	0.068	0.065	0.003
Louisiana	Calcasieu	0.072	0.067	0.005
Louisiana	East Baton Rouge	0.077	0.074	0.003
Louisiana	Grant	0.063	0.059	0.004
Louisiana	Iberville	0.076	0.072	0.004
Louisiana	Jefferson	0.072	0.069	0.003
Louisiana	Lafayette	0.070	0.064	0.006
Louisiana	Lafourche	0.072	0.068	0.004
Louisiana	Livingston	0.072	0.068	0.004
Louisiana	Orleans	0.060	0.058	0.002
Louisiana	Ouachita	0.068	0.064	0.004

Louisiana	Pointe Coupee	0.064	0.060	0.004
Louisiana	St Bernard	0.067	0.065	0.002
Louisiana	St Charles	0.068	0.066	0.002
Louisiana	St James	0.069	0.065	0.004
Louisiana	St John The Baptist	0.072	0.069	0.003
Louisiana	St Mary	0.068	0.062	0.006
Louisiana	West Baton Rouge	0.074	0.071	0.003
Maine	Cumberland	0.065	0.063	0.002
Maine	Hancock	0.070	0.067	0.003
Maine	Kennebec	0.060	0.057	0.003
Maine	Knox	0.063	0.060	0.003
Maine	Penobscot	0.062	0.059	0.003
Maine	York	0.069	0.066	0.003
Maryland	Anne Arundel	0.076	0.074	0.002
Maryland	Baltimore	0.077	0.075	0.002
Maryland	Calvert	0.065	0.063	0.002
Maryland	Carroll	0.068	0.066	0.002
Maryland	Cecil	0.078	0.075	0.003
Maryland	Charles	0.070	0.068	0.002
Maryland	Frederick	0.067	0.065	0.002
Maryland	Harford	0.084	0.082	0.002
Maryland	Kent	0.075	0.072	0.003
Maryland	Montgomery	0.072	0.070	0.002
Maryland	Prince Georges	0.075	0.072	0.003
Maryland	Washington	0.067	0.063	0.004
Massachusetts	Barnstable	0.072	0.070	0.002
Massachusetts	Berkshire	0.067	0.066	0.001
Massachusetts	Bristol	0.072	0.069	0.003
Massachusetts	Essex	0.071	0.070	0.001
Massachusetts	Hampden	0.070	0.068	0.002
Massachusetts	Hampshire	0.068	0.066	0.002
Massachusetts	Middlesex	0.067	0.064	0.003
Massachusetts	Suffolk	0.067	0.065	0.002
Massachusetts	Worcester	0.064	0.062	0.002
Michigan	Allegan	0.075	0.072	0.003
Michigan	Benzie	0.070	0.068	0.002
Michigan	Berrien	0.072	0.070	0.002
Michigan	Cass	0.069	0.067	0.002
Michigan	Clinton	0.066	0.062	0.004

Michigan	Genesee	0.067	0.064	0.003
Michigan	Huron	0.070	0.067	0.003
Michigan	Ingham	0.066	0.062	0.004
Michigan	Kalamazoo	0.065	0.062	0.003
Michigan	Kent	0.067	0.064	0.003
Michigan	Lenawee	0.069	0.063	0.006
Michigan	Macomb	0.080	0.078	0.002
Michigan	Mason	0.072	0.070	0.002
Michigan	Missaukee	0.064	0.061	0.003
Michigan	Muskegon	0.074	0.071	0.003
Michigan	Oakland	0.077	0.075	0.002
Michigan	Ottawa	0.070	0.067	0.003
Michigan	St Clair	0.073	0.071	0.002
Michigan	Washtenaw	0.076	0.072	0.004
Michigan	Wayne	0.076	0.073	0.003
Minnesota	Anoka	0.058	0.057	0.001
Minnesota	Washington	0.059	0.059	0.000
Mississippi	De Soto	0.069	0.067	0.002
Mississippi	Hancock	0.070	0.068	0.002
Mississippi	Harrison	0.064	0.067	-0.003
Mississippi	Hinds	0.055	0.053	0.002
Mississippi	Jackson	0.069	0.070	-0.001
Mississippi	Warren	0.054	0.051	0.003
Missouri	Clay	0.070	0.068	0.002
Missouri	Jefferson	0.076	0.072	0.004
Missouri	Platte	0.069	0.068	0.001
Missouri	St Charles	0.076	0.072	0.004
Missouri	St Louis	0.079	0.075	0.004
Missouri	St Louis City	0.078	0.075	0.003
Missouri	Ste Genevieve	0.068	0.064	0.004
Nevada	Clark	0.072	0.072	0.000
Nevada	Washoe	0.063	0.063	0.000
New Hampshire	Hillsborough	0.063	0.060	0.003
New Hampshire	Rockingham	0.063	0.061	0.002
New Jersey	Atlantic	0.071	0.069	0.002
New Jersey	Bergen	0.077	0.075	0.002
New Jersey	Camden	0.082	0.080	0.002
New Jersey	Cumberland	0.073	0.071	0.002
New Jersey	Essex	0.056	0.055	0.001

New Jersey	Gloucester	0.080	0.078	0.002
New Jersey	Hudson	0.074	0.073	0.001
New Jersey	Hunterdon	0.078	0.077	0.001
New Jersey	Mercer	0.083	0.081	0.002
New Jersey	Middlesex	0.081	0.079	0.002
New Jersey	Monmouth	0.078	0.077	0.001
New Jersey	Morris	0.077	0.075	0.002
New Jersey	Ocean	0.084	0.081	0.003
New Jersey	Passaic	0.071	0.069	0.002
New Mexico	Dona Ana	0.071	0.070	0.001
New Mexico	San Juan	0.071	0.068	0.003
New York	Albany	0.064	0.063	0.001
New York	Bronx	0.069	0.068	0.001
New York	Chautauqua	0.074	0.070	0.004
New York	Dutchess	0.067	0.066	0.001
New York	Erie	0.079	0.075	0.004
New York	Jefferson	0.075	0.072	0.003
New York	Monroe	0.073	0.072	0.001
New York	Niagara	0.076	0.075	0.001
New York	Orange	0.063	0.061	0.002
New York	Putnam	0.070	0.068	0.002
New York	Queens	0.068	0.067	0.001
New York	Richmond	0.074	0.072	0.002
New York	Saratoga	0.066	0.065	0.001
New York	Suffolk	0.086	0.084	0.002
New York	Ulster	0.065	0.063	0.002
New York	Wayne	0.070	0.068	0.002
New York	Westchester	0.075	0.074	0.001
North Carolina	Alexander	0.066	0.064	0.002
North Carolina	Buncombe	0.065	0.065	0.000
North Carolina	Camden	0.063	0.062	0.001
North Carolina	Caswell	0.063	0.059	0.004
North Carolina	Chatham	0.063	0.061	0.002
North Carolina	Cumberland	0.065	0.063	0.002
North Carolina	Davie	0.067	0.065	0.002

North Carolina	Durham	0.063	0.060	0.003
North Carolina	Edgecombe	0.066	0.064	0.002
North Carolina	Forsyth	0.068	0.065	0.003
North Carolina	Franklin	0.063	0.060	0.003
North Carolina	Granville	0.067	0.065	0.002
North Carolina	Guilford	0.064	0.061	0.003
North Carolina	Johnston	0.062	0.059	0.003
North Carolina	Lincoln	0.069	0.067	0.002
North Carolina	Mecklenburg	0.074	0.072	0.002
North Carolina	New Hanover	0.062	0.061	0.001
North Carolina	Northampton	0.067	0.064	0.003
North Carolina	Person	0.071	0.068	0.003
North Carolina	Randolph	0.063	0.060	0.003
North Carolina	Rockingham	0.064	0.061	0.003
North Carolina	Rowan	0.073	0.071	0.002
North Carolina	Union	0.065	0.063	0.002
North Carolina	Wake	0.066	0.064	0.002
Ohio	Allen	0.071	0.067	0.004
Ohio	Ashtabula	0.077	0.073	0.004
Ohio	Butler	0.073	0.070	0.003
Ohio	Clark	0.068	0.063	0.005
Ohio	Clermont	0.071	0.068	0.003
Ohio	Clinton	0.074	0.070	0.004
Ohio	Cuyahoga	0.071	0.068	0.003
Ohio	Delaware	0.071	0.068	0.003
Ohio	Franklin	0.076	0.073	0.003
Ohio	Geauga	0.080	0.076	0.004
Ohio	Greene	0.068	0.062	0.006

Ohio	Hamilton	0.074	0.070	0.004
Ohio	Jefferson	0.067	0.064	0.003
Ohio	Knox	0.069	0.065	0.004
Ohio	Lake	0.076	0.073	0.003
Ohio	Lawrence	0.069	0.065	0.004
Ohio	Licking	0.069	0.066	0.003
Ohio	Lorain	0.071	0.068	0.003
Ohio	Lucas	0.072	0.069	0.003
Ohio	Madison	0.068	0.063	0.005
Ohio	Mahoning	0.071	0.068	0.003
Ohio	Medina	0.069	0.066	0.003
Ohio	Miami	0.065	0.061	0.004
Ohio	Montgomery	0.068	0.062	0.006
Ohio	Portage	0.074	0.070	0.004
Ohio	Preble	0.061	0.058	0.003
Ohio	Stark	0.071	0.068	0.003
Ohio	Summit	0.075	0.071	0.004
Ohio	Trumbull	0.073	0.070	0.003
Ohio	Warren	0.071	0.068	0.003
Ohio	Washington	0.064	0.061	0.003
Ohio	Wood	0.070	0.067	0.003
Oklahoma	Cleveland	0.065	0.064	0.001
Oklahoma	Marshall	0.069	0.067	0.002
Oklahoma	Mc Clain	0.067	0.065	0.002
Oklahoma	Oklahoma	0.067	0.065	0.002
Oklahoma	Tulsa	0.073	0.070	0.003
Pennsylvania	Allegheny	0.079	0.076	0.003
Pennsylvania	Armstrong	0.072	0.069	0.003
Pennsylvania	Beaver	0.076	0.073	0.003
Pennsylvania	Berks	0.071	0.068	0.003
Pennsylvania	Blair	0.065	0.063	0.002
Pennsylvania	Bucks	0.084	0.082	0.002
Pennsylvania	Cambria	0.071	0.068	0.003
Pennsylvania	Centre	0.066	0.064	0.002
Pennsylvania	Chester	0.075	0.073	0.002
Pennsylvania	Clearfield	0.068	0.065	0.003
Pennsylvania	Dauphin	0.070	0.068	0.002
Pennsylvania	Delaware	0.074	0.073	0.001
Pennsylvania	Erie	0.069	0.067	0.002
Pennsylvania	Franklin	0.070	0.068	0.002
Pennsylvania	Greene	0.069	0.066	0.003

Pennsylvania	Lackawanna	0.064	0.062	0.002
Pennsylvania	Lancaster	0.071	0.068	0.003
Pennsylvania	Lawrence	0.063	0.059	0.004
Pennsylvania	Lehigh	0.071	0.069	0.002
Pennsylvania	Luzerne	0.064	0.063	0.001
Pennsylvania	Lycoming	0.059	0.057	0.002
Pennsylvania	Mercer	0.073	0.069	0.004
Pennsylvania	Montgomery	0.078	0.076	0.002
Pennsylvania	Northampton	0.072	0.070	0.002
Pennsylvania	Perry	0.063	0.061	0.002
Pennsylvania	Philadelphia	0.080	0.078	0.002
Pennsylvania	Washington	0.070	0.067	0.003
Pennsylvania	Westmoreland	0.070	0.067	0.003
Pennsylvania	York	0.071	0.067	0.004
Rhode Island	Kent	0.074	0.072	0.002
Rhode Island	Providence	0.071	0.068	0.003
Rhode Island	Washington	0.075	0.072	0.003
South Carolina	Anderson	0.067	0.065	0.002
South Carolina	Berkeley	0.058	0.057	0.001
South Carolina	Charleston	0.057	0.055	0.002
South Carolina	Cherokee	0.063	0.061	0.002
South Carolina	Chester	0.064	0.061	0.003
South Carolina	Edgefield	0.063	0.058	0.005
South Carolina	Pickens	0.065	0.063	0.002
South Carolina	Richland	0.069	0.066	0.003
South Carolina	Spartanburg	0.066	0.063	0.003
South Carolina	Union	0.062	0.059	0.003
South Carolina	York	0.063	0.061	0.002
Tennessee	Anderson	0.064	0.061	0.003
Tennessee	Blount	0.071	0.067	0.004
Tennessee	Davidson	0.064	0.063	0.001
Tennessee	Hamilton	0.066	0.063	0.003

Tennessee	Haywood	0.067	0.063	0.004
Tennessee	Jefferson	0.068	0.065	0.003
Tennessee	Knox	0.071	0.066	0.005
Tennessee	Meigs	0.066	0.063	0.003
Tennessee	Rutherford	0.065	0.063	0.002
Tennessee	Shelby	0.072	0.069	0.003
Tennessee	Sullivan	0.072	0.062	0.010
Tennessee	Sumner	0.068	0.067	0.001
Tennessee	Williamson	0.068	0.066	0.002
Tennessee	Wilson	0.066	0.065	0.001
Texas	Brazoria	0.078	0.076	0.002
Texas	Collin	0.075	0.072	0.003
Texas	Dallas	0.079	0.077	0.002
Texas	Denton	0.078	0.075	0.003
Texas	El Paso	0.070	0.069	0.001
Texas	Ellis	0.074	0.069	0.005
Texas	Galveston	0.078	0.075	0.003
Texas	Gregg	0.079	0.073	0.006
Texas	Harris	0.092	0.090	0.002
Texas	Harrison	0.065	0.062	0.003
Texas	Hood	0.068	0.066	0.002
Texas	Jefferson	0.079	0.072	0.007
Texas	Johnson	0.073	0.069	0.004
Texas	Marion	0.069	0.065	0.004
Texas	Montgomery	0.072	0.070	0.002
Texas	Orange	0.068	0.064	0.004
Texas	Parker	0.068	0.066	0.002
Texas	Rockwall	0.067	0.063	0.004
Texas	Smith	0.071	0.068	0.003
Texas	Tarrant	0.079	0.076	0.003
Utah	Box Elder	0.066	0.065	0.001
Utah	Cache	0.055	0.054	0.001
Utah	Davis	0.071	0.070	0.001
Utah	Salt Lake	0.073	0.072	0.001
Utah	Utah	0.070	0.069	0.001
Utah	Weber	0.067	0.066	0.001
Vermont	Bennington	0.060	0.059	0.001
Virginia	Alexandria City	0.072	0.069	0.003
Virginia	Arlington	0.078	0.075	0.003
Virginia	Caroline	0.063	0.062	0.001
Virginia	Charles City	0.074	0.073	0.001

Virginia	Chesterfield	0.071	0.070	0.001
Virginia	Fairfax	0.077	0.074	0.003
Virginia	Fauquier	0.062	0.061	0.001
Virginia	Frederick	0.067	0.064	0.003
Virginia	Hampton City	0.077	0.076	0.001
Virginia	Hanover	0.074	0.072	0.002
Virginia	Henrico	0.074	0.073	0.001
Virginia	Loudoun	0.070	0.068	0.002
Virginia	Madison	0.067	0.065	0.002
Virginia	Prince William	0.066	0.064	0.002
Virginia	Roanoke	0.069	0.067	0.002
Virginia	Stafford	0.064	0.062	0.002
Virginia	Suffolk City	0.080	0.080	0.000
West Virginia	Berkeley	0.068	0.063	0.005
West Virginia	Cabell	0.073	0.069	0.004
West Virginia	Hancock	0.068	0.065	0.003
West Virginia	Kanawha	0.069	0.064	0.005
West Virginia	Monongalia	0.064	0.063	0.001
West Virginia	Ohio	0.067	0.064	0.003
West Virginia	Wood	0.065	0.062	0.003
Wisconsin	Brown	0.065	0.063	0.002
Wisconsin	Columbia	0.062	0.061	0.001
Wisconsin	Dane	0.062	0.060	0.002
Wisconsin	Dodge	0.063	0.062	0.001
Wisconsin	Door	0.074	0.072	0.002
Wisconsin	Fond Du Lac	0.061	0.060	0.001
Wisconsin	Jefferson	0.066	0.065	0.001
Wisconsin	Kenosha	0.086	0.085	0.001
Wisconsin	Kewaunee	0.074	0.072	0.002
Wisconsin	Manitowoc	0.074	0.072	0.002
Wisconsin	Milwaukee	0.075	0.073	0.002
Wisconsin	Outagamie	0.059	0.057	0.002
Wisconsin	Ozaukee	0.079	0.077	0.002
Wisconsin	Racine	0.079	0.077	0.002
Wisconsin	Rock	0.069	0.068	0.001
Wisconsin	Sheboygan	0.082	0.080	0.002
Wisconsin	Walworth	0.066	0.065	0.001
Wisconsin	Washington	0.065	0.063	0.002
Wisconsin	Waukesha	0.067	0.065	0.002
Wisconsin	Winnebago	0.063	0.062	0.001

Chapter 4:   Approach for Estimating Reductions for Full Attainment Scenario

Synopsis

This chapter presents the methodology used to estimate emission reductions that may be needed to reach national attainment of the proposed tighter alternate primary 8-hour ozone standard of 0.070-0.075 ppm. After applying the hypothetical control strategy described in Chapter 3, there were many areas that were still not projected to attain the more stringent standard modeled of 0.070 ppm. This chapter presents the methodology EPA developed to determine emissions reductions needed for national attainment of the alternate standards on each end of the proposed range (e.g. 0.070 and 0.075 ppm). It also presents estimated emission reductions needed to attain a more stringent option analyzed of 0.065 ppm, and a less stringent option of 0.079 ppm.

4.1   Development of Air Quality Impact Ratios for Determination of Extrapolated Costs

Table 3a.11 lists the highest projected design value in each monitored county for the 2020 baseline (current standard – effectively 0.084 ppm) and after application of the illustrative national control strategy designed to attain an alternate primary standard of 0.070 ppm. From this table one can determine the counties that did not meet the target air quality levels after implementation of the national hypothetical 0.070 control scenario. Because the goal of the RIA is to estimate the estimated incremental costs of full attainment, some estimate of the remaining emissions needed to reach these targets is required for each of these areas.

It was beyond the scope of this illustrative analysis to perform detailed area-specific analyses of the predicted additional emissions reductions needed to meet various air quality goals. Instead, based on existing air quality sensitivity modeling, EPA developed several simple, generic relationships of the expected air quality improvement to be achieved as a result of ozone precursor reductions. These relationships are referred to here as "impact ratios" and have units of ppb of ozone improvement per thousand tons of ozone precursor emissions reduction (ppb/kton). Two separate approaches were used to develop the impact ratios. The following paragraphs describe the development of the impact ratios used in the extrapolated cost analysis of this RIA. Based on data presented later in this chapter and considering the uncertainties and limitations of both approaches, we decided to use a single impact ratio for NOx and a single impact ratio for VOC for the purposes of this illustrative analysis for all areas in the U.S. that are included in the extrapolated cost analysis.

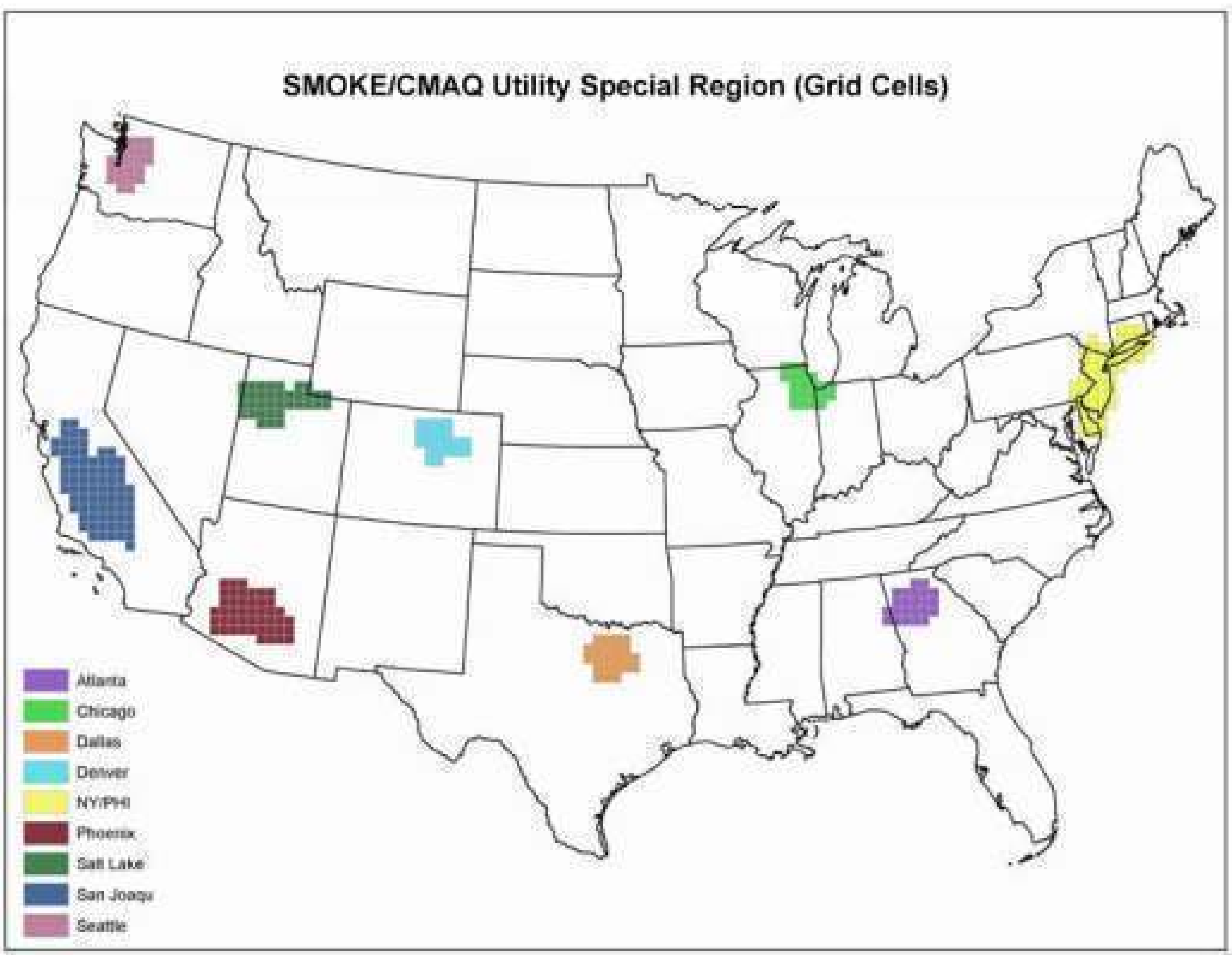
4.1.1   Approach A: Use of Sensitivity Modeling of Local Emissions Reductions

In this approach, the impact ratios were calculated based on modeling results from four existing, 36 km CMAQ 2010 emissions sensitivity simulations and a 2010 base case simulation also derived from previously completed modeling:

1. 90% NOx reduction in all anthropogenic sectors in nine specific local areas,
2. 90% NOx reduction in all anthropogenic sectors over the rest of the U.S.,
3. 90% VOC reduction in all anthropogenic sectors in nine specific local areas,
4. 90% VOC reduction in all anthropogenic sectors over the rest of the U.S.

We calculated the ppb/kton ratios for five of the nine zones shown in Figure 4.1 that are included in the extrapolated costs analysis: Dallas, Atlanta, the Lake Michigan area, the Northeast Corridor, and central California. It is expected that these five zones would provide a representative range of ratios, so the analysis was not done for Denver, Phoenix, and Salt Lake City. Because we were not calculating extrapolated tons for Seattle, the ratio determination was not done for that region. For monitoring sites in each of these five geographic areas we compared the ozone improvement in the 90% control cases (simulations 1 and 3) against the tons of NOx and VOC reduced within the corresponding control area. The impact ratio for each site was calculated by dividing the ozone improvement by the corresponding tons reduced. Impact ratios were calculated for 88 sites over the five analysis zones. The results from Approach A are summarized in Table 4.2

Figure 4.1: Nine Local Control Areas in Existing 2010 Sensitivity Runs



A sample calculation for one of the sites in the five analysis zones (a monitoring site located in Denton TX) is shown below:

- A 90% NOx reduction equals 130.4 ktons in the local Dallas area.
- The ozone improvement from this reduction was 17.6 ppb (87.9 to 70.3).
- This yields an impact ratio of 0.135 ppb/kton for this county.

The advantage to this approach is that it allows for all-sector, local-only controls without consideration of transport effects. This approach is best-suited for areas in which ozone transport is not a large contributor to the local ozone problem, relative to local emissions (e.g., Atlanta, Dallas).

Table 4.1: Summary of site-specific impact ratios over the five analysis zones of Approach A.

	Minimum Impact Ratio	Maximum Impact Ratio	Average Impact Ratio	Controlling County Impact Ratio
Atlanta	0.051	0.187	0.123	0.187
Central CA	0.077	0.106	0.095	0.106
Dallas	0.118	0.138	0.130	0.135
Lake Michigan Area	-0.022[1]	0.052	0.010	0.032
Northeast Corridor	0.002	0.035	0.022	0.035

It is important to note that we are not able to factor in impacts of controls outside of the local regions using this methodology and thus, the impact ratios are likely to be conservative. Additionally, depending upon the source-receptor relationship at a particular location, some impact ratios would be expected to be lower than others due to prevailing transport direction. For instance, one would not expect a location in the southern portion of the Northeast Corridor to show much local air quality improvement when the majority of the controls were implemented upwind. Other limitations to this approach include: the assumption that response to NOx and VOC reductions is linear between 0% and 90% control, the assumption that ratios developed from 2010 base case modeling are applicable to 2020 post-strategy ozone, and the fact that impact ratios calculated from a single month of 36 km modeling may not be appropriate for an analysis of urban scale ozone.

4.1.2 Approach B: Use of 2020 Baseline and RIA Control Scenario

In the second approach, we used the results from the 2020 baseline and the 2020 hypothetical control scenario to calculate impact ratios for Atlanta, Houston, the Lake

[1] The negative value of minimum impact ratio in the Lake Michigan area indicates that ozone levels at one monitoring site are projected to increase slightly with 90% local NOx control. This 'ozone disbenefit' has been projected by the model to occur in a very few, highly localized, areas with large amounts of NOx emissions. This lone negative value is not representative of regional impact ratios."

Michigan Area and the Northeast Corridor. We focused on these four analysis zones because they were expected to require extensive extrapolated tons to attain the air quality targets. We did not use this approach in the western U.S. because there was very little difference in the controls between those two cases in California. We again calculated impact ratios for all monitoring sites in each zone by dividing the ozone change at each site by the NOx emissions reductions that led to that ozone reduction. For the specific purpose of estimating impact ratios, we have made the unrealistic but simplifying assumption that the air quality change can be fully ascribed to the total NOx emissions changes within 200 km of the area. Different assumptions about which emissions are responsible for the air quality change would yield different impact ratios.

A sample calculation for one of the counties (Kenosha WI) is shown below:

- The RIA control scenario resulted in a NOx reduction of 16.8 ktons in the Chicago zone (including 200 km buffer).
- The ozone improvement from this reduction was 1.6 ppb (86.6 to 85.0).
- This yields an impact ratio of 0.095 ppb/kton for this county.

The advantage to Approach B is that it allows for an estimate of the impact of actual controls applied regionally because controls in the hypothetical scenario cover nearly the entire eastern US. Thus, this approach is best suited for areas in which ozone transport is a large contributor to the local ozone problem (e.g., the Lake Michigan area and the Northeast Corridor). The primary disadvantage to this approach is that the 2020 control scenario is weighted toward non-EGU point source controls which may result in non-homogeneous reductions and thereby affect individual county impact ratios. Impact ratios were calculated for 47 counties over the four analysis zones. The results from Approach B are summarized in Table 4.2.

Table 4.2: Summary of site-specific impact ratios over the four analysis zones of Approach B.

	Minimum Impact Ratio	Maximum Impact Ratio	Average Impact Ratio	Controlling County Impact Ratio
Atlanta	0.041	0.129	0.068	0.070
Houston	0.050	0.057	0.054	0.057
Lake Michigan Area	-0.006	0.095	0.064	0.095
Northeast Corridor	0.068	0.155	0.110	0.105

4.2 Results from Impact Ratio Analyses

In general, both approaches indicate that impact ratios could range between 0.03 and 0.20 ppb/kton. However, the approaches did not yield consistent impact ratios for individual analysis zones. Individual local impact ratios are likely influenced by: the importance of transport, the local NOx/VOC ratio, the meteorology within the region, and the location of monitors relative to specific source areas.

Table 4.3 shows the impact ratios for each of the controlling counties[2] within the areas considered. Figure 4.2 shows the range of county-specific impact ratios calculated over the four areas included in the calculations for Approach B. Based on these data and considering the uncertainties and limitations of both approaches, we decided to use a single impact ratio for NOx and a single impact ratio for VOC for the purposes of this illustrative analysis for all areas in the U.S. that are included in the extrapolated cost analysis. These general impact ratios are:

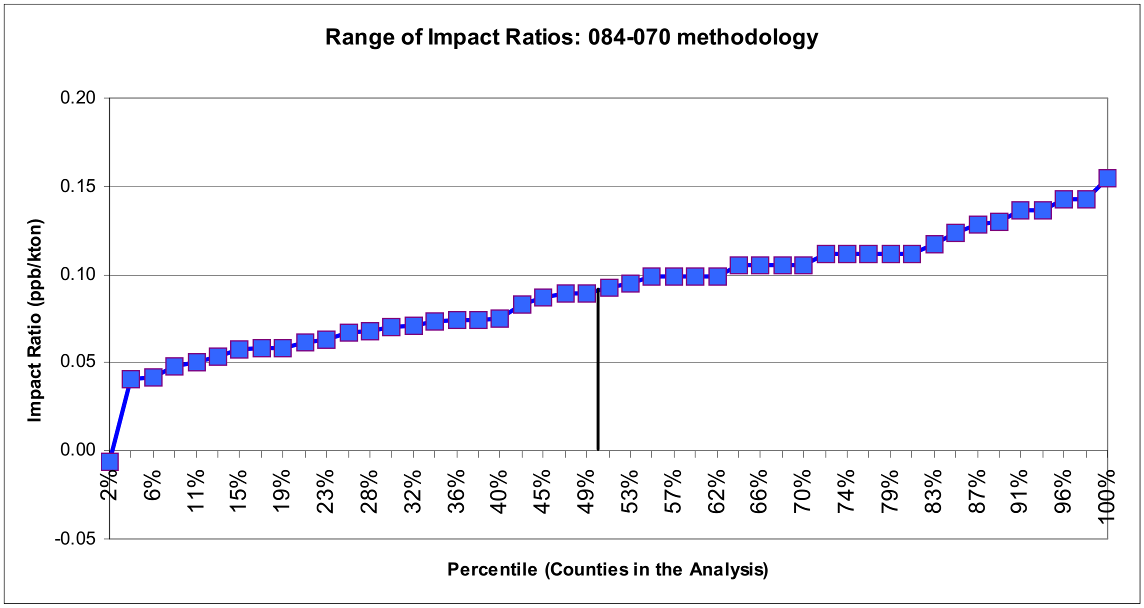
- NOx impact ratio = 0.100 ppb/kton
- VOC impact ratio = 0.025 ppb/kton

Table 4.3. The NOx impact ratios at the controlling counties for each methodology over the analysis zones.

Analysis Area	Impact Ratio at controlling county	
	Approach A	Approach B
Atlanta	0.187	0.070
Central California	0.106	
Dallas	0.135	
Houston		0.057
Lake Michigan area	0.032	0.095
Northeast Corridor	0.035	0.105

[2] The controlling county is the county within an area whose design value is farthest away from attaining the air quality target.

Figure 4.2. The NOx impact ratios at each county (sorted from lowest to highest) for the Approach B over the four analysis areas[3]



The selection of a 0.100 ppb/kton ratio was based on a consideration of all estimated impact ratios from the bounding exercise of both approaches and the technical limitations of approaches. There were three specific reasons why we thought 0.100 ppb/kton represented the best choice for extrapolating the tons needed to attain an air quality target beyond the reductions from the RIA control scenario:

- 0.100 is within, and near the midpoint of, the 0.03 to 0.20 range
- 0.100 is close to the median value from Approach B (0.093 ppb/kton)
- 0.100 is close to the average value at the key sites (0.091 ppb/kton).

As noted above, the various methods did not generate consistent area-specific NOx impact ratios. As the impact ratios are used to estimate extrapolated costs, one should keep in mind that higher impact ratios would yield lower estimates of needed extrapolated tons and lower impact ratios would yield higher estimates of extrapolated tons/costs.

As an example, if in a given area X, our impact ratio of 0.1 ppb/kton for NOx is defined as equivalent to 10 extrapolated ktons of emission reductions needed to achieve a particular air quality target, then a doubling of the impact ratio (thus, this ratio becomes

[3] The lone negative value of impact ratio occurs in the Lake Michigan area and indicates that ozone levels at that site are projected to increase slightly in response to the RIA control scenario. This 'ozone disbenefit' has previously been projected by the model to occur in a very few, highly localized, areas with large amounts of NOx emissions. This lone negative value is not representative of regional impact ratios.

0.2 ppb/kton) means that 5 extrapolated ktons of NOx, or one-half the original tonnage reduction needed, to achieve the same air quality target. As a further example, a reduction in the NOx impact ratio by half (thus, the ratio becomes 0.05 ppb/kton) means that 20 extrapolated ktons of NOx emission reductions, or twice the original tonnage reduction needed, to achieve the same air quality target.

We intend to conduct additional sensitivity analysesfor the final RIA to improve the estimates of extrapolated tons needed to meet various targets. While it is premature to specify the exact nature of these analyses, we expect this will include modeling to provide more information about the non-linear responsiveness of ozone, the geographic variation in ozone responsiveness, the impacts of local versus upwind emissions reductions, and the relationship between NOx and VOC controls in various areas. It will also include an analysis of the geographic application of impact ratios.

4.3 Determination of Extrapolated Tons Control Areas

The extrapolated tons analysis varied slightly from the geographic areas in which controls were applied for the illustrative 0.070 control strategy described in Chapter 3. In the extrapolated tons analysis, we aggregated all counties that were above the air quality goal into discrete control areas, that is, areas from which the tons would need to be extracted in order to meet the target. These control areas were either regional, statewide, or local depending upon the nature of the ozone problem within the area. Two regional areas were identified: the Ozone Transport Region and the Lake Michigan region. Both of these areas have traditionally employed multi-State control plans to lower ozone in those regions. For states with multiple areas above the air quality target, we assumed that statewide control programs would be developed to bring these areas into attainment. For example, for the 0.065 ppm target, Ohio exceeds the air quality target in Cincinnati, Cleveland, and Columbus. We assumed that extrapolated tons could be achieved anywhere in Ohio to meet the targets in all three areas. All remaining counties were treated as places where local controls would be effective. The only exceptions to the statewide assumption were in Texas and California. We separated the El Paso area into its own area due to its distance (i.e., far greater than 200 km, which was the distance used for the 0.070 control strategy) from the Eastern Texas areas (Dallas, Houston). In California, we combined the Sacramento and San Joaquin Valley counties into a single control area, but created a separate control area for Southern California. Table 4.4 shows how the monitoring counties were aggregated into the extrapolated tons control areas for the 0.070 ppm target.

Table 4.4 List of counties that did not reach 0.070 in the RIA control scenario and how they were aggregated into extrapolated tons control areas.

Control Region	State	County	Control Region	State	County
Atlanta, GA	Georgia	Fulton	Las Vegas, NV	Nevada	Clark
	Georgia	De Kalb	Los Angeles South Coast Air Basin, CA	California	San Bernardino
Baton Rouge, LA	Louisiana	East Baton Rouge		California	Los Angeles
	Louisiana	Iberville		California	Riverside
	Louisiana	West Baton Rouge		California	Ventura
Central Califronia	California	Kern		California	San Diego
	California	Fresno		California	Imperial
	California	Tulare	Louisville, KY-IN	Indiana	Clark
	California	Merced		Indiana	Perry
	California	El Dorado	Memphis, TN-AR	Arkansas	Crittenden
	California	Kings	Ozone Transport Region	Connecticut	Fairfield
	California	Stanislaus		New York	Suffolk
	California	Nevada		Connecticut	New Haven
	California	Placer		Pennsylvania	Bucks
	California	Sacramento		Maryland	Harford
	California	Madera		New Jersey	Ocean
	California	Mariposa		New Jersey	Mercer
	California	Tuolumne		New Jersey	Camden
	California	Calaveras		Connecticut	Middlesex
Charlotte-Gastonia-Rock Hill, NC-SC	North Carolina	Mecklenburg		New Jersey	Middlesex
	North Carolina	Rowan		New Jersey	Gloucester
Cleveland-Columbus-Cincinnati	Ohio	Geauga		Pennsylvania	Philadelphia
	Ohio	Ashtabula		New Jersey	Hunterdon
	Kentucky	Campbell		New Jersey	Monmouth
	Ohio	Franklin		Pennsylvania	Allegheny
	Ohio	Lake		Pennsylvania	Montgomery
	Ohio	Summit		Maryland	Cecil
Denver-Boulder	Colorado	Jefferson		New Jersey	Bergen
	Colorado	Douglas		New York	Erie
	Colorado	Arapahoe		Virginia	Arlington
Detroit-Ann Arbor, MI	Michigan	Macomb		Maryland	Baltimore
	Michigan	Oakland		New Jersey	Morris
	Michigan	Wayne		New York	Niagara
	Michigan	Washtenaw		New York	Westchester
	Michigan	St Clair		Virginia	Fairfax
Houston-Dallas	Texas	Harris		Maryland	Anne Arundel
	Texas	Dallas		D.C.	Washington
	Texas	Brazoria		Delaware	New Castle
	Texas	Tarrant		Pennsylvania	Beaver
	Texas	Denton		Pennsylvania	Chester
	Texas	Galveston		Pennsylvania	Delaware
	Texas	Gregg		New Jersey	Hudson
	Texas	Jefferson		Maryland	Prince Georges
	Texas	Collin		Maryland	Kent
Indianapolis, IN	Indiana	Shelby		New York	Richmond
	Indiana	Hamilton		Rhode Island	Washington
	Indiana	Marion		New York	Jefferson
	Indiana	Hancock		Rhode Island	Kent
Lake Michigan region	Wisconsin	Kenosha		New York	Monroe
	Indiana	Lake		New Jersey	Cumberland
	Illinois	Cook	Phoenix-Mesa, AZ	Arizona	Maricopa
	Wisconsin	Sheboygan		Arizona	Pinal
	Indiana	Porter	Richmond-Norfolk	Virginia	Suffolk City
	Wisconsin	Ozaukee		Virginia	Hampton City
	Wisconsin	Racine		Virginia	Henrico
	Wisconsin	Milwaukee		Virginia	Charles City
	Indiana	La Porte		Virginia	Hanover
	Illinois	Lake	Salt Lake City, UT	Utah	Salt Lake
	Wisconsin	Kewaunee	St Louis, MO-IL	Missouri	St Louis City
	Michigan	Allegan		Missouri	St Louis
	Wisconsin	Manitowoc		Missouri	Jefferson
	Wisconsin	Door		Missouri	St Charles
	Michigan	Muskegon	Tampa Bay, FL	Florida	Hillsborough

4.4 Selection of Air Quality Goal for this analysis

Under the Clean Air Act, areas are required to reach the air quality standards as expeditiously as practicable and within certain statutorily defined time periods. In advance of formal designations and ozone pollution level classifications, which will depend upon future air quality data, it is uncertain when areas would be required to attain a new ozone standard. In addition, states may request, and EPA must grant, a higher classification which under the law provides flexibility for a state to justify a later attainment date. (The state implementation plan must show that the attainment date selected for an area is as expeditious as practicable, and no later than the maximum statutory date for the area's classification.) In view of these and other factors, it is beyond our capability to simulate in advance the state implementation process to determine the appropriate attainment date and required controls for each potential nonattainment area for a new standard. Instead, we have constructed an illustrative analysis that provides a level playing field for comparison of the impacts of potential new, alternative standards.

An important consideration in the determination of the amount of air quality improvement needed to reach a tighter ozone standard is the dates by which each area must come into attainment. As discussed earlier, for several analytical reasons we selected the year 2020 (i.e., approximately 10 years from designations), as the analytical target year for this analysis. Therefore, this analysis presents two sets of results. The first reflects attainment of the alternative ozone standards in all locations of the U.S. except two areas of California in 2020. These two areas of California are not planning to meet the current standard by 2020 (see discussion below), so the estimated costs and benefits for these areas are based on reaching an estimated progress point (their "glidepath" targets) in 2020. The second set of results, for California only, estimate the costs and benefits from California fully attaining the alternative standards in a year beyond 2020 (glidepath estimates, plus the increment needed to reach full attainment beyond 2020, added together for a California total). However, as noted above, we are not attempting to prejudge the attainment dates and controls that ultimately will be determined through the SIP process, and it may turn out that attainment occurs later than 2020 for additional areas, particularly in areas where the future SIP process shows that very high-cost controls would be needed to attain by 2020. For reasons explained below, assuming longer attainment dates would reduce costs and benefits of meeting the current and alternative standards, and would reduce costs more sharply in areas assumed to employ high-cost controls to meet an artificial deadline.

The South Coast (Los Angeles area) and San Joaquin Air Quality Management Districts recently have proposed for comment state implementation plans with the statutory maximum 20-year attainment dates (June 2024, with attainment-level reductions by 2023) for meeting the current 8-hour standard, which would involve a request to reclassify those two areas to the "extreme" classification[4]. This presented an analytical

[4] Proposed State Strategy for California's State Implementation Plan (SIP) for the New PM2.5 and 8-Hour Ozone Standard, California Air Resources Board web page, http://www.arb.ca.gov/planning/sip/2007sip/2007sip.html, update May 30, 2007.

dilemma for this analysis because assuming that these areas would be classified severe or extreme for purposes of a new standard, these areas would not be required to attain any new standard until after the analytical year of 2020. If an area is initially classified severe, the law still would allow the state to request reclassification to extreme and to demonstrate that a 20-year attainment date (e.g., in 2030, if designations occurred in 2010) is as expeditious as practicable. Thus, an assumption that these areas would attain a tighter standard by 2020, significantly earlier than would be required under the Clean Air Act, would artificially inflate both the costs and benefits of the nation attaining the new standard in 2020 on a national level.

A further reason that we believe it would be inappropriate for the analysis to assume attainment by 2020 with new, more stringent alternative standards in the San Joaquin and South Coast areas is that existing rules, especially for on-road and non-road mobile sources, will achieve substantial additional reductions in NOx and VOC after 2020 before reaching their full impact in 2030. If San Joaquin and South Coast received the maximum statutory 20-year attainment dates for new alternative standards, for example, they would have an attainment date in 2030, and would benefit from reductions in NOx and VOC from existing rules between 2020 and 2030. By 2029, existing rules for onroad and nonroad engines would achieve 62,000 tons[5] of residual emissions reductions needed for attainment at no cost beyond the baseline for this analysis. By contrast, assuming 2020 attainment for these areas would result in assuming additional high-cost reductions from unknown control measures. Therefore, assuming 2020 attainment for these areas could result in a significant overestimate of costs. Likewise, the benefits would be overestimated because the tons are attributable to these existing rules that have reductions occurring after 2020 and are not part of our hypothetical control strategy.

---

[5] 62,000 tons was estimated by subtracting the California county level Onroad and Nonroad 2030 NOx and VOC emissions from their totals in 2020. These differences were estimated for counties listed under the CA control regions (Los Angeles and Kern County) detailed in Table 4.4. (Los Angeles accounted for 38,500 tons, while Kern accounted for 23,300 tons, for a total of 61,800 rounded to 62,000). In order to estimate total emissions for both VOC and NOx, VOC emission reductions for these counties were adjusted using the adjustment factor detailed earlier in the chapter (4 VOC tons = 1 NOx ton). Given that the San Joaquin and South Coast air quality management districts have adopted plans allowing until June 2024 (20 years from designation) to meet the current standard, EPA believes that it would be consistent for purposes of this analysis to assume a 20-year period for attainment of a new more stringent standard. If designations occurred in 2010, the 20-year attainment period would end in 2030. Significant emissions reductions from implementation of mobile source rules are anticipated between 2020 and 2030. Consistent with the non-EGU growth assumptions for the rest of the RIA, non-EGU emissions are assumed to stay constant. EGU emissions are a small fraction of the California inventory and are assumed not to significantly affect the change in the state's emissions between 2020 and 2030. Accordingly, we have used the difference between 2020 and 2030 mobile emissions to estimate the post-2020 emissions reductions that will assist the two California areas in reaching attainment.

Thus, for this analysis we have chosen to present the 2020 costs and benefits in a way that reflects partial attainment in certain California areas, an outcome consistent with the Clean Air Act. This national estimate includes full attainment in all locations except two areas of California, which do not plan to meet the current standard by 2020, and so have estimates for a progress point in 2020 (their "glidepath" targets). The second set of results presents a total for California only, which adds the 2020 progress point to the additional tons of emissions that may be needed in California to fully attain the standards in a year beyond 2020.

The following table shows the results of the calculation of the glidepath targets for these two areas used in this analysis[6]. The glidepath targets reflect the more stringent of two air quality targets: (1) the improvement assumed by 2020 to meet the current standard by years specified below, or the improvement needed by 2020 to make linear air quality progress between 2010 and a post-2020 attainment date for the more stringent, alternative standards. For Los Angeles County, the glidepath air quality targets below for all four alternative standards are set based on reductions needed to meet the current standard, with the level of the current standard being achieved in 2021. For Kern County in the San Joaquin area, the glidepath for the 0.075 ppm and 0.079 ppm alternative standards is based on achieving the level of the current standard by 2020. For the other two alternative standards, the 2020 glide path targets for San Joaquin are based on meeting the level of the alternative, more stringent standards in 2025.

Table 4-5: 2020 Air Quality Glidepath Targets for LA and Kern County

Alternative Standard Level	LA County	Kern County
0.079 ppm	86.9 ppb*	84.9 ppb
0.075 ppm	86.9 ppb	84.9 ppb
0.070 ppm	86.9 ppb	82.9 ppb
0.065 ppm	86.9 ppb	79.9 ppb

* targets are expressed in ppb for clarity of presentation

As noted above, since our glidepath calculations and cost-benefit estimates were made, the two California districts have proposed state implementation plans for the current standard that allow the statutory maximum 20-year period for attainment. This in turn suggests that that it would be reasonable solely for purposes of this analysis to assume a 20-year period for implementation of new standards. In part because decisions regarding

[6] Assumptions made for the purposes of this analysis were made prior to two California areas adopting SIPs which assumed attainment by June 2024. For purposes of this analysis, San Joaquin (including Kern County) was assumed to meet the current standard by 2020 (consistent with the analysis assumption for most areas), and South Coast (including Los Angeles County) was assumed to meet the current standard in 2021 (the maximum attainment date of a severe-17 area is in June 2021). Because the San Joaquin and South Coast air districts have adopted SIPs with later attainment dates for the current standard, we recognize that the assumptions used in this analysis are not likely to be the actual years of attainment for these two areas.

our analysis were made prior to the California proposals, the assumed time periods in this analysis for attainment by the San Joaquin and Los Angeles areas are shorter -- both for the current standards, and for the potential alternative standards. This suggests that the glidepath figures above are all more stringent than likely implementation of the Clean Air Act, and that as a result our analysis applies more unknown controls than would be needed in these areas for the current and alternative standards assuming 20-year deadlines. Thus, our estimated 2020 costs and benefits for the two California areas, which influence the total cost and benefit figures in this draft RIA, are higher than would likely occur under the Clean Air Act for the current and the potential alternative standards. We intend to consider this issue further in the final RIA.

4.5 National 2020 Estimates of Additional Emissions Reductions Needed to Meet Four Potential Air Quality Targets

This analysis presents two sets of estimates: national 2020 estimates, and California-only estimates. This section presents the national 2020 estimates.

The national 2020 estimates assume full attainment in all locations except two areas of California, which are assumed to meet 2020 air quality glidepath targets on their way toward full attainment after 2020. These 2020 national estimates present incremental tons that may be needed to meet the four separate air quality targets were considered as part of this analysis: a less stringent alternative standard of 0.079 ppm, 0.075 ppm and 0.070 ppm, which bound the range that is being proposed, and a more stringent alternative of 0.065 ppm. After the RIA control scenario, there were 24, 50, 126, and 280 counties above these four thresholds, respectively. The aggregation technique discussed above grouped these counties into 6, 11, 20, and 29 extrapolated ton control areas for the four targets. The calculation of additional tons needed does not account for the ancillary effects of ozone transport reductions (e.g. the impact of Lake Michigan region reductions on the OTR). The national 2020 total estimated incremental tons that may be needed to attain the four targets are summarized below and presented in Tables 4.6 - 4.9.

- 0.079 = 102,000 tons of additional NOx control
- 0.075 = 321,000 tons of additional NOx control
- 0.070 = 1,004,000 tons of additional NOx control
- 0.065 = 2,239,000 tons of additional NOx control[7]

[7] While the proposed rule takes comment on a range of alternate standards from 0.060 ppm to 0.084 ppm, the RIA analysis focused on a more limited range

Table 4.6 Estimated Annual Incremental Tons Needed for an 0.065 ppm Air Quality Target in 2020 (29 areas)

Control Region	Controlling County	Post-scenario design value (ppb)	Incremental Extrapolated NOx Tons
Lake Michigan region	Kenosha WI	85.0	174,000
Ozone Transport Region	Fairfield CT	87.1	173,000
Eastern TX areas (Houston/Dallas/Beaumont)	Harris TX	90.5	166,000
VA areas (Norfolk/Richmond/Roanoke)	Suffolk City VA	80.8	149,000
Detroit, MI	Macomb MI	78.4	125,000
Phoenix, AZ	Maricopa AZ	77.6	117,000
Denver, CO	Jefferson CO	76.9	110,000
OH areas (Cleveland/Columbus/Cincinnati)	Geauga OH	76.5	106,000
Atlanta, GA	Fulton GA	76.0	101,000
St Louis, MO-IL	St Louis City MO	75.7	98,000
Indiana areas (Indianapolis / Evansville)	Shelby IN	74.5	86,000
LA areas (Baton Rouge/New Orleans/Shreveport)	E Baton Rouge LA	74.4	85,000
KY areas (Louisville/Paducah/Bowling Green)	Clark IN	74.0	81,000
TN areas (Knoxville/Memphis/Nashville)	Crittenden AR	72.9	70,000
NC areas (Charlotte / Raleigh)	Mecklenburg NC	72.3	64,000
Salt Lake City, UT	Salt Lake UT	72.2	63,000
Las Vegas, NV	Clark NV	72.0	61,000
FL areas (Tampa / Panama City / Pensacola)	Hillsborough FL	71.4	55,000
Sacramento / San Joaquin Valley / S Fran	Kern CA**	96.3	50,000
Jackson, MS	Jackson MS	70.6	47,000
New Mexico areas (Farmington / Las Cruces)	Dona Ana NM	70.3	44,000
OK areas (Tulsa, Marshall)	Tulsa OK	70.3	44,000
Huntington, WV-KY	Cabell WV	69.9	40,000
El Paso, TX	El Paso TX	69.3	34,000
Kansas City, MO/KS	Wyandotte KS	69.0	31,000
Little Rock, AR	Pulaski AR	68.7	28,000
Mobile AL	Mobile AL	68.6	27,000
Columbia, SC	Richland SC	66.9	10,000
Los Angeles South Coast Air Basin, CA	Los Angeles CA**	105.0	0*

*In EPA's illustrative analysis for the PM NAAQS RIA, there were reductions of NOx in California. The amount of reductions assumed there are sufficient for these counties to achieve their glidepath targets in 2020.

** Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions assumed by this analysis by 2020 or earlier.

Table 4.7. Estimated Annual Incremental Tons Needed for an 0.070 ppm air quality target in 2020 (20 areas)

Control Region	Controlling County	Post-scenario design value (ppb)	Incremental Extrapolated NOx Tons
Lake Michigan region	Kenosha WI	85.0	124,000
Ozone Transport Region	Fairfield CT	87.1	123,000
Eastern TX areas (Houston/Dallas)	Harris TX	90.5	116,000
VA areas (Norfolk/Richmond)	Suffolk City VA	80.8	99,000
Detroit, MI	Macomb MI	78.4	75,000
Phoenix, AZ	Maricopa AZ	77.6	67,000
Denver, CO	Jefferson CO	76.9	60,000
OH areas (Cleveland/Columbus/Cincinnati)	Geauga OH	76.5	56,000
Atlanta, GA	Fulton GA	76.0	51,000
St Louis, MO-IL	St Louis City MO	75.7	48,000
Indiana areas (Indianapolis)	Shelby IN	74.5	36,000
LA areas (Baton Rouge)	E Baton Rouge LA	74.4	35,000
KY areas (Louisville)	Clark IN	74.0	31,000
Sacramento / San Joaquin Valley	Kern CA**	96.3	20,000
TN areas (Memphis)	Crittenden AR	72.9	20,000
NC areas (Charlotte)	Mecklenburg NC	72.3	14,000
Salt Lake City, UT	Salt Lake UT	72.2	13,000
Las Vegas, NV	Clark NV	72.0	11,000
FL areas (Tampa)	Hillsborough FL	71.4	5,000
Los Angeles South Coast Air Basin, CA	Los Angeles CA**	105.0	0*

***** In EPA's illustrative analysis for the PM NAAQS RIA, there were reductions of NOx in California. The amount of reductions assumed there are sufficient for these counties to achieve their glidepath targets in 2020.

****** Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions assumed by this analysis by 2020 or earlier.

Table 4.8. Estimated Annual Incremental Tons Needed for an 0.075 ppm air quality target in 2020 (11 areas)

Control Region	Controlling County	Post-scenario design value (ppb)	Incremental Extrapolated NOx Tons
Lake Michigan region	Kenosha WI	85.0	74,000
Ozone Transport Region	Fairfield CT	87.1	73,000
Eastern TX areas (Houston/Dallas)	Harris TX	90.5	66,000
VA areas (Norfolk)	Suffolk City VA	80.8	49,000
Detroit, MI	Macomb MI	78.4	25,000
Phoenix, AZ	Maricopa AZ	77.6	17,000
Denver, CO	Jefferson CO	76.9	10,000
OH areas (Cleveland)	Geauga OH	76.5	6,000
Atlanta, GA	Fulton GA	76.0	1,000
Sacramento / San Joaquin Valley	Kern CA**	96.3	0*
Los Angeles South Coast Air Basin, CA	Los Angeles CA**	105.0	0*

*In EPA's illustrative analysis for the PM NAAQS RIA, there were reductions of NOx in California. The amount of reductions assumed there are sufficient for these counties to achieve their glidepath targets in 2020.
** Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions assumed by this analysis by 2020 or earlier.

Table 4.9. Estimated Annual Incremental Tons Needed for an 0.079 ppm air quality target in 2020 (6 areas)

Control Region	Controlling County	Post-scenario design value (ppb)	Incremental Extrapolated NOx Tons
Lake Michigan region	Kenosha, WI	85.0	34,000
Ozone Transport Region	Fairfield. CT	87.1	33,000
Eastern TX areas (Houston/Dallas)	Harris, TX	90.5	26,000
VA areas (Norfolk)	Suffolk City, VA	80.8	9,000
Sacramento / San Joaquin Valley	Kern CA**	96.3	0*
Los Angeles South Coast Air Basin, CA	Los Angeles CA**	105.0	0*

*In EPA's illustrative analysis for the PM NAAQS RIA, there were reductions of NOx in California. The amount of reductions assumed there are sufficient for these counties to achieve their glidepath targets in 2020.
** Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions assumed by this analysis by 2020 or earlier.

4.6 Estimates of Additional Tons Needed for Four Potential Air Quality Targets (California only, post-2020 Attainment)

The second estimates presented are for California only. Tables 4.10 – 4.13 below, present the estimated tons needed to attain California's glidepath targets in 2020 and the additional increment of tons that may be needed for full attainment in a year beyond 2020

Table 4.10 California: Estimated Tons Needed For Attainment 0.065 ppm air quality target (beyond 2020)

Control Region	Controlling County	Post-scenario design value (ppb)	Total Extrapolated NOx Tons	Glidepath Extrapolated NOx Tons	Remaining tons needed (2020-attainment)	"Credit" tons from mobile rules 2020-2030	Tons needed after mobile reductions
Sacramento / San Joaquin Valley / S Fran	Kern CA	96.3	190,000	50,000	140,000	23,300	116,700
Los Angeles South Coast Air Basin, CA	Los Angeles CA	105.0	188,000	0	188,000	38,500	149,500

Table 4.11 California: Estimated Tons Needed for Attainment of 0.070 ppm air quality target (beyond 2020)

Control Region	Controlling County	Post-scenario design value (ppb)	Total Extrapolated NOx Tons	Glidepath Extrapolated NOx Tons	Remaining tons needed (2020-attainment)	"Credit" tons from mobile rules 2020-2030	Tons needed after mobile reductions
Sacramento / San Joaquin Valley	Kern CA	96.3	140,000	20,000	120,000	23,300	96,700
Los Angeles South Coast Air Basin, CA	Los Angeles CA	105.0	138,000	0	138,000	38,500	99,500

Table 4.12 California: Estimated Tons Needed for Attainment of 0.075 ppm air quality target (beyond 2020)

Control Region	Controlling County	Post-scenario design value (ppb)	Total Extrapolated NOx Tons	Glidepath Extrapolated NOx Tons	Remaining tons needed (2020-attainment)	"Credit" tons from mobile rules 2020-2030	Tons needed after mobile reductions
Sacramento / San Joaquin Valley	Kern CA	96.3	90,000	0	90,000	23,300	66,700
Los Angeles South Coast Air Basin, CA	Los Angeles CA	105.0	88,000	0	88,000	38,500	49,500

Table 4.13 California: Estimated Tons Needed for Attainment of 0.079 ppm air quality target (beyond 2020)

Control Region	Controlling County	Post-scenario design value (ppb)	Total Extrapolated NOx Tons	Glidepath Extrapolated NOx Tons	Remaining tons needed (2020-attainment)	"Credit" tons from mobile rules 2020-2030	Tons needed after mobile reductions
Sacramento / San Joaquin Valley	Kern CA	96.3	50,000	0	50,000	23,300	26,700
Los Angeles South Coast Air Basin, CA	Los Angeles CA	105.0	48,000	0	48,000	38,500	9,500

Chapter 5: Cost Estimates

Synopsis

This chapter summarizes the data sources and methodology used to estimate the costs of attaining the alternative more stringent levels for the ozone primary standard analyzed in this RIA. This chapter estimates the costs of the bounds of the proposed range, 0.075- 0.070 ppm, a more stringent alternative of 0.065 ppm, as well as a less stringent option of 0.079 ppm. The chapter presents cost estimates for the illustrative control strategy outlined in Chapter 3 (which uses currently available known controls). The control strategy discussion is followed by a presentation of estimates for the costs of the additional tons of emissions that are needed to move to full attainment of the alternate standards analyzed (methodology and numbers discussed in Chapter 4).

As noted in Chapter 3, EPA first modeled an illustrative control strategy aimed at attaining a tighter standard of 0.070 ppm in 2020. These known controls were insufficient to bring all areas into attainment with 0.070 ppm, and EPA then developed methodology to estimate additional tons of emissions needed to attain the bounds of the proposed range, 0.075 and 0.070 ppm, the tighter alternative of 0.065 ppm and the less stringent alternative option of 0.079 ppm. This chapter presents the costs associated with each portion of the control analysis, clearly identifying the relative costs of modeled versus extrapolated emissions reductions as well as providing an estimate of the total cost of attainment nationwide in 2020. Section 5.1 summarizes the methodology and the engineering costs associated with applying known and supplemental controls to partially attain a 0.070 ppm alternative standard, incremental to reaching the current baseline (effectively 0.084 ppm) in 2020.

Section 5.2 describes the methodology used to estimate the cost of extrapolated tons needed to reach attainment of the bounds of the proposed alternative standard (0.070 and 0.075 ppm, the less stringent alternative of 0.079ppm, as well as the more stringent alternative of 0.065 ppm) and provides estimates of how much additional cost will be associated with moving from the modeled partial attainment scenario to the nationwide attainment scenario (see Chapter 4 for discussion of extrapolated tons needed to attain 0.079, 0.075, 0.070, and 0.065 ppm). In general, EPA increased the tons required for each area using the same impact/ton estimate (5 ppb = 50,000 tons) and extrapolated cost approaches in order to estimate additional costs for reaching a standard level of 0.065 ppm as well as estimate cost savings for the 0.075 and 0.079 ppm standard levels (compared to the 0.070 ppm case).

Section 5.3 then combines the results from Sections 5.1 and 5.2 to describe the total estimated cost of full attainment in 2020, including both the costs of modeled controls for reaching partial attainment (engineering costs) and the additional costs of tons of extrapolated emissions reductions needed to reach attainment. This section includes two sets of costs. The first reflects full attainment in 2020 in all locations of the U.S. except two areas of California. These two areas are not planning to meet the current standard by 2020, so the estimated costs for these areas are based on reaching an estimated progress point in 2020 (their "glidepath" targets). The second set of results for California only, estimate the costs from California fully attaining the alternative standards in a year beyond 2020 (glidepath estimates for 2020, plus further increments needed to reach full attainment beyond 2020, added together for California total). The costs described in this chapter generally include the costs of purchasing, installing, and operating the referenced technologies. For a variety of reasons, actual control costs may vary from the estimates EPA presents here. As discussed throughout this report, the technologies and control strategies selected for analysis are illustrative of one way in which nonattainment areas could meet a revised standard. There are numerous ways to construct and evaluate potential control programs that would bring areas into attainment with alternative standards, and EPA anticipates that state and local governments will consider programs that are best suited for local conditions. Furthermore, based on past experience, EPA believes that it is reasonable to anticipate that the marginal cost of control will decline over time due to technological improvements and more widespread adoption of previously niche control technologies. Also, EPA recognizes the extrapolated portion of the cost estimates reflects substantial uncertainty about which sectors, and which technologies, might become available for cost-effective application in the future. This is explained in further detail in Section 5.4.

It is also important to recognize that the cost estimates are limited in their scope. Because we are not certain of the specific actions that states will take to design State Implementation Plans to meet the revised standards, we do not present estimated costs that government agencies may incur for managing the requirement and implementation of these control strategies or for offering incentives that may be necessary to encourage or motivate the implementation of the technologies, especially for technologies that are not necessarily market driven. This analysis does not assume specific control measures that would be required in order to implement these technologies on a regional or local level.

