Proposed NO_2 NAAQS Regulatory Impact Analysis (RIA)

EPA/OAQPS/HEID/ABCG

July 2, 2009

Table of Contents

ES.1 Overview

This Regulatory Impact Analysis (RIA) provides illustrative estimates of the incremental costs and monetized human health benefits of attaining a lower-bound revised short-term Nitrogen Dioxide (NO_2) National Ambient Air Quality Standard (NAAQS) within the current community-wide monitoring network of 409 monitors. Because this analysis only considers counties with NO_2 monitors, the possibility exists that there may be many more potential nonattainment areas than have been analyzed in this RIA.

The proposal would set a new short-term NO_2 standard based on the 3-year average of the 99th percentile of 1-hour daily maximum concentrations, establishing a new standard within the range of 80 to 100 ppb. The proposal also requests comment on standard levels ranging from a low of 65 ppb to a high of 150 ppb. As a lower bound, we chose an alternative primary standard of 50 parts per billion (ppb) for the area-wide analysis. This more stringent NAAQS alternative affects the largest number of geographic areas that may be affected by a new NO_2 standard. Our analysis of this hypothetical scenario is meant to approximate the most comprehensive set of control strategies that areas across the country might employ to attain. (We chose 50 ppb as an analytic lower bound before decisions were made about either the proposed range, or the range for requesting public comment.) For the near-roadway analysis, we analyzed standard levels at 65 ppb, 80 ppb, 100 ppb, and 125 ppb.

It is important to reiterate that this analysis does not attempt to estimate attainment or nonattainment for any areas of the country other than those counties currently served by one of the 409 monitors in the current network. Chapter 2 explains that the current network is focused on community-wide ambient levels of NO_2, and not near-roadway levels, which may be significantly higher, and the proposal also contains requirements for an NO_2 monitoring network that would include monitors near major roadways. We recognize that once a network of near-roadway monitors is put in place, more areas could find themselves exceeding the new hourly NO_2 NAAQS. However for this RIA analysis, we lack sufficient data to predict which additional counties might exceed the new NAAQS after implementation of a near-roadway monitoring network if they do not currently have a monitor. (Regional scale models such as CMAQ do not provide a sufficient level of sub-grid detail to estimate near-road concentrations, and local-scale models such as AERMOD cannot model large regions with appropriate characterization of the near-road component of ambient air quality).

In this RIA, we projected current area-wide monitor values to future year monitor values directly, using future year CMAQ modeling outputs that take into account expected changes in emissions from 2006 to 2020. Because a near-roadway monitoring network does not currently exist, it was not possible to do this same direct projection into the future for near-roadway peaks. Because short-term peak exposures may occur near roadways, we conducted additional analysis to approximate such peak exposures. This analysis relies on current and future estimated air quality concentrations at area-wide monitors, making adjustments to future year projections using derived estimates of the relationship between future year area-wide air quality peaks and current near-roadway peaks. This additional analysis that effectively extrapolates future year near-roadway air quality from projected area-wide concentrations, contained in chapter 7, represents a screening level approximation with significant additional uncertainties.

This RIA chiefly serves two purposes. First, it provides the public with an estimate of the expected costs and benefits of attaining a new NO_2 NAAQS. Second, it fulfills the requirements of 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. As stated above, we chose 50 ppb as an analytic lower bound. Our original intent had been to also analyze a target NAAQS level of 100 ppb as a mid-range target identified in the Risk and Exposure Assessment (REA) as an epidemiological level of concern. We had also intended to analyze an upper bound of 200 ppb. As it turned out, as shown in chapter 3, our projections indicated no counties in the analysis year of 2020 that would have ambient 1-hour peak levels as high as the 80 to 100 ppb proposal range, assuming a baseline of no additional control beyond the controls expected from rules that are already in place (including the current $PM_{2.5}$ and ozone NAAQS).[2] Therefore the bulk of our analysis in this RIA focuses on the lower bound target NAAQS level of 50 ppb.

In setting primary ambient air quality standards, EPA's responsibility under the law is to establish standards that protect public health, regardless of the costs of implementing a new standard. 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.

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

---

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

[2] For this RIA, we chose an analysis year of 2020. Although the actual attainment year is likely to be 2017, time and resource limitations dictated use of pre-existing model runs, which all focused on 2020. In addition, we do not have emission inventory projections for 2017; such projections are done for 5-year intervals.

is essential to making efficient, cost effective decisions for implementation of these standards. The impacts of cost and efficiency are considered by states during this process, as they decide what timelines, strategies, and policies are most appropriate. This RIA is intended to inform the public about the potential costs and benefits associated with a hypothetical scenario that may result when a new NO_2 standard is implemented, but is not relevant to establishing the standards themselves.

ES.2 Summary of Analytic Approach for the Area-wide Analysis

Our assessment of the lower bound NO_2 target NAAQS includes several key elements, including specification of baseline NO_2 emissions and concentrations; development of illustrative control strategies to attain the standard in 2020; and analyses of the control costs and health benefits of reaching the 50 ppb lower bound alternative. Additional information on the methods employed by the Agency for this RIA is presented below.

Overview of Baseline Emissions Forecast and Baseline NO_2 Concentrations

The baseline emissions and concentrations for this RIA are based on NOx emissions data from the 2002 National Emissions Inventory (NEI), and baseline NO_2 concentration values from 2005-2007 across the community-wide monitoring network. We used results from the community multi-scale air quality model (CMAQ) simulations from the ozone NAAQS RIA to calculate the expected reduction in ambient NO_2 concentrations between the 2002 base year and 2020. More specifically, design values (i.e. air quality concentrations at each monitor) were calculated for 2020 using monitored air quality concentrations from 2002 and modeled air quality projections for 2020, countywide emissions inventory data for 2002 and 2005-7, and emissions inventory projections for 2020. These data were used to create ratios between emissions and air quality, and those ratios (relative response factors, or RRFs) were used to estimate air quality monitor design values for 2020. The 2020 baseline air quality estimates revealed that ten monitors in six counties were projected to exceed a 50 ppb lower bound target NAAQS in 2020.

Development of Illustrative Control Strategies

For the lower bound of 50 ppb, we analyzed the impact that additional emissions controls applied to numerous sectors would have on predicted ambient NO_2 concentrations, incremental to the baseline set of controls. Thus the modeled analysis for a revised standard focuses specifically on incremental improvements beyond the current standards, and uses control options that might be available to states for application by 2020. The hypothetical modeled control strategy 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 NO_2 standard should be implemented, and states will make all final decisions regarding implementation strategies once a final NAAQS has been set.

Generally, we expect that the nation would be able to attain some of the tighter NO_2 NAAQS without the addition of new controls beyond those already being planned for the attainment of existing $PM_{2.5}$ and ozone standards by the year 2020. As States develop their plans for attaining these existing standards, they are likely to consider adding controls to reduce NOx, as NOx is a precursor to both $PM_{2.5}$ and ozone. These controls will also directly help areas meet a tighter NO_2 standard.

The 2020 baseline air quality estimates revealed that 10 monitors in 6 counties had projected design values exceeding 50 ppb at area monitors. We then developed a hypothetical control strategy that could be adopted to bring the current highest emitting monitor in each of those six counties into attainment with a primary standard of 50 ppb by 2020. Controls for five emissions sectors were included in the control analysis: non-electricity generating unit point sources (nonEGU), non-point area sources (area), onroad mobile sources (onroad), and nonroad mobile sources (nonroad) and electricity generating unit point sources (EGU). Finally, we note that because it was not possible, in this analysis, to bring all areas into attainment with the alternative standard of 50 ppb in all areas using only identified controls. For two monitor areas we estimated the cost of unspecified emission reductions. In chapter 4 we discuss these areas in more detail.

Analysis of Benefits

Our analysis of the benefits associated with the 50 ppb target includes benefits related to reducing NO_2 concentrations, and the ancillary benefits of reducing concentrations of particulate matter (PM). For the benefits analysis, we use the Environmental Benefits Mapping and Analysis Program (BenMAP) to estimate the health benefits occurring as a result of implementing alternative NO_2 NAAQS levels. Although BenMAP has been used extensively in previous RIAs to estimate the health benefits of reducing exposure to $PM_{2.5}$ and ozone, this is the first RIA to use BenMAP to estimate the health benefits of reducing exposure to NO_2.

The primary input to the benefits assessment is the estimated changes in ambient air quality expected to result from a simulated control strategy or attainment of a particular standard. CMAQ projects both design values at NO_2 monitors and air quality concentrations at 12km grid cells. To estimate the benefits of fully attaining the standards in all areas, EPA employed the “monitor rollback” approach to approximate the air quality change resulting from just attaining alternative NO_2 NAAQS at each design value monitor. This approach relies on data from the existing NO_2 monitoring network and the VNA interpolation method (inverse distance squared) to adjust the CMAQ-modeled NO_2 concentrations such that each areas area just attains the 50 ppb standard alternative.

We then selected health endpoints to be consistent with the conclusions of the Integrated Science Assessment (ISA) for NO_2 . In this analysis, we only estimated the benefits for those endpoints with sufficient evidence to support a quantified concentration-response relationship using the information presented in the NO_2 ISA, which contains an extensive literature review for several health endpoints related to NO_2 exposure. Based on our review of this information, we quantified three short-term morbidity endpoints that the NO_2 ISA identified as “sufficient to infer a likely causal relationship”: asthma exacerbation, respiratory-related emergency department visits, and respiratory-related hospitalizations. After identifying the health endpoints to quantify in this analysis, we then selected concentration-response functions and valuation functions based on criteria detailed in chapter 5. The valuation functions, ambient concentrations, and population data in the monitor areas are combined in BenMAP to provide the benefits estimates for this analysis.

In addition, because NO_x is also a precursor to $PM_{2.5,}$ reducing NO_x emissions in the projected non-attainment areas will also reduce $PM_{2.5}$ formation, human exposure, and the incidence of $PM_{2.5}$-related health effects. In this analysis, we estimated the co-benefits of reducing $PM_{2.5}$ exposure for the alternative standards. Due to analytical limitations, it was not possible to provide a comprehensive estimate of $PM_{2.5}$-related benefits. Instead, we used the “benefit-per-ton” method to estimate these benefits. The $PM_{2.5}$ 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 RIAs, including the recent Ozone NAAQS RIA (U.S. EPA, 2008a) and Portland Cement NESHAP RIA (U.S. EPA, 2009).

The total benefits estimates include NO_2-related benefits as well as $PM_{2.5}$ co-benefits. The two estimates use the unadjusted effect estimates (no-threshold) from two epidemiology studies examining the relationship between $PM_{2.5}$ and premature mortality using large population cohorts: the American Cancer Society cohort (Pope et al., 2002) and the Harvard Six Cities cohort (Laden et al., 2006). These estimates reflect EPA’s most current interpretation of the scientific literature on $PM_{2.5}$ and mortality, including our updated benefits methodology (i.e., a no-threshold model that calculates incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels and incorporates two technical updates) compared to the estimates in previous RIAs that did not include these changes. Table ES.4 identifies the incidences of reduced health effects expected as a result this rule from reductions in exposure to NO_2 and $PM_{2.5}$.

Analysis of Costs

Consistent with our development of the illustrative control strategies described above, our analysis of the costs associated with the 50 ppb lower bound alternative NAAQS focuses on NOx emission controls for nonEGU , area, EGU, and mobile sources.

NonEGU and area source controls largely include measures from the AirControlNET control technology database. For these sources, we estimated costs based on the cost equations included in AirControlNET. The identified controls strategy for nonEGU Point and Area sources incorporated annualized engineering cost per ton caps. These caps were defined as the upper cost per ton for controls of nonEGU point and area sources. The caps used were originally developed for the Ozone NAAQS analysis, where NOx controls were also applied. The number of applied control measures was much larger for that analysis, and therefore provides a more robust estimate of what a potential cap on NOx costs would look like.

The EGU analysis included in this RIA utilizes the latest version of the integrated planning model (IPM) v3.0 as part of the updated modeling platform.[1] IPM v3.0 includes input and model assumption updates in modeling the power sector and incorporates Federal and State rules and regulations adopted before September 2006 and various new source review (NSR) settlements. The NOx control technology options used in IPM v3.0 include Selective Catalytic Reduction (SCR) 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.

For onroad and nonroad mobile sources, costs, in terms of dollars per ton emissions reduced, were applied to emission reductions calculated for the onroad and nonroad mobile sectors that were generated using the National Mobile Inventory Model (NMIM). NMIM is an EPA model for estimating air emissions from highway vehicles and nonroad mobile equipment. NMIM uses current versions of EPA's model for onroad mobile sources, MOBILE6, and nonroad mobile sources, NONROAD, to calculate emission inventories.[2]

---

[1] http://www.epa.gov/airmarkets/progsregs/epa-ipm/past-modeling.html.

[2] More information regarding the National Mobile Inventory Model (NMIM) can be found at http://www.epa.gov/otaq/nmim.htm

Finally, as indicated in the above discussion on illustrative control strategies, implementation of the NOx control measures identified from AirControlNET and other sources does not result in attainment with the selected NAAQS in several areas. In these areas, additional unspecified emission reductions might be necessary to reach a 50 ppb target. In order to bring these monitor areas into attainment, we calculated controls costs using a fixed cost per ton approach similar to that used in the ozone RIA analysis.

ES.3 Results of 50 ppb Area-wide Analysis

Air Quality

Table ES.1. shows the projected ambient NO_2 concentrations for 2020 after application of identified controls for the area-wide analysis. It also shows the additional tons of emission reduction needed from unidentified controls to reach 50 ppb.

Table ES.1. Identified Controls Emission Reductions and Ambient Concentrations in 2020.

State	County	NOx Emission Reductions in 2020 (tons/year)	Design Values Post Application of Identified Controls (99th percentile 1-hr daily max ppb)	NOx Emission Reductions Needed Beyond Identified Controls (tons/year)
CA	**Los Angeles**	**--**	**52.5**	**18,000**
CO	**Adams**	**8,400**	**48.0**	
LA	**East Baton Rouge**	**5,300**	**50.2**	
TX	**El Paso**	**4,400**	**59.6**	**5,600**
UT	**Salt Lake**	**2,600**	**50.3**	
VA	**Charles City**	**47**	**47.9**	

Benefit and Cost Estimates

Tables ES.2 and ES.3 presents total national estimates of costs and benefits for the area-wide analysis at a 3% discount rate and a 7% discount rate.

Table ES.2: Summary of Total Costs for Alternative Standard 50 ppb in 2020 (Millions of 2006$)[a, b]

		3% Discount Rate[c]	7% Discount Rate
Identified Control Costs		$36	$44
Monitoring Costs		$7.1	$7.1
Extrapolated Costs	Fixed Cost ($10,000/ton)	$240	$240
	Fixed Cost ($15,000/ton)	$350	$350
	Fixed Cost ($20,000/ton)	$470	$470
Total Costs	Fixed Cost ($10,000/ton)	$270	$280
	Fixed Cost ($15,000/ton)	**$390**	**$400**
	Fixed Cost ($20,000/ton)	$510	$510

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.

[c] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For the identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized identified control cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

Table ES.3. Summary of Total Monetized Benefits in 2020 to attain 50ppb (millions of 2006$)

	3% Full Attainment	7% Full Attainment	3% Partial Attainment	7% Partial Attainment
NO_2	$6.3	$6.3	$4.6	$4.6
$PM_{2.5}$				
Pope et al	$270	$240	$140	$130
Laden et al	$650	$590	$350	$320
TOTAL with Pope	**$270**	**$250**	**$150**	**$140**
TOTAL with Laden	**$660**	**$600**	**$360**	**$320**

*All estimates are for the analysis year (2020) and are rounded to two significant figures. These benefits estimates do not include several important benefits categories, including NO2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

Table ES.4: Summary of Reductions in Health Incidences from NO_2 and $PM_{2.5}$ to attain 50 ppb*

Avoided Premature Mortality	
Pope	30
Laden	80
Woodruff (Infant Mortality)	< 1
Avoided Morbidity	
Chronic Bronchitis	20
Acute Myocardial Infarction	50
Hospital Admissions, Respiratory	60
Hospital Admissions, Cardiovascular	20
Emergency Room Visits, Respiratory	220
Acute Bronchitis	4,300
Work Loss Days	590
Asthma Exacerbation	86,000
Acute Respiratory Symptoms	53,000
Lower Respiratory Symptoms	640
Upper Respiratory Symptoms	490

*All estimates are for the analysis year (2020) and are rounded to two significant figures.

The net benefits were calculated by subtracting the total cost estimate from the two estimates of total benefits. Table ES.5 shows net benefits of the selected NAAQS and alternative standards. No areas are projected to exceed 80 ppb in the area-wide analysis.

Table ES.5 Summary of Net Benefits for Alternative Standard 50 ppb in 2020 (Millions of 2006$)

	3% Discount Rate	7% Discount Rate
Total RIA Costs + Monitoring Costs	$390 + $3.6	$400 + $3.6
Total Benefits [a]	$270 - $660	$250 - $600
Total	**$(120) - $270**	**$(150) - $200**

[a] These benefits estimates do not include several important benefits categories, including NO_2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

ES.4. Screening-Level Analysis of Approximated Future Near-Roadway NO_2 Exceedances of Target NAAQS

Because a near-roadway monitoring network does not currently exist, it was not possible to do the same direct projection into the future for near-roadway peaks as was done for the area-wide analysis. Therefore, the near-roadway analysis represents a much more uncertain screening level approximation of future year near-roadway air quality. We first select "area-wide" monitors to adjust to approximate near-roadway conditions. The monitors included in this analysis are those considered to be representative of "area-wide" conditions; i.e. those monitors to which it would be appropriate to apply the gradient to scale from area-wide to near-roadway conditions. To reflect the expected roadway gradient discussed in the proposal preamble (i.e., near road monitors can be between 30% to 100% greater than the area wide monitors), we adjust our estimated design values at area-wide locations for the future year of 2020 by 130%, 165%, and 200%.For the near-roadway analysis, we analyzed standard levels at 65 ppb, 80 ppb, 100 ppb, and 125 ppb. We used two analytic methods to determine the 2020 design values and the tons needed to attain the various alternate standard levels: a near roadway gradient adjustment, referred to as Method 1, and a near roadway gradient adjustment with a modification to future CMAQ air quality levels, referred to as Method 2. While the modification is conceptually sound, it is a relatively new methodology. We present the results using both analytic methods.

Because this analysis examines emissions and air quality approximating near-roadway conditions, we applied controls on mobile sources. We have estimated that the annualized average cost of controls to attain the NO_2 NAAQS would be in the range of $3,000 to $6,000 per ton. This estimate is based upon previous estimates of controls for mobile sources. To calculate the near-roadway benefits, we only calculated the $PM_{2.5}$ co-benefits because it would be difficult to estimate NO_2 benefits based on the data available for this analysis, and the area-wide analysis for 50 ppb showed that the monetized NO_2 benefits only accounted for 2% of the total monetized benefits. To calculate the $PM_{2.5}$ co-benefits, we used a benefit-per-ton approach, using the benefit-per-ton estimate corresponding to NO_X emission reductions from the mobile sector.   These estimates reflect EPA's most current interpretation of the scientific literature on $PM_{2.5}$ and mortality, including our updated benefits methodology (i.e., a no-threshold model that calculates incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels and incorporates two technical updates) compared to the estimates in previous RIAs that did not include these changes.

ES.5. Results from Screening Level Near-Roadway Analysis

Tables ES.6 and ES.7 show the cost and benefit results of the near-roadway analysis using the two analytic methods at discount rates of 3% and 7% respectively. The net benefits were calculated by subtracting the total cost estimate from the two estimates of total benefits. The proposed standard range of 80ppb to 100 ppb is highlighted.

Table ES.6: Benefit Cost Comparison for Near Roadway Analysis (in millions of 2006$ at a 3% discount rate for Benefits only)[a]

			Standard Level	Total Costs[b, c]	Total Benefits[d, e]	Net Benefits
Near Roadway Analysis	Method 1	30% Gradient	65 ppb	$170 to $330	$290 to $700	-$40 to $530
			80 ppb	$12 to $20	$14 to $34	-$6.0 to $22
			100 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
			125 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
		65% Gradient	65 ppb	$1,000 to $2,100	$1,800 to $4,400	-$300 to $3,400
			80 ppb	$300 to $600	$520 to $1,300	-$80 to $1,000
			100 ppb	$17 to $30	$23 to $56	-$7.0 to $39
			125 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
		100% Gradient	65 ppb	$2,400 to $4,800	$4,200 to $10,000	-$600 to $7,600
			80 ppb	$1,200 to $2,300	$2,000 to $5,000	-$300 to $3,800
			100 ppb	$270 to $530	$460 to $1,100	-$70 to $830
			125 ppb	$14 to $24	$18 to $43	-$6.0 to $29
	Method 2	30% Gradient	65 ppb	$12 to $21	$15 to $36	-$6.0 to $24
			80 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
			100 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
			125 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
		65% Gradient	65 ppb	$260 to $510	$440 to $1,100	-$70 to $840
			80 ppb	$23 to $42	$33 to $81	-$9.0 to $58
			100 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
			125 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
		100% Gradient	65 ppb	$910 to $1,800	$1,600 to $3,800	-$200 to $2,900
			80 ppb	$280 to $560	$480 to $1,200	-$80 to $920
			100 ppb	$17 to $31	$24 to $59	-$7.0 to $42
			125 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6

---

[a] All estimates are for the analysis year (2020) and are rounded to two significant figures.

[b] Costs are estimated at a 3% discount rate in the Area-wide analysis for sources where there is a capital component and O&M component.

[c] Total Cost estimates for Near roadway analysis are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[d] These benefits estimates for do not include several important benefits categories, including NO_2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

[e] Total Benefit estimates for the Near-roadway analysis are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 7% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

Table ES.7: Benefit Cost Comparison for Near Roadway Analysis (in millions of 2006$ at a 7% discount rate for Benefits only)[a]

			Standard Level	Total Costs[b]			Total Benefits[c, d]			Net Benefits		
Near Roadway Analysis	**Method 1**	30% Gradient	65 ppb	$170	to	$330	$230	to	$550	-$100	to	$380
			80 ppb	$12	to	$20	$11	to	$27	-$9.0	to	$15
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		65% Gradient	65 ppb	$1,000	to	$2,100	$1,400	to	$3,400	-$700	to	$2,400
			80 ppb	$300	to	$600	$410	to	$1,000	-$190	to	$700
			100 ppb	$17	to	$30	$18	to	$44	-$12	to	$27
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		100% Gradient	65 ppb	$2,400	to	$4,800	$3,300	to	$8,100	-$1,500	to	$5,700
			80 ppb	$1,200	to	$2,300	$1,600	to	$3,900	-$700	to	$2,700
			100 ppb	$270	to	$530	$360	to	$880	-$170	to	$610
			125 ppb	$14	to	$24	$14	to	$34	-$10	to	$20
	Method 2	30% Gradient	65 ppb	$12	to	$21	$12	to	$29	-$9.0	to	$17
			80 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		65% Gradient	65 ppb	$260	to	$510	$350	to	$850	-$160	to	$590
			80 ppb	$23	to	$42	$26	to	$64	-$16	to	$41
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		100% Gradient	65 ppb	$910	to	$1,800	$1,300	to	$3,000	-$500	to	$2,100
			80 ppb	$280	to	$560	$380	to	$930	-$180	to	$650
			100 ppb	$17	to	$31	$19	to	$46	-$12	to	$29
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6

[a] All estimates are for the analysis year (2020) and are rounded to two significant figures.

[b] Total Cost estimates for Near roadway analysis are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[c] These benefits estimates for the Area-wide analysis do not include several important benefits categories, including NO_2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

[d] Total Benefit estimates for the Near-roadway analysis are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 7% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

ES.6. Caveats and Limitations

Air Quality Data, Modeling and Emissions

- Current $PM_{2.5}$ and Ozone Controls in Baseline: Our 2020 analysis year baseline assumes that States will put in place the necessary control strategies to attain the current $PM_{2.5}$ and ozone standards. Some of the control strategies employed as part of the ozone RIA, in particular, were of necessity highly uncertain. As States develop their plans for attaining these standards, their NOx control strategies may differ significantly from our analysis.

- Use of Existing CMAQ Model Runs: This analysis represents a screening level analysis. We did not conduct new regional scale modeling specifically targets to NO_2; instead we relied upon impact ratios developed from model runs used in the analysis underlying the ozone NAAQS.

- Analysis Year of 2020: Data limitations necessitated the choice of an analysis year of 2020, as opposed to the presumptive implementation year of 2017. Emission inventory projections are available for 5-year increments; i.e. we have inventories for 2015 and 2020, but not 2017. In addition, the CMAQ model runs upon which we relied were also based on an analysis year of 2020.

- Unknown controls: We have limited information on available controls for some of the monitor areas included in this analysis. For example, a full set of identified controls were applied to Los Angeles County in the Ozone NAAQS RIA; because this analysis is incremental, this left no additional identified control measures to be applied, particularly because we do not have emission reduction estimates for the Port of Long Beach in our analysis.

- Limited monitoring network: For the current monitoring community-wide monitoring network, the universe of monitors exceeding the target NAAQS levels is very small. Once a network of near-roadway monitors is put in place, there could be more potential nonattainment areas than have been analyzed in this RIA.

- Actual State Implementation Plans May Differ from our Simulation: In order to reach attainment with each selected NAAQS, each state will develop its own implementation plan implementing a combination of emissions controls that may differ from those simulated in this analysis. This analysis therefore represents an approximation of the emissions reductions that would be required to reach attainment and should not be treated as a precise estimate.

- Uncertainty associated with unspecified emission reductions: As indicated above, some areas are expected to rely on unspecified emission reductions to reach attainment with the standards. The cost of implementing these measures, though estimated here based on the costs for identified controls, is uncertain.

Costs

- We do not have sufficient information for all of our known control measures to calculate cost estimates that vary with an interest rate. We are able to calculate annualized costs at an interest rate other than 7% (e.g., 3% interest rate) where there is sufficient information—available capital cost data, and equipment life—to annualize the costs for individual control measures. For the vast majority of nonEGU point source control measures, we do have sufficient capital cost and equipment life data for individual control measures to prepare annualized capital costs using the standard capital recovery factor. Hence, we are able to provide annualized cost estimates at different interest rates for the point source control measures.

- 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 “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.

Benefits

- Benefits are most uncertain for the Los Angeles and El Paso areas because a large proportion of the $PM_{2.5}$-related benefits are based on emission reductions attributable to unidentified emission controls. 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.

- The gradient of ambient NO_2 concentrations is difficult to estimate due to the sparsity of the monitoring network. The 12km CMAQ grid, which is the air quality modeling resolution, may be too coarse to accurately estimate the potential near-field health benefits of reducing NO_2 emissions. These uncertainties may under- or over-estimate benefits.

- The interpolation techniques used to estimate the full attainment benefits of the alternative standards contributed some uncertainty to the analysis. The great majority of benefits estimated for the 50 ppb standard alternative were derived through interpolation. As noted previously in chapter 5, these benefits are likely to be more uncertain than if we had modeled the air quality scenario for both NO_2 and $PM_{2.5}$. In general, the VNA interpolation approach will under-estimate benefits because it does not account for the broader spatial distribution of air quality changes that may occur due to the implementation of a regional emission control program.

- There are many uncertainties associated with the health impact functions used in this modeling effort. These include: within study variability; across study variation; the application of concentration-response (C-R) functions nationwide; extrapolation of impact functions across population; and various uncertainties in the C-R function, including causality and thresholds. These uncertainties may under- or over-estimate benefits.

- Co-pollutants present in the ambient air may have contributed to the health effects attributed to NO_2 in single pollutant models. Risks attributed to NO_2 might be overestimated where concentration-response functions are based on single pollutant models. If co-pollutants are highly correlated with NO_2, their inclusion in an NO_2 health effects model can lead to misleading conclusions in identifying a specific causal pollutant. Because this collinearity exists, many of the studies reported statistically insignificant effect estimates for both NO_2 and the co-pollutants. Where available, we have selected multipollutant effect estimates to control for the potential confounding effects of co-pollutants; these include NYDOH (2006), Schwartz et al. (1994) and O'Conner et al. (2007). The remaining studies include single pollutant models.

- This analysis is for the year 2020, and projecting key variables introduces uncertainty. 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.

- This analysis omits certain unquantified effects due to lack of data, time and resources. These unquantified endpoints include other health effects, ecosystem effects, and visibility. EPA will continue to evaluate new methods and models and select those most appropriate for estimating the benefits of reductions in air pollution. Enhanced collaboration between air quality modelers, epidemiologists, toxicologists, ecologists, and economists should result in a more tightly integrated analytical framework for measuring benefits of air pollution policies.

- $PM_{2.5}$ co-benefits represent a substantial proportion of total monetized benefits (97% to 99% of total benefits for the 50 ppb standard), and these estimates are subject to a number of assumptions and uncertainties.

- $PM_{2.5}$ co-benefits were derived through benefit per-ton estimates, which do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual benefits of controlling directly emitted fine particulates.

- We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ produced via transported precursors emitted from EGUs may differ significantly from direct $PM_{2.5}$ released from diesel engines and other industrial sources, but no clear scientific grounds exist for supporting differential effects estimates by particle type.

- We assume that the health impact function for fine particles is linear within the range of ambient concentrations under consideration. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5,}$ including both regions that are in attainment with fine particle standard and those that do not meet the standard down to the lowest modeled concentrations.

- To characterize the uncertainty in the relationship between $PM_{2.5}$ and premature mortality (which typically accounts for 85% to 95% of total monetized benefits), we include a set of twelve estimates based on results of the expert elicitation study in addition to our core estimates. Even these multiple characterizations omit the uncertainty in air quality estimates, baseline incidence rates, populations exposed and transferability of the effect estimate to diverse locations. As a result, the reported confidence intervals and range of estimates give an incomplete picture about the overall uncertainty in the $PM_{2.5}$ estimates. This information should be interpreted within the context of the larger uncertainty surrounding the entire analysis.

Screening-level near-roadway analysis

- Due to the absence of a near-roadway monitoring network, this is a screening level analysis with several simplifying assumptions. It is provided to give a rough projection of the costs and benefits of attaining a revised NO_2 standard based on a yet to be established monitoring network.

- This analysis does not take into account a large variety of localized conditions specific to individual monitors; instead, the analysis attempts to account for some local parameters by adjusting future design values based on average localized impacts near roads from onroad emissions.

- The process of adjusting from a specific 12 km CMAQ receptor to a near-road air quality estimate represents an uncertain approximation at the specific monitor level.

- This analysis is an approximation in that it derives future year (2020) **peak** air quality concentrations in specific locations by relying on CMAQ estimates that are averages over a 12 km grid square.

- This analysis cannot predict air quality in locations for which there is no current NO_2 monitor, or where current monitoring data is incomplete. There are 142 CBSAs for which we are proposing to add new near-road monitors. Of these, 73 either have no existing monitor in the CBSA, or have a monitor with data not complete enough to include in the near-roadway analysis. In these CBSAs, extrapolation to near-roadway levels is not possible.

- This analysis assumes area-wide monitors remain in the same location; however concentrations are adjusted to reflect near-roadway conditions.

- Because the emission reductions in this analysis are solely reductions from mobile sources, this analysis uses an estimated cost per ton for NOx emission reductions that is different from the estimated cost per ton for NOx emission reductions used in the main body of the RIA.

- This analysis omits certain unquantified effects due to lack of data, time and resources. These unquantified endpoints include NO_2 health effects, ozone co-benefits, ecosystem effects, and visibility.

Chapter 1: Introduction and Background

Synopsis

This document estimates the incremental costs and monetized human health benefits of attaining a revised primary nitrogen dioxide (NO_2) National Ambient Air Quality Standard (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 NO_2 NAAQS. EPA weighed the available empirical data and photochemical modeling 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 NO_2 NAAQS, and to meet the requirements of Executive Order 12866 and OMB Circular A-4 (described below in Section 1.2.2).

This RIA provides illustrative estimates of the incremental costs and monetized human health benefits of attaining a revised primary NO_2 National Ambient Air Quality Standard (NAAQS) in 2020 within the current monitoring network[1]. This proposal would add a new short-term (1-hour exposure) standard, in addition to the current annual average standard. It is important to note that there may be many more potential nonattainment areas than have been analyzed in this RIA. The Integrated Science Assessment (ISA) and Risk and Exposure Asessment (REA), discussed in section 1.3 below, summarize available monitoring information, noting elevated short-term NO2 concentrations near roads with high traffic volumes, with significant gradients relative to areas further away. Therefore there may be near-roadway locations that are currently not served by an NO_2 monitor, but which may have relatively high NO_2 concentrations at peak times.

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

---

[1] There are 409 monitors. Currently 131 monitors (representing 81 counties) exceed the most stringent target NAAQS level in this analysis (50 ppb).

health or welfare which may be expected from the presence of [a] pollutant in the ambient air." NO_2 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, regardless of the costs of implementing a new standard. 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.

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 NO_2 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. 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.[2] 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 benefit-cost, and a cost-effectiveness analysis for rules where health is the primary effect. Within this RIA we provide a benefit-cost analysis. Methodological and data limitations prevent us from performing a cost-effectiveness analysis and a meaningful more formal uncertainty analysis for this RIA.

Our original intent had been to also analyze a target NAAQS level of 100 ppb as a mid-range target identified in the Risk and Exposure Assessment (REA) as an epidemiological level of concern. We had also intended to analyze an upper bound of 200 ppb. As it turned out, as shown in chapter 3, our projections indicated no counties in 2020 that would have ambient 1-hour peak levels as high as the 80 to 100 ppb proposal range in 2020, assuming a baseline of no additional control beyond the controls expected from rules that are already in place (including the current $PM_{2.5}$ and ozone NAAQS). In fact, our projections indicate only one county that would have ambient 1-hour peak levels above 65 ppb in 2020 (Adams County, Colorado). Therefore the bulk of our analysis in this RIA focuses on the lower bound target NAAQS level of 50 ppb.

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 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

---

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

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 entities are emitting pollutants, which cause health and environmental problems without compensation for those suffering the problems. 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 NO_2 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 NO_2 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.

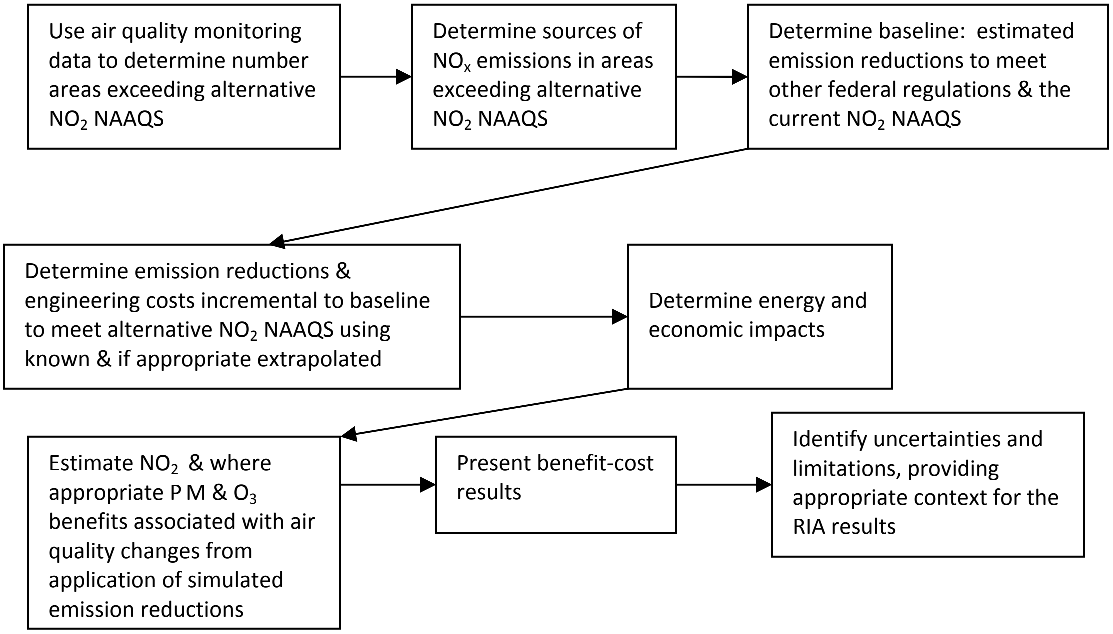
The illustrative goals of this RIA are somewhat different from other EPA analyses of national rules, or the implementation plans states develop, and the distinctions are worth brief mention. This RIA does not assess the regulatory impact of an EPA-prescribed national or regional rule such as the Clean Air Interstate Rule, nor does it attempt to model the specific actions that any state would take to implement a revised NO_2 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 NO2 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. 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 NO_2 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 process used to create 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 approximates the required attainment year under the Clean Air Act. Many areas will reach attainment of any alternative NO_2 standard before 2020. For purposes of this analysis, we assess attainment by 2020 for all areas. 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.

The methodology first estimates what baseline NO_2 levels might look like in 2020 with existing Clean Air Act programs, including application of controls to meet the current NO_2 NAAQS, various maximum achievable control technology (MACT) standards, and the revised particulate matter (PM) and ozone (O_3) NAAQS standards, and then predicts the change in NO_2 levels following the application of additional controls to reach tighter alternative standards. This allows for an analysis of the incremental change between the current standard and alternative standards. Since NO_2 is a precursor of both ozone and PM, it is important that we account for the impact on NO_2 concentrations of both the NO_2 controls used in the hypothetical control scenario in the ozone NAAQS RIA, and the NO_2 and PM controls used in the hypothetical control scenario 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

It should be noted that our original intent had been to analyze target NAAQS levels of 50, 100, and 200 ppb. As it turned out, as shown in chapter 3, our projections indicated no counties in 2020 that would have ambient 1-hour peak levels as high as the 80 to 100 ppb proposal range in 2020, assuming a baseline of no additional control beyond the controls expected from rules that are already in place (including the current $PM_{2.5}$ and ozone NAAQS). In fact, our projections indicate only one county that would have ambient 1-hour peak levels above 65 ppb in 2020 (Adams County, Colorado). Therefore the bulk of our analysis in this RIA focuses on the lower bound target NAAQS level of 50 ppb.

Hypothetical control strategies were developed for the lower bound target NAAQS level of 50 ppb. First, EPA used outputs from CMAQ model runs developed for the ozone RIA analysis to estimate 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 areas with monitoring levels currently exceeding the alternative standards. However, given and the amount of improvement in air quality needed to reach the most stringent alternative standard (50 ppb) in two areas, as well as circumstances specific to those two areas, it was also expected that applying these known controls would not reduce NO_2 concentrations sufficiently to allow these two areas to reach the most stringent standard. In order to bring these monitor areas into attainment, we calculated the cost of unspecified emission reductions by extrapolating from a range of fixed costs per ton of emission control that are generally identified nationally.

1.3.3 Evaluating Costs and Benefits

We applied a two step methodology for estimating emission reductions needed to reach full attainment. First, we quantified the costs associated with applying known controls. Second, we estimated costs of the additional tons of extrapolated emission reductions estimated which were needed to reach full attainment. This methodology enabled us to evaluate nationwide costs and benefits of attaining a tighter NO_2 standard using hypothetical strategies, albeit with substantial additional uncertainty regarding the second step estimates. [3]

To streamline this RIA, this document refers to several previously published documents, including three technical documents EPA produced to prepare for promulgation of the NO_2 NAAQS. The first was a Criteria Document created by EPA's Office of Research and Development (published in 2007), which presented the latest available pertinent information on atmospheric science, air quality, exposure, health effects, and environmental effects of NO_2. The second was an Integrated Science Assessment (ISA) published in 2008 that evaluated the policy implications of the key studies and scientific information contained in the Criteria Document. The third was a risk and exposure assessment (REA) for various standard levels. The REA also includes staff conclusions and recommendations to the Administrator regarding potential revisions to the standards.

1.4 NO_2 Standard Alternatives Considered

EPA has performed an illustrative analysis of the potential costs and human health and visibility benefits of nationally attaining a lower bound NO_2 NAAQS of 50 ppb, noting that our projections indicated no counties in 2020 that would have ambient 1-hour peak levels as high as the 80 to 100 ppb proposal range in 2020, assuming a baseline of no additional control beyond the controls expected from rules that are already in place (including the current $PM_{2.5}$ and ozone NAAQS), and solely within the bounds of the existing monitoring network. 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 PM National Ambient Air Quality Standards (NAAQS). The baseline also includes the MACT program, the clean air interstate rule (CAIR), and implementation of current consent decrees, all of which would help many areas move toward attainment of the proposed NO_2 standard.

1.5 References

U.S. EPA. 1970. Clean Air Act. 40 CFR 50.

---

[3] Because the secondary NO_2 NAAQS is under development in a separate regulatory process, no additional costs and benefits were calculated in this RIA.

U.S. EPA. 2007, Integrated Review Plan and the Health Assessment Plan, U.S. Environmental Protection Agency, Washington, DC, available at http://www.epa.gov/ttn/naaqs/standards/nox/s_nox_cr_pd.html.

U.S. EPA. 2007. Review of the National Ambient Air Quality Standards for NO_2: Integrated Science Assessment. Office of Air Quality Planning and Standards, RTP, NC, available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=194645.

U.S. EPA. 2008. Review of the National Ambient Air Quality Standards for NO_2: Risk and Exposure Assessment. Office of Air Quality Planning and Standards, RTP, NC, available at http://www.epa.gov/ttn/naaqs/standards/nox/s_nox_cr_rea.html.

Chapter 2: NO_2 Emissions and Monitoring Data

Synopsis

This chapter describes the available NO_2 emissions and air quality data used to inform and develop the controls strategies outlined in this RIA. We first describe data on NO_2 emission sources contained in available EPA emission inventories. We then provide an overview of data sources for air quality measurement. For a more in-depth discussion of NO_2 emissions and air quality data, see the Integrated Science Assessment for the NO_2 NAAQS.[1]

2.1 Sources of NO_2

The primary data source for this discussion is the National Emissions Inventory (NEI) for 2002 (USEPA, 2007a). Ambient levels of NO_2 are the product of both direct NO_2 emissions and emissions of other NOx (e.g, NO), which can then be converted to NO_2. Nationally, anthropogenic sources account for approximately 87% of total NOx emissions. (Apart from these anthropogenic sources, there are also natural sources of NOx including microbial activity in soils, lightning, and wildfires.) As a result of Clean Air Act requirements, emissions standards promulgated for many source categories that have taken effect since 2002, including numerous mobile source standards for gasoline and diesel vehicles/engines, are projected to result in much lower emissions of both direct NO_2 and other NOx at the current time or in the near future.

Stationary sources (e.g., electrical utilities and industry) account for about 40% of the national NOx emissions in the 2002 NEI. The main stationary sources of NOx emissions in the 2002 NEI are combustion-related emissions and industrial process-related emissions. Table 2-1 presents emissions estimates for stationary sources grouped into descriptive categories. Presence and relative position of a source category on this list does not necessarily provide an indication of the significance of the emissions from individual sources within the source category. A source category, for example, may be composed of many small (i.e., low-emitting) sources, or of just a few very large (high-emitting) sources.

---

[1] U.S. Environmental Protection Agency (2007c), Review of the National Ambient Air Quality Standards for NO_2: Policy Assessment of Scientific and Technical Information, Integrated Science Assessment, Chapter 2, EPA-452/R-08-xxx, Office of Air Quality Planning and Standards, RTP, NC.

Mobile sources (both on-road and off-road) account for about 60% of the national NOx emissions in the 2002 NEI. Highway vehicles represent the major mobile source component. In the United States, approximately half the mobile source emissions are contributed by diesel engines and half are emitted by gasoline-fueled vehicles and other sources.

Table 2-1. NOx Sources (2002 NEI)

NOx Source Category	Emissions (tons/year)
Electric Utility Fuel Combustion	3,792,292
Industrial Fuel Combustion	1,897,944
Fuel Combustion, other	730,259
Chemical and Allied Product Manufacturing	60,901
Metals Processing	66,173
Petroleum and Related Industries	358,223
Industrial Processes, other	482,007
Solvent Utilization	4,365
Storage and Transport	16,109
Waste Disposal and Recycling	145,678
Highway Vehicles	6,491,821
Off-highway Vehicles	6,027,085
Miscellaneous Source Categories	270,913
Total	**20,343,770**

2.2 Air Quality Monitoring Data

2.2.1 Background on NO_2 monitoring network

From its inception in the late 1970's through the present (2008), the NO_2 network has remained relatively stable with regard to the number of monitoring sites (see memo by Watkins, 2008). As of October 2008, there were 409 NOx monitors within the U.S. actively reporting NO_2 data into the air quality system AQS. The NO_2 network was originally deployed to support implementation of the NO_2 NAAQS established in 1971. Despite the establishment of an NO_2 standard, the first requirements for NO_2 monitoring did not come out until May of 1979. At that time, 40 CFR Part 58, Appendix D, section 3.5 stated:

> "Nitrogen Dioxide NAMS [National Ambient Monitoring Stations, now a defunct term] will be required in those areas of the country which have a population greater than 1,000,000. These areas will have two NO_2 NAMS. It is felt that stations in these major metropolitan areas would provide sufficient data for a

> national analysis of the data, and also because NO_2 problems occur in areas of greater than 1,000,000. Within urban areas requiring [NO_2] NAMS, two permanent monitors are sufficient. The first station (category (a), middle scale or neighborhood scale) would be to measure the photochemical production of NO_2 and would best be located in that part of the urban area where the emission density of NOx is the highest. The second station (category (b) urban scale), would be to measure the NO_2 produced from the reaction of NO with O_3 and should be downwind of the area peak NOx emission areas."

In the October, 2006 monitoring rule, this language was removed from the CFR. Removal was driven by the fact that there is no NO_2 non-attainment problem under the current standards. In the 2006 rule, EPA chose to rewrite 40 CFR Part 58, Appendix D, section 4.3 to state that:

> "There are no minimum requirements for the number of NO_2 monitoring sites. Continued operation of existing SLAMS [State and Local Ambient Monitoring Station] NO_2 sites using FRM [Federal Reference Method] or FEM [Federal Equivalent Method] is required until discontinuation is approved by the EPA Regional Administrator. Where SLAMS NO_2 monitoring is ongoing, at least one NO_2 site in the area must be located to measure the maximum concentration of NO_2."

As noted earlier, the size of the NO_2 network has been fairly stable through time, even though an actual requirement for state and local air agencies to monitor NO_2, other than for Photochemical Assessment Monitoring Stations (PAMS) or Prevention of Significant Deterioration (PSD), was removed in the 2006 monitoring rule. The maintenance of the NO_2 monitoring network has been driven by several factors, including the need to support ozone modeling and forecasting, the need to track PM precursors, and a general desire on the part of states to continue to understand trends in ambient NO_2.

To characterize the current NO_2 network, staff has reviewed the NO_2 network meta-data. The data reviewed are those available from AQS in October 2008, for monitors reporting data in 2008. The meta-data fields are typically created by state and local agencies when a monitor site is opened, moved, or re-characterized. While these files are useful for characterizing specific monitors, there is some uncertainty surrounding this meta-data given that there is no routine or enforced process for updating or correcting meta-data fields. With this uncertainty in mind, staff has compiled information on the monitoring objectives and measurement scales for monitors in the NO_2 network.

The monitor objective meta-data field describes the purpose of the monitor. For example the purpose of a particular monitor could be to characterize health effects, photochemical activity, transport, and/or welfare effects. As of October 2008, there were 489 records of NO_2 monitor objective values (some monitors have multiple monitor objectives). Table 2-2 lists the distribution of monitoring objectives across the network. There are 11 categories of monitor objectives for NO_2 monitors within AQS. The “other” category is for sites likely addressing a state or local need outside of the routine objectives, and the “unknown” category represents missing meta-data. The remaining categories stem directly from categorizations of site types within CFR. In 40 CFR Part 58 Appendix D, there are six examples of NO_2 site types:

1. Sites located to determine the highest concentration expected to occur in the area covered by the network (Highest Concentration).
2. Sites located to measure typical concentrations in areas of high population (Population Exposure).
3. Sites located to determine the impact of significant sources or source categories on air quality (Source Oriented).
4. Sites located to determine general background concentration levels (General Background).
5. Sites located to determine the extent of regional pollutant transport among populated areas; and in support of secondary standards (Regional Transport).
6. Sites located to measure air pollution impacts on visibility, vegetation damage, or other welfare-based impacts (Welfare Related Impacts).

The remaining four categories available are a result of updating the AQS database. In the more recent upgrade to AQS, the data handlers inserted the available site types for Photochemical Assessment Monitoring Stations (PAMS) network. These PAMS site types are spelled out in 40 CFR Part 58 Appendix D:

1. Type 1 sites are established to characterize upwind background and transported ozone and its precursor concentrations entering the area and will identify those areas which are subjected to transport (Upwind Background).

2. Type 2 sites are established to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions are expected to impact and are suited for the monitoring of urban air toxic pollutants (Max. Precursor Impact).
3. Type 3 sites are intended to monitor maximum ozone concentrations occurring downwind from the area of maximum precursor emissions (Max. Ozone Concentration).
4. Type 4 sites are established to characterize the downwind transported ozone and its precursor concentrations exiting the area and will identify those areas which are potentially contributing to overwhelming transport in other areas (Extreme Downwind).

Table 2-2. NOx Network Distribution of Monitor Objectives

NOx Monitor Objective	Number of Monitor Objective Records	Percent Distribution
Population Exposure	177	36.20
Highest Concentration	58	11.86
General Background	51	10.43
Max. Precursor Impact (PAMS Type 2 Site)	21	4.29
Source Oriented	19	3.89
Upwind Background (PAMS Type 1 Site)	18	3.68
Regional Transport	12	2.45
Other	9	1.84
Max. Ozone Concentration (PAMS Type 3 Site)	8	1.64
Extreme Downwind (PAMS Type 4 Site)	3	0.61
Welfare Related Impacts	1	0.20
Unknown	112	22.90
Totals:	**489**	**100%**

The spatial measurement scales are laid out in 40 CFR Part 58, Appendix D, Section 1 “Monitoring Objectives and Spatial Scales.” This part of the regulation spells out what data from a monitor can represent in terms of air volumes associated with area dimensions:

Microscale -	0 to 100 meters

Middle Scale -	100 to 500 meters
Neighborhood Scale -	500 meters to 4 kilometers
Urban Scale -	4 to 50 kilometers
Regional Scale -	50 kilometers up to 1000km

There are meta-data records for the NO_2 network to indicate what the measurement scale of a particular monitor represents. There are 386 NO_2 monitor records in AQS with available measurement scale information. Table 2-3 shows the measurement scale distribution across all NO_2 sites form the available data in AQS of monitors reporting data in 2008.

Table 2-3. NOx Network Distribution across Measurement Scales.

Measurement Scale	Number of Measurement Scale Records	Percent Distribution
Microscale	3	0.78
Middle Scale	23	5.96
Neighborhood	212	54.92
Urban Scale	119	30.83
Regional Scale	29	7.51
Totals:	**386**	**100%**

In summary, upon review of the known 409 monitors reporting data to AQS in 2008, and the distribution of the available data from the categories of monitor objective and measurement scale, we see the NO_2 network is primarily targeting public health and photochemical process monitoring objectives. We note that nearly half of the monitor objective records are directly targeting public health through the population exposure (36.2%) and highest concentration (11.8%) categories alone. The other categories serve to inform public health concerns, but also address photochemistry issues where NOx serves as a precursor to ozone. Further, it appears that approximately 10% of NO_2 monitors are in place to serve the PAMS network. In reality, a large majority of sites likely could serve both public health and photochemistry related objectives due to their proximity to urban areas. The exceptions would likely be categories such as upwind background, extreme downwind, regional transport, and possibly maximum O_3 concentration. These four categories only represent approximately 7% of the NO_2 network, and have a higher likelihood of being rural and regional in scale.

2.2.2 Trends in ambient concentrations of NO_2

As noted above, NO_2 is monitored largely in urban areas and, therefore, data from the NO_2 monitoring network is generally more representative of urban areas than rural areas. According to monitoring data, nationwide levels of ambient NO_2 (annual average) decreased 41% between 1980 and 2006 (ISA, Figure 2.4-15). Between 2003 and 2005, national mean concentrations of NO_2 were about 15 ppb for averaging periods ranging from a day to a year. The average daily maximum hourly NO_2 concentrations were approximately 30 ppb. These values are about twice as high as the 24-h averages. The highest maximum hourly concentrations (~200 ppb) between 2003 and 2005 are more than a factor of ten higher than the mean hourly or 24-h concentrations (ISA, Figure 2.4-13). The highest levels of NO_2 in the United States can be found in and around Los Angeles, in the Midwest, and in the Northeast. Policy-relevant background concentrations, which are those concentrations that would occur in the United States in the absence of anthropogenic emissions in continental North America (defined here as the United States, Canada, and Mexico), are estimated to range from only 0.1 ppb to 0.3 ppb (ISA, section 2.4.6).

Ambient levels of NO_2 exhibit both seasonal and diurnal variation. In southern cities, such as Atlanta, higher concentrations are found during winter, consistent with the lowest mixing layer heights being found during that time of the year. Lower concentrations are found during summer, consistent with higher mixing layer heights and increased rates of photochemical oxidation of NO_2. For cities in the Midwest and Northeast, such as Chicago and New York City, higher levels tend to be found from late winter to early spring with lower levels occurring from summer though the fall. In Los Angeles the highest levels tend to occur from autumn though early winter and the lowest levels from spring though early summer. Mean and peak concentrations in winter can be up to a factor of two larger than in the summer at sites in Los Angeles. In terms of daily variability, NO_2 levels typically peak during the morning rush hours. Monitor siting plays a key role in evaluating diurnal variability as monitors located further away from traffic will show cycles that are less pronounced over the course of a day than monitors located closer to traffic.

2.2.3 Uncertainty Associated with the Ambient NO_2 Monitoring Method

The method for estimating ambient NO_2 levels (i.e., subtraction of NO from a measure of total NOx) is subject to interference by NOx oxidation products. Limited evidence suggests that these compounds result in an overestimate of NO_2 levels by roughly 20 to 25% at typical ambient levels. Smaller relative errors are estimated to occur in measurements taken near strong NOx sources since most of the mass emitted as NO or NO_2 would not yet have been further oxidized. Relatively larger errors appear in locations more distant from strong local NOx sources. Additionally, many NO_2 monitors are elevated above ground level in the cores of large cities. Because most sources of NO_2 are near ground level (i.e., combustion emissions from traffic), this produces a gradient of NO_2 with higher levels near ground level and lower levels being detected at the elevated monitor. One comparison has found an average of a 2.5-fold increase in NO_2 concentration measured at 4 meters above the ground compared to 15 meters above the ground. The ISA notes that levels are likely even higher at elevations below 4 meters (ISA, section 2.5.3.3). Another source of uncertainty in exposure estimates can result from monitor location. NO_2 monitors are sited for compliance with air quality standards rather than for capturing small-scale variability in NO_2 concentrations near sources such as roadway traffic. Significant gradients in NO_2 concentrations near roadways have been observed in several studies, and NO_2 concentrations have been found to be correlated with distance from roadway and traffic volume (ISA, section 2.5.3.2).

Chapter 3: Air Quality Analysis

Synopsis

This chapter describes the approach used to calculate 2020 baseline NO_2 design values and the amount of emissions reductions needed to attain the alternative 1-hour NO_2 NAAQS. The NAAQS being analyzed are 50, 100, and 200 ppb based on design values calculated using the 3-year average of the 98th and 99th percentile 1-hour daily maximum concentrations based on the monitoring network described in Chapter 2. The projected 2020 baseline NO_2 design values are used to identify 2020 nonattainment counties and to calculate, for each such county, the amount of reduction in NO_2 concentration necessary to attain the alternative NAAQS. This chapter also describes the approach for calculating "ppb NO_2 concentration per ton NOx emissions" ratios that are used to estimate the amount of NOx emissions reductions that may be needed to provide for attainment of the alternative NO_2 standards. As described below, the air quality analysis relies on NO_2 predictions from simulations of the Community Multiscale Air Quality (CMAQ) model coupled with ambient 2005-2007 design values and emissions data to project 2020 NO_2 design value concentrations and the "ppb per ton" ratios. A description of CMAQ is provided in the Ozone NAAQS RIA Air Quality Modeling Platform Document (U.S. EPA, 2008a).

3.1 2005-2007 Design Values

The proposed standard is based on the 3-year average of the 98th or 99th percentile concentration of the daily 1-hour maximum concentration for a year. The first step in calculating the 3-year 2005-2007 design values is to identify the daily 1-hour maximum concentration in each of the three years, 2005 through 2007. Next, the 98th and 99th percentile concentration of the daily 1-hour maximum concentration was calculated for each of these years. The three 98th percentile concentrations for each year were averaged to determine a 3-year average concentration. The same process was followed for the 99th percentile concentrations. Monitors that had valid measurements for at least 75% of the day, 75% of the days in a quarter and all 4 quarters for all three years were included in the analysis[1]. The resulting 3-year averaged 98th and 99th percentile daily 1-hour maximum concentrations are shown in Figure 3-1 for 158 monitored counties. Counties in orange and red would exceed the lowest alternative standard considered in the RIA, 50 ppb. Monitors with design values of 50.0 to 50.4 ppb would not exceed the standard as those concentrations would round to 50 ppb. Concentrations 50.5 ppb and higher are considered exceeding the lowest alternative standard.

---

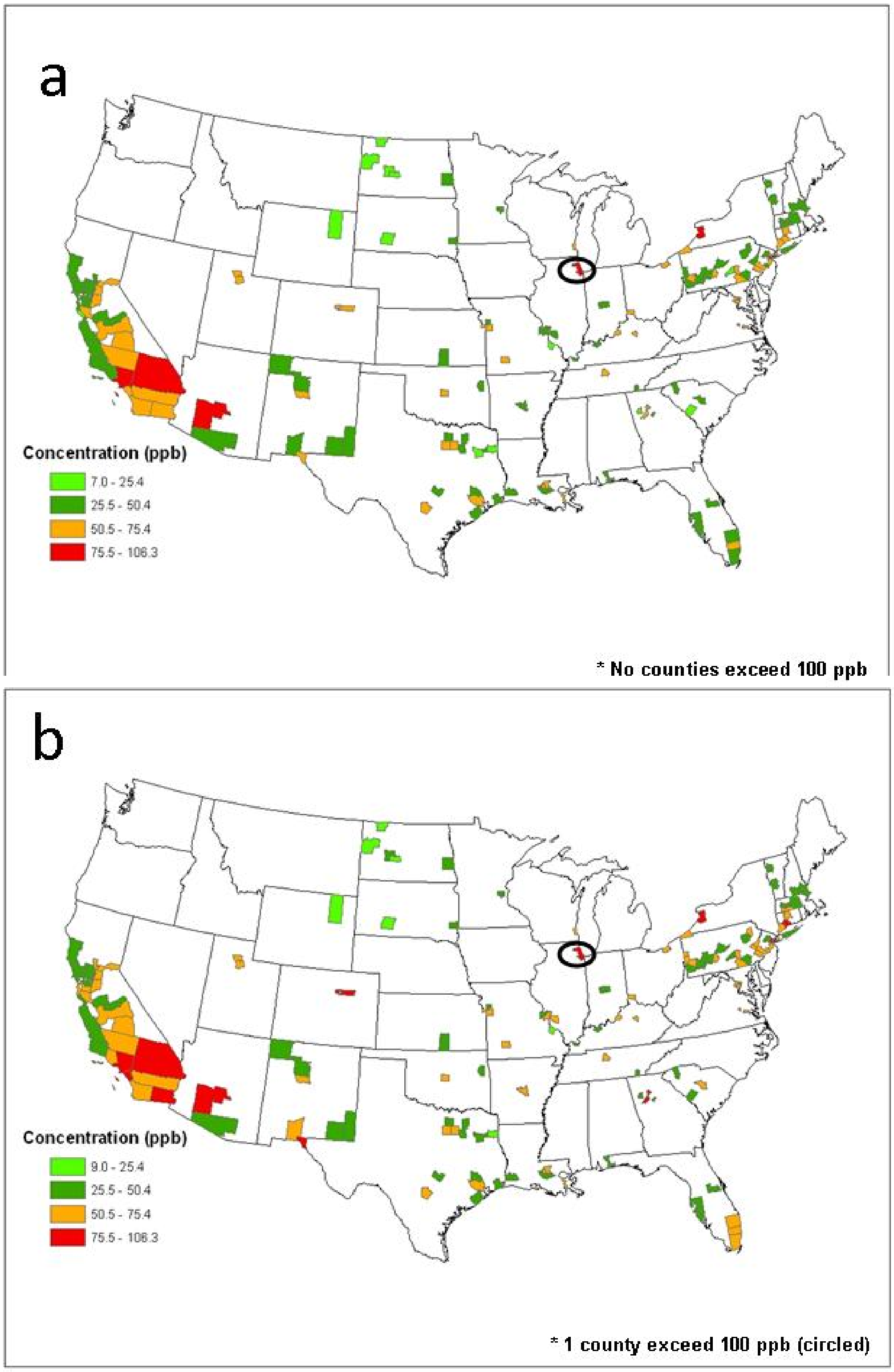
[1] Email from Rhonda Thompson to James Thurman, January 22, 2009.

For the 99th percentile design values, one county exceeds the alternative standard of 100 ppb, Cook County, IL (circled in Figure 3-1). No county exceeds the alternative standard of 200 ppb. A summary of the number of counties exceeding the alternative standards are shown in Table 3-1. Appendix 3 contains the complete list of 2005-2007 design values used in calculation of the 2020 design values.

Table 0.1: Number of monitors and counties exceeding alternative standards for 2005-2007 NO_2 98th and 99th percentile design values.

Alternative standard (ppb)	Percentile	Number of monitors	Number of counties
50	98th	106	63
	99th	131	81
100	98th	0	0
	99th	1	1
200	98th	0	0
	99th	0	0

Figure 0.1: 2005-2007 3-year averaged design values (ppb) for a) 98th percentile and b) 99th percentile daily 1-hour maximum NO_2 concentrations.



* No counties exceed 100 ppb

* 1 county exceed 100 ppb (circled)

3.2 Calculation of 2020 Projected Design Values

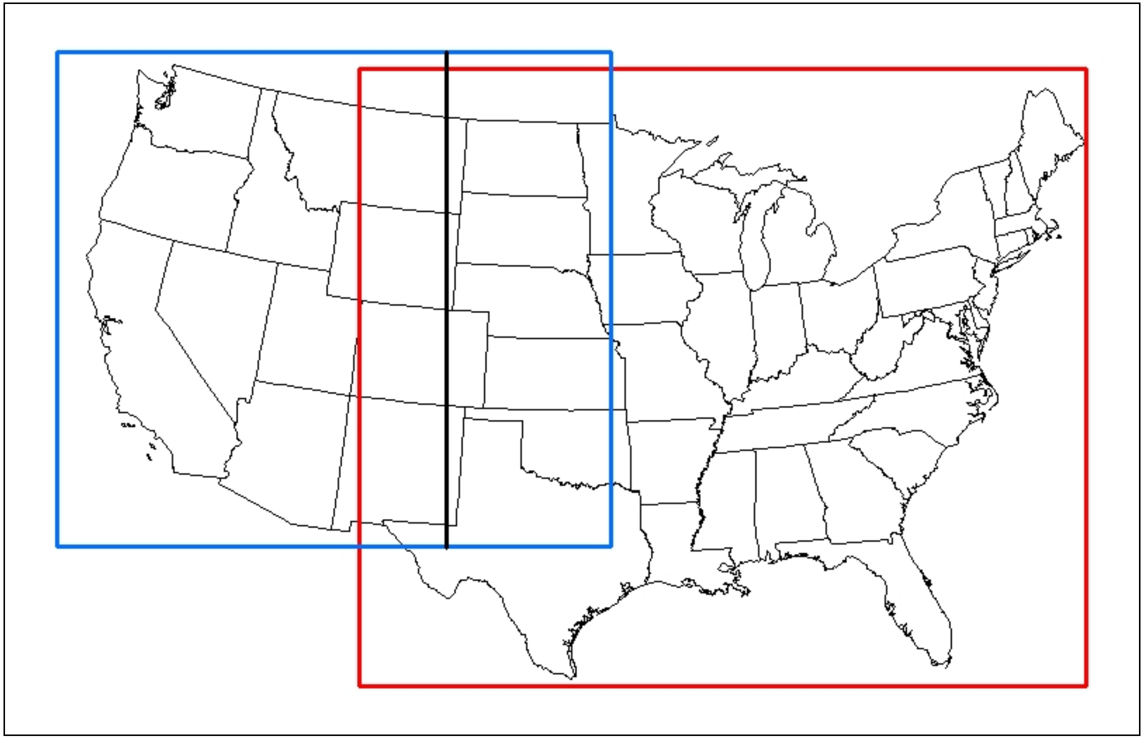
The 2020 baseline design values were determined using CMAQ concentrations for 2002 and 2020 and county emissions for 2002, 2006, and 2020. CMAQ daily 1-hour maximum concentrations from 2002 and 2020 were used to calculate a relative response factor (RRF). The daily 1-hour maximum NO_2 concentrations in 2002 and 2020 were obtained from CMAQ runs performed for the ozone RIA (U.S. EPA, 2008b). Due to timing and resources issues, we decided to use the existing CMAQ modeling results for ozone instead of conducting new modeling. The modeled NOx emissions in the CMAQ runs reflect reductions from federal programs including the Clean Air Interstate Rule (EPA, 2005a), the Clean Air Mercury Rule (EPA, 2005b), the Clean Air Visibility Rule (EPA, 2005c), the Clean Air Nonroad Diesel Rule (EPA, 2004), the Light-Duty Vehicle Tier 2 Rule (EPA, 1999), the Heavy Duty Diesel Rule (EPA, 2000); proposed rules for Locomotive and Marine Vessels (EPA, 2007a) and for Small Spark-Ignition Engines (EPA, 2007b); and national, 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. It should be noted that the emission reductions modeled for the PM2.5 and Ozone standards represent one possible control scenario, while the actual control strategies and resulting levels of emission reductions will be determined as part of the process of developing and implementing state implementation plans over the coming years. We should also note that since the finalization of these recent NAAQS standards, several of the proposed mobile source rules mentioned above have been finalized with updated analyses showing slightly greater levels of expected NOx reductions.

In brief, these CMAQ runs were performed at 12 km horizontal resolution for two modeling domains which, collectively, cover the lower 48 States and adjacent portions of Canada and Mexico. The boundaries of these two domains are shown in Figure 3.2. For 2020 we used CMAQ-predicted NO_2 concentrations from the Ozone NAAQS RIA “2020_070” control case. The 2002 and 2006 NOx emissions were used to project the 2002 NO_2 model-predicted concentrations to 2006 in order to align the base year modeled NO_2 data with the mid-point of the 2005-2007 design value period. In addition to NOx emissions for the modeled 2002_070 scenario, we calculated emissions for the 2020 baseline scenario, based on emissions described in Chapter 4 of the ozone RIA (EPA, 2008b). We refer to this inventory as 2020_075. The RRF values and emissions were used to forecast 2020 design values and the amount of residual nonattainment at each monitored location.

3.2.1 2020 Design Value Calculation Methodology

The following are the steps used in calculating 2020 baseline NO_2 design values from the 2005-2007 monitor design values and CMAQ NO_2 concentrations for the 2002 and 2020_070 scenarios. Example calculations are shown for a monitor in Charles County, VA in Section 3.3.2. The CMAQ domains are shown in Figure 3.2.

Figure 0.2: CMAQ 12 km domains used in air quality analyses. The western domain is outlined in blue and the eastern domain outlined in red. The black vertical line denotes was used as the dividing line to assign monitoring sites to either the eastern or western domains.



1. Beginning with 12-km CMAQ output, we calculated daily 1-hour maximum concentrations for each grid cell for 2002 and 2020_070 model output.

2. After calculating the daily 1-hour maximum concentration for each grid cell, we selected the top ten daily 1-hour maximum concentrations for each grid cell for the 2002 concentrations.

3. For those same days, we then merged the daily 1-hour maximum concentrations for 2020_070 with the 2002 concentrations.

4. After merging in step 3, we averaged the top 10 daily 1-hour maximum concentrations for 2002 as well as the corresponding daily 1-hour maximum concentrations for 2020_070 for the same days.

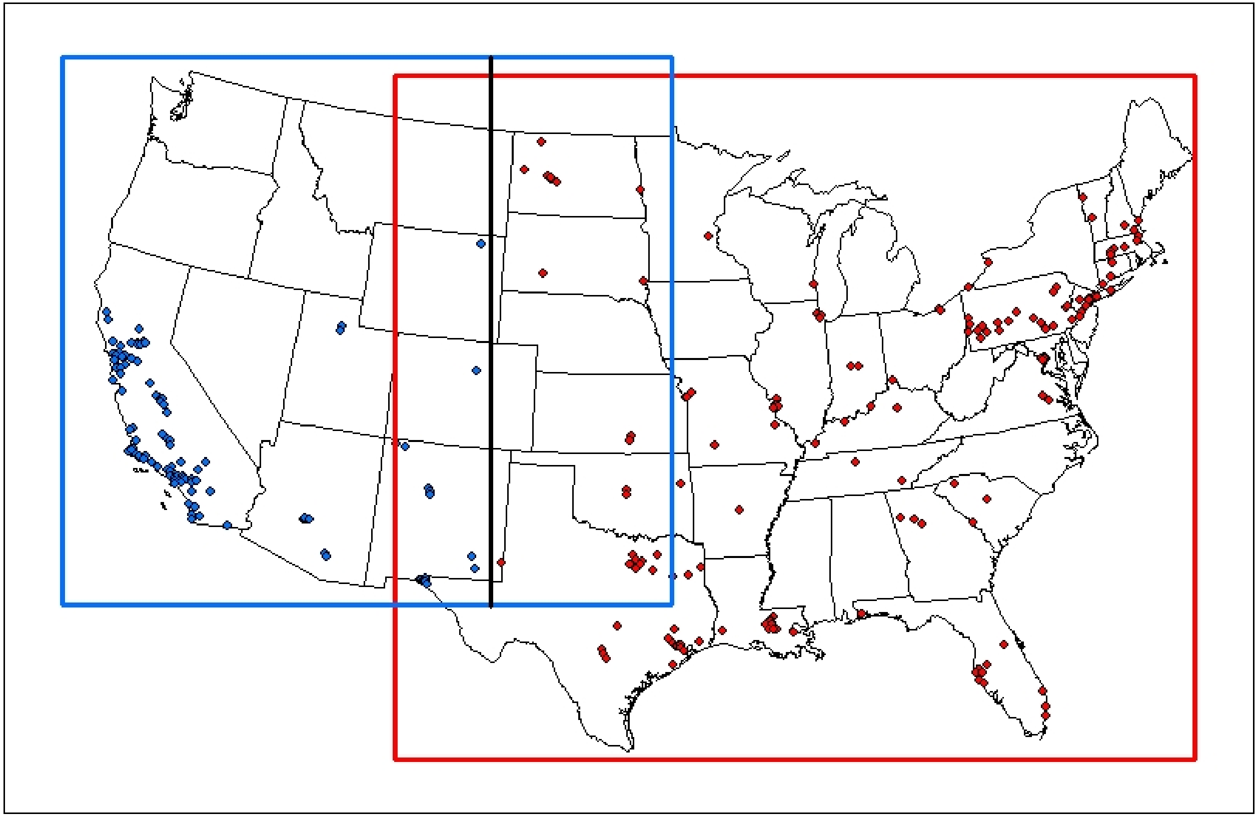
5. Relative response factors (RRF) were calculated by dividing the average of the 2020_070 concentrations by the average of the 2002 concentrations (Equation 3.1).

$$RRF = \frac{C_{2020\_070}}{C_{2002}} \qquad (3.1)$$

   Where C_{2002} is the average of the top 10 daily 1-hour maximum concentrations for 2002 for each grid cell and C_{2020_070} is the average of the 2020 daily 1-hour maximum concentrations for the same days in 2002 (C_{2002}) .

6. Ambient monitored data were assigned to CMAQ grid cells using ArcGIS. Since there were areas of the country where the eastern and western domains overlapped, monitors in these overlapping areas were assigned to the eastern or western grid cells by using a “combined grid.” This combined grid was a mesh of the eastern and western domains, with overlapping areas assigned eastern grid cells or western grid cells based on the location relative to the dividing line shown in Figure 3.2. Figure 3.3 shows the assignment of monitors to the two domains. An example of monitors in both domains was the El Paso County monitors. These monitors were assigned to the western domain.

Figure 0.3: Monitor domain assignments. Western domain is outlined in blue and eastern domain outlined in red. Black vertical line denotes dividing line between eastern and western domains for monitor assignments. Monitors in blue were assigned to the western domain and monitors in red assigned to the eastern domain.



7. We merged output from step 6 with total county emissions for 2002, 2002af, 2006, 2020_070 and 2020_075. Monitors were assigned emissions for the counties in which they were located according to the state/county FIPS code of the monitor.

8. The 2020 baseline design values (i.e., 2020_075 scenario) were calculated by the following steps:
    a. An emissions relative response factor was calculated to represent the emission changes from 2002 to 2020_070 as

$$RRF_{E:2020\_070} = \frac{E_{2020\_070}}{E_{2002}} \tag{3.2}$$

    b. We then calculated an emissions relative response factor for emissions changes from 2006 to 2020_075 as

$$RRF_{E:2020\_075} = \frac{E_{2020\_075}}{E_{2006}} \tag{3.3}$$

c. Using the RRF calculated in equation 3.1 and the results of equations 3.2 and 3.3 above, we calculated a concentration RRF for 2020_075 as

$$RRF_{2020\_075} = 1 - \left[\left({(1 - RRF)} \Big/ {\left(1 - RRF_{E:2020\_070}\right)} \right) \times \left(1 - RRF_{E:2020\_075}\right) \right] \tag{3.4}$$

d. Using the results from above, a 2020 design value was calculated by multiplying the 2020_075 concentration RRF by the 2005-2007 design values

$$DV_{2020\_075:98} = RRF_{2020\_075} \times DV_{2005-07:98} \tag{3.5}$$

$$DV_{2020\_075:99} = RRF_{2020\_075} \times DV_{2005-07:99} \tag{3.6}$$

Where E_{2020_070} are the 2020_070 county emissions, E_{2002} are the 2002 county emissions, $RRF_{E:2020\_070}$ is the relative response factor for 2020_070 emissions, E_{2020_075} are the 2020_075 county emissions, E_{2006} are the 2006 county emissions , $RRF_{E:2020\_075}$ is the relative response factor for 2020_075 emissions, RRF_{2020_075} is the relative response factor for 2020_075 concentrations, $DV_{2020\_075:98}$, $DV_{2020\_075:99}$ are the projected 98th and 99th percentile design values, and $DV_{2005-2007:98}$ and $DV_{2005-2007:99}$ are the monitored 2005-2007 98th and 99th design values.

9. Once 2020_075 design values were calculated, changes in concentrations relative to emissions (ppb/ton) between 2020_075 and 2006 were calculated as:

$$ppb/ton_{98} = {\left(DV_{2020\_075:98} - DV_{2005-2007:98}\right)} \Big/ {\left(E_{2020\_075} - E_{2006}\right)} \tag{3.7}$$

$$ppb/ton_{99} = {\left(DV_{2020\_075:99} - DV_{2005-2007:99}\right)} \Big/ {\left(E_{2020\_075} - E_{2006}\right)} \tag{3.8}$$

Where ppb/ton_{98} and ppb/ton_{99} are the ppb per ton estimates based on the 98th and 99th percentile of projected and 2005-2007 design values. All other variables are as defined previously.

10. Residual nonattainment was calculated for alternative standard (*AS*) levels of 50, 100, and 200 ppb by subtracting the alternative level from the 2020 design value. The actual subtracted alternative levels were not 50, 100, and 200 ppb, but 50.4, 100.4, and 200.4

ppb, the maximum allowable concentration for each level and still meet the level if rounding to the nearest whole number for the standard.

$NA_{98:AS} = DV_{2020\_075:98} - AS$ if NA>0, 0 otherwise.

(3.9)

$$NA_{99AS} = DV_{2020\_075:99} - AS \tag{3.10}$$

Where $NA_{98:AS}$ and $NA_{99:AS}$ are the residual nonattainment (in ppb) for the 98th and 99th percentile 2020_075 design values and the alternative standard AS (50.4, 100.4, 200.4 ppb).

11. For monitors with residual nonattainment in 2020, the emissions tons needed to meet attainment were calculated by dividing the residual nonattainment in step 10 by the ppb/ton in step 9.

$$Tons_{98:AS} = \frac{NA_{98:AS}}{ppb/ton_{98}} \tag{3.11}$$

$$Tons_{99:AS} = \frac{NA_{99:AS}}{ppb/ton_{99}} \tag{3.12}$$

Where $Tons_{98:AS}$ and $Tons_{99:AS}$ are the tons need to reach attainment for the alternative standards AS (as defined above). Other variables are as defined previously.

A complete list of projected design values by monitor can be found in Table 3-1 of Appendix 3.

3.2.2 Example Calculation

Following is an example of the 12 steps for a monitor in Charles City County, VA (Figure 3-4).

Figure 0-4. Location of example monitor with 2005-2007 monitored 98th and 99th percentile design value concentrations (98th percentile listed first). Box denotes the home 12 km grid cell of the monitor. Concentrations are in ppb.

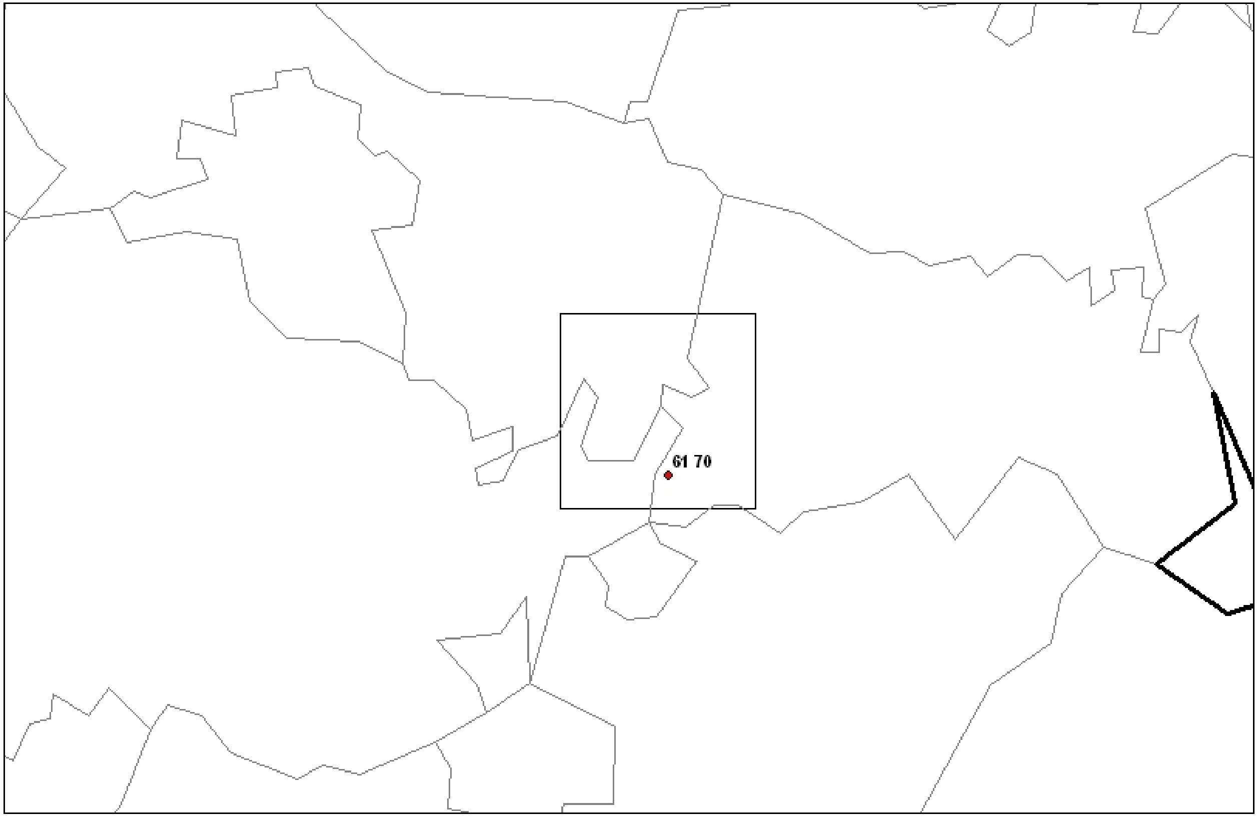


Table 3-2 lists the hourly NO_2 concentrations for January 1, 2002 for the 2002 and 2020_070 CMAQ output for the grid cell (column=228, row=127) containing the Charles City County monitor. The maximum daily 1-hour concentration for 2002 was 29.1724 ppb (green cell) and 6.6763 ppb for the 2020 output (yellow cell). Both maxima occurred for 0300 local standard time (LST).

Table 0-2. Hourly 2002 and 2020_070 CMAQ concentrations for January 1st, 2002. Green cell is maximum 1-hour concentration for 2002 and yellow cell is the maximum 1-hour concentration for 2020_070.

Grid cell (column,row)	Hourly concentration (ppb)			Hourly concentration (ppb)		
	Time (LST)	2002	2020_070	Time (LST)	2002	2020_070
228,127	00	9.2350	2.7208	12	5.5086	1.6846
228,127	01	11.5223	3.1438	13	5.9981	1.7687
228,127	02	20.8849	4.7684	14	6.8937	2.0007
228,127	03	29.1724	6.6763	15	9.7079	3.2760
228,127	04	27.6030	6.6206	16	15.7976	5.8673
228,127	05	21.5481	5.3985	17	17.3960	6.3095
228,127	06	17.5606	4.6264	18	15.8105	5.7491
228,127	07	15.3338	4.4448	19	15.1693	5.5690
228,127	08	12.4741	4.0144	20	16.1220	5.8504
228,127	09	8.1705	2.5817	21	16.8197	6.0161
228,127	10	5.7904	1.8075	22	15.6945	5.6282
228,127	11	5.1665	1.6266	23	5.5086	1.6846

Table 3-3 lists the output for steps 2, 3, and 4, the calculation of the average of the top ten days for 2002, averaging of those days as well as the average of the 2020_070 concentrations for the same days, and calculation of the RRF.

Table 0-3. Top 10 daily 1-hour maximum concentrations for 2002 (ranked in ascending order) with daily 1-hour maximum concentrations for the corresponding days in 2020_070. Averages for 2002 and 2020_070 are also shown.

Rank	Grid cell (col,row)	month	day	Daily 1-hour maximum concentration (ppb)	
				2002	2020_070
1	228,127	10	2	52.4148	40.2211
2	228,127	3	13	50.5558	20.3625
3	228,127	2	19	48.8602	40.9420
4	228,127	11	25	46.8617	32.0588
5	228,127	11	24	45.1550	36.0091
6	228,127	4	15	43.4104	32.2789
7	228,127	11	7	43.3279	28.3178
8	228,127	1	26	43.1155	30.1008
9	228,127	3	28	42.8743	26.0399
10	228,127	6	24	42.8729	33.9933
			Average	**45.9445**	**32.0324**

Table 3-4 lists output for steps 5 through 7, calculating and merging the RRF value for the grid cell with the appropriate monitor 2005-2007 design values and the county emissions.

Table 0-4. Charles City County, VA 2005-2007 design values, CMAQ domain, average 2002 and 2020_070 concentrations used in RRF calculation, RRF, 2002, 2006, 2020_070, and 2020_075 county emissions (tons).

Variable	Value
2005-2007 98th percentile daily 1-hour maximum (ppb)	61.0
2005-2007 99th percentile daily 1-hour maximum (ppb)	70.0
CMAQ domain	Eastern
Average of top 10 daily 1-hour maximum concentrations for 2002 grid cell.	45.9445
Average of 2020_070 daily 1-hour maximum concentrations corresponding to same days as top 10 for 2002	32.032
RRF (equation 1)	0.6972
2002 total emissions	548
2006 total emissions	493
2020_070 total emissions	281
2020_075 total emissions	290

Table 3-5 lists the inputs and results of steps 8 and 9, calculation of emission RRF values and projected 2020 design values.

Table 0-5. Emissions, emission RRF values, projected design values for 2020_075, and ppb per ton estimates.

Variable	Value
E_{2002}	548
E_{2020_070}	281
$RRF_{E:2020\_070}$	0.5713
E_{2006}	493
E_{2020_075}	290
$RRF_{E:2020\_075}$	0.5894
RRF (equation 1)	0.6972
RRF_{2020_075}	0.7446
$DV_{2020\_075:98}$	45.2
$DV_{2020\_075:99}$	52.1
ppb/ton_{98}	7.71E-02
ppb/ton_{99}	8.85E-02

Table 3-6 lists the results for steps 10 and 11 for Charles City County. Negative values of residual nonattainment and tons needed for control mean that the monitor was in attainment for the specified alternative standard.

Table 0-6. Residual nonattainment (ppb) and tons needed to reach attainment for the three alternative standards. Value in red is monitor with nonattainment of an alternative standard

Alternative level (ppb)	Percentile	Residual nonattainment	Tons needed for control
50	98th	-5	-65
	99th	1.7	19
100	98th	-55	-713
	99th	-48.3	-546
200	98th	-155	-2010
	99th	-148.3	-1676

3.3 Results

3.3.1 Nonattainment of alternative standards

A complete list of projected design values for 2020[2] can be found in Table 3-1 of Appendix 3. Figure 3-5 shows the projected design values for 2020 for the 98th and 99th percentile NO_2 design value concentrations. Shown are the highest projected design values for each county for the respective percentiles. Counties in green were below the lowest alternative standard, 50 ppb. No projected design values exceeded the 100 and 200 ppb alternative standards (in fact, all counties were below 70 ppb). Three counties exceeded the 50 ppb for the 98th percentile design values. Table 3-6 shows the 2020 design values and tons needed to meet attainment for the individual monitors in those counties.

For the 99th percentile 2020 design values, six counties exceeded the 50 ppb alternative standard. The individual monitor concentrations for those counties are shown in Table 3-7. Note that in Tables 3-6 and 3-7, not all monitors in the counties are shown. Some monitors in the exceeding counties did not exceed the alternative standards. Only shown in the tables are the monitors that exceeded the 50 ppb alternative standard.

---

[2] Hereafter, 2020 refers to the 2020_075 design values of equations 3.5 and 3.6 in Section 3.3.1

Figure 0-5. 2020 maximum design values (ppb) by county for a) 98th percentile design values and b) 99th percentile design values.

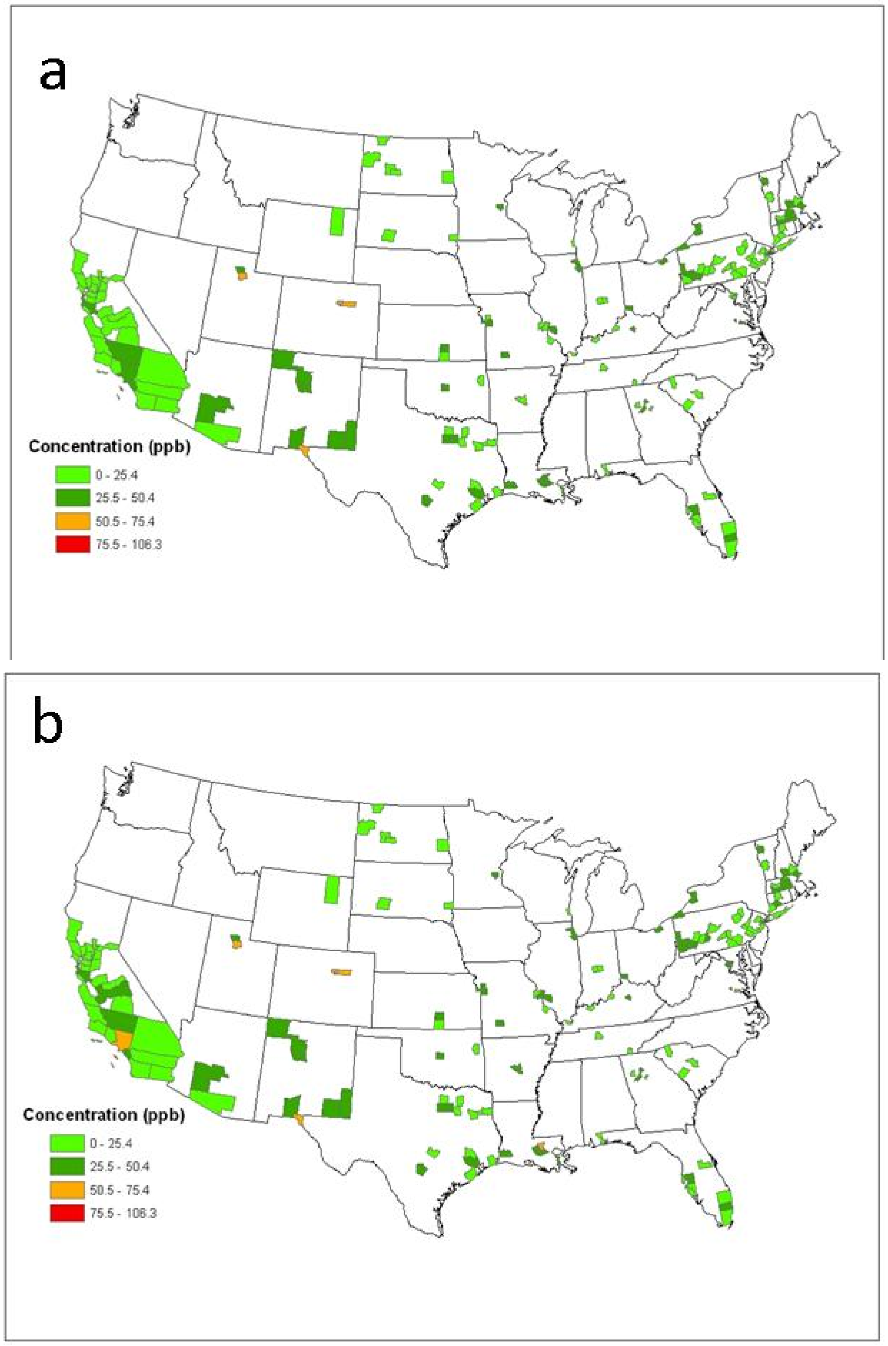


Table 0-7. Monitors exceeding the 50 ppb alternative standard for 98^{th} percentile 2020 design values. Shown are the 2005-2007 monitored 98^{th} design values (ppb), projected 98^{th} design value (ppb), residual nonattainment (ppb) and tons needed to reach attainment.

County	State	2005-07 Design value (ppb)	2020 Design value (ppb)	Residual nonattainment (ppb)	Tons for control
Adams	CO	74.3	59.7	9.3	4700
El Paso	TX	64	53.9	3.5	2500
El Paso	TX	66.6	56.1	5.7	3900
El Paso	TX	68.3	57.5	7.1	4800
Salt Lake	UT	63.6	53.4	3	1700

Table 0-8. Monitors exceeding the 50 ppb alternative standard for 99^{th} percentile 2020 design values. Shown are the 2005-2007 monitored 99th design values (ppb), projected 99th design value (ppb), residual nonattainment (ppb) and tons needed to reach attainment.

County	State	2005-07 Design value (ppb)	2020 Design value (ppb)	Residual nonattainment (ppb)	Tons for control
Los Angeles	CA	81.6	52.5	2.1	18000
Adams	CO	82.6	66.4	16	7300
East Baton Rouge	LA	65.3	54.6	4.2	5100
El Paso	TX	72.6	61.1	10.7	6800
El Paso	TX	76	64	13.6	8200
El Paso	TX	72.3	60.9	10.5	6700
Salt Lake	UT	70.3	59	8.6	4400
Charles City	VA	70	52.1	1.7	20

3.3.2 Discussion of Special Cases

After projection of 2005-2007 design values to 2020, some notable projected values were seen. This section describes the reasons for those values.

3.3.2.1 Non-calculated projected design values

For sixteen monitors (eleven counties), the projected 2020 design values were not calculated for both the 98^{th} and 99^{th} percentile concentrations (see 2020 concentrations denoted by "*" Table 3-1 in Appendix 3). Ten of the counties were in California and one in Pennsylvania. These were counties that were in regions that were not forecast to meet the 0.075 ozone standard as described in Chapter 4 of the ozone RIA (U.S. EPA, 2008b). These counties received across the board reductions in NOx in addition to the reductions included in the 0.070 ozone analysis. In the California counties, the 2020_075 emissions were 20% of the 2020_070 emissions, while in Pennsylvania, the 2020_075 emissions were 13% of the 2020_070 emissions. For more details about the emissions reduction see Chapter 4 of the ozone RIA (U.S. EPA, 2008b). Concentrations could not be calculated because 2020_075 emissions were so low that the methodology described in Section 3.3.1 did not produce reasonable results. Most of the monitors in question were already below the lowest alternative standard of 50 ppb in 2005-2007, so these monitors should not have issues with nonattainment. For monitors with 2005-2007 design values above 50 ppb, we feel that NOx emission reductions in 2020 are such that nonattainment should not be an issue.

3.3.2.2 Los Angeles County

As indicated in Table 3-6, 18,000 tons of NOx emissions reductions are needed to attain the 50 ppb alternative standard in Los Angeles County, CA. The tons needed for attainment of the 99th percentile NAAQS in Los Angeles County appear anomalous compared to the emissions reductions calculated for other nonattainment monitors elsewhere across the U.S. An investigation of the data was made to determine what was causing the large number of tons needed for attainment.

Figures 3-6 and 3-7 show the 2005-2007 99th percentile design values and the 2020 99th percentile design values, respectively, for Los Angeles County. The 2020 nonattainment monitor in question is denoted by the black circle. In the 2005-2007 period the monitor was at 81.6 ppb while it was projected to be 52.5 ppb. In 2005-2007, the nonattainment monitor was not the highest 99th percentile design value in the county but became the monitor with the highest projected design value in 2020.

Figure 0-6. 2005-2007 99th percentile design values (ppb) for Los Angeles County.

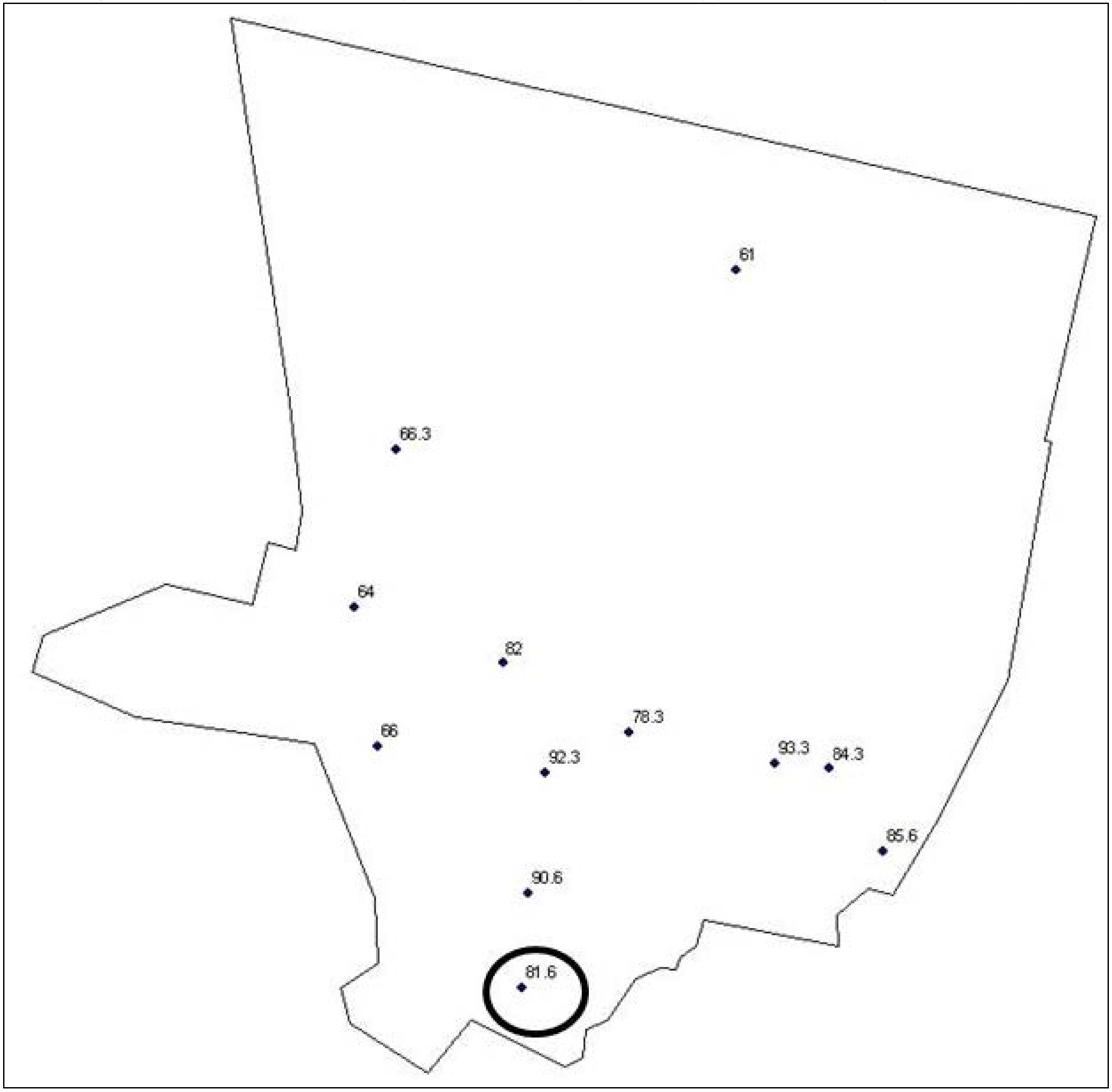
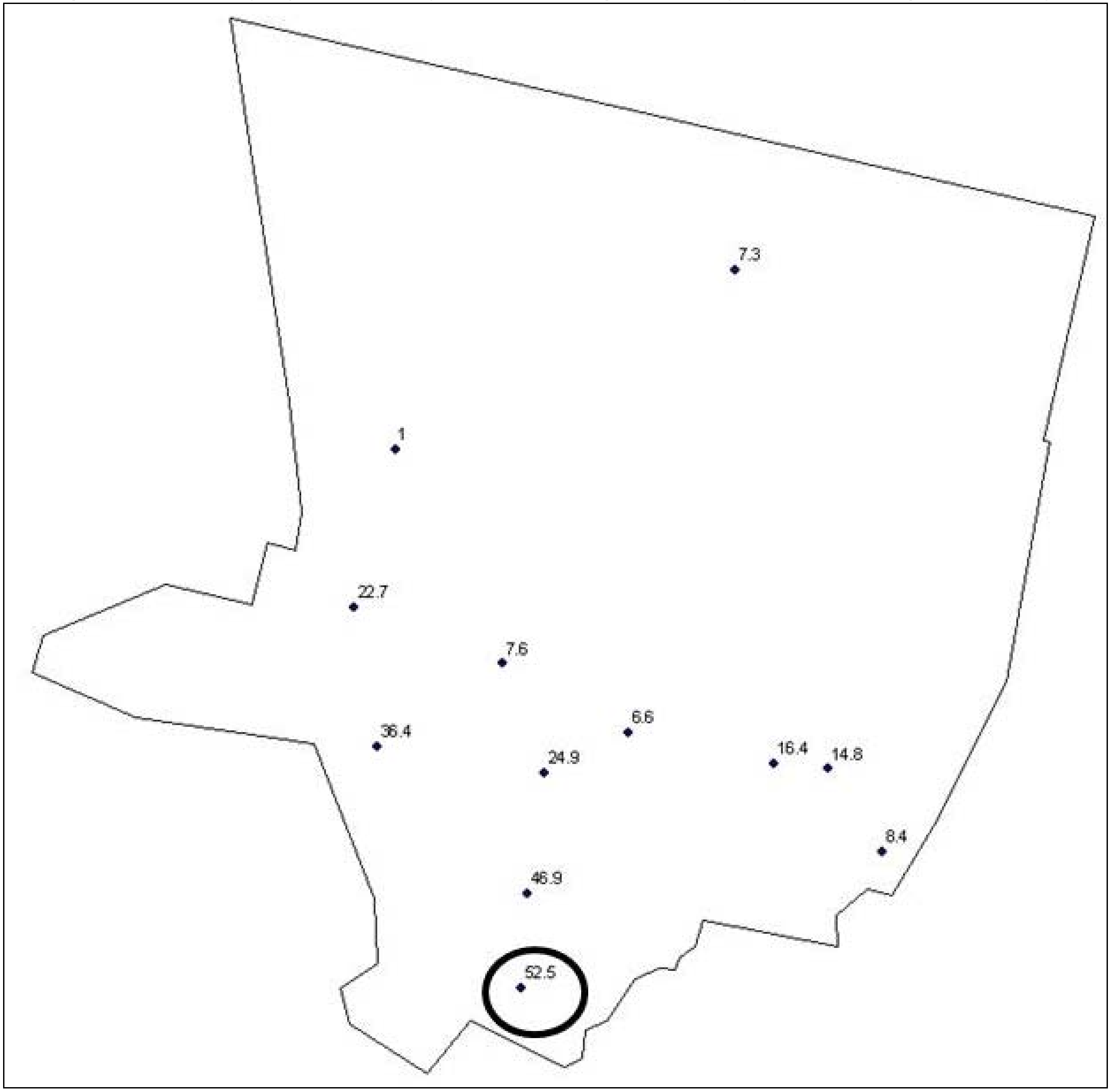


Figure 0-7. 2020 projected 99th percentile design values (ppb) for Los Angeles County.



Examining the steps described in Section 3.2, revealed several key findings. The grid cell containing the 2020 nonattainment monitor had the highest average of the top 10 daily 1-hour maximum concentrations for 2002, 99.2 ppb, (Figure 3-8) and 2020_070, 76.6 ppb, (Figure 3-9) for Los Angeles County.

Figure 0-8. Average of top ten daily 1-hour maximum concentrations (ppb) for 2002 CMAQ output. Monitor in black circle is 2020 nonattainment monitor.

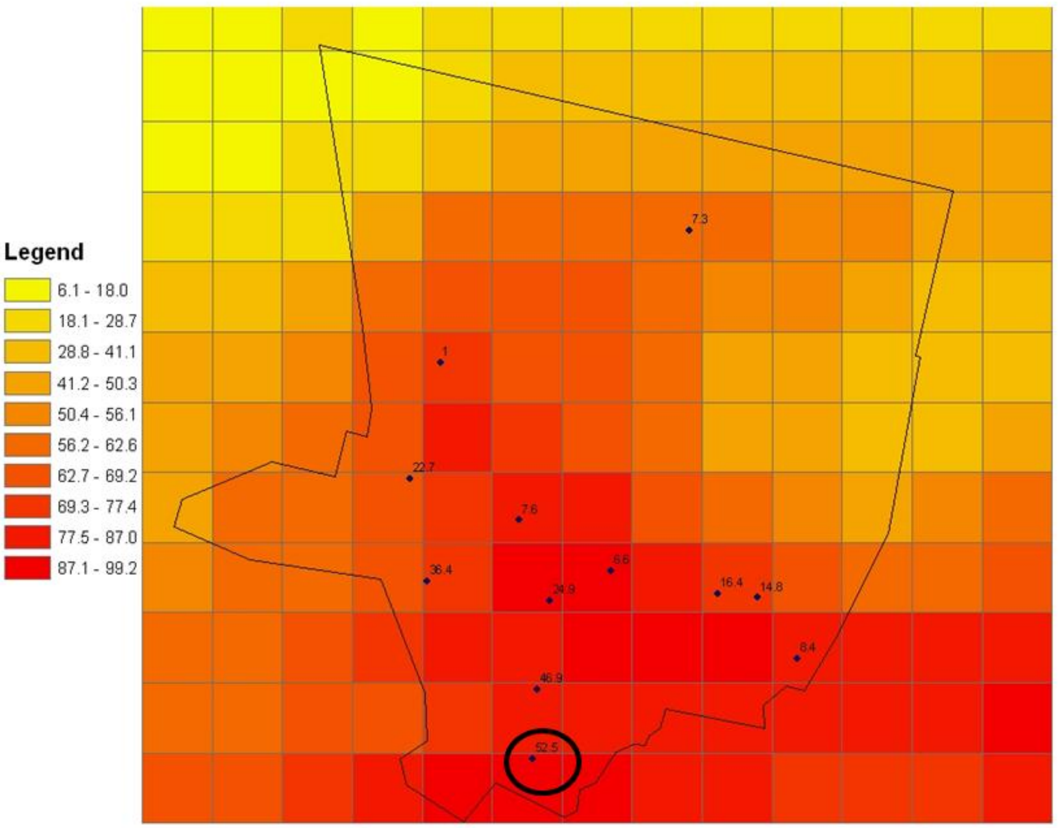
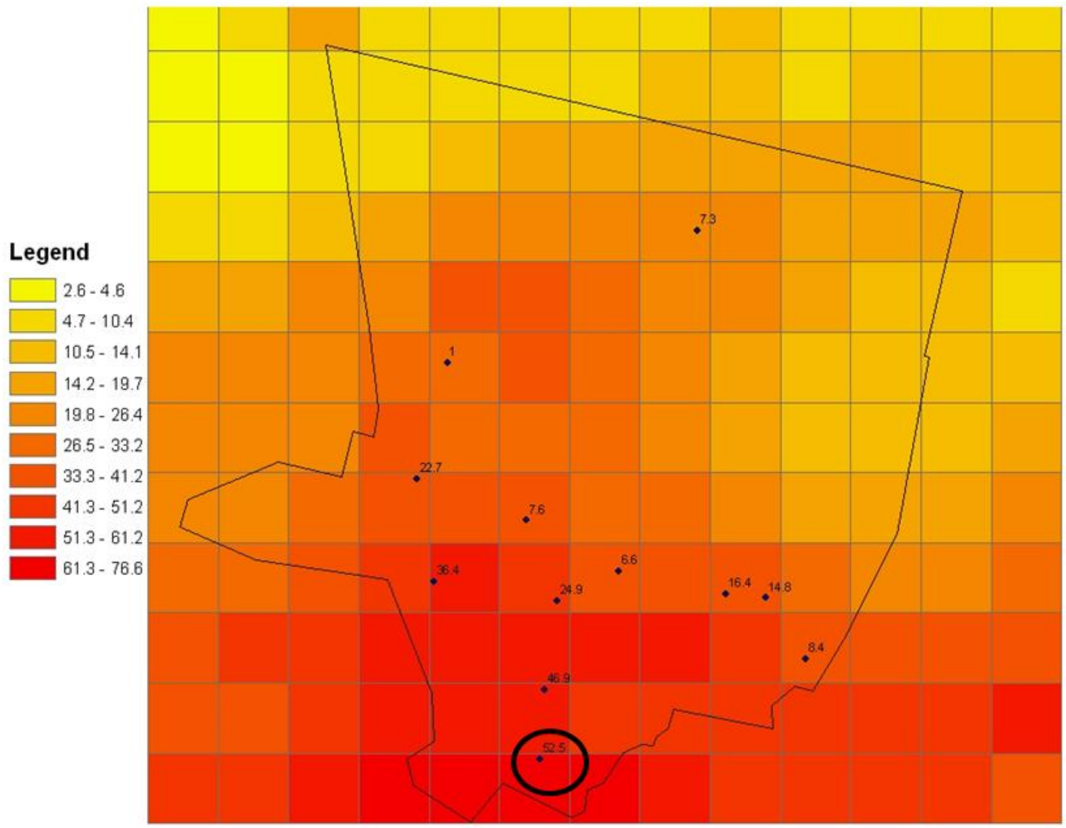
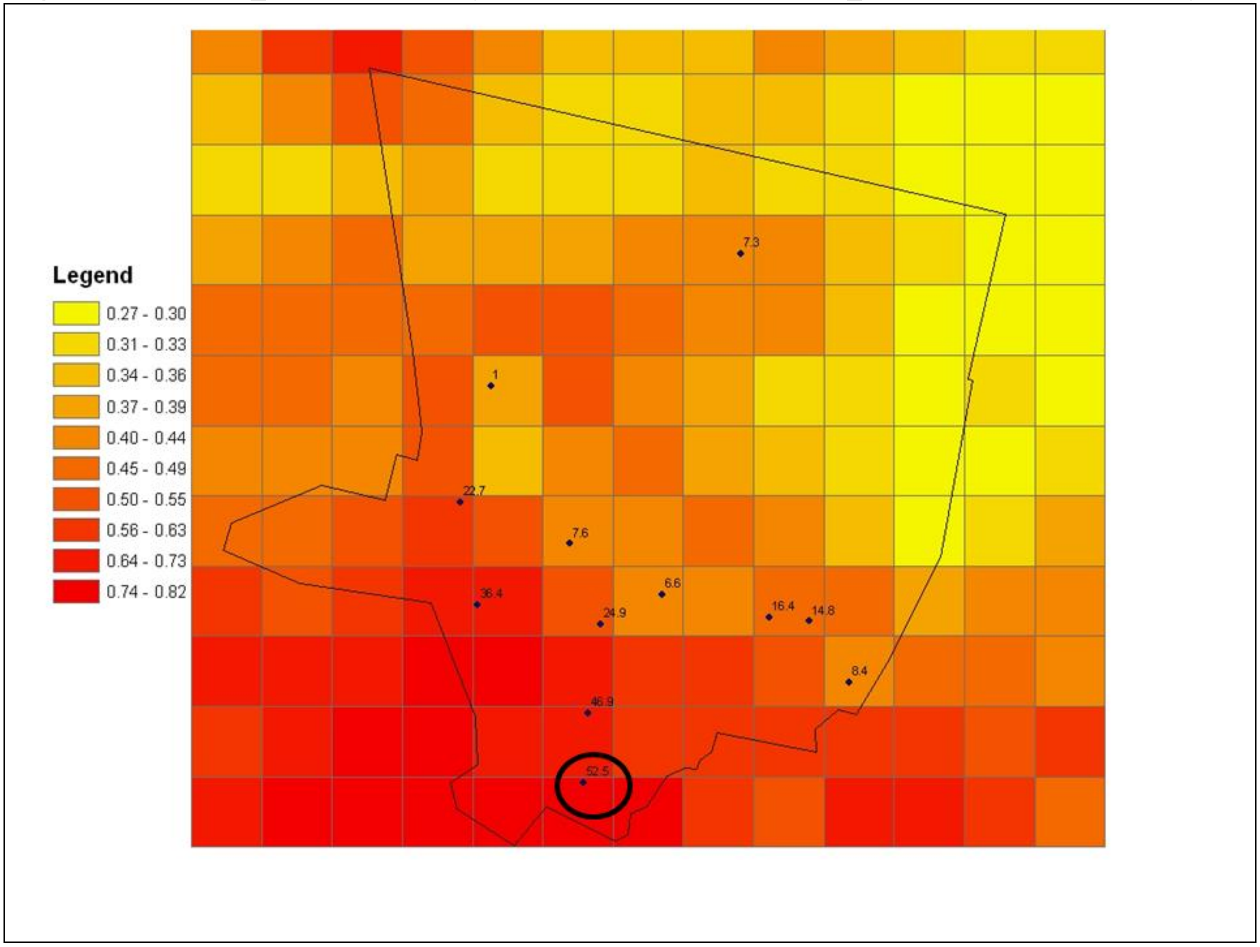


Figure 0-9. Average of daily 1-hour maximum concentrations (ppb) for 2020_070 CMAQ output for the same days as the top ten daily 1-hour concentrations for 2002. Monitor in black circle is 2020 nonattainment monitor.