5.1 Modeled Controls

5.1.1 Sector methodology

5.1.1.1 Non-EGU Point and Area Sources: AirControlNET

After designing a national hypothetical control strategy to meet an alternative standard of 0.070 ppm using the methodology discussed in Chapter 3 (see sub-section 3.2.1), EPA used AirControlNET to estimate engineering control costs. AirControlNET calculates costs using three different methods: (1) by multiplying an average annualized cost-per-ton estimate against the total tons of a pollutant reduced to derive a total cost estimate; (2) by calculating cost using an equation that incorporates information regarding key plant information; or (3) by using both cost per ton and cost equations. Most control cost information within AirControlNET has been developed based on the cost-per-ton approach. This is because estimating cost using an equation requires more data, and parameters used in other non-cost per ton methods may not be readily available or broadly representative across sources within the emissions inventory. The costing equations used in AirControlNET require either plant capacity or stack flow to determine annual, capital and/or operating and maintenance (O&M) costs. Capital costs are converted to annual costs, in dollars per ton, using the capital recovery factor.[1] Applied controls and their respective costs are provided in Ozone NAAQS RIA docket.

The control strategy for Non-EGU Point and Area Sources incorporated cost-per-ton caps. These caps were pollutant specific and applicable only in the eastern U.S. portion of the analysis. For reductions of NOx emissions the cap was $16,000/ton. This was based upon the approximate benefit per ton of reductions in NOx, as well as an examination of the marginal cost curve for NOx reductions from these sectors. There were only two controls whose cost per ton were greater than this cap, and subsequently not included in this analysis, due to the large capital component of installing these controls. A similar process was followed for reductions from VOCs. The marginal cost curve was analyzed and there was a clear break in the curve at approximately $6,000/ton. At this cap, over sixty percent of the possible reductions are being controlled at less than thirty percent of the total cost of the VOC reductions.

Supplemental controls were applied in this illustrative analysis in order to achieve the highest possible emission reduction from Non-EGU point and area sources. Supplemental control measures are those controls that are 1) applied in these analyses but are not found in AirControlNET, and 2) are in AirControlNET but whose data have been modified to better approximate their applicability to source categories in 2020. The controls and associated data such as control cost estimates not found in AirControlNET are taken from technical reports prepared to support preliminary 8-hour ozone State Implementation Plans (SIPs) prepared by States and from various reports prepared by the staffs of various local air quality regulatory agencies (e.g. Bay Area Air Quality Management District). The reports that are the sources of additional controls data are included within footnotes in the Chapter 3 Appendix. Modification of control data, including percent reduction levels and control cost data, in AirControlNET occurred as a result of a review of the nonEGU point and area NOx control measures by technical staff. The changes EPA supplied are provided later in the Chapter 3 Appendix.

5.1.1.2 EGU Sources: the Integrated Planning Model

Costs for the electric power sector are estimated using the Integrated Planning Model (IPM). The model determines the least-cost means of meeting energy and peak demand requirements over a specified period, while complying with specified constraints, including air pollution regulations, transmission bottlenecks, fuel market restrictions, and plant-specific operational constraints. IPM is unique in its ability to provide an assessment that integrates power, environmental, and fuel markets. The model accounts for key operating or regulatory constraints (e.g. emission limits, transmission capabilities, renewable generation requirements, fuel market constraints) that are placed on the power, emissions, and fuel markets. IPM is particularly well-suited to consider complex treatment of emission regulations involving trading and banking of

[1] For more information on this cost methodology and the role of AirControlNext, see Section 6 of the 2006 PM RIA, AirControlNET 4.1 Control Measures Documentation (Pechan, 2006b), or http://www.epa.gov/ttn/catc/products.html#cccinfo

emission allowances, as well as traditional command-and-control emission policies.[2] Applied controls and their respective costs are provided in the docket. IPM is described in further detail in Appendix 3.

5.1.1.3 Onroad and Nonroad Mobile Sources: MOBILE model

Cost information for mobile source controls was taken from studies conducted by EPA for previous rulemakings and studies conducted for development of voluntary and local measures that could be used by state or local programs to assist in improving air quality. Applied controls and their respective costs are provided in the docket.[3]

Cost analysis of the onroad and nonroad mobile sector was performed using the MOBILE6 model. MOBILE is an EPA model for estimating pollution from highway vehicles. MOBILE calculates emissions of hydrocarbons (HC), oxides of nitrogen (NOx), and carbon monoxide (CO) from passenger cars, motorcycles, light- and heavy-duty trucks. The model accounts for the emission impacts of factors such as changes in vehicle emission standards, changes in vehicle populations and activity, and variation in local conditions such as temperature, humidity and fuel quality[4].

5.1.2 Known Controls— Cost by Sector

In this section, we provide engineering cost estimates of the control strategies identified in Chapter 3 that include control technologies on non-EGU stationary sources, area sources, EGUs, and onroad and nonroad mobile sources. Engineering costs generally refer to the capital equipment expense, the site preparation costs for the application, and annual operating and maintenance costs.

The total annualized cost of control in each sector in the control scenario is provided in Table 5.1. These numbers reflect the engineering costs across sectors annualized at a discount rate of 7% and 3%, consistent with the guidance provided in the Office of Management and Budget's (OMB) (2003) Circular A-4. However, it is important to note that it is not possible to estimate

---

[2] The application of the 0.070 EGU control strategy results in NOx allowance price decreasing from $1340/ton in the baseline to $715/ton. See Technical Support Document on EGU Control Strategies for more details. Further detailed information on IPM is available in Section 6 of the 2006 PM RIA or at http://www.epa.gov/airmarkets/epa-ipm

[3] The expected emissions reductions from SCR retrofits are based on data derived from EPA regulations (Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-duty Highway Engines and Vehicles published October 2000), interviews with component manufacturers, and EPA's Summary of Potential Retrofit Technologies available at www.epa.gov/otaq/retrofit/retropotentialtech.htm.

For more information on mobile idle reduction technologies (MIRTs) see EPA's Idle Reduction Technology page at http://www.epa.gov/otaq/smartway/idlingtechnologies.htm.

[4] More information regarding the MOBILE6 model can be found at http://www.epa.gov/otaq/mobile.htm

both 7% and 3% discount rates for each source (see section 5.1.3). In Table 5.1, an annualized control cost is provided to allow for comparison across sectors, and between costs and benefits. A 7% discount rate was used for control measures applied to non-EGU point, area, and mobile sources. Costs from EGU sources, which are calculated using the IPM model and variable interest rates, are captured in this table at an annualized 7% discount rate[5].

Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. In this RIA, the non-EGU point source sector was the only sector with available data to perform a sensitivity analysis of our annualized control costs to the choice of interest rate. Sufficient information on annualized capital calculations was not available for area source and mobile controls to provide a reliable 3 percent discount rate estimate. As such, the 3% value in figure 5.1 is representative of the sum of the non-EGU Point Source sector at a 3% discount rate, and the EGU, mobile, and Area Source sector at a 7% discount rate. It is expected that the 3% discount rate value is overestimated due to the addition of cost sectors at a higher discount rate. With the exception of the 3 % Total Annualized Cost estimate on Table 5.1, cost estimates presented throughout this and subsequent chapters are based on 7% discount rate.

The total annualized engineering costs associated with the application of known and supplemental controls to reach a revised 0.070 ppm standard, incremental to the current standard, are approximately $3.9 billion.

[5] A different plant-specific interest rate is applied in estimating control costs within IPM. See PM RIA for details.

Table 5.1 Comparison of Modeled Annual Control Costs Nationwide, by sector, for a 0.070 ppm control scenario ($1999)[6]

Source Category		0.070 ppm Control Strategy		
		Total Cost ($B 1999)		Average Cost per Ton ($1999)
		East	**West**	
A. Electric Generating Units (EGU) Sector				
Controls for NOx Cap-and-Trade Program and Local Measures in Projected Nonattainment Areas		*$0.20*	*$0*	$2,000
	Total	**$0.20**	**$0**	
B. Onroad		*$0.51*	*$0.11*	$2,300
C. Nonroad		*$0.09*	*$0.02*	$4,400
	Total	**$0.60**	**$0.13**	
D. Non-EGU Sector				
Point Sources (Ex: Pulp & Paper, Iron & Steel, Cement, Chemical Manu.)		*$2.30*	*$0.34*	$3,600
E. Area Sector				
Area Sources (Ex: Res. Woodstoves, Agriculture)		*$0.31*	*$0.01*	$2,000
	Total	**$2.6**	**$0.35**	
	Total Annualized Costs (using a 7% interest rate)	**$3.90**		
	Total Annualized Costs (using a 3% interest rate)	**$3.60**		

5.1.3 Limitations and Uncertainties Associated with Engineering Cost Estimates

EPA bases its estimates of emissions control costs on the best available information from engineering studies of air pollution controls and has developed a reliable modeling framework for analyzing the cost, emissions changes, and other impacts of regulatory controls. The annualized cost estimates of the private compliance costs are meant to show the increase in production (engineering) costs to the various affected sectors in our control strategy analyses. To estimate these annualized costs, EPA uses conventional and widely-accepted approaches that are commonplace for estimating engineering costs in annual terms. However, our cost analysis is subject to uncertainties and limitations.

There are some unquantified costs that are not adequately captured in this illustrative analysis. These costs include the costs of federal and State administration of control programs, which we believe are less than the alternative of States developing approvable SIPs, securing EPA approval of those SIPs, and Federal/State enforcement. Additionally, control measure costs referred to as

[6] All estimates provided reflect the cost of a control strategy for 0.070 pm, incremental to a 2020 baseline of compliance with the current standard of 0.084 ppm. Note, for the final RIA we will be updating our estimates to $2006.

"no cost" may require limited government agency resources for administration and oversight of the program not included in this analysis; those costs are generally outweighed by the saving to the industrial, commercial, or private sector. The Agency also did not consider transactional costs and/or effects on labor supply in the illustrative analysis.

The economic impacts (i.e. social costs) of the cost of these modeled controls were not included in this analysis. Incorporating the economic impact of the extrapolated portion of the costs was too uncertain to be included as part of these estimates, and it was determined best to keep the modeled and extrapolated costs on the same basis. However, incorporating any economic impacts would increase the total cost of attainment in 2020 for a revised ozone standard.

The illustrative analysis does quantify the potential for advancements in the capabilities of pollution control technologies as well as reductions in their costs over time. This is discussed in Section 5.4.

5.2 Extrapolated Costs

This section presents the results and methodology behind the extrapolated cost calculations of attainment of the alternate standards (the ends of the proposed range – 0.075 and 0.070 ppm, the less stringent alternative of 0.079 ppm, and the more stringent alternative of 0.065 ppm). Consistent with the rest of this RIA, this section presents two sets of results. The first reflects full attainment in 2020 in all locations of the U.S. except two areas of California. These two areas are not planning to meet the current standard by 2020, so the estimated costs for these areas are based on reaching an estimated progress point in 2020 (their "glidepath" targets). The second set of results for California only, estimate the costs from California fully attaining the alternative standards in a year beyond 2020 (glidepath estimates for 2020, plus further increments needed to reach full attainment beyond 2020, added together for California total).

As discussed in Chapter 3, the application of the 0.070 ppm control strategy was not successful in reaching nationwide attainment of the alternate ozone standards. Many areas remained in non-attainment for all three alternate standard scenarios; therefore, the engineering costs detailed in Section 5.1 represent only the costs of partial attainment.

The estimation of the costs of unidentified controls needed to reach attainment is inherently a difficult issue. The degree to which unspecified controls are needed to achieve attainment depends upon other variables in the analysis, such as attainment date assumptions. We will better understand the true scope of the issue in the future as states conduct detailed area-by-area analyses to determine available controls and attainment dates that are appropriate under the Clean Air Act. We do not attempt to determine specific attainment dates in this analysis.

This draft RIA used two different approaches to estimating the costs of unspecified control measures. This reflects the difficulty in defining a "best" approach to this issue as well as the uncertainty related to the extrapolated costs. One approach assumes that the marginal cost of abatement increases at a constant rate. The other approach assumes a fixed cost for abatement tons and provides estimates for two fixed cost/ton values. Use of the fixed cost per ton approach reduces the possibility of inflated extrapolated costs that would result from an infinitely increasing marginal cost curve. However it does not take into account the probability that abatement costs would increase as an industry or state reduces a higher portion of available NOx or VOC tons. In turn, the marginal cost approach captures this increase in abatement cost, but its lack of "cost caps" can result in overestimates of costs.

Our approaches have yet to be peer reviewed and reflect a range of views about the likely cost of future techniques and strategies that reduce air pollutant emissions. (The higher-cost estimation approaches are implicitly more pessimistic about prospects for technological advances that avoid large increases in the cost per ton of emission reduction relative to controls employed in the past.) Section 5.4 discusses historical experience which has shown numerous technological advances in emission reduction technologies, and provides a few examples of today's emerging technologies. EPA will continue to consider these issues between now and the publication of the final RIA for the final ozone NAAQS rule.

This section provides the additional costs of reaching nationwide full attainment of the alternate ozone standards utilizing three values: a lower fixed cost per ton estimate based on the majority of the known cost/ton control values, an upper fixed cost per ton estimate based on the cost of the last few known control measures used and an increasing marginal cost estimate similar to that used in the PM NAAQS Final RIA. In addition to presenting the full attainment cost, this section will provide the methodology behind each approach.

Prior to presenting the aforementioned full attainment costs, it is important to provide information from EPA's Science Advisory Board Council Advisory[7], dated June 8, 2007, on the issue of estimating costs of unidentified control measures. In that letter, the Council advises against any approach that deviates from using a fixed cost/ton estimate such as the increasing marginal cost approach provided below. This increasing marginal cost approach 'grows' extrapolated costs that have an unquantifiable level of uncertainty at a rate with an equivalent level of uncertainty. This approach is presented in this Proposal RIA in order to maintain a consistency with the PM NAAQS Final RIA cost extrapolation. EPA is going to reconsider its approach to estimating the full attainment costs in the final RIA, in light of this advice. Consideration of this advice will be balanced with the requirements of E.O. 12866 and OMB circular A-4, which provides guidance on the estimation of benefits and costs of regulations.

> <u>*812 Council Advisory, Direct Cost Report, Unidentified Measures (charge question 2.a)*</u>
>
> *"The Project Team has been unable to identify measures that yield sufficient emission reductions to comply with the National Ambient Air Quality Standards (NAAQS) and relies on unidentified pollution control measures to make up the difference. Emission reductions attributed to unidentified measures appear to account for a large share of*

[7] U.S. Environmental Protection Agency. June 2007. Advisory Council on Clean Air Compliance Analysis (COUNCIL), Council Advisory on OAR's Direct Cost Report and Uncertainty Analysis Plan. Washington, DC

emission reductions required for a few large metropolitan areas but a relatively small share of emission reductions in other locations and nationwide.

"The Council agrees with the Project Team that there is little credibility and hence limited value to assigning costs to these unidentified measures. It suggests taking great care in reporting cost estimates in cases where unidentified measures account for a significant share of emission reductions. At a minimum, the components of the total cost associated with identified and unidentified measures should be clearly distinguished. In some cases, it may be preferable to not quantify the costs of unidentified measures and to simply report the quantity and share of emissions reductions attributed to these measures.

"When assigning costs to unidentified measures, the Council suggests that a simple, transparent method that is sensitive to the degree of uncertainty about these costs is best. Of the three approaches outlined, assuming a fixed cost/ton appears to be the simplest and most straightforward. Uncertainty might be represented using alternative fixed costs per ton of emissions avoided."

5.2.1 Increasing Marginal Cost Methodology

This approach stems from the assumption that each unit of incremental reduction in non-attainment areas will result in an increase in cost per ton or marginal cost of abatement. Therefore, similar to the approach used in the PM NAAQS RIA, EPA estimated constantly increasing marginal cost curves for emission reductions using cost per ton values from control strategy data in representative non-attainment areas. These curves were then used to estimate a cost of full attainment using the emission reduction targets detailed in Chapter 4 of this report.

5.2.1.1 Marginal Cost Regions

EPA grouped the non-attainment areas described in Chapter 4 along with their emission reduction targets into six regions of the country (Table 5.2) in order to acquire sufficient and representative data for deriving the slopes of the marginal cost curves.

- Nonattainment areas in Virginia were grouped with the Northeast due to the fact that Northern Virginia is part of the Ozone Transport Region (OTR) which makes up the Northeast. Resources were not available to disaggregate states by counties.
- Nonattainment areas in Louisiana were grouped with Texas and Oklahoma (Plains region) due to the similarity in industry mix among those states.
- California was separated from the rest of the west due to the severity of the ozone problem in the state, the glide path targets unique to the state, and because EPA determined the rest of the west was not an ideal representation of California.

Table 5.2 Regions and Slopes for Extrapolated Costs

Region	Marginal Cost Slope
Northeast (OTR)	0.035
Midwest	0.045
Southeast	0.036
Plains (TX/LA)	0.033
West (Not CA)	0.152
CA	0.211

5.2.1.2 Derivation of the Marginal Cost Slopes

Due to the efficaciousness and efficiency of NOx controls compared to VOC controls, control strategy cost per ton data was acquired for each region using a selection criteria defined in Table 5.3 and applied in Ordinary Least Squares regression equations. Results of these equations provided the slope for the marginal cost curves. For each equation, the dependant variable (**Y** = cost/ton)[8] and was regressed conditional to (**X** = cumulative emissions reductions).[9]

$$\boldsymbol{Y} = c + \beta \boldsymbol{X} + e$$

c = constant
β = slope
e = residual

The regression equations are not intended to be used for statistical inference in regards to the relation between cost/ton and cumulative emission reductions. They represent a rough approximation of an increasing rate or slope of cost/ton which could be used to project extrapolated costs. This slope would then provide an increasing cost/ton rate in the extrapolated portion of the cost that was equivalent to the rate observed under the modeled costs. As can be seen by the range of the goodness of fit estimates (R^2 = 0.5 to 0.8), there is a high level of uncertainty with these slope estimates which is propagated through the extrapolated cost estimates.

Table 5.3 Data Selection Criteria for Extrapolated Costs
1) Determine if area has sufficient NOx emissions remaining to reach attainment
2) If area has sufficient NOx remaining to reach attainment, then use NOx cost/ton data due to their cost effectiveness compared VOC controls
3) If area does not have sufficient NOx emissions to reach attainment, then include VOC controls in the data set if: • VOC controls were part of the control strategy for the area in question • VOC control cost/ton inclusions to the regression data set would significantly alter the value of the slope for the marginal cost curve derived using only NOx cost/ton data

Note: Data analysis demonstrated that VOC control data would only be needed for California. Due to lack of available ozone data, NOx controls from California also include control cost from the PM NAAQS RIA control strategies.

---

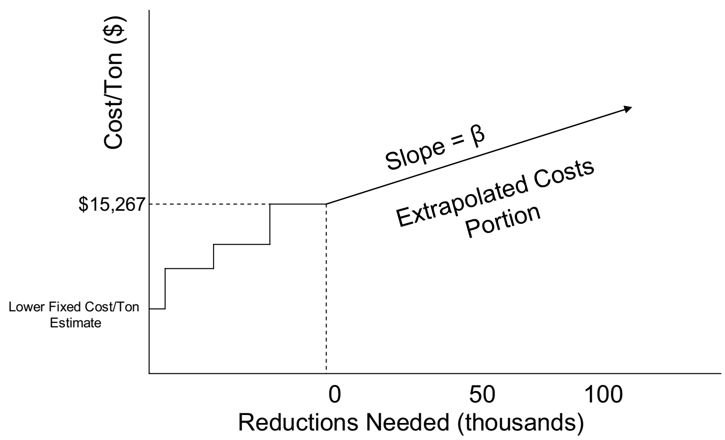
[8] For the east regions, the full cost/ton data set was applied and had a maximum value of \$15,267/ton. For the west, the cost/ton data was truncated at \$15,267/ton in order to maintain a consistent comparison with the east regions and because the few remaining controls had costs greater \$35,000/ton and were therefore judged to be not economically feasible.

[9] EPA recognizes that these regression equations may be misspecified. As stated above, the objective was not to accurately capture the relation between control cost/ton and emission reduction for statistical or economic inference purposes. These equations represent the most statistically adequate models that could be specified given the data, time, and resource constraints.

5.2.1.3 Calculating Extrapolated Costs Using Marginal Cost Approach

Once the slope of the marginal cost curve was derived, the extrapolation was calculated by multiplying that slope with the emission reduction target and adding that value to the highest of the observed cost/ton value (Figure 5.1). For this illustrative analysis, the highest of the observed cost/ton values was roughly $15,267/ton which represented the intercept of the marginal cost equation. Total costs could then be estimated by adding the area under the marginal cost curve in Figure 5.1 or by taking the integral of the marginal cost function and inputting the emission reduction target into the equation for total cost.[10]

Figure 5.1 Extrapolated Cost Example (MC Approach)[11]



5.2.2 Fixed Cost per Ton Values

Similar to the 1997 Ozone NAAQS RIA, a fixed cost/ton value was also applied to estimate the extrapolated costs of nationwide full attainment. Total costs for each non-attainment area was calculated by multiplying the fixed cost/ton value with the emission reduction targets for each region. For this particular illustrative analysis, a pair of fixed cost/ton values was used to calculate costs.

NOx control strategy data for the East and West were examined for 'clustering' within their individual distributions. Cost/ton data for the east and west were stratified into thousands (Ex. $0-$1000, $1000-$2000) with individual source counts aggregated within each interval. California was separated from the west so source cost/ton counts were conducted separately for the state. This was the result of limited ozone NOx data availability for the state, the low number

[10] *Total Cost = $15,267x +* ($\beta$/2)$x^2$, where x = emission reduction target
[11] In the case of 0.075 ppm, negative reductions are needed in order to estimate extrapolated cost savings.

of NOx emissions remaining for CA, and the inclusion of ozone VOC controls as well as NOx controls from PM NAAQS RIA control strategies which were required to resolve these data and emissions issues.

For the East, 90% of the controls were below $6,000/ton. As a result, the control cost closest to $6,000/ton ($6,012) was selected to represent the cost of the majority of the modeled controls as well as the lower estimate of the Eastern fixed cost/ton approach. For the West, 94% of the controls had a cost/ton value below $4,000/ton. Therefore, $4,213 was selected as the lower estimate for the western fixed cost/ton approach. For California, the lower estimate was $9,035 using the same method but including VOC and PM NAAQS NOx control data from the PM NAAQS RIA hypothetical control scenario. This lower estimate for CA captured 81% of the cost/ton data below $15,267 and 65% of all cost/ton data for controls applied in the ozone and PM control strategies after multiplying VOC controls by a 4 to 1 substitution factor.

In addition to a lower fixed cost/ton estimate, an upper fixed cost/ton value was used for calculating extrapolated costs. This upper value as estimated at $15,267 for all regions for the following reasons.

- This value represented the highest, in terms of cost/ton, of the controls applied in the East. The East control strategy made up the majority of the modeled controls for the ozone standard.
- In the case of the West, the next highest controls were roughly $35,000 and $39,000 per ton. Controls with these costs were determined to be significantly less feasible to implement compared other controls.
- This value provides a consistent platform from which to incorporate and compare marginal cost values derived using the increasing marginal cost approach.

5.2.3 Results

Tables 5.4 to 5.7 provide the extrapolated cost values for 2020 attainment of the 0.079, 0.075, 0.070, 0.065 ppm standards in each area (including the California 2020 glidepath targets) applying the increasing marginal cost value as well as the two fixed cost/ton values. The reader should be aware of the following stipulations prior to making inferences from the extrapolated costs presented in the following tables.

- The two extrapolated cost approaches provide three rough estimates of potential costs with the marginal cost approach providing the highest value. Neither result includes a probability or a link to sectors where reductions will be attained. Therefore, there are no expected values within this range of outcomes and no assumptions made about the types of controls that would be applied in 2020. Although the amount of reduction assumed to occur using unknown controls increases, the uncertainty of the associated costs and benefits calculations increases.
- 0.070 ppm extrapolated costs were estimated using data from the 0.070 ppm control strategy. Therefore, although the degree of uncertainty is still significant, these results can be expected to have a higher level of confidence than results for the 0.079, 0.075, and 0.065 ppm alternate standards.

- The use of the 0.070 ppm control strategy as a starting point for extrapolating the 0.079 and 0.075 ppm standard resulted in over attainment of these targets in some areas. For over attaining areas, cost savings and emission increases were extrapolated using the impact/ton estimates derived in Chapter 4 and their appropriate emission targets until reaching the respective alternate standard.
- Several new non-attainment counties were added to the analysis as a result of moving to the 0.065 ppm alternate standard. Most of these counties were in states within the 0.070 ppm control strategy region described in Chapter 3. For the east, this region was made up of counties with 0.070 ppm violating monitors and their 200 km buffers which made up most of the eastern part of the US. In the west, this region was made up of six states (AZ, CA, CO, NM, NV, UT). Due to the geographic scope of the 0.070 control strategy, no additional controls were available and costs had to be extrapolated using the same impact/ton estimates applied in the 0.070 ppm estimates. Two new states were added to the non-attainment region (KS and AL). Since controls were available for these states, AirControlNET was used to identify controls that would achieve the required emission reduction targets.
- Consistent with OMB Circular A-4, costs are presented at a 7% discount rate. It is more consistent to present the extrapolated costs at the same discount rate as the modeled control costs, for which a 7% rate was determined to be more representative of actual costs (see section 5.1.3)

Table 5.4 Extrapolated Costs of Meeting the 0.079 ppm Standard				
Extrapolated Costs for 0.079 Standard	**MC Curve Estimate ($M 1999)**	**Lower Fixed Cost/Ton Estimate ($M 1999)**	**Upper Fixed Cost/Ton Estimate[a] ($M 1999)**	**Cost/Ton Estimate of Last Control Applied on MC Curve Estimate ($1,999)**
Extrapolated Costs				
CA – Los Angeles[b]	$0	$0	$0	
CA – Kern County[b]	$0	$0	$0	
Houston / Dallas	$477	$158	$400	$18,765
Ozone Transport Region	$568	$200	$504	$17,787
Lake Michigan region	$571	$206	$519	$17,562
Richmond / Norfolk	$139	$55	$137	$15,582
Total Cost	$1,755	$619		
Extrapolated Cost Savings				
Atlanta, GA	($568)	($236)	c	
Cleveland, OH	($493)	($206)	c	
Detroit, MI	($224)	($91)	c	
Control Deletions				
Charlotte, Memphis, Las Vegas, Salt Lake City, Tampa	($119)	($119)	c	
Colorado, Arizona	($676)	($676)	c	
Baton Rouge, Indianapolis, Louisville, St. Louis	($241)	($241)	c	
Total Cost Savings	($2,321)	($1,569)		
Total Extrapolated Cost	**($566)**	**($950)**		
Average cost per ton	$2,113	$3,549		

[a]Due to the limited amount of controls in the modeled control strategy which had this value, deducting this amount would likely result in an over estimate of the savings. For example, estimating cost savings by multiplying changes in emission reduction by $15,267 would result in an overestimate of cost savings since not all of the applied controls had a cost/ton as high as $15,267.

[b]Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions expected by 2020 or earlier.

[c] We did not calculate the cost savings which would result from using the upper bound values. This would result in an unrealistic savings because none of these cities with less significant air quality problems would be expected to be getting **all** their expected emission reductions at such a high cost/ton. We therefore used the lower cost estimate which included roughly 90% of the controls applied.

Table 5.5 Extrapolated Costs of Meeting the 0.075 ppm Standard				
Extrapolated Costs for 075 Standard	**MC Curve Estimate ($M 1999)**	**Lower Fixed Cost/Ton Estimate ($M 1999)**	**Upper Fixed Cost/Ton Estimate[a] ($M 1999)**	**Cost/Ton Estimate of Last Control Applied on MC Curve Estimate ($ 1999)**
Extrapolated Costs				
CA – Los Angeles[b]	$0	$0	$0	
CA – Kern County[b]	$0	$0	$0	
Houston / Dallas	$1,254	$400	$1,008	$20,085
Ozone Transport Region	$1,307	$443	$1,114	$19,187
Lake Michigan region	$1,310	$449	$1,130	$19,362
Richmond / Norfolk	$790	$297	$748	$16,982
Detroit	$396	$152	$382	$16,392
Phoenix	$282	$72	$260	$17,851
Denver	$160	$42	$153	$16,787
Cleveland/Columbus/Cincinnati	$92	$36	$92	$15,537
Atlanta	$15	$6	$15	$15,303
Total Cost	$5,606	$1,896		
Extrapolated Cost Savings				
Baton Rouge, LA	($225)	($91)	c	
Indianapolis, IN	($209)	($85)	c	
Louisville, KY-IN	($284)	($115)	c	
St. Louis, MO-IL	($30)	($12)	c	
Total Cost Savings	($748)	($303)		
Total Extrapolated Cost	**$4,858**	**$1,593**		
Average cost per ton	$23,000	$7,600		

[a]Due to the limited amount of controls in the modeled control strategy which had this value, deducting this amount would likely result in an over estimate of the savings. For example, estimating cost savings by multiplying changes in emission reduction by $15,267 would result in an overestimate of cost savings since not all of the applied controls had a cost/ton as high as $15,267.

[b]Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions expected by 2020 or earlier.

[c] We did not calculate the cost savings which would result from using the upper bound values. This would result in an unrealistic savings because none of these cities with less significant air quality problems would be expected to be getting **all** their expected emission reductions at such a high cost/ton. We therefore used the lower cost estimate which included roughly 90% of the controls applied.

Table 5.6 Extrapolated Costs of Meeting the 0.070 ppm Standard [a]				
Extrapolated Costs for 0.070 Standard	**MC Curve Estimate ($M 1999)**	**Lower Fixed Cost/Ton Estimate ($M 1999)**	**Upper Fixed Cost/Ton Estimate ($M 1999)**	**Cost/Ton Estimate of Last Control Applied on MC Curve Estimate ($ 1999)**
CA – Los Angeles[b]	$0	$0	$0	
CA – Kern County [b]	$829	$181	$305	$43,541
Houston / Dallas	$2,299	$703	$1,771	$21,735
Ozone Transport Region	$2,310	$746	$1,878	$20,937
Lake Michigan region	$2,334	$752	$1,893	$21,612
Richmond / Norfolk	$1,683	$600	$1,511	$18,732
Detroit	$1,272	$455	$1,145	$18,642
Phoenix	$1,364	$282	$1,023	$25,451
Denver	$1,190	$253	$916	$24,387
Cleveland/Columbus/Cincinnati	$926	$339	$855	$17,787
Atlanta	$825	$309	$779	$17,103
St. Louis	$785	$291	$733	$17,427
Indianapolis	$579	$218	$550	$16,887
Baton Rouge	$555	$212	$534	$16,422
Louisville	$491	$188	$473	$16,383
Memphis	$313	$121	$305	$15,987
Charlotte	$217	$85	$214	$15,771
Salt Lake City	$211	$55	$198	$17,243
Las Vegas	$177	$46	$168	$16,939
Tampa	$77	$30	$76	$15,447
Total Extrapolated Cost	**$18,441**	**$5,867**	**$15,328**	
Average cost per ton	*$18,400*	*$5,900*	*$15,300*	

[a] EPA was not able to estimate benefit changes when moving the standard from 0.070 to 0.075 for Memphis, Charlotte, Salt Lake City, Las Vegas, and Tampa. Therefore, in order to maintain a consistent comparison, cost savings were not estimated for these locations.
[b] Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions expected by 2020 or earlier.

Table 5.7 Extrapolated Costs of Meeting the 0.065 ppm Standard				
Extrapolated Costs for 065 Standard	**MC Curve Estimate ($M 1999)**	**Lower Fixed Cost/Ton Estimate ($M 1999)**	**Upper Fixed Cost/Ton Estimate ($M 1999)**	**Cost/Ton Estimate of Last Control Applied on MC Curve Estimate ($ 1999)**
CA – Los Angeles[a]	$0	$0	$0	$15,267
CA – Kern County[a]	$2,230	$452	$763	$49,871
Houston / Dallas	$3,427	$1,006	$2,534	$23,385
Ozone Transport Region	$3,401	$1,049	$2,641	$22,687
Lake Michigan region	$3,471	$1,055	$2,656	$23,862
Richmond / Norfolk	$2,663	$903	$2,275	$20,482
Detroit	$2,260	$758	$1,908	$20,892
Phoenix	$2,827	$493	$1,786	$33,051
Denver	$2,599	$463	$1,679	$31,987
Cleveland/Columbus/Cincinnati	$1,871	$643	$1,618	$20,037
Atlanta	$1,726	$612	$1,542	$18,903
St. Louis	$1,712	$594	$1,496	$19,677
Indianapolis	$1,479	$521	$1,313	$19,137
Baton Rouge	$1,417	$515	$1,298	$18,072
Louisville	$1,355	$491	$1,237	$18,183
Memphis	$1,157	$424	$1,069	$17,787
Charlotte	$1,051	$388	$977	$17,571
Salt Lake City	$1,263	$265	$962	$24,843
Las Vegas	$1,214	$257	$931	$24,539
Tampa	$894	$333	$840	$17,247
Jackson, MS	$757	$285	$718	$16,959
New Mexico areas (Farmington / Las Cruces)	$819	$185	$672	$21,955
OK areas (Tulsa, Marshall)	$704	$267	$672	$16,719
Huntington, WV-KY	$639	$242	$611	$16,707
El Paso, TX	$538	$206	$519	$16,389
Kansas City, MO/KS	$325	$142	$317	$16,122
Little Rock, AR	$442	$170	$427	$16,275
Mobile AL	$70	$70	$70	$16,239
Columbia, SC	$154	$61	$153	$15,627
Extrapolated Total	**$42,465**	**$12,851**	**$33,684**	
Average cost per ton	*$19,300*	*$5,800*	*$15,300*	

[a] Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions expected by 2020 or earlier.

5.3 Summary of Costs

Table 5.8 presents a summary of the total national cost of attaining 0.079, 0.075, 0.070, and 0.065 ppm standards in 2020 (including the California glidepath). This summary includes the costs presented above from the modeled controls and the extrapolated costs. The range presented in the extrapolated costs and the total costs represent the upper and lower bound cost estimates. Consistent with OMB Circular A-4, costs are presented at a 7% discount rate. It is more consistent to present the extrapolated costs at the same discount rate as the modeled control costs, for which a 7% rate was determined to be more representative of actual costs (see section 5.1.3). Although the amount of reduction assumed to occur using unknown controls increases, the uncertainty of the associated costs and benefits calculations increases.

Table 5.8 Total Costs of Attainment in 2020 for Different Levels of the Ozone Standard (National Attainment in 2020)

	Level of Standard in 2020			
	0.065 ppm	0.070 ppm	0.075 ppm	0.079 ppm
Modeled Costs ($B)	$3.9	$3.9	$3.9	$3.9
Extrapolated Costs ($B)	$13 to $42	$5.9 to $18	$1.6 to $4.9	($0.95) to ($0.57)*
Total Costs ($B)	$17 to $46	$10 to $22	$5.5 to $8.8	$3 to $3.3

* The use of the 0.070 ppm control strategy as a starting point for extrapolating the 0.079 standard resulted in over attainment in some areas. For over attaining areas, cost savings were applied. For the 0.079 ppm standard the cost savings from over attaining areas was greater than the costs for areas still needing extrapolated tons (see Table 5.4).

Table 5.9 presents an estimate of total costs of California only, for fully attaining the alternative standards in a year beyond 2020 (glidepath estimates for 2020, plus further increments needed to reach full attainment beyond 2020, added together for California total).

Table 5.9 California Extrapolated Costs ($M)					
		0.079	**0.075**	**0.070**	**0.065**
CA (Glidepath)					
	Marginal Cost Approach	$0	$0	$829	$2,230
	Lower Estimate (fixed cost)	$0	$0	$181	$452
	Upper Estimate (fixed cost)	*	*	$305	$763
CA Increment Needed for Full Attainment	**Marginal Cost Approach**	$4,566	$6,227	$12,022	$18,301
	Lower Estimate (fixed cost)	$1,187	$1,050	$1,773	$2,405
	Upper Estimate (fixed cost)	*	*	$2,995	$4,064
CA (Full Attainment-Later Year)					
	Marginal Cost Approach	$4,566	$6,227	$12,851	$20,530
	Lower Estimate (fixed cost)	$1,187	$1,050	$1,953	$2,857
	Upper Estimate (fixed cost)	*	*	$3,301	$4,827

* Due to the limited amount of controls in the modeled control strategy which had this value, deducting this amount would likely result in an over estimate of the savings.

It is not appropriate to add together the 2020 national attainment, California glidepath estimate and the estimate of California full attainment as an estimate of national full attainment in 2020. The extra increment of attainment that is estimated for California will not occur in 2020, so it is not accurate to add it to our nationwide estimate of the "glidepath" benefits and costs to arrive at a "full attainment" estimate for 2020[12]. It is also not accurate to add the two estimates together to arrive at an estimate of future, post-2020 full attainment benefits and costs, because EPA's nationwide full attainment estimates do not allow other areas of the nation to take credit for the reductions in NOx from the mobile source rules that will occur after 2020.[13]

5.4 Technology Innovation and Regulatory Cost Estimates

The history of the Clean Air Act provides many examples in which technological innovation and "learning by doing" have made it possible to achieve greater emissions reductions than had been feasible earlier, or have reduced the costs of emission control in relation to original estimates. Innovative companies have successfully responded to the regulatory challenges and market opportunities provided by the Act, producing breakthrough technologies for multiple sectors.

[12] The California full attainment costs calculated using the offset in NOx emissions from mobile programs would understate the costs of fully attaining in 2020, however, California will not be required to attain in 2020.

[13] This approach would be an overestimate of national full attainment costs in a future year after 2020 because it would not take into account that other states (not just California) could replace more expensive NOx reductions from other sources with the post-2020 reductions obtained from implementation of mobile source rules that are included in the regulatory baseline.

Studies[14] have suggested that costs of some EPA programs have been less than originally estimated due in part to inadequate inability to predict and account for future technological innovation in regulatory impact analyses.

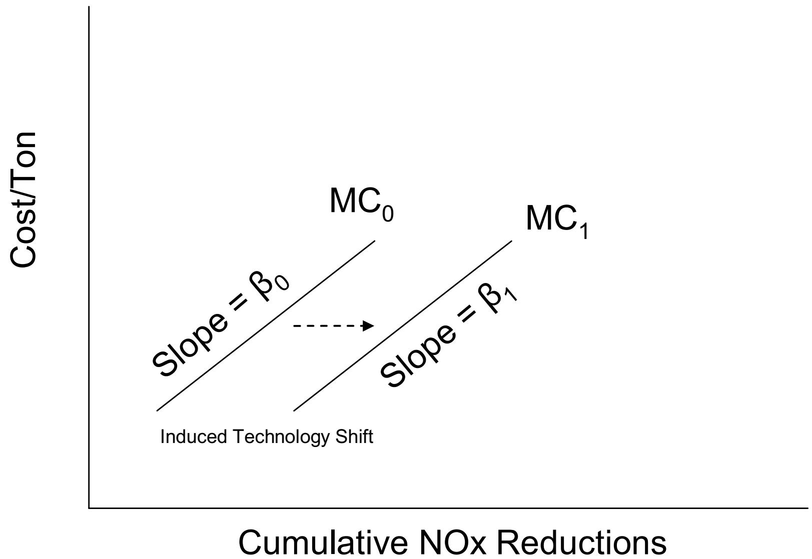
Technological change will affect baseline conditions for our analysis. This change may lead to potential improvements in the efficiency with which firms produce goods and services, for example, firms may use less energy to produce the same quantities of output. In addition, technological change may result in improvements in the quality of health care, which can have impacts on the baseline health of the population, potentially reducing the susceptibility of the population to the effects of air pollution. While our baseline mortality incidence rates account for increasing life expectancy, and thus reflect projected improvements in health care, our baseline incidence rates for other health endpoints such as hospital admissions do not reflect any future advances in health care, and thus, our estimates of avoided health impacts for these endpoints will potentially be overstated. For other endpoints, such as asthma, there has been an observed upward trend in prevalence, which we have not captured in our incidence rates. For these endpoints, our estimates will potentially be understated. In general, for non-mortality endpoints, there is increased uncertainty in our estimates due to our use of current baseline incidence and prevalence rates.

A constantly increasing marginal cost curve similar to the one utilized for estimating extrapolated costs in this RIA is likely to induce the type of innovation that would result in lower costs than estimated early in this chapter. Breakthrough technologies in control equipment could by 2020 result in a rightward shift in the marginal cost curve (Figure 5.2)[15] as well as perhaps a decrease in its slope, reducing marginal costs per unit of abatement, and thus deviate from the assumption of one constantly increasing marginal cost curve. In addition, elevated abatement costs may result in significant increases in the cost of production and would likely induce production efficiencies, in particular those related to energy inputs, which would lower emissions from the production side.

[14] Harrinton et al ,2000, and previous studies cited by Harrington

[15] Figure 5.2 shows a linear marginal abatement cost curve. It is possible that the shape of the marginal abatement cost curve is non-linear.

Figure 5.2 Technological Innovation Reflected by Marginal Cost Shift



5.4.1 Examples of Technological Advances in Pollution Control

There are numerous examples of low-emission technologies developed and/or commercialized over the past 15 or 20 years, such as:

- Selective catalytic reduction (SCR) and ultra-low NOx burners for NOx emissions
- Scrubbers which achieve 95% and even greater SO2 control on boilers
- Sophisticated new valve seals and leak detection equipment for refineries and chemical plans
- Low or zero VOC paints, consumer products and cleaning processes
- Chlorofluorocarbon (*CFC)* free air conditioners, refrigerators, and solvents
- Water and power-based coatings to replace petroleum-based formulations
- Vehicles far cleaner than believed possible in the late 1980s due to improvements in evaporative controls, catalyst design and fuel control systems for light-duty vehicles; and treatment devices and retrofit technologies for heavy-duty engines
- Continued development of activated carbon injection (ACI) technology for control of mercury from electric generating units
- Development of integrated gasification combined cycle (IGCC) and ultra-super critical pulverized coal technologies for electricity generation
- Idle-reduction technologies for engines, including truck stop electrification efforts
- Market penetration of gas-electric hybrid vehicles, biodiesel and other clean fuels

These technologies were not commercially available two decades ago, and some were not even in existence. Yet today, all of these technologies are on the market, and many are widely employed. Several are key components of major pollution control programs,

5.4.2 Influence on Regulatory Cost Estimates

Studies indicate that it is not uncommon for pre-regulatory cost estimates to be higher than later estimates, in part because of inability to predict technological advances. Over longer time horizons, such as the time allowed for areas with high levels of ozone pollution to meet the ozone NAAQS, the opportunity for technical advances is greater.

- *Multi-rule study:* Harrington et al. of Resources for the Future (2000) conducted an analysis of the predicted and actual costs of 28 federal and state rules, including 21 issued by EPA and the Occupational Safety and Health Administration (OSHA), and found a tendency for predicted costs to overstate actual implementation costs. Costs were considered accurate if they fell within the analysis error bounds or if they fall within 25 percent (greater or less than) the predicted amount. They found that predicted total costs were overestimated for 14 of the 28 rules, while total costs were underestimated for only three rules. Differences can result because of quantity differences (e.g., overestimate of pollution reductions) or differences in per-unit costs (e.g., cost per unit of pollution reduction). Per-unit costs of regulations were overestimated in 14 cases, while they were underestimated in six cases. In the case of EPA rules, the agency overestimated per-unit costs for five regulations, underestimated them for four regulations (three of these were relatively small pesticide rules), and accurately estimated them for four. Based on examination of eight economic incentive rules, "for those rules that employed economic incentive mechanisms, overestimation of per-unit costs seems to be the norm," the study said.

  Based on the case study results and existing literature, the authors identified technological innovation as one of five explanations of why predicted and actual regulatory cost estimates differ: "Most regulatory cost estimates ignore the possibility of technological innovation … Technical change is, after all, notoriously difficult to forecast … In numerous case studies actual compliance costs are lower than predicted because of unanticipated use of new technology."[16]

  It should be noted that many (though not all) of the EPA rules examined by Harrington had compliance dates of several years, which allowed a limited period for technical innovation. Much longer time periods (ranging up to 20 years) are allowed by the statute for meeting the ozone NAAQS in areas with high ozone levels, where a substantial fraction of the estimated cost in this analysis is incurred.

- *Acid Rain SO2 Trading Program*: Recent cost estimates of the Acid Rain SO2 trading program by Resources for the Future (RFF) and MIT have been as much as 83 percent

[16] Harrington et al., 2000.

lower than originally projected by EPA.[17] Note that the original EPA cost analysis also relied on an optimization model like IPM to approximate the results of emissions trading. As noted in the RIA for the Clean Air Interstate Rule, the ex ante numbers in 1989 were an overestimate in part because of the limitation of economic modeling to predict technological improvement of pollution controls and other compliance options such as fuel switching. Harrington et al report that scrubbing turned out to be more efficient (95% removal vs. 80-85% removal) and more reliable (95% vs. 85% reliability) than expected, and that unanticipated opportunities arose to blend low and high sulfur coal in older boilers up to a 40/60 mixture, compared with the 5/95 mixture originally estimated.

Phase 2 Cost Estimates	
Ex ante estimates	$2.7 to $6.2 billion[18]
Ex post estimates	$1.0 to $1.4 billion

- *EPA Fuel Control Rules:* A 2002 study by two economists with EPA's Office of Transportation and Air Quality[19] examined EPA vehicle and fuels rules and found a general pattern that "all ex ante estimates tended to exceed actual price impacts, with the EPA estimates exceeding actual prices by the smallest amount." The paper notes that cost is not the same as price, but suggests that a comparison nonetheless can be instructive.[20] An example focusing on fuel rules is provided:

[17] Carlson et al., 2000; Ellerman, 2003.
[18] 2010 Phase II cost estimate in $1995.
[19] Anderson et al, 2002.
[20] The paper notes: "Cost is not the same as price. This simple statement reflects the fact that a lot happens between a producer's determination of manufacturing cost and its decisions about what the market will bear in terms of price change."

Table 5.10 Comparison of Inflation-Adjusted Estimated Costs and Actual Price Changes for EPA Fuel Control Rules[21]

	Inflation-adjusted Cost Estimates (c/gal)				Actual Price Changes (c/gal)
	EPA	DOE	API	Other	
Gasoline					
Phase 2 RVP Control (7.8 RVP - Summer) (1995$)	1.1		1.8		0.5
Reformulated Gasoline Phase 1 (1997$)	3.1-5.1	3.4-4.1	8.2-14.0	7.4 (CRA)	2.2
Reformulated Gasoline Phase 2 (Summer) (2000$)	4.6-6.8	7.6-10.2	10.8-19.4	12	7.2 (5.1, when corrected to 5yr MTBE price)
30 ppm sulfur gasoline (Tier 2)	1.7-1.9	2.9-3.4	2.6	5.7 (NPRA), 3.1 (AIAM)	N/A
Diesel					
500 ppm sulfur highway diesel fuel (1997$)	1.9-2.4			3.3 (NPRA)	2.2
15 ppm sulfur highway diesel fuel	4.5	4.2-6.0	6.2	4.2-6.1 (NPRA)	N/A

- Chlorofluorocarbon (*CFC) Phase-Out:* EPA used a combination of regulatory, market based (i.e., a cap-and-trade system among manufacturers), and voluntary approaches to phase out the most harmful ozone depleting substances. This was done more efficiently than either EPA or industry originally anticipated. The phaseout for Class I substances was implemented 4-6 years faster, included 13 more chemicals, and cost 30 percent less than was predicted at the time the 1990 Clean Air Act Amendments were enacted.[22]

  The Harrington study states, "When the original cost analysis was performed for the CFC phase-out it was not anticipated that the hydrofluorocarbon HFC-134a could be substituted for CFC-12 in refrigeration. However, as Hammit (1997) notes, 'since 1991 most new U.S. automobile air conditioners have contained HFC-134a (a compound for which no commercial production technology was available in 1986) instead of CFC-12" (p.13). He cites a similar story for HCFRC-141b and 142b, which are currently substituting for CFC-11 in important foam-blowing applications."

[21] Anderson et al., 2002.
[22] Holmstead, 2002.

5.5 References

Anderson, J.F., and Sherwood, T., 2002. "Comparison of EPA and Other Estimates of Mobile Source Rule Costs to Actual Price Changes," Office of Transportation and Air Quality, U.S. Environmental Protection Agency. Technical Paper published by the Society of Automotive Engineers. SAE 2002-01-1980.

Babiker, M.H., and T.F. Rutherford. 1997. "Input Output and General Equilibrium Estimates of Embodied CO2: A Data Set and Static Framework for Assessment." University of Colorado at Boulder, Working Paper 97 2. Available at http://debreu.colorado.edu/papers/gtaptext.html.

Babiker, M.H., J.M. Reilly, M. Mayer, R.S. Eckaus, I.S. Wing, and R.C. Hyman. 2001. "The MIT Emissions Prediction and CO2 Policy Analysis (EPPA) Model: Revisions, Sensitivities, and Comparisons of Results." MIT Joint Program on the Science and Policy of Global Change, Report No. 71. Available at http://web.mit.edu/globalchange/www/eppa.html.

Bovenberg, L.A., and L.H. Goulder. 1996. "Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analysis." American Economic Review 86(4):985-1000. Available at <http://www.aeaweb.org/aer/>.

Brooke, A., D. Kendrick, A. Meeraus, and R. Raman. 1998. GAMS: A User's Guide. GAMS Development Corporation. Available at http://www.gams.com.

Carlson, Curtis, Dallas R. Burtraw, Maureen, Cropper, and Karen L. Palmer. 2000. "SulfurDioxide Control by Electric Utilities: What Are the Gains from Trade?" *Journal of Political Economy* 108(#6):1292-1326.

Ellerman, Denny. January 2003. Ex Post Evaluation of Tradable Permits: The U.S. SO2 Cap-and-Trade Program. Massachusetts Institute of Technology Center for Energy and Environmental Policy Research.

Feenberg, D., and E. Coutts. 1993. "An Introduction to the TAXSIM Model." Journal of Policy Analysis and Management 12(1):189 194. Available at http://www.nber.org/~taxsim/.
Fullerton, D., and D. Rogers. 1993. "Who Bears the Lifetime Tax Burden?" Washington, DC: The Brookings Institute. Available at http://bookstore.brookings.edu/book_details.asp?product%5Fid=10403.

Goulder, L.H., and R.C. Williams. 2003. "The Substantial Bias from Ignoring General Equilibrium Effects in Estimating Excess Burden, and a Practical Solution." Journal of Political Economy 111:898 927. Available at http://www.journals.uchicago.edu/JPE/home.html

Harrington, W., R.D. Morgenstern, and P. Nelson. 2000. "On the Accuracy of Regulatory Cost Estimates." *Journal of Policy Analysis and Management* 19(2):297-322.

Hammit, J.K. (1997). "Are the costs of proposed environmental regulations overestimated? Evidence from the CFC phaseout." Unpublished paper, Center for Risk Analysis, Harvard School of Public Health, Cambridge, MA.

Holmstead, Jeffrey, 2002. "Testimony of Jeffrey Holmstead, Assistant Administrator, Office of Air and Radiation, U.S. Environmental Protection Agency, Before the Subcommittee on Energy and air Quality of the committee on Energy and Commerce, U.S. House of Representatives, May 1, 2002, p. 10.

Minnesota IMPLAN Group. 2003. State Level Data for 2000. Available from http://www.implan.com/index.html.

Nestor, D.V., and C.A. Pasurka. 1995. The U.S. Environmental Protection Industry: A Proposed Framework for Assessment. U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation. EPA 230-R-95-001. Available at http://yosemite.epa.gov/ee/epa/eermfile.nsf/11f680ff78df42f585256b45007e6235/41b8b642ab9371df852564500004b543/$FILE/EE 0217A 1.pdf.

U.S. Department of Energy, Energy Information Administration. Undated (b). State Energy Price and Expenditure Report. Washington DC. Available at http://www.eia.doe.gov/emeu/states/price_multistate.html.

U.S. Department of Energy, Energy Information Administration. 2001. Manufacturing Energy Consumption Survey 1998. Washington DC. Available at http://www.eia.doe.gov/emeu/mecs/.

U.S. Department of Energy, Energy Information Administration. January 2003. Annual Energy Outlook 2003. DOE/EIA 0383(2003). Washington DC. Available at http://www.eia.doe.gov/oiaf/archive/aeo03/pdf/0383(2003).pdf.

U.S. Department of Energy, Energy Information Administration. January 2004. Annual Energy Outlook 2004. DOE/EIA-0383(2003). Washington, DC. Available at http://www.eia.doe.gov/oiaf/aeo/pdf/0383 (2001).

U.S. Environmental Protection Agency. June 2007. Advisory Council on Clean Air Compliance Analysis (COUNCIL), Council Advisory on OAR's Direct Cost Report and Uncertainty Analysis Plan. Washington, DC. http://www.epa.gov/sab/pdf/council-07-002.pdf

Appendix- Chapter 5

5a.1 Cost Information for Non-EGU and area sources

(Full details on controls can be found in Appendix Chapter 3)

Low Emission Combustion (LEC)

The average cost effectiveness for large IC engines using LEC technology was estimated to be $532/ton (ozone season).[1] The EC/R report on IC engines (Ec/R, September 1, 2000) estimates the average cost effectiveness for IC engines using LEC technology to range from $420-840/ton (ozone season) for engines in the 2,000-8,000 bhp range. The key variables in determining average cost effectiveness for LEC technology are the average uncontrolled emissions at the existing source, the projected level of controlled emissions, annualized costs of the controls, and number of hours of operation in the ozone season. The ACT document uses an average uncontrolled level of 16.8 g/bhp-hr, a controlled level of 2.0 g/bhp-hr (87% decrease), and nearly continuous operation in the ozone season. The EPA believes the ACT document provides a reasonable approach to calculating cost effectiveness for LEC technology.

Leak Detection and Repair (LDAR) for Fugitive Leaks

The control efficiency is 80 percent reduction of VOC at an annualized cost of $4,800 per ton. We do not include the costs of this control measure in our analyses in the Houston nonattainment area since these controls are already included in the 8-hour Ozone SIP for this area.

Enhanced LDAR for Fugitive Leaks

The control efficiency of this measure is estimated at 50 percent at a cost of $3,050/ton of VOC reduced[2].

Flare Gas Recovery

The control efficiency of this measure is 98 percent reduction of VOC emissions at a cost of $2,700/ton. Costs may become negligible as the size of the flare increases due to recovery credit.[3]

---

[1] "NOx Emissions Control Costs for Stationary Reciprocating Internal Combustion Engines in the NOx SIP Call States," E.H. Pechan and Associates, Inc., Springfield, VA, August 11, 2000. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/cost/pechan8-11.pdf

[2] "Suggested Short List and Evaluation of Point and Area Source Emission Control Measures for the Houston-Galveston-Brazoria 8-Hour Ozone Nonattainment Area," Texas Council on Environmental Quality," Prepared by ENVIRON International Corp. for Lamar Univ. June 15, 2006. Available on the Internet at http://www.h-gac.com/NR/rdonlyres/e4cgpdlu4wd3tiguvvxkg5ziefqy36adm2o5cz5jpm36c67ksxbtfurvvwvgdquy362skyhnsel5uh4rdkfz2rusphd/Final+Short+List+%26+Evaluations.pdf.

[3] MARAMA Multipollutant Rule Basis for Flares, part of "Assessment of Control Technology Options for Petroleum Refineries in the mid-Atlantic Region." February 19, 2007. Found on the Internet at http://www.marama.org/reports/021907_Refinery_Control_Options_TSD_Final.pdf.

Cooling Towers

There is not a general estimate of control efficiency for this measure; one is to apply a continuous flow monitor until VOC emissions have reached a level of 1.7 tons/year for a given cooling tower.[4] The annualized cost for a continuous flow monitor is $63,000 – this is constant over a variety of cooling tower sizes.

Wastewater Drains and Separators

The control efficiency is 65 percent reduction of VOC emissions at a cost of $3,050/ton. This is based on actual sampling and cost data for 5 refineries in the Bay Area Air Quality Management District (BAAQMD).[5]

5a.2 Cost Information for EGU sources

(Full details on controls can be found in Appendix Chapter 3)

Cost of Controls as a Result of Lower Sub-regional Caps within the MWRPO and OTC and other Local Controls outside of these Regions within CAIR

As previously discussed, the power sector will achieve significant emission reductions under the Clean Air Interstate Rule (CAIR) over the next 10 to 15 years. When fully implemented, CAIR (in conjunction with NOx SIP Call) will reduce ozone season NOx emissions by over 60 percent from 2003 levels within the CAIR states. These reductions will greatly improve air quality and will lessen the challenges that some areas face when solving nonattainment issues significantly.

Power sector impacts analyzed in detail in the Final PM NAAQS RIA 15/35 (http://www.epa.gov/ttn/ecas/ria.html) provides the baseline for this RIA. The analysis and projections in this section attempt to show the potential impacts of the additional controls applied (see section 3.3.3 of this RIA) to facilitate attainment of the more stringent 8-hr ozone standard of 0.070 ppm. Generally, the incremental impacts of these controls on the power sector are marginal.

Projected Costs. EPA projects that the annual incremental cost of the proposed new ozone standard approach is $0.2billion in 2020. The additional annual costs reflect additional retrofits (SCR and SNCR) and generation shifts,. Annualized cost of CAIR is projected to be $6.17 billion in 2020. The proposed approach applied in this RIA would add $0.2 billion incremental to this cost.

Projected Generation Mix**.** Coal-fired generation and natural gas/oil-fired generation are projected to remain almost unchanged. Installation of approximately 3.7 GWs of SCR and 1.1 GWs of SNCR incremental to the base case are projected as a result of the lower sub-regional caps. There are very small changes in the generation mix. Coal-fired generation increases about 12 GWh (an increase of approximately 0.25% of the total generation) and gas-fired generation

[4] Bay Area Air Quality Management District (BAAQMD). Proposed Revision of Regulation 8, Rule 8: Wastewater Collection Systems. Staff Report, March 17, 2004.

[5] Bay Area Air Quality Management District (BAAQMD). Proposed Revision of Regulation 8, Rule 8: Wastewater Collection Systems. Staff Report, March 17, 2004.

decreases a similar amount. Hydo, nuclear, other, and renewable based generation projected to remain the same. Projected retirements of coal units is marginal, accounting to about 0.4 GWs compared to the base case approach.

Projected Nationwide Retail Electricity Prices**.** Retail electricity prices are projected to change marginally, only about 1%. The extension of the cap-and-trade approach in the form of lower sub-regional caps allows industry to meet the requirements of CAIR in the most cost-effective manner, thereby minimizing the costs passed on to consumers. Retail electricity prices are projected to increase less than 1% within the MWRPO and OTC regions, and decrease about 1% in the rest of the CAIR region.

5a.3 Cost information for Onroad and Nonroad Mobile Sources

(Full details on controls can be found in Appendix Chapter 3)

Diesel Retrofits and Vehicle Replacement

To calculate costs for the use of selective catalytic reduction as a retrofit technology, the assumption was made that all relevant vehicles would be affected by the control. Therefore, all on-road heavy duty diesel vehicles that received a retrofit were assumed to employ selective catalytic reduction as a retrofit technology. The average cost of a selective catalytic reduction system ranges from $10,000 to $20,000 per vehicle depending on the size of the engine, the sales volume, and other factors (Pechan, 2003). For AirControlNET analysis, the average estimated cost of this system is $15,000 per heavy duty diesel vehicle. (Source: AirControlNET Documentation, III-160). OTAQ conducted an additional assessment of current SCR costs and calculated that for the year 2020, the cost of SCRs will be approximately $13,000 per unit. This estimate reflects an economy of scale cost reduction of 33%, which is consistent with trends in other mobile source control technologies that enter large scale production.

The rebuild/upgrade kit is applied to nonroad equipment. OTAQ estimates the cost of this kit to be $2,000 to $4,000 per vehicle. For this analysis, the average estimated cost is $3,000 per vehicle.

Table 5a.1: Summary of Cost Effectiveness for Rebuild/Upgrade Kit for Various Nonroad Vehicles

Nonroad Vehicle	Retrofit Technology	Range of $/ton NOx Emission Reduced		Range of $/ton HC Emission Reduced	
Tractors/Loaders/Backhoes	Rebuild/ Upgrade kit	$1,300	$2,200	$9,600	$18,900
Excavators		$1,100	$4,200	$8,100	$43,400
Crawler Tractor/Dozers		$1,100	$4,200	$8,300	$43,500
Skid Steer Loaders		$1,000	$1,600	$7,400	$14,800
Agricultural Tractors		$1,200	$4,900	$9,300	$34,300

Table 5a.2: Summary of Cost Effectiveness for SCR for Various Nonroad Vehicles

Nonroad Vehicle	Retrofit Technology	Range of $/ton NOx Emission Reduced		Range of $/ton HC Emission Reduced	
Tractors/Loaders/Backhoes	SCR	$2,900	$5,300	$32,200	$63,700
Excavators		$2,700	$10,400	$27,400	$146,200
Crawler Tractor/Dozers		$2,800	$10,400	$27,900	$146,700
Skid Steer Loaders		$2,600	$4,000	$24,900	$52,100
Agricultural Tractors		$3,000	$7,600	$31,200	$115,500

Table 5a.3: Summary of Cost Effectiveness for SCR for Various Highway Vehicles

Highway Vehicle	Retrofit Technology	Range of $/ton NOx Emission Reduced		Range of $/ton HC Emission Reduced	
Class 6&7 Truck	SCR	$5,600	$14,100	$46,900	$126,200
Class 8b Truck		$1,100	$2,500	$14,900	$44,600

Implement Continuous Inspection and Maintenance Using Remote Onboard Diagnostics (OBD)
Continuous I/M can significantly lower test costs and "convenience" costs of I/M programs. Using radio frequency transmission, there is a one-time cost for the Continuous I/M device and its installation. In the case of Oregon, this cost is $50. The unit is then good for the life of the vehicle. Annual or biennial test fees are not required beyond this initial fee to operate the system but there may be additional operational costs to cover data processing, reporting, and oversight. For the proposal RIA, we present estimated cost savings of the Continuous I/M program, but do not include the cost savings in the overall cost estimates. For the final RIA, we plan to include the Continuous I/M cost savings in the overall costs. This will result in a significant reduction of overall cost.