From the concentrations presented in Figures 3-8 and 3-9, the RRF calculations are shown in Figure 3-10. The RRF for the nonattainment monitor was the highest of the grid cells containing monitors in Los Angeles County, 0.78. The average RRF value for the other monitors in the county is approximately 0.50. Since all of the monitors in Los Angeles County received the same county emissions for 2020 design value projections, the driving factor in the calculations were the RRF values.

Figure 0-10. 2020_070 relative response factors (RRF) for 2020_070 and 2002 CAMQ output.



In Figure 3-11, the mean daily 1-hour maximum concentration for 2020_070 is shown. Essentially, this is the annual mean of the daily 1-hour maximum concentrations. As with the other variables, the mean max daily 1-hour concentration for the nonattainment monitor's grid cell was the highest at 62.9 ppb. The RRF values and associated concentrations along with the high mean daily 1-hour maximum concentration in the county warranted an investigation of what emission sources may have been contributing to the high concentrations and subsequent high RRF. Figure 3-12 shows an aerial view of the grid cell containing the nonattainment monitor. The monitor is located in the northern area of the grid cell (denoted by yellow dot and 2020 99th percentile design value). To the east of the monitor is the Long Beach Municipal Airport (LGB) (outlined in red) and to the south is the Long Beach Port (general area denoted by green box). In the lower right corner of Figure 3-12 is a wind rose of winds for LGB for the period 2005-2007. Winds are predominantly from the south and northwest. One of the runways for LGB is aligned from northwest to southeast, in alignment with the predominant northwest wind direction. Given that aircraft used that direction to land and take off and the close proximity of the monitor to the airport, aircraft NOx emissions may have impacted the monitor.

The most likely driver for the high concentration and RRF was the port of Long Beach emissions. Port emissions from ships alone were 37,000 tons in 2002. Those emissions were not controlled in the 2020_070 scenario, resulting in the high concentrations for the grid cell containing the monitor. (As noted in section 4.1.1, the Port of Long Beach is currently planning significant emission reduction activity.) The monitor located just north of the nonattainment monitor, was not impacted by the port and was below the 50 ppb alternative standard.

Figure 0-11. Annual mean daily 1-hour maximum concentration (ppb) for 2020_070 CMAQ output.

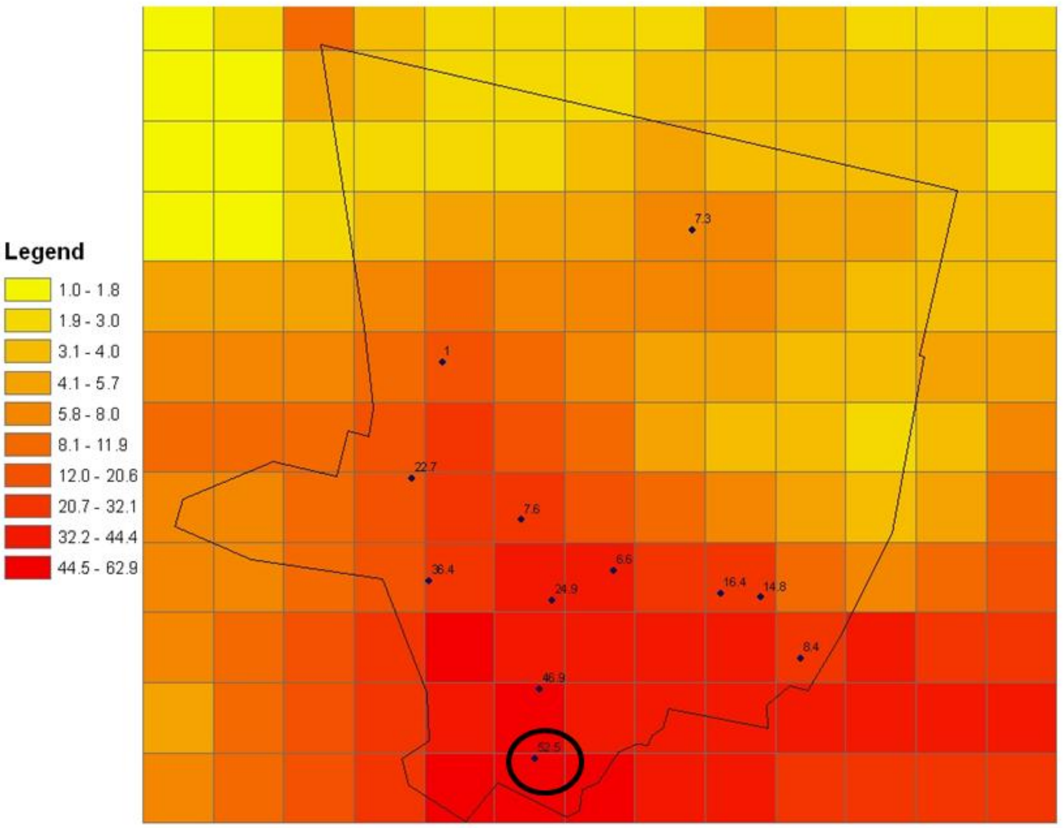
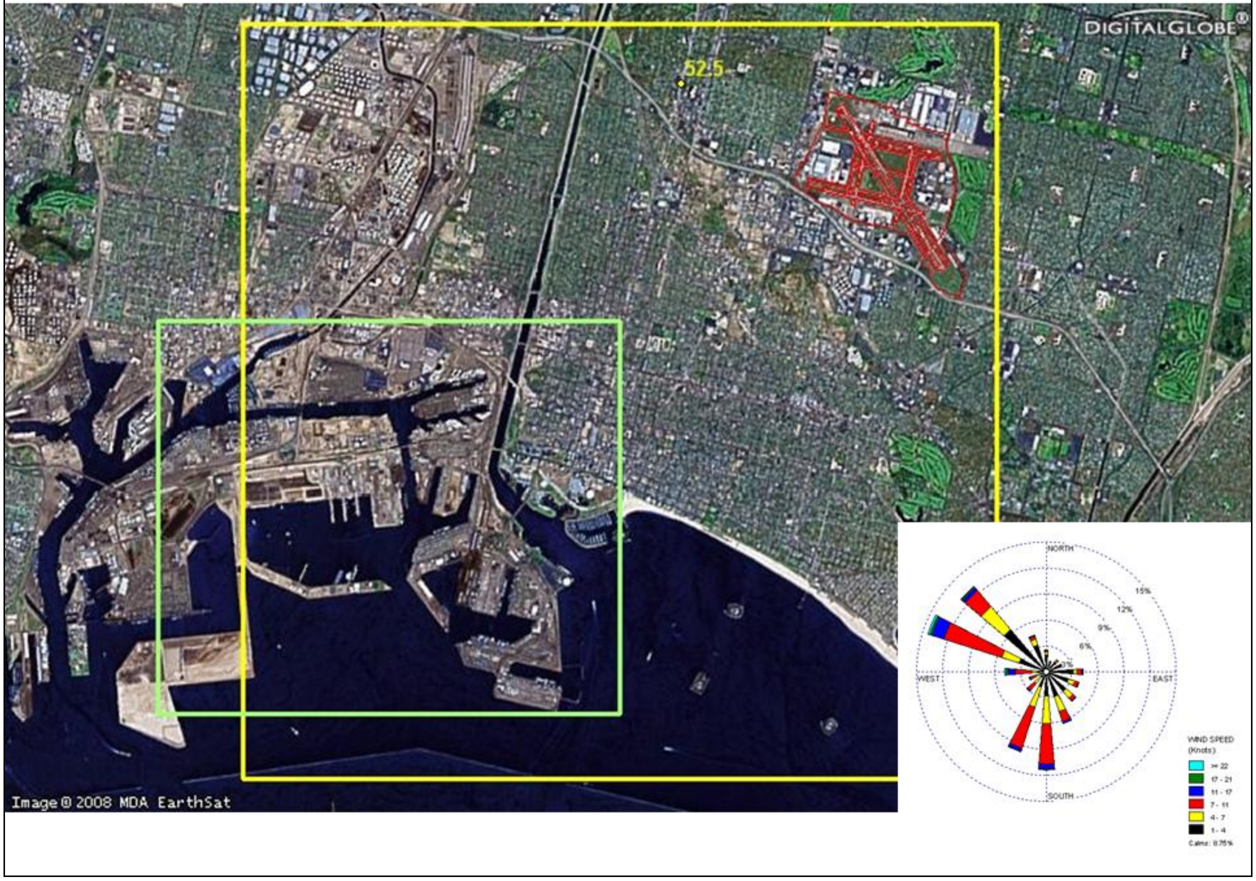


Figure 0-12. Aerial photograph of 2020 design value nonattainment monitor for Los Angeles County.



In summary:

- A monitor in Los Angeles County was a high monitor in the 2005-2007 99th percentile design values, but not the highest in the county.
- The monitor became the highest 2020 99th percentile design value monitor in the county.
- The grid cell containing the monitor had the highest average of the top 10 daily 1-hour maximum concentrations for 2002 for grid cells containing monitors in Los Angeles County.
- Also, the monitor's grid cell had the highest average of the 2020_070 daily 1-hour maximum concentrations for the same days as the ten days in the average of the 2002 daily 1-hour maximum concentrations.
- The monitor's grid cell had the highest RRF value for all monitor grid cells in the county.

- Since the all of the monitors in the county used the same 2002, 2006, 2020_070, and 2020_075 emissions for emissions RRF calculations (Equations 3.2 and 3.3), the driving factor was the high RRF for the grid cell.
- The grid cell contained the Long Beach port, which had high NOx emissions and were not controlled in the 2020_070 inventory, resulting in higher daily 1-hour maximum concentrations when compared to other monitor grid cells.

3.3.2.3 El Paso County

El Paso County represents a case of nonattainment where international emissions may have played a role. The 2005-2007 99th percentile design values are shown in Figure 3-13. The three monitors in the black circle were the highest monitors. The 2020 99th percentile design values are shown in Figure 3-14.

Figure 0-13. 2005-2007 99th percentile design values (ppb) for El Paso County.

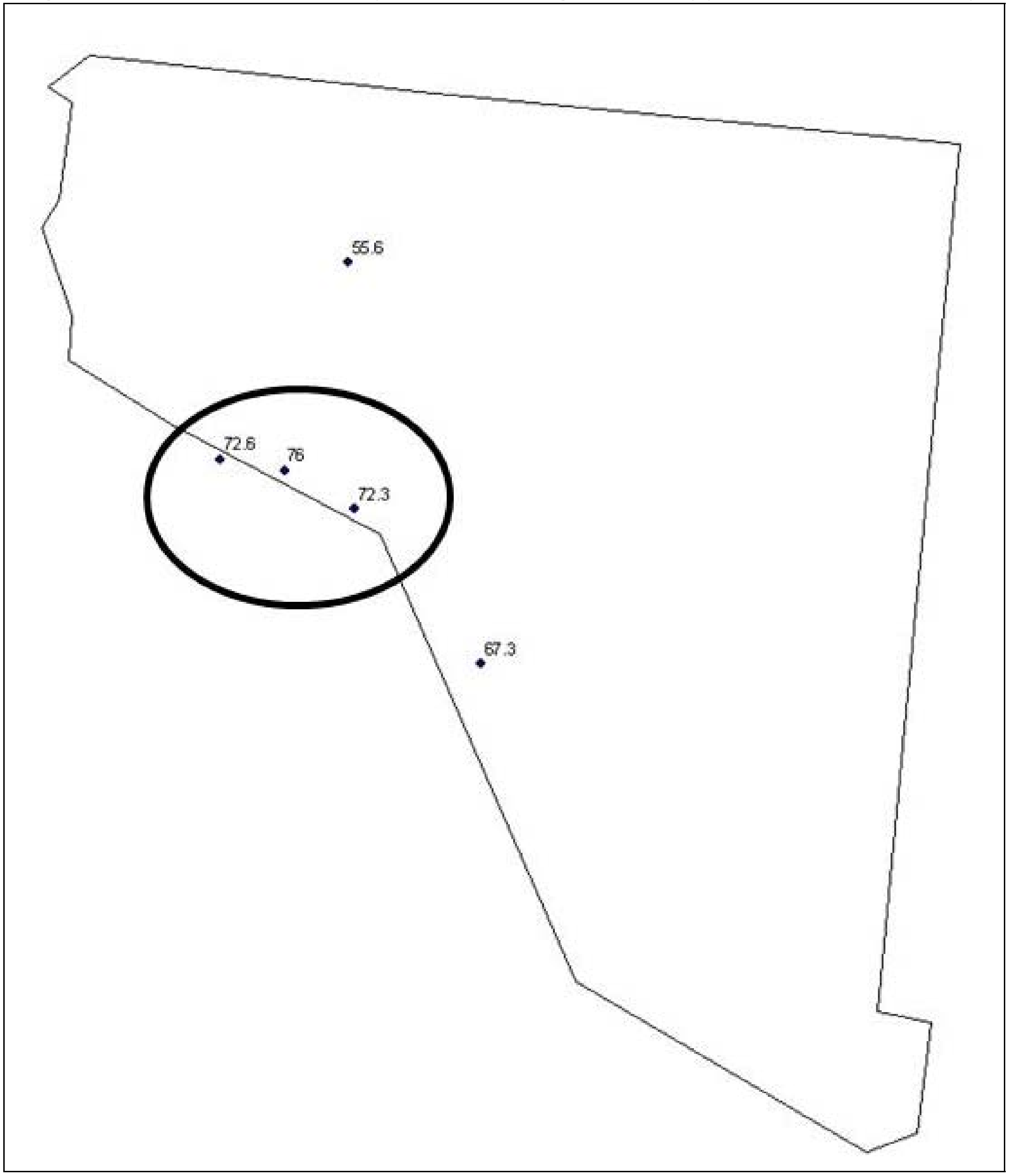
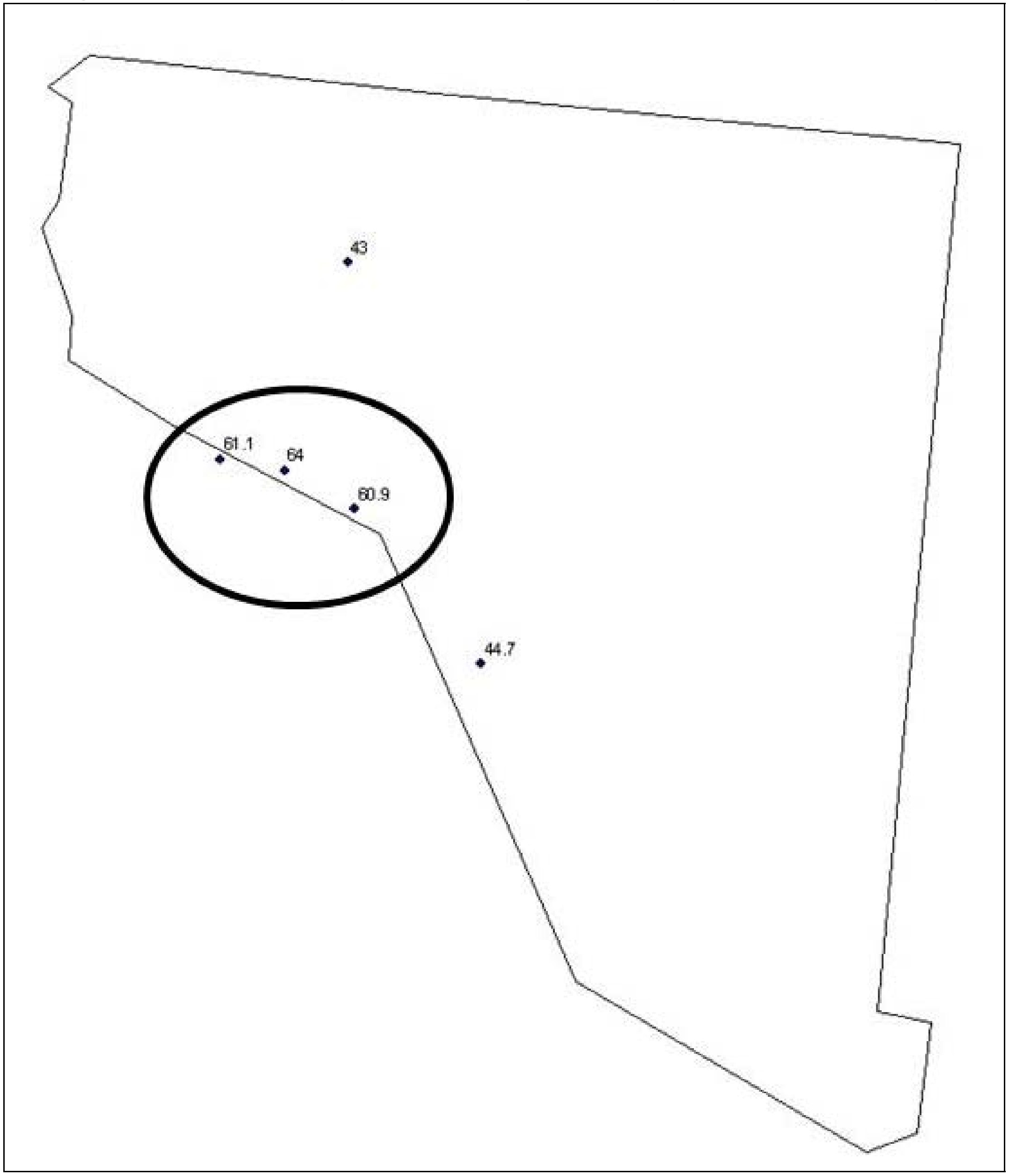


Figure 0-14. 2020 99th percentile design values (ppb) for El Paso County.



Concentrations decreased from 2005-2007 to 2020 but were above the 50 ppb alternative level and were the only ones above the 50 ppb alternative standard. Examining the average of the top ten daily 1-hour maximum concentrations for 2002 (Figure 3-15), and the average of the daily 1-hour maximum concentrations for the same ten days in 2020 (Figure 3-16), showed that the grid cell containing the three nonattainment monitors was the highest value among the grid cells containing monitors. The RRF calculated for the grid cells also was the highest for grid cells containing monitors (Figure 3-17) as well as the mean daily 1-hour maximum concentration in 2020 (Figure 3-18).

Figure 0-15. Average of the top ten daily 1-hour maximum concentrations (ppb) by grid cell for 2002 for grid cells in El Paso county.

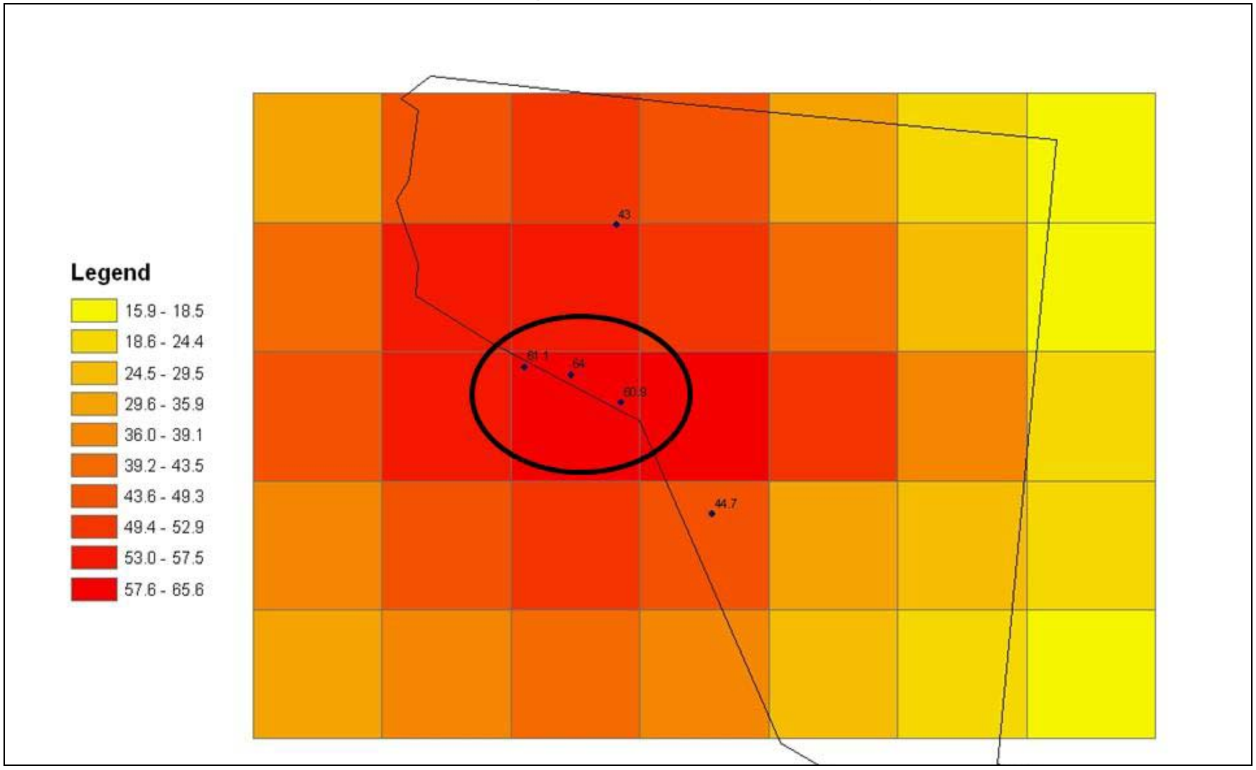


Figure 0-16. Average of the daily 1-hour maximum concentrations (ppb) by grid cell for 2020_070 corresponding to the top ten days in 2002 for grid cells in El Paso county.

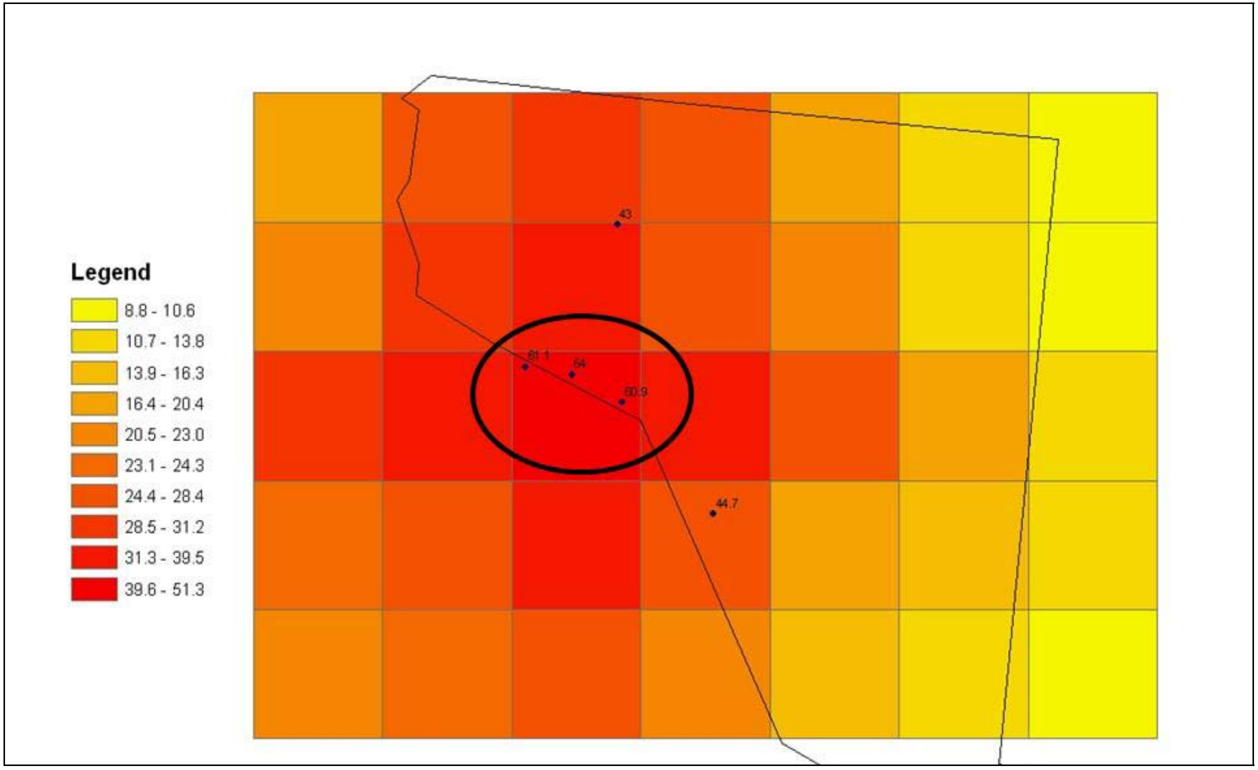


Figure 0-17. 2020_070 RRF values for grid cells in El Paso County.

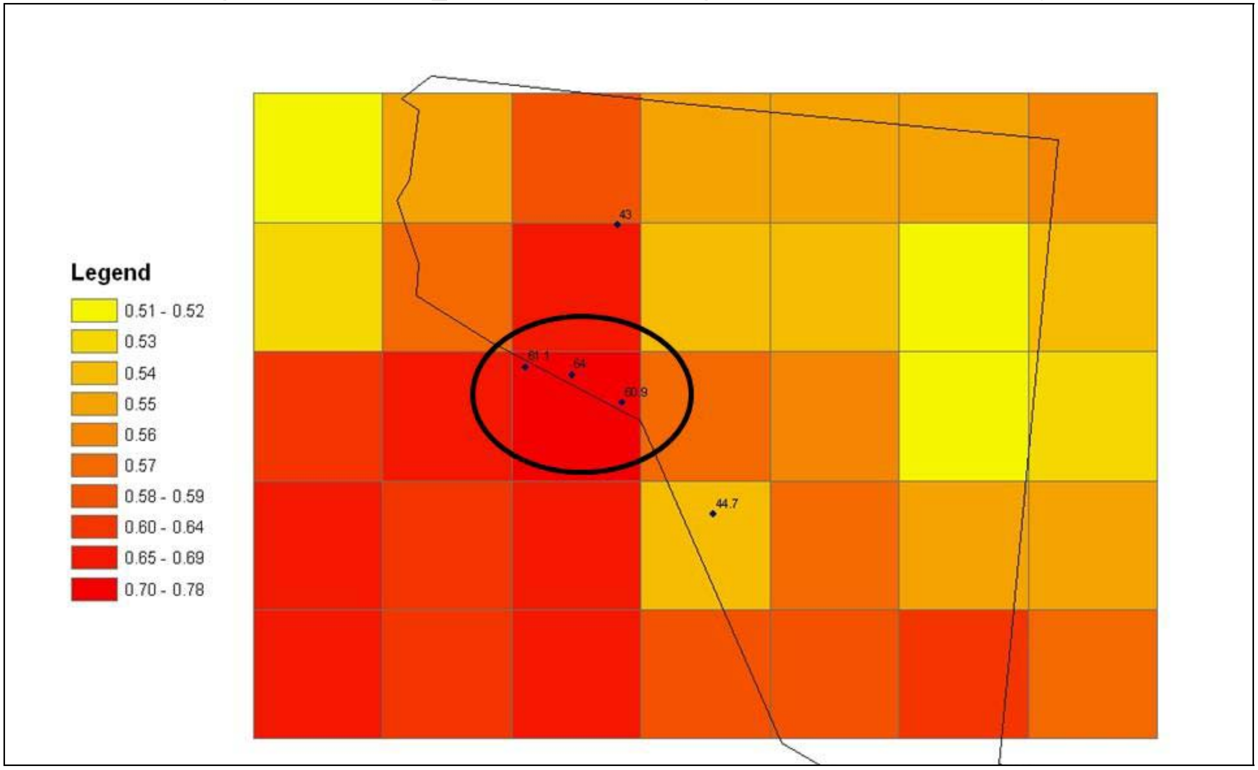
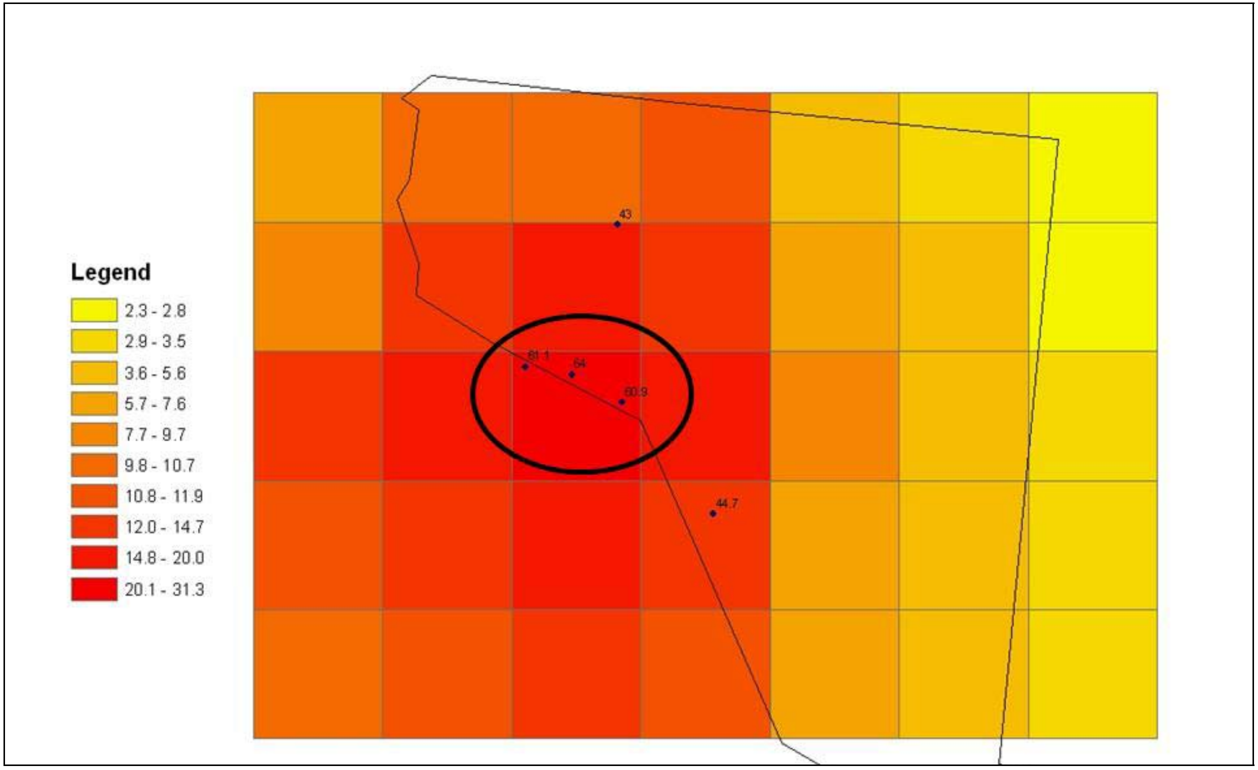
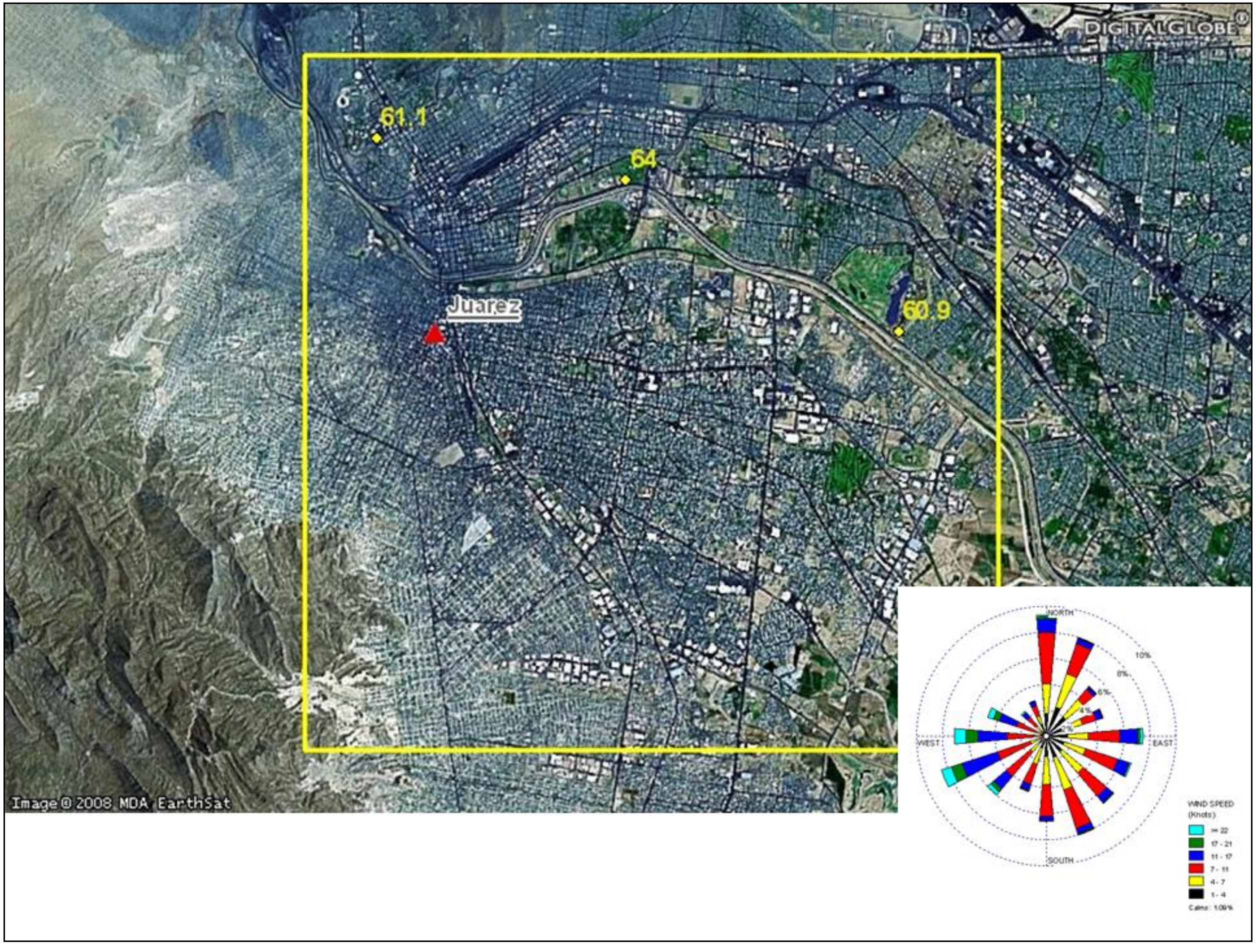


Figure 0-18. 2020_070 mean daily 1-hour maximum concentration (ppb) for grid cells in El Paso County.



Note that these monitors are not only located along the border highway, but they are also very close to the international border with city of Juarez just to the southwest (Figure 3-19). A wind rose from El Paso Airport for 2005-2007 shows a relatively high frequency of winds from the east-southeast through west-southwest that would transport pollutants from Juarez toward the three NO_2 monitoring sites across the river in El Paso.. The grid cell that contains the three monitors is mostly in Mexico. Emissions from across the international border could impact the modeled concentrations of the grid cells containing the monitors. However, for our emission inventories, we do not forecast controls on international emissions over which we have no jurisdiction.

Figure 0-19. Aerial photograph of CMAQ grid cell containing nonattainment monitors for El Paso County. Yellow box is 12 x 12 km grid cell and El Paso 2005-2007 wind rose is shown in lower right corner.



In summary:

- Three monitors in El Paso County were the highest monitors in the 2005-2007 and 2020_075 99th percentile design values in the county.
- The grid cell containing the monitor had the highest average of the top 10 daily 1-hour maximum concentrations for 2002 for grid cells containing monitors in El Paso County.
- Also, the monitors' grid cell had the highest average of the 2020_070 daily 1-hour maximum concentrations for the same days as the ten days in the average of the 2002 daily 1-hour maximum concentrations.
- The monitors' grid cell had the highest RRF value for all monitor grid cells in the county.
- Since the all of the monitors in the county used the same 2002, 2006, 2020_070, and 2020_075 emissions for emissions RRF calculations (Equations 3.2 and 3.3), the driving factor was the high RRF for the grid cell.

- The grid cell contained international emissions and were not controlled in the 2020_070 inventory, resulting in higher daily 1-hour maximum concentrations when compared to other monitor grid cells.[3]

3.4 Metrics for input into benefits analysis

Several metrics were calculated from the 2020cc_070 CMAQ concentrations for input in the EPA Benefits Modeling and Analysis Program (BenMAP). (See chapter 5 for more on BenMAP). The metrics include:

- Annual mean of the daily 1-hour maximum NO_2 concentration in each grid cell (Figure 3-20)
- Annual mean of the daily NO_2 concentration in each grid cell (Figure 3-21)
- Annual mean of the daily 8-hour maximum NO_2 concentration in each grid) (Figure 3-22)
- Annual mean of the 4-hour (0600 LST to 1000 LST) NO_2 concentration in each grid cell (Figure 3-23)

From Figures 3-20 through 3-23, the urban areas in the contiguous 48 states can be seen, as well as several interstate corridors.

---

[3] See section 4.1.1 for further discussion of El Paso's situation with regard to international emissions.

Figure 0-20. Annual mean daily 1-hour maximum NO_2 concentration (ppb) for 2020_070.

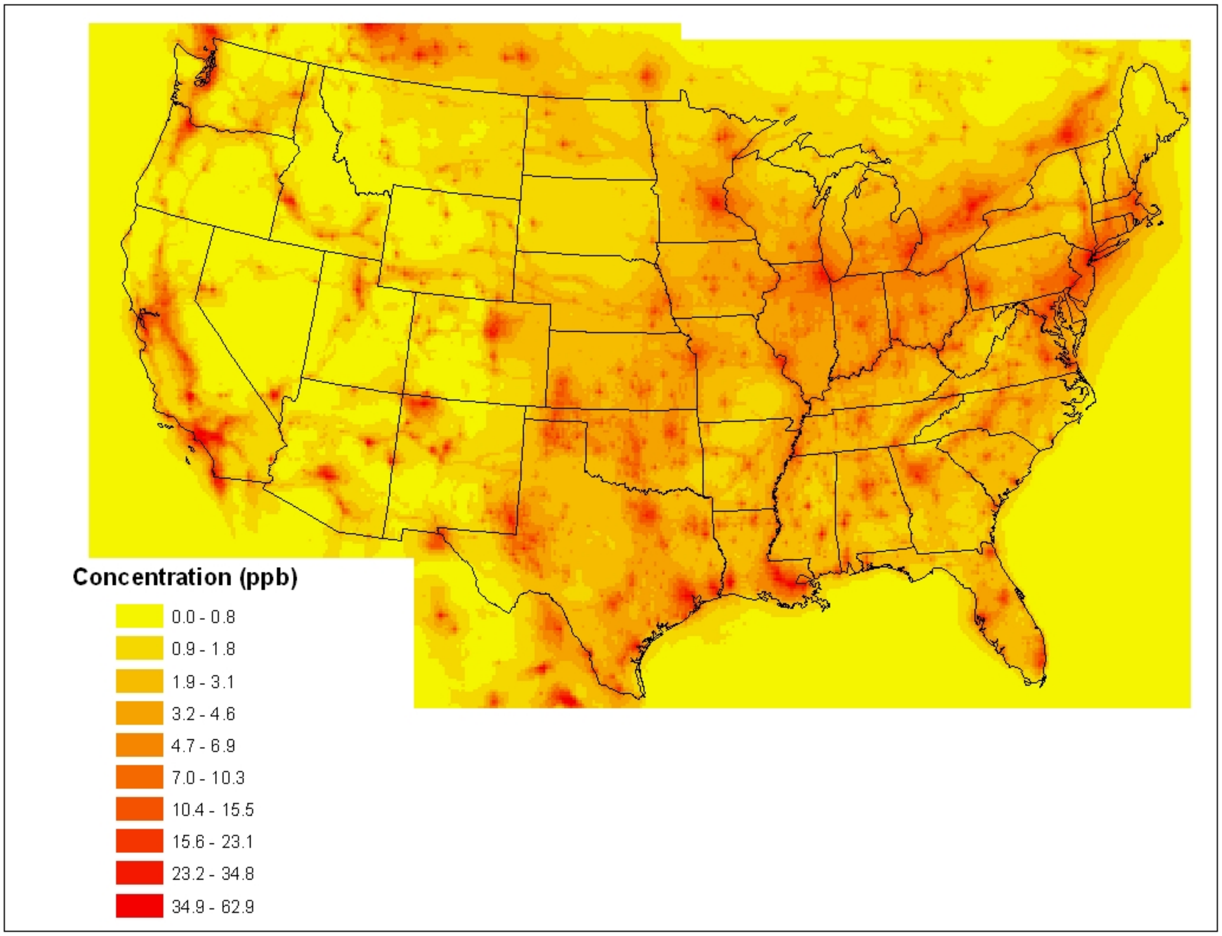


Figure 0-21. Annual mean daily NO_2 concentration (ppb) for 2020_070.

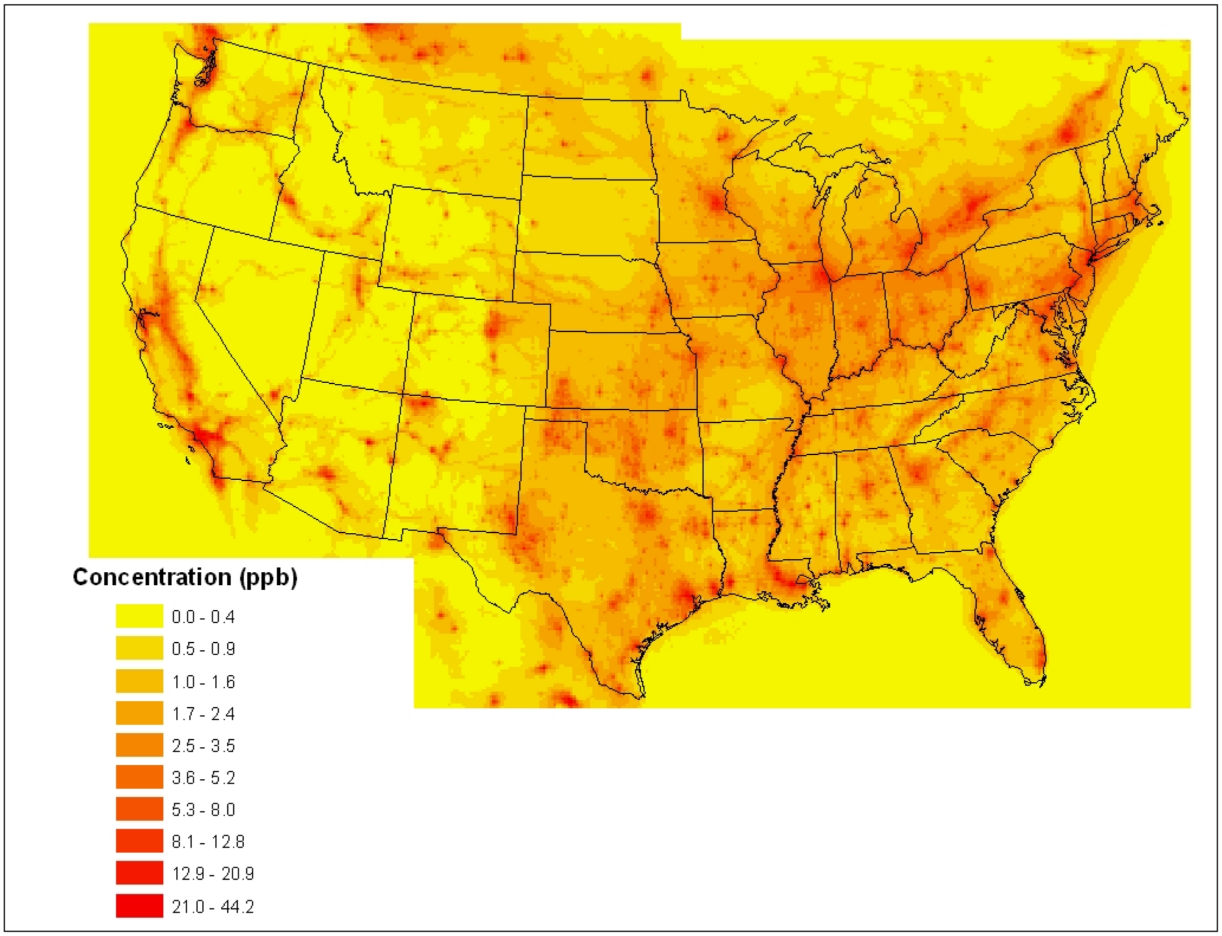


Figure 0-22. Annual mean of the 8-hour maximum NO_2 concentration (ppb) for 2020_070.

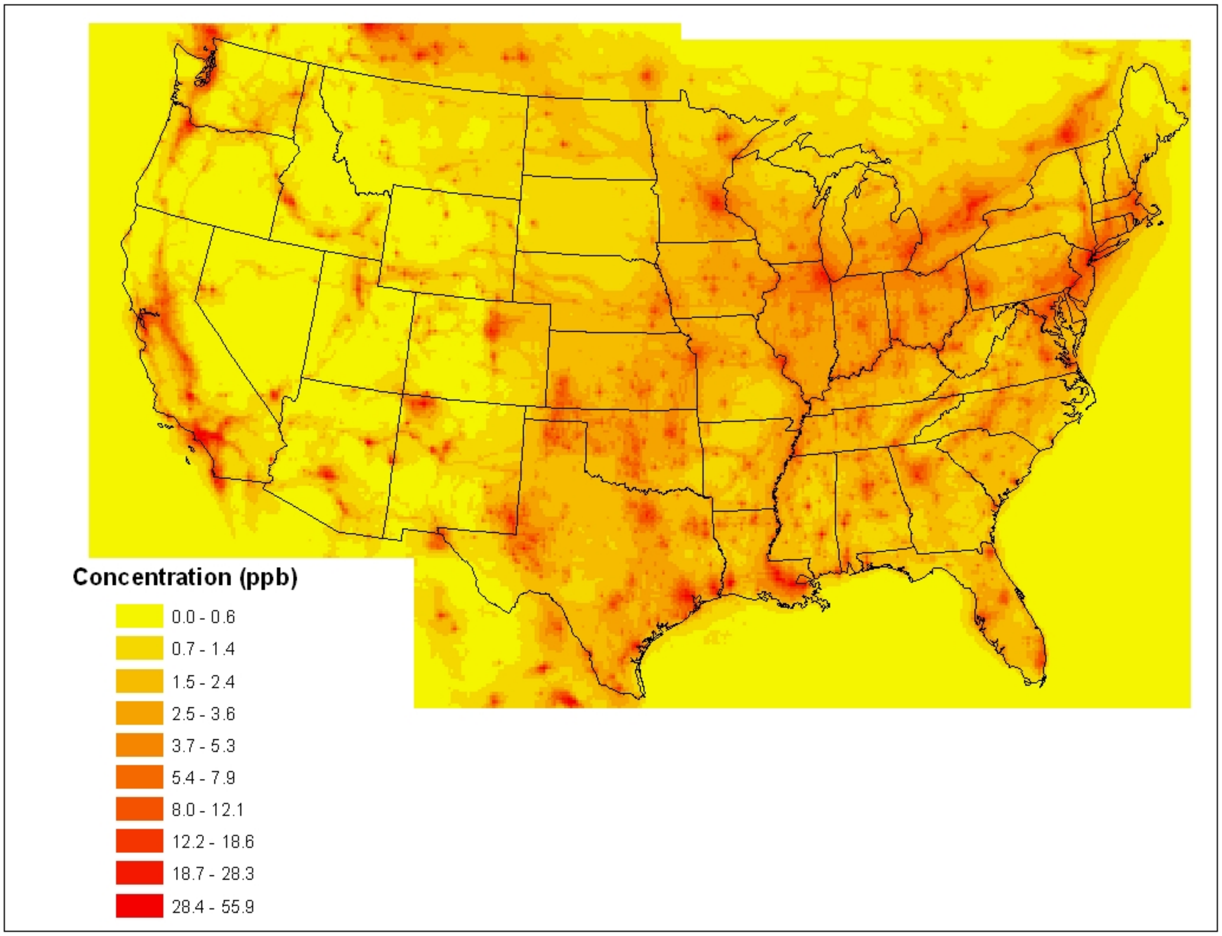
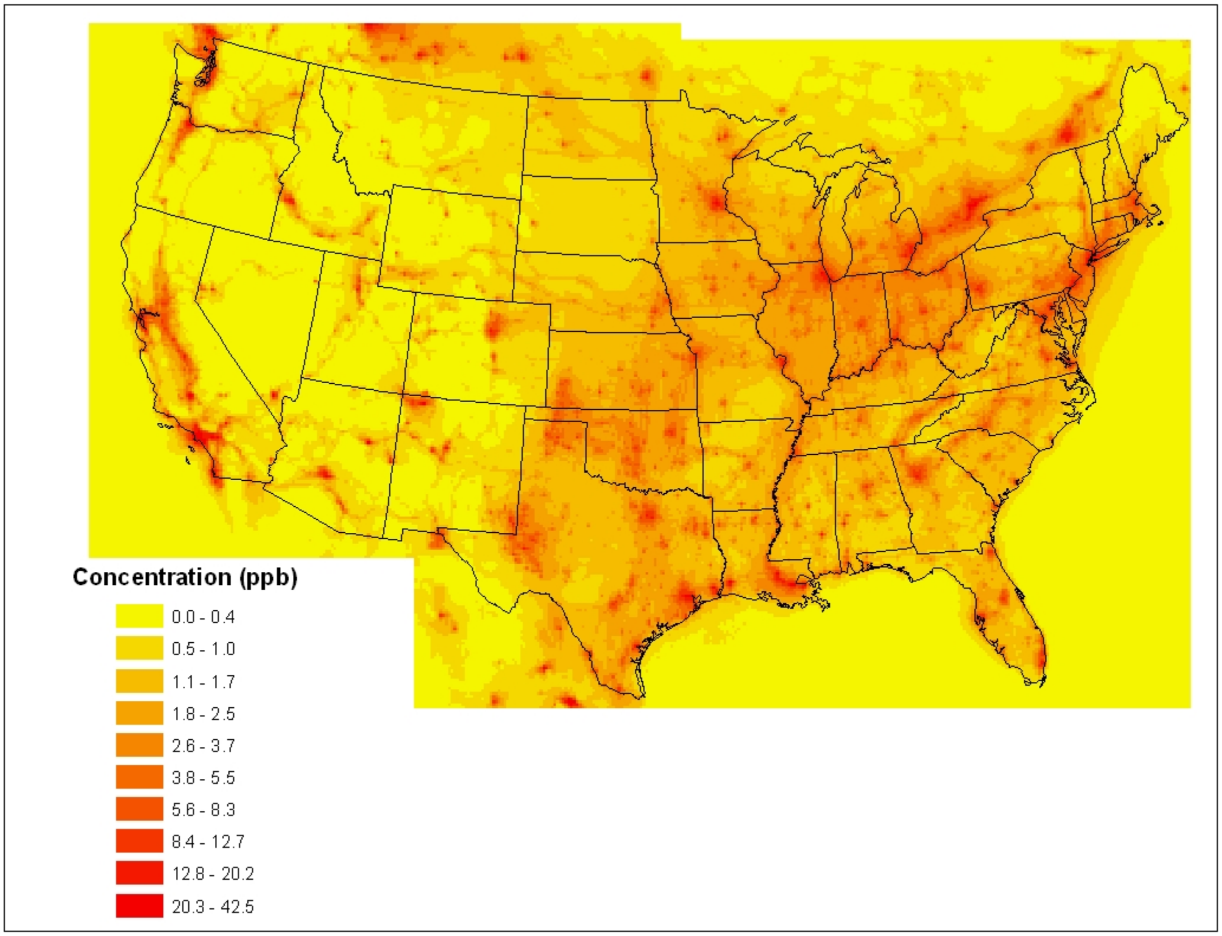


Figure 0-23. Annual mean of the 4-hour mean NO_2 concentration (ppb) for 2020_070.



3.5 Summary

In summary, 2020 baseline NO_2 design value concentrations were projected from 2005-2007 observed design values using CMAQ output from the 2002 and the 2020_070 scenario simulations performed for the ozone NAAQS RIA (U.S. EPA, 2008b). County emissions for 2002, 2006, and 2020 were used in conjunction with the CMAQ output to project the 2005-2007 design values for the 2020 baseline. Results of the projections showed that, in 2020, three counties are projected to exceed the 50 ppb alternative standard for the 98th percentile design values and six counties are projected to exceed the 50 ppb alternative standard for the 99th percentile design values. For either percentile, no monitors are projected to exceed the alternative standards of 100 and 200 ppb. Two counties, Los Angeles, CA and El Paso, TX were investigated in detail as their nonattainment were examples of large emission sources contributing to the nonattainment. For Los Angeles County, the Long Beach Port was located in the same grid cell as the violating monitor and emissions from activities at the Long Beach Port (as well as the nearby LA Port) were not controlled in the 2020_070 CMAQ simulation. El Paso represented a case of international emissions contributing to nonattainment.

3.6 References

Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division, Ann Arbor, MI 48105, EPA420-R-99-023, December 1999. Available at http://www.epa.gov/tier2/frm/ria/r99023.pdf.

U.S. Environmental Protection Agency (EPA). 2000. *Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements*, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division, Ann Arbor, MI 48105, EPA420-R-00-026, December 2000. Available at http://www.epa.gov/otaq/highway-diesel/regs/exec-sum.pdf

U.S. Environmental Protection Agency (EPA). 2004. *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division, Ann Arbor, MI 48105, EPA420-R-04-007, May 2004. Available at http://www.epa.gov/nonroaddiesel/2004fr/420r04007.pdf.

U.S. Environmental Protection Agency (EPA). 2005a. *Clean Air Interstate Rule Emissions Inventory Technical Support Document*, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March 2005. Available at http://www.epa.gov/cair/pdfs/finaltech01.pdf.

U.S. Environmental Protection Agency (EPA). 2005b. *Emissions Inventory and Emissions Processing for the Clean Air Mercury Rule (CAMR),* U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March 2005. Available at http://www.epa.gov/ttn/atw/utility/emiss_inv_oar-2002-0056-6129.pdf

U.S. Environmental Protection Agency (EPA). 2005c. *Regulatory Impact Analysis for the Final Clean Air Visibility Rule or the Guidelines for Best Available Retrofit Technology (BART) Determinations Under the Regional Haze Regulations,* U.S. Environmental Protection Agency, Office of Air and Radiation, June 2005. EPA-452-R-05-004. Available at http://www.epa.gov/visibility/pdfs/bart_ria_2005_6_15.pdf

U.S. Environmental Protection Agency (EPA). 2007a. *Regulatory Announcement: EPA Proposal for More Stringent Emissions Standards for Locomotives and Marine Compression-Ignition Engines*. EPA420-F-07-015.

U.S. Environmental Protection Agency (EPA). 2007b, *Proposed Emission Standards for New Nonroad Spark-Ignition Engines, Equipment, and Vessels*. EPA420-F-07-032.

U.S. Environmental Protection Agency (EPA). 2008a. *Air Quality Modeling Platform for the Ozone National Ambient Air Quality Standard Final Rule Regulatory Impact Analysis*. North Carolina. EPA-454/R-08-003.

U.S. Environmental Protection Agency (EPA). 2008b. *Final Ozone NAAQS Regulatory Impact Analysis*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March 2005. EPA-452/R-08-003.

Appendix 3a: 2005-2007 Design Values

Table 3a-1 lists the 2005-2007 design values used in projecting 2020 design values. 2020 design values denoted by "*" were monitors where a projected design value could not be calculated. See Section 3.3.2.1 of Chapter 3 for an explanation.

Table 0a-1. NO_2 2005-2007 and 2020 projected 98th and 99th percentile design values (ppb).

State	County	Site	Concentrations (ppb			
			2005-2007		2020	
			98th	99th	98th	99th
Arizona	Maricopa Co	19	68.0	76.0	34.2	38.3
Arizona	Maricopa Co	3002	70.3	74.6	33.8	35.9
Arizona	Maricopa Co	3003	60.3	64.0	25.4	26.9
Arizona	Maricopa Co	3010	83.3	92.6	41.9	46.6
Arizona	Maricopa Co	9997	64.0	66.6	30.8	32.0
Arizona	Pima Co	1011	47.0	49.6	23.2	24.5
Arizona	Pima Co	1028	46.6	49.0	21.1	22.2
Arkansas	Pulaski Co	7	50.0	54.6	24.0	26.2
California	Alameda Co	7	48.3	52.3	3.0	3.3
California	Alameda Co	1001	49.0	54.3	16.3	18.0
California	Contra Costa Co	2	38.6	43.6	0.4	0.5
California	Contra Costa Co	1002	33.0	37.0	3.1	3.5
California	Contra Costa Co	1004	43.6	47.3	12.6	13.6
California	Contra Costa Co	3001	43.6	48.0	13.3	14.7
California	Fresno Co	7	62.6	66.3	23.2	24.6
California	Fresno Co	8	62.3	65.6	20.4	21.5
California	Fresno Co	242	44.6	49.6	7.5	8.4
California	Fresno Co	4001	45.0	49.6	10.1	11.1
California	Fresno Co	5001	59.8	64.3	23.8	25.6
California	Imperial Co	5	75.0	85.0	8.0	9.1
California	Kern Co	7	42.6	47.0	15.2	16.8
California	Kern Co	10	65.3	69.3	29.5	31.3
California	Kern Co	14	63.3	66.3	28.6	30.0
California	Kern Co	5001	38.0	40.3	7.4	7.9
California	Kern Co	6001	64.3	73.0	38.7	43.9
California	Los Angeles Co	2	82.3	93.3	14.5	16.4
California	Los Angeles Co	16	77.3	84.3	13.6	14.8
California	Los Angeles Co	113	63.1	66.0	34.8	36.4
California	Los Angeles Co	1002	75.0	82.0	6.9	7.6
California	Los Angeles Co	1103	83.6	92.3	22.5	24.9
California	Los Angeles Co	1201	60.6	64.0	21.5	22.7
California	Los Angeles Co	1301	79.0	90.6	40.9	46.9
California	Los Angeles Co	1701	79.6	85.6	7.8	8.4

State	County	Site	Concentrations (ppb			
			2005-2007		2020	
			98th	99th	98th	99th
California	Los Angeles Co	2005	73.0	78.3	6.2	6.6
California	Los Angeles Co	4002	74.0	81.6	47.6	52.5
California	Los Angeles Co	6012	61.3	66.3	0.9	1.0
California	Los Angeles Co	9033	57.0	61.0	6.8	7.3
California	Madera Co	4	41.3	45.0	*	*
California	Marin Co	1	45.0	48.6	23.5	25.4
California	Mendocino Co	8	31.6	34.0	*	*
California	Mendocino Co	9	27.3	29.6	0.1	0.2
California	Merced Co	3	43.0	48.3	4.0	4.5
California	Monterey Co	1003	37.0	41.0	*	*
California	Napa Co	3	41.3	46.6	10.6	12.0
California	Orange Co	5001	73.3	78.0	30.9	32.9
California	Placer Co	6	57.0	60.3	*	*
California	Riverside Co	5001	50.0	54.0	*	*
California	Riverside Co	8001	64.3	67.6	19.7	20.7
California	Riverside Co	9001	53.0	57.3	8.1	8.8
California	Sacramento Co	6	47.0	50.0	5.2	5.5
California	Sacramento Co	10	54.3	58.0	18.4	19.7
California	Sacramento Co	12	35.0	38.6	2.7	3.0
California	Sacramento Co	13	55.6	58.6	19.9	21.0
California	San Bernardino Co	1	72.0	76.3	*	*
California	San Bernardino Co	306	65.6	68.6	*	*
California	San Bernardino Co	2002	80.0	85.0	0.3	0.3
California	San Bernardino Co	9004	70.6	76.6	2.7	3.0
California	San Diego Co	1	60.6	65.6	11.5	12.4
California	San Diego Co	6	61.1	66.6	11.5	12.5
California	San Diego Co	1002	59.6	64.0	5.8	6.2
California	San Diego Co	1006	42.6	46.0	*	*
California	San Diego Co	1008	62.3	68.3	8.7	9.5
California	San Francisco Co	5	54.6	59.3	27.2	29.5
California	San Joaquin Co	1002	58.0	64.3	18.5	20.5
California	San Luis Obispo Co	3001	35.3	40.0	6.4	7.3
California	San Luis Obispo Co	4002	30.3	32.3	2.9	3.1
California	San Luis Obispo Co	8001	44.3	48.0	6.4	6.9
California	San Mateo Co	1001	50.0	54.0	26.2	28.3
California	Santa Barbara Co	8	31.6	34.3	5.9	6.4
California	Santa Barbara Co	1013	8.0	10.6	*	*
California	Santa Barbara Co	1014	6.6	8.3	*	*
California	Santa Barbara Co	1018	26.0	27.6	2.7	2.8
California	Santa Barbara Co	1021	19.6	26.3	*	*
California	Santa Barbara Co	1025	14.6	20.0	2.7	3.7
California	Santa Barbara Co	2004	30.0	32.6	*	*
California	Santa Barbara Co	2011	37.0	39.3	17.1	18.1
California	Santa Barbara Co	4003	8.3	11.6	*	*

State	County	Site	Concentrations (ppb			
			2005-2007		2020	
			98th	99th	98th	99th
California	Santa Clara Co	5	57.3	63.6	31.3	34.7
California	Santa Cruz Co	3	24.3	26.6	*	*
California	Solano Co	4	43.0	48.3	16.9	19.0
California	Sonoma Co	3	39.3	41.3	6.3	6.7
California	Sutter Co	3	50.1	54.0	*	*
California	Tulare Co	2002	58.6	63.0	10.3	11.1
California	Ventura Co	2002	47.6	50.6	0.9	1.0
California	Ventura Co	3001	40.6	42.6	1.3	1.3
California	Yolo Co	4	37.6	41.3	6.5	7.2
Colorado	Adams Co	3001	74.3	82.6	59.7	66.4
Connecticut	Fairfield Co	9003	56.6	59.6	3.2	3.4
Connecticut	Hartford Co	1003	51.8	57.6	12.6	14.1
Connecticut	New Haven Co	27	68.3	78.3	22.3	25.5
District of Columbia	Washington	25	56.0	58.6	24.5	25.6
District of Columbia	Washington	41	63.0	74.0	25.0	29.3
District of Columbia	Washington	43	60.6	63.0	24.0	25.0
Florida	Broward Co	8002	54.0	57.0	31.9	33.7
Florida	Escambia Co	4	33.6	36.6	18.8	20.5
Florida	Hillsborough Co	81	33.0	38.6	22.0	25.7
Florida	Hillsborough Co	1065	38.6	42.3	28.8	31.6
Florida	Hillsborough Co	3002	32.0	34.0	17.7	18.9
Florida	Manatee Co	4012	31.3	36.0	11.4	13.1
Florida	Miami-Dade Co	27	48.0	51.6	20.6	22.2
Florida	Orange Co	2002	44.3	47.3	15.8	16.9
Florida	Palm Beach Co	1004	46.0	52.3	20.5	23.4
Florida	Pinellas Co	18	39.6	41.6	19.5	20.5
Florida	Sarasota Co	1006	27.6	30.6	11.1	12.3
Georgia	Fulton Co	48	73.0	75.6	32.1	33.3
Georgia	Paulding Co	3	25.0	28.6	12.3	14.0
Georgia	Rockdale Co	1	29.6	33.0	15.4	17.2
Illinois	Cook Co	63	100.0	106.3	17.8	18.9
Illinois	Cook Co	76	63.6	67.6	11.5	12.2
Illinois	Cook Co	3103	74.6	82.3	37.9	41.8
Illinois	Cook Co	4002	68.3	74.6	16.0	17.4
Illinois	St Clair Co	10	50.3	52.6	30.6	32.0
Indiana	Hendricks Co	2	41.0	44.0	7.4	7.9
Indiana	Marion Co	73	47.6	49.6	24.2	25.2
Kansas	Sedgwick Co	10	46.5	48.3	27.4	28.5
Kansas	Sumner Co	2	27.0	30.0	14.9	16.6
Kansas	Wyandotte Co	21	57.0	59.6	27.2	28.5
Kentucky	Daviess Co	5	34.6	39.0	15.2	17.2
Kentucky	Fayette Co	12	53.0	56.0	30.4	32.1
Kentucky	Jefferson Co	1021	51.5	52.6	14.9	15.3
Kentucky	Mc Cracken Co	1024	43.5	46.0	14.7	15.6

State	County	Site	Concentrations (ppb			
			2005-2007		2020	
			98th	99th	98th	99th
Louisiana	Ascension Par	4	43.0	46.0	38.0	40.6
Louisiana	Calcasieu Par	8	39.3	44.3	35.8	40.4
Louisiana	East Baton Rouge	3	56.3	61.3	45.3	49.3
Louisiana	East Baton Rouge	9	58.0	65.3	48.5	54.6
Louisiana	East Baton Rouge	13	22.3	26.3	16.4	19.4
Louisiana	East Baton Rouge	1001	42.0	46.3	34.9	38.5
Louisiana	Iberville Par	7	27.6	31.3	23.0	26.1
Louisiana	Iberville Par	9	30.6	34.6	25.8	29.2
Louisiana	Iberville Par	12	40.3	42.3	34.8	36.5
Louisiana	Jefferson Par	1001	52.0	55.0	37.5	39.7
Louisiana	West Baton Rouge Par	1	53.0	58.6	45.5	50.3
Massachusetts	Essex Co	2006	43.3	47.6	26.8	29.4
Massachusetts	Essex Co	5005	40.6	44.3	22.4	24.5
Massachusetts	Hampden Co	8	43.3	44.6	26.3	27.1
Massachusetts	Hampden Co	16	46.6	51.6	26.5	29.4
Massachusetts	Hampshire Co	4002	32.6	36.0	17.9	19.7
Massachusetts	Suffolk Co	2	57.0	62.6	31.8	34.9
Massachusetts	Suffolk Co	42	50.3	56.3	28.1	31.4
Massachusetts	Worcester Co	23	45.0	49.6	26.1	28.8
Minnesota	Anoka Co	1002	44.0	47.6	31.4	34.0
Missouri	Clay Co	5	39.0	42.0	23.7	25.5
Missouri	Greene Co	36	52.0	54.3	29.4	30.7
Missouri	Jackson Co	34	59.6	65.0	33.9	37.0
Missouri	St Charles Co	1002	37.0	43.0	17.4	20.3
Missouri	Ste Genevieve Co	5	19.6	22.6	13.0	15.0
Missouri	St Louis Co	4	45.0	49.0	22.7	24.7
Missouri	St Louis Co	3001	49.3	52.6	24.4	26.1
Missouri	St Louis	86	62.0	63.0	40.6	41.3
New Hampshire	Hillsborough Co	20	44.3	46.0	26.2	27.2
New Hampshire	Rockingham Co	14	39.0	41.3	20.5	21.7
New Jersey	Essex Co	1003	74.0	81.6	22.5	24.8
New Jersey	Hudson Co	6	69.3	77.6	30.4	34.1
New Jersey	Mercer Co	5	48.6	52.6	15.8	17.1
New Jersey	Middlesex Co	11	55.6	62.6	21.9	24.7
New Jersey	Morris Co	3001	41.6	45.3	16.5	18.0
New Jersey	Union Co	4	80.6	90.6	37.3	42.0
New Mexico	Bernalillo Co	23	56.0	59.3	37.5	39.7
New Mexico	Bernalillo Co	24	48.0	56.3	32.1	37.7
New Mexico	Dona Ana Co	21	49.6	56.0	30.5	34.4
New Mexico	Dona Ana Co	22	44.0	48.3	25.2	27.7
New Mexico	Eddy Co	1004	30.3	33.0	28.6	31.1
New Mexico	Eddy Co	1005	22.6	25.0	20.3	22.5
New Mexico	Lea Co	8	45.3	49.0	43.9	47.5

State	County	Site	Concentrations (ppb			
			2005-2007		2020	
			98th	99th	98th	99th
New Mexico	Sandoval Co	1003	46.6	50.3	30.3	32.7
New Mexico	San Juan Co	9	42.3	44.3	40.8	42.7
New Mexico	San Juan Co	1005	47.3	50.0	42.4	44.8
New York	Erie Co	5	79.0	88.3	44.7	50.0
New York	New York Co	56	78.3	85.3	22.9	24.9
New York	Queens Co	124	68.6	74.0	23.3	25.1
New York	Suffolk Co	9	44.6	47.3	8.8	9.3
North Dakota	Burke Co	4	13.0	15.3	10.7	12.6
North Dakota	Cass Co	1004	37.3	41.3	19.1	21.1
North Dakota	Mc Kenzie Co	2	7.0	9.3	4.8	6.4
North Dakota	Mercer Co	4	21.6	24.6	16.9	19.2
North Dakota	Mercer Co	102	21.0	26.0	16.4	20.3
North Dakota	Mercer Co	124	23.0	25.6	17.8	19.8
North Dakota	Oliver Co	2	21.0	24.6	16.3	19.2
Ohio	Cuyahoga Co	60	62.0	69.0	36.3	40.4
Ohio	Cuyahoga Co	70	59.0	66.0	34.5	38.6
Ohio	Hamilton Co	40	60.3	64.3	28.5	30.3
Oklahoma	Cherokee Co	9002	38.3	40.6	22.4	23.8
Oklahoma	Oklahoma Co	33	53.3	56.6	29.4	31.3
Oklahoma	Oklahoma Co	1037	43.0	45.6	22.1	23.5
Pennsylvania	Allegheny Co	8	49.6	53.0	34.4	36.7
Pennsylvania	Allegheny Co	10	63.6	67.6	44.1	46.8
Pennsylvania	Allegheny Co	1005	46.3	53.3	30.0	34.5
Pennsylvania	Beaver Co	14	48.3	55.0	25.6	29.2
Pennsylvania	Blair Co	801	50.6	55.3	23.4	25.6
Pennsylvania	Bucks Co	12	53.6	58.6	8.3	9.1
Pennsylvania	Cambria Co	11	43.6	45.6	23.1	24.2
Pennsylvania	Centre Co	100	38.0	39.6	17.5	18.2
Pennsylvania	Dauphin Co	401	51.0	56.0	4.5	5.0
Pennsylvania	Erie Co	3	54.0	57.3	26.6	28.2
Pennsylvania	Indiana Co	4	33.0	36.3	12.1	13.3
Pennsylvania	Lackawanna Co	2006	47.3	51.3	4.4	4.8
Pennsylvania	Lancaster Co	7	46.0	49.0	8.5	9.1
Pennsylvania	Lawrence Co	15	49.0	53.0	33.5	36.2
Pennsylvania	Lehigh Co	4	47.3	51.6	9.2	10.0
Pennsylvania	Luzerne Co	1101	44.3	47.3	3.6	3.8
Pennsylvania	Montgomery Co	13	54.0	57.3	11.0	11.7
Pennsylvania	Northampton Co	25	47.3	54.6	7.1	8.2
Pennsylvania	Perry Co	301	24.0	26.6	*	*
Pennsylvania	Washington Co	5	43.0	47.3	25.0	27.5
Pennsylvania	Washington Co	5001	29.6	34.0	16.4	18.9
Pennsylvania	Westmoreland Co	8	43.0	47.6	26.3	29.1
Pennsylvania	York Co	8	57.3	61.0	4.1	4.3
South Carolina	Aiken Co	3	23.3	25.6	8.8	9.6

State	County	Site	Concentrations (ppb			
			2005-2007		2020	
			98th	99th	98th	99th
South Carolina	Greenville Co	9	43.6	46.6	20.5	21.9
South Carolina	Richland Co	7	49.6	52.6	14.2	15.1
South Dakota	Jackson Co	1	7.6	9.0	4.8	5.7
South Dakota	Minnehaha Co	7	33.0	35.6	17.8	19.2
Tennessee	Bradley Co	102	37.3	40.6	16.8	18.3
Tennessee	Davidson Co	11	55.6	58.3	19.6	20.6
Texas	Bexar Co	46	54.6	59.0	32.2	34.8
Texas	Bexar Co	52	25.0	28.0	12.3	13.7
Texas	Bexar Co	59	33.6	36.0	16.5	17.7
Texas	Brazoria Co	1016	26.3	30.0	3.9	4.4
Texas	Dallas Co	69	58.0	60.6	31.6	33.0
Texas	Dallas Co	75	45.0	47.6	23.4	24.8
Texas	Denton Co	34	38.6	41.6	19.4	20.9
Texas	El Paso Co	37	64.0	72.6	53.9	61.1
Texas	El Paso Co	44	66.6	76.0	56.1	64.0
Texas	El Paso Co	55	68.3	72.3	57.5	60.9
Texas	El Paso Co	57	58.0	67.3	38.5	44.7
Texas	El Paso Co	58	50.6	55.6	39.2	43.0
Texas	Gregg Co	1	29.3	32.0	18.9	20.7
Texas	Harris Co	26	52.0	66.0	34.5	43.8
Texas	Harris Co	29	35.6	39.6	15.2	16.9
Texas	Harris Co	47	60.3	66.0	26.7	29.3
Texas	Harris Co	75	61.8	66.6	40.1	43.2
Texas	Harris Co	1034	56.3	63.0	39.1	43.7
Texas	Harris Co	1035	58.3	62.0	40.5	43.0
Texas	Harris Co	1039	46.6	53.0	25.2	28.7
Texas	Harris Co	1050	34.0	38.0	22.1	24.7
Texas	Harrison Co	2	23.0	25.0	15.9	17.3
Texas	Hunt Co	1006	34.3	37.3	14.5	15.8
Texas	Jefferson Co	22	29.6	31.0	13.9	14.5
Texas	Kaufman Co	5	31.3	34.3	16.4	18.0
Texas	Montgomery Co	78	37.3	41.3	19.9	22.0
Texas	Smith Co	7	25.3	28.6	14.9	16.8
Texas	Tarrant Co	1002	59.6	63.0	28.6	30.3
Texas	Tarrant Co	3009	43.6	47.0	26.3	28.4
Texas	Tarrant Co	3011	46.3	49.3	23.3	24.9
Texas	Travis Co	20	28.3	34.0	12.3	14.8
Utah	Davis Co	4	65.0	71.0	36.0	39.4
Utah	Salt Lake Co	3006	63.6	70.3	53.4	59.0
Vermont	Chittenden Co	14	44.4	47.7	27.0	29.0
Vermont	Rutland Co	2	44.5	48.8	19.6	21.5
Virginia	Charles City Co	2	61.0	70.0	45.4	52.1
Virginia	Fairfax Co	1005	51.6	56.3	23.4	25.5
Virginia	Fairfax Co	5001	53.6	59.0	22.2	24.4

State	County	Site	Concentrations (ppb			
			2005-2007		2020	
			98th	99th	98th	99th
Virginia	Richmond	24	59.5	62.6	35.1	36.9
Wisconsin	Milwaukee Co	26	51.0	54.3	5.0	5.3
Wyoming	Campbell Co	123	11.6	14.3	9.3	11.5

Chapter 4: Emissions Controls Analysis – Design and Analytical Results

Synopsis

This chapter documents the illustrative emission control strategy we applied to simulate attainment with the alternative standards being analyzed for the proposed NO_2 NAAQS. Section 4.1 describes the approach we followed to select emissions controls to simulate attainment in each geographic area of analysis. Section 4.2 summarizes the emission reductions we simulated in each area based on current knowledge of identified emission controls, while Section 4.3 presents the air quality impacts of these emissions reductions. Section 4.4 discusses the application of additional controls, beyond the level of control already assumed to be in place for the analysis year[1], that we estimate will be necessary to reach attainment in certain monitor areas. Section 4.5 discusses key limitations in the approach we used to estimate the optimal control strategies for each alternative standard.

The proposal would set a new short-term NO_2 standard based on the average of the 99th percentile of 1-hour daily maximum concentrations from three consecutive years. The proposal would set the level of this new standard within the range of 80 to 100 parts per billion (ppb). The proposal also requests comment on standard levels ranging from a low of 65 ppb to a high of 125 ppb. As a lower bound, we chose an alternative primary standard of 50 parts per billion (ppb). This level captures the largest number of geographic areas that may be affected by a new NO_2 standard. Our analysis of this hypothetical scenario is meant to approximate the most comprehensive set of control strategies that areas across the country might employ to attain. (Note that we chose 50 ppb as an analytic lower bound well before decisions were made about either the proposed range, or the range for requesting public comment.)

OMB Circular A-4 requires the RIA to contain, in addition to analysis of the impacts of the proposed NAAQS, analysis of a level more stringent and a level less stringent than the proposed NAAQS. Our original intent had been to also analyze a target NAAQS level of 100 ppb as a mid-range target identified in the Risk and Exposure Assessment (REA) as an epidemiological level of concern. In addition we had intended to analyze an upper bound of 200 ppb. As it turned out, as shown in Chapter 3, our projections indicated no counties in 2020 that would have ambient 1-hour peak levels as high as the 80 to 100 ppb proposal range in 2020, assuming a baseline of no additional control beyond the controls expected from rules that are already in place (including the current $PM_{2.5}$ and ozone NAAQS). In fact, our projections indicate only one county that would have ambient 1-hour peak levels above 65 ppb

---

[1] Note that the baseline or starting point for this analysis includes rules that are already "on the books" and will take affect prior to the analysis year, as well as control strategies applied in the recent PM and O3 NAAQS RIAs.

in 2020 (Adams County, Colorado). Therefore the bulk of our analysis in this RIA focuses on the lower bound target NAAQS level of 50 ppb.

For the lower bound of 50 ppb, we analyzed the impact that additional emissions controls applied to numerous sectors would have on predicted ambient NO_2 concentrations, incremental to the baseline set of controls. Thus the modeled analysis for a revised standard focuses specifically on incremental improvements beyond the current standards, and uses control options that might be available to states for application by 2020. The hypothetical modeled control strategy 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 NO_2 standard should be implemented, and states will make all final decisions regarding implementation strategies once a final NAAQS has been set.

Generally, we expect that the nation will be able to attain a tighter NO_2 NAAQS without the addition of new controls beyond those already being planned for the attainment of existing $PM_{2.5}$ and ozone standards by the year 2020. As States develop their plans for attaining these existing standards, they are likely to consider adding controls to reduce NOx, as NOx is a precursor to both $PM_{2.5}$ and ozone. These controls will also directly help areas meet a tighter NO_2 standard.

As part of our economic analysis of the tighter NO_2 standard, our 2020 analysis baseline assumes that States will put in place the necessary control strategies to attain the current $PM_{2.5}$ and ozone standards. The cost of these control strategies was included in the RIAs for those rulemakings. We do not include the cost of those controls in this analysis, in order to prevent counting the cost of installing and operating the controls twice. Of course, the health and environmental benefits resulting from installation of those controls were attributed to attaining those standards, and are not counted again for the analysis of this NO_2 standard.

It is important to note also that this analysis does not attempt to estimate attainment or nonattainment for any areas of the country other than those counties currently served by one of the 409 monitors in the current network. Chapter 2 explains that the current network is focused on community-wide ambient levels of NO_2, and not near-roadway levels, which may be significantly higher, and the proposal also contains requirements for an NO_2 monitoring network that will include monitors near major roadways. We recognize that once a network of near-roadway monitors is put in place, more areas could find themselves exceeding the new hourly NO_2 NAAQS. However for this RIA analysis, we lack sufficient data to predict which counties might exceed the new NAAQS after implementation of a near-roadway monitoring network. Therefore we lack a credible analytic path to estimating costs and benefits for such a future scenario.

Finally, we note that because it was not possible, in this analysis, to bring all areas into attainment with the alternative standard of 50 ppb in all areas using only identified controls, EPA conducted a second step in the analysis, and estimated the cost of further tons of emission reductions needed to attain the alternative primary NAAQS. It is uncertain what controls States would put in place to attain a tighter standard, since additional abatement strategies are not currently recognized as being commercially available. We should also note that because of data and resource limitations, we are not able to adequately represent in this analysis the impacts of some local emission control programs such as the California ports initiative discussed in Chapter 3.

4.1 Developing the Identified Control Strategy Analysis

The 2020 baseline air quality estimates revealed that 10 monitors in 6 counties had projected design values exceeding 50 ppb. We then developed a hypothetical control strategy that could be adopted to bring the current highest emitting monitor in each of those six counties into attainment with a primary standard of 50 ppb by 2020. (For more information on the development of the air quality estimates for this analysis see Chapter 3.) Controls for five emissions sectors were included in the control analysis: Non-Electricity Generating Unit Point Sources (nonEGU), Non-Point Area Sources (Area), Onroad Mobile Sources (Onroad), and Nonroad Mobile Sources (Nonroad) and Electricity Generating Unit Point Sources (EGU). Each of these sectors is defined below for clarity.

- NonEGU point sources as defined in the National Emissions Inventory (NEI) are stationary sources that emit 100 tons per year or more of at least one criteria pollutant. NonEGU point sources are found across a wide variety of industries, such as chemical manufacturing, cement manufacturing, petroleum refineries, and iron and steel mills.
- Area Sources[2] 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.

---

[2] Areas Sources include the nonpoint emissions sector only.

- Onroad Mobile Sources are mobile sources that travel on roadways. These sources include automobiles, buses, trucks, and motorcycles traveling on roads and highways.
- Nonroad Mobile Sources[3] are any combustion 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 are stationary sources of 25 megawatts (MW) capacity or greater producing and selling electricity to the grid, such as fossil-fuel-fired boilers and combustion turbines.

The air quality impact of the needed emissions reductions were calculated using impact ratios as discussed further in Chapter 3 (section 3.2.1). The results of analyzing the control strategy indicate that there were two areas projected not to attain 50 ppb in 2020 using all known control measures. To complete the analysis, 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 Section 4.4.

4.1.1 Specific Monitor Area Analysis

Due to the limited number of geographic areas analyzed in this analysis EPA was able to take a closer look at each county to determine, given the 2020 projections, what the contributing sources of NOx emissions were for each violating monitor. Below are the results of this screening-level analysis of monitors, emissions, and high traffic roadways.

- For Los Angeles County, CA the violating monitor appeared to be located within 500 meters of a major highway, but also within the county are a major port, the Port of Long Beach and airport, Long Beach Airport. Point source emissions within this county were small. (For a more complete discussion of air quality in this county see Chapter 3). Los Angeles County was forecasted to be heavily controlled for the compliance with the new ozone standard in the Ozone NAAQS RIA and because this analysis is incremental, this left no additional identified control measures to be applied. (In reality, the Port of Long Beach, which is one of the largest ports in the US, is currently undertaking its own significant action to reduce both NOx and PM emissions from ships, trucks, trains, and cargo-handling equipment.[4] The port

---

[3] For the purposes of presentation nonroad mobile sources incorporates both the nonroad emissions sector and the aircraft, locomotive, and marine vessels emissions sector.
[4] See http://www.polb.com/environment/air.quality/default.asp

estimated its emissions of NOx from these sources to be 48 tons per day (about 17,000 tons per year), for the period from 2002 to 2005. In part because we do not have emission reduction estimates for this planned significant emission reduction activity at the port in our analysis, emission reductions beyond identified controls were needed for this area to reach attainment with a 50 ppb standard. In addition, it should be noted that the California Air Resources (CARB) included a number of control measures to reduce emissions at the Port of Los Angeles and the Port of Long Beach in its 2007 state implementation plan (SIP) that addresses the 8-hour ozone and PM2.5 nonattainment problems in the South Coast nonattainment area. These control measures are expected to result in significant NOx emission reductions, but are not reflected in this analysis due to data and resource limitations. See the discussion in Chapter 3 for more details on local control programs underway in southern California.

- The Adams County, CO violating monitor did not appear to be located within 500 meters of major roadways, yet there were a few nonEGU point sources and a large EGU source within the county that had relatively high emissions values. EPA determined the least cost solution for this county was to apply controls to the EGU sources within 30 km of the violating monitor. These controls were projected to reach attainment with a 50 ppb standard for Adams County.
- The East Baton Rouge Parish, LA violating monitor was located in the downtown area and was within 500m of a major highway, yet there were also many nonEGU point sources within this county. The emission reductions were achieved through nonEGU point source controls applied within 20 km of the violating monitor. These controls were projected to reach attainment with a 50 ppb standard for East Baton Rouge Parish.
- The El Paso County, TX highest violating monitor was located within 50 meters of two major roadways and within 500 meters of a third major roadway. Yet due to the severity of the nonattainment problem for this county all emission sectors needed to be examined for control. Controls were applied to nonEGU point sources, area, onroad, and nonroad mobile sources. EGU controls were investigated but no controls were available to be applied for this county. Even after applying all available identified control measures, we were not able to demonstrate attainment for El Paso County.[5] Emission reductions beyond identified controls were needed for

---

[5] Section 3.4.2.3 points out that the El Paso monitors are very close to the international border, with the city of Juarez just to the southwest. Emissions from across the international border, which are not controlled in the inventories, could affect the modeled concentrations of the grid cells containing the monitors. In the past, state implementation plan (SIP) policy has allowed for a waiver of full attainment in similar instances.

this area to reach attainment of the 50 ppb standard being analyzed. For additional information on the air quality projections for the county see Chapter 3.

- The Salt Lake County, UT monitor appears to be located in a neighborhood, not close to major roads. Due to the large quantity of emission reductions needed to be controlled for this county, onroad mobile controls as well as EGU and nonEGU point source controls were applied. Additionally, it appears that the high NO_2 values occur concurrently with seasonal particulate matter inversions. This mix of applied controls was projected to reach attainment with a 50 ppb standard for Salt Lake County.
- Charles City County, VA's violating monitor appears to be located in a field, not near major roadways. The closest emissions are from nonEGU point sources. Due to the small quantity of emission reductions needed for this county, control was applied to one of the closest uncontrolled emission points to the violating monitor. This control was projected to reach attainment with a 50 ppb standard for Charles City County.

4.1.2 Controls Applied for the NonEGU Point and Area Sectors

NonEGU point and Area control measures were identified using AirControlNET 4.2.[6,7] as well as the Control Strategy Tool[8] (CoST). AircontrolNET has been used for developing control strategies as part of the PM NAAQS, Ozone NAAQS, and Lead NAAQS RIAs. To reduce nonEGU point NOx emissions least cost control measures were identified for emission sources within 30 km of the violating monitor (see Chapter 3 for rationale). Area source emissions data are generated at the county level, and therefore controls for this emission sector were applied to the county containing the violating monitor. The NOx emission control measures used in this analysis are identical to those used in the recent Ozone NAAQS RIA. NOx emission controls used here are described in the AirControlNET documentation report[6].

---

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

[7] 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. See http://www.epa.gov/particles/measures/pm_control_measures_tables_ver1.pdf for more details on this control measures database. In addition, the control measure data within AirControlNET has been used by various States and 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 Association 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.

[8] See http://www.epa.gov/ttn/ecas/cost.htm for a description of CoST.

4.1.3 Controls Applied for EGU Sector

EGU controls were applied to two counties in our analysis: Salt Lake County, UT and Adams County, CO. EGU control measures applied in this analysis are those used in the Ozone RIA where appropriate. This analysis focuses on coal-fired EGUs, and the applied controls are two: a) SNCR (selective non-catalytic reduction), which is applicable to coal-fired EGUs with unit capacities between 25 MW and 100 MW, and b) SCR (selective catalytic reduction), which is applicable to coal-fired EGUs with unit capacities above 100 MW. SNCR is expected to achieve 35 percent reduction of NOx, and SCR is expected to achieve 90 percent NOx reduction for coal-fired EGUs. More information on these measures can be found in Chapter 3 of the final ozone NAAQS RIA[11] and in the documentation for the Integrated Planning Model[9] (IPM) used by EPA for analyzing the impacts of emission control strategies on EGUs.

4.1.4 Controls Applied for the Onroad and Nonroad Mobile Sectors

Onroad and Nonroad Mobile source control measures used in the recent Ozone RIA were used in this RIA, where appropriate. If mobile source control measures were cost effective for the geographic area being analyzed, compared to other control options, and if they were not already in place in the specific geographic area or had not been applied in the area as part of EPA's analysis for the recent Ozone or PM NAAQS[10] revision, then these controls were applied. Mobile source control measures that were considered for this analysis are:

- Diesel Retrofits (Onroad)
- Diesel Retrofits and Engine Rebuilds (Nonroad)
- Elimination of Long Duration Idling (Onroad)
- Continuous Inspection and Maintenance (Onroad)
- Commuter Programs (Onroad)

Information describing these measures and the effectiveness of each measure is contained in Chapter 3 of the document "Final Ozone NAAQS Regulatory Impact Analysis"[11]. Mobile source emissions data is generated at the county level, and therefore controls for this emission sector were applied to the county containing the violating monitor. Because these mobile source control measures did not result in sufficient emission reductions for several of the geographic areas of analysis, and because few cost-effective stationary source measures

---

[9] http://www.epa.gov/airmarkt/progsregs/epa-ipm/index.html

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

[11] http://www.epa.gov/ttn/ecas/regdata/RIAs/452_R_08_003.pdf

were available that resulted in the necessary emission reductions for most of the areas, mobile source measures were employed only in Salt Lake County and El Paso.

4.1.5 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.

4.2 NOx Emission Reductions Achieved with Identified Controls Analysis

We identified illustrative control strategies that might be employed to reduce emissions to bring air quality into compliance with the alternative standard being analyzed. As part of this exercise, we considered the cost-effectiveness of various control options and selected the lowest cost controls, based on available cost information. Applying identified control options, we were able to illustrate attainment for most, but not all of the areas.[12] Table 4.1 presents the NOx emissions reductions realized in each geographic area under the control strategies followed for the alternative standard of 50 ppb. Figure 4.1 presents the percentage of emission reductions by sector. As the figure reveals, a majority of the emission reductions were achieved through point source emission controls. The mobile controls applied for the identified controls analysis yielded co-control for $PM_{2.5}$, SO_2, and VOC. In addition, NOx emission reductions for the additional counties in the Salt Lake metropolitan area are included as co-control since they are not included in the calculations of emission reductions credited towards attainment for Salt Lake County. Table 4.2 presents the co-impacts of emission reductions of the NOx mobile control measures applied.

---

[12] As will be discussed below, the application of identified controls was insufficient to bring all monitor areas into compliance with the selected standard and the alternative standards.

Table 4.1: Emission Reductions by County in 2020 for Alternative Standard 50 ppb[a]

State	County	NOx Emission Reductions in 2020 (tons/year)
CA	Los Angeles	0[*]
CO	Adams	8,400
LA	East Baton Rouge	5,300
TX	El Paso	4,400[*]
UT	Salt Lake	2,600
VA	Charles City	47

[a] All estimates rounded to two significant figures.

[*] Indicates a county that does not reach attainment of the alternative standard using identified controls.

Figure 4.1: Percentage of Emission Reductions by Sector in 2020

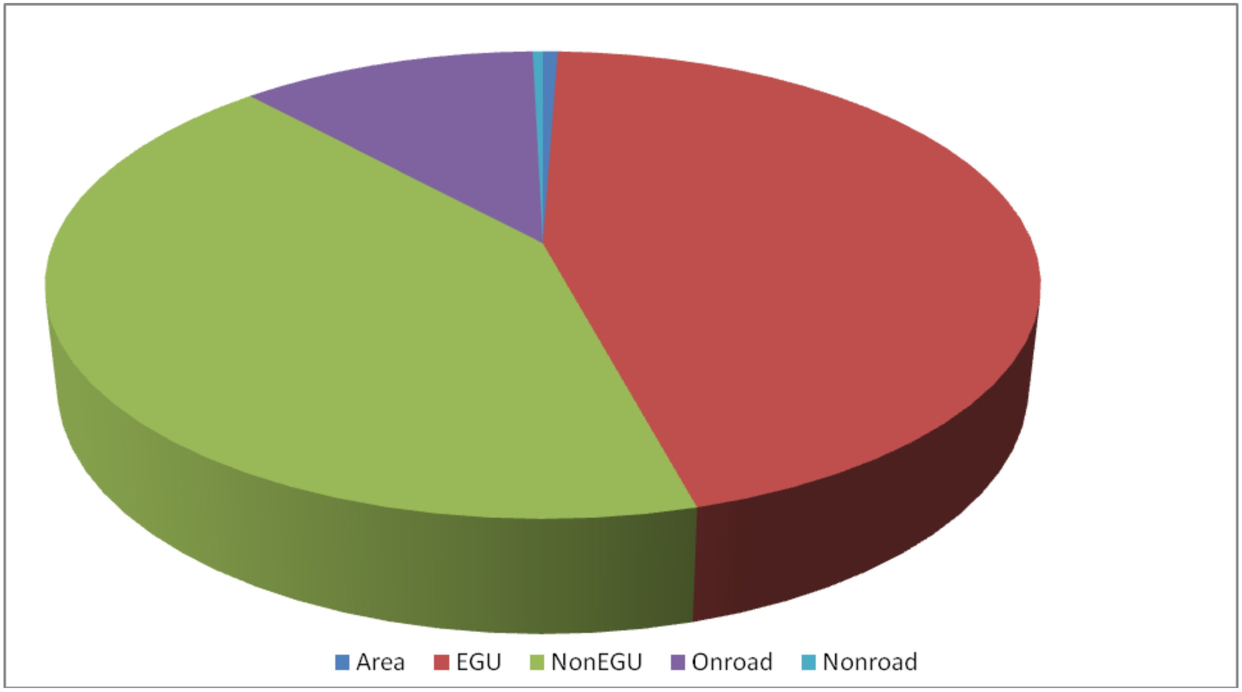


Table 4.2: Co-Impact Emission Reductions[a]

State	Geographic Area	Emission Reductions in 2020 (tons/year)			
		NOx	$PM_{2.5}$	SO_2	VOC
TX	El Paso County	0	25	1	210
UT	Salt Lake Area[b]	480	11	0	1,200

[a] All estimates are rounded to two significant figures.

[b] For the purposes of co-impact emission reductions the Salt Lake Area is made up of three counties, Davis, Salt Lake, and Weber counties. For the purposes of NOx co-impacts only Davis and Weber counties are represented.

4.3 Impacts Using Identified Controls

We estimated the overall change in ambient air quality achieved as a result of each of the control strategies identified above using an impact ratio of emission reductions to air quality improvement. Table 4.3 presents a detailed breakdown of the estimated ambient NO_2 concentrations in 2020 at each of the 6 counties under the alternative standard of 50 ppb.

According to the data presented in Table 4.3, four of the six monitor areas are expected to reach attainment with the alternative standard of 50 ppb following implementation of the identified control strategy. For some areas, identified controls are not sufficient to reach attainment with the alternative standard.

For the areas projected to violate the NAAQS with the application of identified controls, we assume that emission reductions beyond identified controls will be applied, as discussed further below.

Table 4.3: 2020 NO_2 Concentrations Achieved with Identified Controls for the Alternative Standard of 50 ppb

State	County	2020 NO_2 Concentration (ppb)
CA	Los Angeles	52.5*
CO	Adams	48.0
LA	East Baton Rouge	50.2
TX	El Paso	59.7*
UT	Salt Lake	50.3
VA	Charles City	48.0

[*] Indicates a county that does not reach attainment of the alternative standard using identified controls.

4.4 Emission Reductions Needed Beyond Identified Controls

As shown through the identified control strategy analysis, there were not enough identified controls to achieve attainment with a 50 ppb alternative standard in 2020. Therefore additional emission reductions will be needed for these areas to attain a 50 ppb alternative standard. Table 4.4 shows the emission reductions needed for Los Angeles and El Paso counties to attain the alternative standard being analyzed. Table 4.5 presents the ambient concentrations in 2020 after the application of identified controls and emission reductions needed beyond identified controls. Lastly, Figure 4.2 presents the portion of emission reductions that are achieved through identified controls and emission reductions needed beyond identified controls. Chapter 6 presents the discussion of extrapolated costs associated with the emission reductions needed beyond identified controls.

Table 4.4: 2020 Emission Reductions Needed Post Identified Controls Analysis[a]

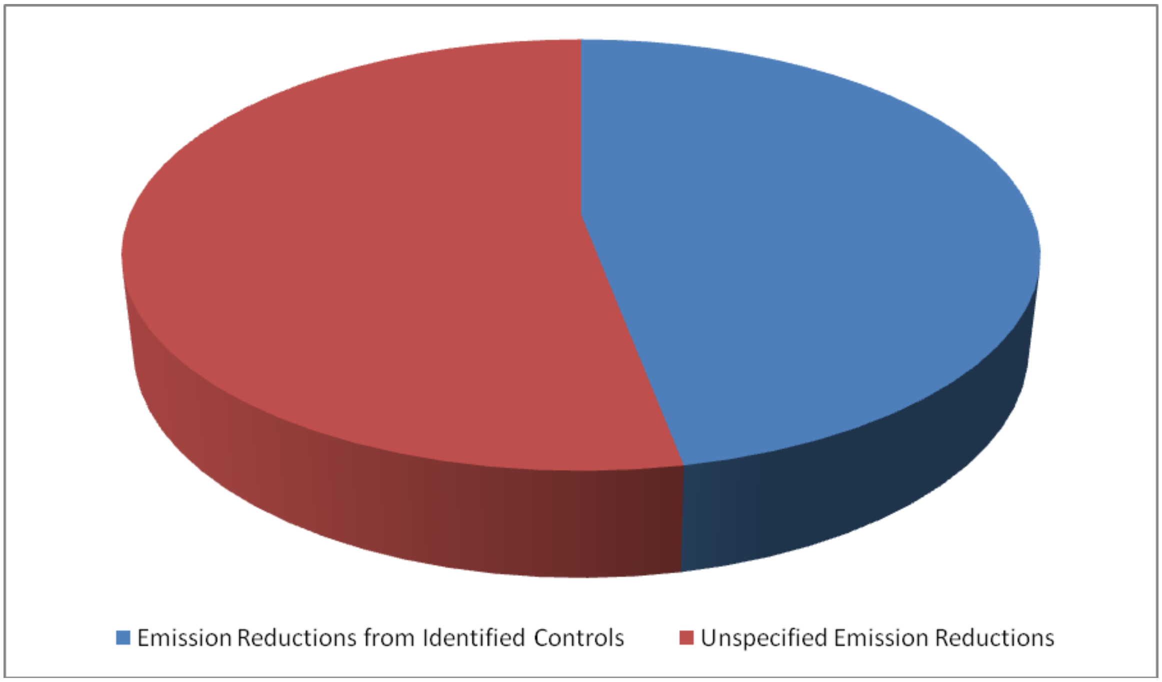
State	County	NOx Emission Reductions Needed in 2020 (tons/year)
CA	Los Angeles	18,000
TX	El Paso	5,600

[a] All estimates rounded to two significant figures.

Table 4.5: 2020 Ambient NO_2 Concentrations Achieved with Identified & Unidentified Controls for the Alternative Standard of 0.050 ppb

State	County	Ambient NO_2 Concentration (ppb)
CA	Los Angeles	50.4
CO	Adams	48.0
LA	East Baton Rouge	50.2
TX	El Paso	50.4
UT	Salt Lake	50.3
VA	Charles City	48.0

Figure 4.2: Portion of Emission Reductions Achieved Through Application of Identified Controls and Emission Reductions from Unidentified Controls



4.5 Key Limitations

The estimates of emission reductions associated with the control strategies described above are subject to important limitations and uncertainties. We summarize these limitations as follows:

- *Actual State Implementation Plans May Differ from our Simulation*: In order to reach attainment with the proposed NAAQS, each state will develop its own implementation plan implementing a combination of emissions controls that may differ from those simulated in this analysis. This analysis therefore represents an approximation of the emissions reductions that would be required to reach attainment and should not be treated as a precise estimate.

- *Current PM2.5 and Ozone Controls in Baseline*: Our 2020 analysis year baseline assumes that States will put in place the necessary control strategies to attain the current $PM_{2.5}$ and ozone standards. Some of the control strategies assumed to be employed in the ozone RIA, in particular, were of necessity highly uncertain. As States develop their plans for attaining these standards, their NOx control strategies may differ significantly from our analysis.

- *Use of Existing CMAQ Model Runs*: This analysis represents a screening level analysis. We did not conduct new regional scale modeling specifically targets to NO_2; instead we relied upon impact ratios developed from model runs used in the analysis underlying the ozone NAAQS.

- *Analysis Year of 2020*: Data limitations necessitated the choice of an analysis year of 2020, as opposed to the presumptive implementation year of 2017. Emission inventory projections are available for 5-year increments; i.e. we have inventories for 2015 and 2020, but not 2017. In addition, the CMAQ model runs upon which we relied were also based on an analysis year of 2020.

- *Unidentified controls*: We have limited information on available controls for some of the monitor areas included in this analysis. For example, a full set of identified controls were applied to Los Angeles County in the Ozone NAAQS RIA; because this analysis is incremental, this left no additional identified control measures to be applied, particularly because we do not have emission reduction estimates for the Port of Long Beach in our analysis (as discussed above).

Appendix 4a. Description of Mobile Source Control Measures

4a.1 Diesel Retrofits and Engine Rebuilds

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 4a.1 and Table 4a.2, respectively. The groupings of model years for highway vehicles reflect changes in EPA's published emissions standards for new engines.

Table 4a.1: 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 4a.2: 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 4a.3 and Table 4a.4, respectively.

Table 4a.3: Percentage Emissions Reduction by Highway Vehicle Retrofit Strategy

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

Table 4a.4: 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.12 and 3a.13 to the specified model years in Tables 3a.10 and 3a.11 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.

4a.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.

Source Categories Affected by Measure:

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

4a.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: NO_x

Table 4a.5: 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

4a.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.[1] 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.

---

[1] 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.

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

Table 4a.6: 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%

Chapter 5: Benefits Analysis Approach and Results

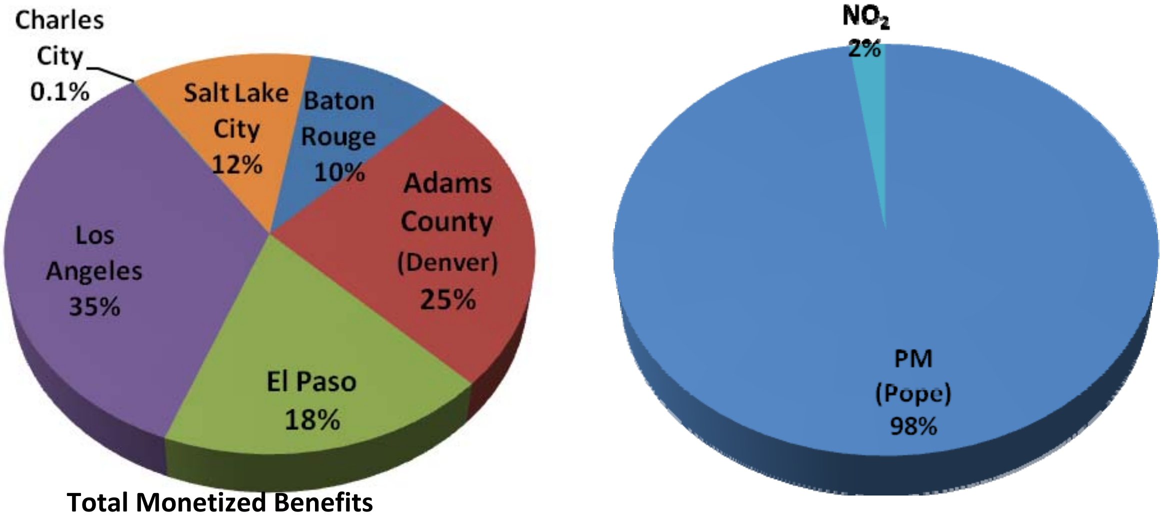
Synopsis

EPA estimates the monetized human health benefits of reducing cases of morbidity and premature mortality among populations exposed to NO_2 and $PM_{2.5}$ to be $270 to $660 million (2006$, 3% discount rate) in 2020 for the 50 ppb alternative standard. At a 7% discount rate, the monetized benefits would be $250 to $600 million (2006$). These estimates reflect EPA's most current interpretation of the scientific literature on $PM_{2.5}$ and mortality, including our updated benefits methodology (i.e., a no-threshold model that calculates incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels and incorporates two technical updates) compared to the estimates in previous RIAs that did not include these changes.[1] These benefits are incremental to an air quality baseline that reflects attainment with the 2008 ozone and 2006 $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS). We expect the benefits of attaining alternative standards of 100 ppb and 200 ppb to be zero because we believe that all areas of the country with NO_2 monitors would attain these alternative standards with emission controls planned for the ozone and $PM_{2.5}$ NAAQS. Therefore, the remainder of this analysis focuses on the benefits of attaining a standard of 50 ppb. More than 97% of the total dollar benefits are attributable to reductions in $PM_{2.5}$ exposure resulting from NOx emission controls (see Figure 5.1). The NO_2 and $PM_{2.5}$ co-benefits occur in six geographic areas, each projected to not attain an alternative standard of 50 ppb, with the majority of the estimated benefits in the densely populated areas of Los Angeles and Adams County (Denver) (see Figure 5.1 and 5.3). Higher or lower estimates of benefits are possible using other assumptions (see Figure 5.2). Methodological limitations prevented EPA from monetizing the benefits from several important benefit categories, including health co-benefits from ozone exposure, ecosystem effects from nitrogen deposition, or improvements in visibility. Other benefits from reduced NO_2 exposure have not been quantified, including reductions in premature mortality.