We can compare the costs of periodic testing to Continuous I/M. The cost of data processing, reporting and oversight is estimated to be $2 per vehicle per year in the typical I/M area. If we assume an average vehicle life span of 14 years, with the first test at 4 years of age, vehicles will get 5 inspections in a biennial program and 10 in an annual program (not including additional change of ownership inspections, which are required in some areas). Thus, in a Continuous I/M program, an additional cost of $10-$20 will be incurred for each vehicle over its life, assuming the same costs apply in a Continuous I/M program as in a tailpipe test program.

In addition to test costs, Continuous I/M avoids most of the convenience costs associated with I/M – the time and fuel it takes to drive to the station, get a test, and return home. The one-time installation of the transmitter requires a visit to the test station, but no further visits are required after that. So, if we assume, conservatively, that the typical test cycle requires a total of two hours of time at $20 per hour and a half-gallon of gas (10 miles round trip with an average fuel economy of 20 mpg) at $3 per gallon gives us a cost of $41.50. Over the life of the vehicle that works out to $207.50 in a biennial program or $415 in an annual program. Compare this to the one time trip for Continuous I/M OBD at a cost of $41.50 and substantial savings are realized. Application of Continuous I/M resulted in NOx reductions of 4.2 to 6.5 percent (approximately 10,000 tons), depending on the geographic area, vehicle class, and type of existing I/M program. Some areas have no I/M, some I/M programs require annual testing, some require biennial testing, and some areas are piloting continuous I/M. We applied continuous I/M reductions only to those areas that currently have annual or biennial programs.

Putting it all together, the table below shows the lifetime inspection and convenience costs of Continuous I/M versus periodic I/M (assuming the current mix of annual and biennial testing and current test costs). Periodic I/M testing costs about $20 billion over a 10 year lifecycle with an additional $25 billion in convenience costs for a total of $45 billion. By contrast, Remote OBD has a test and installation cost of $4.3 billion dollars over the same 10 year period, and a convenience cost of $2.5 billion for a total of $6.8 billion. Thus, nationwide installation of Remote OBD would save the nation's motorists about $38 billion in inspection and convenience costs over a 10 year period.

Table 5a.4 Lifetime Inspection and Convenience Costs of I/M

	Test/Install Cost	**Convenience Cost**	**Total Cost**
Continuous I/M	$20 billion	$25 billion	$45 billion
Remote I/M	$4.3 billion	$2.5 billion	$6.8 billion
Savings	*$15.7 billion*	*$22.5 billion*	*$38.2 billion*

Given that Continuous I/M will actually reduce the cost of I/M, implementation of this measure is highly cost-effective. More information on I/M can be found at http://www.epa.gov/otaq/regs/im/im-tsd.pdf and www.epa.gov/obd/regtech/inspection.htm

Eliminating Long Duration Truck Idling

For purposes of this RIA, we identified this measure as a no cost strategy i.e. $0/ton NOx. Both TSEs and MIRTs have upfront capital costs, but these costs can be fully recovered by the fuel savings. The examples below illustrate the potential rate of return on investments in idle reduction strategies.

TSE

The average price of TSE technology is $11,500 per parking space. The average service life of this technology is 15 years. Truck engines at idle consume approximately 1 gallon per hour of idle. Current TSE projects are operating in environments where trucks are idling, on average, for 8 hours per day per space for 365 days per year (or about 2,920 hours per year). Since TSE technology can completely eliminate long duration idling at truck spaces (i.e. a 100% fuel savings), this translates into 2,920 gallons of fuel saved per year per space. At current diesel prices ($2.90/gallon), this fuel savings translates into $8,468. Therefore, an $11,500 capital investment should be recovered within about 17 months. In this scenario, TSE investments offer over a 70% annual rate of return over the life of the technology.

While it is technically feasible to electrify all parking spaces that support long duration idling trucks, we should note that TSE technology is generally deployed at a minimum of 25-50 parking spaces per location to maximize economies of scale. The financial attractiveness of installing TSE technology will depend on the demonstrated truck idling behavior – the greater the rates of idling, the greater the potential emissions reductions and associated fuel and cost savings.

MIRTs
The price of MIRT technologies ranges from $1,000-$10,000. The most popular of these technologies is the auxiliary power unit (APU) because it provides air conditioning, heat, and electrical power to operate appliances. The average price of an APU is $7,000. The average service life of an APU is 10 years. An APU consumes two-tenths of a gallon per hour, so the net fuel savings is 0.80 gallons per hour. EPA estimates that trucks idle for 7 hours per rest period, on average, and about 300 days per year (or 2,100 hours per year). Since idling trucks consume 1 gallon of fuel per hour of idle, APUs can reduce fuel consumption for truck drivers/owners by approximately 1,680 gallons per year. At current diesel prices ($2.90/gallon), truck drivers/owners would save $4,872 on fuel if they used an APU. Therefore, a $7,000 capital investment should be recovered within about 18 months. In this scenario, APU investments offer almost a 70% annual rate of return over the life of the technology.

Cost-Effectiveness of Measure: $0/ton NOx

Commuter Programs
We used the Transportation Research Board's (TRB) cost-effectiveness analysis of Congestion Mitigation and Air Quality Improvement Program (CMAQ) projects to estimate the cost-effectiveness of this measure.[6] TRB conducted an extensive literature review and then synthesized the data to develop comparable estimates of cost-effectiveness of a wide range of CMAQ-funded measures. We took the average of the median cost-effectiveness of a sampling of CMAQ-funded measures and then applied this number to the overarching commuter reduction measure. The CMAQ-funded measures we selected were:

- regional rideshares
- vanpool programs
- park-and-ride lots
- regional transportation demand management
- employer trip reduction programs

We felt that these measures were a representative sampling of commuter reduction incentive programs. There is a great deal of variability, however, in the type of programs and the level of incentives that employers offer which can impact both the amount of emissions reductions and the cost of commuter reduction incentive programs.

[6] Transportation Research Board, National Research Council, 2002. *The Congestion Mitigation and Air Quality Improvement Program: assessing 10 years of experience*, Committee for the Evaluation of the Congestion Mitigation and Air Quality Improvement Program.

We chose to apply the resulting average cost-effectiveness estimate to one pollutant – NO_x – in order to be able to compare commuter reduction programs to other NO_x reduction strategies. TRB reported the cost-effectiveness of each measure, however, as a $/ton reduction of both VOC and NOx by applying the total cost of the program to a 1:4 weighted sum of VOC and NOx [[total emissions reduction = (VOC * 1) + (NO_x * 4)). There was not enough information in the TRB study to isolate the $/ton cost-effectiveness for just NO_x reductions, so we used the combined NO_x and VOC estimate. The results are presented in Table 5a.5.

Table 5a.5 Cost-Effectiveness of Best Workplaces for Commuters Type Measures from the 2002 TRB Study,
$/ton (2000$) 1:4 VOC:NOx *(reported in the RIA as $/ton NOx)*

	Low	**High**	**Median**
Regional Rideshare	$1,200	$16,000	$7,400
Vanpool Programs	$5,200	$89,000	$10,500
Park-and-ride lots	$8,600	$70,700	$43,000
Regional TDM	$2,300	$33,200	$12,500
Employer trip reduction programs	$5,800	$175,500	$22,700
Average of All Measures	$4,620	$76,900	**$19,200**

Cost-Effectiveness of Measure: $19,200/ton NOx

Reduce Gasoline RVP from 7.8 to 7.0 in Remaining Nonattainment Areas
Cost-Effectiveness of Measure: Cost per ton will be $5,700 to $36,000 / ton VOC

For more information on RVP:

- Michigan Department of Environmental Quality and Southeast Michigan Council of Governments. *Proposed Revision to State of Michigan State Implementation Plan for 7.0 Low Vapor Pressure Gasoline Vapor Request for Southeast Michigan*. May 24, 2006.
- U.S. EPA. *Guide on Federal and State Summer RVP Standards for Conventional Gasoline Only.* EPA420-B-05-012. November 2005

Chapter 6. Incremental Benefits of Attaining Alternative Ozone Standards Relative to the Current 8-hour Standard (0.08 ppm)

Synopsis

Based on projected emissions and air quality modeling, in 2020, 203 counties in the U.S. with ozone monitors are estimated to fail to meet an alternative ozone standard of 0.070 ppm for the 4th highest maximum 8-hour ozone concentration. This number falls to 82 for an alternative standard of 0.075 ppm, and further to 29 for an ozone standard of 0.079 ppm and increases to 360 for an alternative standard of 0.065 ppm. We estimated the health benefits of attaining these alternative ozone standards across the U.S. using the EPA Environmental Benefits Modeling and Analysis Program (BenMAP). We performed a two-stage analysis.

In the first stage we estimated the benefits associated with changes in modeled air quality following application of control technologies known to be currently available. These control strategies were sufficient to bring some, but not all, areas into attainment with the various standard levels. Thus, the benefits computed during this first stage were for partial attainment in some areas. In the second stage, we estimated the benefits of fully attaining the standards in all areas by using a "rollback" methodology to reduce ozone concentrations at residually nonattaining monitors to a level that would just meet the standards. We deviated from this two-stage approach when analyzing the 0.075 ppm standard alternative, where we applied an interpolation technique that is detailed further in this chapter. To calculate the monetary value of the adverse health outcomes potentially avoided due to these reductions in ambient ozone levels, we used health impact functions based on published epidemiological studies, and valuation functions derived from the economics literature.[1] Key health endpoints analyzed included premature mortality, hospital and emergency room visits, school absences, and minor restricted activity days.

There is considerable uncertainty in the magnitude of the association between ozone and premature mortality. This analysis presents four alternative estimates for the association based upon different functions reported in the scientific literature.. We also note that there are uncertainties within each study that are not fully captured by this range of estimates. Recognizing that additional research is needed to more fully establish underlying mechanisms by which such effects occur, we also consider the possibility that the observed associations between ozone and mortality may not be causal in nature. Using the National Morbidity, Mortality and Air Pollution Study (NMMAPS) that was used as the primary basis for the risk analysis presented in our Staff Paper and reviewed by Clean Air Science Advisory Committee (CASAC), we estimated 280 avoided premature deaths annually in 2020 from reducing ozone levels to meet a standard of 0.070 ppm, which, when added to the other projected benefits from reduced ozone, including 5,600 hospital and emergency room admissions, 780,000 school absences, and over 2,100,000 minor restricted activity days, leads to an estimated total ozone-related benefit of $2

[1] Health impact functions measure the change in a health endpoint of interest, such as hospital admissions, for a given change in ambient ozone or PM concentration

billion/yr (1999$). Using three studies that synthesize data across a large number of individual studies, we estimate between 1,100 and 1,400 avoided premature deaths annually in 2020 from reducing ozone to 0.070 ppm, leading to total monetized ozone-related benefits of between $7.4 and $9.1 billion/yr. Alternatively, if there is no causal relationship between ozone and mortality, avoided premature deaths associated with reduced ozone exposure would be zero and total monetized ozone-related morbidity benefits would be $190 million/yr.

For a less stringent standard of 0.075 ppm, using the NMMAPS ozone mortality study resulted in 200 premature deaths avoided and total monetized benefits of $1.6 billion/yr. Using the three synthesis studies, estimated premature deaths avoided for the less stringent standard are between 880 and 1,100, with total monetized ozone benefits between $5.9 and $7.3 billion/yr. Alternatively, if there is no causal relationship between ozone and mortality, avoided premature deaths associated with reduced ozone exposure would be zero and total monetized ozone-related morbidity benefits would be $150 million/yr.

For a less stringent standard of 0.079 ppm, using the NMMAPS ozone mortality study resulted in 19 premature deaths avoided and total monetized benefits of $140 million/yr. Using the three synthesis studies, estimated premature deaths avoided for the less stringent standard are between 78 and 85, with total monetized ozone benefits between $510 and $560 million/yr. Alternatively, if there is no causal relationship between ozone and mortality, avoided premature deaths associated with reduced ozone exposure would be zero and total monetized ozone-related morbidity benefits would be $12 million/yr.

For a more stringent standard of 0.065 ppm, using the NMMAPS ozone mortality study resulted in 530 premature deaths avoided and total monetized benefits of $3.7 billion/yr. Using the three synthesis studies, estimated premature deaths avoided for the more stringent standard are between 2,100 and 2,400, with total monetized ozone benefits between $14 and $16 billion/yr. Alternatively, if there is no causal relationship between ozone and mortality, avoided premature deaths associated with reduced ozone exposure would be zero and total monetized ozone-related morbidity benefits would be $330 million/yr. These estimates reflect EPA's interim approach to characterizing the benefits of reducing premature mortality associated with ozone exposure. EPA has requested advice from the National Academy of Sciences on how best to quantify uncertainty in the relationship between ozone exposure and premature mortality in the context of quantifying benefits associated with alternative ozone control strategies.

In addition to the direct benefits from reduced ozone concentrations, attainment of the standards would likely result in health and welfare benefits from the reduction of $PM_{2.5}$ that would occur as ozone precursor emissions (NOx and VOC) are reduced. Using both modeled and extrapolated reductions in these precursor emissions, we estimated PM-related co-benefits for the four alternative standards. For each alternative standard, we provide a range of estimated benefits based on several different PM mortality effect estimates. These effect estimates were derived from two different sources: the published epidemiology literature and an expert elicitation study conducted by EPA in 2006. For the partial attainment of the 0.070 ppm standard, we estimated PM co-benefits including between 220 and 2,200 premature deaths avoided, with total monetized PM co-benefits of between $1 and $9.9 billion/yr (3% discount rate, 1999$). For the 2020 attainment of the 0.070 ppm alternative, incremental to attainment of the 0.08 ppm standard, we estimate total ozone and $PM_{2.5}$-related co-benefits to be between $2.5 and $33 billion/yr; this range encompasses the expert functions and the ozone mortality functions as well as the possibility that there is no causal relationship between ozone and mortality. For the 2020 attainment of the 0.065 ppm alternative, incremental to attainment of the 0.08 ppm standard, we estimate total benefits of between $4.3 and $57 billion/yr; this range encompasses the expert functions and the ozone mortality functions as well as the possibility that there is no causal relationship between ozone and mortality. For the 2020 attainment of the 0.075 ppm alternative, incremental to attainment of the 0.08 ppm standard, we estimate total ozone and $PM_{2.5}$-related co-benefits to be between $1.5 and $22 billion/yr; this range encompasses the expert functions and the ozone mortality functions as well as the possibility that there is no causal relationship between ozone and mortality. For the 2020 attainment of the 0.079 ppm alternative, incremental to attainment of the 0.08 ppm standard, we estimate total ozone and $PM_{2.5}$-related co-benefits to be between $1.1 and $12 billion/yr; this range encompasses the expert functions and the ozone mortality functions as well as the possibility that there is no causal relationship between ozone and mortality.

6.1. Background

Our purpose for this analysis is to assess the human health benefits of attaining alternative 8-hour ozone standards, including 0.075 ppm, 0.070 ppm, and 0.065 ppm, incremental to attainment of the current 8-hour ozone standard of 0.08 ppm.[2] We applied a damage function approach similar to those used in several recent U.S. EPA regulatory impact analyses, including those for the 2006 Particulate Matter (PM) NAAQS (U.S. EPA, 2006) and the Clean Air Interstate Rule (U.S. EPA, 2005). This approach estimates changes in individual health and welfare endpoints (specific effects that can be associated with changes in air quality) and assigns values to those changes assuming independence of the individual values. Total benefits are calculated simply as the sum of the values for all non-overlapping health and welfare endpoints. This analysis largely builds off of both the analytical approach used in the 2006 PM NAAQS RIA and the analysis of ozone health impacts reported in Hubbell et al. (2005) and the Clean Air Interstate Rule RIA (2005). For a more detailed discussion of the principles of benefits analysis used here, we refer the reader to those documents, as well as to the EPA Guidelines for Economic Analysis.[3,4,5]

We applied a two-stage approach to estimate the benefits of fully attaining each alternative standard. In the first stage, we estimated the benefits associated with changes in modeled air

---

[2] This is effectively 0.084 ppm due to current rounding conventions. When calculating benefits in this chapter we followed the rounding convention and rounded to 0.084 ppm.

[3] U.S. EPA. 2006. Regulatory Impact Analysis, 2006 National Ambient Air Quality Standards for Particle Pollution, Chapter 5. Available at http://www.epa.gov/ttn/ecas/ria.html.

[4] Hubbell, B., A. Hallberg, D.R. McCubbin, and E. Post. 2005. Health-Related Benefits of Attaining the 8-Hr Ozone Standard. Environmental Health Perspectives 113:73–82. U.S. EPA. 2000. Guidelines for Preparing Economic Analyses. http://yosemite1.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html/$file/Guidelines.pdf

[5] U.S. EPA. 2000. Guidelines for Preparing Economic Analyses. http://yosemite1.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html/$file/Guidelines.pdf

quality following application of control technologies known to be currently available. These control strategies were sufficient to bring some, but not all, areas into attainment with the various standard levels. Thus, the benefits computed during this first stage were for partial attainment in some areas (see Chapter 3 for details on these control technologies and the results of the air quality modeling). In the second stage, we estimated the benefits of fully attaining the standards in all areas by using a "rollback" methodology to reduce ozone concentrations at residually nonattaining monitors to a level that would just meet the standards (see Appendix 6 for details on this methodology). We conducted analyses to examine the sensitivity of our results to a number of different assumptions about the choice of health effects and effect estimates from published epidemiological studies, as well as parameters that affect the economic valuation of health effects. A quantitative assessment of non-health benefits, e.g. benefits from reduced ozone-related crop damage, was outside of the scope of this analysis due to data and resource limitations.

For this assessment, we estimated benefits of changes in ozone and PM co-benefits resulting from application of illustrative control strategies on ozone precursor emissions to attain alternative ozone NAAQS. With the exception of ozone-related premature mortality, we use methods consistent with previous PM and ozone benefits assessments. Specifically, the analysis of PM co-benefits uses an approach identical to that used in the 2006 PM NAAQS RIA (U.S. EPA, 2006). The ozone benefits analysis for non-mortality endpoints uses an approach nearly identical to that for the Clean Air Interstate Rule RIA (U.S. EPA, 2005).[6]

All ozone and $PM_{2.5}$ co-benefits estimates in this chapter are incremental to a baseline of national full attainment with 0.08 ppm.[7] This baseline incorporates emission reductions projected to be achieved as a result of an array of federal rules such as the Clean Air Interstate and Non-Road Diesel Rule, as well as ozone and $PM_{2.5}$ state implementation plans. Moreover, the $PM_{2.5}$ co-benefits are incremental to an assumption of full attainment of the 2006 $PM_{2.5}$ NAAQS. A complete discussion of the baseline may be found in Chapter 3. The PM co-benefits presented in this chapter are incremental to the PM benefits estimated in the 2006 PM NAAQS RIA and reflect the PM benefits from NOx reductions associated with each ozone control strategy.

The remainder of this chapter describes the data and methods used in this analysis, along with the results. Additional details of the analysis are provided in Appendix 6 of this RIA. Section 6.2 discusses the probabilistic framework for the benefits analysis and how key uncertainties are addressed in the analysis. Section 6.3 discusses the literature on ozone- and PM-related health effects and describes the specific set of health impact functions we used in the benefits analysis. Section 6.4 describes the economic values selected to estimate the dollar value of ozone- and PM- related health impacts. Finally, Section 6.5 presents the results and implications of the analysis.

---

[6] The one exception relates to the use of updated health impact functions for emergency department visits. These new functions are detailed further in this chapter.

[7] The PM2.5 benefits presented below reflect the NOx emission reductions from the ozone control strategy. Reductions from Ocean-Going Vessels burning residual diesel fuel were included both East and West in the baseline PM co-benefits, but not included in the ozone baseline for the west. See chapter 3 for more details of this rule and its application.

6.2. Characterizing Uncertainty: Moving Toward a Probabilistic Framework for Benefits Assessment

The National Research Council (NRC) (2002) highlighted the need for EPA to conduct rigorous quantitative analysis of uncertainty in its benefits estimates and to present these estimates to decision makers in ways that foster an appropriate appreciation of their inherent uncertainty. In response to these comments, EPA's Office of Air and Radiation (OAR) is developing a comprehensive strategy for characterizing the aggregate impact of uncertainty in key modeling elements on both health incidence and benefits estimates. Components of that process include emissions modeling, air quality modeling, health effects incidence estimation, and valuation.

Two aspects of OAR's approach that have been used in several recent RIAs are employed here.[8,9,10] First, we use Monte Carlo methods for estimating characterizing random sampling error associated with the concentration response functions from epidemiological studies and economic valuation functions. Monte Carlo simulation uses random sampling from distributions of parameters to characterize the effects of uncertainty on output variables, such as incidence of premature mortality. Specifically, we used Monte Carlo methods to generate confidence intervals around the estimated health impact and dollar benefits. Distributions for individual effect estimates are based on the reported standard errors in the epidemiological studies. Distributions for unit values are described in Table 6-4.

Second, we use a recently completed expert elicitation of the concentration response function describing the relationship between premature mortality and ambient $PM_{2.5}$ concentration.[11] We note that incorporating only the uncertainty from random sampling error omits important sources of uncertainty (e.g., in the functional form of the model—e..g., whether or not a threshold may exist). Use of the expert elicitation and incorporation of the standard errors approaches provide insights into the likelihood of different outcomes and about the state of knowledge regarding the benefits estimates. Both approaches have different strengths and weaknesses, which are full described in Chapter 5 of the PM NAAQS RIA.

In benefit analyses of air pollution regulations conducted to date, the estimated impact of reductions in premature mortality has accounted for 85% to 95% of total benefits. Therefore, in characterizing the uncertainty related to the estimates of total benefits it is particularly important to attempt to characterize the uncertainties associated with this endpoint. The health impact

---

[8] U.S. Environmental Protection Agency, 2004a. Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines. EPA420-R-04-007. Prepared by Office of Air and Radiation. Available at http://www.epa.gov/nonroad-diesel/2004fr/420r04007.pdf

[9] U.S. Environmental Protection Agency, 2005. Regulatory Impact Analysis for the Clean Air Interstate Rule. EPA 452/-03-001. Prepared by Office of Air and Radiation. Available at: http://www.epa.gov/interstateairquality/tsd0175.pdf

[10] U.S. Environmental Protection Agency, 2006. Regulatory Impact Analysis for the PM NAAQS. EPA Prepared by Office of Air and Radiation. Available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/Chapter%205--Benefits.pdf

[11] Expert elicitation is a formal, highly structured and well documented process whereby expert judgments, usually of multiple experts, are obtained (Ayyb, 2002).

functions used to estimate avoided premature deaths associated with reductions in ozone have associated standard errors that represent the statistical errors around the effect estimates in the underlying epidemiological studies.[12] In our results, we report credible intervals based on these standard errors, reflecting the uncertainty in the estimated change in incidence of avoided premature deaths. We also provide multiple estimates, to reflect model uncertainty between alternative study designs. In addition, we characterize the uncertainty introduced by the inability of existing empirical studies to discern whether the relationship between ozone and pre-mature mortality is causal by providing an effect estimate preconditioned on an assumption that the effect estimate for pre-mature mortality from ozone is zero.

For premature mortality associated with exposure to PM, we follow the same approach used in the RIA for 2006 PM NAAQS (U.S. EPA, 2006), presenting several empirical estimates of premature deaths avoided, and a set of twelve estimates based on results of the expert elicitation study.[13] Even these multiple characterizations, including confidence intervals, omit the contribution to overall uncertainty of uncertainty in air quality changes, baseline incidence rates, populations exposed and transferability of the effect estimate to diverse locations. Furthermore, the approach presented here does not yet include methods for addressing correlation between input parameters and the identification of reasonable upper and lower bounds for input distributions characterizing uncertainty in additional model elements. As a result, the reported confidence intervals and range of estimates give an incomplete picture about the overall uncertainty in the estimates. This information should be interpreted within the context of the larger uncertainty surrounding the entire analysis.

6.3. Health Impact Functions

Health impact functions measure the change in a health endpoint of interest, such as hospital admissions, for a given change in ambient ozone or PM concentration. Health impact functions are derived from primary epidemiology studies, meta-analyses of multiple epidemiology studies, or expert elicitations. A standard health impact function has four components: 1) an effect estimate from a particular study; 2) a baseline incidence rate for the health effect (obtained from either the epidemiology study or a source of public health statistics such as the Centers for Disease Control); 3) the size of the potentially affected population; and 4) the estimated change in the relevant ozone or PM summary measures.

A typical health impact function might look like:

$$\Delta y \quad y_0 \cdot (e^{\beta \cdot \Delta x} - 1),$$

[12] Health impact functions measure the change in a health endpoint of interest, such as hospital admissions, for a given change in ambient ozone or PM concentration.
[13] Industrial Economics, Inc. 2006. Expanded Expert Judgment Assessment of the Concentration-Response Relationship Between PM2.5 Exposure and Mortality. Prepared for EPA Office of Air Quality Planning and Standards, September. Available at: http://www.epa.gov/ttn/ecas/regdata/Uncertainty/pm_ee_report.pdf

where y_0 is the baseline incidence (the product of the baseline incidence rate times the potentially affected population), β is the effect estimate, and x is the estimated change in the summary ozone measure. There are other functional forms, but the basic elements remain the same. Chapter 3 described the ozone and PM air quality inputs to the health impact functions. The following subsections describe the sources for each of the other elements: size of potentially affected populations; effect estimates; and baseline incidence rates.

6.3.1 Potentially Affected Populations

The starting point for estimating the size of potentially affected populations is the 2000 U.S. Census block level dataset (Geolytics 2002). Benefits Modeling and Analysis Program (BenMAP) incorporates 250 age/gender/race categories to match specific populations potentially affected by ozone and other air pollutants. The software constructs specific populations matching the populations in each epidemiological study by accessing the appropriate age-specific populations from the overall population database. BenMAP projects populations to 2020 using growth factors based on economic projections (Woods and Poole Inc. 2001).

6.3.2 Effect Estimate Sources

The most significant monetized benefits of reducing ambient concentrations of ozone and PM are attributable to reductions in human health risks. EPA's Ozone and PM Criteria Documents and the World Health Organization's 2003 and 2004 reports outline numerous health effects known or suspected to be linked to exposure to ambient ozone and PM (US EPA, 2006; US EPA, 2005; WHO, 2003; Anderson et al., 2004). EPA recently evaluated the PM literature for use in the benefits analysis for the 2006 PM NAAQS RIA. Because we use the same literature for the PM co-benefits analysis in this RIA, we do not provide a detailed discussion of individual effect estimates for PM in this section. Instead, we refer the reader to the 2006 PM NAAQS RIA for details.[14]

More than one thousand new ozone health and welfare studies have been published since EPA issued the 8-hour ozone standard in 1997. Many of these studies investigated the impact of ozone exposure on health effects such as: changes in lung structure and biochemistry; lung inflammation; asthma exacerbation and causation; respiratory illness-related school absence; hospital and emergency room visits for asthma and other respiratory causes; and premature death.

We were not able to separately quantify all of the PM and ozone health effects that have been reported in the ozone and PM criteria documents in this analysis for four reasons: (1) the possibility of double counting (such as hospital admissions for specific respiratory diseases); (2) uncertainties in applying effect relationships that are based on clinical studies to the potentially

[14] U.S. Environmental Protection Agency, 2005. Regulatory Impact Analysis for the PM NAAQS. EPA Prepared by Office of Air and Radiation. Available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/Chapter%205--Benefits.pdf pp. 5-29.

affected population; (3) the lack of an established concentration-response relationship; or 4) the inability to appropriately value the effect (for example, changes in forced expiratory volume) in economic terms. Table 6-1 lists the human health and welfare effects of pollutants affected by the alternate standards. Table 6-2 lists the health endpoints included in this analysis.

Table 6-1 Human Health and Welfare Effects of Pollutants Affected by the Alternate Standards

Pollutant/Effect	*Quantified and Monetized in Base Estimates*[a]	*Unquantified Effects - Changes in:*
PM/Health[b]	Premature mortality based on both cohort study estimates and on expert elicitation[c,d] Bronchitis: chronic and acute Hospital admissions: respiratory and cardiovascular Emergency room visits for asthma Nonfatal heart attacks (myocardial infarction) Lower and upper respiratory illness Minor restricted-activity days Work loss days Asthma exacerbations (asthmatic population) Respiratory symptoms (asthmatic population) Infant mortality	Subchronic bronchitis cases Low birth weight Pulmonary function Chronic respiratory diseases other than chronic bronchitis Nonasthma respiratory emergency room visits UVb exposure (+/-)[e]
PM/Welfare		Visibility in Southeastern Class I areas Visibility in northeastern and Midwestern Class I areas Household soiling Visibility in western U.S. Class I areas Visibility in residential and non-Class I areas UVb exposure (+/-)[e]
Ozone/Health[f]	Premature mortality: short-term exposures Hospital admissions: respiratory Emergency room visits for asthma Minor restricted-activity days School loss days Asthma attacks Acute respiratory symptoms	Cardiovascular emergency room visits Chronic respiratory damage Premature aging of the lungs Nonasthma respiratory emergency room visits UVb exposure (+/-)[e]
Ozone/Welfare		Decreased outdoor worker productivity Yields for commercial crops Yields for commercial forests and noncommercial crops Damage to urban ornamental plants Recreational demand from damaged forest aesthetics Ecosystem functions UVb exposure (+/-)[e]

[a] Primary quantified and monetized effects are those included when determining the primary estimate of total monetized benefits of the proposed standards.
[b] In addition to primary economic endpoints, there are a number of biological responses that have been associated with PM health effects including morphological changes and altered host defense mechanisms. The public health impact of these biological responses may be partly represented by our quantified endpoints.

[c] Cohort estimates are designed to examine the effects of long term exposures to ambient pollution, but relative risk estimates may also incorporate some effects due to shorter term exposures (see Kunzli, 2001 for a discussion of this issue).
[d] While some of the effects of short-term exposure are likely to be captured by the cohort estimates, there may be additional premature mortality from short-term PM exposure not captured in the cohort estimates included in the primary analysis.
[e] May result in benefits or disbenefits.
[f] In addition to primary economic endpoints, there are a number of biological responses that have been associated with ozone health including increased airway responsiveness to stimuli, inflammation in the lung, acute inflammation and respiratory cell damage, and increased susceptibility to respiratory infection. The public health impact of these biological responses may be partly represented by our quantified endpoints.
[g] The categorization of unquantified toxic health and welfare effects is not exhaustive.

Table 6-2. Ozone and PM Related Health Endpoints basis for the concentration-response function associated with that endpoint, and sub-populations for which they were computed.

Endpoint	*Pollutant*	*Study*	*Study Population*
Premature Mortality			
Premature mortality – daily time series, non-accidental	O3 (24-hour avg)	Bell et al (2004) (NMMAPS study)	All ages
		Meta-analyses:	
	O3 (24-hour avg)	Bell et al (2005)	
	O3 (1-hour max)	Ito et al (2005)	
	O3 (1-hour max)	Levy et al (2005)	
Premature mortality —cohort study, all-cause	$PM_{2.5}$ (annual avg)	Pope et al. (2002) Laden et al. (2006)	>29 years >25 years
Premature mortality, total exposures	$PM_{2.5}$ (annual avg)	Expert Elicitation (IEc, 2006)	>24 years
Premature mortality — all-cause	$PM_{2.5}$ (annual avg)	Woodruff et al. (1997)	Infant (<1 year)
Chronic Illness			
Chronic bronchitis	$PM_{2.5}$ (annual avg)	Abbey et al. (1995)	>26 years
Nonfatal heart attacks	$PM_{2.5}$ (24-hour avg)	Peters et al. (2001)	Adults (>18 years)
Hospital Admissions			
Respiratory	O3 (24-hour avg)	Pooled estimate: Schwartz (1995) - ICD 460-519 (all resp) Schwartz (1994a; 1994b) - ICD 480-486 (pneumonia) Moolgavkar et al. (1997) - ICD 480-487 (pneumonia) Schwartz (1994b) - ICD 491-492, 494-496 (COPD) Moolgavkar et al. (1997) – ICD 490-496 (COPD)	>64 years
		Burnett et al. (2001)	<2 years
	$PM_{2.5}$ (24-hour avg)	Pooled estimate: Moolgavkar (2003)—ICD 490-496 (COPD) Ito (2003)—ICD 490-496 (COPD)	>64 years
	$PM_{2.5}$ (24-hour avg)	Moolgavkar (2000)—ICD 490-496 (COPD)	20–64 years
	$PM_{2.5}$ (24-hour avg)	Ito (2003)—ICD 480-486 (pneumonia)	>64 years
	$PM_{2.5}$ (24-hour avg)	Sheppard (2003)—ICD 493 (asthma)	<65 years
Cardiovascular	$PM_{2.5}$ (24-hour avg)	Pooled estimate: Moolgavkar (2003)—ICD 390-429 (all cardiovascular) Ito (2003)—ICD 410-414, 427-428 (ischemic heart disease, dysrhythmia, heart failure)	>64 years
	$PM_{2.5}$ (24-hour avg)	Moolgavkar (2000)—ICD 390-429 (all cardiovascular)	20–64 years

Endpoint	*Pollutant*	*Study*	*Study Population*
Asthma-related ER visits	O_3 (8-hour max)	Pooled estimate: Jaffe et al (2003) Peel et al (2005) Wilson et al (2005)	 5–34 years All ages All ages
Asthma-related ER visits (con't)	$PM_{2.5}$ (24-hour avg)	Norris et al. (1999)	0–18 years
Other Health Endpoints			
Acute bronchitis	$PM_{2.5}$ (annual avg)	Dockery et al. (1996)	8–12 years
Upper respiratory symptoms	PM_{10} (24-hour avg)	Pope et al. (1991)	Asthmatics, 9–11 years
Lower respiratory symptoms	$PM_{2.5}$ (24-hour avg)	Schwartz and Neas (2000)	7–14 years
Asthma exacerbations	$PM_{2.5}$ (24-hour avg)	Pooled estimate: Ostro et al. (2001) (cough, wheeze and shortness of breath) Vedal et al. (1998) (cough)	6–18 years[a]
Work loss days	$PM_{2.5}$ (24-hour avg)	Ostro (1987)	18–65 years
School absence days	O_3 (8-hour avg) O_3 (1-hour max)	Pooled estimate: Gilliland et al. (2001) Chen et al. (2000)	5–17 years[b]
Minor Restricted Activity Days (MRADs)	O_3 (24-hour avg)	Ostro and Rothschild (1989)	18–65 years
	$PM_{2.5}$ (24-hour avg)	Ostro and Rothschild (1989)	18–65 years

[a] The original study populations were 8 to 13 for the Ostro et al. (2001) study and 6 to 13 for the Vedal et al. (1998) study. Based on advice from the Science Advisory Board Health Effects Subcommittee (SAB-HES), we extended the applied population to 6 to 18, reflecting the common biological basis for the effect in children in the broader age group. See: U.S. Science Advisory Board. 2004. Advisory Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis –Benefits and Costs of the Clean Air Act, 1990—2020. EPA-SAB-COUNCIL-ADV-04-004. See also National Research Council (NRC). 2002. *Estimating the Public Health Benefits of Proposed Air Pollution Regulations*. Washington, DC: The National Academies Press.

[b] Gilliland et al. (2001) studied children aged 9 and 10. Chen et al. (2000) studied children 6 to 11. Based on recent advice from the National Research Council and the EPA SAB-HES, we have calculated reductions in school absences for all school-aged children based on the biological similarity between children aged 5 to 17.

In selecting epidemiological studies as sources of effect estimates, we applied several criteria to develop a set of studies that is likely to provide the best estimates of impacts in the U.S. To account for the potential impacts of different health care systems or underlying health status of populations, we give preference to U.S. studies over non-U.S. studies. In addition, due to the potential for confounding by co-pollutants, we give preference to effect estimates from models including both ozone and PM over effect estimates from single-pollutant models.[15,16]

A number of endpoints that are not health-related also may significantly contribute to monetized benefits. Potential welfare benefits associated with ozone exposure include: increased outdoor worker productivity; increased yields for commercial and non-commercial crops; increased commercial forest productivity; reduced damage to urban ornamental plants; increased recreational demand for undamaged forest aesthetics; and reduced damage to ecosystem functions (U.S. EPA 1999, 2006). While we include estimates of the value of increased outdoor worker productivity, estimation of other welfare impacts is beyond the scope of this analysis.

6.3.2.1 Premature Mortality Effects Estimates

While particulate matter is the criteria pollutant most clearly associated with premature mortality, recent research suggests that short-term repeated ozone exposure likely contributes to premature death. The 2006 Ozone Criteria Document states: "Consistent with observed ozone-related increases in respiratory- and cardiovascular-related morbidity, several newer multi-city studies, single-city studies, and several meta-analyses of these studies have provided relatively strong epidemiologic evidence for associations between short-term ozone exposure and all-cause mortality, even after adjustment for the influence of season and PM" (EPA, 2006: E-17). The epidemiologic data are also supported by newly available experimental data from both animal and human studies which provide evidence suggestive of plausible pathways by which risk of respiratory or cardiovascular morbidity and mortality could be increased by ambient ozone. With respect to short-term exposure, the ozone Criteria Document concludes: "This overall body of evidence is highly suggestive that ozone directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality, but additional research is needed to more fully establish underlying mechanisms by which such effects occur" (pg. E-18).

With respect to the time-series studies, the conclusion regarding the relationship between short-term exposure and premature mortality is based, in part, upon recent city-specific time-series studies such as the Schwartz (2004) analysis in Houston and the Huang et al. (2004) analysis in Los Angeles.[17] This conclusion is also based on recent meta-analyses by Bell et al. (2005), Ito et al. (2005), and Levy et al. (2005), and a new analysis of the National Morbidity, Mortality, and Air Pollution Study (NMMAPS) data set by Bell et al. (2004), which specifically sought to disentangle the roles of ozone, PM, weather-related variables, and seasonality. The 2006 Criteria Document states that "the results from these meta-analyses, as well as several single- and

---

[15] U.S. Science Advisory Board. 2004. Advisory Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis –Benefits and Costs of the Clean Air Act, 1990—2020. EPA-SAB-COUNCIL-ADV-04-004.

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

[17] For an exhaustive review of the city-specific time-series studies considered in the ozone staff paper, see: U.S. Environmental Protection Agency, 2007. Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information. Prepared by the Office of Air and Radiation. Available at http://www.epa.gov/ttn/naaqs/standards/ozone/data/2007_01_ozone_staff_paper.pdf. pp. 5-36.

multiple-city studies, indicate that co-pollutants generally do not appear to substantially confound the association between ozone and mortality" (p. 7-103). However, CASAC raised questions about the implications of these time-series results in a policy context. Specifically, CASAC emphasized that "…while the time-series study design is a powerful tool to detect very small effects that could not be detected using other designs, it is also a blunt tool" (Henderson, 2006: 3). They point to findings (e.g., Stieb et al., 2002, 2003) that indicated associations between premature mortality and all of the criteria pollutants, indicating that "findings of time-series studies do not seem to allow us to confidently attribute observed effects to individual pollutants" (id.). They note that "not only is the interpretation of these associations complicated by the fact that the day-to-day variation in concentrations of these pollutants is, to a varying degree, determined by meteorology, the pollutants are often part of a large and highly correlated mix of pollutants, only a very few of which are measured" (id.). Even with these uncertainties, the CASAC Ozone Panel, in its review of EPA's Staff Paper, found "…premature total non-accidental and cardiorespiratory mortality for inclusion in the quantitative risk assessment to be appropriate."

Consistent with the methodology used in the ozone risk assessment found in the Characterization of Health Risks found in the Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information, we included ozone mortality in the primary health effects analysis, with the recognition that the exact magnitude of the effects estimate is subject to continuing uncertainty. We used effect estimates from the Bell et al. (2004) NMMAPS analysis, as well as effect estimates from the three meta-analyses. In addition, we include the possibility that there is not a causal association between ozone and mortality, i.e., that the effect estimate for premature mortality could be zero.

We estimate the change in mortality incidence and estimated credible interval[18] resulting from application of the effect estimate from each study and present them separately to reflect differences in the study designs and assumptions about causality. However, it is important to note that this procedure only captures the uncertainty in the underlying epidemiological work, and does not capture other sources of uncertainty, such as uncertainty in the estimation of changes in air pollution exposure (Levy et al., 2000).

6.3.2.2 Respiratory Hospital Admissions Effect Estimates

Detailed hospital admission and discharge records provide data for an extensive body of literature examining the relationship between hospital admissions and air pollution. This is especially true for the portion of the population aged 65 and older, because of the availability of detailed Medicare records. In addition, there is one study (Burnett et al., 2001) providing an effect estimate for respiratory hospital admissions in children under two.

Because the number of hospital admission studies we considered is so large, we used results from a number of studies to pool some hospital admission endpoints. Pooling is the process by which multiple study results may be combined in order to produce better estimates of the effect

[18] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics.

estimate, or β. For a complete discussion of the pooling process, see Abt (2005).[19] To estimate total respiratory hospital admissions associated with changes in ambient ozone concentrations for adults over 65, we first estimated the change in hospital admissions for each of the different effects categories that each study provided for each city. These cities included Minneapolis, Detroit, Tacoma and New Haven. To estimate total respiratory hospital admissions for Detroit, we added the pneumonia and COPD estimates, based on the effect estimates in the Schwartz study (1994b). Similarly, we summed the estimated hospital admissions based on the effect estimates the Moolgavkar study reported for Minneapolis (Moolgavkar et al., 1997). To estimate total respiratory hospital admissions for Minneapolis using the Schwartz study (1994a), we simply estimated pneumonia hospital admissions based on the effect estimate. Making this assumption that pneumonia admissions represent the total impact of ozone on hospital admissions in this city will give some weight to the possibility that there is no relationship between ozone and COPD, reflecting the equivocal evidence represented by the different studies. We then used a fixed-effects pooling procedure to combine the two total respiratory hospital admission estimates for Minneapolis. Finally, we used random effects pooling to combine the results for Minneapolis and Detroit with results from studies in Tacoma and New Haven from Schwartz (1995). As noted above, this pooling approach incorporates both the precision of the individual effect estimates and between-study variability characterizing differences across study locations.

6.3.2.3 *Asthma-Related Emergency Room Visits Effect Estimates*

We used three studies as the source of the concentration-response functions we used to estimate the effects of ozone exposure on asthma-related emergency room (ER) visits: Peel et al. (2005); Wilson et al. (2005); and Jaffe et al. (2003). We estimated the change in ER visits using the effect estimate(s) from each study and then pooled the results using the random effects pooling technique (see Abt, 2005). The study by Jaffe et al. (2003) examined the relationship between ER visits and air pollution for populations aged five to 34 in the Ohio cities of Cleveland, Columbus and Cincinnati from 1991 through 1996. In single-pollutant Poisson regression models, ozone was linked to asthma visits. We use the pooled estimate across all three cities as reported in the study. The Peel et al. study (2005) estimated asthma-related ER visits for all ages in Atlanta, using air quality data from 1993 to 2000. Using Poisson generalized estimating equations, the authors found a marginal association between the maximum daily 8-hour average ozone level and ER visits for asthma over a 3-day moving average (lags of 0, 1, and 2 days) in a single pollutant model. Wilson et al. (2005) examined the relationship between ER visits for respiratory illnesses and asthma and air pollution for all people residing in Portland, Maine from 1998-2000 and Manchester, New Hampshire from 1996-2000. For all models used in the analysis, the authors restricted the ozone data incorporated into the model to the months ozone levels are usually measured, the spring-summer months (April through September). Using the generalized additive model, Wilson et al. (2005) found a significant association between the maximum daily 8-hour average ozone level and ER visits for asthma in Portland, but found no significant association for Manchester. Similar to the approach used to generate effect estimates for hospital admissions, we used random effects pooling to combine the results across the

[19] Abt Associates, Incorporated. Environmental Benefits Mapping and Analysis Program, Technical Appendices. May 2005. pp. I-3

individual study estimates for ER visits for asthma. The Peel et al. (2005) and Wilson et al. (2005) Manchester estimates were not significant at the 95 percent level, and thus, the confidence interval for the pooled incidence estimate based on these studies includes negative values. This is an artifact of the statistical power of the studies, and the negative values in the tails of the estimated effect distributions do not represent improvements in health as ozone concentrations are increased. Instead these should be viewed as a measure of uncertainty due to limitations in the statistical power of the study. Note that we included both hospital admissions and ER visits as separate endpoints associated with ozone exposure, because our estimates of hospital admission costs do not include the costs of ER visits, and because most asthma ER visits do not result in a hospital admission.

6.3.2.4 Minor Restricted Activity Days Effects Estimate

Minor restricted activity days (MRADs) occur when individuals reduce most usual daily activities and replace them with less-strenuous activities or rest, but do not miss work or school. We estimated the effect of ozone exposure on MRADs using a concentration-response function derived from Ostro and Rothschild (1989). These researchers estimated the impact of ozone and $PM_{2.5}$ on MRAD incidence in a national sample of the adult working population (ages 18 to 65) living in metropolitan areas. We developed separate coefficients for each year of the Ostro and Rothschild analysis (1976-1981), which we then combined for use in EPA's analysis. The effect estimate used in the impact function is a weighted average of the coefficients in Ostro and Rothschild (1989, Table 4), using the inverse of the variance as the weight.

6.3.2.5 School Absences Effect Estimate

Children may be absent from school due to respiratory or other acute diseases caused, or aggravated by, exposure to air pollution. Several studies have found a significant association between ozone levels and school absence rates. We use two studies (Gilliland et al., 2001; Chen et al., 2000) to estimate changes in school absences resulting from changes in ozone levels. The Gilliland et al. study estimated the incidence of new periods of absence, while the Chen et al. study examined daily absence rates. We converted the Gilliland et al. estimate to days of absence by multiplying the absence periods by the average duration of an absence. We estimated 1.6 days as the average duration of a school absence, the result of dividing the average daily school absence rate from Chen et al. (2000) and Ransom and Pope (1992) by the episodic absence duration from Gilliland et al. (2001). Thus, each Gilliland et al. period of absence is converted into 1.6 absence days.

Following recent advice from the National Research Council (2002), we calculated reductions in school absences for the full population of school age children, ages five to 17. This is consistent with recent peer-reviewed literature on estimating the impact of ozone exposure on school absences (Hall et al. 2003). We estimated the change in school absences using both Chen et al. (2000) and Gilliland et al. (2001) and then, similar to hospital admissions and ER visits, pooled the results using the random effects pooling procedure.

6.3.2.6 Worker Productivity

To monetize benefits associated with increased worker productivity resulting from improved ozone air quality, we used information reported in Crocker and Horst (1981). Crocker and Horst examined the impacts of ozone exposure on the productivity of outdoor citrus workers. The study measured productivity impacts. Worker productivity is measuring the value of the loss in productivity for a worker who is at work on a particular day, but due to ozone, cannot work as hard. It only applies to outdoor workers, like fruit and vegetable pickers, or construction workers. Here, productivity impacts are measured as the change in income associated with a change in ozone exposure, given as the elasticity of income with respect to ozone concentration. The reported elasticity translates a ten percent reduction in ozone to a 1.4 percent increase in income. Given the national median daily income for outdoor workers engaged in strenuous activity reported by the U.S. Census Bureau (2002), $68 per day (2000$), a ten percent reduction in ozone yields about $0.97 in increased daily wages. We adjust the national median daily income estimate to reflect regional variations in income using a factor based on the ratio of county median household income to national median household income. No information was available for quantifying the uncertainty associated with the central valuation estimate. Therefore, no uncertainty analysis was conducted for this endpoint.

6.3.2.7 Visibility Benefits

Changes in the level of ambient $PM_{2.5}$ caused by the reduction in emissions associated with the proposed standards will change the level of visibility throughout the United States. Increases in PM concentrations cause increases in light extinction, a measure of how much the components of the atmosphere absorb light. Due to time limitations, this benefits assessment does not consider the value of improvements in visibility associated with simulated attainment of alternate ozone standards. We anticipate that the benefits assessment supporting the promulgated ozone standard will consider this important benefits category.

6.3.2.8 Other Unquantified Effects

6.3.2.8.1 Direct Ozone Effects on Vegetation

The Ozone Criteria Document notes that "current ambient concentrations in many areas of the country are sufficient to impair growth of numerous common and economically valuable plant and tree species." (U.S. EPA, 2006, page 9-1). Changes in ground-level ozone resulting from the implementation of alternative ozone standards are expected to affect crop and forest yields throughout the affected area. Recent scientific studies have also found the ozone negatively impacts the quality or nutritive value of crops (U.S. EPA, 2006, page 9-16).

Well-developed techniques exist to provide monetary estimates of these benefits to agricultural producers and to consumers. These techniques use models of planting decisions, yield response functions, and the supply of and demand for agricultural products. The resulting welfare measures are based on predicted changes in market prices and production costs. Models also exist to measure benefits to silvicultural producers and consumers. However, these models have not been adapted for use in analyzing ozone-related forest impacts. Because of resource limitations, we are unable to provide agricultural or benefits estimates for the proposed rule.

An additional welfare benefit expected to accrue as a result of reductions in ambient ozone concentrations in the United States is the economic value the public receives from reduced aesthetic injury to forests. There is sufficient scientific information available to reliably establish that ambient ozone levels cause visible injury to foliage and impair the growth of some sensitive plant species (U.S. EPA, 2006, page 9-19). However, present analytic tools and resources preclude EPA from quantifying the benefits of improved forest aesthetics.

Urban ornamentals (floriculture and nursery crops) represent an additional vegetation category likely to experience some degree of negative effects associated with exposure to ambient ozone levels and likely to affect large economic sectors. In the absence of adequate exposure-response functions and economic damage functions for the potential range of effects relevant to these types of vegetation, no direct quantitative economic benefits analysis has been conducted. The farm production value of ornamental crops was estimated at over $14 billion in 2003 (USDA, 2004). This is therefore a potentially important welfare effects category. However, information and valuation methods are not available to allow for plausible estimates of the percentage of these expenditures that may be related to impacts associated with ozone exposure.

6.3.2.8.2 Nitrogen Deposition

Deposition to Estuarine and Coastal Waters

Excess nutrient loads, especially 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 (Bricker et al., 1999). A recent study found that for the period 1990-2002, atmospheric deposition accounted for 17 percent of nitrate loadings in the Gulf of Mexico, where severe hypoxic zones have been existed over the last two decades (Booth and Campbell, 2007)[20].

Reductions in atmospheric deposition of NOx are expected to reduce the adverse impacts associated with nitrogen deposition to estuarine and coastal waters. However, direct functions relating changes in nitrogen loadings to changes in estuarine benefits are not available. The preferred WTP-based measure of benefits depends on the availability of these functions and on estimates of the value of environmental responses. Because neither appropriate functions nor sufficient information to estimate the marginal value of changes in water quality exist at present, calculation of a WTP measure is not possible.

---

[20] Booth, M.S., and C. Campbell. 2007. Spring Nitrate Flux in the Mississippi River Basin: A Landscape Model with Conservation Applications. Environ. Sci. Technol.; 2007; ASAP Web Release Date: 20-Jun-2007; (Article) DOI: 10.1021/es070179e

Deposition to Agricultural and Forested Land

Implementation strategies for alternative standards which reduce NO_X emissions, will also reduce nitrogen deposition on agricultural land and forests. There is some evidence that nitrogen deposition may have positive effects on agricultural output through passive fertilization. Holding all other factors constant, farmers' use of purchased fertilizers or manure may increase as deposited nitrogen is reduced. Estimates of the potential value of this possible increase in the use of purchased fertilizers are not available, but it is likely that the overall value is very small relative to other health and welfare effects. The share of nitrogen requirements provided by this deposition is small, and the marginal cost of providing this nitrogen from alternative sources is quite low. In some areas, agricultural lands suffer from nitrogen over-saturation due to an abundance of on-farm nitrogen production, primarily from animal manure. In these areas, reductions in atmospheric deposition of nitrogen from PM represent additional agricultural benefits.

Information on the effects of changes in passive nitrogen deposition on forests 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 (US EPA, 1993). Moreover, any positive effect that nitrogen deposition has on forest productivity would enhance the level of carbon dioxide sequestration as well.[21,22,23]

On the other hand, there is evidence that forest ecosystems in some areas of the United States (such as the western U.S.) are nitrogen saturated (US 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.

6.3.2.8.3 Ultraviolet Radiation

Atmospheric ozone absorbs a harmful band of ultraviolet radiation from the sun called UV-B, providing a protective shield to the Earth's surface. The majority of this protection occurs in the stratosphere where 90% of atmospheric ozone is located. The remaining 10% of the Earth's ozone is present at ground level (referred to as tropospheric ozone) (NAS, 1991; NASA). Only a portion of the tropospheric fraction of UV-B shielding is from anthropogenic sources (e.g., power plants, byproducts of combustion). The portion of ground level ozone associated with

---

[21] Peter M. Vitousek et. al., "Human Alteration of the Global Nitrogen Cycle: Causes and Consequences" *Issues in Ecology* No. 1 (Spring) 1997.

[22] Knute J. Nadelhoffer et. al., "Nitrogen deposition makes a minor contribution to carbon sequestration in temperate forests" *Nature* 398, 145-148 (11 March 1999)

[23] Martin Köchy and Scott D. Wilson, "Nitrogen deposition and forest expansion in the northern Great Plains Journal of Ecology *Journal of Ecology* 89 (5), 807–817

anthropogenic sources varies by locality and over time. Even so, it is reasonable to assume that reductions in ground level ozone would lead to increases in the same health effects linked to in UV-B exposures. These effects include fatal and nonfatal melanoma and non-melanoma skin cancers and cataracts. The values of $15,000 per case for non-fatal melanoma skin cancer, $5,000 per case for non-fatal non-melanoma skin cancer, and $15,000 per case of cataracts have been used in analyses of stratospheric ozone depletion (U.S. EPA, 1999). Fatal cancers are valued using the standard VSL estimate, which for 2020 is $6.6 million (1999$). UV-B has also been linked to ecological effects including damage to crops and forest. For a more complete listing of quantified and unquantified UV-B radiation effects, see Table G-4 and G-7 in the Benefits and Costs of the Clean Air Act, 1990-2010 (U.S. EPA, 1999. UV-B related health effects are also discussed in the context of stratospheric ozone in a 2006 report by ICF Consulting, prepared for the U.S. EPA.

There are many factors that influence UV-B radiation penetration to the earth's surface, including latitude, altitude, cloud cover, surface albedo, PM concentration and composition, and gas phase pollution. Of these, only latitude and altitude can be defined with small uncertainty in any effort to assess the changes in UV-B flux that may be attributable to any changes in tropospheric O3 as a result of any revision to the O3 NAAQS. Such an assessment of UV-B related health effects would also need to take into account human habits, such as outdoor activities (including age- and occupation-related exposure patterns), dress and skin care to adequately estimate UV-B exposure levels. However, little is known about the impact of these factors on individual exposure to UV-B.

Moreover, detailed information does not exist regarding other factors that are relevant to assessing changes in disease incidence, including: type (e.g., peak or cumulative) and time period (e.g., childhood, lifetime, current) of exposures related to various adverse health outcomes (e.g., damage to the skin, including skin cancer; damage to the eye, such as cataracts; and immune system suppression); wavelength dependency of biological responses; and interindividual variability in UV-B resistance to such health outcomes. Beyond these well recognized adverse health effects associated with various wavelengths of UV radiation, the Criteria Document (section 10.2.3.6) also discusses protective effects of UV-B radiation. Recent reports indicate the necessity of UV-B in producing vitamin D, and that vitamin D deficiency can cause metabolic bone disease among children and adults, and may also increase the risk of many common chronic diseases (e.g., type I diabetes and rheumatoid arthritis) as well as the risk of various types of cancers. Thus, the Criteria Document concludes that any assessment that attempts to quantify the consequences of increased UV-B exposure on humans due to reduced ground-level O3 must include consideration of both negative and positive effects. However, as with other impacts of UVB on human health, this beneficial effect of UVB radiation has not previously been studied in sufficient detail. We will develop approaches for estimating the effects of increased UVB exposures resulting from reductions in tropospheric ozone and will work to present peer-reviewed quantified estimates for the final rule.

6.3.2.8.4 Climate Implications of Tropospheric Ozone

Although climate and air quality are generally treated as separate issues, they are closely coupled through atmospheric processes. Ozone, itself, is a major greenhouse gas and climate directly influences ambient concentrations of ozone.

The concentration of tropospheric ozone has increased substantially since the pre-industrial era and has contributed to warming. Tropospheric ozone is (after CO2 and CH4) the third most important contributor to greenhouse gas warming. The National Academy of Sciences recently stated[24] that regulations targeting ozone precursors would have combined benefits for public health and climate. As noted in the OAQPS Staff Paper, the overall body of scientific evidence suggests that high concentrations of ozone on a regional scale could have a discernible influence on climate. However, the Staff Paper concludes that insufficient information is available at this time to quantitatively inform the secondary NAAQS process with regard to this aspect of the ozone-climate interaction.

Climate change can affect tropospheric ozone by modifying emissions of precursors, chemistry, transport and removal.[25] Climate change affects the sources of ozone precursors through physical response (lightning), biological response (soils, vegetation, and biomass burning) and human response (energy generation, land use, and agriculture). Increases in regional ozone pollution are expected due to higher temperatures and weaker circulation. Simulations with global climate models for the 21st century indicate a decrease in the lifetime of tropospheric ozone due to increasing water vapor which could decrease global background ozone concentrations.

The Intergovernmental Panel on Climate Change (IPCC) recently released a report[26] which projects, with "virtual certainty," declining air quality in cities due to warmer and fewer cold days and nights and/or warmer/more frequent hot days and nights over most land areas. The report states that projected climate change-related exposures are likely to affect the health status of millions of people, in part, due to higher concentrations of ground level ozone related to climate change.

---

[24] National Academy of Sciences, "Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties," October 2005.

[25] Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S Ramachandran, P.L. da Silva Dias, S.C. Wofsy and X. Zhang, 2007: Couplings Between Changes in the Climate System and Biogeochemistry. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[26] IPCC, Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability, Summary for Policymakers

The IPCC also reports[27] that the current generation of tropospheric ozone models is generally successful in describing the principal features of the present-day global ozone distribution. However, there is much less confidence in the ability to reproduce the changes in ozone associated with perturbations of emissions or climate. There are major discrepancies with observed long-term trends in ozone concentrations over the 20th century, including after 1970 when the reliability of observed ozone trends is high. Resolving these discrepancies is needed to establish confidence in the models.

The EPA is currently leading a research effort with the goal of identifying changes in regional US air quality that may occur in a future (2050) climate, focusing on fine particles and ozone. The research builds first on an assessment of changes in US air quality due to climate change, which includes direct meteorological impacts on atmospheric chemistry and transport and the effect of temperature changes on air pollution emissions. Further research will result in an assessment that adds the emission impacts from technology, land use, demographic changes, and air quality regulations to construct plausible scenarios of US air quality 50 years into the future. As noted in the Staff Paper, results from these efforts are expected to be available for consideration in the next review of the ozone NAAQS.

6.3.3 Baseline Incidence Rates

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 estimating the absolute number of avoided cases. For example, a typical result might be that a 100 ppb decrease in daily ozone levels might, in turn, 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. A baseline incidence rate is the estimate of the number of cases of the health effect per year in the assessment location, as it corresponds to baseline pollutant levels in that location. To derive the total baseline incidence per year, this rate must be multiplied by the corresponding population number. For example, if the baseline incidence rate is the number of cases per year per 100,000 people, that number must be multiplied by the number of 100,000s in the population.

Table 6-3 summarizes the sources of baseline incidence rates and provides average incidence rates for the endpoints included in the analysis. For both baseline incidence and prevalence data, we used age-specific rates where available. We applied concentration-response functions to individual age groups and then summed over the relevant age range to provide an estimate of total population benefits. In most cases, we used a single national incidence rate, due to a lack of more spatially disaggregated data. Whenever possible, the national rates used are national averages, because these data are most applicable to a national assessment of benefits. For some studies, however, the only available incidence information comes from the studies themselves; in these cases, incidence in the study population is assumed to represent typical incidence at the national level. Regional incidence rates are available for hospital admissions, and county-level

[27] Denman, et al, 2007: Couplings Between Changes in the Climate System and Biogeochemistry. In: *Climate Change 2007: The Physical Science Basis.*

data are available for premature mortality. We have projected mortality rates such that future mortality rates are consistent with our projections of population growth (Abt Associates, 2005).

Table 6-3. National Average Baseline Incidence Rates

Endpoint	Source	Notes	Rate per 100 people per year [D] by Age Group						
			<18	*18-24*	*25-34*	*35-44*	*45-54*	*55-64*	*65+*
Mortality	CDC Compressed Mortality File, accessed through CDC Wonder (1996-1998)	non-accidental	0.025	0.022	0.057	0.150	0.383	1.006	4.937
Respiratory Hospital Admissions.	1999 NHDS public use data files[B]	incidence	0.043	0.084	0.206	0.678	1.926	4.389	11.629
Asthma ER visits	2000 NHAMCS public use data files[C]; 1999 NHDS public use data files[B]	incidence	1.011	1.087	0.751	0.438	0.352	0.425	0.232
Minor Restricted Activity Days (MRADs)	Ostro and Rothschild (1989, p. 243)	incidence	–	780	780	780	780	780	–
School Loss Days	National Center for Education Statistics (1996) and 1996 HIS (Adams et al., 1999, Table 47); estimate of 180 school days per year	all-cause	990.0	–	–	–	–	–	–

[A] The following abbreviations are used to describe the national surveys conducted by the National Center for Health Statistics: HIS refers to the National Health Interview Survey; NHDS - National Hospital Discharge Survey; NHAMCS - National Hospital Ambulatory Medical Care Survey.

[B] See ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHDS/

[C] See ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHAMCS/

[D] All of the rates reported here are population-weighted incidence rates per 100 people per year. Additional details on the incidence and prevalence rates, as well as the sources for these rates are available upon request.

Table 6-3 National Average Baseline Incidence Rates (continued)

Endpoint	Source	Notes		Rate per 100 people per year [4]
Asthma Exacerbations	Ostro et al. (2001)	Incidence (and prevalence) among asthmatic African-American children	Daily wheeze	0.076 (0.173)
			Daily cough	0.067 (0.145)
			Daily dyspnea	0.037 (0.074)
	Vedal et al. (1998)	Incidence (and prevalence) among asthmatic children	Daily wheeze	0.038
			Daily cough	0.086
			Daily dyspnea	0.045

6.4 Economic Values for Health Outcomes

Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects for a large population. Therefore, the appropriate economic measure is willingness-to-pay (WTP) for changes in risk of a health effect rather than WTP for a health effect that would occur with certainty (Freeman, 1993). Epidemiological studies generally provide estimates of the relative risks of a particular health effect that is avoided because of a reduction in air pollution. We converted those to units of avoided statistical incidence for ease of presentation. We calculated the value of avoided statistical incidences by dividing individual WTP for a risk reduction by the related observed change in risk. For example, suppose a pollution-reduction regulation is able to reduce the risk of premature mortality from 2 in 10,000 to 1 in 10,000 (a reduction of 1 in 10,000). If individual WTP for this risk reduction is $100, then the WTP for an avoided statistical premature death is $1 million ($100/0.0001 change in risk).