---

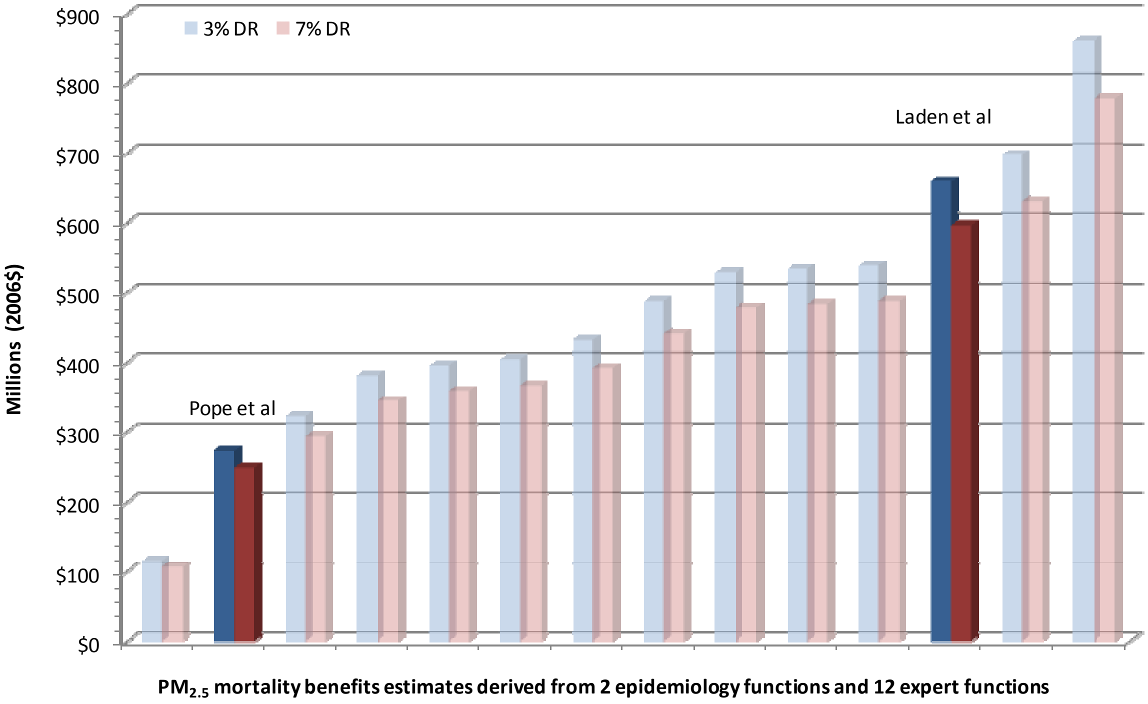
[1] Using the previous methodology (i.e., a threshold model at 10 $\mu g/m^3$ without two technical updates), EPA estimates the total monetized benefits of attaining a 50 ppb standard to be $210 million to $450 million (2006$) in 2020.

Figure 5.1: Breakdown of Monetized Benefits of Attaining 50 ppb by Geographic Area and Pollutant



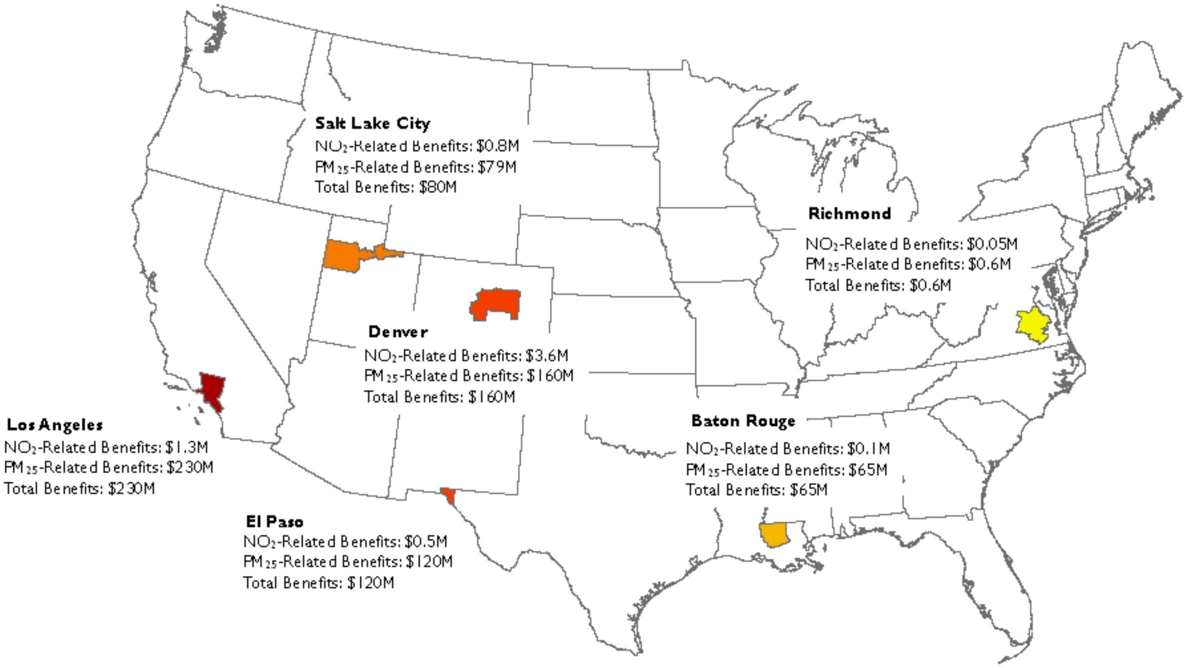
Total Monetized Benefits
3% Discount: $270m to $660m
7% Discount: $250m to $600m

Figure 5.2: Total Monetized Benefits (NO_2 and $PM_{2.5}$) of Attaining 50ppb



*This graph shows the estimated total monetized benefits in 2020 using the no-threshold model at discount rates of 3% and 7% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

Figure 5.3: Monetized Benefits by Projected Non-Attainment Area in 2020*



* $PM_{2.5}$ co-benefits calculated using Laden et al. (2006) and discounted at 3%. Relative comparisons between areas would be similar if shown using estimates using Pope et al. (2002) or a 7% discount rate.

5.1 Introduction

This chapter documents our analysis of health benefits expected to result from achieving alternative levels of the NO_2 NAAQS in 2020, relative to baseline ambient concentrations that represent attainment with the ozone and $PM_{2.5}$ NAAQS. We first describe our approach for estimating and monetizing the health benefits associated with reductions of NO_2. Next, we provide a summary of our results, including an analysis of the sensitivity of several assumptions in our model. We then estimate the $PM_{2.5}$ co-benefits from controlling NO_2 emissions. Finally, we discuss the key results of the benefits analysis and indicate limitations and areas of uncertainty in our approach.

5.2 Primary Benefits Approach

This section presents our approach for estimating avoided adverse health effects due to NO_2 exposure in humans resulting from achieving alternative levels of the NO_2 NAAQS, relative to a baseline concentration of ambient NO_2. First, we summarize the scientific evidence concerning potential health effects of NO_2 exposure, and then we present the health endpoints we selected for our primary benefits estimate. Next, we describe our benefits model, including the key input data and assumptions. Finally, we describe our approach for assigning an economic value to the NO_2 health benefits. The approach for estimating the benefits associated with exposure to PM is described in section 5.7 below.

5.2.1 Benefits Scenario

We estimated the economic benefits from annual avoided health effects expected to result from achieving alternative levels of the NO_2 NAAQS (the "control scenarios") in the year 2020. We estimated benefits in the control scenarios relative to the incidence of health effects consistent with the ambient NO_2 concentration expected in 2020 (the "baseline"). Note that this "baseline" reflects emissions reductions and ambient air quality improvements that we anticipate will result from implementation of other air quality rules, including compliance with all relevant rules up to the recently revised NAAQS for ozone in March 2008 (U.S. EPA, 2008a).

We compare benefits across three alternative NO_2 NAAQS levels: 50 ppb, 100 ppb, and 200 ppb (99th percentile). Because the air quality estimates indicated that all currently monitored areas would be in attainment with the 100 ppb and 200 ppb alternative standards in 2020, we did not analyze the benefits of those alternative standards. The benefits of those alternative standards would be zero. The following analysis reflects the benefits of attaining a 50 ppb (99th percentile) alternative standard.

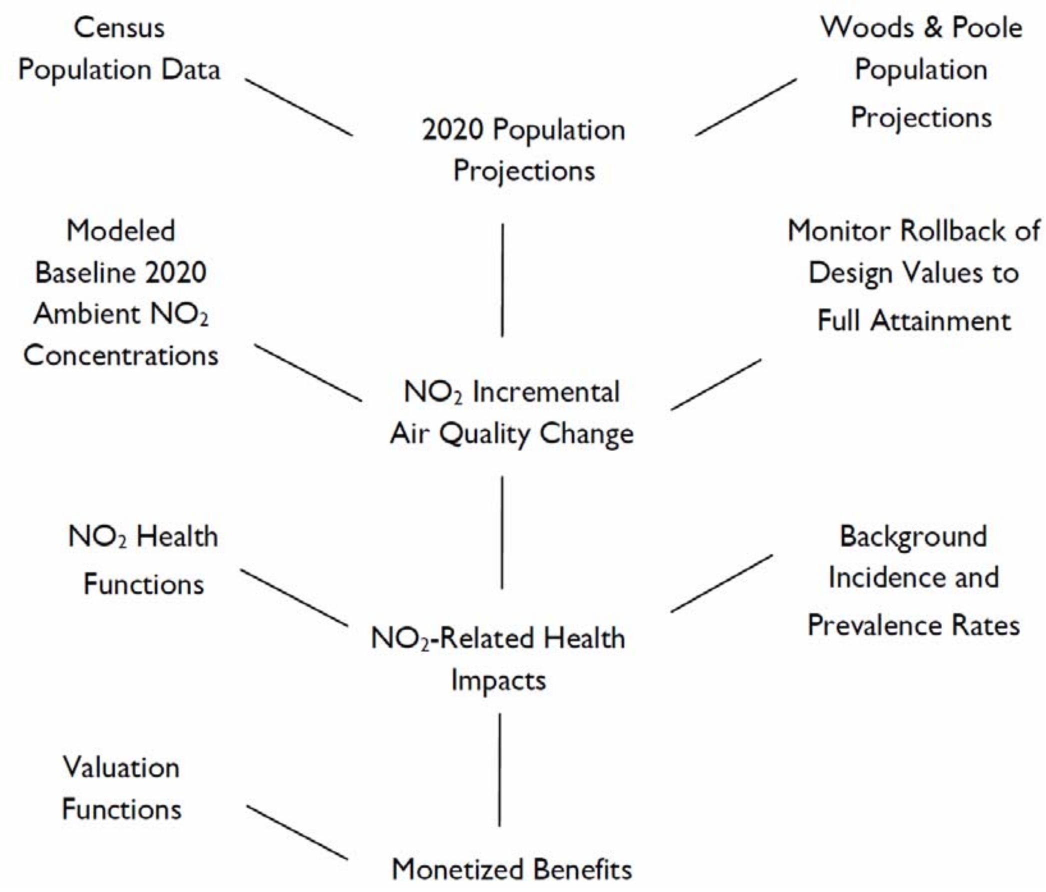
Consistent with EPA's approach for RIA benefits assessments, we estimate the health effects associated with an incremental difference in ambient concentrations between a baseline scenario and a pollution control strategy. As indicated in Chapter 4, two areas of the country may not be able to attain the 50 ppb alternative standard using known pollution control methods. For this reason, we provide an estimate of the benefits associated with partially attaining the standard using known controls adjacent to the full attainment results in Table 5.10. In addition, we test the sensitivity of the attainment status for El Paso and Los Angeles in Tables 5.12 and 5.13. Because these two geographic areas require large emission reductions to attain the 50 ppb standard compared to the other projected non-attainment areas, the results are very sensitive to their assumed attainment status. All of the other results tables in this chapter assume full attainment with the 50 ppb alternative standard.

5.3 Overview of analytical framework for benefits analysis

5.3.1 Benefits Model

For the primary benefits analysis, we use the Environmental Benefits Mapping and Analysis Program (BenMAP) to estimate the health benefits occurring as a result of implementing alternative NO_2 NAAQS levels. Although BenMAP has been used extensively in previous RIAs to estimate the health benefits of reducing exposure to $PM_{2.5}$ and ozone, this is the first RIA to use BenMAP to estimate the health benefits of reducing exposure to NO_2. Figure 5.4 below shows the major components of and inputs to the BenMAP model.

Figure 5.4: Diagram of Inputs to BenMAP model for NO_2 Analysis



5.3.2 Air Quality Estimates

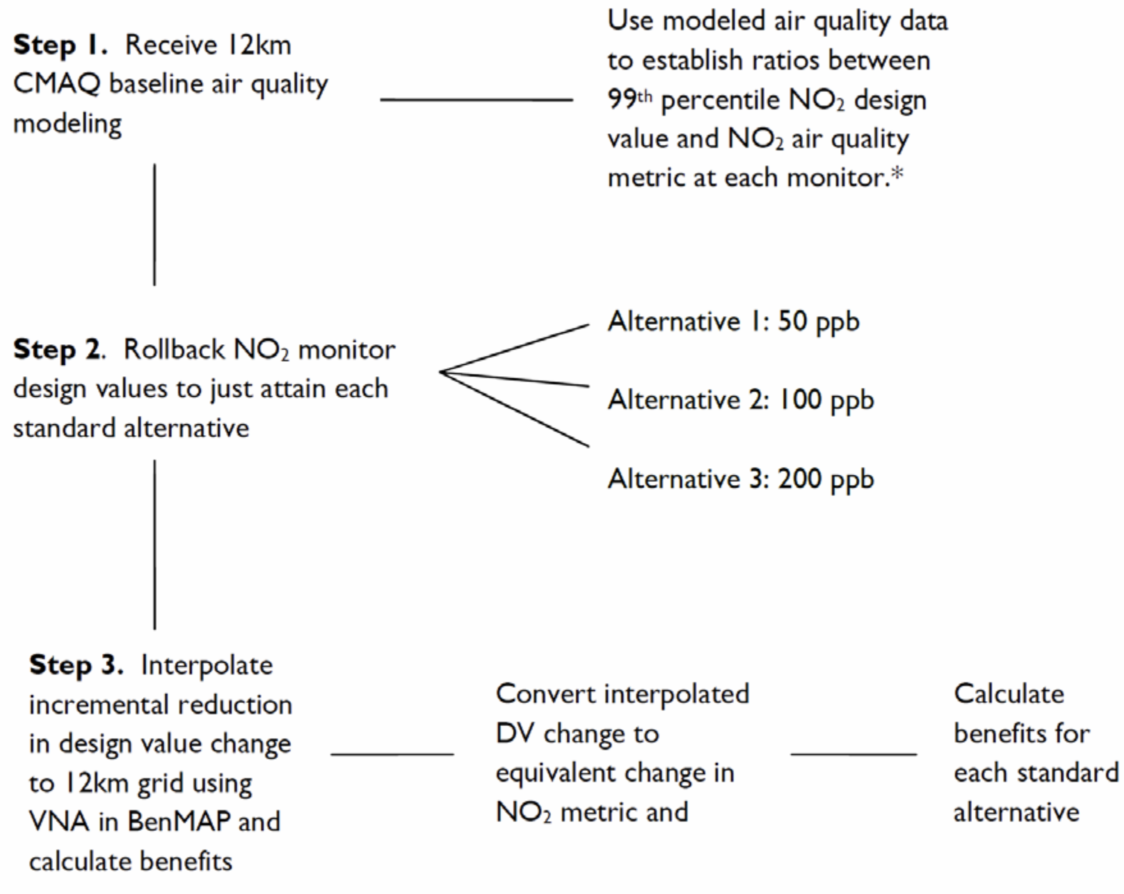
As Figure 5.4 shows, the primary input to any benefits assessment is the estimated changes in ambient air quality expected to result from a simulated control strategy or attainment of a particular standard. EPA typically relies upon air quality modeling to generate these data, but time and technical limitations described in Chapter 3 prevented us from generating new air quality modeling specifically for this analysis. Instead, we utilize the ambient NO_2 concentrations modeled by CMAQ as part of the Ozone RIA as our baseline. This air quality data has a 12km grid resolution and assumes the control strategy for a target ozone concentration of 0.070 ppm in 2020.[2]

The CMAQ air quality model provides projects both design values at NO_2 monitors and air quality concentrations at 12km grid cells. To estimate the benefits of fully attaining the standards in all areas, EPA employed the "monitor rollback" approach to approximate the air quality change resulting from just attaining alternative NO_2 NAAQS at each design value monitor. Figure 5.5 depicts the rollback process, which differs from the technique described in chapter 3. The emission control strategy estimated the level of emission reductions necessary to attain an alternate NAAQS. The approach described here aims to estimate the change in population exposure associated with attaining an alternate NAAQS. This approach relies on data from the existing NO_2 monitoring network and the inverse distance squared variant of the Veronoi Neighborhood Averaging (VNA) interpolation method to adjust the CMAQ-modeled NO_2 concentrations such that each area just attains the 50 ppb standard alternative. We believe that the interpolation method using inverse distance squared most appropriately reflects the steep exposure gradient for NO_2 around each monitor (see: EPA, 2008f). We test the sensitivity of alternate VNA interpolation methods in Table 5.12. This analysis shows that the results are not very sensitive to the interpolation method.

---

[2] See Chapter 3 for more detail regarding the air quality data used in this analysis.

Figure 5.5: Diagram of Rollback Method



*Metrics used in the epidemiology studies include the 24hr mean, 8hr max, and 1hr max.

Because the VNA rollback approach interpolates monitor values, it is most reliable in areas with a denser monitoring network. In areas with a sparser monitoring network, there is less observed monitoring data to support the VNA interpolation and we have less confidence in the predicted air quality values further away from the monitors. For this reason, we interpolated air quality values—and estimated health impacts—within the CMAQ grid cells that are located within30 km of the monitor, assuming that emission changes within this radius would affect the NO_2 concentration at each monitor. Limiting the interpolation to this radius attempts to account for the limitations of the VNA approach, the air quality data limitations identified in Chapter 3 and ensures that the benefits and costs analyses consider a consistent geographic area.[3] Therefore, the primary benefits analysis assesses health impacts occurring to populations living in the CMAQ grid cells located within the 30km buffer for the specific geographic areas assumed to not attain the alternate standard levels. We test the sensitivity of this assumption relative to other exposure buffers in Table 5.12.

---

[3] Please see Chapter 3 for more information regarding the technical basis for the 30 km assumption.

5.4 Estimating Avoided Health Effects from NO_2 Exposure

5.4.1 Selection of Health Endpoints for NO_2

Epidemiological researchers have associated NO_2 exposure with adverse health effects in numerous toxicological, clinical and epidemiological studies, as described in the Integrated Science Assessment for Oxides of Nitrogen - Health Criteria (Final Report) (U.S. EPA, 2008c; hereafter, "NO_2 ISA"). The NO_2 ISA provides a comprehensive review of the current evidence of health and environmental effects of NO_2. The Risk and Exposure Assessment for NO_2 summarizes the NO_2 ISA conclusions regarding health effects from NO_2 exposure as follows (U.S. EPA, 2008f; Section 4.2.1):

> "The ISA concludes that, taken together, recent studies provide scientific evidence that is sufficient to infer a likely causal relationship between short-term NO_2 exposure and adverse effects on the respiratory system (ISA, section 5.3.2.1). This finding is supported by the large body of recent epidemiologic evidence as well as findings from human and animal experimental studies. These epidemiologic and experimental studies encompass a number of endpoints including [Emergency Department (ED)] visits and hospitalizations, respiratory symptoms, airway hyperresponsiveness, airway inflammation, and lung function. Effect estimates from epidemiologic studies conducted in the United States and Canada generally indicate a 2-20% increase in risks for ED visits and hospital admissions and higher risks for respiratory symptoms (ISA, section 5.4)."

Previous reviews of the NO_2 primary NAAQS, completed in 1985 and 1996, did not include a quantitative benefits assessment for NO_2 exposure. As the first health benefits assessment for NO_2 exposure, we build on the methodology and lessons learned from the NO_2 risk and exposure assessment (U.S. EPA, 2008f) and the benefits assessments for the recent $PM_{2.5}$ and O_3 NAAQS (U.S. EPA, 2006a; U.S. EPA, 2008a).

We selected the health endpoints to be consistent with the conclusions of the NO_2 ISA. In general, we follow a weight of evidence approach, based on the biological plausibility of effects, availability of concentration-response functions from well conducted peer-reviewed epidemiological studies, cohesiveness of results across studies, and a focus on endpoints reflecting public health impacts (like hospital admissions) rather than physiological responses (such as changes in clinical measures like Forced Expiratory Volume (FEV1)). The differing evidence and associated strength of the evidence for these different effects is described in detail in the NO_2 ISA.

Although a number of adverse health effects have been found to be associated with NO_2 exposure, this benefits analysis only includes a subset due to limitations in understanding and quantifying the dose-response relationship for some of these health endpoints. In this analysis, we only estimated the benefits for those endpoints with sufficient evidence to support a quantified concentration-response relationship using the information presented in the NO_2 ISA, which contains an extensive literature review for several health endpoints related to NO_2 exposure. Because the ISA only included studies published or accepted for publication through December 2007, we also performed supplemental literature searches in the online search engine PubMed® to identify relevant studies published between January 2008, and the present.[4] Based on our review of this information, we quantified three short-term morbidity endpoints that the NO_2 ISA identified as "sufficient to infer a likely causal relationship": asthma exacerbation, respiratory-related emergency department visits, and respiratory-related hospitalizations.

Table 5.1 presents the health effects related to NO_2 exposure quantified in this benefits analysis. In addition, the table includes other endpoints potentially linked to NO_2 exposure, but which we are not yet ready to quantify with dose-response functions. For a list of the health effects related to $PM_{2.5}$ exposure that we quantify in this analysis, please see Table 5.6 in section 5.7. Even though NO_x is a precursor to ozone, we are unable to quantify the health effects related to ozone co-benefits in this analysis because we lack the necessary air quality data.

The NO_2 ISA concluded that the relationship between short-term NO_2 exposure and premature mortality was "suggestive but not sufficient to infer a causal relationship" because it is difficult to attribute the mortality risk effects to NO_2 alone. Therefore, we decided not to quantify premature mortality from NO_2 exposure in this analysis despite evidence suggesting a positive association (U.S. EPA, 2008c, Section 3.3.2). Although the NO_2 ISA stated that studies consistently reported a relationship between NO_2 exposure and mortality, the effect was generally smaller than that for other pollutants such as PM. We may revisit this decision in future benefits assessment for NO_2.

As noted in Table 5.1, we are not quantifying the ecosystem benefits of reducing nitrogen deposition in this analysis. Nitrogen deposition contributes to acidification of aquatic and terrestrial ecosystems, as well as terrestrial N-nutrient enrichment and eutrophication (U.S. EPA, 2008g). Instead, the ecosystem benefits of reducing NO_2 emissions will be assessed in the

---

[4] The O'Conner et al. study (2008) is the only study included in this analysis that was published after the cut-off date for inclusion in the NO_2 ISA.

RIA for the NOx SOx secondary NAAQS. In addition, we are not quantifying the economic value of changes in visibility because we are limited by the available air quality data for this analysis.

Table 5.1: Human Health and Welfare Effects of NO_2

Pollutant / Effect	Quantified and Monetized in Primary Estimates [a]	Unquantified Effects [b, c] Changes in:
NO_2/Health	Asthma Hospital Admissions Chronic Lung Disease Hospital Admissions Asthma ER visits Asthma exacerbation Acute Respiratory symptoms	Premature mortality Pulmonary function Other respiratory emergency department visits Other respiratory hospital admissions
NO_2/Welfare		Visibility Commercial fishing and forestry from acidic deposition Recreation in terrestrial and aquatic ecosystems from acid deposition Commercial fishing, agriculture, and forestry from nutrient deposition Recreation in terrestrial and estuarine ecosystems from nutrient deposition Other ecosystem services and existence values for currently healthy ecosystems

[a] Primary quantified and monetized effects are those included when determining the primary estimate of total monetized benefits of the alternative standards.
[b] The categorization of unquantified toxic health and welfare effects is not exhaustive.
[c] Health endpoints in the unquantified benefits column include both a) those for which there is not consensus on causality and those for which causality has been determined but empirical data are not available to allow calculation of benefits.

5.4.2 Selection of Concentration-Response Functions

After identifying the health endpoints to quantify in this analysis, we then selected concentration-response functions drawn from the epidemiological literature identified in the NO_2 ISA. We considered several factors in selecting the appropriate epidemiological studies and concentration-response functions for this benefits assessment.

- First, we considered ambient NO_2 studies that were identified as key studies in the NO_2 ISA (or a more recent study), excluding those affected by the general additive model (GAM) S-Plus issue.[5]

---

[5] The S-Plus statistical software is widely used for nonlinear regression analysis in time-series research of health effects. However, in 2002, a problem was discovered with the software's default conversion criteria in the general additive model (GAM), which resulted in biased relative risk estimates in many studies. This analysis does not include any studies that encountered this problem. For more information on this issue, please see U.S. EPA (2002).

- Second, we judged that studies conducted in the United States are preferable to those conducted outside the United States, given the potential for effect estimates to be affected by factors such as the ambient pollutant mix, the placement of monitors, activity patterns of the population, and characteristics of the healthcare system especially for hospital admissions and emergency department visits. We include Canadian studies in sensitivity analyses, when available.
- Third, we only incorporated concentration-response functions for which there was a corresponding valuation function. Currently, we only have a valuation function for asthma-related emergency department visits, but we do not have a valuation function for all-respiratory-related emergency department visits.
- Fourth, we preferred concentration-response functions that correspond to the age ranges most relevant to the specific health endpoint, with non-overlapping ICD-9 codes. We preferred completeness when selecting functions that correspond to particular age ranges and ICD codes. Age ranges and ICD codes associated with the selected functions are identified in Table 5.2.
- Fifth, we preferred multi-city studies or combined multiple single city studies, when available.
- Sixth, when available, we judged that effect estimates with distributed or cumulative lag structures were most appropriate for this analysis.
- Seventh, when available, we selected NO_2 concentration-response functions based on multi-pollutant models. Studies with multi-pollutant models are identified in Table 5.2.

These criteria reflect our preferences for study selection, and it was possible to satisfy many of these, but not all. There are trade-offs inherent in selecting among a range of studies, as not all studies met all criteria outlined above. At minimum, we ensured that none of the studies were GAM affected, we selected only U.S. based studies, and we quantified health endpoints for which there was a corresponding valuation function.

We believe that U.S.-based studies are most appropriate studies to use in this analysis to estimate the number of hospital admissions associated with NO_2 exposure because of the characteristics of the ambient air, population, and healthcare system. Using only U.S.-based studies, we are limited to estimating the hospital admissions for asthma (ICD-9 493) and chronic lung disease (ICD-9 490-496) rather than all respiratory-related hospital admission, which is a more complete measure of health impacts. However, there are several Canada-based epidemiology studies that provide a more complete estimate of respiratory hospital admissions (Fung, 2006; Luginaah, 2005; Yang, 2003). Table 5.12 provides the sensitivity of the NO_2

benefits using the effect estimates from the Canadian studies. Compared to the U.S. based studies, the Canadian studies produce a larger estimate of hospital admissions associated with NO_2 exposure.

When selecting concentration-response functions to use in this analysis, we reviewed the scientific evidence regarding the presence of thresholds in the concentration-response functions for NO_2-related health effects to determine whether the function is approximately linear across the relevant concentration range. The NO_2 ISA concluded that, “[t]hese results do not provide adequate evidence to suggest that nonlinear departures exist along any part of this range of NO_2 exposure concentrations.” Therefore, we have not incorporated thresholds in the concentration-response function for NO_2-related health effects in this analysis.

Table 5.2 shows the studies and health endpoints that we selected for this analysis. Table 5.3 shows the baseline health data used in combination with these health functions. Following these tables is a description of each of the epidemiology studies used in this analysis.

Table 5.2: NO_2-Related Health Endpoints Quantified, Studies Used to Develop Health Impact Functions and Sub-Populations to which They Apply

Endpoint	Study	Study Population
Hospital Admissions [b]		
Asthma	Linn et al. (2000)—ICD-9 493	All ages
Chronic Lung Disease	Moolgavkar (2003) —ICD-9 490-496	> 65
Emergency Department Visits		
Asthma	Pooled Estimate: Ito et al. (2007)—ICD-9 493 NYDOH (2006)[c]—ICD-9 493 Peel et al. (2005)—ICD-9 493	All ages
Other Health Endpoints		
Asthma exacerbations	Pooled estimate: O'Connor et al. (2008) (slow play, missed school days, nighttime asthma) [c] Ostro et al. (2001) (cough, cough (new cases), shortness of breath, shortness of breath (new cases), wheeze, wheeze (new cases) [a] Schildcrout et al. (2006) (one or more symptoms)	4 - 12
	Delfino et al. (2002) (one or more symptoms)	13 - 18[a]
Acute Respiratory Symptoms	Schwartz et al. (1994)[c]	7 - 14

[a] The original study populations were 9 to 18 for the Delfino et al. (2002) study, and 8-13 for the Ostro et al. (2001) study. We extended the applied population to facilitate the pooling process, recognizing the common biological basis for the effect in children in the broader age group. See: National Research Council (NRC). 2002. *Estimating the Public Health Benefits of Proposed Air Pollution Regulations*. Washington, DC: The National Academies Press, pg 117.

[b] We recognize that the ICD codes for asthma and chronic lung disease overlap partially, suggesting that our combined estimate of respiratory hospital admissions may be overstated to a small degree. However, we believe that using the other available health impact functions to quantify this endpoint would have resulted in a more biased and uncertain estimate, as these functions failed to meet key selection criteria.

[C] Study specifies a multipollutant model

Table 5.3: National Average Baseline Incidence Rates used to Calculate NO_2-Related Health Impacts [a]

Endpoint	Source	Notes	Rate per 100 people per year by Age Group						
			<18	18–24	25–34	35–44	45–54	55–64	65+
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)	Schwartz (1994, table 2)	incidence	0.416	—	—	—	—	—	—
Asthma Exacerbations	Delfino et al. (2002)	Incidence (and prevalence) among asthmatic children		Asthma symptoms			0.157 (0.0567)		
	O’Connor et al. (2008)	Incidence (and prevalence) among asthmatic children		Missed school			0.057 (0.0567)		
				One or more symptoms			0.207 (0.0567)		
				Slow play			0.157 (0.0567)		
				Nighttime asthma			0.121 (0.0567)		
	Ostro et al. (2001)	Incidence (and prevalence) among asthmatic African American children		Cough			0.145 (0.0726)		
				Cough (new cases)			0.067 (0.0726)		
				Shortness of breath			0.074 (0. 0726)		
				Shortness of breath (new cases)			0.037 (0. 0726)		
				Wheeze			0.173 (0.0726)		
				Wheeze (new cases)			0.076 (0.0726)		
	Schildcrout et al. (2006)	Incidence (and prevalence) among asthmatic children		One or more symptoms			0.52 (0.0567)		

[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/

Linn et al. (2000)

Linn et al. (2000) evaluated associations between air pollution and hospital admissions for cardiopulmonary illnesses in metropolitan Los Angeles during 1992-1995. In a single-pollutant Poisson regression model, daily average of NO_2 (year-round) was found significantly associated with same-day asthma hospital admissions for both age groups (i.e., 0-29 and 30-99). The results for winter and autumn were also reported but insignificant.

Moolgavkar (2003)

Moolgavkar (2003) presented re-analyses of Moolgavkar(2000c; 2000a; 2000b) of the associations between air pollution and daily deaths and hospital admissions in Los Angeles and Cook counties in the United States.[6] The author also reported the results of generalized linear model (GLM) analyses using natural splines with the same degree of freedom as the smoothing splines he used in the generalized additive model (GAM) analyses. In single-pollutant Poisson regression models, hospital admissions for chronic obstructive pulmonary disorder (COPD) (ICD-9 code 490-496) were associated with daily average of NO_2 levels at lags of 0, 1, 2, 3, 4 and 5 days for individuals 65 and older. The association was strongest at lag 0 using both GAM (stringent convergence) and GLM.

Ito et al. (2007)

Ito et al. (2007) assessed associations between air pollution and asthma emergency department visits in New York City for all ages. Specifically they examined the temporal relationships among air pollution and weather variables in the context of air pollution health effects models. The authors compiled daily data for $PM_{2.5,}$ O_3, NO_2, SO_2, CO, temperature, dew point, relative humidity, wind speed, and barometric pressure for New York City for the years 1999-2002.The authors evaluated the relationship between the various pollutants' risk estimates and their respective concurvities, and discuss the limitations that the results imply about the interpretability of multi-pollutant health effects models.

NYDOH (2006)

New York State Department of Health (NYDOH) investigated whether day-to-day variations in air pollution were associated with asthma emergency department (ED) visits in Manhattan and Bronx, NYC and compared the magnitude of the air pollution effect between the two communities. NYDOH (2006) used Poisson regression to test for effects of 14 key air

---

[6] The principal reason for conducting these re-analyses was to assess the impact of using convergence criteria that are more stringent than the default criteria used in the S-Plus software package.

contaminants on daily ED visits, with control for temporal cycles, temperature, and day-of-week effects. The core analysis utilized the average exposure for the zero- to four-day lags. Mean daily NO_2 was found significantly associated with asthma ED visits in Bronx but not Manhattan. Their findings of more significant air pollution effects in the Bronx are likely to relate in part to greater statistical power for identifying effects in the Bronx where baseline ED visits were greater, but they may also reflect greater sensitivity to air pollution effects in the Bronx.

Peel et al. (2005)

Peel et al. (2005) examined the associations between air pollution and respiratory emergency department visits (i.e., asthma (ICD-9 code 493, 786.09), COPD (491,492,496), upper respiratory infection (URI) (460-466, 477), pneumonia (480-486), and an all respiratory-disease group) in Atlanta, GA from 1 January 1993 to 31 August 2000. They used 3-Day Moving Average (Lags of 0, 1, and 2 Days) and unconstrained distributed lag (Lags of 0 to 13 Days) in the Poisson regression analyses. In single-pollutant models, the authors found that positive associations persisted beyond 3 days for several outcomes, and over a week for asthma. Standard deviation increases of O_3, NO_2, CO, and PM_{10} were associated with 1-3% increases in URI visits; a 2 $\mu g/m^3$ increase of $PM_{2.5}$ organic carbon was associated with a 3% increase in pneumonia visits; and standard deviation increases of NO_2 and CO were associated with 2-3% increases in chronic obstructive pulmonary disease visits.

Delfino et al. (2002)

Delfino et al.(2002) examined the association between air pollution and asthma symptoms among 22 asthmatic children (9-19 years of age) followed March through April 1996 (1,248 person-days) in Southern California. Air quality data for PM_{10}, NO_2, O_3, fungi and pollen were used in a logistic model with control for temperature, relative humidity, day-of-week trends and linear time trends. The odds ratio (95% confidence interval) for asthma episodes in relation to lag0 (i.e. immediate) 20 ppb changes in 8-hr max NO_2 is 1.49 (0.95-2.33). The authors also considered subgroups of asthmatic children who were on versus not on regularly scheduled anti-inflammatory medications and found that pollutant associations were stronger during respiratory infections in subjects not on anti-inflammatory medications.

O'Connor et al. (2008)

O'Connor et al.(2008) investigated the association between fluctuations in outdoor air pollution and asthma exacerbation among 861 inner-city children (5-12 years of age) with asthma in seven US urban communities. Asthma symptom data were collected every two months during the 2-year study period. Daily pollution measurements were obtained from the

Aerometric Information Retrieval System between August 1998 and July 2001. The relationship of symptoms to fluctuations in pollutant concentrations was examined by using logistic models. In single-pollutant models, significant or nearly significant positive associations were observed between higher NO_2 concentrations and each of the health outcomes. Significant positive associations with symptoms but not school absence were observed in the single-pollutant model for CO. The O_3, $PM_{2.5,}$ and SO_2 concentrations did not appear significantly associated with symptoms or school absence except for a significant association between $PM_{2.5}$ and school absence. The authors concluded that the associations with NO_2 suggest that motor vehicle emissions may be causing excess morbidity in this population. This study is not included in the NO_2 ISA only because it was published after the cut-off date, but it met all of the other criteria for inclusion in this analysis.

Ostro et al. (2001)

Ostro et al.(2001) examined relations between several air pollutants and asthma exacerbation in African-Americans children (8 to 13 years old) in central Los Angeles from August to November 1993. Air quality data for PM_{10}, $PM_{2.5,}$ NO_2, and O_3 were used in a logistic regression model with control for age, income, time trends, and temperature-related weather effects. Asthma symptom endpoints were defined in two ways: "probability of a day with symptoms" and "onset of symptom episodes". New onset of a symptom episode was defined as a day without symptoms followed by a day with symptoms. The authors found cough prevalence associated with PM_{10} and $PM_{2.5}$ and cough incidence associated with $PM_{2.5,}$ PM_{10}, and NO_2. Ozone was not significantly associated with cough among asthmatics. The authors found that both the prevalent and incident episodes of shortness of breath were associated with $PM_{2.5}$ and PM_{10}. Neither ozone nor NO_2 were significantly associated with shortness of breath among asthmatics. The authors found both the prevalence and incidence of wheeze associated with $PM_{2.5,}$ PM_{10}, and NO_2. Ozone was not significantly associated with wheeze among asthmatics.

Schildcrout et al. (2006)

Schildcrout et al.(2006) investigated the relation between ambient concentrations of the five criteria pollutants (PM_{10}, O_3, NO_2, SO_2, and CO) and asthma exacerbations (daily symptoms and use of rescue inhalers) among 990 children in eight North American cities during the 22-month prerandomization phase (November 1993-September 1995) of the Childhood Asthma Management Program. Short-term effects of CO, NO_2, PM_{10}, SO_2, and warm-season O_3 were examined in both one-pollutant and two-pollutant models, using lags of up to 2 days in logistic and Poisson regressions. Lags in CO and NO_2 were positively associated with both measures of asthma exacerbation, and the 3-day moving sum of SO_2 levels was marginally related to asthma symptoms. PM_{10} and O_3 were unrelated to exacerbations. The strongest effects tended to be seen with 2-day lags, where a 1-parts-per-million change in CO and a 20-parts-per-billion change in NO_2 were associated with symptom odds ratios of 1.08 (95% confidence interval (CI): 1.02, 1.15) and 1.09 (95% CI: 1.03, 1.15), respectively.

Schwartz et al. (1994)

Schwartz et al.(1994) studied the association between ambient air pollution exposures and respiratory illness among 1,844 schoolchildren (7-14 years of age) in six U.S. cities during five warm season months between April and August. Daily measurements of ambient SO_2, NO_2, O_3, PM_{10}, $PM_{2.5}$, light scattering, and sulfate particles were made, along with integrated 24-h measures of aerosol strong acidity. Significant associations in single pollutant models were found between SO_2, NO_2, or $PM_{2.5}$ and incidence of cough, and between sulfur dioxide and incidence of lower respiratory symptoms. Significant associations were also found between incidence of coughing symptoms and incidence of lower respiratory symptoms and PM_{10}, and a marginally significant association between upper respiratory symptoms and PM_{10}.

5.4.3 Pooling Multiple Health Studies

After selecting which health endpoints to analyze and which epidemiology studies provide appropriate effect estimates, we then selected a method to combine the multiple health studies to provide a single benefits estimate for each health endpoint. The purpose of pooling multiple studies together is to generate a more robust estimate by combining the evidence across multiple studies and cities. Because we used a single study for acute respiratory symptoms and a single study for hospital admission for asthma, there was no pooling necessary for those endpoints.

For the hospital admission studies for chronic lung disease, we pooled the effect estimates reported for two counties (Los Angeles, CA, and Cook, IL) from Moolgavkar (2003) using random/fixed effects.[7] For the emergency department visit studies, we pooled the three studies (Ito et al., 2007; NYDOH, 2003; Peel et al., 2005) using random/fixed effects. For the asthma studies, we pooled the three studies (O'Conner et al, 2008; Ostro et al, 2001; Schildcrout et al, 2006) using random/fixed effects for ages 4 to 12, and then we summed this results with the Delfino study (2002) for ages 13 to 18. See Table 5.2 for more information on

---

[7] Random/fixed effects pooling allows for the possibility that the effect estimates reported among different studies may in fact be estimates of different parameters, rather than just different estimates of the same underlying parameter. For additional information regarding BenMAP pooling techniques, please consult the BenMAP technical appendices available at http://www.epa.gov/air/benmap/models/BenMAPappendicesSept08.pdf .

how the asthma studies were adjusted. Because asthma represents the largest benefits category in this analysis, we tested the sensitivity of the NO_2 benefits to alternate pooling choices in Table 5.12. In general, the estimate using the Ostro study is much lower than the estimate that combines Ostro with the new studies, and the estimate for one-or-more asthma symptoms is much higher than the estimate that combines all of the asthma endpoints.

5.5 Valuation of Avoided Health Effects from NO_2 Exposure

The selection of valuation functions is largely consistent with the $PM_{2.5}$ NAAQS (U.S. EPA, 2006a) with two exceptions. First, in this analysis, we only estimate chronic lung disease and asthma, two types of hospital admissions, whereas the $PM_{2.5}$ NAAQS estimated changes in all respiratory hospital admissions, which generated a larger monetized value. Second, we use the any-of-19 symptoms valuation for acute respiratory symptoms instead of the "minor-restricted activity day" (MRADs) estimated for the $PM_{2.5}$ NAAQS. The valuation for any-of-19-symptoms is approximately 50% of the valuation for MRADs. Consistent with economic theory, these valuation functions include adjustments for inflation (2006$) and income growth over time (2020 income levels). Table 5.4 describes the valuation functions used to monetize the benefits of reduced exposure to NO_2.

Table 5.4: Central Unit Values NO_2 Health Endpoints (2006$)

Health Endpoint	Central Unit Value Per Statistical Incidence (2020 income level)	Derivation of Distributions of Estimates
Hospital Admissions and ER Visits		
Asthma Admissions	$10,000	No distributional information available. The cost-of-illness (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).
Chronic Lung Disease Admissions	$16,000	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).
Asthma Emergency Room Visits	$370	No distributional information available. Simple average of two unit COI values: (1) $400 (2006$), from Smith et al. (1997) and (2) $340 (2006$), from Stanford et al. (1999).
Respiratory Ailments Not Requiring Hospitalization		
Asthma Exacerbation	$53	Asthma exacerbations are valued at $49 (2006$) 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 $19 and $83 (2006$).
Acute Respiratory Symptoms	$30	The valuation estimate for "any of 19 acute respiratory symptoms” is derived from Krupnick et al. (1990) assuming that this health endpoint consists either of upper respiratory symptoms (URS) or lower respiratory symptoms (LRS), or both. We assumed the following probabilities for a day of "any of 19 acute respiratory symptoms": URS with 40 percent probability, LRS with 40 percent probability, and both with 20 percent probability. The point estimate of WTP to avoid a day of “the presence of any of 19 acute respiratory symptoms” is $28 (2006$). The value is assumed have a uniform distribution between $0 and $56 (2006$).

5.6 Health Benefits of NO_2 Reduction Results

EPA estimates that the NO_2 health benefits of attaining the 50 ppb alternative standard are $6.3 million. Figure 5.6 shows the breakdown of the monetized NO_2 benefits by health endpoint, and Figure 5.7 shows the breakdown of the monetized NO_2 benefits by geographic area. Table 5.5 shows the incidences of health effects and monetized benefits of attaining the 50 ppb alternative standard by geographic area and health endpoint. Because all health effects from NO_2 exposure are expected to occur in 2020, the monetized benefits for NO_2 do not need to be discounted. Please note that these benefits do not include any of the benefits listed as "unquantified" in Table 5.1, nor do they include the PM co-benefits, which are presented in the section 5.7.

Figure 5.6: Breakdown of Monetized Benefits by Health Endpoint for NO_2

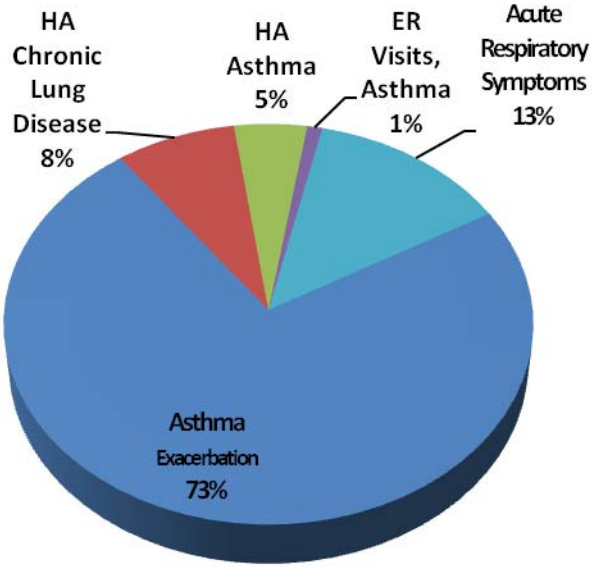


Figure 5.7: Breakdown of Monetized Benefits by Geographic Area for NO_2

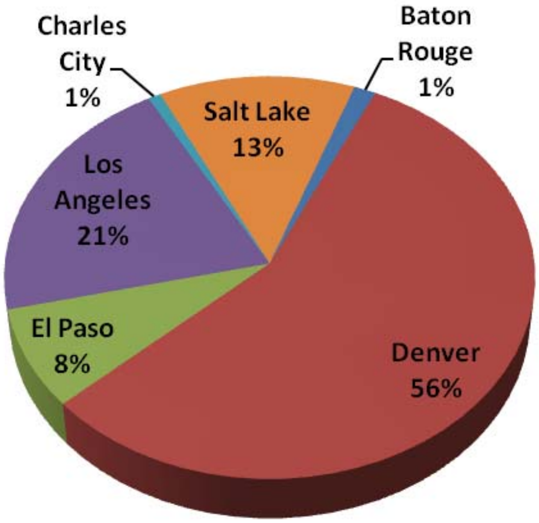


Table 5.5: NO_2 Benefits of Attaining 50 ppb standard (95th percentile confidence interval)*

		Incidence		Valuation	
Baton Rouge	Asthma Exacerbation	1,200	(-1 -- 3,000)	$62,000	($3,200 -- $170,000)
	Hospital Admissions, Chronic Lung Disease	1	(0 -- 1)	$9,700	($7,900 -- $11,000)
	Hospital Admissions, Asthma	0.4	(0 -- 1)	$4,300	($1,900 -- $6,700)
	Emergency Room Visits, Respiratory	3	(1 -- 7)	$1,300	($290 -- $2,400)
	Acute Respiratory Symptoms	360	(-100 -- 1,000)	$11,000	(-$2,900 -- $36,000)
Denver	Asthma Exacerbation	50,000	(290 -- 130,000)	$2,700,000	($140,000 -- $7,100,000)
	Hospital Admissions, Chronic Lung Disease	14	(11 -- 17)	$240,000	($190,000 -- $270,000)
	Hospital Admissions, Asthma	15	(6 -- 28)	$160,000	($72,000 -- $260,000)
	Emergency Room Visits, Respiratory	88	(16 -- 180)	$32,000	($7,100 -- $61,000)
	Acute Respiratory Symptoms	16,000	(-4,500 -- 43,000)	$470,000	(-$130,000 -- $1,600,000)
El Paso	Asthma Exacerbation	6,600	(-19 -- 16,000)	$350,000	($18,000 -- $940,000)
	Hospital Admissions, Chronic Lung Disease	4	(3 -- 5)	$70,000	($57,000 -- $81,000)
	Hospital Admissions, Asthma	2	(1 -- 4)	$24,000	($10,000 -- $37,000)
	Emergency Room Visits, Respiratory	19	(4 -- 37)	$6,900	($1,500 -- $13,000)
	Acute Respiratory Symptoms	1,700	(-480 -- 4,600)	$50,000	(-$13,000 -- $170,000)
Los Angeles	Asthma Exacerbation	17,000	(-95 -- 45,000)	$920,000	($44,000 -- $2,500,000)
	Hospital Admissions, Chronic Lung Disease	7	(6 -- 9)	$120,000	($99,000 -- $140,000)
	Hospital Admissions, Asthma	6	(2 -- 11)	$65,000	($29,000 -- $100,000)
	Emergency Room Visits, Respiratory	33	(7 -- 67)	$12,000	($2,900 -- $23,000)
	Acute Respiratory Symptoms	5,700	(-1,600 -- 16,000)	$170,000	(-$46,000 -- $580,000)
Charles City	Asthma Exacerbation	660	(0 -- 1,700)	$35,000	($1,800 -- $97,000)
	Hospital Admissions, Chronic Lung Disease	0.4	(0 -- 0)	$6,800	($5,500 -- $7,800)
	Hospital Admissions, Asthma	0.3	(0 -- 0)	$2,700	($1,200 -- $4,200)
	Emergency Room Visits, Respiratory	2	(0 -- 4)	$780	($180 -- $1,500)
	Acute Respiratory Symptoms	210	(-60 -- 590)	$6,300	(-$1,700 -- $21,000)
Salt Lake	Asthma Exacerbation	12,000	(78 -- 29,000)	$620,000	($33,000 -- $1,700,000)
	Hospital Admissions, Chronic Lung Disease	3	(2 -- 3)	$45,000	($37,000 -- $52,000)
	Hospital Admissions, Asthma	3	(1 -- 6)	$37,000	($17,000 -- $58,000)
	Emergency Room Visits, Respiratory	19	(4 -- 38)	$7,000	($1,600 -- $13,000)
	Acute Respiratory Symptoms	3,800	(-1,100 -- 11,000)	$110,000	(-$31,000 -- $380,000)
Total	Asthma Exacerbation	87,000	(250 -- 220,000)	$4,700,000	($240,000 -- $13,000,000)
	Hospital Admissions, Chronic Lung Disease	28	(23 -- 35)	$490,000	($400,000 -- $560,000)
	Hospital Admissions, Asthma	27	(11 -- 50)	$300,000	($130,000 -- $460,000)
	Emergency Room Visits, Respiratory	160	(32 -- 330)	$61,000	($14,000 -- $110,000)
	Acute Respiratory Symptoms	27,000	(-7,900 -- 75,000)	$820,000	(-$220,000 -- $2,700,000)
Grand Total				**$6,300,000**	**($570,000 -- $16,000,000)**

*All estimates are rounded to two significant figures. The negative 5th percentile incidence estimates for acute respiratory symptoms are a result of the weak statistical power of the study and should not be inferred to indicate that decreased NO_2 exposure may cause an increase in this health endpoint.

5.7 $PM_{2.5}$ Co-Benefits

Because NO_x is also a precursor to $PM_{2.5}$, reducing NO_x emissions in the projected non-attainment areas will also reduce $PM_{2.5}$ formation, human exposure and the incidence of $PM_{2.5}$-related health effects. In this analysis, we estimated the co-benefits of reducing $PM_{2.5}$ exposure for the alternative standards. Due to analytical limitations, it was not possible to provide a comprehensive estimate of $PM_{2.5}$-related benefits. Instead, we used the "benefit-per-ton" method to estimate these benefits. Please see Chapter 4 for more information on the emission reductions calculated for the control strategy.[8]

The $PM_{2.5}$ benefit-per-ton methodology incorporates key assumptions described in detail below. 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 the benefit per-ton technique in previous RIAs, including the recent Ozone NAAQS RIA (U.S. EPA, 2008a) and Portland Cement NESHAP RIA (U.S. EPA, 2009). Table 5.6 shows the quantified and unquantified benefits captured in those benefit-per-ton estimates.

Table 5.6: Human Health and Welfare Effects of $PM_{2.5}$

Pollutant / Effect	Quantified and Monetized in Primary Estimates	Unquantified Effects Changes in:
$PM_{2.5}$	Adult premature mortality 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) Infant mortality	Subchronic bronchitis cases Low birth weight Pulmonary function Chronic respiratory diseases other than chronic bronchitis Non-asthma respiratory emergency room visits Visibility Household soiling

---

[8] In addition to reducing NO_2 emissions, the control strategy also reduces direct $PM_{2.5}$ and VOC emissions. Please see Table 5.7 for the total estimate of emission reductions used to calculate $PM_{2.5}$ co-benefits.

Consistent with the Portland Cement NESHAP[9], the benefits estimates utilize the concentration-response functions as reported in the epidemiology literature, as well as the 12 functions obtained in EPA's expert elicitation study as a sensitivity analysis.

- One estimate is based on the concentration-response (C-R) function developed from the extended analysis of American Cancer Society (ACS) cohort, as reported in Pope et al. (2002), a study that EPA has previously used to generate its primary benefits estimate. When calculating the estimate, EPA applied the effect coefficient as reported in the study without an adjustment for assumed concentration threshold of 10 μg/m^3 as was done in recent (post-2006) Office of Air and Radiation RIAs.
- One estimate is based on the C-R function developed from the extended analysis of the Harvard Six Cities cohort, as reported by Laden et al (2006). This study, published after the completion of the Staff Paper for the 2006 $PM_{2.5}$ NAAQS, has been used as an alternative estimate in the $PM_{2.5}$ NAAQS RIA and $PM_{2.5}$ co-benefits estimates in RIAs completed since the $PM_{2.5}$ NAAQS. When calculating the estimate, EPA applied the effect coefficient as reported in the study without an adjustment for assumed concentration threshold of 10 μg/m^3 as was done in recent (post 2006) RIAs.
- Twelve estimates are based on the C-R functions from EPA's expert elicitation study[10,11] on the $PM_{2.5}$ -mortality relationship and interpreted for benefits analysis in EPA's final RIA for the $PM_{2.5}$ NAAQS. For that study, twelve experts (labeled A through L) provided independent estimates of the $PM_{2.5}$ -mortality concentration-response function. EPA practice has been to develop independent estimates of $PM_{2.5}$ -mortality estimates corresponding to the concentration-response function provided by each of the twelve experts, to better characterize the degree of variability in the expert responses.

Readers interested in reviewing the complete methodology for creating the benefit-per-ton estimates used in this analysis can consult the Technical Support Document (TSD) accompanying the recent final ozone NAAQS RIA (USEPA 2008a).[12] As described in the documentation for the benefit per-ton estimates cited above, national per-ton estimates are developed for selected pollutant/source category combinations. The per-ton values calculated

---

[9] We provide the entire benefits chapter of the Portland Cement NESHAP as an appendix (Appendix 5A) to this RIA. Although we summarize the main issues in this chapter, we encourage interested readers to see this appendix for a more detailed description of the changes to the PM benefits presentation and preference for the no-threshold model.

[10] Industrial Economics, Inc., 2006. *Expanded Expert Judgment Assessment of the Concentration-Response Relationship Between $PM_{2.5}$ Exposure and Mortality*. Prepared for the U.S. EPA, Office of Air Quality Planning and Standards, September. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/Uncertainty/pm_ee_report.pdf.

[11] Roman et al., 2008. *Expert Judgment Assessment of the Mortality Impact of Changes in Ambient Fine Particulate Matter in the U.S*. Environ. Sci. Technol., 42, 7, 2268–2274.