WTP estimates generally are not available for some health effects, such as hospital admissions. In these cases, we used the cost of treating or mitigating the effect as a primary estimate. These cost-of-illness (COI) estimates generally understate the true value of reducing the risk of a health effect, because they reflect the direct expenditures related to treatment, but not the value of avoided pain and suffering (Harrington and Portney, 1987; Berger, 1987). We provide unit values for health endpoints (along with information on the distribution of the unit value) in Table 6-4. All values are in constant year 2000 dollars, adjusted for growth in real income out to 2020 using projections provided by Standard and Poor's. Economic theory argues that WTP for most goods (such as environmental protection) will increase if real income increases. Many of the valuation studies used in this analysis were conducted in the late 1980s and early 1990s. Because real income has grown since the studies were conducted, people's willingness to pay for reductions in the risk of premature death and disease likely has grown as well. We did not adjust cost of illness-based values because they are based on current costs. Similarly, we did not adjust the value of school absences, because that value is based on current wage rates. Table 6.4 presents the values for individual endpoints adjusted to year 2020 income levels. The discussion below provides additional details on ozone related endpoints. For details on valuation estimates for PM related endpoints, see the 2006 PM NAAQS RIA.

6.4.1 Mortality Valuation

To estimate the monetary benefit of reducing the risk of premature death, we used the "value of statistical lives" saved (VSL) approach, which is a summary measure for the value of small changes in mortality risk for a large number of people. The VSL approach applies information from several published value-of-life studies to determine a reasonable monetary value of preventing premature mortality. The mean value of avoiding one statistical death is estimated to be roughly $5.5 million at 1990 income levels (2000 $), and $6.6 million at 2020 income levels. This represents an intermediate value from a variety of estimates in the economics literature (see the 2006 PM NAAQS RIA for more details on the calculation of VSL).

6.4.2 Hospital Admissions Valuation

In the absence of estimates of societal WTP to avoid hospital visits/admissions for specific illnesses, estimates of total cost of illness (total medical costs plus the value of lost productivity) typically are used as conservative, or lower bound, estimates. These estimates are biased downward, because they do not include the willingness-to-pay value of avoiding pain and suffering.

The International Classification of Diseases (ICD-9, 1979) code-specific COI estimates used in this analysis consist of estimated hospital charges and the estimated opportunity cost of time spent in the hospital (based on the average length of a hospital stay for the illness). We based all estimates of hospital charges and length of stays on statistics provided by the Agency for Healthcare Research and Quality (AHRQ 2000). We estimated the opportunity cost of a day spent in the hospital as the value of the lost daily wage, regardless of whether the hospitalized individual is in the workforce. To estimate the lost daily wage, we divided the 1990 median weekly wage by five and inflated the result to year 2000$ using the CPI-U "all items." The resulting estimate is $109.35. The total cost-of-illness estimate for an ICD code-specific hospital stay lasting *n* days, then, was the mean hospital charge plus $109 • *n.*

6.4.3 Asthma-Related Emergency Room Visits Valuation

To value asthma emergency room visits, we used a simple average of two estimates from the health economics literature. The first estimate comes from Smith et al. (1997), who reported approximately 1.2 million asthma-related emergency room visits in 1987, at a total cost of $186.5 million (1987$). The average cost per visit that year was $155; in 2000$, that cost was $311.55 (using the CPI-U for medical care to adjust to 2000$). The second estimate comes from Stanford et al. (1999), who reported the cost of an average asthma-related emergency room visit at $260.67, based on 1996-1997 data. A simple average of the two estimates yields a (rounded) unit value of $286.

6.4.4 Minor Restricted Activity Days Valuation

No studies are reported to have estimated WTP to avoid a minor restricted activity day. However, one of EPA's contractors, IEc (1993) has derived an estimate of willingness to pay to avoid a minor *respiratory* restricted activity day, using estimates from Tolley et al. (1986) of WTP for avoiding a combination of coughing, throat congestion and sinusitis. The IEc estimate of WTP to avoid a minor respiratory restricted activity day is $38.37 (1990$), or about $52 ($2000).

Although Ostro and Rothschild (1989) statistically linked ozone and minor restricted activity days, it is likely that most MRADs associated with ozone exposure are, in fact, minor *respiratory* restricted activity days. For the purpose of valuing this health endpoint, we used the estimate of mean WTP to avoid a minor respiratory restricted activity day.

6.4.5 School Absences

To value a school absence, we: (1) estimated the probability that if a school child stays home from school, a parent will have to stay home from work to care for the child; and (2) valued the lost productivity at the parent's wage. To do this, we estimated the number of families with school-age children in which both parents work, and we valued a school-loss day as the probability that such a day also would result in a work-loss day. We calculated this value by multiplying the proportion of households with school-age children by a measure of lost wages.

We used this method in the absence of a preferable WTP method. However, this approach suffers from several uncertainties. First, it omits willingness to pay to avoid the symptoms/illness that resulted in the school absence; second, it effectively gives zero value to school absences that do not result in work-loss days; and third, it uses conservative assumptions about the wages of the parent staying home with the child. Finally, this method assumes that parents are unable to work from home. If this is not a valid assumption, then there would be no lost wages.

For this valuation approach, we assumed that in a household with two working parents, the female parent will stay home with a sick child. From the Statistical Abstract of the United States (U.S. Census Bureau, 2001), we obtained: (1) the numbers of single, married and "other" (widowed, divorced or separated) working women with children; and (2) the rates of participation in the workforce of single, married and "other" women with children. From these two sets of statistics, we calculated a weighted average participation rate of 72.85 percent.

Our estimate of daily lost wage (wages lost if a mother must stay at home with a sick child) is based on the year 2000 median weekly wage among women ages 25 and older (U.S. Census Bureau, 2001). This median weekly wage is $551. Dividing by five gives an estimated median daily wage of $103. To estimate the expected lost wages on a day when a mother has to stay home with a school-age child, we first estimated the probability that the mother is in the workforce then multiplied that estimate by the daily wage she would lose by missing a work day: 72.85 percent times $103, for a total loss of $75. This valuation approach is similar to that used by Hall et al. (2003).

Table 6-4. Unit Values for Economic Valuation of Health Endpoints (2000$)

	Central Estimate of Value Per Statistical Incidence		
Health Endpoint	*1990 Income Level*	*2020 Income Level*	*Derivation of Distributions of Estimates*
Premature Mortality (Value of a Statistical Life)	$5,500,000	$6,600,000	Point estimate is the mean of a normal distribution with a 95% confidence interval between $1 and $10 million. Confidence interval is based on two meta-analyses of the wage-risk VSL literature: $1 million represents the lower end of the interquartile range from the Mrozek and Taylor (2002) meta-analysis and $10 million represents the upper end of the interquartile range from the Viscusi and Aldy (2003) meta-analysis. The mean of the distribution is consistent with the mean estimate from a third meta-analysis (Kochi et al 2006). The VSL represents the value of a small change in mortality risk aggregated over the affected population.
Chronic Bronchitis (CB)	$340,000	$420,000	The WTP to avoid a case of pollution-related CB is calculated as $WTP_x \quad WTP_{13} * e^{-\beta *(13-x)}$, where x is the severity of an average CB case, WTP_{13} is the WTP for a severe case of CB, and is the parameter relating WTP to severity, based on the regression results reported in Krupnick and Cropper (1992). The distribution of WTP for an average severity-level case of CB was generated by Monte Carlo methods, drawing from each of three distributions: (1) WTP to avoid a severe case of CB is assigned a 1/9 probability of being each of the first nine deciles of the distribution of WTP responses in Viscusi et al. (1991); (2) the severity of a pollution-related case of CB (relative to the case described in the Viscusi study) is assumed to have a triangular distribution, with the most likely value at severity level 6.5 and endpoints at 1.0 and 12.0; and (3) the constant in the elasticity of WTP with respect to severity is normally distributed with mean = 0.18 and standard deviation = 0.0669 (from Krupnick and Cropper [1992]). This process and the rationale for choosing it is described in detail in the *Costs and Benefits of the Clean Air Act, 1990 to 2010* (EPA, 1999).

(continued)

Table 6-4: Unit Values Used for Economic Valuation of Health Endpoints (2000$) (continued)

Health Endpoint	Central Estimate of Value Per Statistical Incidence: 1990 Income Level	Central Estimate of Value Per Statistical Incidence: 2020 Income Level	Derivation of Distributions of Estimates
Nonfatal Myocardial Infarction (heart attack)			No distributional information available. Age-specific cost-of-illness values reflect lost earnings and direct medical costs over a 5-year period following a nonfatal MI. Lost earnings estimates are based on Cropper and Krupnick (1990). Direct medical costs are based on simple average of estimates from Russell et al. (1998) and Wittels et al. (1990).
<u>3% discount rate</u>			<u>Lost earnings</u>:
Age 0–24	$66,902	$66,902	Cropper and Krupnick (1990). Present discounted value of 5 years of lost earnings:
Age 25–44	$74,676	$74,676	<u>age of onset</u>: <u>at 3%</u> <u>at 7%</u>
Age 45–54	$78,834	$78,834	25-44 $8,774 $7,855
Age 55–65	$140,649	$140,649	45-54 $12,932 $11,578
Age 66 and over	$66,902	$66,902	55-65 $74,746 $66,920
<u>7% discount rate</u>			<u>Direct medical expenses</u>: An average of:
Age 0–24	$65,293	$65,293	1. Wittels et al. (1990) ($102,658—no discounting)
Age 25–44	$73,149	$73,149	2. Russell et al. (1998), 5-year period ($22,331 at 3% discount rate; $21,113 at 7% discount rate)
Age 45–54	$76,871	$76,871	
Age 55–65	$132,214	$132,214	
Age 66 and over	$65,293	$65,293	
Hospital Admissions			
Chronic Obstructive Pulmonary Disease (COPD)	$12,378	$12,378	No distributional information available. The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
Asthma Admissions	$6,634	$6,634	No distributional information available. The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total asthma category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
All Cardiovascular	$18,387	$18,387	No distributional information available. The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total cardiovascular category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
All respiratory (ages 65+)	$18,353	$18,353	No distributions available. The COI point estimates (lost earnings plus direct medical costs) are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Agency for Healthcare Research and Quality, 2000 (www.ahrq.gov).

Table 6-4: Unit Values Used for Economic Valuation of Health Endpoints (2000$) (continued)

Health Endpoint	Central Estimate of Value Per Statistical Incidence: 1990 Income Level	Central Estimate of Value Per Statistical Incidence: 2020 Income Level	Derivation of Distributions of Estimates
All respiratory (ages 0-2)	$7,741	$7,741	No distributions available. The COI point estimates (lost earnings plus direct medical costs) are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Agency for Healthcare Research and Quality, 2000 (www.ahrq.gov).
Emergency Room Visits for Asthma	$286	$286	No distributional information available. Simple average of two unit COI values: (1) $311.55, from Smith et al. (1997) and (2) $260.67, from Stanford et al. (1999).
Respiratory Ailments Not Requiring Hospitalization			
Upper Respiratory Symptoms (URS)	$25	$27	Combinations of the three symptoms for which WTP estimates are available that closely match those listed by Pope et al. result in seven different "symptom clusters," each describing a "type" of URS. A dollar value was derived for each type of URS, using mid-range estimates of WTP (IEc, 1994) to avoid each symptom in the cluster and assuming additivity of WTPs. In the absence of information surrounding the frequency with which each of the seven types of URS occurs within the URS symptom complex, we assumed a uniform distribution between $9.2 and $43.1.
Lower Respiratory Symptoms (LRS)	$16	$18	Combinations of the four symptoms for which WTP estimates are available that closely match those listed by Schwartz et al. result in 11 different "symptom clusters," each describing a "type" of LRS. A dollar value was derived for each type of LRS, using mid-range estimates of WTP (IEc, 1994) to avoid each symptom in the cluster and assuming additivity of WTPs. The dollar value for LRS is the average of the dollar values for the 11 different types of LRS. In the absence of information surrounding the frequency with which each of the 11 types of LRS occurs within the LRS symptom complex, we assumed a uniform distribution between $6.9 and $24.46.
Asthma Exacerbations	$42	$45	Asthma exacerbations are valued at $45 per incidence, based on the mean of average WTP estimates for the four severity definitions of a "bad asthma day," described in Rowe and Chestnut (1986). This study surveyed asthmatics to estimate WTP for avoidance of a "bad asthma day," as defined by the subjects. For purposes of valuation, an asthma exacerbation is assumed to be equivalent to a day in which asthma is moderate or worse as reported in the Rowe and Chestnut (1986) study. The value is assumed have a uniform distribution between $15.6 and $70.8.

(continued)

Table 6-4: Unit Values Used for Economic Valuation of Health Endpoints (2000$) (continued)

Health Endpoint	*Central Estimate of Value Per Statistical Incidence* — *1990 Income Level*	*Central Estimate of Value Per Statistical Incidence* — *2020 Income Level*	*Derivation of Distributions of Estimates*
Acute Bronchitis	$360	$380	Assumes a 6-day episode, with the distribution of the daily value specified as uniform with the low and high values based on those recommended for related respiratory symptoms in Neumann et al. (1994). The low daily estimate of $10 is the sum of the mid-range values recommended by IEc (1994) for two symptoms believed to be associated with acute bronchitis: coughing and chest tightness. The high daily estimate was taken to be twice the value of a minor respiratory restricted-activity day, or $110.
Work Loss Days (WLDs)	Variable (U.S. median=$110)		No distribution available. Point estimate is based on county-specific median annual wages divided by 50 (assuming 2 weeks of vacation) and then by 5—to get median daily wage. U.S. Year 2000 Census, compiled by Geolytics, Inc.
Minor Restricted Activity Days (MRADs)	$51	$54	Median WTP estimate to avoid one MRAD from Tolley et al. (1986). Distribution is assumed to be triangular with a minimum of $22 and a maximum of $83, with a most likely value of $52. Range is based on assumption that value should exceed WTP for a single mild symptom (the highest estimate for a single symptom—for eye irritation—is $16.00) and be less than that for a WLD. The triangular distribution acknowledges that the actual value is likely to be closer to the point estimate than either extreme.
School Absence Days	$75	$75	No distribution available

6.5 Results and Implications

Tables 6-5 through 6-28 summarize the reduction in incidence for ozone- and PM-related health endpoints for each of the alternative ozone standards evaluated. Tables 6-29 through 6-44 summarize the ozone-related economic benefits for each of the alternative standards.[28] Note that incidence and valuation estimates for each standard alternative are broken into two sets of tables. The first set of tables summarizes incidence and valuation for simulated national attainment with the standard alternative in the East and areas outside of California, and "glidepath" attainment in California. The second set of tables present incidence and valuation estimates for California post-2020, to account for the additional emission reductions projected to occur as a result of full implementation of a series of mobile source rules. In addition to the mean incidence estimates, we have included 5th and 95th percentile estimates, except where noted, based on the Monte Carlo simulations described above. In the tables presenting the 0.065 ppm and 0.070 ppm estimates, the total change in ozone-related incidence from fully attaining the alternative standards is broken out into the change in incidence associated with the modeled partial attainment scenario and the sum of the change in incidence associated with achieving the partial attainment increment plus the residual attainment increment. As described in Appendix 6, to calculate the change in ozone concentrations to reach full attainment, we rolled back the ozone monitor data so that the 4th highest daily maximum 8-hour average just met the level required to attain the alternative standard. This approach will likely understate the benefits that would occur due to implementation of actual controls to reduce ozone precursor emissions because controls implemented to reduce ozone concentrations at the highest monitor would likely result in some reductions in ozone concentrations at attaining monitors down-wind (i.e. the controls would lead to concentrations below the standard in down-wind locations). Therefore, air quality improvements and resulting health benefits from full attainment would be more widespread than we have estimated in our rollback analyses. The incidence and valuation results for attainment of the 0.075 ppm alternative are derived through an interpolation technique described in Appendix 6. As such, these estimates are presented as full attainment only. The incidence and valuation estimates for attainment of the 0.079 ppm alternative are derived through monitor rollbacks alone and thus are presented as full attainment only.

In addition to disaggregating ozone benefits between modeled and rollback for the 0.070 ppm and 0.065 ppm standard alternatives, we also provide disaggregation by region, with separate benefits estimates for the Eastern U.S., California, and the Western U.S. outside of California. The estimates of ozone-related mortality and morbidity for California are broken into glidepath and full attainment. Certain California projected non-attainment counties are required to meet an ozone target above the actual standard (that is, a "glidepath") by 2020 due to the severity of non-attainment. The estimates in this column reflect the benefits of meeting this target.

6.5.1 Glidepath incidence and valuation estimates for 0.065 ppm and 0.075 ppm alternatives

This analysis includes an assessment of the benefits of reaching the glidepath targets for each of the standard alternatives in 2020 in California. Due to time and resource limitations, we were able

---

[28] Note that the valuation estimates for ozone benefits are not discounted. Because these are short term benefits that occur the same year in which the alternate standard is met, discounting is not necessary.

to perform a full scale benefits analysis of the California glidepath targets for the 0.070 ppm alternative only. Thus, we derived the glidepath benefits estimates for the 0.075 ppm and 0.065 ppm alternatives by applying a scaling factor. This scaling factor represents the ratio of the California 0.070 ppm glidepath full attainment benefits to the California 0.070 ppm full attainment benefits. This process entailed the following steps: (1) calculate the ratio of the California 0.070 ppm glidepath target benefits to the California 0.070 ppm full attainment benefits for each incidence and valuation estimate; (2) multiply this ratio by the California full attainment 0.075 ppm and 0.065 ppm incidence and valuation estimate to derive glidepath estimates. Because these results are scaled, it was not possible to generate confidence intervals.

While clearly the 2020 glidepath targets for the current and alternative standards vary among the standard alternatives, the relative air quality increment between the glidepath base and control cases in California is nearly identical among the standard alternatives. As such, we believe this scaling approach is a valid technique to develop screening-level estimates of 0.065 ppm and 0.075 ppm California glidepath benefits.

6.5.2 $PM_{2.5}$ co-benefit estimates

As discussed further below, tables 6-9, 6-10, 6-15, 6-16, 6-21, 6-22, 6-27 and 6-28 present the $PM_{2.5}$ co-benefits associated with full attainment of the 0.065 ppm, 0.070 ppm, 0.075 ppm and 0.079 ppm alternatives. To derive estimates of incidence and valuation for the $PM_{2.5}$ related co-benefits of full attainment of each ozone standard alternative, we applied two different scaling techniques. To estimate total valuation estimates, we applied benefit per-ton metrics; this procedure is detailed further below. Note that the valuation estimates of the $PM_{2.5}$-related full attainment benefits are presented at a 3% discount rate; due to time and resource limitations it was not possible to calculate these benefits at a 7% discount rate. Had we performed this calculation, we estimate that $PM_{2.5}$-related full attainment co-benefits would be approximately 15% lower. All $PM_{2.5}$ co-benefit estimates are incremental to the 2006 PM NAAQS RIA.

To estimate total incidence estimates, we applied a simple scaling factor. To estimate $PM_{2.5}$-related incidence associated with the attainment of each ozone alternative, we calculated a separate scaling factor as follows: (1) we calculated the ratio of the full attainment $PM_{2.5}$ valuation estimate (calculated using the benefit per ton metrics described below) to the partial attainment to the partial attainment $PM_{2.5}$ valuation estimate; (2) multiply this scaling ratio against each of the $PM_{2.5}$ partial attainment mortality and morbidity endpoints to generate a scaled estimate of mortality and morbidity. While there are clearly substantial uncertainties inherent in this technique, it does produce useful screening-level estimates of $PM_{2.5}$-related incidence

Table 6-5: Illustrative Strategy to Attain 0.065 ppm: Estimated Annual Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure in 2020 (Incremental to Current Ozone Standard)[D]

		Eastern U.S.		**Western U.S. Excluding California**		**California**	
		Modeled Partial Attainment	Full Attainment	Modeled Partial Attainment	Full Attainment	*Glidepath[E]*	**National 2020 Benefits**
Model or Assumption[A]	*Reference*	*Arithmetic Mean[B] (95% Credible Intervals)[C]*					
NMMAPS	Bell et al. 2004	130 (45--220)	480 (160—790)	0.23 (0.08--0.37)	43 (15-72)	8.5	530
Meta-Analysis	Bell et al. 2005	540 (260--820)	1,900 (930—2,900)	0.86 (0.42—1.3)	180 (86—270)	34	2,100
	Levy et al. 2005	780 (540--1,000)	2,100 (1,500—2,800)	31 (22--41)	190 (130—250)	32	2,400
	Ito et al. 2005	590 (360--820)	2,100 (1,300—2,900)	1 (0.6--1.4)	190 (120—270)	37	2,300
Assumption that association is not causal		0	0	0	0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean and 95% credible interval around the mean estimates of the annual number of lives saved are based on an assumption of a normal distribution.

[C] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics.

[D] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

[E] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-6: Illustrative Strategy to Attain 0.065 ppm: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard, 95% Confidence Intervals in Parentheses)[B]

	Eastern U.S.		**Western U.S. Excluding California**		**California**	
Morbidity Endpoint	Modeled Partial Attainment	Full Attainment	Modeled Partial Attainment	Full Attainment	Glidepath Attainment[C]	*National 2020 Benefits*
Hospital Admissions (ages 0-1)	960 (410--1,500)	2,700 (1,200—4,300)	53 (23--83)	330 (150—520)	48	3,100
Hospital Admissions (ages 65-99)	1,100 (52—2,800)	3,900 (180—9,800)	3.8 (0.17--9.4)	320 (16—790)	57	4,300
Emergency Department Visits, Asthma-Related[A]	830 (-230--2,500)	2,500 (-680—7,700)	21 (-5.8--66)	130 (-35—400)	19	2,600
School Absences	410,000 (100,000--1,000,000)	1,200,000 (290,000—3,000,000)	20,000 (4,900--53,000)	120,000 (30,000—310,000)	19,000	1,300,000
Minor Restricted Activity Days	1,100,000 (460,000--1,800,000)	3,200,000 (1,300,000—5,000,000)	49,000 (20,000--78,000)	310,000 (130,000—490,000)	50,000	3,500,000

[A] The negative 5th percentile incidence estimates for this health endpoint are a result of the weak statistical power of the study and should not be inferred to indicate that decreased ozone exposure may cause an increase in asthma-related emergency department visits.

[B] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

[C] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-7: Illustrative Strategy to Attain 0.065 ppm in California: Estimated Annual Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

Model or Assumption[A]	*Reference*	*California Glidepath*[B]	*California Incremental Post-2020 Benefits*[C]	*California Total*[D]
NMMAPS	Bell et al. 2004	8.5	95	100
Meta-Analysis	Bell et al. 2005	34	390	420
	Levy et al. 2005	32	420	450
	Ito et al. 2005	37	420	450
Assumption that association is not causal		0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] Two areas in California have high levels of ozone and are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[D] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[E] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-8: Illustrative Strategy to Attain 0.065 ppm in California: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure [D]

Morbidity Endpoint	*California Glidepath*[A]	*California Incremental Post-2020 Benefits*[B]	*California Total*[C]
Hospital Admissions (ages 0-1)	48	830	880
Hospital Admissions (ages 65-99)	57	620	670
Emergency Department Visits, Asthma-Related[A]	19	290	310
School Absences	19,000	320,000	340,000
Minor Restricted Activity Days	50,000	780,000	830,000

[A] Two areas in California have high levels of ozone and are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[B] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[C] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[D] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-9: Illustrative 0.065 ppm Full Attainment Scenario: Estimated Annual Reductions in the Incidence of PM Premature Mortality associate with PM co-benefit[C]

	National + 2020 California Glidepath Benefits	*California*		
		Glidepath	**Incremental Post-2020 Benefits**	**Total**
Mortality Impact Functions Derived from Epidemiology Literature				
ACS Study[A]	1,800	33	160	190
Harvard Six-City Study[B]	4,000	75	360	430
Woodruff et al 1997 (infant mortality)	4	0.1	0.34	0.41
Mortality Impact Functions Derived from Expert Elicitation				
Expert A	5,500	100	490	590
Expert B	4,200	78	370	450
Expert C	4,100	77	370	450
Expert D	2,900	55	260	320
Expert E	6,800	130	610	740
Expert F	3,800	71	340	410
Expert G	2,400	45	220	260
Expert H	3,100	58	280	330
Expert I	4,100	77	370	440
Expert J	3,300	62	300	360
Expert K	660	12	59	72
Expert L	3,000	57	270	330

[A] The estimate is based on the concentration-response (C-R) function developed from the study of the American Cancer Society cohort reported in Pope et al (2002), which has previously been reported as the primary estimate in recent RIAs
[B] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.
[C] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA. Estimates do not include confidence intervals because they were derived through a scaling technique described above.

Table 6-10: Illustrative 0.065 ppm Full Attainment Scenario: Estimated Annual Reductions in the Incidence of Morbidity Associated with PM Co-benefit[A]

	National + 2020 California Glidepath Benefits	*California*		
		Glidepath	**Incremental Post-2020 Benefits**	**Total**
Morbidity Impact Functions Derived from Epidemiology Literature				
Chronic Bronchitis (age >25 and over)	1,300	25	120	150
Nonfatal myocardial infarction (age >17)	4,000	74	350	430
Hospital admissions--respiratory (all ages)	460	9	41	50
Hospital admissions-- cardiovascular (age >17)	930	17	83	100
Emergency room visits for asthma (age <19)	2,000	35	180	210
Acute bronchitis (age 8-12)	3,500	65	310	380
Lower respiratory symptoms (age 7-14)	29,000	550	2,600	3,200
Upper respiratory symptoms (asthmatic children age 9-18)	22,000	400	1,900	2,300
Asthma exacerbation (asthmatic children age 6--18)	27,000	500	2,400	2,900
Work loss days (age 18-65)	190,000	3,500	17,000	20,000
Minor restricted activity days (age 18-65)	1,100,000	21,000	100,000	120,000

[A] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA. Estimates do not include confidence intervals because they were derived through a scaling technique described above.

Table 6-11: Illustrative Strategy to Attain 0.070 ppm: Estimated Annual Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

		Eastern U.S.		**Western U.S. Excluding California**		**California**	
		Modeled Partial Attainment	Full Attainment	Modeled Partial Attainment	Full Attainment	Glidepath Attainment[D]	**2020 National Attainment**
Model or Assumption[A]	*Reference*	*Arithmetic Mean[B] (95% Credible Intervals)[C]*					
NMMAPS	Bell et al. 2004	130 (45--220)	260 (88--440)	0.23 (0.08--0.37)	11 (3.8--19)	5.5 (1.8--9.1)	280 (93—470)
Meta-Analysis	Bell et al. 2005	540 (260--820)	1,100 (510—1,600)	0.86 (0.42--1.3)	47 (23--71)	22 (11--34)	1,100 (540—1,700)
	Levy et al. 2005	780 (540--1,000)	1,300 (900—1,700)	31 (22--41)	73 (50--95)	21 (14--27)	1,400 (960—1,800)
	Ito et al. 2005	590 (360--820)	1,200 (700--1,600)	1 (0.6--1.4)	50 (30--70)	24 (15--34)	1,200 (740—1,700)
Assumption that association is not causal		0	0	0	0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean and 95% credible interval around the mean estimates of the annual number of lives saved are based on an assumption of a normal distribution.

[C] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics.

[D] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[E] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-12: Illustrative Strategy to Attain 0.070 ppm: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard, 95% Confidence Intervals in Parentheses)[C]

	Eastern U.S.		Western U.S. Excluding California		California	
Morbidity Endpoint	Modeled Partial Attainment	Full Attainment	Modeled Partial Attainment	Full Attainment	Glidepath Attainment[B]	**2020 National Benefits**
Hospital Admissions (ages 0-1)	960 (410--1,500)	1,700 (720--2,600)	53 (23--83)	130 (55--200)	33 (14--51)	1,800 (790—2,900)
Hospital Admissions (ages 65-99)	1,100 (52—2,800)	2,100 (100--5,400)	3.8 (0.17--9.4)	86 (4.2--210)	37 (1.8--92)	2,300 (110—5,700)
Emergency Department Visits, Asthma-Related[A]	830 (-230--2,500)	1,500 (-400--4,300)	21 (-5.8--66)	50 (-13--150)	13 (-3.5--37)	1,500 (-420—4,500)
School Absences	410,000 (100,000--1,000,000)	720,000 (170,000--1,800,000)	20,000 (4,900--53,000)	47,000 (11,000--120,000)	13,000 (3,100--33,000)	780,000 (190,000—1,900,000)
Minor Restricted Activity Days	1,100,000 (460,000--1,800,000)	1,900,000 (790,000--3,000,000)	49,000 (20,000--78,000)	120,000 (49,000--190,000)	34,000 (14,000--53,000)	2,100,000 (850,000—3,300,000)

[A] The negative 5th percentile incidence estimates for this health endpoint are a result of the weak statistical power of the study and should not be inferred to indicate that decreased ozone exposure may cause an increase in asthma-related emergency department visits.

[B] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns.

Table 6-13: Illustrative Strategy to Attain 0.070 ppm in California: Estimated Annual Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

Model or Assumption[A]	*Reference*	*California Glidepath*[B]	*California Incremental Post-2020 Benefits*[C]	*California Total*[D]
NMMAPS	Bell et al. 2004	5.5 (1.8--9.1)	56	62
Meta-Analysis	Bell et al. 2005	22 (11--34)	230	250
	Levy et al. 2005	21 (14--27)	250	280
	Ito et al. 2005	24 (15--34)	250	270
Assumption that association is not causal		0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] Two areas in California have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[D] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[E] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-14: Illustrative Strategy to Attain 0.070 ppm in California: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard, 95% Confidence Intervals in Parentheses)[D]

Morbidity Endpoint	*California Glidepath*[A]	*California Incremental Post-2020 Benefits*[B]	*California Total*[C]
Hospital Admissions (ages 0-1)	33 (14--51)	520	560
Hospital Admissions (ages 65-99)	37 (1.8--92)	370	400
Emergency Department Visits, Asthma-Related[A]	13 (-3.5--37)	180	190
School Absences	13,000 (3,100--33,000)	200,000	210,000
Minor Restricted Activity Days	34,000 (14,000--53,000)	480,000	520,000

[A] Two areas in California have high levels of ozone and not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[B] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[C] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[D] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-15: Illustrative 0.070 ppm Full Attainment Scenario: Estimated Annual Reductions in the Incidence of PM Premature Mortality associate with PM co-benefit[C]

	National + 2020 California Glidepath Benefits	*California*		
		Glidepath	**Incremental Post-2020 Benefits**	**Total**
Mortality Impact Functions Derived from Epidemiology Literature				
ACS Study[A]	1,000	13	120	130
Harvard Six-City Study[B]	2,300	30	270	300
Woodruff et al 1997 (infant mortality)	2	0	0.3	0.3
Mortality Impact Functions Derived from Expert Elicitation				
Expert A	3,200	41	360	410
Expert B	2,400	31	280	310
Expert C	2,400	31	280	310
Expert D	1,700	22	190	220
Expert E	4,000	51	450	500
Expert F	2,200	28	250	280
Expert G	1,400	18	160	180
Expert H	1,800	23	200	230
Expert I	2,400	31	270	300
Expert J	1,900	25	220	250
Expert K	390	5	44	49
Expert L	1,800	23	200	220

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

[B] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[C] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA. Estimates do not include confidence intervals because they were derived through a scaling technique described above.

Table 6-16: Illustrative 0.070 ppm Full Attainment Scenario: Estimated Annual Reductions in the Incidence of Morbidity Associated with PM Co-benefit[A]

	National + 2020 California Glidepath Benefits	*California* Glidepath	*California* Incremental Post-2020 Benefits	*California* Total
Morbidity Impact Functions Derived from Epidemiology Literature				
Chronic Bronchitis (age >25 and over)	780	10	89	99
Nonfatal myocardial infarction (age >17)	2,300	30	260	290
Hospital admissions--respiratory (all ages)	270	3	31	34
Hospital admissions-- cardiovascular (age >17)	540	7	62	69
Emergency room visits for asthma (age <19)	1,200	14	130	150
Acute bronchitis (age 8-12)	2,000	26	230	260
Lower respiratory symptoms (age 7-14)	17,000	220	2,000	2,200
Upper respiratory symptoms (asthmatic children age 9-18)	13,000	160	1,400	1,600
Asthma exacerbation (asthmatic children age 6--18)	16,000	200	1,800	2,000
Work loss days (age 18-65)	110,000	1,400	12,000	14,000
Minor restricted activity days (age 18-65)	650,000	8,300	74,000	82,000

[A] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA. Estimates do not include confidence intervals because they were derived through a scaling technique described above.

Table 6-17: Illustrative Strategy to Attain 0.075 ppm: Estimated Annual Reductions in the Incidence of Premature Mortality Ozone Exposures (Incremental to Current Ozone Standard)[D]

Model or Assumption[A]	Reference	Eastern U.S.	Western U.S. Excluding California	California: Glidepath Attainment[E]	2020 National Benefits
		Arithmetic Mean[B] (95% Credible Intervals)[C]			
NMMAPS	Bell et al. 2004	190	8.9	0	200
Meta-Analysis	Bell et al. 2005	840	40	0	880
	Levy et al. 2005	1,100	65	0	1,100
	Ito et al. 2005	920	43	0	960
Assumption that association is not causal		0	0	0 0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean and 95% credible interval around the mean estimates of the annual number of lives saved are based on an assumption of a normal distribution.

[C] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics. Credible intervals not provided due to the fact that the incidence estimates were derived through an interpolation technique (see Appendix 6) that precluded us from generating such estimates.

[D] All estimates rounded to two significant figures. As such, totals will not sum across columns

[E] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-18: Illustrative Strategy to Attain 0.075 ppm: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard)[A,B]

Morbidity Endpoint	*Eastern U.S.*	*Western U.S. Excluding California*	*California*	*2020 National Benefits*
			Glidepath Attainment[C]	
Hospital Admissions (ages 0-1)	1,300	110	0	1,400
Hospital Admissions (ages 65-99)	1,700	76	0	1,800
Emergency Department Visits, Asthma-Related	1,200	44	0	1,200
School Absences	570,000	42,000	0	610,000
Minor Restricted Activity Days	1,500,000	110,000	0	1,600,000

[A] Confidence intervals not provided due to the fact that the incidence estimates were derived through an interpolation technique (see Appendix 6) that precluded us from generating such estimates.

[B] All estimates rounded to two significant figures. As such, totals will not sum across columns

[C] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-19: Illustrative Strategy to Attain 0.075 ppm in California: Estimated Annual Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

Model or Assumption[A]	*Reference*	*California Glidepath[B]*	*California Incremental Post-2020 Benefits[C]*	*California Total[D]*
NMMAPS	Bell et al. 2004	0	35	35
Meta-Analysis	Bell et al. 2005	0	140	140
	Levy et al. 2005	0	150	150
	Ito et al. 2005	0	160	160
Assumption that association is not causal		0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] Two areas in California have high levels of ozone and not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[D] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[E] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-20: Illustrative Strategy to Attain 0.075 ppm in California: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard, 95% Confidence Intervals in Parentheses)[D]

Morbidity Endpoint	*California Glidepath[A]*	*California Incremental Post-2020 Benefits[B]*	*California Total[C]*
Hospital Admissions (ages 0-1)	0	320	320
Hospital Admissions (ages 65-99)	0	230	230
Emergency Department Visits, Asthma-Related[A]	0	110	110
School Absences	0	120,000	120,000
Minor Restricted Activity Days	0	290,000	290,000

[A] Two areas in California have high levels of ozone and are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[B] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[C] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[D] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-21: Illustrative 0.075 ppm Full Attainment Scenario: Estimated Annual Reductions in the Incidence of PM Premature Mortality associate with PM co-benefit[C]

	National + 2020 California Glidepath Benefits	California Glidepath	California Incremental Post-2020 Benefits	California Total
Mortality Impact Functions Derived from Epidemiology Literature				
ACS Study[A]	620	0	70	70
Harvard Six-City Study[B]	1,400	0	160	160
Woodruff et al 1997 (infant mortality)	1	0	0.2	0.2
Mortality Impact Functions Derived from Expert Elicitation				
Expert A	1,900	0	220	220
Expert B	1,500	0	170	170
Expert C	1,400	0	160	160
Expert D	1,000	0	120	120
Expert E	2,400	0	270	270
Expert F	1,200	0	150	150
Expert G	840	0	96	96
Expert H	1,100	0	120	120
Expert I	1,400	0	160	160
Expert J	1,200	0	130	130
Expert K	230	0	26	26
Expert L	1,100	0	120	120

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

[B] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[C] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA. Estimates do not include confidence intervals because they were derived through a scaling technique described above.

Table 6-22: Illustrative 0.075 ppm Full Attainment Scenario: Estimated Annual Reductions in the Incidence of Morbidity Associated with PM Co-benefit[A]

	National + 2020 California Glidepath Benefits	*California* **Glidepath**	*California* **Incremental Post-2020 Benefits**	*California* **Total**
Morbidity Impact Functions Derived from Epidemiology Literature				
Chronic Bronchitis (age >25 and over)	470	0	53	53
Nonfatal myocardial infarction (age >17)	1,400	0	160	160
Hospital admissions--respiratory (all ages)	160	0	18	18
Hospital admissions-- cardiovascular (age >17)	320	0	37	37
Emergency room visits for asthma (age <19)	690	0	78	78
Acute bronchitis (age 8-12)	1,200	0	140	140
Lower respiratory symptoms (age 7-14)	10,000	0	1,200	1,200
Upper respiratory symptoms (asthmatic children age 9-18)	7,500	0	850	850
Asthma exacerbation (asthmatic children age 6--18)	9,400	0	1,100	1,100
Work loss days (age 18-65)	65,000	0	7,400	7,400
Minor restricted activity days (age 18-65)	390,000	0	44,000	44,000

[A] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA. Estimates do not include confidence intervals because they were derived through a scaling technique described above.

Table 6-23: Illustrative Strategy to Attain 0.079 ppm: Estimated Annual Reductions in the Incidence of Premature Mortality Ozone Exposures (Incremental to Current Ozone Standard)[D]

Model or Assumption[A]	*Reference*	Eastern U.S.	Western U.S. Excluding California	California: Glidepath Attainment[E]	2020 National Benefits
		Arithmetic Mean[B] *(95% Credible Intervals)*[C]			
NMMAPS	Bell et al. 2004	19 (7.6—31)	0	0	19 (7.6—31)
Meta-Analysis	Bell et al. 2005	78 (41—120)	0	0	78 (41—120)
	Levy et al. 2005	78 (56—100)	0	0	78 (56—100)
	Ito et al. 2005	85 (55—120)	0	0	85 (55—120)
Assumption that association is not causal		0	0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean and 95% credible interval around the mean estimates of the annual number of lives saved are based on an assumption of a normal distribution.

[C] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics. Credible intervals not provided due to the fact that the incidence estimates were derived through an interpolation technique (see Appendix 6) that precluded us from generating such estimates.

[D] All estimates rounded to two significant figures. As such, totals will not sum across columns

[E] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-24: Illustrative Strategy to Attain 0.079 ppm: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard)[B]

Morbidity Endpoint	*Eastern U.S.*	*Western U.S. Excluding California*	*California* **Glidepath Attainment**[A,c]	*2020 National Benefits*
Hospital Admissions (ages 0-1)	120 (56—180)	0	0	120 (56—180)
Hospital Admissions (ages 65-99)	160 (7.4—310)	0	0	160 (7.4—310)
Emergency Department Visits, Asthma-Related	94 (-5.7—250)	0	0	94 (-5.7—250)
School Absences	50,000 (15,000—76,000)	0	0	50,000 (15,000—76,000)
Minor Restricted Activity Days	130,000 (58,000—190,000)	0	0	130,000 (58,000—190,000)

[A] Confidence intervals not provided due to the fact that the incidence estimates were derived through an interpolation technique (see Appendix 6) that precluded us from generating such estimates.

[B] All estimates rounded to two significant figures. As such, totals will not sum across columns

[C] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-25: Illustrative Strategy to Attain 0.079 ppm in California: Estimated Annual Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

Model or Assumption[A]	*Reference*	*California Glidepath*[B]	*California Incremental Post-2020 Benefits*[C]	*California Total*[D]
NMMAPS	Bell et al. 2004	0	8.4	8.4
Meta-Analysis	Bell et al. 2005	0	34	34
	Levy et al. 2005	0	38	38
	Ito et al. 2005	0	37	37
Assumption that association is not causal		0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] Two areas of California that have high levels of ozone are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[D] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[E] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-26: Illustrative Strategy to Attain 0.079 ppm in California: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard, 95% Confidence Intervals in Parentheses)[D]

Morbidity Endpoint	*California Glidepath[A]*	*California Incremental Post-2020 Benefits[B]*	*California Total[C]*
Hospital Admissions (ages 0-1)	0	80	80
Hospital Admissions (ages 65-99)	0	55	55
Emergency Department Visits, Asthma-Related[A]	0	27	27
School Absences	0	30,000	30,000
Minor Restricted Activity Days	0	73,000	73,000

[A] Two areas have high levels of ozone and are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[B] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[C] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[D] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-27: Illustrative 0.079 ppm Full Attainment Scenario: Estimated Annual Reductions in the Incidence of PM Premature Mortality associate with PM co-benefit[C]

	National + 2020 California Glidepath Benefits	*California*		
		Glidepath	**Incremental Post-2020 Benefits**	**Total**
Mortality Impact Functions Derived from Epidemiology Literature				
ACS Study[A]	480	0	22	22
Harvard Six-City Study[B]	1,100	0	50	50
Woodruff et al 1997 (infant mortality)	1	0	0.05	0.05
Mortality Impact Functions Derived from Expert Elicitation				
Expert A	1,500	0	68	68
Expert B	1,200	0	52	52
Expert C	1,100	0	51	51
Expert D	800	0	36	36
Expert E	1,900	0	84	84
Expert F	1,000	0	47	47
Expert G	660	0	30	30
Expert H	840	0	38	38
Expert I	1,100	0	51	51
Expert J	910	0	41	41
Expert K	180	0	8.2	8.2
Expert L	830	0	37	37

[A] The estimate is based on the concentration-response (C-R) function developed from the study of the American Cancer Society cohort reported in Pope et al (2002), which has previously been reported as the primary estimate in recent RIAs
[B] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.
[C] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA. Estimates do not include confidence intervals because they were derived through a scaling technique described above.

Table 6-28: Illustrative 0.079 ppm Full Attainment Scenario: Estimated Annual Reductions in the Incidence of Morbidity Associated with PM Co-benefit (95th percentile confidence intervals provided in parentheses)[A]

	National + 2020 California Glidepath Benefits	*California*		
		Glidepath	**Incremental Post-2020 Benefits**	**Total**
Morbidity Impact Functions Derived from Epidemiology Literature				
Chronic Bronchitis (age >25 and over)	370	0	17	17
Nonfatal myocardial infarction (age >17)	1,100	0	49	49
Hospital admissions--respiratory (all ages)	130	0	5.7	5.7
Hospital admissions-- cardiovascular (age >17)	250	0	12	12
Emergency room visits for asthma (age <19)	540	0	24	24
Acute bronchitis (age 8-12)	950	0	43	43
Lower respiratory symptoms (age 7-14)	8,100	0	360	360
Upper respiratory symptoms (asthmatic children age 9-18)	5,900	0	270	270
Asthma exacerbation (asthmatic children age 6--18)	7,300	0	330	330
Work loss days (age 18-65)	51,000	0	2,300	2,300
Minor restricted activity days (age 18-65)	310,000	0	14,000	14,000

[A] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA. Estimates do not include confidence intervals because they were derived through a scaling technique described above.

Table 6-29: Illustrative Strategy to Attain 0.065 ppm: Estimated Annual Valuation of Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard, Millions of 1999$)[D]

		Eastern U.S.		**Western U.S. Excluding California**		**California**	
		Modeled Partial Attainment	Full Attainment	Modeled Partial Attainment	Full Attainment	Glidepath Attainment[E]	**2020 National Benefits**
Model or Assumption[A]	*Reference*	*Arithmetic Mean[B] (95% Credible Intervals)[C]*					
NMMAPS	Bell et al. 2004	$850 ($120—$1,900)	$3,100 ($430--$6,800)	$1.4 ($0.2--$3.2)	$280 ($39--$620)	$54	$3,400
Meta-Analysis	Bell et al. 2005	$3,500 ($550--$7,500)	$12,000 ($2,000--$26,000)	$5.5 ($0.9--$12)	$1,100 ($180--$2,400)	$220	$14,000
	Levy et al. 2005	$5,000 ($890--$9,600)	$14,000 ($2,400--$26,000)	$200 ($36--$390)	$1,200 ($220--$2,400)	$200	$15,000
	Ito et al. 2005	$3,800 ($650--$7,500)	$13,000 ($2,300--$27,000)	$6.3 ($1.1--$13)	$1,200 ($210--$2,400)	$240	$15,000
Assumption that association is not causal		0	0	0	0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean and 95% credible interval around the mean estimates of the annual number of lives saved are based on an assumption of a normal distribution.

[C] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics.

[D] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

[E] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-30: Illustrative Strategy to Attain 0.065 ppm: Estimated Annual Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard, 95% Confidence Intervals in Parentheses, Millions of 1999$)[A]

	Eastern U.S.		Western U.S. Excluding California		California	2020 National Benefits
Morbidity Endpoint	Modeled Partial Attainment	Full Attainment	Modeled Partial Attainment	Full Attainment	Glidepath Attainment[B]	
Hospital Admissions (ages 0-1)	$7.1 ($3.1--$11)	$20 ($8.8--$32)	$0.39 ($0.17--$0.62)	$2.5 ($1.1--$3.9)	$0.4	$23
Hospital Admissions (ages 65-99)	$19 ($0.9--$49)	$68 ($3.2--$170)	$0.67 ($0.003—$0. 2)	$5.6 ($0.28--$14)	$1	$75
Emergency Department Visits, Asthma-Related	$0.23 ($-0.06--$0.67)	$0.7 ($-0.2--$2)	--	$0.04 ($-0.009--$0.1)	--	$0.7
School Absences	$30 ($7.2-$72)	$87 ($21--$210)	$1.5 ($0.35--$3.8)	$8.9 ($2.1--$22)	$1.4	$97
Worker Productivity	$15	$38	$0.38	$3.9	$2.9	$45
Minor Restricted Activity Days	$27 ($1.2--$63)	$79 ($3.4--$180)	$1.2 ($0.05--$2.8)	$7.6 ($0.3--$18)	$1.3	$87

[A] All estimates rounded to two significant figures. As such, totals will not sum across columns

[B] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-31: Illustrative Strategy to Attain 0.065 ppm in California: Estimated Annual Valuation of Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

Model or Assumption[A]	*Reference*	*California Glidepath*[B]	*California Incremental Post-2020 Benefits*[C]	*California Total*[D]
NMMAPS	Bell et al. 2004	$54	$610	$660
Meta-Analysis	Bell et al. 2005	$220	$2,500	$2,700
	Levy et al. 2005	$200	$2,600	$2,900
	Ito et al. 2005	$240	$2,700	$2,900
Assumption that association is not causal		0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[D] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[E] All estimates rounded to two significant figures. As such, totals will not sum across columns

Table 6-32: Illustrative Strategy to Attain 0.065 ppm in California: Estimated Annual Valuation of Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard)[D]

Morbidity Endpoint	*California Glidepath[A]*	*California Incremental Post-2020 Benefits[B]*	*California Total[C]*
Hospital Admissions (ages 0-1)	$0.4	$6.2	$6.6
Hospital Admissions (ages 65-99)	$1	$11	$12
Emergency Department Visits, Asthma-Related[A]	--	$0.8	$0.9
School Absences	$1.4	$23	$25
Worker Productivity	$2.9	$26	$29
Minor Restricted Activity Days	$1.3	$19	$21

[A] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[B] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[C] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[D] All estimates rounded to two significant figures. As such, totals will not sum across columns

Table 6-33: Illustrative Strategy to Attain 0.070 ppm: Estimated Annual Valuation of Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard, Millions of 1999$)[E]

		Eastern U.S.		Western U.S. Excluding California		California	
		Modeled Partial Attainment	Full Attainment	Modeled Partial Attainment	Full Attainment	Glidepath Attainment[D]	**2020 National Benefits**
Model or Assumption[A]	*Reference*	*Arithmetic Mean[B] (95% Credible Intervals)[C]*					
NMMAPS	Bell et al. 2004	$850 ($120—$1,900)	$1,700 ($240--$3,800)	$1.4 ($0.2--$3.2)	$73 ($10--$160)	$35 ($5--$78)	$1,800 ($250--$4,000)
Meta-Analysis	Bell et al. 2005	$3,500 ($550--$7,500)	$6,800 ($1,100--$14,000)	$5.5 ($0.9--$12)	$300 ($48--$630)	$140 ($23--$300)	$7,200 ($1,200--$15,000)
	Levy et al. 2005	$5,000 ($890--$9,600)	$8,300 ($1,500--$16,000)	$200 ($36--$390)	$470 ($83--$900)	$130 ($24--$260)	$8,900 ($1,600--$17,000)
	Ito et al. 2005	$3,800 ($1,300--$9,300)	$7,400 ($1,300--$15,000)	$6.3 ($1.1--$13)	$320 ($56--$640)	$150 ($27--$310)	$7,900 ($1,400--$16,000)
Assumption that association is not causal		0	0	0	0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean and 95% credible interval around the mean estimates of the annual number of lives saved are based on an assumption of a normal distribution.

[C] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics.

[D] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[E] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-34: Illustrative Strategy to Attain 0.070 ppm: Estimated Annual Valuation of Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard, 95% Confidence Intervals in Parentheses, Millions of 1999$)[B]

	Eastern U.S.		**Western U.S. Excluding California**		**California**	
Morbidity Endpoint	Modeled Partial Attainment	Full Attainment	Modeled Partial Attainment	Full Attainment	Glidepath Attainment[A]	**2020 National Benefits**
Hospital Admissions (ages 0-1)	$7.1 ($3.1--$11)	$12 ($5.3--$19)	$0.39 ($0.17--$0.62)	$1 ($0.41--$1.5)	$0.24 ($0.11--$0.38)	$14 ($5.9--$21)
Hospital Admissions (ages 65-99)	$19 ($0.9--$49)	$38 ($1.8--$95)	$0.67 ($0.003— $0. 2)	$1.5 ($0.074-- $3.8)	$0.65 ($0.32--$1.6)	$40 ($1.9--$100)
Emergency Department Visits, Asthma-Related	$0.23 ($-0.06--$0.67)	$0.4 ($-0.1--$1.2)	--	--	--	$0.5 (-$0.1--$1.2)
School Absences	$30 ($7.2-$72)	$52 ($13--$130)	$1.5 ($0.35--$3.8)	$3.4 ($0.8--$8.4)	$0.93 ($0.2--$2.4)	$56 ($14--$140)
Worker Productivity	$15	$22	$0.38	$1.4	$1.9	$26
Minor Restricted Activity Days	$27 ($1.2--$63)	$47 ($2--$110)	$1.2 ($0.05--$2.8)	$2.9 ($0.13--$6.8)	$0.83 ($0.036--$1.9)	$51 ($2.2--$120)

[A] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.
[B] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-35: Illustrative Strategy to Attain 0.070 ppm in California: Estimated Annual Valuation of Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

Model or Assumption[A]	*Reference*	*California Glidepath*[B]	*California Incremental Post-2020 Benefits*[C]	*California Total*[D]
NMMAPS	Bell et al. 2004	$35 ($5--$78)	$360	$390
Meta-Analysis	Bell et al. 2005	$140 ($23--$300)	$1,500	$1,600
	Levy et al. 2005	$130 ($24--$260)	$1,600	$1,800
	Ito et al. 2005	$150 ($27--$310)	$1,600	$1,700
Assumption that association is not causal		0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[D] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[E] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-36: Illustrative Strategy to Attain 0.070 ppm in California: Estimated Annual Valuation of Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard, 95% Confidence Intervals in Parentheses)[D]

Morbidity Endpoint	*California Glidepath[A]*	*California Incremental Post-2020 Benefits[B]*	*California Total[C]*
Hospital Admissions (ages 0-1)	$0.24 ($0.11--$0.38)	$3.9	$4.2
Hospital Admissions (ages 65-99)	$0.65 ($0.32--$1.6)	$6.5	$7.2
Emergency Department Visits, Asthma-Related[A]	--	$0.05	$0.05
School Absences	$0.93 ($0.2--$2.4)	$15	$15
Worker Productivity	$1.9	$16	$17
Minor Restricted Activity Days	$0.83 ($0.036--$1.9)	$12	$13

[A] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[B] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[C] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[D] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns

Table 6-37: Illustrative Strategy to Attain 0.075 ppm: Estimated Annual Monetary Value of Reductions in the Incidence of Mortality Associated with Exposure to Ozone (Millions of 1999$, Incremental to Current Standard)[B]

Model or Assumption[A]	*Reference*	**Eastern U.S.**	**Western U.S. Excluding California**	**California** Glidepath Attainment[E]	**2020 National Benefits**
		Arithmetic Mean[B] *(95% Credible Intervals)*[C]			
NMMAPS	Bell et al. 2004	$1,400	$66	0	$1,400
Meta-Analysis	Bell et al. 2005	$5,400	$270	0	$5,700
	Levy et al. 2005	$6,700	$430	0	$7,100
	Ito et al. 2005	$5,900	$290	0	$6,200
Assumption that association is not causal		0	0	0	0

[A] Confidence intervals not provided due to the fact that the incidence estimates were derived through an interpolation technique (see Appendix 6) that precluded us from generating such estimates.

[B] All estimates rounded to two significant figures. As such, totals will not sum across columns

[C] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-38: Illustrative Strategy to Attain 0.075 ppm: Estimated Annual Monetary Value of Reductions in the Incidence of Morbidity Associated with Exposure to Ozone (Millions of 1999$, Incremental to Current Standard)[A]

Morbidity Endpoint	*Eastern U.S.*	*Western U.S. Excluding California*	*California* Glidepath Attainment[B]	*2020 National Benefits*
Hospital Admissions (ages 0-1)	$9.9	$0.9	0	$11
Hospital Admissions (ages 65-99)	$31	$1.4	0	$32
Emergency Department Visits, Asthma-Related	$0.3	$0.013	0	$0.3
School Absences	$41	$3	0	$44
Worker Productivity	$20	$1.3	0	$21
Minor Restricted Activity Days	$38	$2.6	0	$40

[A] All estimates rounded to two significant figures. As such, totals will not sum across columns

[B] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-39: Illustrative Strategy to Attain 0.075 ppm in California: Estimated Annual Valuation of Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

Model or Assumption[A]	*Reference*	*California Glidepath*[B]	*California Incremental Post-2020 Benefits*[C]	*California Total*[D]
NMMAPS	Bell et al. 2004	0	$220	$220
Meta-Analysis	Bell et al. 2005	0	$910	$910
	Levy et al. 2005	0	$990	$990
	Ito et al. 2005	0	$990	$990
Assumption that association is not causal		0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[D] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[E] All estimates rounded to two significant figures. As such, totals will not sum across columns

Table 6-40: Illustrative Strategy to Attain 0.075 ppm in California: Estimated Annual Valuation of Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard)[D]

Morbidity Endpoint	*California Glidepath*[A]	*California Incremental Post-2020 Benefits*[B]	*California Total*[C]
Hospital Admissions (ages 0-1)	0	$2.4	$2.4
Hospital Admissions (ages 65-99)	0	$4	$4
Emergency Department Visits, Asthma-Related[A]	0	$0.03	$0.03
School Absences	0	$8.7	$8.7
Worker Productivity	0	$9	$9
Minor Restricted Activity Days	0	$7.3	$7.3

[A] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[B] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[C] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[D] All estimates rounded to two significant figures. As such, totals will not sum across columns

Table 6-41: Illustrative Strategy to Attain 0.079 ppm: Estimated Annual Monetary Value of Reductions in the Incidence of Premature Mortality Associated with Exposure to Ozone (Millions of 1999$, Incremental to Current Standard)[B]

Model or Assumption[A]	*Reference*	**Eastern U.S.**	**Western U.S. Excluding California**	**California** Glidepath Attainment[E]	**2020 National Benefits**
		Arithmetic Mean[B] *(95% Credible Intervals)*[C]			
NMMAPS	Bell et al. 2004	$120 ($18--$280)	0	0	$120 ($18--$280)
Meta-Analysis	Bell et al. 2005	$500 ($82--$1,100)	0	0	$500 ($82--$1,100)
	Levy et al. 2005	$500 ($89--$960)	0	0	$500 ($89--$960)
	Ito et al. 2005	$550 ($94--$1,100)	0	0	$550 ($94--$1,100)
Assumption that association is not causal		0	0	0	0

[A] Confidence intervals not provided due to the fact that the incidence estimates were derived through an interpolation technique (see Appendix 6) that precluded us from generating such estimates.

[B] All estimates rounded to two significant figures. As such, totals will not sum across columns

[C] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-42: Illustrative Strategy to Attain 0.079 ppm: Estimated Annual Monetary Value of Reductions in the Incidence of Morbidity Associated with Exposure to Ozone (Millions of 1999$, Incremental to Current Standard)[A]

Morbidity Endpoint	*Eastern U.S.*	*Western U.S. Excluding California*	*California*	*2020 National Benefits*
			Glidepath Attainment[B]	
Hospital Admissions (ages 0-1)	$0.9 ($0.5--$1.3)	0	0	$0.9 ($0.5--$1.3)
Hospital Admissions (ages 65-99)	$2.8 ($0.4--$5.1)	0	0	$2.8 ($0.4--$5.1)
Emergency Department Visits, Asthma-Related	$0.03 (0--$0.07)	0	0	$0.03 (0--$0.07)
School Absences	$3.6 ($1.3--$5.3)	0	0	$3.6 ($1.3--$5.3)
Worker Productivity	$1.3	0	0	$1.3
Minor Restricted Activity Days	$3.1 ($0.1--$7.6)	0	0	$3.1 ($0.1--$7.6)

[A] All estimates rounded to two significant figures. As such, totals will not sum across columns

[B] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

Table 6-43: Illustrative Strategy to Attain 0.079 ppm in California: Estimated Annual Valuation of Reductions in the Incidence of Premature Mortality Associated with Ozone Exposure (Incremental to Current Ozone Standard)[E]

Model or Assumption[A]	*Reference*	*California Glidepath[B]*	*California Incremental Post-2020 Benefits[C]*	*California Total[D]*
NMMAPS	Bell et al. 2004	0	$46	$46
Meta-Analysis	Bell et al. 2005	0	$190	$190
	Levy et al. 2005	0	$180	$180
	Ito et al. 2005	0	$200	$200
Assumption that association is not causal		0	0	0

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[C] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[D] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described above.

[E] All estimates rounded to two significant figures. As such, totals will not sum across columns

Table 6-44: Illustrative Strategy to Attain 0.079 ppm in California: Estimated Annual Valuation of Reductions in the Incidence of Morbidity Associated with Ozone Exposure (Incremental to Current Ozone Standard)[D]

Morbidity Endpoint	*California Glidepath[A]*	*California Incremental Post-2020 Benefits[B]*	*California Total[C]*
Hospital Admissions (ages 0-1)	0	$0.3	$0.3
Hospital Admissions (ages 65-99)	0	$1	$1
Emergency Department Visits, Asthma-Related[A]	0	$0.1	$0.1
School Absences	0	$1.3	$1.3
Worker Productivity	0	$0.5	$0.5
Minor Restricted Activity Days	0	$1.2	$1.2

[A] This table reflects full attainment in all locations of the U.S. except two areas of California. These two areas, which have high levels of ozone, are not planning to meet the current standard until after 2020. The estimates in the table reflect a progress point in 2020 or "glidepath target" for the two California areas.

[B] Certain mobile source programs including Tier-2 and Non-Road Diesel are projected to generate NOx emission reductions in California between 2020 and 2030. The estimates in this column are the benefits of full attainment with the alternate standard post-2020 with mobile source emission reductions in the baseline, incremental to 2020 glidepath attainment.

[C] This column sums the glidepath and incremental post-2020 benefits. The estimates in this column do not include confidence intervals because they were derived through a scaling technique described below.

[D] All estimates rounded to two significant figures. As such, totals will not sum across columns

Estimated reductions in ozone mortality incidence provided in Tables 6-5, 6-7, 6-11, 6-13, 6-17, 6-19, 6-23 and 6-25 represent the number of premature deaths potentially avoided due to reductions in ozone exposure in 2020 using warm season functions from the recent ozone-mortality NMMAPS analysis of 95 U.S. communities (Bell et al., 2004) and three meta-analyses of the available published literature on ozone-mortality effects (Bell et al., 2005; Ito et al., 2005; Levy et al., 2005). These same tables also include the possibility that there is not a causal association between ozone and mortality, i.e., that the estimate for premature mortality avoided could be zero. As noted above, for each standard alternative we break out estimates between 2020 national glidepath and California post-2020. Model uncertainty, including whether or not the relationship is assumed to be causal, is a key source of uncertainty. Although multiple estimates are presented in these tables, no attempt was made to quantify the likelihood of a causal relationship between short-term ozone exposure and increased mortality or to weigh the results of the various models.

The estimate of central tendency for premature mortality is expressed as the arithmetic mean, with the assumption of a normal distribution, and represents the central estimate of the number of premature deaths avoided in association with the proposed standard based on each study. Statistical uncertainty associated with the model estimate for each study is characterized by the 95% credible interval[29] around the mean estimate (i.e., 2.5th and 97.5th percent interval). Of the four available studies, the NMMAPS study by Bell et al. (2004) is considered to be the most representative for evaluating potential mortality-related benefits associated with the proposed standard due to its extensive coverage (examination of 95 large communities across the United States over an extended period of time, from 1987 to 2000) and its specific focus on the ozone-mortality relationship. Annual estimates of lives saved from this study are lower than those from the three meta-analyses, possibly due to more stringent adjustment for meteorological factors (Ito et al., 2005; Ostro et al., 2006), publication bias in the meta-analyses (Bell et al., 2005; Ito et al., 2005) or other factors. Clearly, the ozone-mortality reduction estimates are conditional on a causal relationship.

The Ozone Criteria Document (U.S. EPA, 2006) and Staff Paper (U.S. EPA, 2007) concluded that the overall body of evidence is highly suggestive that (short-term exposure to) ozone directly or indirectly contributes to non-accidental cardiopulmonary-related mortality. However, various sources of uncertainty remain, including the possibility that there is no causal relationship between ozone and mortality (i.e., zero effect). For instance, because results of time-series studies implicate all of the criteria air pollutants, and those who would be expected to be potentially more susceptible to ozone exposure are likely to have lower exposure to ozone due to the amount of time that they spend indoors, CASAC[30] stated that it seems unlikely that the observed associations between short-term ozone concentrations and daily mortality are due

---

[29] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics.

[30] Clean Air Scientific Advisory Committee's Peer Review of the Agency's 2nd Draft Ozone Staff Paper, October 24, 2006. EPA-CASAC-07-001. Available at http://www.epa.gov/sab/pdf/casac-07-001.pdf

solely to ozone itself (i.e., ozone may be serving as a marker for other agents that are contributing to the short-term exposure effects on mortality). Even so, CASAC concluded that the evidence was strong enough to support a quantitative risk assessment of the relationship between short-term exposure to ozone and premature mortality as part of the Staff Paper. EPA has asked the National Academy of Sciences[31] for their advice on how best to quantify the uncertainty about the relationship between ambient ozone exposure and premature mortality within the context of quantifying projected benefits of alternative control strategies.

Using the NMMAPS study that was used as the basis for the risk analysis presented in our Staff Paper, we estimate 280 avoided premature deaths annually in 2020 from reducing ozone levels to meet a proposed standard of 0.070 ppm, which, when added to the other projected ozone related benefits, leads to an estimated total benefit of $1.8 billion/yr. Using three studies that synthesize data across a large number of individual studies, we estimate between 1,100 and 1,400 avoided premature deaths annually in 2020, leading to total monetized benefits of between $7.2 and $8.9 billion/yr. Alternatively, if there is no causal relationship between ozone and mortality, avoided premature deaths would be zero. For a proposed standard of 0.075 ppm, using the NMMAPS ozone mortality study, we estimate 200 premature deaths avoided and total monetized benefits of $1.4 billion/yr. Using the three synthesis studies, we estimate premature deaths avoided for the less stringent standard to be between 880 and 1,100, with total monetized ozone benefits to be between $5.7 and $7.1 billion/yr. For a proposed standard of 0.079 ppm, using the NMMAPS ozone mortality study, we estimate 19 premature deaths avoided and total monetized benefits of $140 million/yr. Using the three synthesis studies, we estimate premature deaths avoided for the less stringent standard to be between 78 and 85, with total monetized ozone benefits to be between $510 and $560 million/yr. Because EPA is taking comment on alternatives as low as 0.065 ppm, we show that a more stringent standard of 0.065 ppm, using the NMMAPS ozone mortality study is estimated to result in 530 premature deaths avoided and total monetized benefits of $3.4 billion/yr. Using the three synthesis studies, estimated premature deaths avoided for the more stringent standard are between 2,100 and 2,400, with total monetized ozone benefits between $14 and $15 billion/yr. Including premature mortality in our estimates had the largest impact on the overall magnitude of benefits: Premature mortality benefits account for more than 95 percent of the total benefits we can monetize. We note that these estimates reflect EPA's interim approach to characterizing the benefits of reducing premature mortality associated with ozone exposure. EPA has requested advice from the NAS on how best to quantify uncertainty in the relationship between ozone exposure and premature mortality in the context of quantifying benefits associated with alternative ozone control strategies.

6.5.3 $PM_{2.5}$ Co-Benefits Resulting from Attainment of 0.070 ppm incremental to 0.08 ppm

The summary of $PM_{2.5}$ related co-benefits in the tables above represent the benefits of partially attaining 0.070 ppm incremental to a partial attainment of 0.08 ppm. Thus, these estimates overstate the benefits of 0.070 ppm partial attainment relative to the actual incremental benefits

---

[31] National Academy of Sciences (2007) Project Scope. Estimating Mortality Risk Reduction Benefits from Decreasing Tropospheric Ozone Exposure. Division on Earth and Life Studies, Board on Environmental Studies and Toxicology. Available at http://www8.nationalacademies.org/cp/projectview.aspx?key=48768

of this scenario; this is due to the fact that the benefits estimates in these tables include the benefits of NOx reductions that would be required to attain a baseline of 0.08 ppm. Of greater analytical value would be an estimate of the $PM_{2.5}$ co-benefits associated with fully attaining 0.070 ppm incremental to full attainment of the 0.08 ppm standard.

To generate such an estimate, we calculated a new $PM_{2.5}$ baseline that established the $PM_{2.5}$ air quality associated with full attainment of 0.08 ppm. To create such a baseline, EPA utilized benefit $PM_{2.5}$ per-ton estimates. These $PM_{2.5}$ benefit per-ton estimates provide the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of $PM_{2.5}$ from a specified source. EPA has used a similar technique in previous Regulatory Impact Analyses.[32] These estimates are based on the sum of the valuation of the Pope (2002) estimates of mortality (3% discount rate, 1999$) and valuation of the morbidity incidence. Readers interested in reviewing the complete methodology for creating the benefit per-ton estimates used in this analysis can consult the Technical Support Document accompanying this RIA.

Estimating the $PM_{2.5}$ benefits that represented the full attainment of both 0.070 ppm incremental to full attainment of 0.08 ppm entailed the following four steps:

1. *Estimate the number of tons of NOx necessary to attain a baseline of 0.08 ppm*. Chapter 3 described the method used to estimate the extrapolated NOx emissions reductions necessary to attain a baseline of 0.08 ppm full attainment.
2. *Calculate the benefits of attaining 0.08 ppm.* To estimate the benefits of fully attaining 0.08 ppm incremental to partial attainment of 0.08 ppm, the relevant benefit per ton is simply multiplied by the total number of extrapolated NOx tons abated.
3. *Calculate the benefits of partially attaining 0.070 ppm incremental to full attainment of 0.08 ppm.* Subtract the benefits of fully attaining 0.080 ppm incremental to the partial attainment of 0.08 ppm to create a new estimate of incremental 0.070 ppm partial attainment.
4. *Calculate the $PM_{2.5}$ benefits of fully attaining 0.070 ppm*. Multiplying the estimate of the extrapolated NOx tons necessary to attain 0.070 ppm fully (found in chapter 3) produces an estimate of the incremental benefits of fully attaining 0.070 ppm incremental to partial attainment of 0.070 ppm. By adding this incremental benefit estimate to the benefits generated in step 3, we derived a total benefit estimate of attaining 0.070 ppm incremental to 0.08 ppm.

The process for estimating the $PM_{2.5}$ co-benefits of fully attaining 0.065 ppm and 0.075 ppm is identical to the steps above, with the following exception; in step four we substituted the number of extrapolated tons necessary to attain 0.065 ppm and 0.075 ppm, respectively. Table 5-21 below provides the inputs to the calculation steps described above. In the example below we

[32] *Final Regulatory Impact Analysis: Industrial Boilers and Process Heaters*. Prepared by Office of Air and Radiation. Available: http://www.epa.gov/ttn/ecas/regdata/EIAs/chapter10.pdf [accessed 18 May 2007].

calculate total benefits using the Pope et al. (2002) mortality estimate. However, in subsequent tables we present benefits using Laden et al. (2006) as well as the twelve expert functions described previously in this document. Note that while our benefit per ton estimates are associated with broad source categories (in this case, NOx Electrical Generating Units, Other NOx point sources and Mobile NOx sources) the extrapolated tons were not. For this reason we simply assumed that the total number of extrapolated NOx tons were evenly distributed between these three source types.

Table 6-45: Estimated $PM_{2.5}$ Co-Benefits Associated with Full Attainment of 0.070 ppm incremental to 0.08 ppm[A]

Calculation	*Extrapolated NOx Tons*	*Benefit per ton estimate*	*Valuation of PM2.5 Benefits (Billions 1999$)[B]*
Benefits of attaining 0.08 ppm partially and 0.070 ppm partially:	---	---	$2.9B
Benefits of attaining 0.08 ppm from a baseline of 0.08 ppm partial attainment:	NOx EGU: 45,000 NOx Point: 45,000 NOx Mobile: 45,000	$3,100 $2,800 $4,600	$0.48B
Benefits of attaining 0.070 ppm partially, incremental to attainment of 0.08 ppm	---	---	= $2.9B - $0.48B =$2.5 B
Benefits of attaining 0.070 ppm in 2020 incremental to partial attainment of 0.070 ppm	NOx EGU: 340,000 NOx Point: 340,000 NOx Mobile: 340,000	$3,100 $2,800 $4,600	$3.5B
Benefits of attaining 0.070 ppm incremental to attainment of 0.08 ppm			=$2.5B + 3.5B =$6.0B

[A] Numbers have been rounded to two significant figures and therefore summation may not match table estimates. $PM_{2.5}$ benefit estimates do not include confidence intervals because they are derived using benefit per-ton estimates.
[B] All estimates derived using the Pope et al. (2002) mortality estimate at a 3% discount rate, in 1999$.

The procedure for calculating the $PM_{2.5}$ benefits resulting from full attainment of 0.079 ppm, 0.075 ppm and 0.065 ppm is identical to this example, with the exception of step 4; the $PM_{2.5}$ benefits of attaining 0.065 ppm, 0.075 ppm and 0.079 ppm incremental to partial attainment of 0.070 ppm are $7.8B, $1.1B and $0.4B respectively. Thus, the total $PM_{2.5}$ benefits of attaining 0.065 ppm, 0.075 ppm and 0.079 ppm are $10.2B, $3.6B and $2.5B respectively. The full attainment $PM_{2.5}$ benefits do not include confidence intervals. Because this full attainment estimate was derived by summing the modeled $PM_{2.5}$ benefits and the benefits derived using the benefit per-ton metrics—and these benefit per ton metrics do not include confidence intervals—the resulting sum of total $PM_{2.5}$ benefits do not include confidence intervals.

6.5.4 *Estimate of Full Attainment Benefits*

Tables 6-36 through 6-43 below summarize the estimates of full attainment and 2020 California glidepath attainment ozone benefits and $PM_{2.5}$ co-benefit estimate for each standard alternative. The presentation of ozone benefits and $PM_{2.5}$ co-benefits for each standard alternative is broken into two tables. The first table presents the national glidepath ozone benefits and $PM_{2.5}$ co-benefits. The second table presents California-only glidepath and post-2020 ozone benefits and $PM_{2.5}$ co-benefits. Tables 6-44 through 6-53 summarize the combined ozone and $PM_{2.5}$ co-benefits. The presentation of combined ozone and $PM_{2.5}$ co-benefit tables is broken into four components for each standard alternative. The first table presents national glidepath benefits. The second table presents the California-only glidepath benefits. The third table presents the incremental benefits that accrue in California from full attainment of the alternative standard after 2020. The last table presents total California benefits—the sum of glidepath benefits and post-2020 benefits.

Table 6-46: Estimate of Total Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.065 ppm Standard Alternative: National Glidepath Attainment

Ozone Mortality and Morbidity Benefits of Attaining 0.065 ppm		
Standard Alternative and Model or Assumption[A]		*Ozone Benefits, Arithmetic Mean*[B]
NMMAPS	Bell (2004)	$3,700
Meta-Analysis	Bell (2005)	$14,000
	Ito (2005)	$15,000
	Levy (2005)	$16,000
No Causality		$330
$PM_{2.5}$ Mortality and Morbidity Benefits of Attaining 0.065 ppm		
Mortality Impact Functions Derived from Epidemiology Literature		
ACS Study[C]		$10,000
Harvard Six-City Study[D]		$23,000
Mortality Impact Functions Derived from Expert Elicitation		
Expert A		$33,000
Expert B		$25,000
Expert C		$25,000
Expert D		$17,000
Expert E		$41,000
Expert F		$23,000
Expert G		$15,000
Expert H		$19,000
Expert I		$25,000
Expert J		$20,000
Expert K		$4,000
Expert L		$18,000

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics. Credible intervals for ozone estimates and confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates.

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

[D] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[E] All estimates incremental to 2006 PM NAAQS RIA. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-47: Estimate of Total Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.065 ppm Standard Alternative: California Attainment

Ozone Mortality and Morbidity Benefits of Attaining 0.065 ppm

Standard Alternative and Model or Assumption[A]		Ozone Benefits, Arithmetic Mean[B] *Glidepath*	*Incremental Post-2020 Benefits*	*Total*
NMMAPS	Bell (2004)	$61	$690	$750
Meta-Analysis	Bell (2005)	$230	$2,600	$2,800
	Ito (2005)	$210	$2,800	$3,000
	Levy (2005)	$240	$2,700	$3,000
No Causality		$6.8	$93	$100

$PM_{2.5}$ Mortality and Morbidity Benefits of Attaining 0.065 ppm

Mortality Impact Functions Derived from Epidemiology Literature	*Glidepath*	*Incremental Post-2020 Benefits*	*Total*
ACS Study[C]	$180	$930	$1,100
Harvard Six-City Study[D]	$380	$2,000	$2,400
Mortality Impact Functions Derived from Expert Elicitation			
Expert A	$570	$3,000	$3,600
Expert B	$430	$2,300	$2,700
Expert C	$430	$2,300	$2,700
Expert D	$300	$1,600	$1,900
Expert E	$710	$3,800	$4,500
Expert F	$390	$2,100	$2,500
Expert G	$250	$1,300	$1,600
Expert H	$320	$1,700	$2,000
Expert I	$420	$2,200	$2,700
Expert J	$340	$1,800	$2,200
Expert K	$68	$360	$430
Expert L	$310	$1,700	$2,000

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics. Credible intervals for ozone estimates and confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates.

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

[D] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[E] All estimates incremental to 2006 PM NAAQS RIA. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-48: Estimate of Total Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.070 ppm Standard Alternative: National Glidepath Attainment

Ozone Mortality and Morbidity Benefits of Attaining 0.070 ppm		
Standard Alternative and Model or Assumption[A]		*Ozone Benefits, Arithmetic Mean*[B] *(95% Credible Intervals)*[C]
NMMAPS	Bell (2004)	$2,000 ($300--$4,400)
Meta-Analysis	Bell (2005)	$7,400 ($1,200--$16,000)
	Ito (2005)	$8,000 ($1,400--$16,000)
	Levy (2005)	$9,100 ($1,600--$18,000)
No Causality		$190 ($49--$400)
$PM_{2.5}$ Mortality and Morbidity Benefits of Attaining 0.070 ppm		
Mortality Impact Functions Derived from Epidemiology Literature		
ACS Study[D]		$6,000
Harvard Six-City Study[E]		$14,000
Mortality Impact Functions Derived from Expert Elicitation		
Expert A		$19,000
Expert B		$15,000
Expert C		$15,000
Expert D		$10,000
Expert E		$24,000
Expert F		$13,000
Expert G		$8,500
Expert H		$11,000
Expert I		$14,000
Expert J		$12,000
Expert K		$2,300
Expert L		$11,000

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean and 95% credible interval around the mean estimates of the annual number of lives saved are based on an assumption of a normal distribution. Confidence intervals not available for $PM_{2.5}$ valuation estimates due to the fact that they were derived through a scaling technique (see above) that precluded us from generating such estimates.

[C] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics.

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

[E] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[F] All estimates incremental to 2006 PM NAAQS RIA. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-49: Estimate of Total Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.070 ppm Standard Alternative: California Attainment

Ozone Mortality and Morbidity Benefits of Attaining 0.070 ppm

Standard Alternative and Model or Assumption[A]		Ozone Benefits, Arithmetic Mean[B] *Glidepath*	*Incremental Post-2020 Benefits*	*Total*
NMMAPS	Bell (2004)	$40 ($7.2--$86)	$410	$450
Meta-Analysis	Bell (2005)	$150 ($25--$310)	$1,500	$1,700
	Ito (2005)	$160 ($29--$320)	$1,600	$1,800
	Levy (2005)	$140 ($26--$270)	$1,700	$1,800
No Causality		$4.5 ($2.3--$8.2)	$57	$61

$PM_{2.5}$ Mortality and Morbidity Benefits of Attaining 0.070 ppm

	Glidepath	*Incremental Post-2020 Benefits*	*Total*
Mortality Impact Functions Derived from Epidemiology Literature			
ACS Study[C]	$70	$690	$760
Harvard Six-City Study[D]	$150	$1,500	$1,600
Mortality Impact Functions Derived from Expert Elicitation			
Expert A	$230	$2,200	$2,400
Expert B	$170	$1,700	$1,900
Expert C	$170	$1,700	$1,900
Expert D	$120	$1,200	$1,300
Expert E	$280	$2,800	$3,100
Expert F	$160	$1,500	$1,700
Expert G	$100	$980	$1,100
Expert H	$130	$1,200	$1,400
Expert I	$170	$1,700	$1,800
Expert J	$140	$1,300	$1,500
Expert K	$27	$270	$300
Expert L	$120	$1,200	$1,300

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics. Credible intervals for ozone estimates and confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates.

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

[D] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[E] All estimates incremental to 2006 PM NAAQS RIA. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-50: Estimate of Total Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.075 ppm Standard Alternative: National Glidepath Attainment

Ozone Mortality and Morbidity Benefits of Attaining 0.075 ppm

Standard Alternative and Model or Assumption[A]		*Ozone Benefits, Arithmetic Mean*[B]
NMMAPS	Bell (2004)	$1,600
Meta-Analysis	Bell (2005)	$5,900
	Ito (2005)	$6,400
	Levy (2005)	$7,300
No Causality		$150

$PM_{2.5}$ Mortality and Morbidity Benefits of Attaining 0.075 ppm

Mortality Impact Functions Derived from Epidemiology Literature	
ACS Study[C]	$3,600
Harvard Six-City Study[D]	$8,600
Mortality Impact Functions Derived from Expert Elicitation	
Expert A	$12,000
Expert B	$8,800
Expert C	$8,700
Expert D	$6,100
Expert E	$14,000
Expert F	$7,900
Expert G	$5,100
Expert H	$6,500
Expert I	$8,600
Expert J	$7,000
Expert K	$1,400
Expert L	$6,300

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean estimates of the annual number of lives saved are based on an assumption of a normal distribution. Credible intervals for ozone estimates and confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates..

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

[D] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[F] All estimates incremental to 2006 PM NAAQS RIA. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-51: Estimate of Total Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.075 ppm Standard Alternative: California Attainment

Ozone Mortality and Morbidity Benefits of Attaining 0.075 ppm

Standard Alternative and Model or Assumption[A]		Ozone Benefits, Arithmetic Mean[B] *Glidepath*	*Incremental Post-2020 Benefits*	*Total*
NMMAPS	Bell (2004)	0	$260	$260
Meta-Analysis	Bell (2005)	0	$940	$940
	Ito (2005)	0	$1,000	$1,000
	Levy (2005)	0	$1,000	$1,000
No Causality		0	$33	$33

$PM_{2.5}$ Mortality and Morbidity Benefits of Attaining 0.075 ppm

	Glidepath	*Incremental Post-2020 Benefits*	*Total*
Mortality Impact Functions Derived from Epidemiology Literature			
ACS Study[C]	0	$410	$410
Harvard Six-City Study[D]	0	$870	$870
Mortality Impact Functions Derived from Expert Elicitation			
Expert A	0	$1,300	$1,300
Expert B	0	$1,000	$1,000
Expert C	0	$990	$990
Expert D	0	$690	$690
Expert E	0	$1,600	$1,600
Expert F	0	$900	$900
Expert G	0	$580	$580
Expert H	0	$740	$740
Expert I	0	$980	$980
Expert J	0	$790	$790
Expert K	0	$160	$160
Expert L	0	$720	$720

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics. Credible intervals for ozone estimates and confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates.

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

[D] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[E] All estimates incremental to 2006 PM NAAQS RIA. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-52: Estimate of Total Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.079 ppm Standard Alternative: National Glidepath Attainment

<u>Ozone Mortality and Morbidity Benefits of Attaining 0.075 ppm</u>

Standard Alternative and Model or Assumption[A]		*Ozone Benefits, Arithmetic Mean*[B]
NMMAPS	Bell (2004)	$140 ($22--$300)
Meta-Analysis	Bell (2005)	$510 ($86--$1,100)
	Ito (2005)	$560 ($98--$1,100)
	Levy (2005)	$510 ($93--$980)
No Causality		$12 ($3.5--$21)

<u>$PM_{2.5}$ Mortality and Morbidity Benefits of Attaining 0.075 ppm</u>

Mortality Impact Functions Derived from Epidemiology Literature	
ACS Study[C]	$2,800
Harvard Six-City Study[D]	$7,000
Mortality Impact Functions Derived from Expert Elicitation	
Expert A	$9,100
Expert B	$6,900
Expert C	$6,800
Expert D	$4,800
Expert E	$11,000
Expert F	$6,200
Expert G	$4,000
Expert H	$5,100
Expert I	$6,800
Expert J	$5,500
Expert K	$1,100
Expert L	$5,000

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] With the exception of the assumption of no causal relationship, the arithmetic mean estimates of the annual number of lives saved are based on an assumption of a normal distribution. Credible intervals for ozone estimates and confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates..

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

[D] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[F] All estimates incremental to 2006 PM NAAQS RIA. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-53: Estimate of Total Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.079 ppm Standard Alternative: California Attainment

Ozone Mortality and Morbidity Benefits of Attaining 0.075 ppm

Standard Alternative and Model or Assumption[A]		Ozone Benefits, Arithmetic Mean[B]		
		Glidepath	*Incremental Post-2020 Benefits*	*Total*
NMMAPS	Bell (2004)	0	$50	$50
Meta-Analysis	Bell (2005)	0	$190	$190
	Ito (2005)	0	$210	$210
	Levy (2005)	0	$190	$190
No Causality		0	$4.3	$4.3

$PM_{2.5}$ Mortality and Morbidity Benefits of Attaining 0.075 ppm

	Glidepath	*Incremental Post-2020 Benefits*	*Total*
Mortality Impact Functions Derived from Epidemiology Literature			
ACS Study[C]	0	$130	$130
Harvard Six-City Study[D]	0	$270	$270
Mortality Impact Functions Derived from Expert Elicitation			
Expert A	0	$410	$410
Expert B	0	$310	$310
Expert C	0	$310	$310
Expert D	0	$220	$220
Expert E	0	$510	$510
Expert F	0	$280	$280
Expert G	0	$180	$180
Expert H	0	$230	$230
Expert I	0	$310	$310
Expert J	0	$250	$250
Expert K	0	$49	$49
Expert L	0	$220	$220

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

[B] A credible interval is a posterior probability interval used in Bayesian statistics, which is similar to a confidence interval used in frequentist statistics. Credible intervals for ozone estimates and confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates.

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

[D] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[E] All estimates incremental to 2006 PM NAAQS RIA. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-54: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.065 ppm Alternative Standard: National Glidepath Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$14,000	$24,000	$25,000	$26,000	$11,000
Harvard Six-City Study[C]	$27,000	$37,000	$38,000	$38,000	$23,000
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$37,000	$47,000	$48,000	$49,000	$33,000
Expert B	$29,000	$39,000	$40,000	$41,000	$26,000
Expert C	$29,000	$39,000	$40,000	$40,000	$25,000
Expert D	$21,000	$32,000	$33,000	$33,000	$18,000
Expert E	$45,000	$55,000	$56,000	$57,000	$42,000
Expert F	$26,000	$37,000	$38,000	$38,000	$23,000
Expert G	$18,000	$29,000	$30,000	$30,000	$15,000
Expert H	$22,000	$33,000	$34,000	$34,000	$19,000
Expert I	$28,000	$39,000	$40,000	$40,000	$25,000
Expert J	$24,000	$34,000	$35,000	$35,000	$20,000
Expert K	$7,700	$18,000	$19,000	$20,000	$4,300
Expert L	$22,000	$32,000	$33,000	$34,000	$19,000

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-55: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of \$1999) for the 0.065 ppm Alternative Standard: California Glidepath Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$240	$400	$390	$420	$180
Harvard Six-City Study[C]	$440	$600	$590	$620	$380
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$630	$790	$780	$810	$570
Expert B	$490	$660	$650	$670	$440
Expert C	$490	$650	$640	$670	$430
Expert D	$360	$520	$510	$540	$300
Expert E	$770	$930	$920	$950	$710
Expert F	$450	$620	$600	$630	$400
Expert G	$310	$480	$460	$490	$260
Expert H	$380	$540	$530	$560	$320
Expert I	$480	$650	$630	$660	$430
Expert J	$400	$570	$550	$580	$350
Expert K	$130	$300	$280	$310	$75
Expert L	$370	$540	$520	$550	$320

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-56: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.065 ppm Alternative Standard: Incremental Benefits of California Post 2020 Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$1,600	$3,400	$3,600	$3,600	$1,000
Harvard Six-City Study[C]	$2,600	$4,500	$4,700	$4,700	$2,100
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$3,600	$5,500	$5,700	$5,700	$3,100
Expert B	$2,900	$4,800	$5,000	$5,000	$2,400
Expert C	$2,900	$4,800	$5,000	$4,900	$2,400
Expert D	$2,200	$4,100	$4,300	$4,300	$1,700
Expert E	$4,400	$6,200	$6,500	$6,400	$3,800
Expert F	$2,700	$4,600	$4,800	$4,700	$2,200
Expert G	$2,000	$3,800	$4,000	$4,000	$1,400
Expert H	$2,300	$4,200	$4,400	$4,400	$1,800
Expert I	$2,900	$4,700	$5,000	$4,900	$2,300
Expert J	$2,500	$4,300	$4,500	$4,500	$1,900
Expert K	$1,000	$2,900	$3,100	$3,000	$450
Expert L	$2,300	$4,100	$4,400	$4,300	$1,700

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-57: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.065 ppm Alternative Standard: Total California Benefits of Post 2020 Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$1,800	$3,800	$4,000	$4,000	$1,200
Harvard Six-City Study[C]	$3,100	$5,100	$5,300	$5,300	$2,500
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$4,300	$6,300	$6,500	$6,500	$3,700
Expert B	$3,400	$5,400	$5,700	$5,600	$2,800
Expert C	$3,400	$5,400	$5,600	$5,600	$2,800
Expert D	$2,600	$4,600	$4,800	$4,800	$2,000
Expert E	$5,200	$7,200	$7,400	$7,400	$4,600
Expert F	$3,200	$5,200	$5,400	$5,400	$2,600
Expert G	$2,300	$4,300	$4,500	$4,500	$1,700
Expert H	$2,700	$4,700	$4,900	$4,900	$2,100
Expert I	$3,400	$5,400	$5,600	$5,600	$2,800
Expert J	$2,900	$4,900	$5,100	$5,100	$2,300
Expert K	$1,100	$3,100	$3,400	$3,300	$520
Expert L	$2,700	$4,700	$4,900	$4,900	$2,100

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-58: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.070 ppm Alternative Standard: National Glidepath Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$7,900	$13,000	$14,000	$15,000	$6,200
Harvard Six-City Study[C]	$16,000	$21,000	$22,000	$23,000	$14,000
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$21,000	$27,000	$27,000	$28,000	$19,000
Expert B	$17,000	$22,000	$23,000	$24,000	$15,000
Expert C	$17,000	$22,000	$23,000	$24,000	$15,000
Expert D	$12,000	$18,000	$18,000	$19,000	$10,000
Expert E	$26,000	$31,000	$32,000	$33,000	$24,000
Expert F	$15,000	$21,000	$21,000	$22,000	$13,000
Expert G	$11,000	$16,000	$17,000	$18,000	$8,700
Expert H	$13,000	$18,000	$19,000	$20,000	$11,000
Expert I	$16,000	$22,000	$22,000	$23,000	$15,000
Expert J	$14,000	$19,000	$20,000	$21,000	$12,000
Expert K	$4,300	$9,700	$10,000	$11,000	$2,500
Expert L	$13,000	$18,000	$19,000	$20,000	$11,000

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-59: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.070 ppm Alternative Standard: California Glidepath Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$110	$220	$230	$210	$75
Harvard Six-City Study[C]	$190	$300	$310	$290	$150
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$270	$370	$380	$360	$230
Expert B	$210	$320	$330	$310	$180
Expert C	$210	$320	$330	$310	$180
Expert D	$160	$270	$280	$260	$120
Expert E	$320	$430	$440	$420	$290
Expert F	$200	$300	$310	$290	$160
Expert G	$140	$250	$260	$240	$100
Expert H	$170	$270	$290	$260	$130
Expert I	$210	$320	$330	$310	$170
Expert J	$180	$280	$300	$270	$140
Expert K	$67	$170	$190	$170	$32
Expert L	$160	$270	$280	$260	$130

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-60: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.070 ppm Alternative Standard: Incremental Benefits of California Post 2020 Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$1,100	$2,200	$2,300	$2,300	$740
Harvard Six-City Study[C]	$1,900	$3,000	$3,100	$3,100	$1,500
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$2,600	$3,700	$3,800	$3,900	$2,300
Expert B	$2,100	$3,200	$3,300	$3,300	$1,800
Expert C	$2,100	$3,200	$3,300	$3,300	$1,700
Expert D	$1,600	$2,700	$2,800	$2,800	$1,200
Expert E	$3,200	$4,300	$4,400	$4,400	$2,800
Expert F	$1,900	$3,000	$3,100	$3,200	$1,600
Expert G	$1,400	$2,500	$2,600	$2,600	$1,000
Expert H	$1,600	$2,700	$2,900	$2,900	$1,300
Expert I	$2,000	$3,200	$3,300	$3,300	$1,700
Expert J	$1,700	$2,800	$3,000	$3,000	$1,400
Expert K	$650	$1,800	$1,900	$1,900	$320
Expert L	$1,600	$2,700	$2,800	$2,900	$1,300

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-61: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.070 ppm Alternative Standard: California Post 2020 Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$1,200	$2,400	$2,500	$2,300	$810
Harvard Six-City Study[C]	$2,100	$3,300	$3,400	$3,400	$1,700
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$2,900	$4,100	$4,200	$4,200	$2,500
Expert B	$2,300	$3,500	$3,600	$3,700	$1,900
Expert C	$2,300	$3,500	$3,600	$3,600	$1,900
Expert D	$1,700	$2,900	$3,100	$3,100	$1,300
Expert E	$3,500	$4,700	$4,800	$4,800	$3,100
Expert F	$2,100	$3,300	$3,400	$3,500	$1,700
Expert G	$1,500	$2,700	$2,800	$2,900	$1,100
Expert H	$1,800	$3,000	$3,100	$3,200	$1,400
Expert I	$2,300	$3,500	$3,600	$3,600	$1,900
Expert J	$1,900	$3,100	$3,200	$3,300	$1,500
Expert K	$720	$1,900	$2,100	$2,100	$350
Expert L	$1,800	$3,000	$3,100	$3,100	$1,400

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-62: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.075 ppm Alternative Standard: National Glidepath Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$5,100	$9,400	$10,000	$11,000	$3,700
Harvard Six-City Study[C]	$10,000	$15,000	$15,000	$16,000	$8,800
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$13,000	$17,000	$18,000	$19,000	$12,000
Expert B	$10,000	$15,000	$15,000	$16,000	$9,000
Expert C	$10,000	$15,000	$15,000	$16,000	$8,900
Expert D	$7,600	$12,000	$13,000	$13,000	$6,200
Expert E	$16,000	$20,000	$21,000	$22,000	$15,000
Expert F	$9,500	$14,000	$14,000	$15,000	$8,100
Expert G	$6,700	$11,000	$12,000	$12,000	$5,200
Expert H	$8,000	$12,000	$13,000	$14,000	$6,600
Expert I	$10,000	$15,000	$15,000	$16,000	$8,800
Expert J	$8,500	$13,000	$13,000	$14,000	$7,100
Expert K	$3,000	$7,300	$7,800	$8,700	$1,500
Expert L	$7,900	$12,000	$13,000	$14,000	$6,500

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-63: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.075 ppm Alternative Standard: California Post 2020 Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$660	$1,400	$1,400	$1,400	$440
Harvard Six-City Study[C]	$1,100	$1,800	$1,900	$1,900	$900
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$1,600	$2,300	$2,300	$2,300	$1,400
Expert B	$1,300	$2,000	$2,000	$2,000	$1,000
Expert C	$1,300	$1,900	$2,000	$2,000	$1,300
Expert D	$950	$1,600	$1,700	$1,700	$950
Expert E	$1,900	$2,600	$2,700	$2,700	$1,900
Expert F	$1,200	$1,900	$1,900	$1,900	$1,200
Expert G	$830	$1,500	$1,600	$1,600	$830
Expert H	$990	$1,700	$1,800	$1,800	$990
Expert I	$1,200	$1,900	$2,000	$2,000	$1,200
Expert J	$1,100	$1,700	$1,800	$1,800	$1,100
Expert K	$410	$1,100	$1,200	$1,200	$410
Expert L	$980	$1,700	$1,700	$1,700	$980

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-64: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.079 ppm Alternative Standard: National Glidepath Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$3,100	$4,000	$4,000	$4,000	$3,100
Harvard Six-City Study[C]	$7,300	$8,100	$8,200	$8,200	$7,000
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$9,200	$9,600	$9,600	$9,600	$9,100
Expert B	$7,100	$7,400	$7,500	$7,400	$6,900
Expert C	$7,000	$7,400	$7,400	$7,400	$6,900
Expert D	$4,900	$5,300	$5,300	$5,300	$4,800
Expert E	$11,000	$12,000	$12,000	$12,000	$11,000
Expert F	$6,400	$6,700	$6,800	$6,700	$6,200
Expert G	$4,100	$4,500	$4,600	$4,500	$4,000
Expert H	$5,200	$5,600	$5,600	$5,600	$5,100
Expert I	$6,900	$7,300	$7,300	$7,300	$6,800
Expert J	$5,600	$6,000	$6,000	$6,000	$5,500
Expert K	$1,200	$1,600	$1,700	$1,600	$1,100
Expert L	$5,100	$5,500	$5,500	$5,500	$5,000

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

Table 6-65: Combined Estimate of Annual Ozone and $PM_{2.5}$ Benefits (95% Confidence Intervals, Millions of $1999) for the 0.079 ppm Alternative Standard: California Post 2020 Attainment

	Alternative Standard and Model or Assumption[A]				
	Bell (2004)	*Bell (2005)*	*Ito (2005)*	*Levy (2005)*	*No Causality*
Mortality Impact Functions Derived from Epidemiology Literature					
ACS Study[B]	$180	$320	$330	$320	$130
Harvard Six-City Study[C]	$320	$460	$480	$460	$280
Mortality Impact Functions Derived from Expert Elicitation					
Expert A	$460	$600	$620	$600	$410
Expert B	$360	$500	$520	$500	$320
Expert C	$360	$500	$520	$500	$310
Expert D	$270	$400	$420	$400	$220
Expert E	$560	$700	$720	$700	$520
Expert F	$330	$470	$490	$470	$290
Expert G	$230	$370	$390	$370	$190
Expert H	$280	$420	$440	$420	$230
Expert I	$360	$500	$510	$490	$310
Expert J	$300	$440	$450	$440	$250
Expert K	$100	$240	$260	$240	$54
Expert L	$270	$410	$430	$410	$230

[A] Does not represent equal weighting among models or between assumption of causality vs. no causality (see text on page 63).

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

[C] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[D] All estimates incremental to 2006 PM NAAQS RIA. Confidence intervals for $PM_{2.5}$ estimates not provided due to the fact that the valuation estimates were derived through a scaling technique (see above) that precluded us from generating such estimates. Estimates derived using benefit per ton estimates discounted at 3%.Estimates derived using a 7% discount rate would be approximately 15% lower.

6.5.5 *Discussion of Results and Uncertainties*

This analysis has estimated the health and welfare benefits of reductions in ambient concentrations of ozone and particulate matter resulting from a set of illustrative control strategies to reduce emissions of ozone. The results suggest there will be significant additional health and welfare benefits arising from reducing emissions from a variety of sources in and around projected nonattaining counties in 2020. While 2020 is the expected date that states would need to demonstrate attainment with the revised standard, it is expected that benefits (and costs) will begin occurring much earlier, as states begin implementing control measures to show reasonable progress towards attainment. Using the full range of benefits (including the results of the expert elicitation), we estimate that total ozone and $PM_{2.5}$ benefits would be between and $2.5 and $33 billion annually for the 0.070 ppm alternative when the emissions reductions from implementing the new standard is fully realized provides additional evidence of the important role that implementation of the standards plays in reducing the health risks associated with exceeding the standard.

There are several important factors to consider when evaluating the relative benefits of the attainment strategies for each of the alternative ozone standards.

1. California accounts for a substantial share of the total benefits for each of the evaluated standards. Benefits are most uncertain for California given the unique challenge of modeling attainment with the standards due to the high levels of ozone, difficulties of modeling the impacts of emissions controls on air quality, and the very large proportion of California benefits that were derived through extrapolation are very large relative to other areas of the U.S. for each standard alternative. On the one hand, these California benefits are likely to understate the actual benefits of attainment strategies, because we applied an estimation approach that reduced concentrations only at the specific violating monitors and not surrounding monitors that did not violate the standards. The magnitude of this underestimate is unknown. On the other hand, it is possible that new technologies might not meet the specifications, development timelines, or cost estimates provided in this analysis, thereby increasing the uncertainty in when and if such benefits would be truly achieved.

2. There are substantial uncertainties associated with the estimated benefits of the 0.065 ppm, 0.075 ppm, and 0.079 ppm alternatives, which were derived through extrapolation and interpolation, respectively. The great majority of benefits estimated for the 0.065 ppm standard alternative were derived through extrapolation. As noted above, these benefits are likely to be more uncertain than the modeled benefits. The 0.075 ppm benefits were derived through an interpolation technique (described in Appendix 6) which scaled-down the benefits of the 0.070 ppm benefits analysis. A key assumption in this approach is that the control strategy to attain 0.075 ppm would share the same characteristics of the 0.070 ppm strategy—namely, regional emission controls on electrical generating units and emission controls applied to counties within 200km of projected non-attainment monitors. To the extent that states utilized fewer regional emission controls, total benefits for the 0.075 ppm strategy may be smaller.

EPA employed a monitor rollback approach to estimate the benefits of attaining an alternative standard of 0.079 ppm nationwide. This approach likely understates the benefits that would occur due to implementation of actual controls because controls implemented to reduce ozone concentrations at the highest monitor would likely result in some reductions in ozone concentrations at attaining monitors down-wind (i.e. the controls would lead to concentrations below the standard in down-wind locations). Therefore, air quality improvements and resulting health benefits from full attainment would be more widespread than we have estimated in our rollback analysis.

EPA calculated 0.075 ppm benefits by interpolating the 0.070 ppm benefits estimates.[33] This interpolation approach may overestimate benefits relative to a modeled control scenario developed specifically to attain the 0.075 ppm alternative. The interpolation method scales down benefits only at the monitors we project to exceed 0.075 ppm—but it still captures the benefits achieved by the 0.070 ppm regional control strategy that occur outside of these projected non-attainment areas. To the extent that a modeled emission control strategy to attain 0.075 ppm does not include these broader regional emission reductions, total benefits would be lower than those we have estimated in this RIA.

Interpolation and monitor rollback methods of benefits estimation are inherently different. As described above, for the purposes of reviewing this analysis, the reader should understand that the benefits described for attaining a standard of 0.079 ppm are likely understated, whereas the estimated benefits of attaining a standard of 0.075 ppm are likely overstated. We will develop and present consistent approaches for the alternative standards for the final RIA.

3. There are a variety of uncertainties associated with the health impact functions used in this modeling effort. These include: within study variability, which is the precision with which a given study estimates the relationship between air quality changes and health effects; across study variation, which refers to the fact that different published studies of the same pollutant/health effect relationship typically do not report identical findings and in some instances the differences are substantial.; the application of C-R functions nationwide, which does not account for any relationship between region and health effect, to the extent that such a relationship exists; extrapolation of impact functions across population, in which we assumed that certain health impact functions applied to age ranges broader than that considered in the original epidemiological study; and, finally, there are various uncertainties in the C-R function, including causality, the correlation among multiple pollutants, the shape of the C-R function and the relative toxicity of PM component species, and the lag between exposure and the onset of the health effect.

4. There are a variety of uncertainties associated with the economic valuation of the health endpoints estimated in this analysis. Uncertainties specific to the valuation of premature mortality include across study variation; the assumption that WTP for mortality risk

[33] This procedure is detailed in Appendix 6A.

reduction is linear; assuming that voluntary and involuntary mortality risk will be valued equally; assuming that premature mortality from air pollution risk, which tend to involve longer periods of time, will be valued the same as short catastrophic events; the possibility for self-selection in avoiding risk, which may bias WTP estimates upward.

5. This analysis includes estimates of $PM_{2.5}$ co-benefits that were derived through benefit per-ton estimates derived from the Pope et. al (2002) mortality estimate. These benefit per-ton estimates represent regional averages. As such, they do not reflect any local variability in the incremental $PM_{2.5}$ benefits per ton of NOx abated. As discussed in the PM NAAQS RIA (Table 5.5), there are a large number of uncertainties associated with these PM benefits.

6. For the 0.070 ppm alternative, we estimate co-benefits from PM to be between 20% and 99% of total benefits, depending on the PM2.5 and ozone mortality functions used. In our calculation of $PM_{2.5}$ co-benefits we assume that states will pursue an ozone strategy that reduces NOx emissions. As such, these estimates are strongly influenced by the assumption that all PM components are equally toxic. We also acknowledge that when implementing any new standard, states may elect to pursue a different ozone strategy, which would in turn affect the level of $PM_{2.5}$ co-benefits.

7. Inherent in any analysis of future regulatory programs are uncertainties in projecting atmospheric conditions and source-level emissions, as well as population, health baselines, incomes, technology, and other factors. In addition, data limitations prevent an overall quantitative estimate of the uncertainty associated with estimates of total economic benefits. If one is mindful of these limitations, the magnitude of the benefits estimates presented here can be useful information in expanding the understanding of the public health impacts of reducing ozone precursor emissions.

8. There are certain unquantified effects not considered in this benefits analysis due to lack of data, time and resources. These unquantified endpoints include the direct effects of of ozone on vegetation, the deposition of nitrogen to estuarine and coastal waters and agricultural and forested land, and the changes in the level of exposure to ultraviolet radiation from ground level ozone.

EPA will continue to evaluate new methods and models and select those most appropriate for estimating the health benefits of reductions in air pollution. It is important to continue improving benefits transfer methods in terms of transferring economic values and transferring estimated impact functions. The development of both better models of current health outcomes and new models for additional health effects such as asthma, high blood pressure, and adverse birth outcomes (such as low birth weight) will be essential to future improvements in the accuracy and reliability of benefits analyses (Guo et al., 1999; Ibald-Mulli et al., 2001). Enhanced collaboration between air quality modelers, epidemiologists, toxicologists, and economists should result in a more tightly integrated analytical framework for measuring health benefits of air pollution policies. Readers interested in a more extensive discussion of the sources of uncertainty in human health benefits analyses should consult the PM NAAQS RIA.[34]

6.5.6 *Summary of Total Benefits*

Tables 6-54 presents the total number of estimated ozone and $PM_{2.5}$-related premature mortalities and morbidities avoided nationwide in 2020. Table 6-55 presents these estimates for California, post 2020.

[34] U.S. Environmental Protection Agency, 2006. Regulatory Impact Analysis for the PM NAAQS. EPA Prepared by Office of Air and Radiation. Available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/Chapter%205--Benefits.pdf

Table 6-66: Summary of Total Number of Annual Ozone and $PM_{2.5}$-Related Premature Mortalities and Premature Morbidity Avoided: 2020 National Benefits

Combined Estimate of Mortality

Standard Alternative and Model or Assumption[A]		*Combined Range of Ozone Benefits and $PM_{2.5}$ Co-Benefits* 0.079 ppm	0.075 ppm	0.070 ppm	0.065 ppm
NMMAPS	Bell (2004)	200 to 1,900	430 to 2,600	670 to 4,300	1,200 to 7,400
Meta-Analysis	Bell (2005)	260 to 2,000	1,100 to 3,300	1,500 to 5,100	2,800 to 9,000
	Ito (2005)	270 to 2,000	1,200 to 3,300	1,600 to 5,200	3,000 to 9,200
	Levy (2005)	260 to 2,000	1,300 to 3,500	1,800 to 5,400	3,000 to 9,200
No Causality		180 to 1,900	230 to 2,400	390 to 4,000	660 to 6,900

Combined Estimate of Morbidity

Acute Myocardial Infarction	1,100	1,400	2,300	4,000
Hospital and ER Visits	1,300	5,600	7,600	13,000
Chronic Bronchitis	370	470	780	1,300
Acute Bronchitis	950	1,200	2,000	3,500
Asthma Exacerbation	7,300	9,400	16,000	27,000
Lower Respiratory Symptoms	8,100	10,000	17,000	29,000
Upper Respiratory Symptoms	5,900	7,500	13,000	22,000
School Loss Days	50,000	610,000	780,000	1,300,000
Work Loss Days	51,000	65,000	110,000	190,000
Minor Restricted Activity Days	430,000	2,000,000	2,700,000	4,700,000

Table 6-67: Summary of Total Number of Annual Ozone and $PM_{2.5}$-Related Premature Mortalities and Premature Morbidity Avoided: California Post 2020 Attainment

Combined Estimate of Mortality

Standard Alternative and Model or Assumption[A]		*Combined Range of Ozone Benefits and $PM_{2.5}$ Co-Benefits*			
		0.079 ppm	0.075 ppm	0.070 ppm	0.065 ppm
NMMAPS	Bell (2004)	17 to 93	61 to 310	110 to 570	180 to 840
Meta-Analysis	Bell (2005)	42 to 120	170 to 410	300 to 760	490 to 1,200
	Ito (2005)	45 to 120	180 to 430	320 to 780	530 to 1,200
	Levy (2005)	46 to 120	180 to 430	320 to 780	520 to 1,200
No Causality		8.2 to 84	26 to 270	49 to 500	72 to 740

Combined Estimate of Morbidity

Acute Myocardial Infarction	49	160	290	430
Hospital and ER Visits	200	790	1,400	2,200
Chronic Bronchitis	17	53	99	150
Acute Bronchitis	43	140	260	380
Asthma Exacerbation	330	1,100	2,000	2,900
Lower Respiratory Symptoms	360	1,200	2,200	3,200
Upper Respiratory Symptoms	270	850	1,600	2,300
School Loss Days	30,000	120,000	210,000	340,000
Work Loss Days	2,300	7,400	14,000	20,000
Minor Restricted Activity Days	87,000	340,000	600,000	960,000

6.6 References:

Abt Associates, Inc. October 2005. *Methodology for County-level Mortality Rate Projections.* Memorandum to Bryan Hubbell and Zachary Pekar, U.S. EPA.

Adams PF, Hendershot GE, Marano MA. 1999. Current Estimates from the National Health Interview Survey, 1996. Vital Health Stat 10(200):1-212.

Agency for Healthcare Research and Quality. 2000. HCUPnet, Healthcare Cost and Utilization Project. Rockville, Maryland. Available: http://www.ahrq.gov/HCUPnet/ [accessed 29 September 2004].

Anderson HR, Atkinson RW, Peacock JL, Marston L, Konstantinou K. 2004. Meta-analysis of time-series studies and panel studies of Particulate Matter (PM) and Ozone (O3): Report of a WHO task group. Copenhagen, Denmark: World Health Organization.

Bell, M.L., et al. Ozone and short-term mortality in 95 US urban communities, 1987-2000. Jama, 2004. 292(19): p. 2372-8.

Bell, M.L., F. Dominici, and J.M. Samet. A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study. Epidemiology, 2005. 16(4): p. 436-45.

Berger MC, Blomquist GC, Kenkel D, Tolley GS. 1987. Valuing Changes in Health Risks: A Comparison of Alternative Measures. The Southern Economic Journal 53:977-984.

Burnett RT, Smith-Doiron M, Stieb D, Raizenne ME, Brook JR, Dales RE, et al. 2001. Association between ozone and hospitalization for acute respiratory diseases in children less than 2 years of age. Am J Epidemiol 153(5):444-452.

Chen L, Jennison BL, Yang W, Omaye ST. 2000. Elementary school absenteeism and air pollution. Inhal Toxicol 12(11):997-1016.

Crocker, T.D. and R.L. Horst, Jr. Hours of Work, Labor Productivity, and Environmental Conditions: A Case Study. The Review of Economics and Statistics, 1981. 63: p. 361-368.

Freeman(III), AM. 1993. The Measurement of Environmental and Resource Values: Theory and Methods. Washington, DC: Resources for the Future.

Gilliland FD, Berhane K, Rappaport EB, Thomas DC, Avol E, Gauderman WJ, et al. 2001. The effects of ambient air pollution on school absenteeism due to respiratory illnesses. Epidemiology 12(1):43-54.

GeoLytics Inc. 2002. Geolytics CensusCD® 2000 Short Form Blocks. CD-ROM Release 1.0. GeoLytics, Inc. East Brunswick, NJ. Available: http://www.geolytics.com/ [accessed 29 September 2004].

Hall JV, Brajer V, Lurmann FW. 2003. Economic Valuation of Ozone-related School Absences in the South Coast Air Basin of California. Contemporary Economic Policy 21(4):407-417.

Harrington W, Portney PR. 1987. Valuing the Benefits of Health and Safety Regulation. Journal of Urban Economics 22:101-112.

Industrial Economics Incorporated (IEc). 1993. Memorandum to Jim DeMocker, U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Policy Analysis and Review. September 30. Washington, D.C.

International Classification of Diseases, Ninth Revision. 1979. Hyattsville, MD: National Center for Health Statistics. Available: http://www.cdc.gov/nchs/about/major/dvs/icd9des.htm [accessed 29 September 2004].

Ito, K., S.F. De Leon, and M. Lippmann. Associations between ozone and daily mortality: analysis and meta-analysis. Epidemiology, 2005. 16(4): p. 446-57.

Jaffe DH, Singer ME, Rimm AA. 2003. Air pollution and emergency department visits for asthma among Ohio Medicaid recipients, 1991-1996. Environ Res 91(1):21-28.

Köchy, Martin and Scott D. Wilson, "Nitrogen deposition and forest expansion in the northern Great Plains Journal of Ecology *Journal of Ecology* 89 (5), 807–817

Kunzli, N., S. Medina, R. Kaiser, P. Quenel, F. Horak Jr, and M. Studnicka. 2001. "Assessment of Deaths Attributable to Air Pollution: Should We Use Risk Estimates Based on Time Series or on Cohort Studies?" *American Journal of Epidemiol*ogy 153(11):1050-55.

Levy JI, Carrothers TJ, Tuomisto JT, Hammitt JK, Evans JS. 2001. Assessing the Public Health Benefits of Reduced Ozone Concentrations. Environ Health Perspect 109(12):1215-1226

Levy, J.I., S.M. Chemerynski, and J.A. Sarnat. Ozone exposure and mortality: an empiric bayes metaregression analysis. Epidemiology, 2005. 16(4): p. 458-68.

Moolgavkar SH, Luebeck EG, Anderson EL. 1997. Air pollution and hospital admissions for respiratory causes in Minneapolis St. Paul and Birmingham. Epidemiology 8(4):364-370.

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

Ostro BD, Rothschild S. 1989. Air Pollution and Acute Respiratory Morbidity - an Observational Study of Multiple Pollutants. Environ Res 50(2):238-247.

Ostro, B., M. Lipsett, J. Mann, H. Braxton-Owens, and M. White. 2001. "Air Pollution and Exacerbation of Asthma in African-American Children in Los Angeles." *Epidemiology* 12(2):200-208.

Nadelhoffer, Knute J. et. al., "Nitrogen deposition makes a minor contribution to carbon sequestration in temperate forests" *Nature* 398, 145-148 (11 March 1999)

Peel, J. L., P. E. Tolbert, M. Klein, et al. 2005. Ambient air pollution and respiratory emergency department visits. Epidemiology. Vol. 16 (2): 164-74.

Schwartz J. 1994a. PM(10) Ozone, and Hospital Admissions For the Elderly in Minneapolis St Paul, Minnesota. Arch Environ Health 49(5):366-374.

Schwartz J. 1994b. Air Pollution and Hospital Admissions For the Elderly in Detroit, Michigan. Am J Respir Crit Care Med 150(3):648-655.

Schwartz J. 1995. Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. Thorax 50(5):531-538.

Smith DH, Malone DC, Lawson KA, Okamoto LJ, Battista C, Saunders WB. 1997. A national estimate of the economic costs of asthma. Am J Respir Crit Care Med. 156(3 Pt 1):787-793.

Stanford R, McLaughlin T, Okamoto LJ. 1999. The cost of asthma in the emergency department and hospital. Am J Respir Crit Care Med 160(1):211-215.

Thurston GD, Ito K. 2001. Epidemiological studies of acute ozone exposures and mortality. *J* Expo Anal Environ Epidemiol 11(4):286-294.

Tolley GS, Babcock L, Berger M, Bilotti A, Blomquist G, Brien M, et al. 1986. Valuation of Reductions in Human Health Symptoms and Risks. Prepared for U.S. Environmental Protection Agency. January. Washington, D.C.

U.S. Bureau of the Census. 2001. Statistical Abstract of the United States, 2001, Section 12: Labor Force, Employment, and Earnings, Table No. 521. Washington, DC.

U.S. Department of Education. 1996. The Condition of Education 1996, Indicator 42: Student Absenteeism and Tardiness. National Center for Education Statistics. Washington DC.

U.S. EPA. 1970. Clean Air Act. 40CFR50.

U.S. Environmental Protection Agency. 1999. The Benefits and Costs of the Clean Air Act, 1990-2010. Prepared for U.S. Congress by U.S. EPA, Office of Air and Radiation/Office of Policy Analysis and Review, Washington, DC, November; EPA report no. EPA-410-R-99-001.

U.S. Environmental Protection Agency, 2004. Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines. EPA420-R-04-007. Prepared by Office of Air and Radiation. Available: http://www.epa.gov/nonroad-diesel/2004fr/420r04007.pdf [accessed 29 September 2004].

Vedal, S., J. Petkau, R. White, and J. Blair. 1998. "Acute Effects of Ambient Inhalable Particles in Asthmatic and Nonasthmatic Children." *American Journal of Respiratory and Critical Care Medicine* 157(4):1034-1043.

Vitousek, Peter M. et. al., "Human Alteration of the Global Nitrogen Cycle: Causes and Consequences" *Issues in Ecology* No. 1 (Spring) 1997.

Wilson, A. M., C. P. Wake, T. Kelly, et al. 2005. Air pollution, weather, and respiratory emergency room visits in two northern New England cities: an ecological time-series study. Environ Res. Vol. 97 (3): 312-21.

Woods & Poole Economics Inc. 2001. Population by Single Year of Age CD. CD-ROM. Woods & Poole Economics, Inc. Washington, D.C.

World Health Organization (WHO). 2003. Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide: Report on a WHO Working Group. World Health Organization. Bonn, Germany. EUR/03/5042688.

Appendix Chapter 6a: Additional Benefits Information

Summary

This appendix provides additional information regarding the benefits analysis, including (1) methods for developing estimate of full attainment air quality; (2) the process for interpolating the 0.075 ppm benefits estimate; (3) the partial attainment $PM_{2.5}$ incidence and valuation estimates.

6a.1 Developing an air quality estimate of full attainment with the alternative ozone standards

As discussed in chapter 3, the modeled attainment scenarios were not sufficient to simulate full attainment with each of the three alternative ozone standards analyzed. To meet our analytical goal of estimating the human health benefits of full simulated attainment with each of these standard alternatives, it became necessary to derive an estimate of the full attainment air quality increment through a simple monitor rollback approach.

We rolled back the values at each monitor such that no monitor in the U.S. exceeded the alternative standard in question. This approach makes the bounding assumption that ozone concentrations can be reduced only at monitors projected to exceed the alternative standards. From a benefits perspective, this approach leads to a downward bias in the estimates because populations are assumed to be exposed at a distance weighted average of surrounding monitors. Thus, any individual's reduction in exposure from a change at a given monitor will be weighted less if there are other attaining monitors in close proximity.

We determined projected attainment status of each monitor by calculating design values. However, to estimate changes in ozone-related health effects resulting from improvement in air quality, the BenMAP model requires a series of metrics. When performing a benefits assessment with air quality modeling data, BenMAP calculates these metrics based on the distribution of CMAQ-modeled hourly ozone concentrations for the ozone season. However, because we were performing a benefits assessment based on monitor values that have been rolled-back, it was necessary to derive each of these metrics outside of the BenMAP model. Thus, we first developed a scaling ratio that related the calculated design value to each of the ozone metrics.

A summary of this procedure is as follows:

1. Import partial attainment 0.08 ppm calculated design values into the BenMAP model
2. Perform a spatial interpolation of these design values using the Voronoi Neighborhood Averaging algorithm. Design values are then interpolated to the CMAQ grid cell.
3. Import distribution of air quality modeled daily and hourly ozone concentrations into BenMAP. Create air quality grid in BenMAP using spatial and temporal scaling

technique.[1] This procedure creates grid cell level summer season ozone metrics (1 hour maximum, 5 hour average, 8 hour maximum, 8 hour average and 24 hour average).

4. Calculate grid cell-level ratio of each ozone metric to calculated design value. The result of this calculation is a grid cell-level ratio of metric to design value that can then be subsequently used to scale the calculated design value and thus derive each of the metrics.

After having calculated these scaling ratios we then performed the monitor rollback as follows:

1. Roll back the calculated 0.08 ppm partial attainment design value to just equal the 0.08 ppm standard. This process creates a new baseline design value grid.
2. Scale the design value grid cell values to ozone metric grid cell values by using ratios described above.
3. Create new 0.084 ppm baseline air quality grid from grid cell-level ozone metrics.
4. Roll back the calculate calculated 0.070 ppm and 0.065 ppm partial attainment design values at each monitor to just each the 0.070 ppm and 0.065 ppm standards, respectively.
5. Scale the calculated full attainment design value to grid cell-level ozone metric using ratios described above.
6. Create new 0.070 ppm and 0.065 ppm air quality grids from grid cell-level ozone metrics.
7. Perform benefits analysis with baseline and control grids.

To develop a 0.075 ppm full attainment air quality grid we performed an interpolation of the 0.070 ppm full attainment air quality grid, rather than a monitor rollback. This interpolation entailed the following steps:

1. We identified any monitors that were projected to not attain 0.075 ppm alternative in the 0.084 ppm base case air quality grid.
2. For these monitors we calculated an adjustment factor that would scale down the air quality improvement at that monitor. The purpose of this adjustment was to ensure that the improvement in air quality at that monitor reflected the attainment of the 0.075 ppm standard. This ratio was calculated by dividing the improvement in the design value necessary to attain 0.075 ppm by the improvement in the design value necessary to attain 0.070 ppm. For example, a monitor whose baseline is 0.084 would receive 2/3 of the air quality improvement from attaining 0.075 ppm than they would from attaining 0.070 ppm.
3. We then interpolated these monitor-specific ratios to the grid cell-level in BenMAP.
4. Finally, we used these grid cell-level ratios as the basis for scaling down the grid cell-level estimates of incidence and valuation from the 0.070 ppm analysis.

6a.2 Partial Attainment $PM_{2.5}$ Incidence and Valuation Estimates

Tables 6a.1 through 6a.5 below summarize the estimates of $PM_{2.5}$ incidence and valuation resulting from the 0.070 ppm partial attainment scenario. These estimates provided the basis for the full attainment $PM_{2.5}$ co-benefit estimates found in Chapter 6 of this RIA.

[1] BenMAP Technical Appendices, Abt Associates: May 2005. Page C-12.