[12] The Technical Support Document (U.S. EPA, 2008b), entitled: Calculating Benefit Per-Ton Estimates, can be found in EPA Docket EPA-HQ-OAR-2007-0225-0284.

therefore apply only to tons reduced from those specific pollutant/source combinations (e.g., SO_2 emitted from electric generating units; NO_2 emitted from mobile sources). Our estimate of $PM_{2.5}$ co-control benefits is therefore based on the total $PM_{2.5}$ emissions controlled by sector and multiplied by this per-ton value.

The effect coefficients are drawn from epidemiology studies examining two large population cohorts: the American Cancer Society cohort (Pope et al., 2002) and the Harvard Six Cities cohort (Laden et al., 2006).[13] These are logical choices for anchor points in our presentation because, while both studies are well designed and peer reviewed, there are strengths and weaknesses inherent in each, which we believe argues for using both studies to generate benefits estimates. Previously, EPA had calculated benefits based on these two empirical studies, but derived the range of benefits, including the minimum and maximum results, from an expert elicitation of the relationship between exposure to $PM_{2.5}$ and premature mortality (Roman et al., 2008).[14] Within this assessment, we include the benefits estimates derived from the concentration-response function provided by each of the twelve experts to better characterize the uncertainty in the concentration-response function for mortality and the degree of variability in the expert responses. Because the experts used these cohort studies to inform their concentration-response functions, benefits estimates using these functions generally fall between results using these epidemiology studies (see Figure 5.9). In general, the expert elicitation results support the conclusion that the benefits of $PM_{2.5}$ control are very likely to be substantial.

The benefit-per-ton coefficients in this analysis were derived using modified versions of the health impact functions used in the PM NAAQS Regulatory Impact Analysis. Specifically, this analysis uses the benefit-per-ton estimates first applied in the Portland Cement NESHAP RIA (U.S. EPA, 2009), which incorporated three updates: a new population dataset, an expanded geographic scope of the benefit-per-ton calculation, and the functions directly from the epidemiology studies without an adjustment for an assumed threshold. Removing the threshold assumption is a key difference between the method used in this analysis of PM-co benefits and the methods used in RIAs prior to Portland Cement, and we now calculate incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels. Approximately 60% of the difference between the old methodology and the new methodology for this rule is due to removing thresholds with 40% due to the two technical updates, but this percentage would vary depending on the combination of emission reductions from different sources and $PM_{2.5}$ precursor pollutants.

---

[13] These two studies specify multi-pollutant models that control for NOx, among other co-pollutants.

[14] Please see the Section 5.2 of the Portland Cement RIA in Appendix 5A for more information regarding the change in the presentation of benefits estimates.

EPA strives to use the best available science to support our benefits analyses, and we recognize that interpretation of the science regarding air pollution and health is dynamic and evolving. Based on our review of the body of scientific literature, EPA applied the no-threshold model in this analysis. EPA's draft Integrated Science Assessment (2008g), which was recently reviewed by EPA's Clean Air Scientific Advisory Committee (U.S. EPA-SAB, 2009a; U.S. EPA-SAB, 2009b), concluded that the scientific literature consistently finds that a no-threshold log-linear model most adequately portrays the PM-mortality concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response function. Although this document does not represent final agency policy that has undergone the full agency scientific review process, it provides a basis for reconsidering the application of thresholds in $PM_{2.5}$ concentration-response functions used in EPA's RIAs. It is important to note that while CASAC provides advice regarding the science associated with setting the National Ambient Air Quality Standards, typically other scientific advisory bodies provide specific advice regarding benefits analysis. Because the Portland Cement RIA was completed while CASAC was reviewing the PM ISA, we solicited comment on the use of the no-threshold model for benefits analysis within the preamble of that proposed rule. The comment period for the Portland Cement proposed NESHAP has been extended until September 4, 2009.[15]

Because the benefits are sensitive to the assumption of a threshold, we also provide a sensitivity analysis using the previous methodology (i.e., a threshold model at 10 $\mu g/m^3$ without the two technical updates) as a historical reference. Table 5.13 shows the sensitivity of an assumed threshold on the monetized results, with and without an assumed threshold at 10 $\mu g/m^3$. Using the threshold model at 10 $\mu g/m^3$ without the two technical updates, we estimate the monetized benefits to be $170 million to $370 million (2006$, 3 percent discount rate) for the 50 ppb standard alternative.

As is the nature of Regulatory Impact Analyses (RIAs), the assumptions and methods used to estimate air quality benefits evolve over time to reflect the Agency's most current interpretation of the scientific and economic literature. For a period of time (2004-2008), the Office of Air and Radiation (OAR) valued mortality risk reductions using a value of statistical life (VSL) estimate derived from a limited analysis of some of the available studies. OAR arrived at a VSL using a range of $1 million to $10 million (2000$) consistent with two meta-analyses of the wage-risk literature. The $1 million value represented the lower end of the interquartile range from the Mrozek and Taylor (2002) meta-analysis of 33 studies. The $10 million value

---

[15] Readers interested in commenting on the use of the no-threshold model for benefits analysis should direct their comments to Docket ID No. EPA–HQ–OAR–2002–0051 (available at http://www.regulations.gov) before the comment period closes.

represented the upper end of the interquartile range from the Viscusi and Aldy (2003) meta-analysis of 43 studies. The mean estimate of \$5.5 million (2000\$)[16] was also consistent with the mean VSL of \$5.4 million estimated in the Kochi et al. (2006) meta-analysis. However, the Agency neither changed its official guidance on the use of VSL in rule-makings nor subjected the interim estimate to a scientific peer-review process through the Science Advisory Board (SAB) or other peer-review group.

During this time, the Agency continued work to update its guidance on valuing mortality risk reductions, including commissioning a report from meta-analytic experts to evaluate methodological questions raised by EPA and the SAB on combining estimates from the various data sources. In addition, the Agency consulted several times with the Science Advisory Board Environmental Economics Advisory Committee (SAB-EEAC) on the issue. With input from the meta-analytic experts, the SAB-EEAC advised the Agency to update its guidance using specific, appropriate meta-analytic techniques to combine estimates from unique data sources and different studies, including those using different methodologies (i.e., wage-risk and stated preference) (U.S. EPA-SAB, 2007).

Until updated guidance is available, the Agency determined that a single, peer-reviewed estimate applied consistently best reflects the SAB-EEAC advice it has received. Therefore, the Agency has decided to apply the VSL that was vetted and endorsed by the SAB in the Guidelines for Preparing Economic Analyses (U.S. EPA, 2000)[17] while the Agency continues its efforts to update its guidance on this issue. This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is \$6.3 million (2000\$).[18]

The Agency is committed to using scientifically sound, appropriately reviewed evidence in valuing mortality risk reductions and has made significant progress in responding to the SAB-EEAC's specific recommendations. The Agency anticipates presenting results from this effort to the SAB-EEAC in the Fall 2009 and that draft guidance will be available shortly thereafter.

Because epidemiology studies have indicated that there is a lag between exposure to $PM_{2.5}$ and premature mortality, the discount rate has a substantial effect on the final monetized

---

[16] In this analysis, we adjust the VSL to account for a different currency year (\$2006) and to account for income growth to 2020. After applying these adjustments to the \$5.5 million value, the VSL is \$7.7m.

[17] In the (draft) update of the Economic Guidelines (U.S. EPA, 2008), EPA retained the VSL endorsed by the SAB with the understanding that further updates to the mortality risk valuation guidance would be forthcoming in the near future. Therefore, this report does not represent final agency policy.

[18] In this analysis, we adjust the VSL to account for a different currency year (\$2006) and to account for income growth to 2020. After applying these adjustments to the \$6.3 million value, the VSL is \$8.9m.

benefits. We test the sensitivity of the results to discount rates of 3% and 7% in Table 5.13, and we provide the PM co-benefit results using both discount rates in Table 5.9 and the total monetized benefits results using both discount rates in Table 5.10.

The core monetized results are provided in Table 5.7 and the health incidences are provided in Table 5.8. Table 5.9 shows the monetized results using the two epidemiology-based estimates as well as the 12 expert-based estimates. Figure 5.8 provides a graphical breakdown of the $PM_{2.5}$ co-benefits by sector. Figure 5.9 provides a graphical representation of all 14 of the $PM_{2.5}$ co-benefits, at both a 3 percent and 7 percent discount rate.

Table 5.7: $PM_{2.5}$ Co-benefits associated with 50 ppm NO_2 at discount rates of 3% and 7% (millions of 2006$)*

$PM_{2.5}$ Precursor	Tons	Benefit per Ton Estimate (Pope)	Benefit per Ton Estimate (Laden)	Valuation of $PM_{2.5}$ Co-Benefits (Pope, millions)	Valuation of $PM_{2.5}$ Co-Benefits (Laden, millions)
NO_x EGU:	10,000	$7,600	$19,000	$77	$190
NO_x Point:	14,000	$5,000	$12,000	$70	$170
NO_x Mobile:	20,000	$5,200	$13,000	$110	$260
Direct $PM_{2.5}$:	36	$280,000	$700,000	$10.0	$25
VOC:	1,400	$1,200	$3,100	$1.8	$4.3
Other NO_x Mobile:	480	$5,200	$13,000	$2.5	$6.1
TOTAL	**44,000**			**$270**	**$650**

*Numbers have been rounded to two significant figures and therefore summation may not match table estimates. This table includes extrapolated tons, spread across the sectors in proportion to the emissions in the county. $PM_{2.5}$ co-benefit estimates do not include confidence intervals because they are derived using benefit per-ton estimates. All estimates use a 3% discount rate. Estimates at a 7% discount rate would be about 9% lower.

Table 5.8: Summary of Reductions in Health Incidences from $PM_{2.5}$ Co-Benefits to Attain 50 ppb*

Avoided Premature Mortality	
Pope	30
Laden	80
Woodruff (Infant Mortality)	< 1
Avoided Morbidity	
Chronic Bronchitis	20
Acute Myocardial Infarction	50
Hospital Admissions, Respiratory	7
Hospital Admissions, Cardiovascular	20
Emergency Room Visits, Respiratory	30
Acute Bronchitis	50
Work Loss Days	4,300
Asthma Exacerbation	590
Acute Respiratory Symptoms	25,000
Lower Respiratory Symptoms	640
Upper Respiratory Symptoms	490

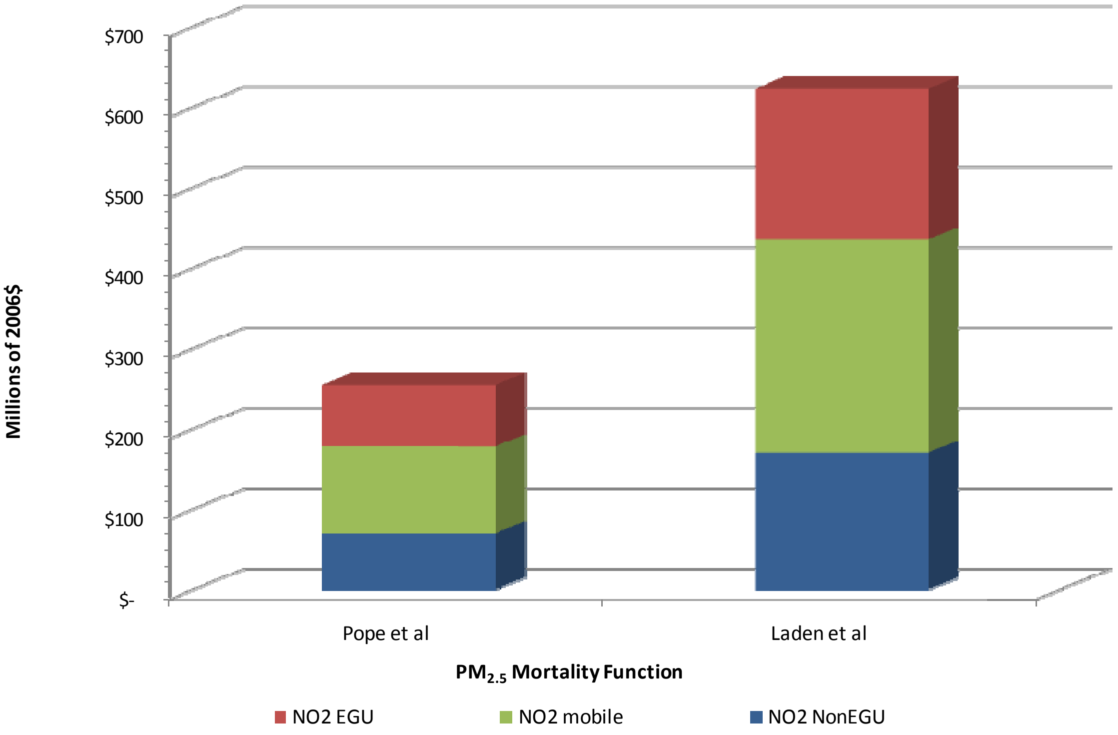
*All estimates are for the analysis year (2020) and are rounded to two significant figures. All fine particles are assumed to have equivalent health effects, but each $PM_{2.5}$ precursor pollutant has a different propensity to form $PM_{2.5}$.

Table 5.9: All $PM_{2.5}$ Co-Benefits Estimates to fully attain 50 ppb (in millions of 2006$)*

	3% Discount Rate	7% Discount Rate
Benefit-per-ton Coefficients Derived from Epidemiology Literature		
Pope et al.	$270	$240
Laden et al.	$650	$590
Benefit-per-ton Coefficients Derived from Expert Elicitation		
Expert A	$690	$620
Expert B	$530	$480
Expert C	$530	$480
Expert D	$370	$340
Expert E	$860	$770
Expert F	$480	$430
Expert G	$320	$290
Expert H	$400	$360
Expert I	$520	$470
Expert J	$430	$390
Expert K	$110	$100
Expert L	$390	$350

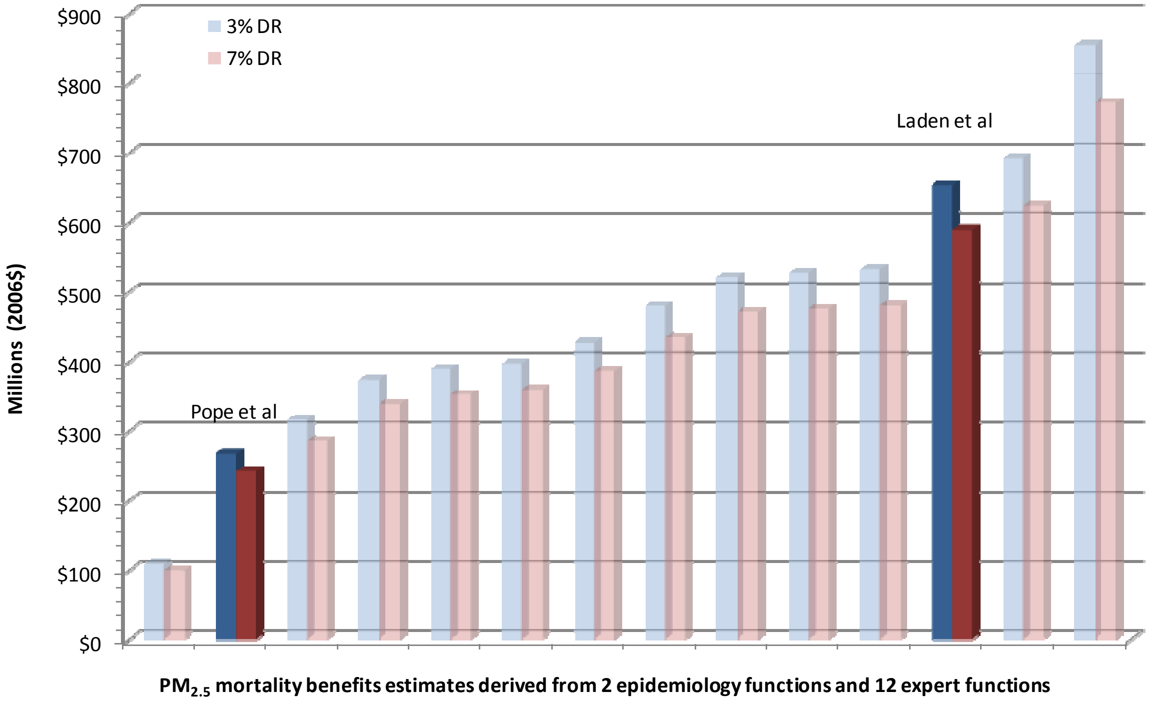
*All estimates are rounded to two significant figures. Estimates do not include confidence intervals because they were derived through the benefit-per-ton technique described above. The benefits estimates from the Expert Elicitation are provided as a reasonable characterization of the uncertainty in the mortality estimates associated with the concentration-response function.

Figure 5.8: Monetized $PM_{2.5}$ Co-Benefits of Fully Attaining 50 ppb by $PM_{2.5}$ Precursor



*This graph includes extrapolated tons of abatement that were allocated across all sectors in proportion to the emissions in El Paso and Los Angeles counties. All estimates are for the analysis year (2020). All fine particles are assumed to have equivalent health effects, but each $PM_{2.5}$ precursor pollutant has a different propensity to form $PM_{2.5}$. Results using a 7% discount rate would show a similar breakdown.

Figure 5.9: Monetized $PM_{2.5}$ Co-Benefits of Attaining 50 ppb



*This graph shows the estimated co-benefits in 2020 using the no-threshold model at discount rates of 3% and 7% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

5.8 Summary of Total Monetized Benefits (NO_2 and $PM_{2.5}$)

EPA estimates that total the NO_2 benefits and the $PM_{2.5}$ co-benefits of fully attaining the 50 ppb alternative NAAQS level are $270 to $660 million (2006$) at a 3% discount rate.[19] At a 7% discount rate, the total monetized benefits of full attainment are $250 to $600 million. Partial attainment only incorporates the emission reductions from identified controls without the extrapolated emission reductions.[20] Table 5.10 shows the total monetized benefits for full and partial attainment at discount rates of 3% and 7%. Figure 5.10 shows the breakdown primary benefits from NO_2 and co-benefits from $PM_{2.5}$. Figure 5.11 shows the breakdown of benefits by geographic area. Table 5.11 shows the total incidences of avoided health effects.

---

[19] These estimates use the no-threshold model for $PM_{2.5}$ co-benefits. Using a threshold model, the estimates would be $210m to $450m (2006$, 3% discount rate). Estimates using a 7% discount rate would be about 9% lower.

[20] See Chapters 4 and 6 for more information regarding the control strategy, including the identified and extrapolated emission reductions.

Figure 5.12 provides a graphical representation of all 14 total monetized benefits estimates, at both a 3 percent and 7 percent discount rate.

Table 5.10: Total NO_2 and $PM_{2.5}$ benefits to attain 50 ppm at discount rates of 3% and 7% (millions of 2006$)*

	3% Full Attainment	7% Full Attainment	3% Partial Attainment	7% Partial Attainment
NO_2	$6.3	$6.3	$4.6	$4.6
$PM_{2.5}$				
Pope et al	$270	$240	$140	$130
Laden et al	$650	$590	$350	$320
TOTAL with Pope	**$270**	**$250**	**$150**	**$140**
TOTAL with Laden	**$660**	**$600**	**$360**	**$320**

*Numbers have been rounded to two significant figures and therefore summation may not match table estimates.

Table 5.11: Summary of Reductions in Health Incidences from NO_2 and $PM_{2.5}$ to attain 50 ppb*

Avoided Premature Mortality	
Pope	30
Laden	80
Woodruff (Infant Mortality)	< 1
Avoided Morbidity	
Chronic Bronchitis	20
Acute Myocardial Infarction	50
Hospital Admissions, Respiratory	60
Hospital Admissions, Cardiovascular	20
Emergency Room Visits, Respiratory	220
Acute Bronchitis	4,300
Work Loss Days	590
Asthma Exacerbation	86,000
Acute Respiratory Symptoms	53,000
Lower Respiratory Symptoms	640
Upper Respiratory Symptoms	490

*All estimates are for the analysis year (2020) and are rounded to two significant figures.

Figure 5.10: Relative Contribution of Primary Benefits and Co-Benefits to Total Monetized Benefits

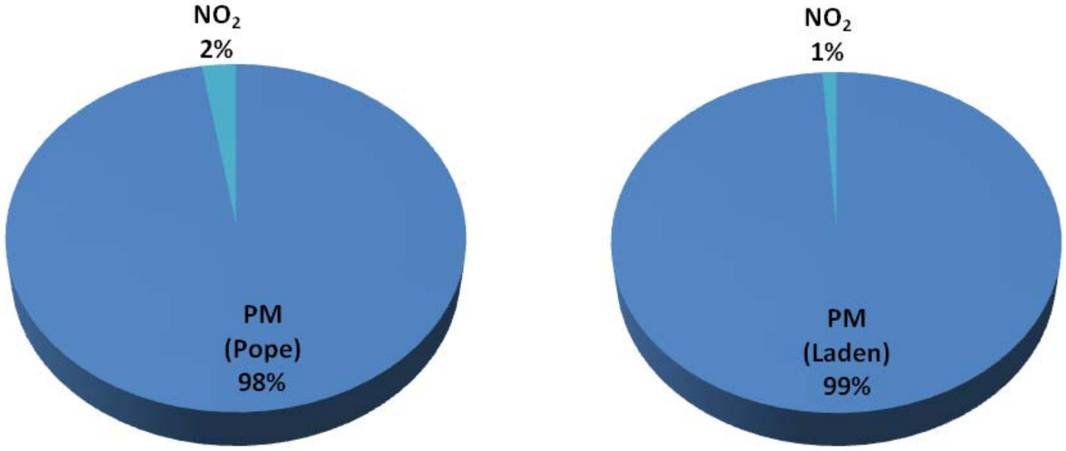
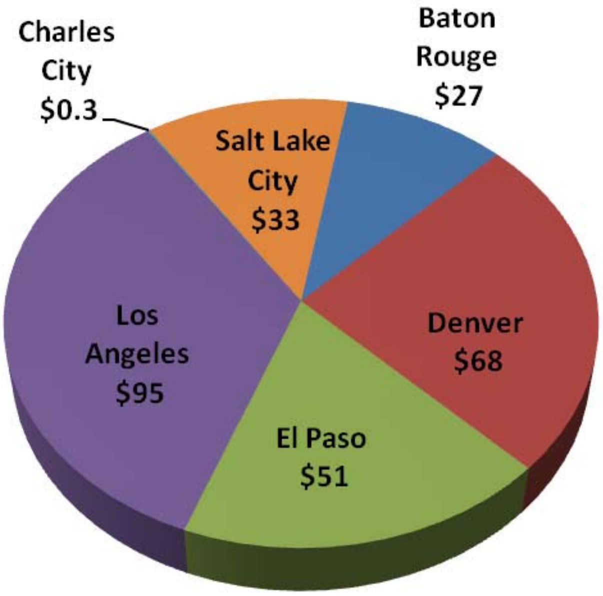
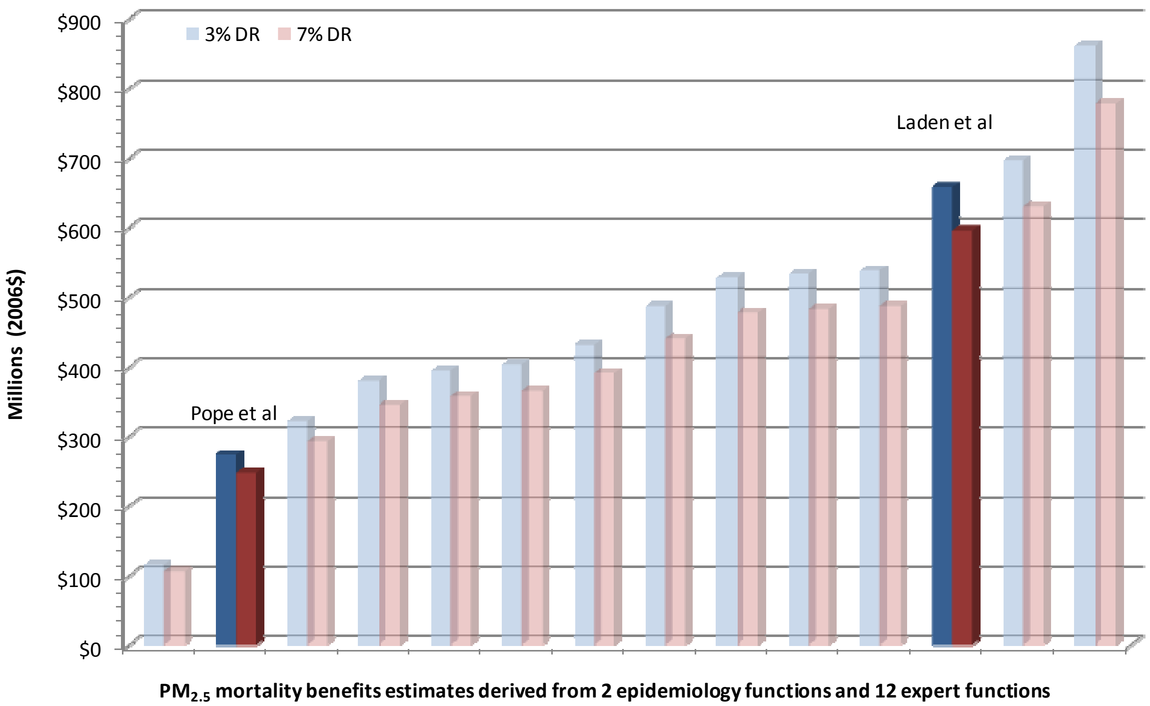


Figure 5.11: Summary of Total Monetized Benefits by Geographic Area (millions of 2006$)*



* This pie chart shows the benefits of attaining a 50 ppb standard using the Pope et al. function at a 3% discount rate. The relative breakdown between geographic areas would be the same if we showed the benefits using the Laden et al. function or a 7% discount rate.

Figure 5.12: Total Monetized Benefits of Attaining 50 ppb



*This graph shows the estimated total monetized benefits in 2020 using the no-threshold model at discount rates of 3% and 7% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

5.9 Limitations and Uncertainties

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 strategy include emissions modeling, air quality modeling, health effects incidence estimation, and valuation.

In this analysis, we use three methods to assess uncertainty quantitatively: Monte Carlo analysis, sensitivity analysis, and alternate concentration-response functions for PM mortality. We also provide a qualitative assessment for those aspects that we are unable to address quantitatively in this analysis. Each of these analyses is described in detail in the following sections.

This analysis includes many data sources as inputs, including emission inventories, air quality data from models (with their associated parameters and inputs), population data, health effect estimates from epidemiology studies, and economic data for monetizing benefits. Each of these inputs may be uncertain and would affect the benefits estimate. When the uncertainties from each stage of the analysis are compounded, small uncertainties can have large effects on the total quantified benefits. In this analysis, we are unable to quantify the cumulative effect of all of these uncertainties, but we provide the following analyses to characterize many of the largest sources of uncertainty.

5.9.1 Monte Carlo analysis

Similar to other recent RIAs, we used Monte Carlo methods for estimating characterizing random sampling error associated with the concentration response functions 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 morbidity. Specifically, we used Monte Carlo methods to generate confidence intervals around the estimated health impact and dollar benefits. The reported standard errors in the epidemiological studies determined the distributions for individual effect estimates, as shown in Table 5.5 for NO_2 benefits. Unfortunately, the associated confidence intervals are not available for the $PM_{2.5}$ co-benefits because of the benefit-per-ton methodology.

5.9.2 Sensitivity analyses

We performed a variety of sensitivity analyses on the benefits results to assess the sensitivity of the primary results to various data inputs and assumptions. We then changed each default input one at a time and recalculated the total monetized benefits to assess the percent change from the default. In Tables 5.12 and 5.13, we present the results of this sensitivity analysis. We indicate each input parameter, the value used as the default, and the values for the sensitivity analyses, and then we provide the total monetary benefits for each input and the percent change from the default value. This sensitivity analysis indicates that the results are most sensitive to assumptions regarding the attainment status and the threshold assumption in the PM-mortality relationship, and the results are less sensitive to alternate assumptions regarding the interpolation method, discount rate, and various assumptions regarding NO_2 exposure. To account for the large difference in magnitude between benefits from reduced NO_2 exposure and $PM_{2.5}$ exposure, we provide separate sensitivity analyses. Descriptions of the sensitivity analyses are provided in the relevant sections of this chapter.

Table 5.12: Sensitivity Analyses for NO_2 Health Benefits to Fully Attain 50 ppb

		Total NO_2 Benefits (millions of 2006$)	% Change from Default
Exposure Estimation Method	30km radius	$6.3	N/A
	12km grid cell	$1.4	-77%
	15km radius	$5.1	-19%
	CBSA	$6.3	0.6%
	Unconstrained	$8.9	42%
Location of Hospital Admission Studies	w/US-based studies only	$6.3	N/A
	w/Canada-based studies only*	$11	79%
Simulated Attainment	Just attainment	$6.3	N/A
	Over-control attainment	$6.8	10%
	Partial Attainment (El Paso)	$5.8	-6.2%
	Partial Attainment (El Paso and Los Angeles)	$4.6	-27%
Asthma Pooling Method	Pool all endpoints together	$6.3	N/A
	Ostro et al only	$2.1	-66%
	One or more symptoms only	$6.9	11%
Interpolation Method	Inverse Distance Squared	$6.3	N/A
	Inverse Distance	$5.8	-6.2%

*Using Canadian studies is not a direct comparison because it includes a more complete endpoint (all respiratory hospital admissions, ages 65+), whereas the US-based studies only include hospital admissions for asthma (all ages) and chronic lung disease (ages 65+).

Table 5.13: Sensitivity Analyses for $PM_{2.5}$ Health Co-Benefits for 50 ppb alternative standard

		Total $PM_{2.5}$ Benefits (millions of 2006$)	**% Change from Default**
Threshold Assumption (with Epidemiology Study)	No Threshold (Pope)	$270	N/A
	No Threshold (Laden)	$650	N/A
	Threshold (Pope)*	$210	-23%
	Threshold (Laden)*	$450	-32%
Discount Rate (with Epidemiology Study)	3% (Pope)	$270	N/A
	3% (Laden)	$650	N/A
	7% (Pope)	$240	-9%
	7% (Laden)	$590	-10%
Simulated Attainment (using Pope)	Full attainment	$230	N/A
	Partial Attainment (El Paso)	$210	-11%
	Partial Attainment (El Paso and Los Angeles)	$130	-46%

* The threshold model is not directly comparable to the no-threshold model. The threshold estimates do not include two technical updates, and they are based on data for 2015, instead of 2020. Directly comparable estimates are not available.

5.9.3 Alternate concentration-response functions for PM mortality

$PM_{2.5}$ mortality co-benefits are the largest benefit category that we monetized in this analysis. To better understand the concentration-response relationship between $PM_{2.5}$ exposure and premature mortality, EPA conducted an expert elicitation in 2006 (Roman et al., 2008; IEc, 2006). In general, the results of the expert elicitation support the conclusion that the benefits of $PM_{2.5}$ control are very likely to be substantial. In previous RIAs, EPA presented benefits estimates using concentration response functions derived from the $PM_{2.5}$ Expert Elicitation as a range from the lowest expert value (Expert K) to the highest expert value (Expert E). However, this approach did not indicate the agency’s judgment on what the best estimate of PM benefits may be, and EPA’s Science Advisory Board described this presentation as misleading. Therefore, we began to present the cohort-based studies (Pope et al, 2002; and Laden et al., 2006) as our core estimates in the Portland Cement RIA (U.S. EPA, 2009). Using alternate relationships between $PM_{2.5}$ and premature mortality supplied by experts, higher and lower benefits estimates are plausible, but most of the expert-based estimates fall between the two epidemiology-based estimates (Roman et al., 2008).

In this analysis, we present the results derived from the expert elicitation as indicative of the uncertainty associated with a major component of the health impact functions, and we provide the independent estimates derived from each of the twelve experts to better characterize the degree of variability in the expert responses. In this chapter, we provide the results using the concentration-response functions derived from the expert elicitation in both tabular (Table 5.9) and graphical form (Figure 5.9). Please note that these results are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies. Because in this RIA we estimate benefits using benefit-per-ton estimates, technical limitations prevent us from providing the associated credible intervals with the expert functions.

5.9.4 Qualitative assessment of uncertainty and other analysis limitations

Although we strive to incorporate as many quantitative assessments of uncertainty, there are several aspects for which we are only able to address qualitatively. These aspects are important factors to consider when evaluating the relative benefits of the attainment strategies for each of the alternative standards:

1. Benefits are most uncertain for the Los Angeles and El Paso areas because a large proportion of the $PM_{2.5}$-related benefits are based on emission reductions attributable to unidentified emission controls. 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. The gradient of ambient NO_2 concentrations is difficult to estimate due to the sparsity of the monitoring network. The 12km CMAQ grid, which is the air quality modeling resolution, may be too coarse to accurately estimate the potential near-field health benefits of reducing NO_2 emissions. These uncertainties may under- or over-estimate benefits.
3. The interpolation techniques used to estimate the full attainment benefits of the alternative standards contributed some uncertainty to the analysis. The great majority of benefits estimated for the 50 ppb standard alternative were derived through interpolation. As noted previously in this chapter, these benefits are likely to be more uncertain than if we had modeled the air quality scenario for both NO_2 and $PM_{2.5}$. In general, the VNA interpolation approach will under-estimate benefits because it does not account for the broader spatial distribution of air quality changes that may occur due to the implementation of a regional emission control program.
4. There are many uncertainties associated with the health impact functions used in this modeling effort. These include: within study variability (the precision with which a given

study estimates the relationship between air quality changes and health effects); across study variation (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 (does not account for any relationship between region and health effect, to the extent that such a relationship exists); the possibility of exposure misclassification in the study due to unmeasured variability in NO_2 concentrations near roadways; extrapolation of impact functions across population (we assumed that certain health impact functions applied to age ranges broader than that considered in the original epidemiological study); and various uncertainties in the C-R function, including causality and thresholds. These uncertainties may under- or over-estimate benefits.

5. Co-pollutants present in the ambient air may have contributed to the health effects attributed to NO_2 in single pollutant models. Risks attributed to NO_2 might be overestimated where concentration-response functions are based on single pollutant models. If co-pollutants are highly correlated with NO_2, their inclusion in an NO_2 health effects model can lead to misleading conclusions in identifying a specific causal pollutant. Because this collinearity exists, many of the studies reported statistically insignificant effect estimates for both NO_2 and the co-pollutants; this is due in part to the loss of statistical power as these models control for co-pollutants. Where available, we have selected multipollutant effect estimates to control for the potential confounding effects of co-pollutants; these include NYDOH (2006), Schwartz et al. (1994) and O'Conner et al. (2007). The remaining studies include single pollutant models.
6. This analysis is for the year 2020, and projecting key variables introduces uncertainty. 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.
7. This analysis omits certain unquantified effects due to lack of data, time and resources. These unquantified endpoints include other health effects, ecosystem effects, and visibility. EPA will continue to evaluate new methods and models and select those most appropriate for estimating the benefits of reductions in air pollution. Enhanced collaboration between air quality modelers, epidemiologists, toxicologists, ecologists, and economists should result in a more tightly integrated analytical framework for measuring benefits of air pollution policies.
8. $PM_{2.5}$ co-benefits represent a substantial proportion of total monetized benefits (98% to 99% of total monetized benefits for the 50 ppb standard), and these estimates are subject to a number of assumptions and uncertainties.

a. $PM_{2.5}$ co-benefits were derived through benefit per-ton estimates, which do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual benefits of controlling directly emitted fine particulates.

b. We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ produced via transported precursors emitted from EGUs may differ significantly from direct $PM_{2.5}$ released from diesel engines and other industrial sources, but no clear scientific grounds exist for supporting differential effects estimates by particle type.

c. We assume that the health impact function for fine particles is linear within the range of ambient concentrations under consideration. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5,}$ including both regions that are in attainment with fine particle standard and those that do not meet the standard down to the lowest modeled concentrations.

d. To characterize the uncertainty in the relationship between $PM_{2.5}$ and premature mortality (which typically accounts for 85% to 95% of total monetized benefits), we include a set of twelve estimates based on results of the expert elicitation study in addition to our core estimates. Even these multiple characterizations, omit the uncertainty in air quality estimates, baseline incidence rates, populations exposed and transferability of the effect estimate to diverse locations. As a result, the reported confidence intervals and range of estimates give an incomplete picture about the overall uncertainty in the $PM_{2.5}$ estimates. This information should be interpreted within the context of the larger uncertainty surrounding the entire analysis. For more information on the uncertainties associated with $PM_{2.5}$ co-benefits, please consult the $PM_{2.5}$ NAAQS RIA (Table 5.5).

5.10 Discussion

The results of this benefits analysis suggest that attaining a more stringent NO_2 standard of 50 ppb will produce substantial health benefits in six urban areas in the form of fewer respiratory hospitalizations, respiratory emergency department visits and cases of acute respiratory symptoms from reduced NO_2 exposure. In addition, attaining an NO_2 standard of 50 ppb will also produce substantial health co-benefits from reducing $PM_{2.5}$ exposure in the form of avoided premature mortality and other morbidity effects. Benefits are expected to be somewhat larger in the west due to the magnitude of the projected non-attainment problem in the four western urban areas and the magnitude of the non-attainment problem in those areas.

This analysis is the first time that EPA has estimated the monetized human health benefits of reducing exposure to NO_2 to support a proposed change in the NAAQS. In contrast to recent $PM_{2.5}$ and ozone-related benefits assessments, there was far less analytical precedent on which to base this assessment. For this reason, we developed entirely new components of the health impact analysis, including the identification of health endpoints to be quantified and the selection of relevant effect estimates within the epidemiology literature. As the NO_2 health literature continues to evolve, EPA will reassess the health endpoints and risk estimates used in this analysis.

While the monetized benefits of this regulation appear small when compared to recent NAAQS analyses, readers should not necessarily infer that the total monetized benefits of attaining a new NO_2 standard are used to justify the standard. The standard is set to be health protective independent of current or future ambient concentrations. For this NO2, it so happens that a health-protective standard does not require significant reductions in emissions, and thus not large benefits. Further, the size of the benefits is related to three principle factors. First, only a few areas of the country are not expected to attain the most stringent alternative NAAQS level in 2020. As demonstrated in previous RIA's, the magnitude and geographic extent of emission reductions in the control strategy necessary to bring an area into attainment are well correlated with the size of the monetized health benefits. Second, the size of monetized benefits is correlated with both the severity of those health effects correlated of NO_2 exposure. Because all areas of the country are expected to attain alternative NAAQS levels of 100 ppb and 200 ppb in 2020, the benefits are zero. For the most stringent alternative NAAQS of 50 ppb, we estimate the monetized human health benefits of reducing cases of morbidity and premature mortality among populations exposed to NO_2 and $PM_{2.5}$ to be $270 to $660 million (2006$, 3% discount rate).

Third, the monetized benefits are in part a function of the health endpoints quantified in the analysis. Compared to the $PM_{2.5}$ co-benefits, the benefits from reduced NO_2 exposure appear small. This is primary due to the decision not to quantify NO_2-related premature mortality and other morbidity endpoints due to the uncertainties associated with estimating this endpoint. Studies have shown that there is a relationship between NO_2 exposure and premature mortality, but that relationship is generally weaker than the PM-mortality relationship and efforts to quantify that relationship have been hampered by confounding with other pollutants. As shown in Figure 5.10, the $PM_{2.5}$ co-benefits represent over 97% of the total monetized benefits. This result is consistent with recent RIA's, where the $PM_{2.5}$ co-benefits represent a large proportion of total monetized benefits. Because premature mortality generally comprises over 90% of the total monetized benefits, this decision may underestimate the monetized health benefits of reduced NO_2 exposure.

In addition to NO_2-related premature mortality, there are several health benefits categories that we were unable to quantify due to data limitations, several of which could be substantial. Because NO_X is also a precursor to ozone, reductions in NO_X would also reduce ozone formation and the health effects associated with ozone exposure. Unfortunately, we did not have the air quality data available for this analysis to estimate the health effects of reduced ozone exposure as a result of the NO_X emission reductions. As the RIA for the Ozone NAAQS (U.S. EPA, 2008a) demonstrated, the monetized benefits of reducing ozone exposure can be substantial, up to 40% as much as the $PM_{2.5}$ co-benefits. However, in certain areas of the country, reductions in NO_2 emissions cause localized increases in ozone concentrations, which are sometimes referred to as “ozone disbenefits”. In urban cores, which are often dominated by fresh emissions of NOx, the ozone catalysts are removed via the production of nitric acid, which slows the ozone formation rate. Because NO_X is generally depleted more rapidly than VOCs, this effect is usually short-lived and the emitted NO_X can lead to ozone formation later and further downwind. Therefore, the net effect of NO_2 reductions is generally an overall decrease in ozone exposure.

We were unable to estimate the benefits from several welfare benefit categories, including improvements in visibility from reducing light-scattering particles because we lacked the necessary air quality data. Visibility directly affects people’s enjoyment of a variety of daily activities. Individuals value visibility both in the places they live and work, in the places they travel to for recreational purposes, and at sites of unique public value, such as the Great Smokey Mountains National Park. Previous RIAs for ozone (U.S. EPA, 2008a) and $PM_{2.5}$ (U.S. EPA, 2006a) indicate that visibility is an important benefit category, and previous efforts to monetize those benefits have only included a subset of visibility benefits, excluding benefits in urban areas and many national and state parks. Even this subset accounted for up to 5% of total monetized benefits in the Ozone NAAQS RIA.

We were also unable to estimate the ecosystem benefits of reduced nitrogen deposition because we lacked the necessary methodology to estimate ecosystem benefits. Previous assessments (U.S. EPA, 1999; U.S. EPA, 2005; U.S. EPA, 2008d; U.S. EPA, 2008g) indicate that ecosystem benefits are also an important benefits category, but those efforts were only able to monetize a tiny subset of ecosystem benefits in specific geographic locations, such as recreational fishing effects from lake acidification in the Adirondacks. Although there is some evidence that nitrogen deposition may have positive effects on agricultural output through passive fertilization, it is likely that the overall value is very small relative to other health and welfare effects. Despite methodological and data limitations that prevent an estimate of welfare benefits in this analysis, EPA is planning to assess the benefits of reducing nitrogen deposition as part of the RIA for the NOx/SOx secondary NAAQS, currently scheduled to be proposed in February 2010.

It is important to note that this analysis does not attempt to estimate attainment or nonattainment for any areas of the country other than those counties currently served by one of the 409 monitors in the current monitoring network. We recognize that once a network of near-roadway monitors is in place, more areas could exceed the new NO_2 NAAQS. However for this RIA analysis, we lack sufficient data to predict which counties might exceed the new NAAQS after implementation of a near-roadway monitoring network. Therefore, we are unable to estimate the benefits of that scenario.

In section 5.7 of this RIA, we discuss the revised presentation using benefits based on Pope et al. and Laden et al. as anchor points instead of the low and high end of the expert elicitation. This change was incorporated in direct response to recommendations from EPA's Science Advisory Board (U.S.EPA-SAB, 2008). Although using benefit-per-ton estimates limited our ability to incorporate all of their suggestions fully, we have incorporated the following recommendations into this analysis:

- Added "bottom line" statements where appropriate
- Clarified that the benefits results shown are not the actual judgments of the experts
- Acknowledged uncertainties exist at each stage of the analytic process, although difficult to quantify when using benefit-per-ton estimates
- Did not use the expert elicitation range to characterize the uncertainty as it focuses on the most extreme judgments with zero weight to all the others,
- Described the rationale for using expert elicitation in the context of the regulatory process (to characterize uncertainty)
- Identified results based on epidemiology studies and expert elicitation separately
- Showed central mass of expert opinion using graphs
- Presented the quantitative results using diverse tables and more graphics

5.11 References

American Lung Association. 2002. Trends in Asthma Morbidity and Mortality. American Lung Association, Best Practices and Program Services, Epidemiology and Statistics Unit. Available on the Internet at <http://www.lungusa.org/data/asthma/ASTHMAdt.pdf>.

Cropper, M. L. and A. J. Krupnick. 1990. The Social Costs of Chronic Heart and Lung Disease. Resources for the Future. Washington, DC. Discussion Paper QE 89-16-REV.

Delfino, R. J., H. Gong, Jr., W. S. Linn, E. D. Pellizzari and Y. Hu. 2003. Asthma symptoms in Hispanic children and daily ambient exposures to toxic and criteria air pollutants. Environ Health Perspect. Vol. 111 (4): 647-56.

Delfino, R. J., R. S. Zeiger, J. M. Seltzer, D. H. Street and C. E. McLaren. 2002. Association of asthma symptoms with peak particulate air pollution and effect modification by anti-inflammatory medication use. Environ Health Perspect. Vol. 110 (10): A607-17.

Dewanji, A. and S. H. Moolgavkar. 2000. A Poisson process approach for recurrent event data with environmental covariates. Environmetrics. Vol. 11: 665-673.

Dewanji, A. and S. H. Moolgavkar. 2002. Choices of stratification in Poisson process analysis of recurrent event data with environmental covariates. Stat. Med. Vol. 21: 3383-3393.

Fung, K. Y., S. Khan, D. Krewski and Y. Chen. 2006. Association between air pollution and multiple respiratory hospitalizations among the elderly in Vancouver, Canada. Inhal Toxicol. Vol. 18 (13): 1005-11.

Fung, K. Y. K., Daniel; Chen, Yue; Burnett, Rick; Cakmak, Sabit 2003. Comparison of time series and case-crossover analyses of air pollution and hospital admission data. International Journal of Epidemiology. Vol. 32: 1064–1070.

Industrial Economics, Inc. 2006. Expanded Expert Judgment Assessment of the Concentration-Response Relationship Between $PM_{2.5}$ Exposure and Mortality. Prepared for the U.S. EPA, Office of Air Quality Planning and Standards, September. Available on the Internet at <http://www.epa.gov/ttn/ecas/regdata/Uncertainty/pm_ee_report.pdf>.

Ito, K., G. D. Thurston and R. A. Silverman. 2007. Characterization of $PM_{2.5,}$ gaseous pollutants, and meteorological interactions in the context of time-series health effects models. J Expo Sci Environ Epidemiol. Vol. 17 Suppl 2: S45-60.

Kochi, I., B. Hubbell, and R. Kramer. 2006. An Empirical Bayes Approach to Combining Estimates of the Value of Statistical Life for Environmental Policy Analysis. Environmental and Resource Economics. 34: 385-406.

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. July.

Laden, F., J. Schwartz, F.E. Speizer, and D.W. Dockery. 2006. “Reduction in Fine Particulate Air Pollution and Mortality.” American Journal of Respiratory and Critical Care Medicine 173:667-672. Estimating the Public Health Benefits of Proposed Air Pollution Regulations. Washington, DC: The National Academies Press.

Linn, W. S., Y. Szlachcic, H. Gong, Jr., P. L. Kinney and K. T. Berhane. 2000. Air pollution and daily hospital admissions in metropolitan Los Angeles. Environ Health Perspect. Vol. 108 (5): 427-34.

Luginaah, I. N., K. Y. Fung, K. M. Gorey, G. Webster and C. Wills. 2005. Association of ambient air pollution with respiratory hospitalization in a government-designated "area of concern": the case of Windsor, Ontario. Environ Health Perspect. Vol. 113 (3): 290-6.

Moolgavkar, S. H. 2000a. Air Pollution and Daily Mortality in Three U.S. Counties. Environ Health Perspect. Vol. 108 (8): 777-784.

Moolgavkar, S. H. 2000b. Air Pollution and Hospital Admissions for Chronic Obstructive Pulmonary Disease in Three Metropolitan Areas in the United States. Inhalation Toxicology. Vol. 12 (Supplement 4): 75-90.

Moolgavkar, S. H. 2000c. Air pollution and hospital admissions for diseases of the circulatory system in three U.S. metropolitan areas. J Air Waste Manag Assoc. Vol. 50 (7): 1199-206.

Moolgavkar, S. H. 2003. Air Pollution and Daily Deaths and Hospital Admissions in Los Angeles and Cook Counties. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. Health Effects Institute. Boston, MA. May.

Mortimer, K. M., L. M. Neas, D. W. Dockery, S. Redline and I. B. Tager. 2002. The effect of air pollution on inner-city children with asthma. Eur Respir J. Vol. 19 (4): 699-705.

Mrozek, J.R., and L.O. Taylor. 2002. "What Determines the Value of Life? A Meta-Analysis." Journal of Policy Analysis and Management 21(2):253-270.

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

NYDOH. 2006. A Study of Ambient Air Contaminants and Asthma in New York City. New York State Department of Health Center for Environmental Health.

O'Connor, G. T., L. Neas, B. Vaughn, M. Kattan, H. Mitchell, E. F. Crain, R. Evans, 3rd, R. Gruchalla, W. Morgan, J. Stout, G. K. Adams and M. Lippmann. 2008. Acute respiratory health effects of air pollution on children with asthma in US inner cities. J Allergy Clin Immunol. Vol. 121 (5): 1133-1139 e1.

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. Vol. 12 (2): 200-8.

Peel, J. L., P. E. Tolbert, M. Klein, K. B. Metzger, W. D. Flanders, K. Todd, J. A. Mulholland, P. B. Ryan and H. Frumkin. 2005. Ambient air pollution and respiratory emergency department visits. Epidemiology. Vol. 16 (2): 164-74.

Pope, C.A., III, R.T. Burnett, M.J. Thun, E.E. Calle, 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.

Roman, Henry A., Katherine D. Walker, Tyra L. Walsh, Lisa Conner, Harvey M. Richmond, Bryan J. Hubbell, and Patrick L. Kinney. 2008. Expert Judgment Assessment of the Mortality Impact of Changes in Ambient Fine Particulate Matter in the U.S. Environ. Sci. Technol., 42(7):2268-2274.

Rowe, R. D. and L. G. Chestnut. 1986. Oxidants and Asthmatics in Los Angeles: A Benefits Analysis -- Executive Summary. Prepared for U.S. Environmental Protection Agency, Office of Policy Analysis. Prepared by Energy and Resource Consultants, Inc. Washington, DC. EPA-230-09-86-018. March.

Schildcrout, J. S., L. Sheppard, T. Lumley, J. C. Slaughter, J. Q. Koenig and G. G. Shapiro. 2006. Ambient air pollution and asthma exacerbations in children: an eight-city analysis. Am J Epidemiol. Vol. 164 (6): 505-17.

Schwartz, J., D. W. Dockery, L. M. Neas, D. Wypij, J. H. Ware, J. D. Spengler, P. Koutrakis, F. E. Speizer and B. G. Ferris. 1994. Acute Effects of Summer Air Pollution on Respiratory Symptom Reporting in Children. Am J Respir Crit Care Med. Vol. 150 (5): 1234-1242.

Smith, D. H., D. C. Malone, K. A. Lawson, L. J. Okamoto, C. Battista and W. B. Saunders. 1997. A national estimate of the economic costs of asthma. Am J Respir Crit Care Med. Vol. 156 (3 Pt 1): 787-93.

Stanford, R., T. McLaughlin and L. J. Okamoto. 1999. The cost of asthma in the emergency department and hospital. Am J Respir Crit Care Med. Vol. 160 (1): 211-5.

U.S. Environmental Protection Agency (U.S. EPA). 1999. The Benefits and Costs of the Clean Air Act 1990 to 2010: EPA Report to Congress. Office of Air and Radiation, Office of Policy, Washington, DC. November. Available on the Internet at < http://www.epa.gov/air/sect812/1990-2010/fullrept.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2000. Guidelines for Preparing Economic Analyses. EPA 240-R-00-003. National Center for Environmental Economics, Office of Policy Economics and Innovation. Washington, DC. September. Available on the Internet at <http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html/$file/cover.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2002. Letter to Recipients of Third Draft EPA PM Criteria Document. National Center for Environmental Assessment, Research Triangle Park, NC. June 5, 2002. Available on the Internet at <http://oaspub.epa.gov/eims/eimscomm.getfile?p_download_id=42380>.

U.S. Environmental Protection Agency (U.S. EPA). 2005. Regulatory Impact Analysis for the Final Clean Air Interstate Rule. Office of Air and Radiation. March. Available on the Internet at < http://www.epa.gov/cair/pdfs/finaltech08.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2006a. Regulatory Impact Analysis, 2006 National Ambient Air Quality Standards for Particulate Matter, Chapter 5. Office of Air Quality Planning and Standards, Research Triangle Park, NC. October. Available on the Internet at <http://www.epa.gov/ttn/ecas/regdata/RIAs/Chapter%205--Benefits.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2006b. Willingness to Pay for Environmental Health Risk Reductions when there are Varying Degrees of Life Expectancy: A White Paper. August. Available on the Internet at < http://yosemite.epa.gov/ee/epa/eerm.nsf/vwRepNumLookup/EE-0495>.

U.S. Environmental Protection Agency (U.S. EPA). 2008a. Regulatory Impact Analysis, 2008 National Ambient Air Quality Standards for Ground-level Ozone, Chapter 6. Office of Air Quality Planning and Standards, Research Triangle Park, NC. March. Available at <http://www.epa.gov/ttn/ecas/regdata/RIAs/6-ozoneriachapter6.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2008b. Technical Support Document: Calculating Benefit Per-Ton estimates, Ozone NAAQS Docket #EPA-HQ-OAR-2007-0225-0284. Office of Air Quality Planning and Standards, Research Triangle Park, NC. March. Available on the Internet at <http://www.regulations.gov>.

U.S. Environmental Protection Agency (U.S. EPA). 2008c. Integrated Science Assessment for Oxides of Nitrogen - Health Criteria (Final Report). National Center for Environmental Assessment, Research Triangle Park, NC. July. Available on the Internet at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=194645>.

U.S. Environmental Protection Agency (U.S. EPA). 2008d. Risk and Exposure Assessment for Review of the Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur (First Draft). Office of Air Quality Planning and Standards, Research Triangle Park, NC. August. Available on the Internet at <http://www.epa.gov/ttn/naaqs/standards/no2so2sec/data/20080923_rea_ch1-6_wattach.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2008e. Guidelines for Preparing Economic Analyses: External Review Draft. National Center for Environmental Economics, Office of Policy Economics and Innovation. Washington, DC. September. Available on the Internet at <http://yosemite.epa.gov/ee/epa/eermfile.nsf/vwAN/EE-0516-01.pdf/$File/EE-0516-01.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2008f. Risk and Exposure Assessment to Support the Review of the NO_2 Primary National Ambient Air Quality Standard (Final Report). Office of Air Quality Planning and Standards, Research Triangle Park, NC. November. Available on the Internet at <http://www.epa.gov/ttn/naaqs/standards/nox/data/20081121_NO2_REA_final.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2008g. Integrated Science Assessment for Particulate Matter (External Review Draft). National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-08/139. December. Available on the Internet at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=201805>.