Table 6a-1: Illustrative 0.070 ppm Partial Attainment Scenario: Estimated Reductions in PM Premature Mortality associate with PM co-benefit (95th percentile confidence intervals provided in parentheses)

	Eastern U.S.	*Western U.S. Excluding California*	*California*	*National PM co-benefits*
Mortality Impact Functions Derived from Epidemiology Literature				
ACS Study[A]	510 (170--840)	0.17 (0.06--0.27)	47 (16—77)	550 (190--920)
Harvard Six-City Study[B]	1,100 (570--1,700)	0.4 (0.18--0.6)	110 (53--160)	1,300 (630--1,900)
Woodruff et al 1997 (infant mortality)	1.1 (0.5—1.7)	0.04 (0.02--0.06)	0.14 (0.07--0.2)	1.3 (0.6—2)
Mortality Impact Functions Derived from Expert Elicitation				
Expert A	1,600 (170--3,000)	77 (8.2--150)	140 (15--270)	1,800 (190--3,400)
Expert B	1,200 (140--2,600)	56 (4--130)	110 (13--240)	1,400 (160--3,000)
Expert C	1,200 (140--2,700)	58 (6.6--130)	110 (12--250)	1,400 (150--3,000)
Expert D	820 (85--1,400)	40 (4.1—68)	76 (7.8--130)	940 (96—1,600)
Expert E	2,000 (890—3,000)	95 (44--150)	180 (82--280)	2,200 (1,000--3,500)
Expert F	1,100 (740--1,600)	51 (33—74)	99 (67--150)	1,200 (840—1,800)
Expert G	690 (0—1,300)	34 (0—65)	63 (0--120)	790 (0--1,500)
Expert H	880 (-46--2,100)	43 (-2.2—100)	80 (-4.2--200)	1,000 (-52—2,400)
Expert I	1,200 (60--2,200)	57 (3--110)	110 (5.5--200)	1,300 (69—2,500)
Expert J	950 (230--2,200)	46 (11—110)	87 (21--200)	1,100 (260--2,500)
Expert K	190 (0--970)	8.8 (0—47)	19 (0—95)	220 (0--1,100)
Expert L	860 (120--1,600)	33 (0.04--81)	79 (11--150)	970 (130—1,900)

[A] The estimate is based on the concentration-response (C-R) function developed from the study of the American Cancer Society cohort reported in Pope et al (2002), which has previously been reported as the primary estimate in recent RIAs
[B] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.
[C] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA

Table 6a-2: Illustrative 0.070 ppm Partial Attainment Scenario: Estimated Reductions in Morbidity Associated with PM Co-benefit (95th percentile confidence intervals provided in parentheses)

	Eastern U.S.	*Western U.S. Excluding California*	*California*	*National PM co-benefits*
Morbidity Impact Functions Derived from Epidemiology Literature				
Chronic Bronchitis (age >25 and over)	380 (42-720)	12 (1.3—21)	43 (4.6—81)	440 (47—820)
Nonfatal myocardial infarction (age >17)	1,100 (560—1,700)	0.4 (0.2—0.6)	94 (47—140)	1,200 (610—1,800)
Hospital admissions--respiratory (all ages)	130 (59—200)	--	10 (4.4-15)	140 (63—220)
Hospital admissions-- cardiovascular (age >17)	270 (160—370)	--	20 (12—28)	290 (170—400)
Emergency room visits for asthma (age <19)	560 (310—820)	--	22 (12—32)	590 (320—850)
Acute bronchitis (age 8-12)	990 (-130—2,100)	32 (-4.1—67)	130 (-17—270)	1,200 (-150—2,400)
Lower respiratory symptoms (age 7-14)	8,400 (3,600—13,000)	3.6 (1.6—5.5)	1,200 (520—1,900)	9,600 (4,200—15,000)
Upper respiratory symptoms (asthmatic children age 9-18)	6,100 (1,500—11,000)	2.6 (0.7—4.6)	870 (220—1,500)	7,000 (1,800—12,000)
Asthma exacerbation (asthmatic children age 6--18)	7,700 (550—24,000)	3.4 (0.24—11)	1,100 (77—3,400)	8,700 (620—28,000)
Work loss days (age 18-65)	53,000 (46,000—61,000)	20 (17—22)	7,200 (6,100—8,200)	61,000 (52,000—69,000)
Minor restricted activity days (age 18-65)	320,000 (260,000—370,000)	120 (100—140)	42,000 (35,000—49,000)	360,000 (300,000—420,000)

[A] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA

Table 6a-3: Illustrative Strategy to Partially Attain 0.070 ppm: Estimated Partial Attainment Value of Reductions in $PM_{2.5}$-Related Premature Mortality Associated with PM co-benefit (3 percent discount rate, in millions of 1999$) 95th Percentile Confidence Intervals Provided in Parentheses

	Eastern U.S.	Western U.S. Excluding California	California	National PM co-benefits
Mortality Impact Functions Derived from Epidemiology Literature				
ACS Study[A]	$2,900 ($410--$6,700)	$1 ($0.14--$2.2)	$270 ($38--$610)	$3,200 ($450--$7,300)
Harvard Six-City Study[B]	$6,600 ($1,100--$14,000)	$2.1 ($0.35--$4.6)	$610 ($98--$1,300)	$7,200 ($1,200--$15,000)
Woodruff et al 1997 (infant mortality)	$6.3 ($1--$14)	$0.2 ($0.03--$0.5)	$0.8 ($0.12--$1.7)	$7.3 ($1.1--$16)
Mortality Impact Functions Derived from Expert Elicitation				
Expert A	$9,100 ($810--$23,000)	$440 ($51--$1,100)	$830 ($75--$2,100)	$10,000 ($930--$26,000)
Expert B	$6,900 ($470--$21,000)	$320 ($16--$1,000)	$630 ($42--$2,000)	$7,900 ($520--$24,000)
Expert C	$6,800 ($620--$21,000)	$340 ($38--$990)	$630 ($57--$1,900)	$7,800 ($710--$23,000)
Expert D	$4,800 ($500--$11,000)	$230 ($30--$550)	$440 ($46--$1,000)	$5,400 ($570--$13,000)
Expert E	$11,000 ($1,800--$25,000)	$550 ($120--$1,200)	$1,000 ($160--$2,300)	$13,000 ($2,000--$28,000)
Expert F	$6,200 ($1,100--$14,000)	$290 ($67--$630)	$570 (100--$1,200)	$7,100 ($1,300--$15,000)
Expert G	$4,000 (0--$11,000)	$200 (0--$530)	$370 (0--$990)	$4,600 (0--$12,000)
Expert H	$5,100 ($11--$16,000)	$250 (0.7--$770)	$470 ($1--$1,500)	$5,800 ($12--$18,000)
Expert I	$6,800 ($570--$17,000)	$330 ($35--$840)	$620 ($53--$1,600)	$7,700 ($650--$19,000)
Expert J	$5,500 ($700--$17,000)	$270 ($44--$810)	$500 ($64--$1,500)	$6,200 ($790--$19,000)
Expert K	$1,100 (0--$6,500)	$51 (0--$320)	$110 (0--$650)	$1,300 (0--$7,500)
Expert L	$5,000 ($440--$13,000)	$190 ($0.2--$640)	$460 ($39--$1,200)	$5,700 ($480--$15,000)

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

[B] Based on Laden et al (2006) reporting of the extended Six-cities study; to be reviewed by the EPA-SAB for advice on the appropriate method for incorporating what has previously been a sensitivity estimate.

[C] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS RIA

Table 6a-4: Illustrative Strategy to Partially Attain 0.070 ppm: Estimated Partial Attainment Value of Reductions in $PM_{2.5}$-Related Premature Mortality Associated with PM co-benefit (7 percent discount rate, in millions of 1999$) 95th Percentile Confidence Intervals Provided in Parentheses

	Eastern U.S.	Western U.S. Excluding California	California	National PM co-benefits
Mortality Impact Functions Derived from Epidemiology Literature				
ACS Study[A]	$2,500 ($350--$5,600)	$0.8 (0.1--$1.9)	$230 ($32--$520)	$2,700 ($380--$6,100)
Harvard Six-City Study[B]	$5,600 ($890--$12,000)	$1.8 ($0.3--$3.9)	$510 ($82--$1,100)	$6,100 ($980--$13,000)
Woodruff et al 1997 (infant mortality)	$5.3 ($0.81--$12)	$0.2 ($0.03--$0.38)	$0.7 ($0.1--$1.4)	$6.2 ($0.9--$14)
Mortality Impact Functions Derived from Expert Elicitation				
Expert A	$7,700 ($880--$19,000)	$370 ($43--$940)	$700 ($81--$1,800)	$8,700 ($780--$22,000)
Expert B	$5,800 ($510--$18,000)	$270 ($13--$870)	$530 ($46--$1,700)	$6,600 ($440--$21,000)
Expert C	$5,800 ($660--$17,000)	$280 ($32--$830)	$530 ($61--$1,600)	$6,600 ($600--$19,400)
Expert D	$4,000 ($520--$9,500)	$200 ($26--$470)	$370 ($48--$880)	$4,600 ($480--$11,000)
Expert E	$9,500 ($2,000--$21,000)	$470 ($98--$1,000)	$870 ($180--$1,900)	$11,000 ($1,700--$24,000)
Expert F	$5,300 ($1,300--$11,000)	$250 ($57--$530)	$480 ($120--$1,000)	$6,000 ($1,100--$13,000)
Expert G	$3,400 (0--$9,100)	$160 (0--$440)	$310 (0--$830)	$3,800 (0--$10,00)
Expert H	$4,300 ($12--$13,000)	$210 ($0.6--$650)	$390 ($1.1--$1,200)	$4,900 ($10--$15,000)
Expert I	$5,900 ($600--$14,000)	$290 ($30--$700)	$540 ($55--$1,300)	$6,700 ($550--$16,000)
Expert J	$4,600 ($750--$14,000)	$230 ($37--$680)	$420 ($69--$1,300)	$5,300 ($670--$16,000)
Expert K	$920 (0--$5,500)	$43 (0--$270)	$93 (0--$550)	$1,100 (0--$6,300)
Expert L	$4,200 ($460--$11,000)	$160 ($0.16--$540)	$380 ($42--$1,000)	$4,700 ($400--$13,000)

Table 6a-5: Illustrative Strategy to Partially Attain 0.070 ppm: Estimated Partial Attainment Monetary Value of Reductions in Risk of $PM_{2.5}$-Related Morbidity Reductions Associated with PM co-benefit (in millions of 1999$) 95th Percentile Confidence Intervals Provided in Parentheses

	Eastern U.S.	*Western U.S. Excluding California*	*California*	*National PM co-benefits*
Morbidity Impact Functions Derived from Epidemiology Literature				
Chronic Bronchitis (age >25 and over)	$160 ($8.7--$720)	$4.7 ($0.3--$22)	$17 ($1--$80)	$180 ($10--$820)
Nonfatal myocardial infarction (age >17)	$93 ($25--$200)	$0.03 ($0.01--$0.7)	$8 ($2.1--$17)	$100 ($27--$220)
Hospital admissions--respiratory (all ages)	$90 ($23--$200)	$0.03 ($0.01--$0.7)	$7.7 ($2--$17)	$98 ($25--$220)
Hospital admissions-- cardiovascular (age >17)	$2.1 ($1--$3.1)	---	$0.2 ($0.08--$0.2)	$2.3 ($1.1--$3.4)
Emergency room visits for asthma (age <19)	$5.5 ($3.4--$7.5)	---	$0.4 ($0.3--$0.57)	$5.9 ($3.7--$8.1)
Acute bronchitis (age 8-12)	$0.2 ($0.04--$0.3)	---	---	$0.2 ($0.09--$0.26)
Lower respiratory symptoms (age 7-14)	$0.4 ($-0.02--$1)	---	$0.05 ($-0.002--$0.1)	$0.4 ($-0.02--$1.2)
Upper respiratory symptoms (asthmatic children age 9-18)	$0.1 ($0.04--$0.27)	---	$0.02 ($0.006--$0.04)	$0.15 ($0.05--$0.3)
Asthma exacerbation (asthmatic children age 6--18)	$0.2 ($0.03—0.38)	---	$0.022 ($0.005--$0.05)	$0.2 ($0.04--$0.44)
Work loss days (age 18-65)	$0.34 ($0.03--$1.3)	---	$0.05 ($0.004--$0.18)	$0.4 ($0.03--$1.5)
Minor restricted activity days (age 18-65)	$5.3 ($4.6--$6)	---	$0.9 ($0.7--$1)	$7.4 ($6.4--$8.3)

[A] All estimates rounded to two significant figures. As such, confidence intervals may not be symmetrical and totals will not sum across columns. All estimates incremental to 2006 PM NAAQS

Appendix Chapter 6b: Health-Based Cost-Effectiveness of Reductions in Ambient $PM_{2.5}$ Associated with Illustrative Ozone NAAQS 0.070ppm Attainment Strategy

6b.1 Summary

Health-based cost-effectiveness analysis (CEA) and cost-utility analysis (CUA) have been used to analyze numerous health interventions but have not been widely adopted as tools to analyze environmental policies. The Office of Management and Budget (OMB) recently issued Circular A-4 guidance on regulatory analyses, requiring federal agencies to "prepare a CEA for all major rulemakings for which the primary benefits are improved public health and safety to the extent that a valid effectiveness measure can be developed to represent expected health and safety outcomes." Environmental quality improvements may have multiple health and ecological benefits, making application of CEA more difficult and less straightforward. For the Ozone NAAQS, CEA may provide a useful framework for evaluation: non-health benefits are substantial, but the majority of quantified benefits come from health effects. Therefore, EPA is including in the Ozone NAAQS RIA a preliminary and experimental application of one type of CEA—a modified quality-adjusted life-years (QALYs) approach.

This cost effectiveness analysis considers the $PM_{2.5}$ benefits resulting from the illustrative ozone control strategies only. Estimation of QALY or Morbidity Inclusive Life Year (MILY, discussed below) impacts associated with reducing ozone concentrations is difficult for several reasons. First, with the exception of premature death, the set of ozone-related health endpoints includes only acute diseases and impacts. As discussed below, there are a number of reasons that the QALY method is not appropriate for valuing acute health effects. Second, calculation of QALY or MILY impacts for premature mortality is complicated by a lack of information, including the change in life expectancy associated with the risk reduction (for MILYs and QALYs) and the baseline quality of life for individuals experiencing the risk reduction (for QALY calculations). The EPA has recently asked the National Academies of Sciences[1] for advice on characterizing the mortality risk reduction benefits of reducing ozone concentrations. In their evaluation, the NAS Committee on Estimating Mortality Risk Reduction Benefits from Decreasing Tropospheric Ozone Exposure will provide advice on, among other topics, the adequacy of a basis for estimating the likely impact on life expectancy from reductions in short-term daily exposures to ozone. If there is an adequate basis, they will, to the extent practicable, estimate the magnitude and associated uncertainties of this impact. While awaiting the recommendations of the NAS committee, EPA is electing to not calculate QALY or MILY impacts for ozone related health effects for this proposal RIA. EPA will investigate the feasibility of performing such an analysis for the final RIA. As a result, the overall $/MILY estimates for attainment of alternative ozone NAAQS reported in this appendix will overstate the expected $/MILY incorporating ozone effects.

---

[1] National Academy of Sciences (2007) Project Scope. Estimating Mortality Risk Reduction Benefits from Decreasing Tropospheric Ozone Exposure. Division on Earth and Life Studies, Board on Environmental Studies and Toxicology. Available at: http://www8.nationalacademies.org/cp/projectview.aspx?key=48768

QALYs were developed to evaluate the effectiveness of individual medical treatments, and EPA is still evaluating the appropriate methods for CEA for environmental regulations. Agency concerns with the standard QALY methodology include the treatment of people with fewer years to live (the elderly); fairness to people with preexisting conditions that may lead to reduced life expectancy and reduced quality of life; and how the analysis should best account for non-health benefits, such as improved visibility.

The Institute of Medicine (a member institution of the National Academies of Science) established the Committee to Evaluate Measures of Health Benefits for Environmental, Health, and Safety Regulation to assess the scientific validity, ethical implications, and practical utility of a wide range of effectiveness measures used or proposed in CEA. This committee prepared a report titled "Valuing Health for Regulatory Cost-Effectiveness Analysis" which concluded that CEA is a useful tool for assessing regulatory interventions to promote human health and safety, although not sufficient for informed regulatory decisions (Miller, Robinson, and Lawrence, 2006). They emphasized the need for additional data and methodological improvements for CEA analyses, and urged greater consistency in the reporting of assumptions, data elements, and analytic methods. They also provided a number of recommendations for the conduct of regulatory CEA analyses. EPA is evaluating these recommendations and will determine a response for upcoming analyses. For this analysis, we use the same approach that was applied in the CEA that accompanied the RIA's for the Clean Air Interstate Rule and the PM NAAQS.

The methodology presented in this appendix is not intended to stand as precedent either for future air pollution regulations or for other EPA regulations where it may be inappropriate. It is intended solely to demonstrate one particular approach to estimating the cost-effectiveness of reductions in ambient $PM_{2.5}$ in achieving improvements in public health. Reductions in ambient $PM_{2.5}$ likely will have other health and environmental benefits that will not be reflected in this CEA. Other EPA regulations affecting other aspects of environmental quality and public health may require additional data and models that may preclude the development of similar health-based CEAs. A number of additional methodological issues must be considered when conducting CEAs for environmental policies, including treatment of nonhealth effects, aggregation of acute and long-term health impacts, and aggregation of life extensions and quality-of-life improvements in different populations. The appropriateness of health-based CEA should be evaluated on a case-by-case basis subject to the availability of appropriate data and models, among other factors.

Attainment of the revised Ozone NAAQS is expected to result in substantial reductions in potential population exposure to ambient concentrations of PM by 2020. The benefit-cost analysis presented in the RIA shows that partial attainment of the revised 0.070 ppm ozone standard achieves substantial health benefits whose monetized value is roughly equal to costs (net benefits are between -$6B and $4.1B). Despite the risk of oversimplifying benefits, cautiously-interpreted cost-effectiveness calculations may provide further evidence of whether the costs associated with attainment strategies for the Ozone NAAQS are a reasonable health investment for the nation.

This analysis provides estimates of commonly used health-based effectiveness measures, including lives saved, life years saved (from reductions in mortality risk), and QALYs saved (from reductions in morbidity risk) associated with the reduction of ambient $PM_{2.5}$ due to illustrative attainment strategies for a more stringent annual ozone standard. In addition, we use an alternative aggregate effectiveness metric, Morbidity Inclusive Life Years (MILY) to address some of the concerns about aggregation of life extension and quality-of-life impacts. It represents the sum of life years gained due to reductions in premature mortality and the QALY gained due to reductions in chronic morbidity. This measure may be preferred to existing QALY aggregation approaches because it does not devalue life extensions in individuals with preexisting illnesses that reduce quality of life. However, the MILY measure is still based on life years and thus still inherently gives more weight to interventions that reduce mortality and morbidity impacts for younger populations with higher remaining life expectancy. This analysis focuses on life extensions and improvements in quality of life through reductions in two diseases with chronic impacts: chronic bronchitis (CB) and nonfatal acute myocardial infarctions. Monte Carlo simulations are used to propagate uncertainty in several analytical parameters and characterize the distribution of estimated impacts. While the benefit-cost analysis presented in the RIA characterizes mortality impacts using a number of different sources for the PM mortality effect estimate, for this analysis, we focus on the mortality results generated using the effect estimates derived from the Pope et al. (2002) and Laden et al. (2005) studies.

Presented in three different metrics, the analysis suggests the following:

- In 2020 the illustrative attainment strategy for the revised 0.070 ppm standards will result in:
  - Between 550 (95% CI: 215 – 890) and 1,300 (95% CI: 680 – 1,800) premature deaths avoided using the Pope (2002) and Laden (2006) studies, respectively, or
  - Between 6,100 (95% CI: 2,400 – 9,800) and 14,000 (95% CI: 7,500 – 20,000) life years gained (discounted at 3 percent) using the Pope (2002) and Laden (2006) studies, respectively, or
  - Between 9,100 (95% CI: 3,100 – 16,000) and 17,000 (95% CI: 8,200 – 27,000) MILYs gained (discounted at 3 percent) using the Pope (2002) and Laden (2006) studies, respectively.
- Using a 7 percent discount rate, mean discounted life years gained are between 4,600 and 10,400 using the Pope (2002) and Laden (2006) studies, respectively; mean MILYs gained are 6,800 and 13,000 using the two studies (The estimates of premature deaths avoided are not affected by the discount rate.)
- The associated reductions in CB and nonfatal acute myocardial infarctions will reduce medical costs by approximately $140 million based on a 3 or 7 percent discount rate.

Direct private compliance costs for the 0.070 ppm partial attainment strategy, are $3.9 billion in 2020. Based on these costs, the incremental cost effectiveness (net of cost of illness and other health and visibility benefits) of the 0.070 ppm partial attainment strategy is $430,000/MILY using a 3 percent discount rate and $580,000/MILY using a 7 percent discount rate if one calculates MILY's using the Pope (2002) mortality estimate. The incremental cost effectiveness (again, net of cost of illness and other health and visibility benefits) of the 0.070 ppm partial attainment strategy is $230,000/MILY using a 3 percent discount rate and $310,000/MILY using a 7 percent discount rate if one calculates MILY's using the Laden (2006) mortality estimate. See Chapters 3 and 5 of this RIA for more discussion of the control strategies and cost estimates.

6b.2 Introduction

Analyses of environmental regulations have typically used benefit-cost analysis to characterize impacts on social welfare. Benefit-cost analyses allow for aggregation of the benefits of reducing mortality risks with other monetized benefits of reducing air pollution, including acute and chronic morbidity, and nonhealth benefits such as improved visibility. One of the great advantages of the benefit-cost paradigm is that a wide range of quantifiable benefits can be compared to costs to evaluate the economic efficiency of particular actions. However, alternative paradigms such as CEA and CUA analyses may also provide useful insights. CEA involves estimation of the costs per unit of benefit (e.g., lives or life years saved). CUA is a special type of CEA using preference-based measures of effectiveness, such as QALYs.

CEA and CUA are most useful for comparing programs that have similar goals, for example, alternative medical interventions or treatments that can save a life or cure a disease. They are less readily applicable to programs with multiple categories of benefits, such as those reducing ambient air pollution, because the cost-effectiveness calculation is based on the quantity of a single benefit category. In other words, we cannot readily convert improvements in nonhealth benefits such as visibility to a health metric such as life years saved. For these reasons, environmental economists prefer to present results in terms of monetary benefits and net benefits.

However, QALY-based CUA has been widely adopted within the health economics literature (Neumann, 2003; Gold et al., 1996) and in the analysis of public health interventions (US FDA, 2004). QALY-based analyses have not been as accepted in the environmental economics literature because of concerns about the theoretical consistency of QALYs with individual preferences (Hammitt, 2002), treatment of nonhuman health benefits, and a number of other factors (Freeman, Hammitt, and De Civita, 2002). For environmental regulations, benefit-cost analysis has been the preferred method of choosing among regulatory alternatives in terms of economic efficiency. Recently several academic analyses have proposed the use of life years-based benefit-cost or CEAs of air pollution regulations (Cohen, Hammitt, and Levy, 2003; Coyle et al., 2003; Rabl, 2003; Carrothers, Evans, and Graham, 2002). In addition, the World Health Organization has adopted the use of disability-adjusted life years, a variant on QALYs, to assess the global burden of disease due to different causes, including environmental pollution (Murray et al., 2002; de Hollander et al., 1999).

Recently, the U.S. OMB (Circular A-4, 2003) issued new guidance requiring federal agencies to provide both CEA and benefit-cost analyses for major regulations. The OMB Circular A-4 directs agencies to "prepare a CEA for all major rulemakings for which the primary benefits are improved public health and safety to the extent that a valid effectiveness measure can be developed to represent expected health and safety outcomes." We are including a CEA for the illustrative PM NAAQS attainment strategies to illustrate one potential approach for conducting a CEA. EPA is still evaluating the appropriate methods for CEA for environmental regulations with multiple outcomes.

The methodology presented in this appendix is not intended to stand as precedent either for future air pollution regulations or for other EPA regulations governing water, solid waste, or other regulatory objectives. It is intended solely to demonstrate one particular approach to estimating the effectiveness of reductions in ambient $PM_{2.5}$ in achieving improvements in public health. This analysis focuses on effectiveness measured by improvements in life expectancy and reductions in the incidence of two diseases with chronic impacts on quality of life: CB and nonfatal acute myocardial infarctions. Other EPA regulations affecting other aspects of environmental quality and public health may require additional data and models that may preclude the development of similar QALY-based analyses. The appropriateness of QALY-based CEA should be evaluated on a case-by-case basis subject to the availability of appropriate data and models.

Preparation of a CEA requires identification of an appropriate measure of rule effectiveness. Given the significant impact of reductions in ambient $PM_{2.5}$ on reductions in the risk of mortality, lives saved is an important measure of effectiveness. However, one of the ongoing controversies in health impact assessment regards whether reductions in mortality risk should be reported and valued in terms of statistical lives saved or in terms of statistical life years saved. Life years saved measures differentiate among premature mortalities based on the remaining life expectancy of affected individuals. In general, under the life years approach, older individuals will gain fewer life years than younger individuals for the same reduction in mortality risk during a given time period, making interventions that benefit older individuals seem less beneficial relative to similar interventions benefiting younger individuals. A further complication in the debate is whether to apply quality adjustments to life years lost. Under this approach, individuals with preexisting health conditions would have fewer QALYs lost relative to healthy individuals for the same loss in life expectancy, making interventions that primarily benefit individuals with poor health seem less beneficial to similar interventions affecting primarily healthy individuals.

In addition to substantial mortality risk reduction benefits, strategies for attaining the revised PM NAAQS will also result in significant reductions in chronic and acute morbidity. Several approaches have been developed to incorporate both morbidity and mortality into a single effectiveness metric. The most common of these is the QALY approach, which expresses all morbidity and mortality impacts in terms of quality of life multiplied by the duration of time with that quality of life. The QALY approach has some appealing characteristics. For example, it can account for morbidity effects as well as losses in life expectancy without requiring the assignment of dollar values to calculate total benefits. By doing so it provides an alternative framework to benefit-cost analysis for aggregating quantitative measures of health impacts.

While used extensively in the economic evaluation of medical interventions (Gold et al., 1996), QALYs have not been widely used in evaluating environmental health regulations. A number of specific issues arise with the use of QALYs in evaluating environmental programs that affect a broad and heterogeneous population and that provide both health and nonhealth benefits. The U.S. Public Health Service report on cost-effectiveness in health and medicine notes the following:

> *For decisions that involve greater diversity in interventions and the people to whom they apply, cost-effectiveness ratios continue to provide essential information, but*

that information must, to a greater degree, be evaluated in light of circumstances and values that cannot be included in the analysis. Individuals in the population will differ widely in their health and disability before the intervention, or in age, wealth, or other characteristics, raising questions about how society values gains for the more and less health, for young and old, for rich and poor, and so on. The assumption that all QALYs are of equal value is less likely to be reasonable in this context. (Gold et al., 1996, p. 11)

Use of QALYs as a measure of effectiveness for environmental regulations is still developing, and while this analysis provides one framework for using QALYs to evaluate environmental regulations, there are clearly many issues, both scientific and ethical, that need to be addressed with additional research. The Institute of Medicine panel evaluating QALYs and other effectiveness measures prepared a report titled "Valuing Health for Regulatory Cost-Effectiveness Analysis" which concluded that "the QALY is the best measure at present on which to standardize Health Adjusted Life Year estimation because of its widespread use, flexibility, and relative simplicity" (Miller, Robinson, and Lawrence, 2006). EPA is evaluating this recommendation and will determine a response for upcoming analyses. For this analysis, for reasons discussed in the text, we use the same MILY approach that was applied in the CEA that accompanied the RIA for the Clean Air Interstate Rule.

This appendix presents cost-effectiveness methodologies for evaluating programs such as attainment strategies for the revised Ozone NAAQS that are intended to reduce both ozone and $PM_{2.5}$ precursors, such as NOx and VOCs, starting from the standard QALY literature and seeking a parallel structure to benefit-cost analysis in the use of air quality and health inputs (see Hubbell [2004a] for a discussion of some of the issues that arise in comparing QALY and benefit-cost frameworks in analyzing air pollution impacts). For the purposes of this analysis, we calculate effectiveness using several different metrics, including lives prolonged, life years gained, and modified QALYs. For the life years and QALY-type approaches, we use life table methods to calculate the change in life expectancy expected to result from changes in mortality risk from PM. We use existing estimates of preferences for different health states to obtain QALY weights for morbidity endpoints associated with air pollution. In general, consistent with the Gold et al. (1996) recommendations, we use weights obtained from a societal perspective when available. We explore several different sources for these weights to characterize some of the potential uncertainty in the QALY estimates. We follow many of the principles of the reference case analysis as defined in Gold et al. (1996), although in some cases we depart from the reference case approach when data limitations require us to do so (primarily in the selection of quality-of-life weights for morbidity endpoints). We also depart from the reference case (and the recommendations of the IOM report) in the method of combining life expectancy and quality-of-life gains.

Results in most tables are presented only at a discount rate of 3 percent, rather than at both 3 percent and 7 percent as recommended in EPA and OMB guidance. This is strictly for ease of presentation. Aggregate results at 7 percent are presented in the summary, and the impact of using a 7 percent discount rate instead of 3 percent rate is summarized in a sensitivity analysis.

Monte Carlo simulation methods are used to propagate uncertainty in several of the model parameters throughout the analysis. We characterize overall uncertainty in the results with 95 percent confidence intervals based on the Monte Carlo simulations. In addition, we examine the impacts of changing key parameters, such as the discount rate, on the effectiveness measures and the cost-effectiveness metrics.

The remainder of this appendix provides an overview of the key issues involved in life year- and QALY-based approaches for evaluating the health impacts of air pollution regulations, provides detailed discussions of the steps required for each type of effectiveness calculation, and presents the CEA for the PM NAAQS illustrative attainment strategies. Section G.3 introduces the various effectiveness measures and discusses some of the assumptions required for each. Section G.4 details the methodology used to calculate changes in life years and quality adjustments for mortality and morbidity endpoints. Section G.5 provides the results for the illustrative attainment strategies for the revised and more stringent alternative PM NAAQS and discusses their implications for cost-effectiveness of these attainment strategies.

6b.3 Effectiveness Measures

Three major classes of benefits are associated with reductions in air pollution: mortality, morbidity, and nonhealth (welfare). For the purposes of benefit-cost analysis, EPA has presented mortality-related benefits using estimates of avoided premature mortalities, representing the cumulative result of reducing the risk of premature mortality from long-term exposure to $PM_{2.5}$ for a large portion of the U.S. population. Morbidity benefits have been characterized by numbers of new incidences avoided for chronic diseases such as CB, avoided admissions for hospitalizations associated with acute and chronic conditions, and avoided days with symptoms for minor illnesses. Nonhealth benefits are characterized by the monetary value of reducing the impact (e.g., the dollar value of improvements in visibility at national parks).

For the purposes of CEA, we focus the effectiveness measure on the quantifiable health impacts of the reduction in $PM_{2.5}$. Treatment of nonhealth benefits is important and is discussed in some detail later in this section. If the main impact of interest is reductions in mortality risk from air pollution, the effectiveness measures are relatively straightforward to develop. Mortality impacts can be characterized similar to the benefits analysis, by counting the number of premature mortalities avoided, or can be characterized in terms of increases in life expectancy or life years.[2] Estimates of premature mortality have the benefit of being relatively simple to calculate, are consistent with the benefit-cost analysis, and do not impose additional assumptions on the degree of life shortening. However, some have argued that counts of premature mortalities avoided are problematic because a gain in life of only a few months would be

---

[2] Life expectancy is an *ex ante* concept, indicating the impact on an entire population's expectation of the number of life years they have remaining, before knowing which individuals will be affected. Life expectancy thus incorporates both the probability of an effect and the impact of the effect if realized. Life years is an *ex post* concept, indicating the impact on individuals who actually die from exposure to air pollution. Changes in population life expectancy will always be substantially smaller than changes in life years per premature mortality avoided, although the total life years gained in the population will be the same. This is because life expectancy gains average expected life years gained over the entire population, while life years gained measures life years gained only for those experiencing the life extension.

considered equivalent to a gain of a many life years, and the true effectiveness of an intervention is the gain in life expectancy or life years (Rabl, 2003; Miller and Hurley, 2003).

Calculations of changes in life years and life expectancy can be accomplished using standard life table methods (Miller and Hurley, 2003). However, the calculations require assumptions about the baseline mortality risks for each age cohort affected by air pollution. A general assumption may be that air pollution mortality risks affect the general mortality risk of the population in a proportional manner. However, some concerns have been raised that air pollution affects mainly those individuals with preexisting cardiovascular and respiratory disease, who may have reduced life expectancy relative to the general population. This issue is explored in more detail below.

Air pollution is also associated with a number of significant chronic and acute morbidity endpoints. Failure to consider these morbidity effects may understate the cost-effectiveness of air pollution regulations or give too little weight to reductions in particular pollutants that have large morbidity impacts but no effect on life expectancy. The QALY approach explicitly incorporates morbidity impacts into measures of life years gained and is often used in health economics to assess the cost-effectiveness of medical spending programs (Gold et al., 1996). Using a QALY rating system, health quality ranges from 0 to 1, where 1 may represent full health, 0 death, and some number in between (e.g., 0.8) an impaired condition. QALYs thus measure morbidity as a reduction in quality of life over a period of life. QALYs assume that duration and quality of life are equivalent, so that 1 year spent in perfect health is equivalent to 2 years spent with quality of life half that of perfect health. QALYs can be used to evaluate environmental rules under certain circumstances, although some very strong assumptions (detailed below) are associated with QALYs. The U.S. Public Health Service Panel on Cost Effectiveness in Health and Medicine recommended using QALYs when evaluating medical and public health programs that primarily reduce both mortality and morbidity (Gold et al., 1996). Although there are significant nonhealth benefits associated with air pollution regulations, over 90 percent of quantifiable monetized benefits are health-related, as is the case with the attainment strategies for the PM NAAQS. Thus, it can be argued that QALYs are more applicable for these types of regulations than for other environmental policies. However, the value of nonhealth benefits should not be ignored. As discussed below, we have chosen to subtract the value of nonhealth benefits from the costs in the numerator of the cost-effectiveness ratio.

In the following sections, we lay out a phased approach to describing effectiveness. We begin by discussing how the life-extending benefits of air pollution reductions are calculated, and then we incorporate morbidity effects using the QALY approach. We also introduce an alternative aggregated health metric, Morbidity Inclusive Life Years (MILY) to address some of the ethical concerns about aggregating life extension impacts in populations with preexisting disabling conditions.

The use of QALYs is predicated on the assumptions embedded in the QALY analytical framework. As noted in the QALY literature, QALYs are consistent with the utility theory that underlies most of economics only if one imposes several restrictive assumptions, including independence between longevity and quality of life in the utility function, risk neutrality with respect to years of life (which implies that the utility function is linear), and constant proportionality in trade-offs between quality and quantity of life (Pliskin, Shepard, and

Weinstein, 1980; Bleichrodt, Wakker, and Johannesson, 1996). To the extent that these assumptions do not represent actual preferences, the QALY approach will not provide results that are consistent with a benefit-cost analysis based on the Kaldor-Hicks criterion.[3] Even if the assumptions are reasonably consistent with reality, because QALYs represent an average valuation of health states rather than the sum of societal WTP, there are no guarantees that the option with the highest QALY per dollar of cost will satisfy the Kaldor-Hicks criterion (i.e., generate a potential Pareto improvement [Garber and Phelps, 1997]).

Benefit-cost analysis based on WTP is not without potentially troubling underlying structures as well, incorporating ability to pay (and thus the potential for equity concerns) and the notion of consumer sovereignty (which emphasizes wealth effects). Table G-1 compares the two approaches across a number of parameters. For the most part, WTP allows parameters to be determined empirically, while the QALY approach imposes some conditions *a priori*.

Table 6b-1: Comparison of QALY and WTP Approaches

Parameter	*QALY*	*WTP*
Risk aversion	Risk neutral	Empirically determined
Relation of duration and quality	Independent	Empirically determined
Proportionality of duration/ quality trade-off	Constant	Variable
Treatment of time/age in utility function	Utility linear in time	Empirically determined
Preferences	Community/Individual	Individual
Source of preference data	Stated	Revealed and stated
Treatment of income and prices	Not explicitly considered	Constrains choices

6b.4 Changes in Premature Death, Life Years, and Quality of Life

To generate health outcomes, we used the same framework as for the benefit-cost analysis described in Chapter 6. For convenience, we summarize the basic methodologies here. For more details, see Chapter 6 and the BenMAP user's manual (http://www.epa.gov/ttn/ecas/benmodels.html).

BenMAP uses health impact functions to generate changes in the incidence of health effects. Health impact functions are derived from the epidemiology literature. A standard health impact function has four components: an effect estimate from a particular epidemiological study, a baseline incidence rate for the health effect (obtained from either the epidemiology study or a

[3] The Kaldor-Hicks efficiency criterion requires that the "winners" in a particular case be potentially able to compensate the "losers" such that total societal welfare improves. In this case, it is sufficient that total benefits exceed total costs of the regulation. This is also known as a potential Pareto improvement, because gains could be allocated such that at least one person in society would be better off while no one would be worse off.

source of public health statistics like CDC), the affected population, and the estimated change in the relevant PM summary measure.

A typical health impact function might look like this:

$$\Delta y = y_0 \cdot (e^{\beta \cdot \Delta x} - 1),$$

where y_0 is the baseline incidence, equal to the baseline incidence rate times the potentially affected population; β is the effect estimate; and Δx is the estimated change in $PM_{2.5}$. There are other functional forms, but the basic elements remain the same.

6b.4.1 Calculating Reductions in Premature Deaths

As in several recent air pollution health impact assessments (e.g., Kunzli et al., 2000; EPA, 2004), we focus on the prospective cohort long-term exposure studies in deriving the health impact function for the estimate of premature mortality. Cohort analyses are better able to capture the full public health impact of exposure to air pollution over time (Kunzli et al., 2001; NRC, 2002). We selected effects estimate from the extended analysis of the ACS cohort (Pope et al., 2002) as well as from the Harvard Six City Study (Laden et al., 2006). Given the focus in this analysis on developing a broader expression of uncertainties in the benefits estimates, and the weight that was placed on both the ACS and Harvard Six-city studies by experts participating in the $PM_{2.5}$ mortality expert elicitation, we have elected to provide estimates derived from both Pope et al. (2002) and Laden et al. (2006).

This latest re-analysis of the ACS cohort data (Pope et al, 2002) provides additional refinements to the analysis of PM-related mortality by (a) extending the follow-up period for the ACS study subjects to 16 years, which triples the size of the mortality data set; (b) substantially increasing exposure data, including consideration for cohort exposure to $PM_{2.5}$ following implementation of $PM_{2.5}$ standard in 1999; (c) controlling for a variety of personal risk factors including occupational exposure and diet; and (d) using advanced statistical methods to evaluate specific issues that can adversely affect risk estimates, including the possibility of spatial autocorrelation of survival times in communities located near each other. The effect estimate from Pope et al. (2002) quantifies the relationship between annual mean $PM_{2.5}$ levels and all-cause mortality in adults 30 and older. We selected the effect estimate estimated using the measure of PM representing average exposure over the follow-up period, calculated as the average of 1979–1984 and 1999–2000 $PM_{2.5}$ levels. The effect estimate from this study is 0.0058, which is equivalent to a relative risk of 1.06 for a 10 μg change in $PM_{2.5}$.

Very recently, a follow up to the Harvard 6-city study was published (Laden et al., 2006), that both confirmed the effect size from the first study and provided additional confirmation that reductions in $PM_{2.5}$ directly result in reductions in the risk of premature death. This additional evidence stems from the observed reductions in $PM_{2.5}$ in each city during the extended follow-up period. Laden et al. (2006) found that mortality rates consistently went down at a rate proportionate to the observed reductions in $PM_{2.5}$. The effect estimate obtained from the Laden et al is 0.0148, which is equivalent to a relative risk of 1.16 for a 10 $\mu g/m^3$ change in $PM_{2.5}$.

Age, cause, and county-specific mortality rates were obtained from CDC for the years 1996 through 1998. CDC maintains an online data repository of health statistics, CDC Wonder, accessible at http://wonder.cdc.gov/. The mortality rates provided are derived from U.S. death records and U.S. Census Bureau postcensal population estimates. Mortality rates were averaged across 3 years (1996 through 1998) to provide more stable estimates. When estimating rates for age groups that differed from the CDC Wonder groupings, we assumed that rates were uniform across all ages in the reported age group. For example, to estimate mortality rates for individuals ages 30 and up, we scaled the 25- to 34-year old death count and population by one-half and then generated a population-weighted mortality rate using data for the older age groups.

The reductions in incidence of premature mortality within each age group associated with the illustrative attainment strategies for the revised and more stringent alternative Ozone NAAQS in 2020 are summarized in Table G-2.

6b.4.2 Calculating Changes in Life Years from Direct Reductions in $PM_{2.5}$-Related Mortality Risk

To calculate changes in life years associated with a given change in air pollution, we used a life table approach coupled with age-specific estimates of reductions in premature mortality. We began with the complete unabridged life table for the United States in 2000, obtained from CDC (CDC, 2002). For each 1-year age interval (e.g., zero to one, one to two) the life table provides estimates of the baseline probability of dying during the interval, person years lived in the interval, and remaining life expectancy. From this unabridged life table, we constructed an abridged life table to match the age intervals for which we have predictions of changes in incidence of premature mortality. We used the abridgement method described in CDC (2002). Table G-3 presents the abridged life table for 10-year age intervals for adults over 30 (to match the Pope et al. [2002] study population). Note that the abridgement actually includes one 5-year interval, covering adults 30 to 34, with the remaining age intervals covering 10 years each. This is to provide conformity with the age intervals available for mortality rates.

Table 6b-2: Estimated Reduction in Incidence of All-cause Premature Mortality Associated with Illustrative Attainment Strategies for the Revised and More Stringent Alternative Ozone NAAQS in 2020

	Reduction in All-Cause Premature Mortality (95% CI)	
Age Interval	*Pope (2002)*	*Laden (2006)*
30 – 34	4 (2 – 6)	9 (5 – 13)
35 – 44	12 (5 – 20)	28 (15 – 40)
45 – 54	26 (10 – 42)	60 (32 – 87)
55 – 64	70 (27 – 110)	160 (86 – 230)
65 – 74	120 (48 – 200)	280 (150 – 400)
75 – 84	140 (56 – 230)	320 (180 – 470)
85+	170 (68 – 280)	390 (210 – 570)
Total	550 (220 – 890)	1,300 (680 – 1,800)

From the abridged life table (Table 6b-3), we obtained the remaining life expectancy for each age cohort, conditional on surviving to that age. This is then the number of life years lost for an individual in the general population dying during that age interval. This information can then be combined with the estimated number of premature deaths in each age interval calculated with BenMAP (see previous subsection). Total life years gained will then be the sum of life years gained in each age interval:

$$Total Life\ Years \quad \sum_{i \quad 1}^{N} LE_i \times M_i \,,$$

where LE_i is the remaining life expectancy for age interval *i*, M_i is the change in incidence of mortality in age interval *i*, and N is the number of age intervals.

For the purposes of determining cost-effectiveness, it is also necessary to consider the time-dependent nature of the gains in life years. Standard economic theory suggests that benefits occurring in future years should be discounted relative to benefits occurring in the present. OMB and EPA guidance suggest discount rates of three and seven percent. As noted earlier, we present gains in future life years discounted at 3 percent. Results based on 7 percent are included in the summary and the overall impact of a 7 percent rate is summarized in Table 6b-16. Selection of a 3 percent discount rate is also consistent with recommendations from the U.S. Public Health Service Panel on Cost Effectiveness in Health and Medicine (Gold et al., 1996).

Table 6b-3: Abridged Life Table for the Total Population, United States, 2000

Age Interval		*Probability of Dying Between Ages x to x+1*	*Number Surviving to Age x*	*Number Dying Between Ages x to x+1*	*Person Years Lived Between Ages x to x+1*	*Total Number of Person Years Lived Above Age x*	*Expectation of Life at Age x*
Start Age	*End Age*	q_x	l_x	d_x	L_x	T_x	e_x
30	35	0.00577	97,696	564	487,130	4,723,539	48.3
35	45	0.01979	97,132	1,922	962,882	4,236,409	43.6
45	55	0.04303	95,210	4,097	934,026	3,273,527	34.4
55	65	0.09858	91,113	8,982	872,003	2,339,501	25.7
65	75	0.21779	82,131	17,887	740,927	1,467,498	17.9
75	85	0.45584	64,244	29,285	505,278	726,571	11.3
85	95	0.79256	34,959	27,707	196,269	221,293	6.3
95	100	0.75441	7,252	5,471	20,388	25,024	3.5
100+		1.00000	1,781	1,781	4,636	4,636	2.6

Discounted total life years gained is calculated as follows:

$$Discounted\ LY \int_0^{LE} e^{-rt}\,dt,$$

where r is the discount rate, equal to 0.03 in this case, t indicates time, and LE is the life expectancy at the time when the premature death would have occurred. Life years are further discounted to account for the lag between the reduction in ambient $PM_{2.5}$ and the reduction in mortality risk. We use the same 20-year segmented lag structure that is used in the benefit-cost analysis (see Chapter 6).

The most complete estimate of the impacts of $PM_{2.5}$ on life years is calculated using the Pope et al. (2002) C-R function relating all-cause mortality in adults 30 and over with ambient $PM_{2.5}$ concentrations averaged over the periods 1979–1983 and 1999–2000. Use of all-cause mortality is appropriate if there are no differences in the life expectancy of individuals dying from air pollution-related causes and those dying from other causes. The argument that long-term exposure to $PM_{2.5}$ may affect mainly individuals with serious preexisting illnesses is not supported by current empirical studies. For example, the Krewski et al. (2000) ACS reanalysis suggests that the mortality risk is no greater for those with preexisting illness at time of enrollment in the study. Life expectancy for the general population in fact includes individuals with serious chronic illness. Mortality rates for the general population then reflect prevalence of chronic disease, and as populations age the prevalence of chronic disease increases.

The only reason one might use a lower life expectancy is if the population at risk from air pollution was limited solely to those with preexisting disease. Also, note that the OMB Circular A-4 notes that "if QALYs are used to evaluate a lifesaving rule aimed at a population that happens to experience a high rate of disability (i.e., where the rule is not designed to affect the disability), the number of life years saved should not necessarily be diminished simply because the rule saves lives of people with life-shortening disabilities. Both analytic simplicity and fairness suggest that the estimate number of life years saved for the disabled population should be based on average life expectancy information for the relevant age cohorts." As such, use of a general population life expectancy is preferred over disability-specific life expectancies. Our primary life years calculations are thus consistent with the concept of not penalizing individuals with disabling chronic health conditions by assessing them reduced benefits of mortality risk reductions.

For this analysis, direct impacts on life expectancy are measured only through the estimated change in mortality risk based on the Pope et al. (2002) C-R function. The SAB-HES has advised against including additional gains in life expectancy due to reductions in incidence of chronic disease or nonfatal heart attacks (EPA-SAB-COUNCIL-ADV-04-002). Although reductions in these endpoints are likely to result in increased life expectancy, the HES has suggested that the cohort design and relatively long follow-up period in the Pope et al. study should capture any life-prolonging impacts associated with those endpoints. Impacts of CB and nonfatal heart attacks on quality of life will be captured separately in the QALY calculation as years lived with improved quality of life. The methods for calculating this benefit are discussed below.

6b.4.2.1 Should Life Years Gained Be Adjusted for Initial Health Status?

The methods outlined above provide estimates of the total number of life years gained in a population, regardless of the quality of those life years, or equivalently, assuming that all life years gained are in perfect health. In some CEAs (Cohen, Hammitt, and Levy, 2003; Coyle et al., 2003), analysts have adjusted the number of life years gained to reflect the fact that 1) the general public is not in perfect health and thus "healthy" life years are less than total life years gained and 2) those affected by air pollution may be in a worse health state than the general population and therefore will not gain as many "healthy" life years adjusted for quality, from an air pollution reduction. This adjustment, which converts life years gained into QALYs, raises a number of serious ethical issues. Proponents of QALYs have promoted the nondiscriminatory nature of QALYs in evaluating improvements in quality of life (e.g., an improvement from a score of 0.2 to 0.4 is equivalent to an improvement from 0.8 to 1.0), so the starting health status does not affect the evaluation of interventions that improve quality of life. However, for life-extending interventions, the gains in QALY will be directly proportional to the baseline health state (e.g., an individual with a 30-year life expectancy and a starting health status of 0.5 will gain exactly half the QALYs of an individual with the same life expectancy and a starting health status of 1.0 for a similar life-extending intervention). This is troubling because it imposes an additional penalty for those already suffering from disabling conditions. Brock (2002) notes that “the problem of disability discrimination represents a deep and unresolved problem for resource prioritization.”

OMB (2003) has recognized this issue in their Circular A-4 guidance, which includes the following statement:

> *When CEA is performed in specific rulemaking contexts, you should be prepared to make appropriate adjustments to ensure fair treatment of all segments of the population. Fairness is important in the choice and execution of effectiveness measures. For example, if QALYs are used to evaluate a lifesaving rule aimed at a population that happens to experience a high rate of disability (i.e., where the rule is not designed to affect the disability), the number of life years saved should not necessarily be diminished simply because the rule saves the lives of people with life-shortening disabilities. Both analytic simplicity and fairness suggest that the estimated number of life years saved for the disabled population should be based on average life expectancy information for the relevant age cohorts. More generally, when numeric adjustments are made for life expectancy or quality of life, analysts should prefer use of population averages rather than information derived from subgroups dominated by a particular demographic or income group. (p. 13)*

This suggests two adjustments to the standard QALY methodology: one adjusting the relevant life expectancy of the affected population, and the other affecting the baseline quality of life for the affected population.

In addition to the issue of fairness, potential measurement issues are specific to the air pollution context that might argue for caution in applying quality-of-life adjustments to life years gained due to air pollution reductions. A number of epidemiological and toxicological studies link exposure to air pollution with chronic diseases, such as CB and atherosclerosis (Abbey et al., 1995; Schwartz, 1993; Suwa et al., 2002). If these same individuals with chronic disease caused by exposure to air pollution are then at increased risk of premature death from air pollution, there is an important dimension of “double jeopardy” involved in determining the correct baseline for assessing QALYs lost to air pollution (see Singer et al. [1995] for a broader discussion of the double-jeopardy argument).

Analyses estimating mortality from acute exposures that ignore the effects of long-term exposure on morbidity may understate the health impacts of reducing air pollution. Individuals exposed to chronically elevated levels of air pollution may realize an increased risk of death and chronic disease throughout life. If at some age they contract heart (or some other chronic) disease as a result of the exposure to air pollution, they will from that point forward have both reduced life expectancy and reduced quality of life. The benefit to that individual from reducing lifetime exposure to air pollution would be the increase in life expectancy plus the increase in quality of life over the full period of increased life expectancy. If the QALY loss is determined based on the underlying chronic condition and life expectancy without regard to the fact that the person would never have been in that state without long-term exposure to elevated air pollution, then the person is placed in double jeopardy. In other words, air pollution has placed more people in the susceptible pool, but then we penalize those people in evaluating policies by treating their subsequent deaths as less valuable, adding insult to injury, and potentially downplaying the importance of life expectancy losses due to air pollution. If the risk of chronic disease and risk of death are considered together, then there is no conceptual problem with measuring QALYs, but this has not been the case in recent applications of QALYs to air pollution (Carrothers, Evans, and Graham, 2002; Coyle et al., 2003). The use of QALYs thus highlights the need for a better understanding of the relationship between chronic disease and long-term exposure and suggests that analyses need to consider morbidity and mortality jointly, rather than treating each as a separate endpoint (this is an issue for current benefit-cost approaches as well).

Because of the fairness and measurement concerns discussed above, for the purposes of this analysis, we do not reduce the number of life years gained to reflect any differences in underlying health status that might reduce quality of life in remaining years. Thus, we maintain the assumption that all direct gains in life years resulting from mortality risk reductions will be assigned a weight of 1.0. The U.S. Public Health Service Panel on Cost Effectiveness in Health and Medicine recommends that "since lives saved or extended by an intervention will not be in perfect health, a saved life year will count as less than 1 full QALY" (Gold et al., 1996). However, for the purposes of this analysis, we propose an alternative to the traditional aggregate QALY metric that keeps separate quality adjustments to life expectancy and gains in life expectancy. As such, we do not make any adjustments to life years gained to reflect the less than perfect health of the general population. Gains in quality of life will be addressed as they accrue because of reductions in the incidence of chronic diseases. This is an explicit equity choice in the treatment of issues associated with quality-of-life adjustments for increases in life expectancy that still capitalizes on the ability of QALYs to capture both morbidity and mortality impacts in a single effectiveness measure.

6b.5 Calculating Changes in the Quality of Life Years (Morbidity)

In addition to directly measuring the quantity of life gained, measured by life years, it may also be informative to measure gains in the quality of life. Reducing air pollution also leads to reductions in serious illnesses that affect quality of life. These include CB and cardiovascular disease, for which we are able to quantify changes in the incidence of nonfatal heart attacks. To capture these important benefits in the measure of effectiveness, they must first be converted into a life-year equivalent so that they can be combined with the direct gains in life expectancy.

For this analysis, we developed estimates of the QALYs gained from reductions in the incidence of CB and nonfatal heart attacks associated with reductions in ambient $PM_{2.5}$. In general, QALY calculations require four elements:

1. the estimated change in incidence of the health condition,
2. the duration of the health condition,
3. the quality-of-life weight with the health condition, and
4. the quality-of-life weight without the health condition (i.e., the baseline health state).

The first element is derived using the health impact function approach. The second element is based on the medical literature for each health condition. The third and fourth elements are derived from the medical cost-effectiveness and cost-utility literature. In the following two subsections, we discuss the choices of elements for CB and nonfatal heart attacks.

The preferred source of quality-of-life weights are those based on community preferences, rather than patient or clinician ratings (Gold et al., 1996). Several methods are used to estimate quality-of-life weights. These include rating scale, standard gamble, time trade-off, and person trade-off approaches (Gold, Stevenson, and Fryback, 2002). Only the standard gamble approach is completely consistent with utility theory. However, the time trade-off method has also been widely applied in eliciting community preferences (Gold, Stevenson, and Fryback, 2002).

Quality-of-life weights can be directly elicited for individual specific health states or for a more general set of activity restrictions and health states that can then be used to construct QALY weights for specific conditions (Horsman et al., 2003; Kind, 1996). For this analysis, we used weights based on community-based preferences, using time trade-off or standard gamble when available. In some cases, we used patient or clinician ratings when no community preference-based weights were available. Sources for weights are discussed in more detail below. Table G-4 summarizes the key inputs for calculating QALYs associated with chronic health endpoints.

6b.5.1 Calculating QALYs Associated with Reductions in the Incidence of Chronic Bronchitis

CB is characterized by mucus in the lungs and a persistent wet cough for at least 3 months a year for several years in a row. CB affects an estimated 5 percent of the U.S. population (American Lung Association, 1999). For gains in quality of life resulting from reduced incidences of PM-induced CB, discounted QALYs are calculated as

$$DISCOUNTED\ QALY\ GAINED \quad \sum_i \Delta CB_i \times D_i^* \times \ w_i - w_i^{CB}$$

where CB_i is the number of incidences of CB avoided in age interval i, w_i is the average QALY weight for age interval i, w_i^{CB} is the QALY weight associated with CB, D_i^* is the discounted duration of life with CB for individuals with onset of disease in age interval i, equal to $\int_{1}^{D_i} e^{-rt}dt$, where D_i is the duration of life with CB for individuals with onset of disease in age interval i.

A limited number of studies have estimated the impact of air pollution on new incidences of CB. Schwartz (1993) and Abbey et al. (1995) provide evidence that long-term PM exposure gives rise to the development of CB in the United States. Because this analysis focuses on the impacts of reducing ambient $PM_{2.5}$, only the Abbey et al. (1995) study is used, because it is the only study focusing on the relationship between $PM_{2.5}$ and new incidences of CB. The number of cases of CB in each age interval is derived from applying the impact function from Abbey et al. (1995), to the population in each age interval with the appropriate baseline incidence rate.[4] The effect estimate from the Abbey et al. (1995) study is 0.0137, which, based on the logistic

[4] Prevalence rates for CB were obtained from the 1999 National Health Interview Survey (American Lung Association, 2002). Prevalence rates were available for three age groups: 18–44, 45–64, and 65 and older. Prevalence rates per person for these groups were 0.0367 for 18–44, 0.0505 for 45–64, and 0.0587 for 65 and older. The incidence rate for new cases of CB (0.00378 per person) was taken directly from Abbey et al. (1995).

specification of the model, is equivalent to a relative risk of 1.15 for a 10 µg change in $PM_{2.5}$. Table G-5 presents the estimated reduction in new incidences of CB associated with the illustrative PM NAAQS attainment strategies.

Table 6b-4: Summary of Key Parameters Used in QALY Calculations for Chronic Disease Endpoints

Parameter	*Value(s)*	*Source(s)*
Discount rate	0.03 (0.07 sensitivity analysis)	Gold et al. (1996), U.S. EPA (2000), U.S. OMB (2003)
Quality of life preference score for chronic bronchitis	0.5 – 0.7	Triangular distribution centered at 0.7 with upper bound at 0.9 (Vos, 1999a) (slightly better than a mild/moderate case) and a lower bound at 0.5 (average weight for a severe case based on Vos [1999a] and Smith and Peske [1994])
Duration of acute phase of acute myocardial infarction (AMI)	5.5 days – 22 days	Uniform distribution with lower bound based on average length of stay for an AMI (AHRQ, 2000) and upper bound based on Vos (1999b).
Probability of CHF post AMI	0.2	Vos, 1999a (WHO Burden of Disease Study, based on Cowie et al., 1997)
Probability of angina post AMI	0.51	American Heart Association, 2003 (Calculated as the population with angina divided by the total population with heart disease)
Quality-of-life preference score for post-AMI with CHF (no angina)	0.80 – 0.89	Uniform distribution with lower bound at 0.80 (Stinnett et al., 1996) and upper bound at 0.89 (Kuntz et al., 1996). Both studies used the time trade-off elicitation method.
Quality-of-life preference score for post-AMI with CHF and angina	0.76 – 0.85	Uniform distribution with lower bound at 0.76 (Stinnett et al., 1996, adjusted for severity) and upper bound at 0.85 (Kuntz et al., 1996). Both studies used the time trade-off elicitation method.
Quality-of-life preference score for post-AMI with angina (no CHF)	0.7 – 0.89	Uniform distribution with lower bound at 0.7, based on the standard gamble elicitation method (Pliskin, Stason, and Weinstein, 1981) and upper bound at 0.89, based on the time trade-off method (Kuntz et al., 1996).
Quality-of-life preference score for post-AMI (no angina, no CHF)	0.93	Only one value available from the literature. Thus, no distribution is specified. Source of value is Kuntz et al. (1996).

CB is assumed to persist for the remainder of an affected individual's lifespan. Duration of CB will thus equal life expectancy conditioned on having CB. CDC has estimated that COPD (of which CB is one element) results in an average loss of life years equal to 4.26 per COPD death, relative to a reference life expectancy of 75 years (CDC, 2003). Thus, we subtract 4.26 from the remaining life expectancy for each age group, up to age 75. For age groups over 75, we apply the ratio of 4.26 to the life expectancy for the 65 to 74 year group (0.237) to the life expectancy for the 75 to 84 and 85 and up age groups to estimate potential life years lost and then subtract that value from the base life expectancy.

Table 6b-5: Estimated Reduction in Incidence of Chronic Bronchitis Associated with Illustrative Attainment Strategies for the Revised and More Stringent Alternative PM NAAQS in 2020

	Reduction in Incidence (95% Confidence Interval)
Age Interval	*070 ppm Partial Attainment Strategy*
25 – 34	74 (14 – 140)
35 – 44	85 (16 – 160)
45 – 54	82 (15 – 150)
55 – 64	88 (16 – 160)
65 – 74	62 (12 – 640)
75 – 84	31 (6 – 56)
85+	14 (3 – 25)
Total	440 (80 – 790)

Quality of life with chronic lung diseases has been examined in several studies. In an analysis of the impacts of environmental exposures to contaminants, de Hollander et al. (1999) assigned a weight of 0.69 to years lived with CB. This weight was based on physicians' evaluations of health states similar to CB. Salomon and Murray (2003) estimated a pooled weight of 0.77 based on visual analogue scale, time trade-off, standard gamble, and person trade-off techniques applied to a convenience sample of health professionals. The Harvard Center for Risk Analysis catalog of preference scores reports a weight of 0.40 for severe COPD, with a range from 0.2 to 0.8, based on the judgments of the study's authors (Bell et al., 2001). The Victoria Burden of Disease (BoD) study used a weight of 0.47 for severe COPD and 0.83 for mild to moderate COPD, based on an analysis by Stouthard et al. (1997) of chronic diseases in Dutch populations (Vos, 1999a). Based on the recommendations of Gold et al. (1996), quality-of-life weights based on community preferences are preferred for CEA of interventions affecting broad populations. Use of weights based on health professionals is not recommended. It is not clear from the Victoria BoD study whether the weights used for COPD are based on community preferences or judgments of health professionals. The Harvard catalog score is clearly identified as based on author judgment. Given the lack of a clear preferred weight, we select a triangular distribution centered at 0.7 with an upper bound at 0.9 (slightly better than a mild/moderate case defined by the Victoria BoD study) and a lower bound at 0.5 based on the Victoria BoD study. We will need additional empirical data on quality of life with chronic respiratory diseases based on community preferences to improve our estimates.

Selection of a reference weight for the general population without CB is somewhat uncertain. It is clear that the general population is not in perfect health; however, there is some uncertainty as to whether individuals' ratings of health states are in reference to a perfect health state or to a generally achievable "normal" health state given age and general health status. The U.S. Public Health Service Panel on Cost Effectiveness in Health and Medicine recommends that "since lives saved or extended by an intervention will not be in perfect health, a saved life year will count as less than 1 full QALY" (Gold et al., 1996). Following Carrothers, Evans, and Graham (2002), we assumed that the reference weight for the general population without CB is 0.95. To allow for uncertainty in this parameter, we assigned a triangular distribution around this weight, bounded by 0.9 and 1.0. Note that the reference weight for the general population is used solely to determine the incremental quality-of-life improvement applied to the duration of life that would have been lived with the chronic disease. For example, if CB has a quality-of-life weight of 0.7 relative to a reference quality-of-life weight of 0.9, then the incremental quality-of-life improvement in 0.2. If the reference quality-of-life weight is 0.95, then the incremental quality-of-life improvement is 0.25. As noted above, the population is assumed to have a reference weight of 1.0 for all life years gained due to mortality risk reductions.

We present discounted QALYs over the duration of the lifespan with CB using a 3 percent discount rate. Based on the assumptions defined above, we used Monte Carlo simulation methods as implemented in the Crystal Ball™ software program to develop the distribution of QALYs gained per incidence of CB for each age interval.[5] Based on the assumptions defined above, the mean 3 percent discounted QALY gained per incidence of CB for each age interval along with the 95 percent confidence interval resulting from the Monte Carlo simulation is presented in Table G-6. Table G-6 presents both the undiscounted and discounted QALYs gained per incidence.

---

[5] Monte Carlo simulation uses random sampling from distributions of parameters to characterize the effects of uncertainty on output variables. For more details, see Gentile (1998).

Table 6b-6: QALYs Gained per Avoided Incidence of CB

Age Interval		*QALYs Gained per Incidence*	
Start Age	*End Age*	*Undiscounted*	*Discounted (3%)*
25	34	12.15 (4.40-19.95)	6.52 (2.36-10.71)
35	44	9.91 (3.54-16.10)	5.94 (2.12-9.66)
45	54	7.49 (2.71-12.34)	5.03 (1.82-8.29)
55	64	5.36 (1.95-8.80)	4.03 (1.47-6.61)
65	74	3.40 (1.22-5.64)	2.84 (1.02-4.71)
75	84	2.15 (0.77-3.49)	1.92 (0.69-3.13)
85+		0.79 (0.27-1.29)	0.77 (0.26-1.25)

6b.5.2 Calculating QALYs Associated with Reductions in the Incidence of Nonfatal Myocardial Infarctions

Nonfatal heart attacks, or acute myocardial infarctions, require more complicated calculations to derive estimates of QALY impacts. The actual heart attack, which results when an area of the heart muscle dies or is permanently damaged because of oxygen deprivation, and subsequent emergency care are of relatively short duration. Many heart attacks result in sudden death. However, for survivors, the long-term impacts of advanced CHD are potentially of long duration and can result in significant losses in quality of life and life expectancy.

In this phase of the analysis, we did not independently estimate the gains in life expectancy associated with reductions in nonfatal heart attacks. Based on recommendations from the SAB-HES, we assumed that all gains in life expectancy are captured in the estimates of reduced mortality risk provided by the Pope et al. (2002) analysis. We only estimate the change in quality of life over the period of life affected by the occurrence of a heart attack. This may understate the QALY impacts of nonfatal heart attacks but ensures that the overall QALY impact estimates across endpoints do not double-count potential life-year gains.