U.S. Environmental Protection Agency (U.S. EPA). 2008h. Integrated Science Assessment for Oxides of Nitrogen and Sulfur –Ecological Criteria National (Final Report). National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-08/139. December. Available on the Internet at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=201485>.

U.S. Environmental Protection Agency (U.S. EPA). 2009. Regulatory Impact Analysis: National Emission Standards for Hazardous Air Pollutants from the Portland Cement Manufacturing Industry. Office of Air Quality Planning and Standards, Research Triangle Park, NC. April. Available on the Internet at <http://www.epa.gov/ttn/ecas/regdata/RIAs/portlandcementria_4-20-09.pdf>.

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2007. SAB Advisory on EPA's Issues in Valuing Mortality Risk Reduction. EPA-SAB-08-001. October. Available on the Internet at <http://yosemite.epa.gov/sab/sabproduct.nsf/4128007E7876B8F0852573760058A978/$File/sab-08-001.pdf>.

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2008. Characterizing Uncertainty in Particulate Matter Benefits Using Expert Elicitation. EPA-COUNCIL-08-002. July. Available on the Internet at < http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/43B91173651AED9E85257487004EA6CB/$File/EPA-COUNCIL-08-002-unsigned.pdf>.

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2009a. Review of EPA's Integrated Science Assessment for Particulate Matter (First External Review Draft, December 2008). EPA-COUNCIL-09-008. May. Available on the Internet at <http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/73ACCA834AB44A10852575BD0064346B/$File/EPA-CASAC-09-008-unsigned.pdf>.

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2009b. Consultation on EPA's Particulate Matter National Ambient Air Quality Standards: Scope and Methods Plan for Health Risk and Exposure Assessment. EPA-COUNCIL-09-009. May. Available on the Internet at <http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/723FE644C5D758DF852575BD00763A32/$File/EPA-CASAC-09-009-unsigned.pdf>.

Viscusi, V.K., and J.E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World." Journal of Risk and Uncertainty 27(1):5-76.

Yang, Q., Y. Chen, D. Krewski, R. T. Burnett, Y. Shi and K. M. McGrail. 2005. Effect of short-term exposure to low levels of gaseous pollutants on chronic obstructive pulmonary disease hospitalizations. Environ Res. Vol. 99 (1): 99-105.

Yang, Q., Y. Chen, Y. Shi, R. T. Burnett, K. M. McGrail and D. Krewski. 2003. Association between ozone and respiratory admissions among children and the elderly in Vancouver, Canada. Inhal Toxicol. Vol. 15 (13): 1297-308.

Chapter 6: Cost Analysis Approach and Results

Synopsis

This chapter describes our illustrative analysis of the engineering costs and monitoring costs associated with attaining the proposed alternative standards for the National Ambient Air Quality Standard (NAAQS) for NO_2. We present our analysis of these costs in four separate sections. Section 6.1 presents the cost estimates. Sections 6.2 and 6.3 summarize the illustrative economic and energy impacts of the proposed alternative standard, respectively, while Section 6.4 outlines the main limitations of the analysis. As mentioned previously, the analysis presented here represents an alternative standard of 50 pbb. We also intended to analyze 100 ppb, and 200 ppb, yet none of the counties in the current monitoring network were projected to exceed these alternative levels in our analysis year of 2020.

Section 6.1 breaks out discussion of cost estimates into five subsections. The first subsection summarizes the data and methods that we employed to estimate the costs associated with the control strategies outlined in Chapter 4. The second subsection presents county level estimates of the costs of identified controls associated with the regulatory alternatives examined in this RIA. Following this discussion, the third subsection describes the approach used to estimate the extrapolated costs of unspecified emission reductions that may be needed to comply with the alternative standards. The fourth subsection provides a brief discussion of the monitoring costs associated with the NAAQS. The fifth subsection provides the estimated total costs of the regulatory alternatives examined. This section concludes with a discussion of technological innovation and how that affects regulatory cost estimates.

It should be noted again that overall data limitations are very significant for this analysis. One critical area of uncertainty is the limited NO_2 monitoring network (discussed in chapter 2). Because monitors are present in only 409 counties nationwide, the universe of monitors exceeding the alternative NAAQS level of 50 ppb is very small—only six counties.

It is important to note also that this analysis does not attempt to estimate attainment or nonattainment for any areas of the country other than those counties currently served by one of the 409 monitors in the current network. Chapter 2 explains that the current network is focused on community-wide ambient levels of NO_2, and not near-roadway levels, which may be significantly higher, and the proposal also contains requirements for an NO_2 monitoring network that will include monitors near major roadways. We recognize that once a network of near-roadway monitors is put in place, more areas could find themselves exceeding the new hourly NO_2 NAAQS. However for this RIA analysis, we lack sufficient data to predict which counties might exceed the new NAAQS after implementation of a near-roadway monitoring network. Therefore we lack a credible analytic path to estimating costs and benefits for such a future scenario.

In addition, this chapter presents cost estimates associated with both identified control measures and unspecified emission reductions needed to reach attainment. Identified control measures include known measures for known sources that may be implemented to attain the alternative standard, whereas the achievement of unspecified emission reductions requires implementation of hypothetical additional measures in areas that would not attain the selected standard following the implementation of identified controls to known sources.

Note that the universe of sources achieving unspecified emission reductions beyond identified controls is not completely understood; therefore we are not able to identify known control devices or work practices to achieve these reductions. We calculated extrapolated costs for unspecified emission reductions using a fixed cost per ton approach. Section 6.1 below describes in more detail our approaches for estimating both the costs of identified controls and the extrapolated costs of unspecified emission reductions needed beyond identified controls.

As is discussed throughout this RIA, the technologies and control strategies selected for this analysis are illustrative of one approach that nonattainment areas may employ to comply with the revised NO_2 standard. Potential control programs may be designed and implemented in a number of ways, and EPA anticipates that State and Local governments will consider those programs that are best suited for local conditions. As such, the costs described in this chapter generally cover the annualized costs of purchasing, installing, and operating the referenced technologies. We also present monitoring costs. Because we are uncertain of the specific actions that State Agencies will take to design State Implementation Plans to meet the revised standard, we do not estimate the costs that government agencies may incur to implement these control strategies.

6.1 Engineering Cost Estimates

6.1.1 Data and Methods: Identified Control Costs

Consistent with the emissions control strategy analysis presented in Chapter 4, our analysis of the costs associated with the final NO_2 NAAQS focuses NOx emission controls for nonEGU, area, EGU, and mobile sources.

6.1.1.1 NonEGU Point and Area Sources

After designing the hypothetical control strategy using the methodology discussed in Chapter 4, EPA used AirControlNET to estimate engineering control costs for nonEGU and Area sources. AirControlNET calculates engineering 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 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 engineering costs 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 using the capital recovery factor (CRF)[1]. Where possible, cost calculations are used to calculate total annual control cost (TACC) which is a function of the capital (CC) and O&M costs. The capital recovery factor incorporates the interest rate and equipment life (in years) of the control equipment. Operating costs are calculated as a function of annual O&M and other variable costs. The resulting TACC equation is TACC = (CRF * CC) + O&M.

Engineering costs will differ based upon quantity of emissions reduced, plant capacity, or stack flow which can vary by emissions inventory year. Engineering costs will also differ by the year the costs are calculated for (i.e., 1999$ versus 2006$). For capital investment, we do not assume early capital investment in order to attain standards by 2020. For 2020, our estimate of annualized costs represents a "snapshot" of the annualized costs, which include annualized capital and O&M costs, for those controls included in our identified control strategy analysis. Our engineering cost analysis uses the equivalent uniform annual costs (EUAC) method, in which annualized costs are calculated based on the equipment life for the control measure along with the interest rate by use of the CRF as mentioned previously in this chapter. Annualized costs are estimated as equal for each year the control is expected to operate. Hence, our annualized costs for nonEGU point and area sources estimated for 2020 are the same whether the control measure is installed in 2019 or in 2010. We make no presumption of additional capital investment in years beyond 2020. The EUAC method is discussed in detail in

---

[1] For more information on this cost methodology and the role of AirControlNET, see Section 6 of the 2006 PM RIA, AirControlNET 4.1 Control Measures Documentation (Pechan, 2006b), or the EPA Air Pollution Control Cost Manual, Section 1, Chapter 2, found at http://www.epa.gov/ttn/catc/products.html#cccinfo.

the EPA Air Pollution Control Cost Manual[2]. Applied controls and their respective engineering costs are provided in the NO_2 NAAQS RIA docket.

6.1.1.2 EGU Sources: the Integrated Planning Model

The EGU analysis included in this RIA utilizes the latest version of IPM (v3.0) as part of the updated modeling platform. Results for EGU sources presented in this RIA do not reflect a new run from that model. Instead, we apply NOx controls to specific EGUs, and the data for these NOx controls are taken from the latest IPM version. IPM v3.0 includes input and model assumption updates in modeling the power sector and incorporates Federal and State rules and regulations adopted before September 2006 and various new source review (NSR) settlements. A detailed discussion of uncertainties associated with the EGU sector modeling can be found in the 2006 PM NAAQS RIA (pg. 3-50).

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[3].

IPM v3.0 includes SO_2, NOx, 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) 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 6.1 summarizes retrofit NOx emission control performance assumptions that are included in IPM v3.0.

---

[2] http://epa.gov/ttn/catc/products.html#cccinfo

[3] http://www.epa.gov/airmarkets/progsregs/epa-ipm.html

Table 6.1: Summary of Retrofit NOx Emission Control Performance Assumptions

	Selective Catalytic Reduction (SCR)		Selective Non-Catalytic Reduction (SNCR)	
Unit Type	**Coal**	**Oil/Gas[a]**	**Coal**	**Oil/Gas[a]**
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

[a] Controls to oil- or gas-fired EGUs are not applied as part of EGU control measures applied for this RIA. The control assumptions in this Table are taken from Khan, S. and Srivastava, R. "Updating Performance and Cost of NOx Control Technologies in the Integrated Planning Model," Mega Symposium, August 30-September 2, 2004, Washington, D.C.

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 v3.0. Detailed cost and performance derivations for NOx controls are discussed in detail in the EPA's documentation of IPM v. 3.0[4].

6.1.1.3 Onroad and Nonroad Mobile Sources

Engineering cost information for mobile source controls is identical to that provided in the recent Ozone NAAQS RIA[Error! Bookmark not defined.], and was taken from studies conducted by EPA for previous rulemakings and programs involving voluntary and local measures that could be used by state or local programs to assist in improving air quality.

Engineering costs, in terms of dollars per ton emissions reduced, were applied to emission reductions calculated for the onroad and nonroad mobile sectors that were generated using the National Mobile Inventory Model (NMIM). NMIM is an EPA model for estimating air emissions from highway vehicles and nonroad mobile equipment. NMIM uses current versions of EPA's model for onroad mobile sources, MOBILE6, and nonroad mobile sources, NONROAD, to calculate emission inventories[5].

6.1.2 Identified Control Strategy Analysis Engineering Costs

In this section, we provide engineering cost estimates of the control strategies identified in Chapter 4 that include control measures applied to nonEGU sources, area sources, EGUs, and onroad and nonroad mobile sources. Engineering costs generally refer to the capital equipment

---

[4] http://www.epa.gov/airmarkets/progsregs/epa-ipm/past-modeling.html.

[5] More information regarding the National Mobile Inventory Model (NMIM) can be found at http://www.epa.gov/otaq/nmim.htm

installation expense, the site preparation costs for the application, and annual operating and maintenance costs.

The total annualized cost of control in each geographic area of our analysis for the hypothetical control scenario is provided in Table 6.2. These numbers reflect the engineering costs across all 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 both 7% and 3% discount rates for controls applied to every emissions sector. 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 point source sectors were the only sectors 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% discount rate estimate. Figure 6.1 does reveal that over two thirds of the costs of the identified control strategy are related to point sources. It is expected that the 3% discount rate value is slightly overestimated due to the addition of cost sectors at a higher discount rate. With the exception of the 3 % Total Annualized Cost estimate in Table 6.2, engineering cost estimates presented throughout this and subsequent chapters are based on a 7% discount rate.

Table 6.2 summarizes these costs by geographic area. As indicated in the table, the estimated costs of these controls under the 50 ppb alternative standard are $44 million per year, assuming a discount rate of seven percent. Applying a three percent discount rate this value becomes $36 million per year. Consistent with Chapter 4's summary of the air quality impacts associated with identified controls, the cost estimates in Table 6.2 reflect partial attainment with the alternative standard being examined in this RIA. Table 6.3 represents the average cost per ton of the applied controls by geographic area. These costs range from $800 to approximately $4,000 per ton using a discount rate of seven percent. Table 6.4 presents the average cost per ton by emissions sector for this analysis. Figure 6.1 indicates the percentage of the costs by emissions sector. Consistent with the identified control strategy analysis emission reductions presented in Chapter 4, a majority of the costs are from point source controls applied to both nonEGU and EGU sources.

Table 6.2: Annual Control Costs of Identified Controls applied for the Alternative Standard Analysis of 50 ppb (Millions of 2006$) [a, b]

State	County	3% Discount Rate[c]	7% Discount Rate
CA	Los Angeles	-[d]	-[d]
CO	Adams	$14	$18
LA	East Baton Rouge	$6.6	$8.3
TX	El Paso	$9.0[d]	$10[d]
UT	Salt Lake	$6.9	$7.7
VA	Charles City	$0.03	$0.04
	Total	**$36**	**$44**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.

[c] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For this identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

[d] These values represent partial attainment costs for the identified control strategy analysis. These locations were not able to attain the alternative standard being analyzed with identified controls only.

Table 6.3: Annual Cost per Ton of Identified Controls applied for the Alternative Standard Analysis of 50 ppb by Geographic Area (2006$) [a, b]

State	County	3% Discount Rate[c]	7% Discount Rate
CA	Los Angeles	-	-
CO	Adams	$1,600	$2,100
LA	East Baton Rouge	$1,200	$1,600
TX	El Paso	$3,400	$3,900
UT	Salt Lake	$1,500	$1,700
VA	Charles City	$700	$800

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.

[c] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For this identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

Table 6.4: Annual Cost per Ton of Identified Controls applied for the Alternative Standard Analysis of 50 ppb by Emissions Sector (2006$) [a, b]

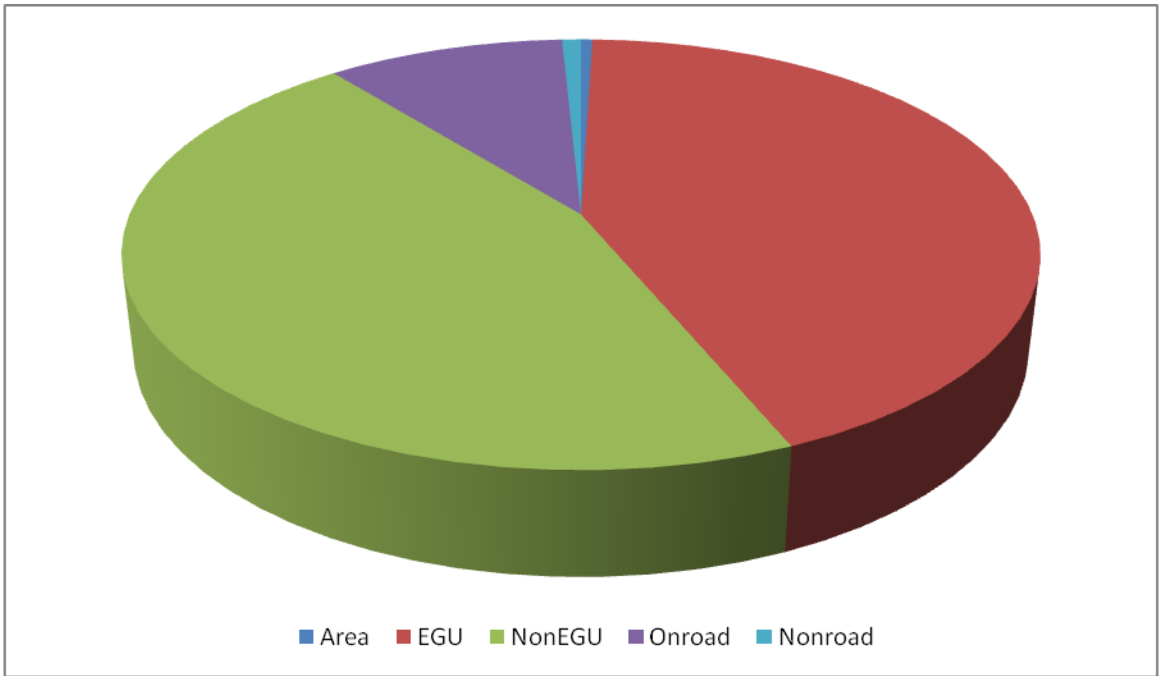
Emissions Sector	3% Discount Rate [c]	7% Discount Rate
NonEGU	$1,800	$2,200
Area	$1,800	$1,800
Onroad	$1,900	$1,900
Nonroad	$4,300	$4,300
EGU	$1,600	$2,000

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.

[c] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For this identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

Figure 6.1: Percentage of Identified Control Costs by Emissions Sector (7% DiscountRate, 2006$)



6.1.3 Extrapolated Costs

Prior to presenting the methodology for estimating costs for unspecified emission reductions, it is important to provide information from EPA's Science Advisory Board Council Advisory on the issue of estimating costs of unidentified control measures.[6]

> *812 Council Advisory, Direct Cost Report, Unidentified Measures (charge question 2.a):*
>
> *"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 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*

---

[6] U.S. Environmental Protection Agency, Advisory Council on Clean Air Compliance Analysis (COUNCIL), *Council Advisory on OAR's Direct Cost Report and Uncertainty Analysis Plan*, Washington, DC. June 8, 2007.

> *simplest and most straightforward. Uncertainty might be represented using alternative fixed costs per ton of emissions avoided."*

EPA has considered this advice and the requirements of E.O. 12866 and OMB circular A-4, which provides guidance on the estimation of benefits and costs of regulations.

As indicated above the identified control costs do not result in attainment of the selected or alternative standards in two areas. In these areas, unspecified emission reductions needed beyond identified controls will likely be necessary to reach attainment. Emission reductions needed beyond identified controls is an issue for Los Angeles County and El Paso County. Unfortunately all identified emission control measures were exhausted for Los Angeles County during the hypothetical controls analysis of the Ozone NAAQS. Due to the complete lack of data on potential additional control measures to be applied in Los Angeles County and very limited data for El Paso County, establishing a credible method to cost emission reductions needed beyond identified potential controls is an extremely challenging task.

Regarding Los Angeles County, it should be noted that the California Air Resources (CARB) included a number of control measures to reduce emissions at the Port of Los Angeles and the Port of Long Beach in its 2007 state implementation plan (SIP) that addresses the 8-hour ozone and PM2.5 nonattainment problems in the South Coast nonattainment area. These control measures are expected to result in significant NOx emission reductions, but are not reflected in this analysis due to data and resource limitations. See the discussion in Chapter 3 for more details on local control programs underway in Southern California.

Taking into consideration the above SAB advice we estimated the costs of unspecified future emission reductions using a fixed cost per ton approach. In previous analyses we have estimated the extrapolated costs using other marginal cost based approaches in addition to the fixed cost per ton approach (the dataset of applied NOx control measures was much more robust for the recent Ozone NAAQS RIA**Error! Bookmark not defined.**). We examine the data available for each analysis and determine on a case by case basis the appropriate extrapolation technique. Less than fifty control measures were applied in the analysis across the six geographic areas analyzed for the area-wide analysis. During the ozone NAAQS analysis the dataset used to calculate extrapolated costs contained many thousand observations. Due to the limited number of control measures applied in this analysis, we concluded that it would not be credible to establish a marginal cost-based approach or a representative value for the costs of further NOx emission reductions.

Another consideration for this analysis is the unique circumstances (Chapter 3, Sections 3.3.2.2 and 3.3.2.3) for Los Angeles and El Paso. These two geographic areas have specific local conditions that may affect their ability to attain any alternative NO_2 standard. The Los Angeles County monitor appears to be affected significantly by port emissions. The Port of Long Beach is currently undertaking its own significant action to reduce both NOx and PM emissions from ships, trucks, trains, and cargo-handling equipment. The nature of these controls appear to be most similar to the types of mobile controls used elsewhere in this analysis; therefore we considered applying the average cost of these controls instead of a higher fixed cost per ton. We decided, however, that we did not have enough information about these controls to assign them emission reductions or definite costs. The nature of these controls appear to be primarily mobile sources also affected our consideration of applying a version of the "hybrid" approach to the extrapolated costs used in the ozone NAAQS RIA. We ultimately decided against applying the "hybrid" cost approach for this analysis since that estimate was based primarily on nonEGU point source control costs. Additionally, the El Paso monitors are very close to the international border with the city of Juarez just to the southwest, and emissions from across the international border could affect the modeled monitor concentrations. In the past, state implementation plan (SIP) policy has allowed for a waiver of full attainment in similar instances.

Therefore the extrapolated costs presented here are perhaps misnamed, in that they represent a lack of information regarding known control or other strategies that may be implemented in Los Angeles and El Paso, and do not necessarily represent unknown control measures that will need to be developed in the future for these areas to attain the alternative standard analyzed. For these reasons, we have relied upon a simple fixed cost approach utilized for the ozone NAAQS analysis to represent the fixed cost of unspecified emission reductions for this analysis. The primary estimate presented is $15,000 (2006$), with sensitivities of $10,000/ton and $20,000/ton. The $15,000 per ton amount is commensurate with that used in the Ozone NAAQS RIA**Error! Bookmark not defined.** using 2006 dollars. The ozone NAAQS estimated the central estimate through averaging the control measure dataset cost per ton utilized in that analyses as well as looking into previous EPA analyses where NOx control measures were applied. In addition, the use of a fixed cost per ton is consistent with what an advisory committee to the Section 812 second prospective analysis on the Clean Air Act

Amendments suggested. In addition, we scanned the most recent NOx emission trades on California's Regional Clean Air Incentives Market (RECLAIM) Program website[7]. These trading values were less than the primary estimate presented in this RIA.

The estimation of engineering costs for unspecified emission reductions needed to reach attainment many years in the future is inherently a difficult issue. The universe of sources where unspecified emission reductions beyond identified controls are achieved is not completely understood; therefore, we are not able to identify known control devices or work practices to achieve these reductions. We expect that additional control measures that we were not able to identify may be available today, or may be developed by 2020. As described later in this chapter, our experience with Clean Air Act implementation shows that technological advances and development of innovative strategies can make possible emissions reductions that are unforeseen today, and to reduce costs of emerging technologies over time. But we cannot quantitatively predict the amount of technology advance in the future. For areas needing significant additional emission reductions, much of the control must be for sources that historically have not been controlled. The relationship of the cost of such control to the cost of control options available today is not at all clear. Available, current known control measures increase in cost beyond the range of what has ever been implemented and would still not provide the needed additional control for full attainment in the analysis year 2020. We recognize that a single fixed cost of control does not account for the different sets of conditions that might describe situations where controls are needed beyond identified controls. Yet, the limited emission controls dataset applied for the identified control strategy analysis does not enable us the ability to estimate extrapolated costs using more sophisticated methods.

We have utilized the fixed cost per ton for this proposed rule RIA, however, Chapter 7 contains a basic analysis of attainment for different standards for a hypothetical near roadway network using simple assumptions regarding the relationship between area and roadway monitors. We will continue to develop this analysis, including identifying specific control measures to illustrate attainment in counties that are projected to violate a new NO_2 standard in 2020. We will investigate alternative options for extrapolating costs of attainment in the final NO_2 NAAQS RIA if the dataset and information is more robust and enables us to credibly extrapolate unknown control costs.

---

[7] http://www.aqmd.gov/RECLAIM/rtc_main.html; page last updated March 31, 2009, data for previous 3 months.

Table 6.5 presents the extrapolated costs for Los Angeles and El Paso. For the primary estimate using the fixed cost of $15,000/ton, over 77% of the extrapolated costs are attributed to Los Angeles County. Both Los Angeles and El Paso have unique air quality situations which contribute to the projected nonattainment for these counties. See Chapter 4 for a complete discussion of the air quality projections for these counties.

Table 6.5: Extrapolated Costs applied for the Alternative Standard Analysis of 50 ppb (Millions of 2006$) [a, b]

State	County	$10,000/ton	**$15,000/ton**	$20,000/ton
CA	Los Angeles	$180	**$270**	$360
TX	El Paso	$56	**$84**	$112
	Total	$240	**$350**	$470

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] Estimates of extrapolated costs are assumed using a 7% discount rate. Given the fixed cost per ton approach used here, 3% discount rate estimates could not be calculated.

6.1.4 Monitoring Costs

The proposed amendments would revise the technical requirements for NO2 monitoring sites, require the siting and operation of additional NO2 ambient air monitors, and the reporting of the collected ambient NO2 monitoring data to EPA's Air Quality System (AQS). We have estimated the burden based on the proposed monitoring requirements of this rule. Details of the burden estimate are contained in the information collection request (ICR) accompanying the proposed rule.[8] The ICR estimates annualized costs of a new monitoring network at approximately $7.1 million per year.

6.1.5 Summary of Cost Estimates

Table 6.6 provides a summary of total costs to achieve the alternative standard of 50 ppb in the year 2020. Figures 6.2 and 6.3 present the portion of total costs that is represented by identified controls and the portion of costs that is represented by extrapolated costs for unspecified emission reductions.

The significant difference between the costs of identified controls alone and the cost of achieving attainment (i.e. including both identified controls and emission reductions beyond identified controls) in this and other areas reflects the limited information available to EPA on the control measures that sources may implement. Although AirControlNET contains information on a large number of different point source controls, we would expect that State and local air quality managers would have access to additional information on the controls available to the most significant sources.

---

[8] ICR 2358.01, May 2009.

Table 6.6: Total Costs for Alternative Standard 50 ppb (Millions of 2006$)[a, b]

		3% Discount Rate[c]	7% Discount Rate
Identified Control Costs		$36	$44
Monitoring Costs		$3.6[d]	$3.6[d]
Extrapolated Costs	Fixed Cost ($10,000/ton)	$240	$240
	Fixed Cost ($15,000/ton)	$350	$350
	Fixed Cost ($20,000/ton)	$470	$470
Total Costs	Fixed Cost ($10,000/ton)	$280	$280
	Fixed Cost ($15,000/ton)	**$390**	**$400**
	Fixed Cost ($20,000/ton)	$510	$520

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.

[c] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For the identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized identified control cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

[d] These numbers do not represent a different discount rate for 3% and 7%.

Figure 6.2: Identified Control Costs versus Extrapolated Costs (Fixed Cost $15,000/ton) by County (Millions of $2006)

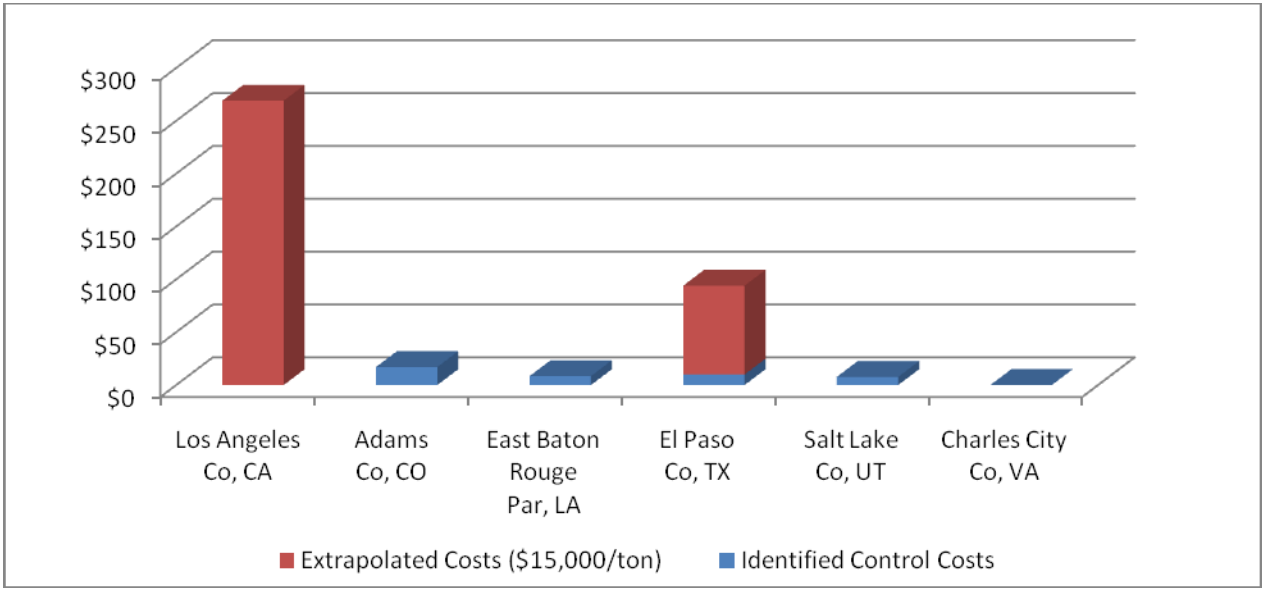
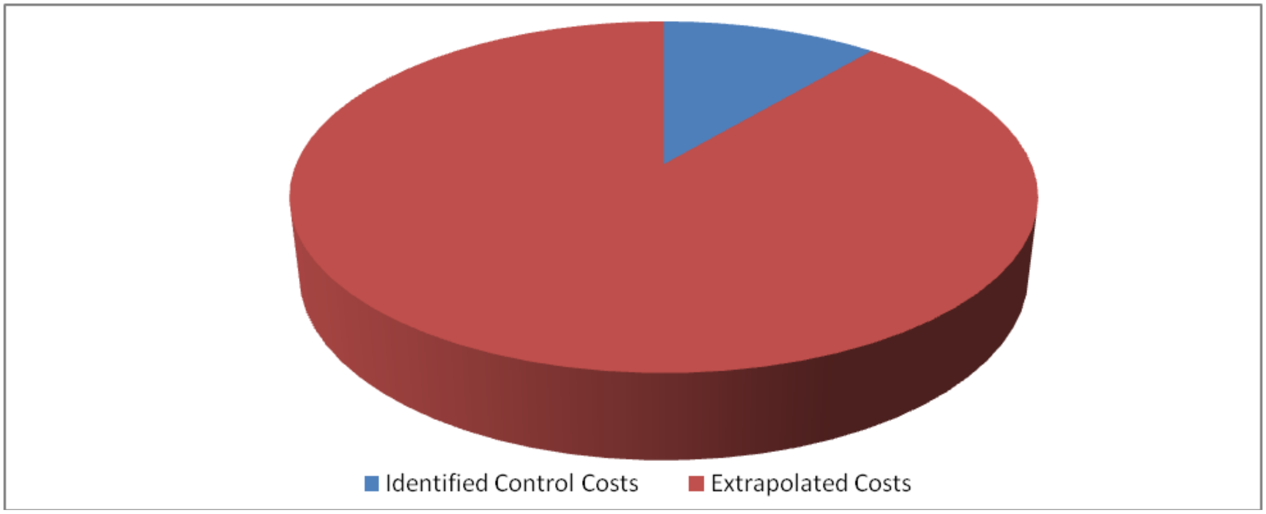


Figure 6.3: Percentage of Total Costs for Identified Control Costs versus Extrapolated Costs

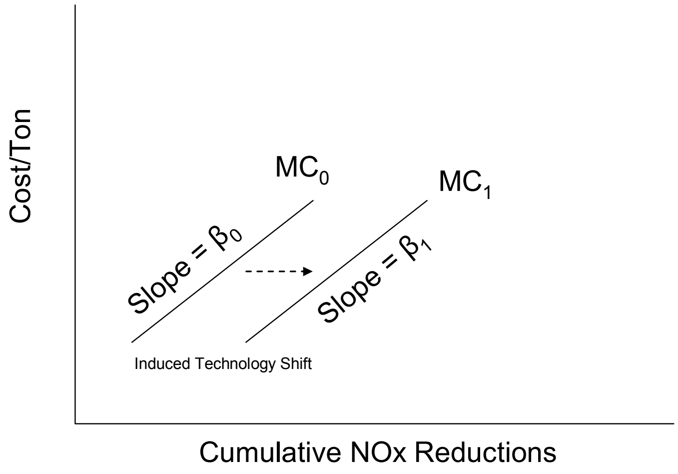


6.1.6 Technology Innovation and Regulatory Cost Estimates

There are 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. Studies[9] 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.

Constantly increasing marginal costs are 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 for such equipment (Figure 6.4)[10] as well as perhaps a decrease in its slope, reducing marginal costs per unit of abatement, and thus deviate from the assumption of a static 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.

Figure 6.4: Technological Innovation Reflected by Marginal Cost Shift



---

[9] Harrington et al. (2000) and previous studies cited by Harrington.
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.

[10] 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.

6.1.6.1 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 powder-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
- Idle-reduction technologies for engines, including truck stop electrification efforts
- Market penetration of gas-electric hybrid vehicles, and clean fuels
- The development of retrofit technology to reduce emissions from in-use vehicles and non-road equipment

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 and most of the examples are discussed further below.

What is known as "learning by doing" or "learning curve impacts", which is a concept distinct from technological innovation, has also 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. Learning curve impacts can be defined generally as the extent to which variable costs (of production and/or pollution control) decline as firms gain experience with a specific technology. Such impacts have been identified to occur in a number of studies conducted for various production processes. Impacts such as these would manifest themselves as a lowering of expected costs for operation of technologies in the future below what they may have been.

The magnitude of learning curve impacts on pollution control costs has been estimated for a variety of sectors as part of the cost analyses done for the Draft Direct Cost Report for the second EPA Section 812 Prospective Analysis of the Clean Air Act Amendments of 1990.[11] In that report, learning curve adjustments were included for those sectors and technologies for which learning curve data was available. A typical learning curve adjustment example is to reduce either capital or O&M costs by a certain percentage given a doubling of output from that sector or for that technology. In other words, capital or O&M costs will be reduced by some percentage for every doubling of output for the given sector or technology.

T.P. Wright, in 1936, was the first to characterize the relationship between increased productivity and cumulative production. He analyzed man-hours required to assemble successive airplane bodies. He suggested the relationship is a log linear function, since he observed a constant linear reduction in man-hours every time the total number of airplanes assembled was doubled. The relationship he devised between number assembled and assembly time is called Wright's Equation (Gumerman and Marnay, 2004)[12]. This equation, shown below, has been shown to be widely applicable in manufacturing:

Wright's Equation: $C_N = C_o * N^b$,

Where:

N = cumulative production

C_N = cost to produce N^{th} unit of capacity

C_o = cost to produce the first unit

B = learning parameter = ln (1-LR)/ln(2), where

LR = learning by doing rate, or cost reduction per doubling of capacity or output.

The percentage adjustments to costs can range from 5 to 20 percent, depending on the sector and technology. Learning curve adjustments were prepared in a memo by IEc supplied to US EPA and applied for the mobile source sector (both onroad and nonroad) and for application of various EGU control technologies within the Draft Direct Cost Report.[13] Advice received from the SAB Advisory Council on Clean Air Compliance Analysis in June 2007 indicated an interest in

---

[11] E.H. Pechan and Associates and Industrial Economics, Direct Cost Estimates for the Clean Air Act Second Section 812 Prospective Analysis: Draft Report, prepared for U.S. EPA, Office of Air and Radiation, February 2007. Available at http://www.epa.gov/oar/sect812/mar07/direct_cost_draft.pdf.

[12] Gumerman, Etan and Marnay, Chris. Learning and Cost Reductions for Generating Technologies in the National Energy Modeling System (NEMS), Ernest Orlando Lawrence Berkeley National Laboratory, University of California at Berkeley, Berkeley, CA. January 2004, LBNL-52559.

[13] Industrial Economics, Inc. Proposed Approach for Expanding the Treatment of Learning Curve Impacts for the Second Section 812 Prospective Analysis: Memorandum, prepared for U.S. EPA, Office of Air and Radiation, August 13, 2007.

expanding the treatment of learning curves to those portions of the cost analysis for which no learning curve impact data are currently available. Examples of these sectors are non-EGU point sources and area sources. The memo by IEc outlined various approaches by which learning curve impacts can be addressed for those sectors. The recommended learning curve impact adjustment for virtually every sector considered in the Draft Direct Cost Report is a 10% reduction in O&M costs for two doubling of cumulative output, with proxies such as cumulative fuel sales or cumulative emission reductions being used when output data was unavailable.

For this RIA, we do not have the necessary data for cumulative output, fuel sales, or emission reductions for sectors included in our analysis in order to properly generate control costs that reflect learning curve impacts. Clearly, the effect of including these impacts would be to lower our estimates of costs for our control strategies in 2020, but we are not able to include such an analysis in this RIA.

6.1.6.2 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 the opportunity for technical advances is greater.

- *Multi-rule study:* Harrington et al. of Resources for the Future[14] 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. It is worth noting here, that the controls applied for this NAAQS do not

---

[14] 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.

use an economic incentive mechanism. In addition, Harrington also states that overestimation of total costs can be due to error in the quantity of emission reductions achieved, which would also cause the benefits to be overestimated.

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."

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.

- *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 lower than originally projected by EPA.[15] 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. The fuel switching from high-sulfur to low-sulfur coal was spurred by a reduction in rail transportation costs due to deregulation of rail rates during the 1990's 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[a]
Ex post estimates	\$1.0 to \$1.4 billion

[a] 2010 Phase II cost estimate in 1995\$.

- *EPA Fuel Control Rules:* A 2002 study by EPA's Office of Transportation and Air Quality[16] examined EPA vehicle and fuels rules and found a general pattern that "all ex ante

---

[15] Carlson, Curtis, Dallas R. Burtraw, Maureen, Cropper, and Karen L. Palmer. 2000. "Sulfur Dioxide 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.

[16] 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.

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.[17] An example focusing on fuel rules is provided:

Table 6.7: Comparison of Inflation-Adjusted Estimated Costs and Actual Price Changes for EPA Fuel Control Rules[a]

	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

[a] 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.

- 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.[18]

---

[17] 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."

[18] 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.

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[19] 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."

- Additional examples of decreasing costs of emissions controls include: SCR catalyst costs decreasing from \$11k-\$14k/m^3 in 1998 to \$3.5k-\$5k/m^3 in 2004, and improved low NOx burners reduced emissions by 50% from 1993-2003 while the associated capital cost dropped from \$25-\$38/kW to \$15/kW[20].

We cannot estimate the precise interplay between EPA regulation and technology improvement, but it is clear that a *priori* cost estimation often results in overestimation of costs because changes in technology (whatever the cause) make less costly control possible.

---

[19] Hammit, J.K. (2000). "Are the costs of proposed environmental regulations overestimated? Evidence from the CFC phaseout." *Environmental and Resource Economics*, 16(#3): 281-302.

[20] ICF Consulting. October 2005. The Clean Air Act Amendment: Spurring Innovation and Growth While Cleaning the Air. Washington, DC. Available at http://www.icfi.com/Markets/Environment/doc_files/caaa-success.pdf.

6.2 Economic Impacts

The assessment of economic impacts (Table 6.8) was conducted simply based on those source categories which are assumed in this analysis to become controlled. The impacts presented here are an extension of the engineering costs, where engineering costs are allocated to specific source categories by North American Industry Classification System (NAICS) code.

Table 6.8: Annual Costs of Identified Controls by Industry for Alternative Standard 50 ppb (Millions of 2006$)[a, b, c]

NAICS Code	Industry Description	3% Discount Rate[d]	7% Discount Rate	Industry Revenue in 2007[e]	Cost/Revenue Ratio
11	Agriculture, Forestry, Fishing, and Hunting	$0.03	$0.03	-	-
212	Mining	$2.7	$3.3	$78,000	< 0.01%
2221	Electric Power Generation, Transmission and Distribution	$15	$19	$560,000	< 0.01%
23	Construction	$0.02	$0.02	$1,700,000	< 0.01%
322	Paper Manufacturing	$0.03	$0.04	$170,000	< 0.01%
324	Petroleum and Coal Products Manufacturing	$7.4	$9.2	$590,000	< 0.01%
325	Chemical Manufacturing	$5.2	$6.5	$720,000	< 0.01%
331	Primary Metal Manufacturing	$0.23	$0.25	$250,000	< 0.01%
484	Truck Transportation	$3.9	$3.9	$220,000	< 0.01%
486	Pipeline Transportation	$0.27	$0.30	$24,000	< 0.01%
488	Support Activities for Transportation	$0.01	$0.01	$93,000	< 0.01%
928	National Security and International Affairs	$0.04	$0.06	-	-

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.

[c] NAICS codes were unavailable for area source controls and the best workplaces for commuters control. These controls account for less than 1% of the total identified control strategy costs.

[d] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For the identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized identified control cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

[e] Source: U.S. Census Bureau 2007 Economic Census

6.2 Energy Impacts

This section summarizes the energy consumption impacts alternative NO_2 NAAQS of 50 ppb. The NO_2 NAAQS revisions do not constitute a "significant energy action" as defined in Executive Order 13211; this information merely represents impacts of the illustrative control strategy applied in the RIA. The rule does not prescribe specific 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.

For this RIA, implementation of the control measures needed for attainment with the alternative standards will likely lead to increased energy consumption among NOx emitting facilities. To control emissions effectively, these measures require a significant amount of electricity that affected facilities are not expected to consume under baseline conditions. The available information on these controls suggests that they are not typically powered by natural gas or other fossil fuels; therefore, our analysis of energy impacts focuses exclusively on electricity consumption. In addition, because the energy consumption associated with emission reductions beyond identified controls is uncertain, we only consider the energy impacts associated with identified controls.

To assess the electricity consumption impacts associated with identified controls, we relied on the AirControlNET outputs generated for this analysis. For most identified controls, AirControlNET estimates electricity costs separately from other operating and maintenance (O&M) costs. Therefore, for sources expected to implement these controls, AirControlNET provides direct estimates of the additional electricity costs expected under the standard alternatives. We calculate the electricity consumption associated with these costs based on the unit cost of electricity assumed by AirControlNET (7.8 cents/kilowatt hour in 2006 dollars).

For a number of identified controls, AirControlNET does not separate the cost of electricity from other O&M costs. Similarly, the cost data for several controls identified from sources other than AirControlNET do not distinguish between electricity and other O&M costs. We estimate the electricity costs associated with these measures based on electricity's assumed share of total O&M, which we estimate based on AirControlNET's results for those controls where it separates electricity costs from other O&M costs. For some controls, O&M costs are not estimated separately from capital costs. In these cases, we assume that O&M represents a fixed share of annual costs based on the cost data for those controls where O&M and capital are calculated separately.

Table 6.9 summarizes the estimated energy impacts associated with the selected and alternative standards. As indicated in the table, we estimate that sources installing identified controls under the alternative standards will increase their electricity consumption in 2020 by approximately 1,400 megawatt-hours (MWh) under the selected standard.

Table 6.9: Summary of Energy Impacts

	Alternative Standard: 50 ppb
Electricity Cost (millions of year 2006$)	$0.11
Electricity Consumption (Megawatt-hours consumed in 2020)	1,400

6.4 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 engineering cost analysis is subject to uncertainties and limitations.

- One of these limitations is that we do not have sufficient information for all of our known control measures to calculate cost estimates that vary with an interest rate. We are able to calculate annualized costs at an interest rate other than 7% (e.g., 3% interest rate) where there is sufficient information—available capital cost data, and equipment life—to annualize the costs for individual control measures. For the vast majority of nonEGU point source control measures, we do have sufficient capital cost and equipment life data for individual control measures to prepare annualized capital costs using the standard capital recovery factor. Hence, we are able to provide annualized cost estimates at different interest rates for the point source control measures.

- For area source control measures, the engineering cost information is available only in annualized cost/ton terms. We have extremely limited capital cost and equipment life data for area source control measures. We know that these annualized cost/ton estimates reflect an interest rate of 7% because these estimates are typically products of technical memos and reports prepared as part of rules issued by EPA over the last 10 years or so, and the costs estimated in these reports have followed the policy provided in OMB circular A-4 that recommends the use of 7% as the interest rate for annualizing regulatory costs. Capital cost information for these area source controls, however, is often limited since these measures are often not the traditional add-on controls where the capital cost is well known and convenient to estimate. The limited availability of useful capital cost data for such control measures has led to our use of annualized cost/ton estimates to represent the engineering costs of these controls in our cost tools and hence in this RIA.

- For mobile source measures, the situation is very much like that for our area source measures. We do not have sufficient capital cost information to compute annualized costs for interest rates other than 7%.

- 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 "no cost" [21] 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 analysis also did not consider transactional costs and/or effects on labor supply in the illustrative analysis.

---

[21] "No cost" options considered in this RIA were continuous I&M and Elimination of Long Duration Idling.

Chapter 7: Screening Level Analysis of Approximated Future Near-Roadway NO_2 Ambient Concentrations

Introduction

In the main body of the RIA, we projected current area-wide monitor values to future year monitor values directly, using future year CMAQ modeling outputs that take into account expected changes in emissions from 2006 to 2020. Because a near-roadway monitoring network does not currently exist, it was not possible to do this same direct projection into the future for near-roadway peaks. This analysis therefore represents a much more uncertain screening level approximation of future year near-roadway air quality. Note in addition that this analysis cannot predict air quality in locations for which there is no current NO_2 monitor.

This analysis relies on current and future estimated air quality concentrations at area-wide monitors, making adjustments to future year projections using derived estimates of the relationship between future year area-wide air quality peaks and current near-roadway peaks.

7.1 Monitor Selection

We first select "areawide" monitors to adjust to approximate near-roadway conditions.[1] The monitors included in this analysis are those considered to be representative of "area-wide" conditions; i.e. those monitors to which it would be appropriate to apply the gradient to scale from area-wide to near-roadway conditions. Accordingly, we did not include monitors that are microscale or middle scale, source oriented, non-EPA, or those affected by a dominant source, including roadways, in this analysis.

OAQPS applied several techniques to identify NO_2 monitors that are appropriate to scale-up to simulate near-road monitor concentrations. Consistent with the NO_2 NAAQS and monitoring rulemaking proposal, we used only "area-wide" monitors to scale-up to simulate near-road concentrations. Area-wide monitors are monitors that are not significantly influenced by point, area, or mobile sources, meaning they typically do not represent the maximum concentration that may be attributable to a source or sources. Further, area-wide sites represent neighborhood, urban, and regional spatially representative scales.

To select monitors for adjustment to near-road conditions, OAQPS used (1) monitor characteristics in the AQS database, (2) visual inspection by using Google Earth geospatial

---

[1] This process excluded no monitoring sites; it merely identified those monitors relevant to adjust for a near-roadway approximation. Monitors not selected for adjustment were still included in the overall analysis.

software, and (3) the condition that only Core Based Statistical Areas (CBSAs) with populations of 350,000 or greater would be required to have at least one maximum concentration site near roadways.

Based on the monitor characteristics in the AQS database, we excluded any site that is:

- Microscale site (measurement scale)
- Middle scale site (measurement scale)
- Source oriented site (monitor objective)
- A combination of metadata: Highest Concentration, Neighborhood scale, and Point source dominated (monitor objective/measurement scale/dominant source)
- Identified as operated by industry, as these sites are usually micro or middle scale, source oriented sites.

Next, we conducted a visual inspection and geospatial analysis using Google Earth of the remaining monitors. The analysis reviewed where the site was physically located in an urban area, checked its proximity to major roads (such as interstates, freeways, and major arterial roads), and its proximity to identifiable sources such as industrial complexes and facilities, commercial facilities (such as trucking depots), or proximity to other area sources (such as airports or shipping ports).

Finally, we did not scale up any sites that were not in CBSAs with a population of 350,000 or greater to be consistent with the proposed population based thresholds that trigger minimum required near-road monitors in the NO_2 NAAQS and monitoring proposal package. Appendix 7.A contains a fuller discussion of the list of monitors included in this analysis.

Using the list of area-wide monitors relevant for near-roadway adjustment, we included only those monitors with sufficient data completeness to estimate a 2020 design value (see Chapter 3, Section 3.3.2.1 for details). One hundred seventy-three monitors were considered relevant for near-road adjustment.

7.2 Adjustment of 2020 area-wide design values to near-roadway

Because there are no NO2 near road monitors currently in existence, any effort to evaluate impacts of a short term NO2 standards requires an ‘estimation’ of future near road levels as we have determined that short term peak NO2 concentrations are likely to occur on or near roads. In an effort to create these near road monitor proxy locations, we have used two analytic approaches to attempt to adjust CMAQ results for 2020 to approximate proxies for near road levels in that same time period. Each method is described below with detailed methodology following.

7.2.1 Near road gradient adjustment

Reflecting the expected roadway gradient discussed in the proposal preamble (i.e., near road monitors can be from 30% to 100% greater than the area wide monitors), we adjust our estimated design values at area-wide locations for the future year of 2020 by 130%, 165%, and 200%. This method of adjustment will be referred to as Method 1 throughout the rest of the chapter.

The simplicity of applying the range of near road gradients to the area-wide locations for 2020 is appealing; however, one significant limitation of the method is that the range may not account for the expected future design values near roads (i.e., we believe this approach may over-estimate future design values near roads and may suggest that the future nonattainment problem is worse than it might be, and that the costs and benefits of addressing the residual nonattainment problem in the future are greater than they will actually be). This potential overestimation results from two related issues: (1) the 2020 projections are from CMAQ which estimates a volume-averaged concentration throughout a 12km grid associated with emissions reductions from all sources that occur between 2006 and 2020, and (2) the greater efficacy of the reductions in on-road mobile source emissions at near road locations that occur between 2006 and 2020. This method does not account for these two issues in projecting 2020 design values for near road locations. Any adjustments to account for these issues may result in estimated future design values at near road locations that are within the range of the gradient between near-road and area monitors.

7.2.2 Near road gradient adjustment with account for greater efficacy of future mobile source emissions reductions

This approach starts with the near road gradient adjustment described above for Method 1. In addition, as stated above, we expect that air quality peak design values near roadways will be affected more significantly by mobile source emission reductions than will air quality peak design values in area-wide locations. Therefore, we presume that future near-roadway peaks are reduced more than future area-wide peaks because (1) the near road proxy monitors are by definition located near the roadway; and (2) on-road mobile source emission reductions between 2006 and 2020 are expected to be significant due to a number of previously-cited Federal mobile source regulations. However, as mentioned above, CMAQ averages the reductions from all sources over the 12km grid which effectively smoothes the concentration changes of source-specific emissions reductions that would have a greater effect at any specific location within the grid, e.g., mobile source emissions reductions near roads. These limitations suggest we should consider an appropriate adjustment of the 2020 design values at 'near roadway' proxy monitors to account for the dilution of mobile emission reductions across entire grid squares by CMAQ. Therefore, based on available data, we calculated a relative effectiveness metric for each county with a proxy monitor reflecting the greater efficacy of mobile source emissions reductions (i.e., ppb/ton) at those locations than predicted by CMAQ for area wide monitor locations. We then applied the resulting national average metric (1.20) across all monitors calculated above to adjust the 2020 design values at the 'near roadway' proxy monitors consistently.

While we believe this approach is conceptually sound, it is a new methodology developed out of necessity to complete this assessment for near roadway monitor locations in the absence of such a monitoring network and based on limited data and modeling results, i.e., information not designed to address near road situations. Furthermore, the use of a national average adjustment as opposed to a county-specific adjustment makes the adjustment more straight forward but does result in some specific under- and over-adjustments at particular locations.

7.2.3 Methodology of concentration adjustments

Following is the methodology used to adjust the 2020 area-wide 99th percentile design values[2] to reflect near-roadway air quality levels based on area-wide concentration data for Methods 1 and 2. For Method 1, the 2020 area-wide design values were adjusted to each of the three levels of near-roadway gradient, 30%, 65%, 100% increase from area-wide to near-roadway, by multiplying the 2020 projected area-wide concentration by 1.3, 1.65, and 2.0 respectively.

For Method 2, near-roadway concentrations will be affected more significantly by on-road mobile emission reductions than locations representing area-wide concentrations as described in Section 7.2.2. The calculation of 2020 near-roadway adjusted design values is described below for both Methods 1 and 2.

1. For Method 2, calculate the 2005-2007 and 2020 onroad components of the 99th percentile area-wide design values by multiplying the area-wide design values by the ratio of county onroad to county total emissions:

---

[2] Hereafter, 2005-2007 and 2020 design values refer to 99th percentile design values.

$$DV_{on:2005-2007} = DV_{2005-2007} \times \frac{E_{onroad:2006}}{E_{total:2006}} \tag{7.1}$$

$$DV_{on:2020} = DV_{2020} \times \frac{E_{onroad:2020}}{E_{total:2020}} \tag{7.2}$$

Where DV_{on} represents on-road design values for a particular year, and E represents emissions. The county emissions for both 2006 and 2020 are the county emissions used to calculate the 2020 area-wide design values as described in Chapter 3. The 2020 emissions are the 2020 emissions used to meet the 0.075 ppm ozone standard [See Chapter 4 of the ozone RIA (EPA, 2008)].

2. After calculating the onroad components of the area-wide design values for 2005-2007 and 2020, the onroad ppb/ton estimate was calculated as:

$$ppb/ton_{onroad} = \frac{DV_{on:2020} - DV_{on:2005-2007}}{E_{on:2020} - E_{on:2006}} \tag{7.3}$$

3. Next, the ratio of onroad to total ppb/ton metric was calculated as:

$$Ratio_{ppb/ton} = \frac{ppb/ton_{onroad}}{ppb/ton_{total}} \tag{7.4}$$

Where ppb/ton_{onroad} is as defined above and ppb/ton_{total} is defined as in Equation 3.8 of Section 3.2.1 in Chapter 3.

4. To simplify the analysis, we used the average Ratio in step 4 above across all monitors in the final adjustment for the near road proxy monitors. The national average ratio was calculated as 1.2, meaning that onroad emissions reductions were approximately 20% more effective at reducing near-roadway concentrations than total emission reductions in the county.
5. After calculating the national average ratio in step 4, the final near-roadway adjusted 2020 design value for Method 1 was calculated as:

$$DV_{NR1} = DV_{2020} \times GRAD \tag{7.5}$$

and for Method 2 as:

$$DV_{NR2} = \frac{DV_{2020} \times GRAD}{1.2} \tag{7.6}$$

Where DV_{NR1} is the 2020 near-roadway adjusted concentration for each gradient with GRAD equal to 1.3, 1.65, or 2 (i.e., reflecting 30%, 65%, or 100% increase respectively),

DV_{NR2} is the 2020 near-roadway adjusted concentration for Method 2, and DV_{2020} is the 2020 area-wide design value.