Our approach adapts a CHD model developed for the Victoria Burden of Disease study (Vos, 1999b). This model accounts for the lost quality of life during the heart attack and the possible health states following the heart attack. Figure G-1 shows the heart attack QALY model in diagrammatic form.

The total gain in QALYs is calculated as:

DISCOUNTED AMI QALY GAINED

$$\sum_{i} \Delta AMI_i \times D_i^{*AMI} \times \; w_i - w_i^{AMI} \; + \sum_{i} \sum_{j \; 1}^{4} \; \Delta AMI_i \times p_j D_{ij}^{*PostAMI} \times \; w_i - w_{ij}^{postAMI}$$

where AMI_i is the number of nonfatal acute myocardial infarctions avoided in age interval *i*, w_i^{AMI} is the QALY weight associated with the acute phase of the AMI, p_j is the probability of being in the *j*th post-AMI status, $w_{ij}^{postAMI}$ is the QALY weight associated with post-AMI health status *j*, w_i is the average QALY weight for age interval i, $D_i^{*AMI} \quad \int_{t \; 1}^{D_i^{AMI}} e^{-rt} dt$, the discounted value of D_i^{AMI}, the duration of the acute phase of the AMI, and $D_i^{*postAMI} \quad \int_{t \; 1}^{D_i^{postAMI}} e^{-rt} dt$, is the discounted value of $D_{ij}^{PostAMI}$, the duration of post-AMI health status *j*.

Deleted: <sp>

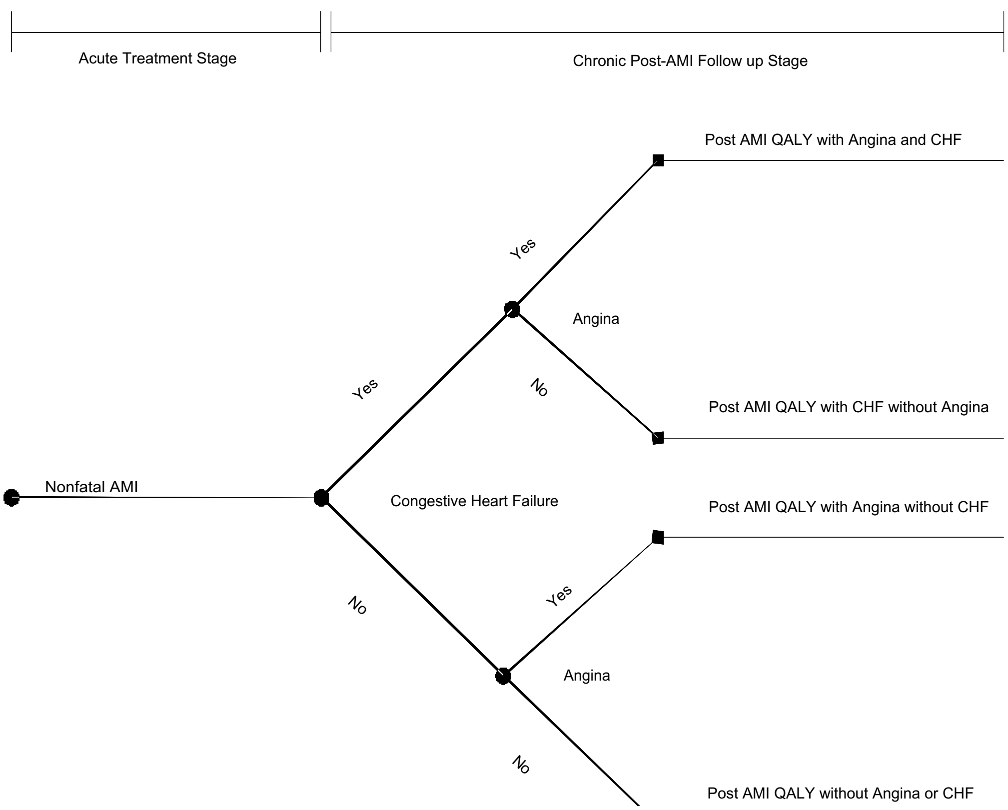


Figure 6b-1. Decision Tree Used in Modeling Gains in QALYs from Reduced Incidence of Nonfatal Acute Myocardial Infarctions

Nonfatal heart attacks have been linked with short-term exposures to $PM_{2.5}$ in the United States (Peters et al., 2001) and other countries (Poloniecki et al., 1997). We used a recent study by Peters et al. (2001) as the basis for the impact function estimating the relationship between $PM_{2.5}$ and nonfatal heart attacks. Peters et al. is the only available U.S. study to provide a specific estimate for heart attacks. Other studies, such as Samet et al. (2000) and Moolgavkar (2000), show a consistent relationship between all cardiovascular hospital admissions, including for nonfatal heart attacks, and PM. Given the lasting impact of a heart attack on longer-term health costs and earnings, we chose to provide a separate estimate for nonfatal heart attacks based on the single available U.S. effect estimate. The finding of a specific impact on heart attacks is consistent with hospital admission and other studies showing relationships between fine particles and cardiovascular effects both within and outside the United States. These studies provide a weight of evidence for this type of effect. Several epidemiologic studies (Liao et al., 1999; Gold et al., 2000; Magari et al., 2001) have shown that heart rate variability (an indicator of how much the heart is able to speed up or slow down in response to momentary stresses) is negatively related to PM levels. Heart rate variability is a risk factor for heart attacks and other CHDs (Carthenon et al., 2002; Dekker et al., 2000; Liao et al., 1997, Tsuji et al., 1996). As such, significant impacts of PM on heart rate variability are consistent with an increased risk of heart attacks.

The number of avoided nonfatal AMI in each age interval is derived from applying the impact function from Peters et al. (2001) to the population in each age interval with the appropriate baseline incidence rate.[6] The effect estimate from the Peters et al. (2001) study is 0.0241, which, based on the logistic specification of the model, is equivalent to a relative risk of 1.27 for a 10 μg change in $PM_{2.5}$. Table 6b-7 presents the estimated reduction in nonfatal AMI associated with the illustrative Ozone NAAQS attainment strategies.

[6] Daily nonfatal myocardial infarction incidence rates per person were obtained from the 1999 National Hospital Discharge Survey (assuming all diagnosed nonfatal AMI visit the hospital). Age-specific rates for four regions are used in the analysis. Regional averages for populations 18 and older are 0.0000159 for the Northeast, 0.0000135 for the Midwest, 0.0000111 for the South, and 0.0000100 for the West.

Table 6b-7: Estimated Reduction in Nonfatal Acute Myocardial Infarctions Associated with Illustrative Attainment Strategies for the Revised and More Stringent Alternative PM NAAQS in 2020

	Reduction in Incidence(95% Confidence Interval)*
Age Interval	*070 ppm Attainment Strategy*
18 – 24	1 (1 – 2)
25 – 34	4 (3 – 6)
35 – 44	37 (20 – 53)
45 – 54	110 (61 – 170)
55 – 64	290 (160 – 430)
65 – 74	350 (190 – 500)
75 – 84	280 (150 – 410)
85+	150 (80 – 220)
Total	1,200 (660 – 1,800)

Acute myocardial infarction results in significant loss of quality of life for a relatively short duration. The WHO Global Burden of Disease study, as reported in Vos (1999b), assumes that the acute phase of an acute myocardial infarction lasts for 0.06 years, or around 22 days. An alternative assumption is the acute phase is characterized by the average length of hospital stay for an AMI in the United States, which is 5.5 days, based on data from the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project (HCUP).[7] We assumed a distribution of acute phase duration characterized by a uniform distribution between 5.5 and 22 days, noting that due to earlier discharges and in-home therapy available in the United States, duration of reduced quality of life may continue after discharge from the hospital. In the period during and directly following an AMI (the acute phase), we assigned a quality of life weight equal to 0.605, consistent with the weight for the period in treatment during and immediately after an attack (Vos, 1999b).

During the post-AMI period, a number of different health states can determine the loss in quality of life. We chose to classify post-AMI health status into four states defined by the presence or absence of angina and congestive heart failure (CHF). This makes a very explicit assumption that without the occurrence of an AMI, individuals would not experience either angina or CHF.

[7] Average length of stay estimated from the HCUP data includes all discharges, including those due to death. As such, the 5.5-day average length of stay is likely an underestimate of the average length of stay for AMI admissions where the patient is discharged alive.

If in fact individuals already have CHF or angina, then the quality of life gained will be overstated. We do not have information about the percentage of the population have been diagnosed with angina or CHF with no occurrence of an AMI. Nor do we have information on what proportion of the heart attacks occurring due to PM exposure are first heart attacks versus repeat attacks. Probabilities for the four post-AMI health states sum to one.

Given the occurrence of a nonfatal AMI, the probability of congestive heart failure is set at 0.2, following the heart disease model developed by Vos (1999b). The probability is based on a study by Cowie et al. (1997), which estimated that 20 percent of those surviving AMI develop heart failure, based on an analysis of the results of the Framingham Heart Study.

The probability of angina is based on the prevalence rate of angina in the U.S. population. Using data from the American Heart Association, we calculated the prevalence rate for angina by dividing the estimated number of people with angina (6.6 million) by the estimated number of people with CHD of all types (12.9 million). We then assumed that the prevalence of angina in the population surviving an AMI is similar to the prevalence of angina in the total population with CHD. The estimated prevalence rate is 51 percent, so the probability of angina is 0.51.

Combining these factors leads to the probabilities for each of the four health states as follows:

I. Post AMI with CHF and angina = 0.102

II. Post AMI with CHF without angina = 0.098

III. Post AMI with angina without CHF = 0.408

IV. Post AMI without angina or CHF = 0.392

Duration of post-AMI health states varies, based in part on assumptions regarding life expectancy with post-AMI complicating health conditions. Based on the model used for established market economies (EME) in the WHO Global Burden of Disease study, as reported in Vos (1999b), we assumed that individuals with CHF have a relatively short remaining life expectancy and thus a relatively short period with reduced quality of life (recall that gains in life expectancy are assumed to be captured by the cohort estimates of reduced mortality risk). Table 6b-8 provides the duration (both discounted and undiscounted) of CHF assumed for post-AMI cases by age interval.

Table 6b-8: Assumed Duration of Congestive Heart Failure

Age Interval		*Duration of Heart Failure (years)*	
Start Age	*End Age*	*Undiscounted*	*Discounted (3%)*
18	24	7.11	6.51
25	34	6.98	6.40
35	44	6.49	6.00
45	54	5.31	4.99
55	64	1.96	1.93
65	74	1.71	1.69
75	84	1.52	1.50
85+		1.52	1.50

Duration of health states without CHF is assumed to be equal to the life expectancy of individuals conditional on surviving an AMI. Ganz et al. (2000) note that "Because patients with a history of myocardial infarction have a higher chance of dying of CHD that is unrelated to recurrent myocardial infarction (for example, arrhythmia), this cohort has a higher risk for death from causes other than myocardial infarction or stroke than does an unselected population." They go on to specify a mortality risk ratio of 1.52 for mortality from other causes for the cohort of individuals with a previous (nonfatal) AMI. The risk ratio is relative to all-cause mortality for an age-matched unselected population (i.e., general population). We adopted the same ratios and applied them to each age-specific all-cause mortality rate to derive life expectancies (both discounted and undiscounted) for each age group after an AMI, presented in Table 6b-9. These life expectancies are then used to represent the duration of non-CHF post-AMI health states (III and IV).

Table 6b-9: Assumed Duration of Non-CHF Post-AMI Health States

Age Interval		*Post-AMI Years of Life Expectancy (non-CHF)*	
Start Age	*End Age*	*Undiscounted*	*Discounted (3%)*
18	24	55.5	27.68
25	34	46.1	25.54
35	44	36.8	22.76
45	54	27.9	19.28
55	64	19.8	15.21
65	74	12.8	10.82
75	84	7.4	6.75
85+		3.6	3.47

For the four post-AMI health states, we used QALY weights based on preferences for the combined conditions characterizing each health state. A number of estimates of QALY weights are available for post-AMI health conditions.

The first two health states are characterized by the presence of CHF, with or without angina. The Harvard Center for Risk Analysis catalog of preference scores provides several specific weights for CHF with and without mild or severe angina and one set specific to post-AMI CHF. Following the Victoria Burden of Disease model, we assumed that most cases of angina will be treated and thus kept at a mild to moderate state. We thus focused our selection on QALY weights for mild to moderate angina. The Harvard database includes two sets of community preference-based scores for CHF (Stinnett et al., 1996; Kuntz et al., 1996). The scores for CHF with angina range from 0.736 to 0.85. The lower of the two scores is based on angina in general with no delineation by severity. Based on the range of the scores for mild to severe cases of angina in the second study, one can infer that an average case of angina has a score around 0.96 of the score for a mild case. Applying this adjustment raises the lower end of the range of preference scores for a mild case of angina to 0.76. We selected a uniform distribution over the range 0.76 to 0.85 for CHF with mild angina, with a midpoint of 0.81. The same two studies in the Harvard catalog also provide weights for CHF without angina. These scores range from 0.801 to 0.89. We selected a uniform distribution over this range, with a midpoint of 0.85.

The third health state is characterized by angina, without the presence of CHF. The Harvard catalog includes five sets of community preference-based scores for angina, one that specifies scores for both mild and severe angina (Kuntz et al., 1996), one that specifies mild angina only (Pliskin, Stason, and Weinstein, 1981), one that specifies severe angina only (Cohen, Breall, and Ho, 1994), and two that specify angina with no severity classification (Salkeld, Phongsavan, and Oldenburg, 1997; Stinnett et al., 1996). With the exception of the Pliskin, Stason, and Weinstein score, all of the angina scores are based on the time trade-off method of elicitation. The Pliskin, Stason, and Weinstein score is based on the standard gamble elicitation method. The scores for the nonspecific severity angina fall within the range of the two scores for mild angina specifically. Thus, we used the range of mild angina scores as the endpoints of a uniform distribution. The range of mild angina scores is from 0.7 to 0.89, with a midpoint of 0.80.

For the fourth health state, characterized by the absence of CHF and/or angina, there is only one relevant community preference score available from the Harvard catalog. This score is 0.93, derived from a time trade-off elicitation (Kuntz et al., 1996). Insufficient information is available to provide a distribution for this weight; therefore, it is treated as a fixed value.

Similar to CB, we assumed that the reference weight for the general population without AMI is 0.95. To allow for uncertainty in this parameter, we assigned a triangular distribution around this weight, bounded by 0.9 and 1.0.

Based on the assumptions defined above, we used Monte Carlo simulation methods as implemented in the Crystal Ball™ software program to develop the distribution of QALYs gained per incidence of nonfatal AMI for each age interval. For the Monte Carlo simulation, all distributions were assumed to be independent. The mean QALYs gained per incidence of nonfatal AMI for each age interval is presented in Table 6b-10, along with the 95 percent confidence interval resulting from the Monte Carlo simulation. Table 6b-10 presents both the undiscounted and discounted QALYs gained per incidence.

Table 6b-10: QALYs Gained per Avoided Nonfatal Myocardial Infarction

Age Interval		*QALYs Gained per Incidence*[a]	
Start Age	*End Age*	*Undiscounted*	*Discounted (3%)*
18	24	4.18 (1.24-7.09)	2.17 (0.70-3.62)
25	34	3.48 (1.09-5.87)	2.00 (0.68-3.33)
35	44	2.81 (0.88-4.74)	1.79 (0.60-2.99)
45	54	2.14 (0.67-3.61)	1.52 (0.51-2.53)
55	64	1.49 (0.42-2.52)	1.16 (0.34-1.95)
65	74	0.97 (0.30-1.64)	0.83 (0.26-1.39)
75	84	0.59 (0.20-0.97)	0.54 (0.19-0.89)
85+		0.32 (0.13-0.50)	0.31 (0.13-0.49)

[a] Mean of Monte Carlo generated distribution; 95% confidence interval presented in parentheses.

6b.6 Cost-Effectiveness Analysis

Given the estimates of changes in life expectancy and quality of life, the next step is to aggregate life expectancy and quality-of-life gains to form an effectiveness measure that can be compared to costs to develop cost-effectiveness ratios. This section discusses the proper characterization of the combined effectiveness measure and the appropriate calculation of the numerator of the cost-effectiveness ratio.

6b.6.1 Aggregating Life Expectancy and Quality-of-Life Gains

To develop an integrated measure of changes in health, we simply sum together the gains in life years from reduced mortality risk in each age interval with the gains in QALYs from reductions in incidence of CB and acute myocardial infarctions. The resulting measure of effectiveness then forms the denominator in the cost-effectiveness ratio. What is this combined measure of effectiveness? It is not a QALY measure in a strict sense, because we have not adjusted life-expectancy gains for preexisting health status (quality of life). It is however, an effectiveness measure that adds to the standard life years calculation a scaled morbidity equivalent. Thus, we term the aggregate measure morbidity inclusive life years, or MILYs. Alternatively, the combined measure could be considered as QALYs with an assumption that the community preference weight for all life-expectancy gains is 1.0. If one considers that this weight might be considered to be a “fair” treatment of those with preexisting disabilities, the effectiveness measure might be termed “fair QALY” gained. However, this implies that all aspects of fairness have been addressed, and there are clearly other issues with the fairness of QALYs (or other effectiveness measures) that are not addressed in this simple adjustment. The MILY measure violates some of the properties used in deriving QALY weights, such as linear substitution between quality of life and quantity of life. However, in aggregating life expectancy and quality-of-life gains, it merely represents an alternative social weighting that is consistent with the spirit of the recent OMB guidance on CEA. The guidance notes that "fairness is important in the choice and execution of effectiveness measures" (OMB, 2003). The resulting aggregate measure of effectiveness will not be consistent with a strict utility interpretation of QALYs; however, it may still be a useful index of effectiveness.

Applying the life expectancies and distributions of QALYs per incidence for CB and AMI to estimated distributions of incidences yields distributions of life expectancy and QALYs gained due to the Ozone NAAQS illustrative attainment strategies. These distributions reflect both the quantified uncertainty in incidence estimates and the quantified uncertainty in QALYs gained per incidence.

For the attainment strategy for the revised 070 ppm standards, Table 6b-11 presents the mean 3 percent discounted MILYs gained for each age interval, broken out by life expectancy and quality-of-life categories. Note that quality-of-life gains occur from age 18 and up, while life expectancy gains accrue only after age 29. This is based on the ages of the study populations in the underlying epidemiological studies. It is unlikely that such discontinuities exist in reality, but to avoid overstating effectiveness, we chose to limit the life-expectancy gains to those occurring in the population 30 and over and the morbidity gains to the specific adult populations examined in the studies.

It is worth noting that around a third of mortality-related benefits are due to reductions in premature deaths among those 75 and older, while only 7 percent of morbidity benefits occur in this age group. This is due to two factors: (1) the relatively low baseline mortality rates in populations under 75, and (2) the relatively constant baseline rates of chronic disease coupled with the relatively long period of life that is lived with increased quality of life without CB and advanced heart disease.

The relationship between age and the distribution of MILYs gained from mortality and morbidity is shown for the 070 ppm attainment strategy in Figure _-2. Because the baseline mortality rate is increasing in age at a much faster rate than the prevalence rate for CB, the share of MILYs gained accounted for by mortality is proportional to age. At the oldest age interval, avoiding incidences of CB leads to only a few MILYs gained, due to the lower number of years lived with CB. MILYs gained from avoided premature mortality is low in the youngest age intervals because of the low overall mortality rates in these intervals, although the number of MILYs per incidence is high. In later years, even though the MILYs gained per incidence avoided is low, the number of cases is very high due to higher baseline mortality rates.

Table 6b-11. Estimated Gains in 3 Percent Discounted MILYs Associated with Illustrative Attainment Strategies for the Revised Ozone NAAQS (0.070 ppm) in 2020: Pope (2002) Estimate of Mortality[a]

Age	*Life Years Gained from Mortality Risk Reductions (95% CI)*	*QALY Gained from Reductions in Chronic Bronchitis (95% CI)*	*QALY Gained from Reductions in Acute Myocardial Infarctions (95% CI)*	*Total Gain in MILYs (95% CI)*
18–24	—	—	3 (1 – 5)	3 (1 – 5)
25–34	100 (41 – 170)	490 (91 – 1,100)	8 (3 – 15)	600 (130 – 1,200)
35–44	310 (120 – 490)	500 (93 – 1,100)	70 (23 – 120)	870 (240 – 1,700)
45–54	580 (230 – 930)	420 (77 – 890)	170 (60 – 320)	1,200 (360 – 2,100)
55–64	1,300 (500 – 2,100)	350 (64 – 760)	330 (110 – 620)	2,000 (680 – 3,400)
65–74	1,700 (680 – 2,800)	180 (33 – 380)	280 (100 – 530)	2,200 (810 – 3,700)
75–84	1,400 (540 – 2,200)	60 (11 – 130)	150 (54 – 280)	1,600 (610 – 2,600)
85+	690 (270 – 1,100)	10 (2 – 22)	43 (16 – 80)	740 (290 – 1,200)
Total	6,100 (2,400 – 9,800)	2,000 (370 – 4,300)	1,100 (370 – 2,000)	9,100 (3,100 – 16,000)

[a] Note that all estimates have been rounded to two significant digits.

Table 6b-12. Estimated Gains in 3 Percent Discounted MILYs Associated with Illustrative Attainment Strategies for the Revised Ozone NAAQS (0.070 ppm) in 2020: Laden (2006) Estimate of Mortality[a]

Age	*Life Years Gained from Mortality Risk Reductions (95% CI)*	*QALY Gained from Reductions in Chronic Bronchitis (95% CI)*	*QALY Gained from Reductions in Acute Myocardial Infarctions (95% CI)*	*Total Gain in MILYs (95% CI)*
18–24	—	—	3 (1 – 5)	3 (1 – 5)
25–34	240 (130 – 340)	490 (91 – 1,100)	8 (3 – 15)	730 (220 – 1,400)
35–44	690 (380 – 1,000)	500 (93 – 1,100)	70 (23 – 120)	1,300 (490 – 2,200)
45–54	1,400 (710 – 1,900)	420 (77 – 890)	170 (60 – 320)	1,900 (850 – 3,100)
55–64	2,900 (1,600 – 4,200)	350 (64 – 760)	330 (110 – 620)	3,600 (1,800 – 5,600)
65–74	3,900 (2,100 – 5,700)	180 (33 – 380)	280 (100 – 530)	4,400 (2,300 – 6,600)
75–84	3,100 (1,700 – 4,600)	60 (11 – 130)	150 (54 – 280)	3,300 (1,800 – 5,000)
85+	1,600 (840 – 2,300)	10 (2 – 22)	43 (16 – 80)	1,600 (860 – 2,400)
Total	14,000 (7,500 – 20,000)	2,000 (370 – 4,300)	1,100 (370 – 2,000)	17,000 (8,200 – 26,000)

[a] Note that all estimates have been rounded to two significant digits.

Summing over the age intervals provides estimates of total MILYs gained for the Ozone NAAQS illustrative attainment strategies. The total number of discounted (3 percent) MILYs gained for the 070 ppm attainment strategy using the Pope (2002) estimate is 9,100 (95% CI: 3,100 – 16,000). Using the Laden (2006) estimate, the total number of discounted (3 percent) MILYs is 17,000 (95% CI: 8,200 – 26,000).

6b.6.2 Dealing with Acute Health Effects and Non-health Effects

Health effects from exposure to particulate air pollution encompass a wide array of chronic and acute conditions in addition to premature mortality (EPA, 1996). Although chronic conditions and premature mortality generally account for the majority of monetized benefits, acute symptoms can affect a broad population or sensitive populations (e.g., asthma exacerbations in asthmatic children. In addition, reductions in air pollution may result in a broad set of nonhealth environmental benefits, including improved visibility in national parks, increased agricultural and forestry yields, reduced acid damage to buildings, and a host of other impacts. QALYs address only health impacts, and the OMB guidance notes that "where regulation may yield several different beneficial outcomes, a cost-effectiveness comparison becomes more difficult to interpret because there is more than one measure of effectiveness to incorporate in the analysis."

With regard to acute health impacts, Bala and Zarkin (2000) suggest that QALYs are not appropriate for valuing acute symptoms, because of problems with both measuring utility for acute health states and applying QALYs in a linear fashion to very short duration health states. Johnson and Lievense (2000) suggest using conjoint analysis to get healthy-utility time equivalences that can be compared across acute effects, but it is not clear how these can be combined with QALYs for chronic effects and loss of life expectancy. There is also a class of effects that EPA has traditionally treated as acute, such as hospital admissions, which may also result in a loss of quality of life for a period of time following the effect. For example, life after asthma hospitalization has been estimated with a utility weight of 0.93 (Bell et al., 2001; Kerridge, Glasziou, and Hillman, 1995).

How should these effects be combined with QALYs for chronic and mortality effects? One method would be to convert the acute effects to QALYs; however, as noted above, there are problems with the linearity assumption (i.e., if a year with asthma symptoms is equivalent to 0.7 year without asthma symptoms, then 1 day without asthma symptoms is equivalent to 0.0019 QALY gained). This is troubling from both a conceptual basis and a presentation basis. An alternative approach is simply to treat acute health effects like nonhealth benefits and subtract the dollar value (based on WTP or COI) from compliance costs in the CEA.

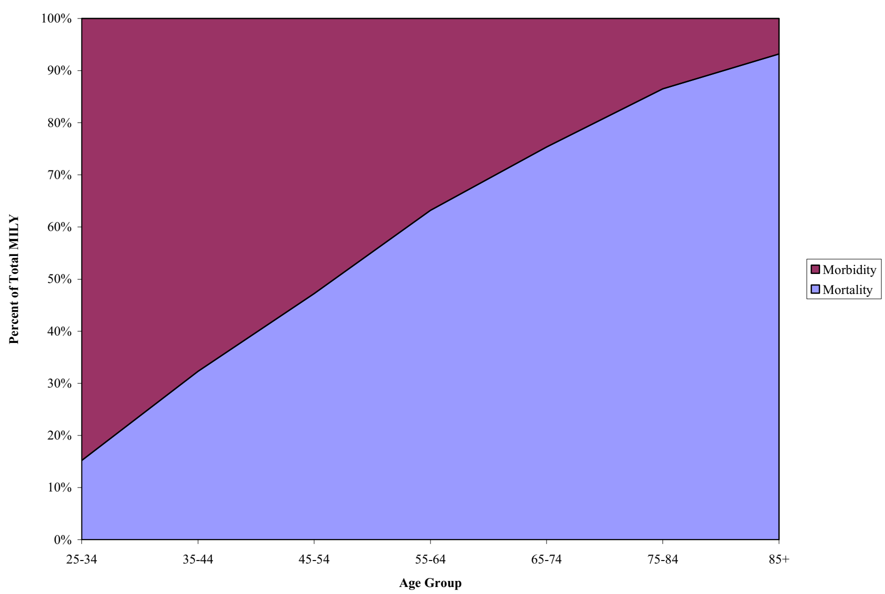


Figure 6b-2. Distribution of Mortality and Morbidity Related MILY Across Age Groups for Illustrative Attainment Strategy for the Revised PM NAAQS (3 percent Discount Rate)

To address the issues of incorporating acute morbidity and nonhealth benefits, OMB suggests that agencies "subtract the monetary estimate of the ancillary benefits from the gross cost estimate to yield an estimated net cost." As with benefit-cost analysis, any unquantified benefits and/or costs should be noted and an indication of how they might affect the cost-effectiveness ratio should be described. We will follow this recommended "net cost" approach in the illustrative exercise, specifically in netting out the benefits of health improvements other than reduced mortality and chronic morbidity, and the benefits of improvements in visibility at national parks (see Chapter 5 for more details on these benefit categories).

6b.6.3 Cost-Effectiveness Ratios

Construction of cost-effectiveness ratios requires estimates of effectiveness (in this case measured by lives saved, life years gained, or MILYs gained) in the denominator and estimates of costs in the numerator. The estimate of costs in the numerator should include both the direct costs of the controls necessary to achieve the reduction in ambient $PM_{2.5}$ and the avoided costs (cost savings) associated with the reductions in morbidity (Gold et al., 1996). In general, because reductions in air pollution do not require direct actions by the affected populations, there are no specific costs to affected individuals (aside from the overall increases in prices that might be expected to occur as control costs are passed on by affected industries). Likewise, because individuals do not engage in any specific actions to realize the health benefit of the pollution reduction, there are no decreases in utility (as might occur from a medical intervention) that need to be adjusted for in the denominator. Thus, the elements of the numerator are direct costs of controls minus the avoided COI associated with CB and nonfatal AMI. In addition, to account for the value of reductions in acute health impacts and nonhealth benefits, we net out the monetized value of these benefits from the numerator to yield a "net cost" estimate. For the MILY aggregate effectiveness measure, the denominator is simply the sum of life years gained from increased life expectancy and the sum of QALYs gained from the reductions in CB and nonfatal AMI.

Avoided costs for CB and nonfatal AMI are based on estimates of lost earnings and medical costs.[8] Using age-specific annual lost earnings and medical costs estimated by Cropper and Krupnick (1990) and a 3 percent discount rate, we estimated a lifetime present discounted value (in 2000$) due to CB of $150,542 for someone between the ages of 27 and 44; $97,610 for someone between the ages of 45 and 64; and $11,088 for someone over 65. The corresponding age-specific estimates of lifetime present discounted value (in 2000$) using a 7 percent discount rate are $86,026, $72,261, and $9,030, respectively. These estimates assumed that 1) lost earnings continue only until age 65, 2) medical expenditures are incurred until death, and 3) life expectancy is unchanged by CB.

Because the costs associated with a myocardial infarction extend beyond the initial event itself, we consider costs incurred over several years. Using age-specific annual lost earnings estimated by Cropper and Krupnick (1990) and a 3 percent discount rate, we estimated a present

---

[8] Gold et al. (1996) recommend not including lost earnings in the cost-of-illness estimates, suggesting that in some cases, they may be already be counted in the effectiveness measures. However, this requires that individuals fully incorporate the value of lost earnings and reduced labor force participation opportunities into their responses to time-tradeoff or standard-gamble questions. For the purposes of this analysis and for consistency with the way costs-of-illness are calculated for the benefit-cost analysis, we have assumed that individuals do not incorporate lost earnings in responses to these questions. This assumption can be relaxed in future analyses with improved understanding of how lost earnings are treated in preference elicitations.

discounted value in lost earnings (in 2000$) over 5 years due to a myocardial infarction of $8,774 for someone between the ages of 25 and 44, $12,932 for someone between the ages of 45 and 54, and $74,746 for someone between the ages of 55 and 65. The corresponding age-specific estimates of lost earnings (in 2000$) using a 7 percent discount rate are $7,855, $11,578, and $66,920, respectively. Cropper and Krupnick (1990) do not provide lost earnings estimates for populations under 25 or over 65. Thus, we do not include lost earnings in the cost estimates for these age groups.

Two estimates of the direct medical costs of myocardial infarction are used. The first estimate is from Wittels, Hay, and Gotto (1990), which estimated expected total medical costs of MI over 5 years to be $51,211 (in 1986$) for people who were admitted to the hospital and survived hospitalization (there does not appear to be any discounting used). Using the CPI-U for medical care, the Wittels estimate is $109,474 in year 2000$. This estimated cost is based on a medical cost model, which incorporated therapeutic options, projected outcomes, and prices (using "knowledgeable cardiologists" as consultants). The model used medical data and medical decision algorithms to estimate the probabilities of certain events and/or medical procedures being used. The second estimate is from Russell et al. (1998), which estimated first-year direct medical costs of treating nonfatal myocardial infarction of $15,540 (in 1995$), and $1,051 annually thereafter. Converting to year 2000$, that would be $23,353 for a 5-year period (without discounting).

The two estimates from these studies are substantially different, and we have not adequately resolved the sources of differences in the estimates. Because the wage-related opportunity cost estimates from Cropper and Krupnick (1990) cover a 5-year period, we used estimates for medical costs that similarly cover a 5-year period. We used a simple average of the two 5-year estimates, or $65,902, and add it to the 5-year opportunity cost estimate. The resulting estimates are given in Table 6b-13.

Table 6b-13: Estimated Costs Over a 5-Year Period (in 2000$) of a Nonfatal Myocardial Infarction

Age Group	*Opportunity Cost*	*Medical Cost*[a]	*Total Cost*
0 – 24	$0	$65,902	$65,902
25-44	$8,774[b]	$65,902	$74,676
45 – 54	$12,253[b]	$65,902	$78,834
55 – 65	$70,619[b]	$65,902	$140,649
>65	$0	$65,902	$65,902

[a] An average of the 5-year costs estimated by Wittels, Hay, and Gotto (1990) and Russell et al. (1998).

[b] From Cropper and Krupnick (1990), using a 3 percent discount rate.

The total avoided COI by age group associated with the reductions in CB and nonfatal acute myocardial infarctions is provided in Table 6b-14. Note that the total avoided COI associated with the revised PM NAAQS is $520 million and is $1,200 million for the more stringent alternative. Note that this does not include any direct avoided medical costs associated with premature mortality. Nor does it include any medical costs that occur more than 5 years from the onset of a nonfatal AMI. Therefore, this is likely an underestimate of the true avoided COI associated with strategies for attainment of the PM NAAQS.

Table 6b-14: Avoided Costs of Illness Associated with Reductions in Chronic Bronchitis and Nonfatal Acute Myocardial Infarctions Associated with Attainment Strategies for the 0.070 ppm alternative Ozone NAAQS in 2020

	Avoided Cost of Illness (in millions of 1999$)	
Age Range	*Chronic Bronchitis*	*Nonfatal Acute Myocardial Infarction*
18-24	—	$0.07
25-34	$11	$0.3
35-44	$13	$2.6
45-54	$7	$8.6
55-64	$8	$40
65-74	$0.7	$22
75-84	$0.3	$18
85+	$0.1	$9.4
Total	$41	$100

6b.7 Discount Rate Sensitivity Analysis

A large number of parameters and assumptions are necessary in conducting a CEA. Where appropriate and supported by data, we have included distributions of parameter values that were used in generating the reported confidence intervals. For the assumed discount rate, we felt it more appropriate to examine the impact of the assumption using a sensitivity analysis rather than through the integrated probabilistic uncertainty analysis.

The choice of a discount rate, and its associated conceptual basis, is a topic of ongoing discussion within the academic community. OMB and EPA guidance require using both a 7 percent rate and a 3 percent rate. In the most recent benefit-cost analyses of air pollution regulations, a 3 and 7 percent discount rate have been adopted in the primary analysis. A 3 percent discount rate reflects a "social rate of time preference" discounting concept. A 3 percent discount rate is also consistent with the recommendations of the NAS panel on CEA (Gold et al., 1996), which suggests that "a real annual (riskless) rate of 3 percent should be used in the Reference Case analysis." We have also calculated MILYs and the implicit cost thresholds using a 7 percent rate consistent with an "opportunity cost of capital" concept to reflect the time value of resources directed to meet regulatory requirements. Further discussion of this topic appears in Chapter 7 of Gold et al. (1996), in Chapter 6 of the EPA *Guidelines for Economic Analysis*, and in OMB Circular A-4.

Table 6b-15: Summary of Results for the Illustrative Partial Attainment Strategies for the Alternative Ozone Standard of 0.070 ppm in 2020[a]

	Result Using 3% Discount Rate (95% Confidence Interval)
	070 ppm Partial Attainment Strategy
Life years gained from mortality risk reductions	
Pope et al. (2002)	6,100 (2,400 – 9,800)
Laden et al. (2006)	14,000 (7,500 – 20,000
QALY gained from reductions in chronic bronchitis	2,000 (370 – 4,300)
QALY gained from reductions in acute myocardial infarctions	1,100 (370 – 2,000)
Total gain in MILYs	
Pope et al. (2002)	9,100 (3,100 – 16,000)
Laden et al. (2006)	17,000 (8,200 – 26,000)
Avoided cost of illness	
Chronic bronchitis	$41 million ($7.6 million – $75 million)
Nonfatal AMI	$100 million ($63 million – $220 million)
Implementation strategy costs[b]	$3.9 billion
Net cost per MILY	
Pope et al. (2002)	$410,000 ($220,000 – $1,300,000)
Laden et al. (2006)	$220,000 ($140,000 – $470,000)

[a] Consistent with recommendations of Gold et al. (1996), all summary results are reported at a precision level of two significant digits to reflect limits in the precision of the underlying elements.

[b] Costs are the private firm costs of control, as discussed in Chapter 6, and reflect discounting using firm specific costs of capital.

Table 6b-16 presents a summary of results using the 7 percent discount rate and the percentage difference between the 7 percent results and the base case 3 percent results. Adoption of a 7 percent discount rate decreases the estimated life years and QALYs gained from implementing the PM NAAQS. Adopting a discount rate of 7 percent results in a 35 percent reduction in the estimated total MILYs gained in each year, while the cost per MILY increases by approximately 60 percent.

Table 6b-16: Impacts of Using a 7 Percent Discount Rate on Cost Effectiveness Analysis for the Illustrative Attainment Strategies for the Revised and More Stringent PM NAAQS in 2020

	Result Using 7 Percent Discount Rate	*Percentage Change Relative to Result Using 3 Percent Discount Rate*
Life years gained from mortality risk reductions		
	4,600	–24%
	10,000	-24%
QALY gained from reductions in chronic bronchitis	1,300	–35%
QALY gained from reductions in acute myocardial infarctions	830	–21%
Total gain in MILYs		
Pope et al. (2002)	6,500	-26%
Laden et al. (2006)	12,000	-25%
Avoided cost of illness		
Chronic bronchitis	$27 million	–36%
Nonfatal AMI	$111 million	+10%
Net cost per MILY		
Pope et al. (2002)	$550,000	+36%
Laden et al. (2006)	$300,000	+33%

6b.8 Conclusions

We calculated the effectiveness of PM NAAQS attainment strategies based on reductions in premature deaths and incidence of chronic disease. We measured effectiveness using several different metrics, including lives saved, life years saved, and QALYs (for improvements in quality of life due to reductions in incidence of chronic disease). We suggested a new metric for aggregating life years saved and improvements in quality of life, morbidity inclusive life years (MILY) which assumes that society assigns a weight of one to years of life extended regardless of preexisting disabilities or chronic health conditions.

CEA of environmental regulations that have substantial public health impacts may be informative in identifying programs that have achieved cost-effective reductions in health impacts and can suggest areas where additional controls may be justified. However, the overall efficiency of a regulatory action can only be judged through a complete benefit-cost analysis that takes into account all benefits and costs, including both health and nonhealth effects. The benefit-cost analysis for the PM NAAQS attainment strategies, provided in Chapter 9, shows that the attainment strategies we modeled have potentially large net benefits, indicating that implementation of the revised PM NAAQS will likely result in improvements in overall public welfare.

6b.9 References

Abbey, D.E., B.L. Hwang, R.J. Burchette, T. Vancuren, and P.K. Mills. 1995. "Estimated Long-Term Ambient Concentrations of PM(10) and Development of Respiratory Symptoms in a Nonsmoking Population." *Archives of Environmental Health* 50(2): 139-152.

Agency for Healthcare Research and Quality. 2000. HCUPnet, Healthcare Cost and Utilization Project.

American Lung Association. 2002. *Trends in Chronic Bronchitis and Emphysema: Morbidity and Mortality*. American Lung Association, Best Practices and Program Services, Epidemiology and Statistics Unit.

American Heart Association. 2003. Heart Disease and Stroke Statistics—2003 Update. Dallas, Texas: American Heart Association.

Bala, M.V., and G.A. Zarkin. 2000. "Are QALYs an Appropriate Measure for Valuing Morbidity in Acute Diseases?" *Health Economics* 9:177-180.

Bell, C.M., R.H. Chapman, P.W. Stone, E.A. Sandberg, and P.J. Neumann. 2001. "An Off-the-Shelf Help List: A Comprehensive Catalog of Preference Scores from Published Cost-Utility Analyses." *Medical Decision Making* 21:288-94.

Bleichrodt, H., P.P. Wakker, and M. Johannesson. 1996. "Characterizing QALYs by Risk Neutrality." *Journal of Risk and Uncertainty* 15:107-114.

Brock, D.W. 2002. "Chapter 14.3: Fairness and Health." In *Summary Measures of Population Health: Concepts, Ethics, Measurement and Applications*, C.J.L. Murray, J.A. Salomon, C.D. Mathers, and A.D. Lopez (eds.). Geneva: World Health Organization.

Carrothers, T. J., J.S. Evans, and J.D. Graham. 2002. "The Lifesaving Benefits of Enhanced Air Quality." Harvard Center for Risk Analysis Working Paper.

Carnethon, M.R., D. Liao, G.W. Evans, W.E. Cascio, L.E. Chambless, W.D. Rosamond, and G. Heiss. 2002. "Does the Cardiac Autonomic Response to Postural Change Predict Incident Coronary Heart Disease and Mortality? The Atherosclerosis Risk in Communities Study." *American Journal of Epidemiology* 155(1):48-56.

Centers for Disease Control and Prevention (CDC) Health, United States. 2003. Table 30. Years of Potential Life Lost before Age 75 for Selected Causes of Death, According to Sex, Race, and Hispanic Origin: United States, Selected Years 1980–2000.

Centers for Disease Control and Prevention (CDC). 2002. *National Vital Statistics Reports* 51(3).

Cohen, D.J., J.A. Breall, and K.K. Ho. 1994. "Evaluating the Potential Cost-Effectiveness of Stenting as a Treatment for Symptomatic Single-Vessel Coronary Disease: Use of a Decision-Analytic Model." *Circulation* 89(4):1859-1874.

Cohen, J.T., J.K. Hammitt, and J.I. Levy. 2003. "Fuels for Urban Transit Buses: A Cost-effectiveness Analysis." *Environmental Science and Technology* 37:1477-1484.

Cowie, M.R., A. Mosterd, D.A. Wood, et al. 1997. "The Epidemiology of Heart Failure." *European Heart Journal* 18:208-25.

Coyle, D., D. Stieb, R.T. Burnett, P. DeCivita, D. Krewski, Y. Chen, and M.J. Thun. 2003. "Impact of Particulate Air Pollution on Quality Adjusted Life Expectancy in Canada." *Journal of Toxicology and Environmental Health, Part A* 66:1847-1863.

Cropper, M.L., and A.J. Krupnick. 1990. "The Social Costs of Chronic Heart and Lung Disease." Discussion Paper QE 89-16-REV. Washington, DC: Resources for the Future.

de Hollander, A.E.M., J.M. Melse, E. Lebret, and P.G.N. Kramers. 1999. "An Aggregate Public Health Indicator to Represent the Impact of Multiple Environmental Exposures." *Epidemiology* 10:606-617.

Dekker, J.M., R.S. Crow, A.R. Folsom, P.J. Hannan, D. Liao, C.A. Swenne, and E.G. Schouten. 2000. "Low Heart Rate Variability in a 2-Minute Rhythm Strip Predicts Risk of Coronary Heart Disease and Mortality From Several Causes: The ARIC Study." *Circulation 2000* 102:1239-1244.

Freeman, A.M., J.K. Hammitt, and P. De Civita. 2002. "On Quality Adjusted Life Years (QALYs) and Environmental/Consumer Safety Valuation." *AERE Newsletter* 22(1):7-12.

Ganz, D.A., K.M. Kuntz, G.A. Jacobson, and J. Avorn. 2000. "Cost-Effectiveness of 3-Hydroxy-3-Methylglutaryl Coenzyme A Reductase Inhibitor Therapy in Older Patients with Myocardial Infarction." *Annals of Internal Medicine* 132:780-787.

Garber, A.M., and C.E. Phelps. 1997. "Economic Foundations of Cost-Effectiveness Analysis." *Journal of Health Economics* 16:1-31.

Gentile, J.E. 1998. *Random Number Generation and Monte Carlo Methods*. New York, NY: Springer Verlag.

Gold, M.R., J.E. Siegel, L.B. Russell, and M.C. Weinstein. 1996. *Cost-effectiveness in Health and Medicine*. New York: Oxford University Press.

Gold, D.R., A. Litonjua, J. Schwartz, E. Lovett, A. Larson, B. Nearing, G. Allen, M. Verrier, R. Cherry, and R. Verrier. 2000. "Ambient Pollution and Heart Rate Variability." *Circulation* 101(11):1267-1273.

Gold, M.R., D. Stevenson, and D.G. Fryback. 2002. "HALYS and QALYS and DALYS, Oh My: Similarities and Differences in Summary Measures of Population Health." *Annual Review of Public Health* 23:115–34.

Hammitt, J.K. 2002. "QALYs versus WTP." *Risk Analysis* 22(5):985-1001.

Harvard Center for Risk Analysis, Catalog of Preference Scores. Available at: http://www.hcra.harvard.edu/pdf/preferencescores.pdf.

Horsman, J., W. Furlong, D. Feeny, and G. Torrance. 2003. "The Health Utilities Index (HUI): Concepts, Measurement Properties, and Applications." *Health and Quality of Life Outcomes* 1:54.

Johnson, F.R., and K. Lievense. 2000. Stated-Preference Indirect Utility and Quality-Adjusted Life Years. Report prepared for Health Canada, July.

Kerridge, R.K., P.P. Glasziou, and K.M. Hillman. 1995. "The Use of "Quality-Adjusted Life Years" (QALYs) to Evaluate Treatment in Intensive Care." *Anaesthia and Intensive Care* 23:322-31.

Kind, P. 1996. The EuroQoL Instrument: An Index of Health-Related Quality of Life. Quality of Life and Pharmacoeconomics in Clinical Trials, Second Edition, B. Spilker (ed.), pp. 191-201. Philadelphia, PA: Lippincott-Raven Publishers.

Krewski, D., R.T. Burnett, M.S. Goldbert, K. Hoover, J. Siemiatycki, M. Jerrett, M. Abrahamowicz, and W.H. White. 2000. *Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality*. Special Report to the Health Effects Institute, Cambridge, MA.

Kuntz, K.M, J. Tsevant, L. Goldman, and M.C. Weinstein. 1996. "Cost-Effectiveness of Routine Coronary Angiography after Acute Myocardial Infarction." *Circulation* 94(5):957-65.

Kunzli, N., R. Kaiser, S. Medina, M. Studnicka, O. Chanel, P. Filliger, M. Herry, F. Horak Jr., V. Puybonnieux-Texier, P. Quenel, J. Schneider, R. Seethaler, J-C Vergnaud, and H. Sommer. 2000. "Public-Health Impact of Outdoor and Traffic-Related Air Pollution: A European Assessment." *The Lancet* 356:795-801.

Kunzli, N., S. Medina, R. Kaiser, P. Quenel, F. Horak Jr, and M. Studnicka. 2001. "Assessment of Deaths Attributable to Air Pollution: Should We Use Risk Estimates Based on Time Series or on Cohort Studies?" *American Journal of Epidemiology* 153(11):1050-55.

Liao, D., J. Cai, W.D. Rosamond, R.W. Barnes, R.G. Hutchinson, E.A. Whitsel, P. Rautaharju, and G. Heiss. 1997. "Cardiac Autonomic Function and Incident Coronary Heart Disease: A Population-Based Case-Cohort Study. The ARIC Study. Atherosclerosis Risk in Communities Study." *American Journal of Epidemiology* 145(8):696-706.

Liao, D., J. Creason, C. Shy, R. Williams, R. Watts, and R. Zweidinger. 1999. "Daily Variation of Particulate Air Pollution and Poor Cardiac Autonomic Control in the Elderly." *Environmental Health Perspectives* 107:521-5.

Magari, S.R., R. Hauser, J. Schwartz, P.L. Williams, T.J. Smith, and D.C. Christiani. 2001. "Association of Heart Rate Variability with Occupational and Environmental Exposure to Particulate Air Pollution." *Circulation* 104(9):986-91.

Miller, B.G., and J.F. Hurley. 2003. "Life Table Methods for Quantitative Impact Assessments in Chronic Mortality." *Journal of Epidemiology and Community Health* 57:200-206.

Moolgavkar, S.H. 2000. "Air Pollution and Hospital Admissions for Diseases of the Circulatory System in Three U.S. Metropolitan Areas." *Journal of the Air Waste Management Assoc*iation 50:1199-206.

Murray, C.J.L., J.A. Salomon, C.D. Mathers, and A.D. Lopez. 2002. "Summary Measures of Population Health: Concepts, Ethics, Measurement and Applications." Geneva: World Health Organization.

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

Neumann, P. 2003. "A Web-based Registry of Cost-utility Analyses." *Risk in Perspective* 11(3).

Peters, A., D.W. Dockery, J.E. Muller, and M.A. Mittleman. 2001. "Increased Particulate Air Pollution and the Triggering of Myocardial Infarction." *Circulation* 103:2810-2815.

Pliskin, J.S., D.S. Shepard, and M.C. Weinstein. 1980. "Utility Functions for Life Years and Health Status." *Operations Research* 28:206-224.

Pliskin, J.S., W.B. Stason, and M.C. Weinstein. 1981. "Coronary Artery Bypass Graft Surgery: Clinical Decision Making and Cost-Effective Analysis." *Medical Decision Making* 1(1):10-28.

Poloniecki, J.D., R.W. Atkinson, A.P. de Leon, and H.R. Anderson. 1997. "Daily Time Series for Cardiovascular Hospital Admissions and Previous Day's Air Pollution in London, UK." *Occupational and Environmental Medicine* 54(8):535-40.

Pope, D.A., R.T. Burnett, M.J. Thun, E.E. Cale, D. Krewski, K. Ito, and G.D. Thurston. 2002. "Lung Cancer, Cardiopulmonary Mortality, and Long-Term Exposure to Fine Particulate Air Pollution." *Journal of the American Medical Association* 287:1132-1141.

Rabl, A. 2003. "Interpretation of Air Pollution Mortality: Number of Deaths or Years of Life Lost?" *Journal of the Air and Waste Management Association* 53:41-50.

Russell, M.W., D.M. Huse, S. Drowns, E.C. Hamel, and S.C. Hartz. 1998. "Direct Medical Costs of Coronary Artery Disease in the United States." *American Journal of Cardiology* 81(9):1110-5.

Salkeld, G., P. Phongsavan, and B. Oldenburg. 1997. "The Cost-Effectiveness of a Cardiovascular Risk Reduction Program in General Practice." *Health Policy* 41:105-19.

Salomon, J.A., and C.J.L. Murray. 2003. "A Multi-Method Approach to Measuring Health-State Valuations." *Health Economics*, online.

Samet, J.M., S.L. Zeger, F. Dominici, F. Curriero, I. Coursac, D.W. Dockery, J. Schwartz, and A. Zanobetti. June 2000. The National Morbidity, Mortality and Air Pollution Study: Part II: Morbidity, Mortality and Air Pollution in the United States. Research Report No. 94, Part II. Cambridge, MA: Health Effects Institute.

Schwartz, J. 1993. "Particulate Air Pollution and Chronic Respiratory Disease." *Environmental Research* 62:7-13.

Singer, P., J. McKie, H. Kuhse, J. Richardson, and J. Harris. 1995. "Double Jeopardy and the Use of QALYs in Health Care Allocation." *Journal of Medical Ethics* 21:144-157.

Smith, K.J., and R.R. Pesce. 1994. "Pulmonary Artery Catheterization in Exacerbations of COPD Requiring Mechanical Ventilation: A Cost-Effectiveness Analysis." *Respiratory Care* 39:961-7.

Stinnett, A.A., M.A. Mittleman, M.C. Weinstein, K.M. Kuntz, D.J. Cohen, L.W. Williams, P.A. Goldman, D.O. Staiger, M.G.M. Hunink, J. Tsevat, A.N.A. Tosteson, and L. Goldman. 1996. "The Cost-effectiveness of Dietary and Pharmacologic Therapy for Cholesterol Reduction in Adults." In *Cost-effectiveness in Health and Medicine*, Gold, M.E., J. E. Siegel, L.B. Russell, and M.C. Weinstein (eds.). New York: Oxford University Press.

Stouthard, M.E.A., J.L. Essink-Bot, G.J. Bonsel, J.J. Barendregt, P.G.N. Kramers, H.P.A. Van de Water, and L.J. Gunning-Schepers. 1997. "Disability Weights for Diseases in the Netherlands." Rotterdam: Department of Public Health, Erasmus University Rotterdam.

Suwa, T. J.C. Hogg, K.B. Quinlan, A. Ohgami, R. Vincent, and S.F. van Eeden. 2002. "Particulate Air Pollution Induces Progression of Atherosclerosis." *Journal of the American College of Cardiology* 39:935-942.

Tsuji, H., M.G. Larson, F.J. Venditti, Jr., E.S. Manders, J.C. Evans, C.L. Feldman, and D. Levy. 1996. "Impact of Reduced Heart Rate Variability on Risk for Cardiac Events. The Framingham Heart Study." *Circulation* 94(11):2850-2855.

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

U.S. Environmental Protection Agency (EPA). 2000. *Guidelines for Preparing Economic Analyses*. EPA 240-R-00-003.

U.S. Environmental Protection Agency (EPA). 2004. Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines.

U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB). EPA-SAB-COUNCIL-ADV-04-002. March 2004. Advisory on Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis—Benefits and Costs of the Clean Air Act, 1990-2020: Advisory by the Health Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis.

U.S. Food and Drug Administration (FDA). 2004. Bar Code Label Requirements for Human Drug Products and Biological Products; Final Rule. Federal Register: February 26, 2004 Volume 69 (38): 9119-9171.

U.S. Office of Management and Budget (OMB). 2003. Circular A-4: Regulatory Analysis, September 17, 2003. Available at: http://www.whitehouse.gov/omb/ circulars/a004/a-4.pdf.

Vos, T. 1999a. Final worksheet VM1 COPD.xls, prepared for Victoria Burden of Disease Study. Available at: http://www.dhs.vic.gov.au/phd/bod/daly.htm.

Vos, T. 1999b. Final worksheet VL2 IHD.xls, prepared for Victoria Burden of Disease Study. Available at: http://www.dhs.vic.gov.au/phd/bod/daly.htm.

Wittels, E.H., J.W. Hay, and A.M. Gotto, Jr. 1990. "Medical Costs of Coronary Artery Disease in the United States." *American Journal of Cardiology* 65(7):432-40.

Appendix Chapter 6-c: Additional Sensitivity Analyses Related To the Benefits Analysis

The analysis presented in Chapter 6 is based on our current interpretation of the scientific and economic literature. That interpretation requires judgments regarding the best available data, models, and modeling methodologies and the assumptions that are most appropriate to adopt in the face of important uncertainties. The majority of the analytical assumptions used to develop the primary estimates of benefits have been reviewed and approved by EPA's SAB. Both EPA and the SAB recognize that data and modeling limitations as well as simplifying assumptions can introduce significant uncertainty into the benefit results and that alternative choices exist for some inputs to the analysis, such as the mortality C-R functions.

This appendix supplements our primary analysis of benefits with three additional sensitivity calculations. These supplemental estimates examine sensitivity to both valuation issues (e.g., the appropriate income elasticity) and for physical effects issues (e.g., the structure of the cessation lag and the sensitivity of the premature mortality estimate to the presence of a presumed threshold). These supplemental estimates are not meant to be comprehensive. Rather, they reflect some of the key issues identified by EPA or commentors as likely to have a significant impact on total benefits. The individual adjustments in the tables should not simply be added together because 1) there may be overlap among the alternative assumptions and 2) the joint probability among certain sets of alternative assumptions may be low.

6c.1 Premature Mortality Cessation Lag Structure

Over the last ten years, there has been a continuing discussion and evolving advice regarding the timing of changes in health effects following changes in ambient air pollution. It has been hypothesized that some reductions in premature mortality from exposure to ambient $PM_{2.5}$ will occur over short periods of time in individuals with compromised health status, but other effects are likely to occur among individuals who, at baseline, have reasonably good health that will deteriorate because of continued exposure. No animal models have yet been developed to quantify these cumulative effects, nor are there epidemiologic studies bearing on this question. The SAB-HES has recognized this lack of direct evidence. However, in early advice, they also note that "although there is substantial evidence that a portion of the mortality effect of PM is manifest within a short period of time, i.e., less than one year, it can be argued that, if no lag assumption is made, the entire mortality excess observed in the cohort studies will be analyzed as immediate effects, and this will result in an overestimate of the health benefits of improved air quality. Thus some time lag is appropriate for distributing the cumulative mortality effect of PM in the population" (EPA-SAB-COUNCIL-ADV-00-001, 1999, p. 9). In recent advice, the SAB-HES suggests that appropriate lag structures may be developed based on the distribution of cause-specific deaths within the overall all-cause estimate (EPA-SAB-COUNCIL-ADV-04-002, 2004). They suggest that diseases with longer progressions should be characterized by longer-term lag structures, while air pollution impacts occurring in populations with existing disease may be characterized by shorter-term lags.

A key question is the distribution of causes of death within the relatively broad categories analyzed in the long-term cohort studies. Although it may be reasonable to assume the cessation lag for lung cancer deaths mirrors the long latency of the disease, it is not at all clear what the appropriate lag structure should be for cardiopulmonary deaths, which include both respiratory and cardiovascular causes. Some respiratory diseases may have a long period of progression, while others, such as pneumonia, have a very short duration. In the case of cardiovascular disease, there is an important question of whether air pollution is causing the disease, which would imply a relatively long cessation lag, or whether air pollution is causing premature death in individuals with preexisting heart disease, which would imply very short cessation lags. The SAB-HES provides several recommendations for future research that could support the development of defensible lag structures, including using disease-specific lag models and constructing a segmented lag distribution to combine differential lags across causes of death (EPA-SAB-COUNCIL-ADV-04-002, 2004). The SAB-HES indicated support for using "a Weibull distribution or a simpler distributional form made up of several segments to cover the response mechanisms outlined above, given our lack of knowledge on the specific form of the distributions" (EPA-SAB-COUNCIL-ADV-04-002, 2004, p. 24). However, they noted that "an important question to be resolved is what the relative magnitudes of these segments should be, and how many of the acute effects are assumed to be included in the cohort effect estimate" (EPA-SAB-COUNCIL-ADV-04-002, 2004, p. 24-25). Since the publication of that report in March 2004, EPA has sought additional clarification from this committee. In its followup advice provided in December 2004, this SAB suggested that until additional research has been completed, EPA should assume a segmented lag structure characterized by 30 percent of mortality reductions occurring in the first year, 50 percent occurring evenly over years 2 to 5 after the reduction in $PM_{2.5}$, and 20 percent occurring evenly over the years 6 to 20 after the reduction in $PM_{2.5}$ (EPA-COUNCIL-LTR-05-001, 2004). The distribution of deaths over the latency period is intended to reflect the contribution of short-term exposures in the first year, cardiopulmonary deaths in the 2- to 5-year period, and long-term lung disease and lung cancer in the 6- to 20-year period. Furthermore, in their advisory letter, the SAB-HES recommended that EPA include sensitivity analyses on other possible lag structures. In this appendix, we investigate the sensitivity of premature mortality-reduction related benefits to alternative cessation lag structures, noting that ongoing and future research may result in changes to the lag structure used for the primary analysis.

In previous advice from the SAB-HES, they recommended an analysis of 0-, 8-, and 15-year lags, as well as variations on the proportions of mortality allocated to each segment in the segmented lag structure (EPA-SAB-COUNCIL-ADV-00-001, 1999, (EPA-COUNCIL-LTR-05-001, 2004). The 0-year lag is representative of EPA's assumption in previous RIAs. The 8- and 15-year lags are based on the study periods from the Pope et al. (1995) and Dockery et al. (1993) studies, respectively.[1] However, neither the Pope et al. nor Dockery et al. studies assumed any lag structure when estimating the relative risks from PM exposure. In fact, the

---

[1]Although these studies were conducted for 8 and 15 years, respectively, the choice of the duration of the study by the authors was not likely due to observations of a lag in effects but is more likely due to the expense of conducting long-term exposure studies or the amount of satisfactory data that could be collected during this time period.

Pope et al. and Dockery et al. analyses do not supporting or refute the existence of a lag. Therefore, any lag structure applied to the avoided incidences estimated from either of these studies will be an assumed structure. The 8- and 15-year lags implicitly assume that all premature mortalities occur at the end of the study periods (i.e., at 8 and 15 years). In addition to the simple 8- and 15-year lags, we have added three additional sensitivity analyses examining the impact of assuming different allocations of mortality to the segmented lag of the type suggested by the SAB-HES. The first sensitivity analysis assumes that more of the mortality impact is associated with chronic lung diseases or lung cancer and less with acute cardiopulmonary causes. This illustrative lag structure is characterized by 20 percent of mortality reductions occurring in the first year, 50 percent occurring evenly over years 2 to 5 after the reduction in $PM_{2.5}$, and 30 percent occurring evenly over the years 6 to 20 after the reduction in $PM_{2.5}$. The second sensitivity analysis assumes the 5-year distributed lag structure used in previous analyses, which is equivalent to a three-segment lag structure with 50 percent in the first 2-year segment, 50 percent in the second 3-year segment, and 0 percent in the 6- to 20-year segment. The third sensitivity analysis assumes a negative exponential relationship between reduction in exposure and reduction in mortality risk. This structure is based on an analysis by Röösli et al. (2004), which estimates the percentage of total mortality impact in each period t as

$$\% \ \text{Mortality Reduction(t)} \quad \frac{\left[RR-1 \ e^{-0.5t} +1\right]-1}{\sum_{t \ 1}^{\infty}\left[RR-1 \ e^{-0.5t} +1\right]-1} \qquad \text{(C.1)}$$

The Röösli et al. (2004) analysis derives the lag structure by calculating the rate constant (–0.5) for the exponential lag structure that is consistent with both the relative risk from the cohort studies and the change in mortality observed in intervention type studies (e.g., Pope et al. [1992] and Clancy et al. [2002]). This is the only lag structure examined that is based on empirical data on the relationship between changes in exposure and changes in mortality.

The estimated impacts of alternative lag structures on the monetary benefits associated with reductions in PM-related premature mortality (estimated with the Pope et al. ACS impact function) are presented in Table J-1. These estimates are based on the value of statistical lives saved approach (i.e., $5.5 million per incidence) and are presented for both a 3 and 7 percent discount rate over the lag period.

Table 6c-1. Sensitivity of Benefits of Premature Mortality Reductions to Alternative Cessation Lag Structures, Using Pope et al (2002) Effect Estimate

Alternative Lag Structures for PM-Related Premature Mortality		Value (billion 1999$)[a,b]	Percent Difference from Base Estimate
None	Incidences all occur in the first year		
	3% discount rate	$3.5	10.4%
	7% discount rate	$3.5	31.2%
8-year	Incidences all occur in the 8th year		
	3% discount rate	$2.9	-10.3%
	7% discount rate	$2.2	-18.3%
15-year	Incidences all occur in the 15th year		
	3% discount rate	$2.3	-27.0%
	7% discount rate	$1.4	-49.1%
Alternative Segmented	20 percent of incidences occur in 1st year, 50 percent in years 2 to 5, and 30 percent in years 6 to 20		
	3% discount rate	$3.1	-3.2%
	7% discount rate	$2.5	-8.7%
5-Year Distributed	50 percent of incidences occur in years 1 and 2 and 50 percent in years 2 to 5		
	3% discount rate	$3.4	4.9%
	7% discount rate	$3.1	17.1%
Exponential	Incidences occur at an exponentially declining rate following year of change in exposure		
	3% discount rate	$3.4	5.6%
	7% discount rate	$3.1	14.8%

[a] Dollar values rounded to two significant digits.

The results of this sensitivity analyses demonstrate that because of discounting of delayed benefits, the lag structure may also have a large impact on monetized benefits, reducing benefits by 30 percent if an extreme assumption that no effects occur until after 15 years is applied. However, for most reasonable distributed lag structures, differences in the specific shape of the lag function have relatively small impacts on overall benefits. For example, the overall impact of moving from the previous 5-year distributed lag to the segmented lag recommended by the SAB-HES in 2004 in the primary estimate is relatively modest, reducing benefits by approximately 5 percent when a 3 percent discount rate is used and 15 percent when a 7 percent discount rate is used. If no lag is assumed, benefits are increased by around 10 percent relative to the segmented lag with a 3 percent discount rate and 30 percent with a 7 percent discount rate.

6c. 2 Threshold Sensitivity Analysis

Chapter 6 presents the results of the $PM_{2.5}$ premature mortality benefits analysis based on an assumed cutpoint in the long-term mortality concentration-response function at 10 $\mu g/m^3$, and an assumed cutpoint in the short-term morbidity concentration-response functions at 10 $\mu g/m^3$. There is ongoing debate as to whether there exists a threshold below which there would be no benefit to further reductions in $PM_{2.5}$. Some researchers have hypothesized the presence of a threshold relationship. The nature of the hypothesized relationship is the possibility that there exists a PM concentration level below which further reductions no longer yield premature mortality reduction benefits. EPA's most recent $PM_{2.5}$ Criteria Document concludes that "the available evidence does not either support or refute the existence of thresholds for the effects of PM on mortality across the range of concentrations in the studies" (U.S. EPA, 2004b, p. 9-44). EPA's Science Advisory Board (SAB) that provides advice on benefits analysis methods[2] has been to model premature mortality associated with PM exposure as a non-threshold effect, that is, with harmful effects to exposed populations regardless of the absolute level of ambient PM concentrations.

For these reasons we provide the results of a sensitivity analysis in which we estimate the change in reduction in incidence of PM2.5-related premature mortality resulting from changes in the presumed threshold. We also provide a corresponding estimate of the valuation of these changes in incidence.

[2] The advice from the 2004 SAB-HES (U.S. EPA-SAB, 2004b) is characterized by the following: "For the studies of long-term exposure, the HES notes that Krewski et al. (2000) have conducted the most careful work on this issue. They report that the associations between $PM_{2.5}$ and both all-cause and cardiopulmonary mortality were near linear within the relevant ranges, with no apparent threshold. Graphical analyses of these studies (Dockery et al., 1993, Figure 3, and Krewski et al., 2000, page 162) also suggest a continuum of effects down to lower levels. Therefore, it is reasonable for EPA to assume a no threshold model down to, at least, the low end of the concentrations reported in the studies."

Table 6c-2: Mortality Threshold Sensitivity Analysis for 0.070 ppm Ozone Scenario (Using Pope et al., 2002 Effect Estimate with Slope Adjustment for Thresholds Above 7.5 ug) 90th Percentile Confidence Intervals Provided in Parentheses [a]

		East	*Western U.S. Excluding CA*	*California*	*Total*
Less Certainty That Benefits Are at Least as Large	No Threshold	570 (230—920)	28 (11—45)	53 (21—85)	650 (260—1,100)
	Threshold at 7.5 μg	580 (230—930)	15 (6—24)	51 (20—85)	650 (250—1,000)
	Threshold at 10 μg	510 (200—810)	0.2 (0.07—0.3)	47 (18—75)	550 (220—890)
	Threshold at 12 μg	100 (40—160)	0.03 (0.01—0.04)	42 (16—67)	140 (56—230)
More Certainty That Benefits are at Least as Large	Threshold at 14 μg	---	---	36 (14—59)	36 (14—59)

a All estimates are rounded to 2 significant digits. All rounding occurs after final summing of unrounded estimates. As such, totals will not sum across columns.

Table 6c-3: Sensitivity of Monetized Benefits of Reductions in Mortality Risk to Assumed Thresholds for 0.070 ppm Partial Attainment Scenario (Using Pope et al., 2002 Effect Estimate with Slope Adjustment for Thresholds Above 7.5 ug) 90th Percentile Confidence Intervals Provided in Parentheses [a]

			Eastern U.S.	*Western U.S. Excluding CA*	*California*	*Total Nationwide Attainment*
Less Certain that Benefits Are at Least as Large	No Threshold	3%	$3,300 ($830--$6,900)	$160 ($41--$340)	$310 ($77--$630)	$3,800 ($950--$7,900)
		7%	$2,800 ($700--$5,800)	$140 ($34--$280)	$260 ($64--$530)	$3,200 ($800--$6,200)
	Threshold at 7.5 ug	3%	$3,400 ($840--$7,000)	$86 ($22--$$180)	$300 ($74--$620)	$3,700 ($940--$7,800)
		7%	$2,800 ($710--$5,900)	$72 ($18--$150)	$250 ($63--$520)	$3,200 ($790--$6,600)
	Threshold at 10 ug	3%	$2,900 ($730--$6,100)	$1 ($0.2--$2)	$270 ($67--$560)	$3,200 ($800--$6,600)
		7%	$2,500 ($620--$5,100)	$0.8 ($0.2--$1.7)	$230 ($57--$470)	$2,700 ($670--$5,600)
	Threshold at 12 ug	3%	$590 ($150--$1,200)	$0.2 ($0.04--$0.3)	$240 ($61--$500)	$830 ($210--$1,700)
		7%	$490 ($120--$1,000)	$0.1 ($0.03--$0.3)	$200 ($51--$420)	$700 ($180--$1,500)
	Threshold at 14 ug	3%	--	--	$210 ($53--$440)	$210 ($53--$440)
More Certain that Benefits Are at Least as Large		7%	--	--	$180 ($44--$370)	$180 ($44--$370)

a All estimates are rounded to 2 significant digits. All rounding occurs after final summing of unrounded estimates. As such, totals will not sum across columns.

6c.3 Income Elasticity of Willingness to Pay

As discussed in Chapter 6, our estimates of monetized benefits account for growth in real GDP per capita by adjusting the WTP for individual endpoints based on the central estimate of the adjustment factor for each of the categories (minor health effects, severe and chronic health effects, premature mortality, and visibility). We examined how sensitive the estimate of total benefits is to alternative estimates of the income elasticities. Table 6c-3 lists the ranges of elasticity values used to calculate the income adjustment factors, while Table 6c-4 lists the ranges of corresponding adjustment factors. The results of this sensitivity analysis, giving the monetized benefit subtotals for the four benefit categories, are presented in Table 6c-5.

Table 6c-4. Ranges of Elasticity Values Used to Account for Projected Real Income Growth[a]

Benefit Category	Lower Sensitivity Bound	Upper Sensitivity Bound
Minor Health Effect	0.04	0.30
Severe and Chronic Health Effects	0.25	0.60
Premature Mortality	0.08	1.00
Visibility[b]	—	—

[a] Derivation of these ranges can be found in Kleckner and Neumann (1999) and Chestnut (1997). COI estimates are assigned an adjustment factor of 1.0.

[b] No range was applied for visibility because no ranges were available in the current published literature.

Table 6c-5. Ranges of Adjustment Factors Used to Account for Projected Real Income Growth[a]

Benefit Category	Lower Sensitivity Bound	Upper Sensitivity Bound
Minor Health Effect	1.018	1.147
Severe and Chronic Health Effects	1.121	1.317
Premature Mortality	1.037	1.591
Visibility[b]	—	—

[a] Based on elasticity values reported in Table C-4, U.S. Census population projections, and projections of real GDP per capita.

[b] No range was applied for visibility because no ranges were available in the current published literature.

Table 6c-6. Sensitivity of Monetized Benefits to Alternative Income Elasticities[a]

Benefit Category	Benefits Incremental to 080 ppm Partial Attainment Strategy (Millions of 1999$)			
	Ozone Analysis		PM Analysis	
	Lower Sensitivity Bound	**Upper Sensitivity Bound**	**Lower Sensitivity Bound**	**Upper Sensitivity Bound**
Minor Health Effect	$64	$72	$9.7	$11
Severe and Chronic Health Effects	--	--	$160	$190
Premature Mortality[b]	$2,000	$3,000	$2,800	$3,600
Total Benefits[b]	$2,000	$3,100	$2,900	$3,800

[a] All estimates rounded to two significant digits.
[b] Using mortality effect estimate from Pope et al (2002) to estimate $PM_{2.5}$ mortality and a 3 percent discount rate and mortality effect estimate from Bell (2004).
[c] No range was applied for visibility because no ranges were available in the current published literature.

Consistent with the impact of mortality on total benefits, the adjustment factor for mortality has the largest impact on total benefits. The value of mortality in 2020 ranges from 90 percent to 130 percent of the primary estimate based on the lower and upper sensitivity bounds on the income adjustment factor. The effect on the value of minor and chronic health effects is much less pronounced, ranging from 98 percent to 105 percent of the primary estimate for minor effects and from 93 percent to 106 percent for chronic effects.

6c.4 References

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. 1990a. *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.

Chestnut, L.G., and R.D. Rowe. 1990b. "A New National Park Visibility Value Estimates." In *Visibility and Fine Particles*, Transactions of an AWMA/EPA International Specialty Conference, C.V. Mathai, ed. Air and Waste Management Association, Pittsburgh.

Clancy, L., P. Goodman, H. Sinclair, and D.W. Dockery. 2002. "Effect of Air-pollution Control on Death Rates in Dublin, Ireland: An Intervention Study." *Lancet* Oct 19;360(9341):1210-4.
Desvousges, W.H., F.R. Johnson, and H.S. Banzhaf. 1998. *Environmental Policy Analysis With Limited Information: Principles and Applications of the Transfer Method (New Horizons in Environmental Economics.)* Edward Elgar Pub: London.

EPA-SAB-COUNCIL-ADV-00-001. October 1999. *The Clean Air Act Amendments (CAAA) Section 812 Prospective Study of Costs and Benefits (1999): Advisory by the Health and Ecological Effects Subcommittee on Initial Assessments of Health and Ecological Effects*. Part 2.

EPA-SAB-COUNCIL-ADV-99-012. July 1999. *The Clean Air Act Amendments (CAAA) Section 812 Prospective Study of Costs and Benefits (1999): Advisory by the Health and Ecological Effects Subcommittee on Initial Assessments of Health and Ecological Effects*. Part 1.

EPA-SAB-COUNCIL-ADV-01-004. September 2001. *Review of the Draft Analytical Plan for EPA's Second Prospective Analysis—Benefits and Costs of the Clean Air Act 1990-2020: An Advisory by a Special Panel of the Advisory Council on Clean Air Compliance Analysis*.

EPA-SAB-COUNCIL-ADV-04-002. March 2004. *Advisory on Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis—Benefits and Costs of the Clean Air Act, 1990-2020: Advisory by the Health Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis*.

Kleckner, N., and J. Neumann. June 3, 1999. "Recommended Approach to Adjusting WTP Estimates to Reflect Changes in Real Income." Memorandum to Jim Democker, US EPA/OPAR.

Roosli M, Kunzli N, Braun-Fahrlander C, Egger M. 2005. "Years of life lost attributable to air pollution in Switzerland: dynamic exposure-response model." *International Journal of Epidemiology* 34(5):1029-35.

U.S. Environmental Protection Agency (EPA). 2004. Air Quality Criteria for Particulate Matter, Volume II. Office of Research and Development. EPA/600/P-99/002bF, October 2004.

Chapter 7: Discussion of Ozone Secondary Standard

Exposures to ozone have been associated with a wide array of vegetation and ecosystem effects in the published literature. These effects include those that damage or impair the intended use of the plant or ecosystem. Such effects are considered adverse to the public welfare and can include: reduced plant growth, visible foliar (leaf) injury, reduced plant vigor (e.g., increased susceptibility to harsh weather, disease, insect pest infestation, and competition), reduced crop yields, and changes in ecosystems and associated ecosystem services.

Vegetation effects research has shown that seasonal air quality indices that cumulate peak-weighted hourly ozone concentrations are the best candidates for relating exposure to plant growth effects. On the basis of this research, as well as other information considered in this review (e.g., policy-relevant background (PRB) levels), the Staff Paper concluded that the cumulative, seasonal index referred to as "W126" is the most appropriate index for relating vegetation response to ambient ozone exposures. Based on additional conclusions regarding appropriate diurnal and seasonal exposure windows, the Staff Paper concluded that it was appropriate for the Administrator to consider a cumulative seasonal secondary standard, expressed as an index of the annual sum of weighted hourly concentrations (using the W126 form), set at a level in the range of 7 to 21 ppm-hours. The index would be cumulated over the 12-hour daylight window (8:00 a.m. to 8:00 p.m.) during the consecutive 3 month period during the ozone season with the maximum index value (hereafter referred to as the 12-hour, maximum 3-month W126).

The Staff Paper also considered the extent to which there is overlap between county-level air quality measured in terms of the 8-hour average form of the current secondary standard and that measured in terms of the 12-hour W126, alternative cumulative, seasonal form. These comparisons were done using 3-year averages for both forms, as well as using the 3-year average current 8-hour form and the annual W126 county-level air quality values. This Staff Paper assessment used 2002-2004 county-level air quality data from the AQS sites and the subset of CASTNET sites having the highest ozone levels for the counties in which they are located. Since the completion of the Staff Paper, this analysis has been updated using the more recent 3-year period of 2003 to 2005. Results from the more recent (2003-2005) 3-year average comparisons (see Table 1 below) showed that after meeting the current 3-year average form of the 0.08-ppm, 8-hour average standard, the number of counties not meeting a 3-year average W126 form ranged from 11 at the upper level of the proposed W126 range (21 ppm-hours) to 76 counties (W126 of 15 ppm-hours- representing the upper bound of the CASAC recommended range), to 221 counties at the lower end of the proposed W126 range (7 ppm-hours). The degree of overlap is greater when levels within the proposed range (0.070-0.075 ppm) for a revised 8-hour average standard are met, specifically the number of counties still exceeding a W126 form of a standard range from 0 at a W126 level of 21 ppm-hours to 25 at a W126 level of 7 ppm-hours. The Staff Paper notes that when individual years are compared (e.g., using the annual W126 level) significant variability occurs between years in the degree of overlap between the numbers of counties meeting various levels of the 8-hour and W126 forms and, therefore, cautions that the degree of protection for vegetation provided by an 8-hour average form in terms of cumulative, seasonal exposures would not be expected to be consistent on a year to year basis.

The Staff Paper also identified additional aspects of this analysis that would suggest caution should be used in interpreting these results. First, due to the lack of more complete monitor coverage in many rural areas, the Staff Paper concluded that this analysis may not be an accurate reflection of the situation in non-monitored, rural counties. Because of the lack of monitoring in rural areas where important vegetation and ecosystems are located, it remains uncertain as to the extent to which air quality improvements designed to reduce 8-hour ozone average concentrations would reduce ozone exposures measured by a seasonal, cumulative W126 index. The Staff Paper indicated this to be an important consideration because: (1) the biological database stresses the importance of cumulative, seasonal exposures in determining plant response; (2) plants have not been specifically tested for the importance of daily maximum 8-hour ozone concentrations in relation to plant response; and (3) the effects of attainment of a 8-hour standard in upwind urban areas on rural air quality distributions cannot be characterized with confidence due to the lack of monitoring data in rural and remote areas.

In addition, though within the range of 8-hour average levels being proposed the numbers of counties exceeding mid- to low levels of W126 are greatly reduced, many of these counties contain areas of national public interest. For example, at the 8-hour level of 0.075 ppm, 12 counties would still exceed the W126 level of 15 ppm-hours. Most of these counties contain high elevation, rural or remote sites where ozone air quality distributions tend to be flatter and the potential for disconnect between 8-hour average and cumulative, seasonal forms, greater. Therefore, the Staff Paper notes that additional rural high elevation areas important for vegetation that are not currently monitored likely experience similar ozone exposure patterns. These factors are important considerations in determining whether the current 8-hour form can appropriately provide requisite protection for vegetation.

Due to time and resource limitations, EPA did not calculate the costs and monetized benefits of a separate secondary standard. Consideration to these costs and benefits will be provided in the final RIA.

Table 7.1 Comparison of number of counties exceeding various W126 levels when meeting various levels of the 8-hr standard for the 3-year period 2003-2005[1]

	Levels of 12-hr W126 (ppm-hrs)		
8-hr level met	>21	>15	>7
0.084 ppm	11 (7-27)	76 (23-173)	221 (244-382)
0.075 ppm	0 (0-7)	11 (3-33)	114 (49-134)
0.070 ppm	0 (0-1)	2 (1-6)	25 (13-36)

[1] The top value in each box represents the number of counties meeting the 8-hour level based on 2003-2005 data but exceeding the W126 level based on a 3-year W126 average for the 2003-2005 period. The numbers in parentheses indicate the range in the number of counties that exceed the W126 level on an annual basis in one of the three years—2003, 2004, 2005– based on 1-year W126 values. The range indicates significant interannual variability.

Chapter 8: Conclusions and Implications of the Illustrative Benefit-Cost Analysis

Synopsis

EPA has performed an illustrative analysis to estimate the costs and human health benefits of nationally attaining alternative ozone standards. We have considered 4 alternative standards incremental to attaining the current ozone standard: 0.079 ppm, 0.075 ppm, 0.070 ppm, and 0.065 ppm. This chapter summarizes these results and discusses the implications of the analysis. This analysis serves both to satisfy the requirements of E.O. 12866 and to provide the public with an estimate of the potential costs and benefits of attaining alternative ozone standards. The benefit and cost estimates below are calculated incremental to a 2020 baseline that incorporates air quality improvements achieved through the projected implementation of existing regulations and full attainment of the current standards for ozone and PM NAAQS (including the hypothetical control strategy developed in the RIA for full attainment of the PM NAAQS 15/35 promulgated in September, 2006). This RIA presents two sets of results: The first reflects full attainment in all locations except two areas of California, which are planning to meet the current standards after 2020, and so have estimated costs and benefits for the analyzed standards for partial attainment in 2020 (their "glidepath" targets).[1] The second estimate, for California only, presents the additional costs and benefits that might result from California fully attaining the standards in a year beyond 2020. Finally, this chapter provides additional context for the RIA analysis and a discussion of limitations and uncertainties. In addition, given the technological limitations associated with reducing ozone precursors, we provide estimated cost and benefit numbers based on both partial attainment (manageable with current technologies) and full attainment (manageable in some locations only with hypothetical technologies).

8.1 Results

Presentation of Results

There are two sets of results presented below. The first set of results is for 2020. For analytical purposes explained previously, we assume that almost all areas of the country will meet each alternative standard in 2020 through the development of technologies at least as effective as the hypothetical strategies used in this illustration. It is expected that benefits and costs will begin occurring earlier, as states begin implementing control measures to attain earlier or to show progress towards attainment. Some areas with very high levels of ozone do not plan to meet even the current standard until after 2020; specifically, two California areas have adopted plans for post-2020 attainment as noted above. In these locations, we provide estimates of the costs and benefits of attaining a "glidepath" target in our 2020 analysis year.[2] The 2020 results thus do

[1] Because these two areas adopted 8-hour ozone implementation plans calling for post-2020 attainment after we had completed much of our analysis, these areas are assumed to meet the current standard in 2020 and 2021 respectively, somewhat earlier than the date in their plans, which results in a steeper glide path, and higher costs and benefits, for all the standards analyzed. See chapter 4.

[2] See footnote 1.

not represent a complete "full attainment" scenario for the entire nation, particularly for more stringent alternative new standards examined. In order to gain an understanding of the possible additional costs and benefits of fully attaining in California, we provide an additional set of results focusing on California.

By the year 2030, various mobile source rules, such as the onroad and nonroad diesel rules, among others, would be expected to be fully implemented. Because California will likely not have to attain until closer to 2030, it is important to reflect the impact those rules might have on the emissions that affect ozone nonattainment. To reflect the emission reductions that are expected from these rules, we subtract those tons from our estimates of the emissions reductions that might be needed for California to fully attain in 2020, thus making our analysis more consistent with full attainment later than 2020. EPA did the analysis this way because to force full attainment in California in an earlier year would not be consistent with the CAA, and would likely lead to an overstatement of costs because those areas might benefit from these existing federal or state programs that would be implemented between 2020 and the attainment year (see detail in Chapter 4); because additional new technologies may become available between 2020 and the attainment year; and/or the cost of existing technologies might fall over time due to economic factors such as economies of scale or improvements in the efficiency of installing and operating controls ('learning by doing'). On the other hand, it is also possible that new technologies might not meet the specifications, development time lines, or cost estimates provided in this analysis.

It is not appropriate to add together the 2020 national attainment, California glidepath estimate and the estimate of California full attainment as an estimate of national full attainment in 2020 It is not appropriate to do this because each estimate is based on different baseline conditions for emissions and air quality. In addition, both estimates include estimates of California glidepath results, leading to the potential for double counting if added together.

The following set of tables summarizes the costs and benefits of the scenarios analyzed, and shows the net benefits for each of the scenarios across a range of modeling assumptions concerning the calculation of costs and benefits. Tables 8.1a-c present benefits and costs of national attainment in 2020, including the "glidepath" targets for California. Companion Table 8.2 provides the estimated reductions in premature mortality and morbidity for national attainment in 2020, including the "glidepath" targets for California. Tables 8.3a-c present the additional costs and benefits of full attainment for California ("glidepath" plus future year attainment added together into one total); Table 8.4 is the companion table showing estimated reductions in premature mortality and morbidity.

The individual row estimates for benefits reflect the variability in the functions available for estimating the largest source of benefits – avoided ozone premature mortality. Ranges within the total benefits column reflect variability in the estimates of PM premature mortality co-benefits across the available effect estimates. Ranges in the total costs column reflect different assumptions about the extrapolation of costs. The low end of the range of net benefits is constructed by subtracting the highest cost from the lowest benefit, while the high end of the range is constructed by subtracting the lowest cost from the highest benefit. Following these tables is a discussion of the implications of these estimates, as well as the uncertainties and limitations that should be considered in interpreting the estimates.

Table 8.1a National Annual Costs and Benefits: 0.079 ppm Standard in 2020 (including California glidepath)

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits*	Total Costs**	Net Benefits
NMMAPS	Bell et al. 2004	$1.2 to $11	$3 to $3.3	-$2.1 to $8.5
Meta-analysis	Bell et al. 2005	$1.6 to $12	$3 to $3.3	-$1.7 to $8.9
	Ito et al. 2005	$1.7 to $12	$3 to $3.3	-$1.7 to $8.9
	Levy et al. 2005	$1.6 to $12	$3 to $3.3	-$1.7 to $8.9
Assumption that association is not causal***		$1.1 to $11	$3 to $3.3	-$2.2 to $8.4

Table 8.1b National Annual Costs and Benefits: 0.075 ppm Standard in 2020 (including California glidepath)

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits*	Total Costs**	Net Benefits
NMMAPS	Bell et al. 2004	$3 to $16	$5.5 to $8.8	-$5.8 to $10.5
Meta-analysis	Bell et al. 2005	$7.3 to $20	$5.5 to $8.8	-$1.5 to $15
	Ito et al. 2005	$7.8 to $21	$5.5 to $8.8	-$1. to $15
	Levy et al. 2005	$8.7 to $22	$5.5 to $8.8	-$0.1 to $16
Assumption that association is not causal***		$1.5 to $15	$5.5 to $8.8	-$7.3 to $9

Table 8.1c National Annual Costs and Benefits: 0.070 ppm Standard in 2020 (including California glidepath)

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits*	Total Costs**	Net Benefits
NMMAPS	Bell et al. 2004	$4.3 to $26	$10 to $22	-$17 to $16
Meta-analysis	Bell et al. 2005	$9.7 to $31	$10 to $22	-$12 to $21
	Ito et al. 2005	$10 to $32	$10 to $22	-$11 to $22
	Levy et al. 2005	$11 to $33	$10 to $22	-$10 to $23
Assumption that association is not causal***		$2.5 to $24	$10 to $22	-$20 to $14

Table 8.1d National Annual Costs and Benefits : 0.065 ppm Standard in 2020 (including California glidepath)

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits*	Total Costs**	Net Benefits
NMMAPS	Bell et al. 2004	$7.7 to $45	$17 to $46	-$38 to $28
Meta-analysis	Bell et al. 2005	$18 to $55	$17 to $46	-$28 to $38
	Ito et al. 2005	$19 to $56	$17 to $46	-$27 to $39
	Levy et al. 2005	$20 to $57	$17 to $46	-$27 to $40
Assumption that association is not causal***		$4.3 to $42	$17 to $46	-$42 to $25

*Includes ozone benefits, and PM 2.5 co-benefits. Range was developed by adding the estimate from the ozone premature mortality function to both the lower and upper ends of the range of the PM2.5 premature mortality functions characterized in the expert elicitation
**Range reflects lower and upper bound cost estimates
***Total includes ozone morbidity benefits only

Table 8.2: Summary of Total Number of Annual Ozone and $PM_{2.5}$-Related Premature Mortalities and Premature Morbidity Avoided: 2020 National Benefits

Combined Estimate of Mortality

Standard Alternative and Model or Assumption		*Combined Range of Ozone Benefits and $PM_{2.5}$ Co-Benefits*			
		0.079 ppm	0.075 ppm	0.070 ppm	0.065 ppm
NMMAPS	Bell (2004)	200 to 1,900	430 to 2,600	670 to 4,300	1,200 to 7,400
Meta-Analysis	Bell (2005)	260 to 2,000	1,100 to 3,300	1,500 to 5,100	2,800 to 9,000
	Ito (2005)	270 to 2,000	1,200 to 3,300	1,600 to 5,200	3,000 to 9,200
	Levy (2005)	260 to 2,000	1,300 to 3,500	1,800 to 5,400	3,000 to 9,200
No Causality		180 to 1,900	230 to 2,400	390 to 4,000	660 to 6,900

Combined Estimate of Morbidity

Acute Myocardial Infarction	1,100	1,400	2,300	4,000
Hospital and ER Visits	1,300	5,600	7,600	13,000
Chronic Bronchitis	370	470	780	1,300
Acute Bronchitis	950	1,200	2,000	3,500
Asthma Exacerbation	7,300	9,400	16,000	27,000
Lower Respiratory Symptoms	8,100	10,000	17,000	29,000
Upper Respiratory Symptoms	5,900	7,500	13,000	22,000
School Loss Days	50,000	610,000	780,000	1,300,000
Work Loss Days	51,000	65,000	110,000	190,000
Minor Restricted Activity Days	430,000	2,000,000	2,700,000	4,700,000

Table 8.3a California: Annual Costs and Benefits of Attaining 0.079 ppm Standard (beyond 2020)*

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits**	Total Costs***	Net Benefits
NMMAPS	Bell et al. 2004	$0.1 to $0.6	$0.3 to $1.7	-$1.6 to $0.2
Meta-analysis	Bell et al. 2005	$0.2 to $0.7	$0.3 to $1.7	-$1.5 to $0.4
	Ito et al. 2005	$0.3 to $0.7	$0.3 to $1.7	-$1.4 to $0.4
	Levy et al. 2005	$0.2 to $0.7	$0.3 to $1.7	-$1.5 to $0.4
Assumption that association is not causal****		$0.05 to $0.5	$0.3 to $1.7	-$1.6 to $0.2

Table 8.3b California: Annual Costs and Benefits of Attaining 0.070 ppm Standard (beyond 2020)*

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits**	Total Costs***	Net Benefits
NMMAPS	Bell et al. 2004	$0.7 to $3.5	$2 to $13	-$12 to $1.5
Meta-analysis	Bell et al. 2005	$1.9 to $4.7	$2 to $13	-$11 to $2.7
	Ito et al. 2005	$2.1 to $4.8	$2 to $13	-$11 to $2.9
	Levy et al. 2005	$2.1 to $4.8	$2 to $13	-$11 to $2.9
Assumption that association is not causal****		$0.4 to $3.1	$2 to $13	-$13 to $1.2

Table 8.3c California: Annual Costs and Benefits of Attaining 0.075 ppm Standard (beyond 2020)*

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$*		
		Total Benefits**	Total Costs***	Net Benefits
NMMAPS	Bell et al. 2004	$0.4 to $1.9	$1.1 to $6.2	-$5.8 to $0.8
Meta-analysis	Bell et al. 2005	$1.1 to $2.6	$1.1 to $6.2	-$5.1 to $1.5
	Ito et al. 2005	$1.2 to $2.7	$1.1 to $6.2	-$5.1 to $1.6
	Levy et al. 2005	$1.2 to $2.7	$1.1 to $6.2	-$5 to $1.6
Assumption that association is not causal****		$0.2 to $1.7	$1.1 to $6.2	-$6 to $0.6

Table 8.3d California: Annual Costs and Benefits of Attaining 0.065 ppm Standard (beyond 2020)*

Premature Mortality Function or Assumption	Reference	*Mean Total Benefits, in Billions of 1999$* Total Benefits**	Total Costs***	Net Benefits
NMMAPS	Bell et al. 2004	$1.1 to $5.2	$2.9 to $21	-$19 to $2.3
Meta-analysis	Bell et al. 2005	$3.1 to $7.2	$2.9 to $21	-$17 to $4.3
	Ito et al. 2005	$3.4 to $7.4	$2.9 to $21	-$17 to $4.5
	Levy et al. 2005	$3.3 to $7.4	$2.9 to $21	-$17 to $4.5
Assumption that association is not causal****		$0.5 to $4.6	$2.9 to $21	-$20 to $1.7

* Tables present the total of CA glidepath in 2020, plus the additional increment needed to reach full attainment in a year beyond 2020
** Includes ozone benefits and PM 2.5 co-benefits. Range was developed by adding the estimate from the ozone premature mortality function to both the lower and upper ends of the range of the PM2.5 premature mortality functions characterized in the expert elicitation
***Range reflects lower and upper bound cost estimates
****Total includes ozone morbidity benefits only

Table 8.4: Summary of Total Number of Annual Ozone and $PM_{2.5}$-Related Premature Mortalities and Premature Morbidity Avoided: California Post 2020 Attainment

Combined Estimate of Mortality

Standard Alternative and Model or Assumption		*Combined Range of Ozone Benefits and $PM_{2.5}$ Co-Benefits*			
		0.079 ppm	0.075 ppm	0.070 ppm	0.065 ppm
NMMAPS	Bell (2004)	17 to 93	61 to 310	110 to 570	180 to 840
Meta-Analysis	Bell (2005)	42 to 120	170 to 410	300 to 760	490 to 1,200
	Ito (2005)	45 to 120	180 to 430	320 to 780	530 to 1,200
	Levy (2005)	46 to 120	180 to 430	320 to 780	520 to 1,200
No Causality		8.2 to 84	26 to 270	49 to 500	72 to 740

Combined Estimate of Morbidity

Acute Myocardial Infarction	49	160	290	430
Hospital and ER Visits	200	790	1,400	2,200
Chronic Bronchitis	17	53	99	150
Acute Bronchitis	43	140	260	380
Asthma Exacerbation	330	1,100	2,000	2,900
Lower Respiratory Symptoms	360	1,200	2,200	3,200
Upper Respiratory Symptoms	270	850	1,600	2,300
School Loss Days	30,000	120,000	210,000	340,000
Work Loss Days	2,300	7,400	14,000	20,000
Minor Restricted Activity Days	87,000	340,000	600,000	960,000

8.2 Discussion of Results

Relative Contribution of PM benefits to total benefits

Because of the relatively strong relationship between PM2.5 concentrations and premature mortality, PM co-benefits resulting from reductions in NOx emissions can make up a large fraction of total montetized benefits, depending on the specific PM mortality impact function used, and on the relative magnitude of ozone benefits, which is dependent on the specific ozone mortality function assumed. PM co-benefits based on daily average concentrations are calculated over the entire year, while ozone related benefits are calculated only during the summer ozone season. Because the control strategies evaluated in this RIA are assumed to operate year round rather than only during the ozone season, this means that PM benefits will accumulate during both the ozone season and the rest of the year.

PM co-benefits account for between 13 and 99 percent of co-benefits, depending on the standard analyzed and on the choice of ozone and PM mortality functions used. The estimate with the lowest fraction from PM co-benefits occurs when ozone mortality is based on the Levy et al (2005) study and when PM2.5 mortality is based on the function provided by "Expert K"[3] from the expert elicitation. The estimate with the highest fraction from PM co-benefits occurs when no ozone mortality reductions are included (following the assumption of no causal relationship between ozone and mortality) and when PM2.5 mortality is based on the function provided by "Expert E"[4] from the expert elicitation.

Impact of Uncertainty in the Magnitude of ozone benefits.

The degree to which net benefits are positive depends largely on the size of the effect estimate used for the relationship between premature mortality and ozone and to a lesser extent on the cost extrapolation methodology. In the cases where net benefits are negative, the magnitude of the economic loss depends largely on the extrapolation method used to calculate the costs of full attainment. Because of the high degree of uncertainty in these calculations, overall conclusions about the magnitude of net benefits and the likelihood they will be positive or negative for any of our evaluated scenarios cannot be drawn with any degree of confidence. As such, we cannot conclude that strategies for attainment of a tighter ozone NAAQS would either pass or fail a cost-benefit test. In other words, we cannot make an estimate of whether costs will outweigh benefits (or vice versa). As we improve our databases of control technologies and refine our understanding of the magnitude of the relationships between air pollution and premature mortality, our confidence in estimates of costs and benefits will likely improve.

---

[3] As discussed in Chapter 6, one way in which we characterize the model uncertainty associated with the relationship between particulate matter and premature mortality was to conduct an expert elicitation. The elicitation yielded twelve different functions, generated by asking 12 experts a structured set of questions, leading each to articulate a functional form for the relationship, in a probabilistic estimate of uncertainty. Among the twelve experts, Expert K's function characterizes the weakest relationship between PM and premature mortality, whereas Expert E's function characterizes the strongest relationship.

[4] See above.

Challenges to Modeling Full Attainment in All Areas

Because of relatively higher ozone levels in several large urban areas (Southern California, Chicago, Houston, and the Northeastern urban corridor, including New York and Philadelphia) and because of limitations on the available database of currently known emissions control technologies, EPA recognized from the outset that known and reasonably anticipated emissions controls would likely be insufficient to bring many areas into attainment with either the current or alternative, more stringent ozone standards. Therefore, we designed this analysis in two stages: the first stage focused on analyzing the air quality improvements that could be achieved through application of documented, well-characterized emissions controls, and the costs and benefits associated with those controls. The second stage utilized extrapolation methods to estimate the costs and benefits of additional emissions reductions needed to bring all areas into full attainment with the standards. Clearly, the second stage analysis is a highly speculative exercise, as it is based on estimating emission reductions and air quality improvements without any information about the specific controls that would be available to do so.

The structure of the RIA reflects this 2-stage analytical approach. Separate chapters are provided for the cost, emissions and air quality impacts of modeled controls and for extrapolated costs and air quality impacts. We have used the information currently available to develop reasonable approximations of the costs and benefits of the extrapolated portion of the emissions reductions necessary to reach attainment. However, due to the high level of uncertainty in all aspects of the extrapolation, we judged it appropriate to provide separate estimates of the costs and benefits for the modeled stage and the extrapolated stage, as well as an overall estimate for reaching full attainment. There is a single chapter on benefits, because the methodology for estimating benefits does not change between stages. However, in that chapter, we again provide separate estimates of the benefits associated with the modeled and extrapolated portions of the analysis.

In both stages of the analysis, it should be recognized that all estimates of future costs and benefits are not intended to be forecasts of the actual costs and benefits of implementing revised standards. Ultimately, states and urban areas will be responsible for developing and implementing emissions control programs to reach attainment with the ozone NAAQS, with the timing of attainment being determined by future decisions by states and EPA. Our estimates are intended to provide information on the general magnitude of the costs and benefits of alternative standards, rather than precise predictions of control measures, costs, or benefits. With these caveats, we expect that this analysis can provide a reasonable picture of the types of emissions controls that are currently available, the direct costs of those controls, the levels of emissions reductions that may be achieved with these controls, the air quality impact that can be expected to result from reducing emissions, and the public health benefits of reductions in ambient ozone levels. This analysis identifies those areas of the U.S. where our existing knowledge of control strategies is not sufficient to allow us to model attainment, and where additional data or research may be needed to develop strategies for attainment. EPA plans to address some of these areas in the RIA analysis for the final rule through additional research on control technologies, sensitivity analyses using air quality models, and refinement of methods for extrapolating the costs and benefits of reaching full attainment.

In many ways, regulatory impact analyses for proposed actions are a learning process that can yield valuable information about the technical and policy issues that are associated with a particular regulatory action. This is especially true for RIAs for proposed NAAQS, where we are required to stretch our understanding of both science and technology to develop scenarios that illustrate how certain we are about how economically feasible the attainment of these standards might be regionally. The proposed ozone NAAQS RIA provided great challenges when compared to previous RIAs. Why was this so? Primarily because as we tighten standards across multiple pollutants with overlapping precursors (e.g. the recent tightening of the $PM_{2.5}$ standards), we move further down the list of cost-effective known and available controls. As we deplete our database of available choices of known controls, we are left with background emissions and remaining anthropogenic emissions for which we do not have enough knowledge to determine how and at what cost reductions can be achieved in the future when attainment would be required. With the more stringent NAAQS, more areas will need to find ways of reducing emissions, and as existing technologies are either inadequate to achieve desired reductions, or as the stock of low-cost existing technologies is depleted (causing the cost per ton of pollution reduced to increase), there will be pressure to develop new technologies to fill these needs. While we can speculate on what some of these technologies might look like based on current research and development and model programs being evaluated by states and localities, the actual technological path is highly uncertain.

Because of the lack of knowledge regarding the development of future emissions control technologies, a significant portion of our analysis is based on extrapolating from available data to generate the emissions reductions necessary to reach full attainment of an alternative ozone NAAQS and the resulting costs and benefits. Studies indicate that it is not uncommon for pre-regulatory cost estimates to be higher than later estimates, in part because of inability to predict technological advances. Over longer time horizons, such as the time allowed for areas with high levels of ozone pollution to meet the ozone NAAQS, the opportunity for technical advances is greater (See Chapter 5 for detail). Also, due to the nature of the extrapolation method for benefits (which focuses on reductions in ozone only at monitors that exceed the NAAQS), we generally understate the total benefits that would result from implementing additional emissions controls to fully attain the ozone NAAQS (i.e., assuming that the application of control strategies would result in ozone reductions both at nonattaining and attaining monitors). On the other hand, the possibility also exists that benefits are overestimated, both because it is possible that new technologies might not meet the specifications, development time lines, or cost estimates provided in this analysis and because the analysis assumes there are quantifiable benefits to reducing ambient ozone below each of the alternative standards.

Estimated benefits and costs may reflect both bias and uncertainty. While we strive to avoid bias and characterize uncertainty to the extent possible, we note that in some cases, biased estimates were used due to data and/or methodological limitations. In these cases we have tried to identify the direction and potential magnitude of the bias." These extrapolated benefits are uncertain, but the relative uncertainty compared to the modeled benefits is similar, once the underestimation bias has been taken into account. The emissions and cost extrapolations do not have a clear directional bias, however, they are much more uncertain relative to the modeled emissions and cost estimates, because of the lack of refined information about the relationship between emissions reductions and ozone changes in specific locations, and because of the difficulties in extrapolating costs along a marginal cost curve well beyond the observed data without accounting for shifts in the cost-curve due to improvements in technology or use of technologies over time. Of course, these benefits and costs will only be realized if the emission reductions projected in this extrapolated approach actually occur in the future.

8.3 What did we learn through this analysis?

1) *As in our analysis for the PM NAAQS RIA, in selecting controls, we focused more on the ozone cost-effectiveness (measured as $/ppb) than on the NOx or VOC cost-effectiveness (measured as $/ton).* When compared on a $/ton basis, many VOC controls (average $/ton of $4,100) appear cost-effective relative to NOx reductions (average $/ton of $3,600). However, when compared on a $/ppb basis, NOx reductions (average $/ppb of $36 million) are almost always more cost-effective than VOC controls (average $/ppb of $164 million) because of the much lower conversion of VOC to ozone. The one exception to this is in urban areas which are VOC limited. In those locations, NOx reductions can actually result in increases in ozone, and as such, VOC reductions can be cost-effective relative to NOx on a $/ppb basis.

2) *Our knowledge of technologies that might achieve NOx and VOC reductions to attain alternative ozone NAAQS is insufficient.* In some areas of the U.S., our existing controls database was insufficient to meet even the current ozone standard. After applying existing rules and the hypothetical controls applied in the PM NAAQS RIA across the nation (excluding California), we were able to identify controls for 35 states and DC that reduced overall NOx emissions by 17 percent and VOC by 4 percent. For California, the percentages were 8 percent for NOx and 10 percent for VOC. After these reductions, remaining emissions were still substantial, with over 7 million tons of NOx and 9 million tons of VOCs remaining. The large remaining inventories of NOx and VOC emissions suggests that additional control measures need to be developed, with appropriate consideration of the relative effectiveness of NOx and VOC in achieving ozone reductions.

3) *Most of the overall reductions in NOx achieved in our illustrative control strategy were from non-EGU point sources.* This was due to the fact that: 1) EGUs have been heavily controlled under the recent NOx SIP call and Clean Air Interstate Rules. The EGU program we included in our strategy for meeting the alternative ozone standards was not intended to achieve overall reductions in NOx beyond the CAIR caps, but instead to obtain NOx emission reductions in areas where they would more effectively reduce ozone concentrations in downwind nonattainment areas; and 2) mobile sources are already subject to ongoing emission reduction programs through the Tier 2 highway, onroad diesel and nonroad diesel rules. Thus, the opportunities for controlling NOx emissions were much greater in the non-EGU sector than in the mobile or EGU sectors. However, the remaining NOx emissions from EGU and mobile sectors are still greater than non-EGU sources, and additional reductions from these sectors may need to be considered

in developing strategies to achieve full attainment. We are evaluating technologies and programs that might be applied in these sectors in the future. Exploratory analyses indicate that there are opportunities to achieve emission reductions from EGU peaking units on High Energy Demand Days (HEDD) with targeted strategies. Another area under analysis is the energy efficiency/clean distributed generation based emission reductions. Potential changes in the generation mix as a result of increase in the use of renewables and Renewable Portfolio Standards (RPS) are also likely to create changes in emission behavior. However, overall regional or national emissions levels stay constant under a given cap.

4) *Some EPA existing mobile source programs will help areas reach attainment.* These programs promise to continue to help areas reduce ozone concentrations between 2020 and 2030. In California, continued implementation of mobile source rules including the onroad and nonroad diesel rules and the locomotive and marine engines rule are projected to reduce NOx emissions by an additional 25 percent and VOC emissions by an additional 11 percent during this time period. These additional reductions will significantly reduce the overall cost of attainment relative to what California might have needed to reduce from other sectors if attainment were to be required in 2020. However, delaying attainment by 10 years will result in delayed health benefits as well. Based on a simple scaling exercise, we estimate that between $0.3 and $1 billion in benefits could have been realized from full attainment with the 0.070 ppm alternative each year between 2020 and 2030. However, the potential for extra costs of up to between $0.3 and $4 billion per year suggests that allowing for delayed attainment until 2030 for these severe nonattainment areas may make economic sense. We are unable at this time to identify controls that would achieve the full attainment in California by 2020.

5) *Tightening the ozone standards can provide significant, but not uniform, health benefits*. The magnitude of the benefits is highly uncertain, <u>and is not expected to be uniform throughout the nation</u>. While our illustrative analyses showed that the benefits of implementing a tighter standard will likely result in reduced health impacts for the nation as a whole, the particular scenarios that we modeled show that some areas of the U.S. will see ozone (and $PM_{2.5}$) levels increase. This is due to two reasons. The first reason is that the complexities involved in the atmospheric processes which govern the transformation of emissions into ozone result in some locations and times when reducing NOx emissions can actually increase ozone levels on some days (see Chapter 2 for more discussion). For most locations, these days are few relative to the days when ozone levels are decreased. However, in some urban areas the net effect of implementing NOx controls is to increase overall ozone levels and increase the health effects associated with ozone. This same phenomenon results in some areas also seeing increases in $PM_{2.5}$ formation. The second reason is that the particular control strategy that we modeled for EGU sources is a modification to controls on sources within the overall cap and trade program in the Eastern U.S, established under the

CAIR. As with any cap and trade program, changes in requirements at particular sources will result in shifts in power generation and emissions at other sources. Because under our chosen EGU control scenario the overall emissions cap for the CAIR region remains the same, some areas of the country will see a decrease in emissions, while others will see an increase. This is not unexpected, and is an essential element of the cap and trade program. Our goal in selecting the EGU control strategy was to focus the emissions reductions in areas likely to benefit the most from EGU NOx emissions reductions, with emissions increases largely occurring in areas in attainment with the ozone NAAQS. However, this necessarily means that in those areas where emissions increases occurred, ozone levels would also be expected to increase, with commensurate increases in health impacts. On a national level, however, we expected overall health benefits of the modeled EGU strategy to be positive. In addition, our air quality modeling analysis showed that while ozone levels did increase in some areas, none of these increases resulted in an attaining area moving into nonattainment. Adjustments to our control scenario might achieve a pattern of reductions that achieves further air quality improvement.

6) *There is uncertainty in Estimating the Benefits of 0.079 ppm and 0.075 ppm*
EPA employed a monitor rollback approach to estimate the benefits of attaining an alternative standard of 0.079 ppm nationwide. This approach likely understates the benefits that would occur due to implementation of actual controls because controls implemented to reduce ozone concentrations at the highest monitor would likely result in some reductions in ozone concentrations at attaining monitors down-wind (i.e. the controls would lead to concentrations below the standard in down-wind locations). Therefore, air quality improvements and resulting health benefits from full attainment would be more widespread than we have estimated in our rollback analysis.

EPA calculated 0.075 ppm benefits by interpolating the 0.070 ppm benefits estimates.[5] This interpolation approach may overestimate benefits relative to a modeled control scenario developed specifically to attain the 0.075 ppm alternative. The interpolation method scales down benefits only at the monitors we project to exceed 0.075 ppm—but it still captures the benefits achieved by the 0.070 ppm regional control strategy that occur outside of these projected non-attainment areas. To the extent that a modeled emission control strategy to attain 0.075 ppm does not include these broader regional emission reductions, total benefits would be lower than those we have estimated in this RIA.

Interpolation and monitor rollback methods of benefits estimation are inherently different. As described above, for the purposes of reviewing this analysis, the reader should understand that the benefits described for attaining a standard of 0.079 ppm are likely understated, whereas the estimated benefits of attaining a standard of 0.075 ppm are likely overstated. EPA will develop and present consistent approaches for the alternative standards for the final RIA.

[5] This procedure is detailed in Appendix 6A.

7) *Tightening the ozone standards can incur significant, but uncertain, costs*
An engineering cost comparison demonstrates that the cost of the 0.070 ppm Ozone NAAQS control strategy ($3.9 billion per year) is only slightly higher than the Clean Air Interstate Rule ($3.6 billion per year) and roughly one and half to just over four times higher than the PM NAAQS 15/35 control strategy with annual engineering costs of $850 million. It should be noted that for the Ozone NAAQS $3.9 billion represent the cost of partial attainment. Full attainment using extrapolation methods are expected to increase total costs significantly. For example, total costs for the 0.070 ppm standard are significant at $13 to $26 billion. Yet, the magnitude and distribution of costs across sectors and areas is highly uncertain. Our estimates of costs for a set of modeled NOx and VOC controls comprise only a small part of the estimated costs of full attainment. These estimated costs for the modeled set of controls are still uncertain, but they are based on the best available information on control technologies, and have their basis in real, tested technologies. Estimating costs of full attainment required significant extrapolation of the cost curve for known technologies, and was based on generalized relationships between emissions and ozone levels. Based on air quality modeling sensitivity analyses, there is clearly significant spatial variability in the relationship between local and regional NOx emission reductions and ozone levels across urban areas. However, because we were unable to analyze all of the urban areas that are expected to need reductions, we used the same ratio of ozone to emissions throughout the U.S. This introduces significant uncertainty into the calculation of the emissions reductions that might be needed to reach full attainment. In addition, because VOCs are generally much less effective than NOx in achieving ozone reductions at key monitors (with the exception of California), we did not use any VOC control data in the extrapolation to full attainment. This meant that in some areas, we assumed the need for more expensive NOx controls than might be required if a specific area chose to use a combination of NOx and VOC controls. However, VOC controls would have to be very inexpensive relative to NOx controls on a per ton basis in order for VOC controls to be a cost-effective substitute for NOx reductions. Extrapolating costs by applying a cost-curve based on known technologies also introduces uncertainties. For some locations, the extrapolation requires only a modest reduction beyond known controls. In these cases, the extrapolation is likely reasonable and not as prone to uncertainties. However, for areas where the bulk of air quality improvements were derived from extrapolated emissions reductions that go well beyond the area of the known controls, the increasing marginal costs can suggest a cost per ton which stretches credibility. For example, in California, extrapolation to full attainment results in a marginal cost for the last ton of NOx of $89,645 in Los Angeles and $74,495 in Kern County, which are five to six times larger than the marginal cost at the last known cost effective control. Economic theory would suggest that as marginal costs rise, research and development to produce new, more cost effective technologies will also increase, leading to a downward shift in the overall cost curve. We did not assume any

shift in the cost curve to reflect technological innovation, instead we provide a sensitivity analysis by showing estimates assuming a high and low fixed cost per ton. We are likely overstating costs in the future when using the marginal cost and high fixed estimates.

8) *Non-EGU point source controls dominate the estimated costs.* These costs account for about 70 percent of modeled costs. The average cost per ton for these reductions is approximately $3,400, and the highest marginal cost for the last cost effective control applied is $15,267. Mobile source controls were also significant contributors to overall costs, accounting for over 25 percent of total modeled costs.

9) *The economic impacts (i.e. social costs) of the cost of these modeled controls were not included in this analysis.* Incorporating the economic impact of the extrapolated portion of the costs was too uncertain to be included as part of these estimates, and it was determined best to keep the modeled and extrapolated costs on the same basis. However, incorporating any economic impacts would increase the total cost of attainment in 2020 for a revised ozone standard.

10) *California costs and benefits are highly uncertain.*. California faces large challenges in meeting any alternative standard, but their largest challenges may be in attaining the existing standard. Because our analysis suggested that all available controls would be exhausted in attempting (unsuccessfully) to meet the current 0.08 ppm standard (effectively 0.084 ppm) all of the benefits and costs in California are based on extrapolation. Both the benefits and the costs associated with the assumed NOx and VOC reductions in California are particularly uncertain. The costs are uncertain to the point where we have little confidence that they represent a meaningful characterization of possible future costs of implementation in California. As such, we recommend comparison of costs and benefits for the rest of the U.S. as a basis for judging the relative merits of implementation. Costs for full attainment in California will clearly be substantial, but the level of uncertainty about those costs is simply too great to provide any useful conclusions. This is also true for many other areas of the U.S., but the uncertainties are magnified in the case of California.

11) Costs and benefits will depend on implementation timeframes. States will ultimately select the specific timelines for implementation as part of their State Implementation Plans. To the extent that states seek classification as extreme nonattainment areas, the timeline for implementation may be extended beyond 2020, meaning that the amount of emissions reductions that will be required in 2020 will be less, and costs and benefits in 2020 will also be lowered.

Chapter 9: Statutory and Executive Order Impact Analyses

Synopsis

This chapter summarizes the Statutory and Executive Order (EO) impact analyses relevant for the ozone NAAQS RIA. In general, because this RIA analyzes an illustrative attainment strategy to meet the revised NAAQS, and because States will ultimately implement the new NAAQS, the Statutory and Executive Orders below did not require additional analysis. For each EO and Statutory requirement we describe both the requirements and the way in which the RIA addresses these requirements. Further analyses of the NAAQS proposal and its impact on these statutory and executive orders are found in section VII of the NAAQS preamble.

9.1 Executive Order 12866: Regulatory Planning and Review

Under section 3(f)(1) of Executive Order (EO) 12866 (58 FR 51735, October 4, 1993), the ozone NAAQS action is an "economically significant regulatory action" because it is likely to have an annual effect on the economy of $100 million or more. Accordingly, EPA prepared this regulatory impact analysis (RIA) of the potential costs and benefits associated with this action. The RIA estimates the costs and monetized human health benefits of attaining three alternative ozone NAAQS nationwide. Specifically, the RIA examines the alternatives of 0.075 ppm, 0.070 ppm, and 0.065 ppm. The RIA contains illustrative analyses that consider a limited number of emissions control scenarios that States and Regional Planning Organizations might implement to achieve these alternative ozone NAAQS. However, the Clean Air Act (CAA) and judicial decisions make clear that the economic and technical feasibility of attaining ambient standards are not to be considered in setting or revising NAAQS, although such factors may be considered in the development of State plans to implement the standards. Accordingly, although an RIA has been prepared, the results of the RIA have not been considered in issuing this rule.

9.2 Paperwork Reduction Act

This RIA does not impose an information collection burden under the provisions of the Paperwork Reduction Act, 44 U.S.C. 3501 et seq. There are no information collection requirements directly associated with revisions to a NAAQS under section 109 of the CAA.

Burden is defined as the total time, effort, or financial resources expended by persons to generate, maintain, retain, or disclose or provide information to or for a Federal agency. This includes the time needed to review instructions; develop, acquire, install, and utilize technology and systems for the purposes of collecting, validating, and verifying information, processing and maintaining information, and disclosing and providing information; adjust the existing ways to comply with any previously applicable instructions and requirements; train personnel to be able to respond to a collection of information; search data sources; complete and review the collection of information; and transmit or otherwise disclose the information.

An agency may not conduct or sponsor information collection, and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number. The OMB control numbers for EPA's regulations in 40 CFR are listed in 40 CFR part 9.

9.3 Regulatory Flexibility Act

The EPA has determined that it is not necessary to prepare a regulatory flexibility analysis in connection with this RIA. For purposes of assessing the impacts of today's rule on small entities, small entity is defined as: (1) a small business that is a small industrial entity as defined by the Small Business Administration's (SBA) regulations at 13 CFR 121.201; (2) a small governmental jurisdiction that is a government of a city, county, town, school district or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field.

After considering the economic impacts of today's rule on small entities, EPA has concluded that this action will not have a significant economic impact on a substantial number of small entities. This rule will not impose any requirements on small entities. This rule establishes national standards for allowable concentrations of ozone in ambient air, as required by section 109 of the CAA. See also *ATA I* at 1044-45 (NAAQS do not have significant impacts upon small entities because NAAQS themselves impose no regulations upon small entities).

9.4 Unfunded Mandates Reform Act

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), Public Law 104-4, establishes requirements for Federal agencies to assess the effects of their regulatory actions on State, local, and Tribal governments and the private sector. Under section 202 of the UMRA, EPA generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with "Federal mandates" that may result in expenditures to State, local, and Tribal governments, in the aggregate, or to the private sector, of $100 million or more in any 1 year. Before promulgating an EPA rule for which a written statement is needed, section 205 of the UMRA generally requires EPA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule. The provisions of section 205 do not apply when they are inconsistent with applicable law. Moreover, section 205 allows EPA to adopt an alternative other than the least costly, most cost-effective or least burdensome alternative if the Administrator publishes with the final rule an explanation why that alternative was not adopted. Before EPA establishes any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments, it must have developed under section 203 of the UMRA a small government agency plan. The plan must provide for notifying potentially affected small governments, enabling officials of affected small governments to have meaningful and timely input in the development of EPA regulatory proposals with significant Federal intergovernmental mandates, and informing, educating, and advising small governments on compliance with the regulatory requirements.

This proposal contains no Federal mandates (under the regulatory provisions of Title II of the UMRA) for State, local, or Tribal governments or the private sector. The rule imposes no new expenditure or enforceable duty on any State, local or Tribal governments or the private sector, and EPA has determined that this rule contains no regulatory requirements that might significantly or uniquely affect small governments. Furthermore, as indicated previously, in setting a NAAQS, EPA cannot consider the economic or technological feasibility of attaining ambient air quality standards, although such factors may be considered to a degree in the development of State plans to implement the standards. See also *ATA I* at 1043 (noting that because EPA is precluded from considering costs of implementation in establishing NAAQS, preparation of a Regulatory Impact Analysis pursuant to the Unfunded Mandates Reform Act would not furnish any information which the court could consider in reviewing the NAAQS). Accordingly, EPA has determined that the provisions of sections 202, 203, and 205 of the UMRA do not apply to this final decision. The EPA acknowledges, however, that any corresponding revisions to associated SIP requirements and air quality surveillance requirements, 40 CFR part 51 and 40 CFR part 58, respectively, might result in such effects. Accordingly, EPA has addressed unfunded mandates in the notice that announces the revisions to 40 CFR part 58, and will, as appropriate, address unfunded mandates when it proposes any revisions to 40 CFR part 51.

9.5 Executive Order 13132: Federalism

Executive Order 13132, entitled "Federalism" (64 FR 43255, August 10, 1999), requires EPA to develop an accountable process to ensure "meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications." "Policies that have federalism implications" is defined in the Executive Order to include regulations that have "substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government."

At the time of this proposal, EPA concludes that the proposed rule would not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government, as specified in Executive Order 13132. However, EPA recognized that States would have a substantial interest in this rule and any corresponding revisions to associated SIP requirements and air quality surveillance requirements, 40 CFR part 51 and 40 CFR part 58, respectively. Therefore, in the spirit of Executive Order 13132, and consistent with EPA policy to promote communications between EPA and State and local governments, EPA specifically solicits comment on the rule from State and local officials at this time.

9.6 Executive Order 13175: Consultation and Coordination with Indian Tribal Governments

Executive Order 13175, entitled "Consultation and Coordination with Indian Tribal Governments" (65 FR 67249, November 9, 2000), requires EPA to develop an accountable process to ensure "meaningful and timely input by tribal officials in the development of regulatory policies that have tribal implications." This rule concerns the establishment of ozone NAAQS. The Tribal Authority Rule gives Tribes the opportunity to develop and implement

CAA programs such as the ozone NAAQS, but it leaves to the discretion of the Tribe whether to develop these programs and which programs, or appropriate elements of a program, they will adopt.

This proposed rule does not have Tribal implications, as specified in Executive Order 13175. It does not have a substantial direct effect on one or more Indian Tribes, since Tribes are not obligated to adopt or implement any NAAQS. Thus, Executive Order 13175 does not apply to this rule. However, in the spirit of efficaciousness, EPA staff participated in the regularly scheduled Tribal Air call sponsored by the National Tribal Air Association during the spring of 2007 as this proposal was under development. EPA specifically solicits additional comment on the proposed NAAQS rule from Tribal officials.

9.7 Executive Order 13045: Protection of Children from Environmental Health & Safety Risks

Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks" (62 FR 19885, April 23, 1997) applies to any rule that: (1) is determined to be "economically significant" as defined under Executive Order 12866, and (2) concerns an environmental health or safety risk that EPA has reason to believe may have a disproportionate effect on children. If the regulatory action meets both criteria, the Agency must evaluate the environmental health or safety effects of the rule on children, and explain why the regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the Agency. This rule is subject to Executive Order 13045 because it is an economically significant regulatory action as defined by Executive Order 12866, and we believe that the environmental health risk addressed by this action may have a disproportionate effect on children.

The NAAQS constitute uniform, national standards for ozone pollution; these standards are designed to protect public health with an adequate margin of safety, as required by CAA section 109. However, the protection offered by these standards may be especially important for children because children, along with other sensitive population subgroups such as the elderly and people with existing heart or lung disease, are potentially susceptible to health effects resulting from ozone exposure. Because children are considered a potentially susceptible population, we have carefully evaluated the environmental health effects of exposure to ozone pollution to this sub-population. These effects and the size of the population affected are summarized in section 8.7 of the Criteria Document and section 3.6 of the Staff Paper, and the results of our evaluation of the effects of ozone pollution on children are discussed in sections II.A-C of the NAAQS proposal preamble.

9.8 Executive Order 13211: Actions that Significantly Affect Energy Supply, Distribution or Use

This proposed rule is not a "significant energy action" as defined in Executive Order 13211, "Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use" (66 FR 28355 (May 22, 2001)) because in the Agency's judgment it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. The purpose of this rule is to establish revised NAAQS for ozone. The rule does not prescribe specific pollution control strategies by which these ambient standards will be met. Such strategies will be developed by States on a case-by-case basis, and EPA cannot predict whether the control options selected by States will include regulations on energy suppliers, distributors, or users. Thus, EPA concludes that this rule is not likely to have any adverse energy effects and does not constitute a significant energy action as defined in Executive Order 13211.

9.9 National Technology Transfer Advancement Act

Section 12(d) of the National Technology Transfer Advancement Act of 1995 (NTTAA), Public Law 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 impractical. 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 applicable voluntary consensus standards. Since EPA is not changing any of the monitoring requirements as part of this proposal, there are no impacts associated with the NTTAA.

9.10 Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations

Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” requires Federal agencies to consider the impact of programs, policies, and activities on minority populations and low-income populations. According to EPA guidance, agencies are to assess whether minority or low-income populations face a risk or a rate of exposure to hazards that are significant and that “appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or to the appropriate comparison group” (EPA, 1998).

In accordance with Executive Order 12898, the Agency has considered whether these decisions may have disproportionate negative impacts on minority or low-income populations. This rule establishes uniform, national ambient air quality standards for ozone, and is not expected to have disproportionate negative impacts on minority or low income populations. In this NAAQS proposal, the Administrator considered the available information regarding health effects among vulnerable and susceptible populations, such as those with preexisting conditions. Thus it remains EPA’s conclusion that this rule is not expected to have disproportionate negative impacts on minority or low income populations.

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Air Quality Strategies and Standards Division Research Triangle Park, NC	Publication No. EPA-452/R-07-008 July 2007