6. Once the near-roadway design values were calculated for 2020 for each of the three gradient increases (30%, 65%, and 100%), residual nonattainment was calculated for four alternative standards (in ppb): 65, 80, 100, and 125. Nonattainment was calculated as:

$$NA_{X;GRAD:AS} = DV_{NR:GRAD} - AS \tag{7.7}$$

Where $NA_{XGRAD:AS}$ is the residual nonattainment (ppb) for GRAD equal to 30, 65, or 100% increase for alternative standard AS of 65, 80, 100, or 125 ppb and $DV_{NR:GRAD}$ is the 2020 near-roadway adjusted design value for the 30%, 65%, or 100% increase for either Method 1 or 2 (denoted by X). For locations exceeding a particular alternative standard AS, the mobile tons needed to reach attainment are calculated as:

$$Tons1_{GRAD:AS} = \frac{NA_{1GRAD:AS}}{ppb/ton_{total}} \tag{7.8}$$

for Method 1 and

$$Tons2_{GRAD:AS} = \frac{NA_{2GRAD:AS}}{\left(ppb/ton_{total} \times 1.2\right)} \tag{7.9}$$

for Method 2,

Where $Tons1_{GRAD:AS}$ and $Tons2_{GRAD:AS}$ are the tons needed for attainment of alternative standard for the near-roadway increase of 30%, 65%, or 100% for Methods 1 and 2 respectively, $NA_{1GRAD:AS}$ and $NA_{2GRAD:AS}$ are as defined in step 6 above, and ppb/ton_{total} is the total (all county emissions) ppb/ton as calculated in Chapter 3. The total ppb/ton is multiplied by 1.2 in Equation 7.9 to approximate the onroad ppb/ton based on the national average of onroad ppb/ton to total ppb/ton.

7.2.4 Adjusted near-roadway concentrations

After calculating the near-roadway adjusted design values for each monitor, the maximum design value was chosen for each county for each of the gradient increases. Lists of the nonattainment counties are shown in Tables 7.1 through 7.3 for each of the three gradient increases for Method 1: 130%, 165%, and 200%. Also shown in each table are the residual nonattainment and mobile tons needed for attainment for each alternative standard that is exceeded. One monitor exceeded the 125 ppb level considered, Adams County, CO for the 100% gradient increase.

Tables 7.4 through 7.6 list the nonattainment counties for Method 2 for each of the three gradient increases: 130%, 165%, and 200% respectively. No monitor exceeded either the 125 ppb level considered, or any level higher than 125 ppb for Method 2. Tables 7.7 shows the results of the calculation of the ppb/ton estimates and onroad to total ppb/ton estimates for Adams County, CO for Method 2 as well as results for Method 1 for the 200% gradient increase and comparison against a 65 ppb alternative standard.

Table 7.1. 2005-2007, 2020 30% increase near-roadway design values with residual nonattainment and mobile tons needed for attainment for 65 and 80 ppb alternative standard for Method 1.

County	State	2005-07 design value (ppb)	2020 design value (ppb)	Alternative standards			
				65 ppb		80 ppb	
				Residual nonattainment (ppb)	Mobile tons needed for attainment	Residual nonattainment (ppb)	Mobile tons needed for attainment
Adams[a]	CO	82.6	86.3	20.9	9,549	5.9	2,696
El Paso[a]	TX	72.6	79.4	14.0	8,855	-	-
Salt Lake[a]	UT	70.3	76.7	11.3	5,818	-	-

[a] These counties were also included in the area-wide analysis presented in Chapter 3. Estimates of tons needed may differ due to the approach used in projecting near roadway air quality concentrations as well as the standard being analyzed.

Table 7.2. 2005-2007, 2020 65% increase near-roadway design values with residual nonattainment and mobile tons needed for attainment for 65, 80, and 100 ppb alternative standards for Method 1.

County	State	2005-07 design value (ppb)	2020 design value (ppb)	Alternative Standards					
				65 ppb		80 ppb		100 ppb	
				Residual nonattainment (ppb)	Mobile tons needed for attainment	Residual nonattainment (ppb)	Mobile tons needed for attainment	Residual nonattainment (ppb)	Mobile tons needed for attainment
Adams[a]	CO	82.6	109.5	44.1	20,148	29.1	13,295	9.1	4,158
El Paso[a]	TX	72.6	100.8	35.4	22,390	20.4	12,903	0.4	253
Salt Lake[a]	UT	70.3	97.3	31.9	16,425	16.9	8,701		-
East Baton Rouge[a]	LA	65.3	90	24.6	29,859	9.6	11,652		-
Los Angeles[a]	CA	81.6	86.6	21.2	180,872	6.2	52,896		-
Charles City[a]	VA	70.0	85.9	20.5	232	5.5	62		-
West Baton Rouge	LA	58.6	82.9	17.5	2,863	2.5	409		-
Allegheny	PA	67.6	77.2	11.8	12,226	-	-		-
Kern	CA	73.0	72.4	7.0	13,777	-			-
Harris	TX	63.0	72.1	6.7	39,979	-	-		-
Union	NJ	90.6	69.3	3.9	1,324	-			-
St Louis	MO	63.0	68.1	2.7	1,015	-	-		-
Ascension	LA	46.0	66.9	1.5	1,164	-	-		-
Jefferson	LA	55.0	65.5	0.1	98	-	-		-
Bernalillo	NM	59.3	65.5	0.1	58	-	-		-

[a] These counties were also included in the area-wide analysis presented in Chapter 3. Estimates of tons needed may differ due to the approach used in projecting near roadway air quality concentrations as well as the standard being analyzed.

Table 7.3. 2005-2007, 2020 100% increase near-roadway design values with residual nonattainment and mobile tons needed for attainment for 65, 80 ppb, and 100 ppb alternative standards for Method 1.

				Alternative standards					
				65 ppb		80 ppb		100 ppb	
County	State	2005-07 design value (ppb)	2020 design value (ppb)	Residual nonattainment (ppb)	Tons needed for attainment	Residual nonattainment (ppb)	Tons needed for attainment	Residual nonattainment (ppb)	Tons needed for attainment
Adams[a]	CO	82.6	132.8	67.4	30,793	52.4	23,940	32.4	14,803
El Paso[a]	TX	72.6	122.2	56.8	35,925	41.8	26,438	21.8	13,788
Salt Lake[a]	UT	70.3	118.0	52.6	27,083	37.6	19,360	17.6	9,062
East Baton Rouge[a]	LA	65.3	109.2	43.8	53,163	28.8	34,957	8.8	10,681
Los Angeles[a]	CA	81.6	105.0	39.6	337,855	24.6	209,880	4.6	39,246
Charles City[a]	VA	70.0	104.2	38.8	438	23.8	269	3.8	43
West Baton Rouge	LA	58.6	100.6	35.2	5,759	20.2	3,305	0.2	33
Allegheny	PA	67.6	93.6	28.2	29,218	13.2	13,677		-
Kern	CA	73.0	87.8	22.4	44,087	7.4	14,565		-
Harris	TX	63.0	87.4	22.0	131,274	7.0	41,769		-
Union	NJ	90.6	84.0	18.6	6,316	3.6	1,222		-
St Louis	MO	63.0	82.6	17.2	6,469	2.2	827		-
Ascension	LA	46.0	81.2	15.8	12,264	0.8	621		-
Jefferson	LA	55.0	79.4	14.0	13,734	-	-		
Bernalillo	NM	59.3	79.4	14.0	8,183	-	-		
Davis	UT	71.0	78.8	13.4	2,767	-	-		
Cuyahoga	OH	66.0	77.2	11.8	9,162	-	-		
Maricopa	AZ	76.0	76.6	11.2	17,946	-	-		
Jackson	MO	65.0	74.0	8.6	5,852	-	-		
Richmond	VA	62.6	73.8	8.4	1,233	-	-		
Iberville	LA	42.3	73.0	7.6	9,096	-	-		
Santa Clara	CA	63.6	69.4	4.0	5,569	-	-		
Hudson	NJ	77.6	68.2	2.8	1,727	-	-		
Anoka	MN	47.6	68.0	2.6	1,085	-	-		
Broward	FL	57.0	67.4	2.0	3,506	-	-		
Fulton	GA	75.6	66.6	1.2	737	-	-		
Dallas	TX	60.6	66.0	0.6	805	-	-		
Orange	CA	78.0	65.8	0.4	510	-	-		

[a] These counties were also included in the area-wide analysis presented in Chapter 3. Estimates of tons needed may differ due to the approach used in projecting near roadway air quality concentrations as well as the standard being analyzed. Adams County, CO also exceeded the 125 ppb level with nonattainment of 7.4 ppb and tons needed for attainment were 3,381 tons.

Table 7.4. 2005-2007, 2020 30% increase near-roadway design values with residual nonattainment and mobile tons needed for attainment for 65 ppb alternative standard for Method 2.

County	State	2005-07 design value (ppb)	2020 design value (ppb)	Alternative standard 65 ppb	
				Residual nonattaintment (ppb)	Mobile tons needed for attainment
Adams[a]	CO	82.6	71.9	6.5	2,475
El Paso[a]	TX	72.6	66.1	0.7	369

[a] These counties were also included in the area-wide analysis presented in Chapter 3. Estimates of tons needed may differ due to the approach used in projecting near roadway air quality concentrations.

Table 7.5. 2005-2007, 2020 65% increase near-roadway design values with residual nonattainment and mobile tons needed for attainment for 65 and 80 ppb alternative standards for Method 2.

County	State	2005-07 design value (ppb)	2020 design value (ppb)	Alternative standards			
				65 ppb		80 ppb	
				Residual nonattaintment (ppb)	Mobile tons needed for attainment	Residual nonattaintment (ppb)	Mobile tons needed for attainment
Adams[a]	CO	82.6	91.3	25.9	9,861	10.9	4,150
El Paso[a]	TX	72.6	84	18.6	9,803	3.6	1,897
Salt Lake[a]	UT	70.3	81.1	15.7	6,736	0.7	300
East Baton Rouge[a]	LA	65.3	75	9.6	9,710	-	-
Los Angeles[a]	CA	81.6	72.1	6.7	47,635	-	-
Charles City[a]	VA	70.0	71.6	6.2	58	-	-
West Baton Rouge[a]	LA	58.6	69.1	3.7	504	-	-

[a] These counties were also included in the area-wide analysis presented in Chapter 3. Estimates of tons needed may differ due to the approach used in projecting near roadway air quality concentrations as well as the standard being analyzed.

Table 7.6. 2005-2007, 2020 100% increase near-roadway design values with residual nonattainment and mobile tons needed for attainment for 65, 80 ppb, and 100 ppb alternative standards for Method 2.

County	State	2005-07 design value (ppb)	2020 design value (ppb)	Alternative standards					
				65 ppb		80 ppb		100 ppb	
				Residual nonattaintment (ppb)	Mobile tons needed for attainment	Residual nonattaintment (ppb)	Mobile tons needed for attainment	Residual nonattaintment (ppb)	Mobile tons needed for attainment
Adams[a]	CO	82.6	110.6	45.2	17,209	30.2	11,498	10.2	3,883
El Paso[a]	TZ	72.6	101.8	36.4	19,185	21.4	11,279	1.4	738
Salt Lake[a]	UT	70.3	98.3	32.9	14,116	17.9	7,680		-
East Baton Rouge[a]	LA	65.3	91	25.6	25,894	10.6	10,722		-
Los Angeles[a]	CA	81.6	87.5	22.1	157,125	7.1	50,479		-
Charles City[a]	VA	70.0	86.8	21.4	202	6.4	60 -		-
West Baton Rouge	LA	58.6	83.8	18.4	2,509	3.4	464 -		-
Allegheny	PA	67.6	78	12.6	10,879		- -	-	-
Kern	CA	73.0	73.1	7.7	12,629		-	-	-
Harris	TX	63.0	72.8	7.4	36,797		- -	-	-
Union	NJ	90.6	70	4.6	1,302		- -	-	-
St Louis	MO	63.0	68.8	3.4	1,066 -		-	-	-
Ascension	LA	46.0	67.6	2.2	1,423 -		-	-	-
Jefferson	LA	55.0	66.1	0.7	572 -		-	-	-
Bernalillo	NM	59.3	66.1	0.7	341 -		-	-	-
Davis	UT	71.0	65.6	0.2	34 -		-	-	-

[a] These counties were also included in the area-wide analysis presented in Chapter 3. Estimates of tons needed may differ due to the approach used in projecting near roadway air quality concentrations as well as the standard being analyzed.

Table 7.7 Example adjustment of 2020 area-wide design value to near-roadway design value for Adams County, CO for 100% adjustment and comparison to 65 ppb standard

Variable	Description	Value
$DV_{2005\text{-}2007}$	2005-2007 area-wide 99th percentile design value concentration (ppb)	82.6
$E_{onroad:2006}$	2006 onroad county emissions (tons)	7,816
$(E_{total:2006})$	2006 total county emissions (tons)	26,368
$DV_{on:2005\text{-}2007}$ (Equation 7.1)	Onroad component of 2005-2007 area-wide design values (ppb)	24.5
DV_{2020}	2020 area-wide 99th percentile design value concentration (ppb)	66.4
$E_{onroad:2020}$	2020 onroad county emissions (tons)	2,747
$E_{total:2020}$	2020 total county emissions (tons)	18,967
$DV_{on:2020}$ (Equation 7.2)	Onroad component of 2020 area-wide design values (ppb)	9.6
ppb/ton_{onroad} (Equation 7.3)	Onroad ppb/ton estimate used in ratio calculation	$2.93\text{x}10^{-3}$
ppb/ton_{total}	Total ppb/ton estimate as calculated for Chapter 3	$2.19\text{x}10^{-3}$
Ratio (Equation 7.4)	Ratio of onroad ppb/ton to total ppb/ton used in national average ratio calculation	1.34
$DV_{1NR:100}$ (Equation 7.5)	Method1 near-roadway adjusted concentration for 2020 for 100% increase from area-wide to near-roadway	132.8
$DV_{2NR:100}$ (Equation 7.6)	Method 2 near-roadway adjusted concentration for 2020 for 100% increase from area-wide to near-roadway	110.6
$NA_{1100:65}$ (Equation 7.7)	Method 1 near-roadway design value residual nonattainment for 100% near-roadway gradient increase for 65 ppb alternative standard	67.4
$NA_{2100:65}$ (Equation 7.7)	Method 2 near-roadway design value residual nonattainment for 100% near-roadway gradient increase for 65 ppb alternative standard	45.2
$Tons1_{100:65}$ (Equation 7.8)	Onroad mobile tons needed to reach attainment of 65 ppb alternative standard for Method 1 100% near-roadway gradient increase	30,793
$Tons2_{100:65}$ (Equation 7.9)	Onroad mobile tons needed to reach attainment of 65 ppb alternative standard for Method 2 100% near-roadway gradient increase	17,209

7.3 Cost Effectiveness for Mobile Source Controls

Because this analysis examines emissions and air quality approximating near-roadway conditions, we believe it is appropriate to focus analysis of controls on mobile sources. For the purposes of this analysis we reviewed existing cost effectiveness estimates for a number of on-road and non-road regulations that have been promulgated in the last several years. These regulations include the Tier 2 regulation for light-duty motor vehicles, the 2001 and 2004 heavy duty diesel rules, the Tier 4 non-road equipment rule, the locomotive/marine rule, and the small spark ignition equipment rule. We also reviewed the cost effectiveness estimates for the mobile source controls that were applied in the area-wide monitor analysis presented in Chapter 4 of this RIA, as well as for the 2008 ozone NAAQS. That RIA included cost effectiveness estimates for mobile source controls that included retrofits for on-road vehicles and non-road equipment, elimination of long duration truck idling, continuous inspection and maintenance of light-duty vehicles, the introduction of plug-in hybrid vehicles into the national vehicle fleet, more stringent requirements for aftermarket replacement catalytic converters, commuter programs to reduce vehicle miles travelled and vehicle trips, and improved emission control systems for new vehicles.

Table 7.8 Estimated $/ton Costs of NOx Emissions Reductions from Recent RIAs

SOURCE CATEGORY[a,]	NO_X COST/TON	NOTES
C3 Marine Coordinated Strategy NPRM, 2009	510	a
Nonroad Small Spark-Ignition Engines 73 FR 59034, October 8, 2008	330-1,200[b,c]	a, b, c
Stationary Diesel (CI) Engines (71 FR 39154, July 11, 2006)	580 – 20,000	a
Locomotives and C1/C2 Marine (Both New and Retrofits) (73 FR 25097, May 6, 2008)	730 [b]	a, b
Heavy Duty Nonroad Diesel Engines (69 FR 38957, June 29, 2004)	1,100 [b]	a, b
Heavy Duty Onroad Diesel Engines (66 FR 5001, January 18, 2001)	2,200 [b]	a, b
Non-road Tier 4 (page 8-64 of the non- road tier 4 RIA)	1,010	b, d, e
Tier 2 (Page VI-18 of the Tier 2 RIA)	2,047	b, f
Continuous Light-duty Vehicle Inspection and Maintenance (2008 ozone RIA Appendix 5a pages 5a-7 – 5a-9)	0	
Eliminate Long Duration Truck Idling (2008 ozone RIA Appendix 5a pages 5a-9 – 5a-10)	0	
Plug-in Hybrid Vehicles (2008 ozone RIA Appendix 7a pages 7a-4 – 7a-96)	0	
Retrofit Class 8b Trucks (2008 ozone RIA Appendix 5a pages 5a-6 – 5a-7)	1,100-2,500	
Retrofit Class 6 & 7 Trucks (2008 ozone RIA Appendix 5a pages 5a-6 – 5a-7)	5,600-14,100	
Retrofit Non-road Equipment – SCR (2008 ozone RIA Appendix 5a pages 5a-6 – 5a-7)	2,600-10,400	
Retrofit Non-road Equipment – Rebuild/Upgrade (2008 ozone RIA Appendix 5a pages 5a-6 – 5a-7)	1,000-4,900	
Improve Aftermarket Replacement Catalytic Converters (2008 ozone RIA Appendix 7a pages 7a-6 – 7a-8)	3,700	
Commuter Programs (2008 ozone RIA Appendix 5a pages 5a-10 – 5a-11)	19,200	
Improve Catalyst Efficiency for New Light-duty Vehicles (2008 ozone RIA Appendix 7a pages 7a-3 – 7a-4)	17,500	

[a] Table presents aggregate program-wide cost/ton over 30 years, discounted at a 3 percent NPV, except for Stationary CI Engines and Locomotive/Marine retrofits, for which annualized costs of control for individual sources are presented. All figures are in 2006 U.S. dollars per short ton.

[b] Includes NO_X plus non-methane hydrocarbons (NMHC). NMHC are also ozone precursors, thus some rules set combined NO_X+NMHC emissions standards. NMHC are a small fraction of NO_X so aggregate cost/ton comparisons are still reasonable.

[c] Low end of range represents costs for marine engines with credit for fuel savings, high end of range represents costs for other nonroad SI engines without credit for fuel savings.

[d] 30 year NPV at a 3% discount rate in 2002 dollars. The RIA also presents a cost effectiveness of $1,160/ton at a 7% discount rate in 2002 dollars.

[e] The non-road tier 4 RIA contained to sensitivity analyses. In those analyses the resulting cost effectiveness values for NOx+NMHC for a 30-year NPV at a 3% discount rate were $1,490 and $920 per ton.

[f] Discounted aggregate cost effectiveness.

As summarized in the table above the majority of these controls have costs of between $1,000 and $5,000 per ton of NOx or NOx+non-methane hydrocarbons. There are some exceptions. Several of the measures produce fuel savings that offset the cost of the control equipment or vehicle and any operating expenses; therefore, these measures produce NOx reductions at no cost. Some non-road retrofits, particularly for agricultural equipment, are more expensive. However, this type of equipment would not be the primary focus of an attainment strategy for the NO_2 NAAQS under a near roadway monitoring scenario. Retrofits of class 6 and 7 heavy duty vehicles and commuter programs also have higher costs per ton. However, these do not provide large emissions reductions. Finally, the estimated cost per ton of NOx reductions from improvements in the emissions control systems for new motor vehicles is also higher. However, as noted in the RIA for 2008 ozone NAAQS, this is a very rough estimate of the cost of these controls. Only one method for achieving the desired level of emissions was considered. A much more detailed analysis would be required to develop a representative cost for such future controls on new vehicles. In addition, when referring back to the area-wide engineering costs presented in Chapter 6 the average cost per ton for applied mobile source controls ranges between $1,900 and $4,300 per ton (2006$).

The purpose of this analysis is to develop an estimate of the average cost per ton of NOx reductions that would be needed to bring projected nonattainment areas into compliance with the revised NO_2 NAAQS. Based on the estimates in these recent RIAs it is evident that there remain mobile source control strategies that provide emissions reductions in the range of $1,000 to $5,000 per ton of NOx. However, we also recognize that the costs of controls will likely increase as additional control measures are implemented. We anticipate that nonattainment areas would employ a mixture of controls that fall within the range the range $1,000 to $5,000 per ton and some additional controls that have higher costs per ton. Given the screening nature of this analysis we have estimated that the annualized average cost of controls to attain the NO_2 NAAQS would be in the range of $3,000 to $6,000 per ton. This estimate is based upon previous estimates, most of which are estimated, using a three percent discount rate. A discount rate of seven percent was not available for all estimates provided in Table 7.8.

To calculate the engineering costs for this screening-level near-roadway analysis we multiplied the tons needed from Section 7.2 for each alternative standard by the lower and upper ends of the range of $3,000 to $6,000/ton (2006$). Cost estimates are provided in Tables 7.9 through 7.12 below. Note that due to the screening level nature of this analysis, we did not examine local conditions for each of these areas and apply known control measures. It is possible that for areas with few mobile measures available, costs could be higher. For example, in the area-wide analysis, Los Angeles had exhausted all known controls, and extrapolated costs were estimated for the alternative standard of 50 ppb. Due to screening nature of the near roadway analysis the same cost per ton was used for all geographic areas. We will continue to develop this analysis for the final RIA, including identifying specific controls to illustrate attainment for areas projected to violate an alternative NO2 standard in 2020. This may include additional analyses for geographic areas where it is difficult to simulate attainment with known control measures.

7.4 Benefits

To calculate the near-roadway benefits, we decided to only calculated the $PM_{2.5}$ co-benefits. Without fine-scale air quality modeling data, it would be difficult to estimate the near-roadway NO_2 benefits. Furthermore, our area-wide analysis for 50 ppb showed that the monetized NO_2 benefits only accounted for 2% of the total monetized benefits, with $PM_{2.5}$ co-benefits accounting for the remainder. To calculate the $PM_{2.5}$ co-benefits, we used a benefit-per-ton approach. To be consistent with the cost analysis, we only used the benefit-per-ton estimate corresponding to NO_X emission reductions from the mobile sector. For more information about the benefit-per-ton approach, please see Chapter 5 of this RIA. These estimates reflect EPA's most current interpretation of the scientific literature on $PM_{2.5}$ and mortality, including our updated benefits methodology (i.e., a no-threshold model that calculates incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels and incorporates two technical updates) compared to the estimates in previous RIAs that did not include these changes. In Tables 7.9 through 7.12, we present the $PM_{2.5}$ co-benefits as a range from Pope et al to Laden et al, using no-threshold functions, at discount rates of 3% and 7% respectively.[3]

7.5 Comparison of Results

Tables 7.9 and 7.10 show the cost and benefit results of the near-roadway analysis at discount rates of 3% and 7% respectively for Method 1 near-roadway design values. Tables 7.11 and 7.12 show the cost and benefit results of the near-roadway analysis at discount rates of 3% and 7% respectively for Method 2 near-roadway design values. The proposed standard range of 80ppb to 100 ppb is highlighted.

---

[3] Using the threshold model at 10 $\mu g/m^3$ without the two technical updates, we estimate the monetized benefits results would be approximately 20% to 40% less than the results shown in Tables 9.7 and 9.8.

Table 7.9: Benefit Cost Comparison for Near Roadway Analysis – Method 1 (in millions of 2006$ at a 3% discount rate for Benefits only)

	Standard Level	Total Costs[a, b]			Total Benefits[c]			Net Benefits		
30% Gradient	65 ppb	$170	to	$330	$290	to	$700	-$40	to	$530
	80 ppb	$12	to	$20	$14	to	$34	-$6.0	to	$22
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
65% Gradient	65 ppb	$1,000	to	$2,100	$1,800	to	$4,400	-$300	to	$3,400
	80 ppb	$300	to	$600	$520	to	$1,300	-$80	to	$1,000
	100 ppb	$17	to	$30	$23	to	$56	-$7.0	to	$39
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
100% Gradient	65 ppb	$2,400	to	$4,800	$4,200	to	$10,000	-$600	to	$7,600
	80 ppb	$1,200	to	$2,300	$2,000	to	$5,000	-$300	to	$3,800
	100 ppb	$270	to	$530	$460	to	$1,100	-$70	to	$830
	125 ppb	$14	to	$24	$18	to	$43	-$6.0	to	$29

[a] Total Cost estimates are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[b] Los Angeles and El Paso counties were also included in the area-wide analysis of extrapolated costs. In that analysis a central estimate of $15,000/ton was used to calculate the cost of emission reductions needed beyond identified controls. If that estimate was used for this analysis of 80ppb with the 65% gradient adjustment the total costs would range from $1.1 to $1.2 billion.

[c] Total Benefit estimates are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 3% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

Table 7.10: Benefit Cost Comparison for Near Roadway Analysis – Method 1 (in millions of 2006$ at a 7% discount rate for Benefits only)

	Standard Level	Total Costs[a, b]			Total Benefits[c]			Net Benefits		
30% Gradient	65 ppb	$170	to	$330	$230	to	$550	-$100	to	$380
	80 ppb	$12	to	$20	$11	to	$27	-$9.0	to	$15
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
65% Gradient	65 ppb	$1,000	to	$2,100	$1,400	to	$3,400	-$700	to	$2,400
	80 ppb	$300	to	$600	$410	to	$1,000	-$190	to	$700
	100 ppb	$17	to	$30	$18	to	$44	-$12	to	$27
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
100% Gradient	65 ppb	$2,400	to	$4,800	$3,300	to	$8,100	-$1,500	to	$5,700
	80 ppb	$1,200	to	$2,300	$1,600	to	$3,900	-$700	to	$2,700
	100 ppb	$270	to	$530	$360	to	$880	-$170	to	$610
	125 ppb	$14	to	$24	$14	to	$34	-$10	to	$20

[a] Total Cost estimates are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[b] Los Angeles and El Paso counties were also included in the area-wide analysis of extrapolated costs. In that analysis a central estimate of $15,000/ton was used to calculate the cost of emission reductions needed beyond identified controls. If that estimate was used for this analysis of 80ppb with the 65% gradient adjustment the total costs would range from $1.1 to $1.2 billion.

[c] Total Benefit estimates are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 7% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

Table 7.11: Benefit Cost Comparison for Near Roadway Analysis – Method 2 (in millions of 2006$ at a 3% discount rate for Benefits only)

	Standard Level	Total Costs[a]			Total Benefits[c]			Net Benefits		
30% Gradient	65 ppb	$12	to	$21	$15	to	$36	-$6.0	to	$24
	80 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
65% Gradient	65 ppb	$260	to	$510	$440	to	$1,100	-$70	to	$840
	80 ppb	$23	to	$42	$33	to	$81	-$9.0	to	$58
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
100% Gradient	65 ppb	$910	to	$1,800	$1,600	to	$3,800	-$200	to	$2,900
	80 ppb	$280	to	$560	$480	to	$1,200	-$80	to	$920
	100 ppb	$17	to	$31	$24	to	$59	-$7.0	to	$42
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6

[a] Total Cost estimates are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m.

[b] Los Angeles and El Paso counties were also included in the area-wide analysis of extrapolated costs. In that analysis a central estimate of $15,000/ton was used to calculate the cost of emission reductions needed beyond identified controls. If that estimate was used for this analysis of 80ppb with the 65% gradient adjustment the total costs would range from $45 to $59 million.

[c] Total Benefit estimates are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 3% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

Table 7.12: Benefit Cost Comparison for Near Roadway Analysis – Method 2 (in millions of 2006$ at a 7% discount rate for Benefits only)

	Standard Level	Total Costs[a, b]			Total Benefits[c]			Net Benefits		
30% Gradient	65 ppb	$12	to	$21	$12	to	$29	-$9.0	to	$17
	80 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
65% Gradient	65 ppb	$260	to	$510	$350	to	$850	-$160	to	$590
	80 ppb	$23	to	$42	$26	to	$64	-$16	to	$41
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
100% Gradient	65 ppb	$910	to	$1,800	$1,300	to	$3,000	-$500	to	$2,100
	80 ppb	$280	to	$560	$380	to	$930	-$180	to	$650
	100 ppb	$17	to	$31	$19	to	$46	-$12.0	to	$29
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6

[a] Total Cost estimates are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[b] Los Angeles and El Paso counties were also included in the area-wide analysis of extrapolated costs. In that analysis a central estimate of $15,000/ton was used to calculate the cost of emission reductions needed beyond identified controls. If that estimate was used for this analysis of 80ppb with the 65% gradient adjustment the total costs would range from $45 to $59 million.

[c] Total Benefit estimates are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 7% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

7.6 Limitations and uncertainties

- Due to the absence of a near-roadway monitoring network, this is a screening level analysis with several simplifying assumptions. It is provided to give a rough projection of the costs and benefits of attaining a revised NO_2 standard based on a yet to be established monitoring network.

- This analysis does not take into account a large variety of localized conditions specific to individual monitors; instead, the analysis attempts to account for some local parameters by adjusting future design values based on average localized impacts near roads from onroad emissions.

- The process of adjusting from a specific 12 km CMAQ receptor to a near-road air quality estimate represents an uncertain approximation at the specific monitor level.

- This analysis is an approximation in that it derives future year (2020) **peak** air quality concentrations in specific locations by relying on CMAQ estimates that are averages over a 12 km grid square.

- This analysis cannot predict air quality in locations for which there is no current NO_2 monitor, or where current monitoring data is incomplete. There are 142 CBSAs for which we are proposing to add new near-road monitors. Of these, 73 either have no existing monitor in the CBSA, or have a monitor with data not complete enough to include in the near-roadway analysis. In these CBSAs, extrapolation to near-roadway levels is not possible.

- This analysis assumes area-wide monitors remain in the same location; however concentrations are adjusted to reflect near-roadway conditions.

- Because the emission reductions in this analysis are solely reductions from mobile sources, this analysis uses an estimated cost per ton for NOx emission reductions that is different from the estimated cost per ton for NOx emission reductions used in the main body of the RIA.

- This analysis omits certain unquantified effects due to lack of data, time and resources. These unquantified endpoints include NO_2 health effects, ozone co-benefits, ecosystem effects, and visibility.

7.7 References

U.S. Environmental Protection Agency (EPA). 1999. *Regulatory Impact Analysis – Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements.* U.S. Environmental Protection Agency, Office of Air and Radiation, December. EPA420-R-99-023.

U.S. Environmental Protection Agency (EPA). 2001. *Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, Final Rule*. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, January 18. 66 FR 5001-5194.

U.S. Environmental Protection Agency (EPA). 2004. *Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines*. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, May. EPA420-R-04-007.

U.S. Environmental Protection Agency (EPA). 2004. *Control of Emissions of Air Pollution from Non-road Diesel Engines and Fuel, Final Rule*. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, June 29. 69 FR 38957-39273.

U.S. Environmental Protection Agency (EPA). 2006. *Standards of Performance for Stationary Compression Ignition Internal Combustion Engines, Final Rule*. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, July 11. 71 FR 39154-85.

U.S. Environmental Protection Agency (EPA). 2008. *Final Ozone NAAQS Regulatory Impact Analysis*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March. EPA-452/R-08-003.

U.S. Environmental Protection Agency (EPA). 2008. *Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition-Engines Less Than 30 Liters per Cylinder, Final Rule*. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, May 6. 73 FR 25097-352.

U.S. Environmental Protection Agency (EPA). 2008. *Control of Emissions from Non-road Spark Ignition Engines and Equipment, Final Rule*. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, October 8. 73 FR 59034-380.

U.S. Environmental Protection Agency (EPA). 2009. *Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines*. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, June. EPA-420-D-09-002. http://epa.gov/otaq/oceanvessels.htm

Appendix 7a. Detailed Discussion of Monitor Selection

OAQPS applied several screening techniques in the effort to select monitors within the NO_2 monitoring network that would be appropriate to scale-up to simulate what a near-road monitor might record. OAQPS used monitor site characteristics and visual inspection by using Google Earth geospatial software to determine which of the monitor sites were appropriate to scale-up to simulate near-road monitors. We then screened that list of monitors so that only those located in Core Based Statistical Areas (CBSAs) with populations of 350,000 or greater, which corresponds to the proposed population threshold in the NO2 NAAQS and monitoring proposal package, would be scaled-up.

All NO_2 monitoring sites that are used for comparison to the NAAQS report their data to the Air Quality System (AQS). Each monitoring site has a profile in AQS containing metadata pertaining to the monitor, including where the monitor is located, the monitoring objective, the scale of representativeness, and whether it is thought to be influenced by a particular type of emission source, among other data metrics. Although, the metadata in AQS are informative, we must note that AQS metadata should be used with caution as there are no formal requirements for the responsible state and local air monitoring agencies that operate the monitoring network to quality assure or update metadata at any frequency.

In conjunction with the language in the NO_2 NAAQS and monitoring proposal package, this exercise was intended to only use “area-wide” monitors to scale-up to simulate near-road concentrations. Area-wide monitors are monitors that are not significantly influenced by point, area, or mobile sources, meaning they typically do not represent the maximum concentration that may be attributable to a source or sources. Further, area-wide sites and are sited to represent neighborhood, urban, and regional spatially representative scales. To identify which sites in the NO_2 network were suitable to classify as “area-wide” site, we screened sites utilizing three particular AQS metadata metrics: 1) monitor objective, 2) spatial (measurement) scale, and 3) dominant source.

The monitor objective meta-data field describes what the data from the monitor are intended to characterize. The focus of the data presented is to show the nature of the network in terms of its attempt to generally characterize health effects, photochemical activity, transport, or welfare effects. There are 11 categories of monitor objective for a NO_2 monitor within AQS. The first six categories listed below stem directly from categorizations of site types within the Code of Federal Regulations (CFR). In 40 CFR Part 58 Appendix D, there are six examples of NO_2 site types:

1. Sites located to determine the highest concentration expected to occur in the area covered by the network (Highest Concentration).
2. Sites located to measure typical concentrations in areas of high population (Population Exposure).
3. Sites located to determine the impact of significant sources or source categories on air quality (Source Oriented).
4. Sites located to determine general background concentration levels (General Background).
5. Sites located to determine the extent of regional pollutant transport among populated areas; and in support of secondary standards (Regional Transport).
6. Sites located to measure air pollution impacts on visibility, vegetation damage, or other welfare-based impacts (Welfare Related Impacts).
7. Sites with unspecified or non-routine monitor objectives (Other).

The remaining four categories available are a result of updating the AQS database. In the more recent upgrade to AQS, the data handlers inserted the available site types for the Photochemical Assessment Monitoring Stations (PAMS) network. These PAMS site types are spelled out in 40 CFR Part 58 Appendix D:

1. Type 1 sites are established to characterize upwind background and transported ozone and its precursor concentrations entering the area and will identify those areas which are subjected to transport (Upwind Background).
2. Type 2 sites are established to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions are expected to impact and are suited for the monitoring of urban air toxic pollutants (Max. Precursor Impact).
3. Type 3 sites are intended to monitor maximum ozone concentrations occurring downwind from the area of maximum precursor emissions (Max. Ozone Concentration).
4. Type 4 sites are established to characterize the downwind transported ozone and its precursor concentrations exiting the area and will identify those areas which are potentially contributing to overwhelming transport in other areas (Extreme Downwind).

It should be noted that any particular monitor can have multiple monitor objectives. For this screening exercise, we selected one reported monitor objective based on a hierarchy to represent an individual monitor. The hierarchy used was to select, in order of priority: 1) source oriented, 2) high concentration, 3) population exposure, or 4) general background, if they existed at a site with multiple monitoring objectives.

The spatial (measurement) scales are also defined in 40 CFR Part 58, Appendix D. This regulation language spells out what data from a monitor can represent in terms of air volumes associated with area dimensions where:

> Microscale – Defines the concentration in air volumes associated with area dimensions ranging from several meters up to about 100 meters.
>
> Middle scale – Defines the concentration typical of areas up to several city blocks in size, with dimensions ranging from about 100 meters to 0.5 kilometers.
>
> Neighborhood scale – Defines concentrations within some extended area of the city that has relatively uniform land use with dimensions in the 0.5 to 4.0 kilometers range.
>
> Urban scale – Defines concentrations within an area of city-like dimensions, on the order of 4 to 50 kilometers. Within a city, the geographic placement of sources may result in there being no single site that can be said to represent air quality on an urban scale. The neighborhood and urban scales have the potential to overlap in applications that concern secondarily formed or homogeneously distributed air pollutants.
>
> Regional scale – Defines usually a rural area of reasonably homogeneous geography without large sources, and extends from tens to hundreds of kilometers.

Therefore the meta-data records for the NO_X network in AQS indicate what the measurement scale of a particular monitor represents. It is important to note that a monitor can only have one measurement scale, as opposed to the possibility of a single monitor having multiple monitor objectives.

The “dominant source” metric in AQS allows responsible state and local air monitoring agencies to identify, if applicable, what type of emission source may be the dominant source influencing the measurements at a particular site. There are three choices for the dominant source category: 1) Point, 2) Area, and 3) Mobile. It should be noted that not all NO_2 monitor records have a value in the dominant source field, either because the responsible state and local monitoring agency does not believe any particular type of source is influencing a particular site, or because the information was simply not entered into the database.

For the first screening to identify area-wide NO_2 monitoring sites, we chose to exclude all sites that met one or more of the following criteria based on AQS metadata:

- Any microscale site (measurement scale)
- Any middle scale site (measurement scale)
- Any source oriented site (monitor objective)
- Any site with the following combination of metadata: Highest Concentration, Neighborhood scale, and Point source dominated
  (monitor objective/measurement scale/dominant source)
- Any site identified as being operated by industry, as these sites are usually micro or middle scale, source oriented sites.

As a result of the first screening, of the original 255 sites used in the RIA, 225 remained for use in the second screening process.

The second screening process was by visual inspection and geospatial analysis using Google Earth of the top eleven NO_2 sites, ranked by estimated ppb/ton and two other monitor sites located in counties with multiple monitoring sites that had higher estimated ppb/ton values. The analysis reviewed where the site was physically located in an urban area, checked its proximity to major roads (such as interstates, freeways, and major arterial roads), and its proximity to identifiable sources such as industrial complexes and facilities, commercial facilities (such as trucking depots), or proximity to other area sources (such as airports or shipping ports). As a result, three more sites were excluded from the pool of NO_2 sites that were to be allowed to be scaled-up to simulate near-road monitoring sites.

The final screening was to remove any sites that were not in CBSAs with a population of 350,000 or greater. This was done to match the proposed population based thresholds that trigger minimum required near-road monitors in the NO_2 NAAQS and monitoring proposal package. This screening removed 41monitors, leaving 181 monitors to use in the scale-up simulation.

Chapter 8: Estimates of Costs and Benefits

Synopsis

As discussed above, under the current area-wide monitoring network, we have found no costs or benefits associated with attaining an NO_2 National Ambient Air Quality Standard (NAAQS) in the proposed range of 80 ppb to 100 ppb, as our analysis projects no monitors in the existing network to have with maximum 1-hour design values as high as 80 ppb in 2020. We did perform an illustrative analysis to estimate the costs and human health benefits of nationally attaining a lower bound alternative NO_2 National Ambient Air Quality Standard (NAAQS) of 50 ppb. As a sensitivity in the area-wide analysis, we also analyzed costs and benefits at 65 ppb, which is the lower end of the range over which we have requested comment. With respect to the area-wide analysis, this chapter presents benefits and costs for 50 ppb, and discusses key uncertainties and limitations. Appendix 8a presents our sensitivity analysis for a target of 65 ppb.

It is important to reiterate that the area-wide analysis does not attempt to estimate attainment or nonattainment for any areas of the country other than those counties currently served by one of the 409 monitors in the current network. Chapter 2 explains that the current area-wide network is focused on community-wide ambient levels of NO_2, and not near-roadway levels, which may be significantly higher, and the proposal also contains requirements for an NO_2 monitoring network that will include monitors near major roadways. We recognize that once a network of near-roadway monitors is put in place, more areas could find themselves exceeding the new hourly NO_2 NAAQS. However for this RIA, we lack sufficient data to predict which counties might exceed the new NAAQS after implementation of a near-roadway monitoring network. In our area-wide analysis, we projected current area-wide monitor values to future year monitor values directly, using future year CMAQ modeling outputs that take into account expected changes in emissions from 2006 to 2020. However regional scale models such as CMAQ do not provide a sufficient level of sub-grid detail to estimate near-road concentrations. (In addition, local-scale models such as AERMOD cannot model large regions with appropriate characterization of the near-road component of ambient air quality).

Because it was not possible, in this analysis, to bring all areas into attainment with the alternative standard of 50 ppb in all areas using only identified controls, EPA conducted a second step in the area-wide analysis, and estimated the cost of further tons of emission reductions needed to attain the alternative primary NAAQS. 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.

In this RIA we took the additional step of conducting a screening level analysis to adjust monitors in the existing area-wide network to approximate future near-roadway peaks in those counties. This analysis, presented in Chapter 7, relies on current and future estimated air quality concentrations at area-wide monitors, making adjustments to future year projections using derived estimates of the relationship between future year area-wide air quality peaks and current near-roadway peaks. This additional analysis, which effectively extrapolates future year near-roadway air quality from projected area-wide concentrations, represents a screening level approximation with significant additional uncertainties. This Chapter also presents the benefits and costs of this screening level analysis to approximate future near-roadway conditions.

8.1 Benefits and Costs from the Area-wide Analysis

The 2020 baseline air quality estimates revealed that ten monitors in six counties had projected design values exceeding 50 ppb in 2020. We then developed a hypothetical control strategy that could be adopted to bring the monitor that currently has the highest measured design values in each of those six counties into attainment with a primary standard of 50 ppb by 2020. Controls for five emissions sectors were included in the control analysis: Non-Electricity Generating Unit Point Sources (NonEGUs), Non-Point Area Sources (Area), Onroad Mobile Sources (Onroad), and Nonroad Mobile Sources (Nonroad) and Electricity Generating Unit Point Sources (EGUs). In addition, the results of analyzing the control strategy indicate that there would be two areas projected not to attain 50 ppb in 2020 using all known control measures. To complete the analysis, we then extrapolated the additional emission reductions required to reach attainment.

The total benefits estimates include NO_2-related benefits as well as $PM_{2.5}$ co-benefits. The two estimates use the unadjusted effect estimates (no-threshold) from two epidemiology studies examining the relationship between $PM_{2.5}$ and premature mortality using large population cohorts: the American Cancer Society cohort (Pope et al., 2002) and the Harvard Six Cities cohort (Laden et al., 2006). These estimates reflect EPA's most current interpretation of the scientific literature on $PM_{2.5}$ and mortality, including our updated benefits methodology (i.e., a no-threshold model that calculates incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels and incorporates two technical updates) compared to the estimates in previous RIAs that did not include these changes.

Tables 8.1 and 8.2 presents total national primary estimates of costs and benefits for a 3% discount rate and a 7% discount rate.

Table 8.1: Summary of Total Costs for Area-wide Analysis of Alternative Standard 50 ppb in 2020 (Millions of 2006$)[a, b]

		3% Discount Rate[c]	**7% Discount Rate**
Identified Control Costs		$36	$44
Monitoring Costs		$3.6[d]	$3.6[d]
Extrapolated Costs	Fixed Cost ($10,000/ton)	$240	$240
	Fixed Cost ($15,000/ton)	$350	$350
	Fixed Cost ($20,000/ton)	$470	$470
Total Costs	Fixed Cost ($10,000/ton)	$280	$280
	Fixed Cost ($15,000/ton)	**$390**	**$400**
	Fixed Cost ($20,000/ton)	$510	$520

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.

[c] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For the identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized identified control cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

[d] These numbers do not represent a different discount rate for 3% and 7%.

Table 8.2. Summary of Total Monetized Benefits in 2020 for Area-wide Analysis to Attain 50ppb (millions of 2006$)

	3% Full Attainment	7% Full Attainment	3% Partial Attainment	7% Partial Attainment
NO_2	$6.3	$6.3	$4.6	$4.6
$PM_{2.5}$				
Pope et al	$270	$240	$140	$130
Laden et al	$650	$590	$350	$320
TOTAL with Pope	**$270**	**$250**	**$150**	**$140**
TOTAL with Laden	**$660**	**$600**	**$360**	**$320**

*All estimates are for the analysis year (2020) and are rounded to two significant figures. These benefits estimates do not include several important benefits categories, including NO2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

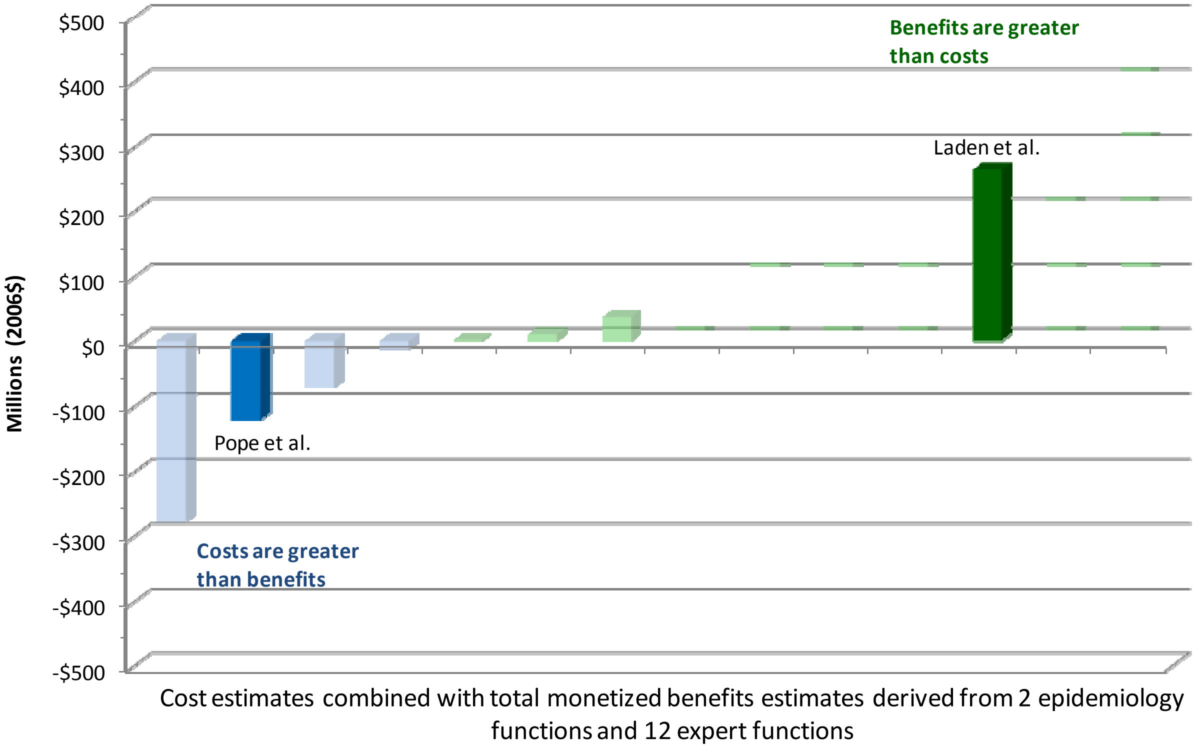
The net benefits were calculated by subtracting the total cost estimate from the two estimates of total benefits. Table 8.3 shows net benefits of the selected NAAQS and alternative standards. Figures 8.1 and 8.2 show the net benefits in graphical form at discount rates of 3% and 7%.

Table 8.3 Summary of Net Benefits for Area-wide Analysis of Alternative Standard 50 ppb in 2020 (Millions of 2006$)

	3% Discount Rate	7% Discount Rate
Total RIA Costs + Monitoring Costs	$390	$400
Total Benefits [a]	$270 - $660	$250 - $600
Total	**$(120) - $270**	**$(150) - $200**

[a] These benefits estimates do not include several important benefits categories, including NO2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

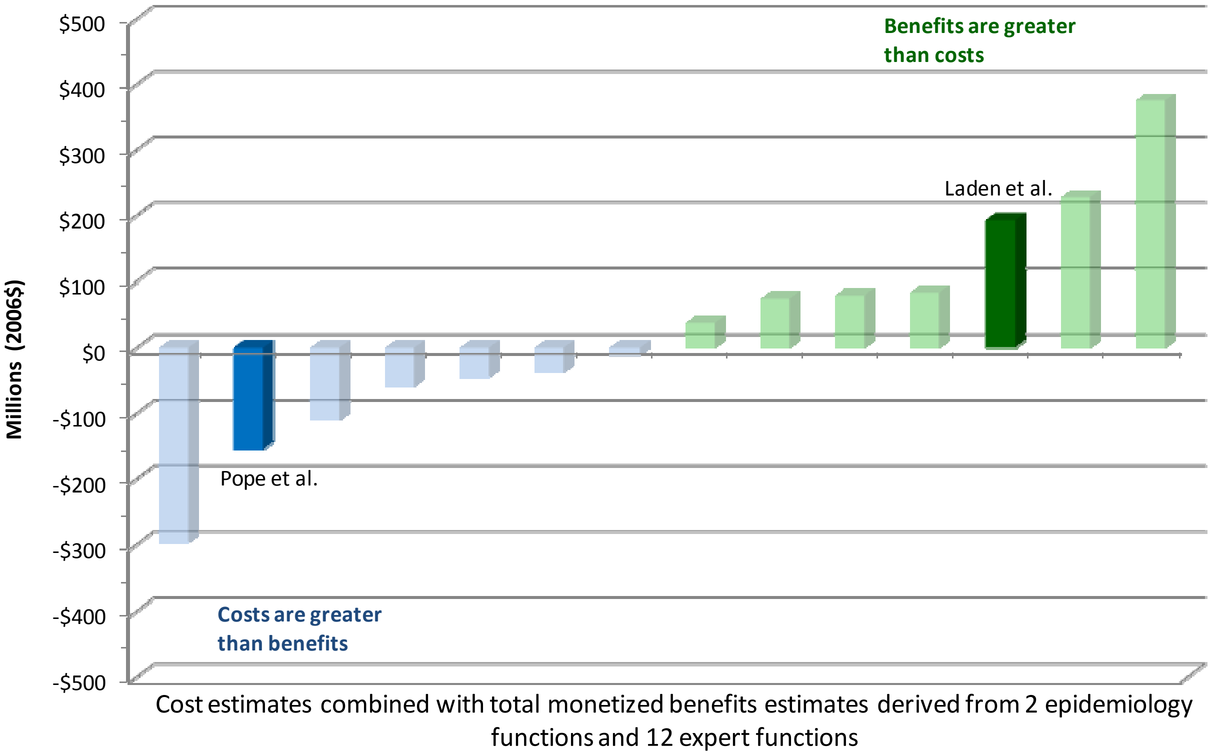
Figure 8.1: Net Benefits for the Area-Wide Analysis of Fully Attaining the 50 ppb NO_2 NAAQS in 2020 (3% Discount Rate)[a, b]



[a] This graph shows the estimated net benefits in 2020 using the no-threshold model at a discount rate of 3% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

[b] Net Benefit results for the near-roadway analysis would be different that the net benefits results shown here.

Figure 8.2: Net Benefits for the Area-wide Analysis of Fully Attaining the 50 ppb NO_2 NAAQS in 2020 (7% Discount Rate)[a, b]



[a] This graph shows the estimated net benefits in 2020 using the no-threshold model at a discount rate of 7% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

[b] Net Benefit results for the near-roadway analysis would be different that the net benefits results shown here.

8.2 Benefits and Costs from the Screening Level Analysis of Approximated Future Near-Roadway NO_2 Levels

Tables 8.4 and 8.5 present the costs and benefits of the screening level analysis of approximated future near roadway levels using the near road gradient adjustment (Method 1) at discount rates of 3% and 7% respectively. These results are also illustrated for the 80 ppb alternative standard utilizing the 65% gradient in Figure 8.3. Tables 8.6 and 8.7 show the cost and benefit results of the near-roadway analysis using the near road gradient adjustment with accounting for greater efficacy of future mobile source emissions reductions (Method 2) at discount rates of 3% and 7% respectively. Figure 8.4 provides the results graphically for the 80 ppb alternative standard using the 65% gradient. The proposed standard range of 80ppb to 100 ppb is highlighted.

Table 8.4: Benefit Cost Comparison for Near Roadway Analysis – Method 1 (in millions of 2006$ at a 3% discount rate for Benefits only)

	Standard Level	Total Costs[a, b]	Total Benefits[c]	Net Benefits
30% Gradient	65 ppb	$170 to $330	$290 to $700	-$40 to $530
	80 ppb	$12 to $20	$14 to $34	-$6.0 to $22
	100 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
	125 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
65% Gradient	65 ppb	$1,000 to $2,100	$1,800 to $4,400	-$300 to $3,400
	80 ppb	$300 to $600	$520 to $1,300	-$80 to $1,000
	100 ppb	$17 to $30	$23 to $56	-$7.0 to $39
	125 ppb	$3.6 to $3.6	$0 to $0	-$3.6 to -$3.6
100% Gradient	65 ppb	$2,400 to $4,800	$4,200 to $10,000	-$600 to $7,600
	80 ppb	$1,200 to $2,300	$2,000 to $5,000	-$300 to $3,800
	100 ppb	$270 to $530	$460 to $1,100	-$70 to $830
	125 ppb	$14 to $24	$18 to $43	-$6.0 to $29

[a] Total Cost estimates are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[b] Los Angeles and El Paso counties were also included in the area-wide analysis of extrapolated costs. In that analysis a central estimate of $15,000/ton was used to calculate the cost of emission reductions needed beyond identified controls. If that estimate was used for this analysis of 80ppb with the 65% gradient adjustment the total costs would range from $1.1 to $1.2 billion.

[c] Total Benefit estimates are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 7% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

Table 8.5: Benefit Cost Comparison for Near Roadway Analysis – Method 1 (in millions of 2006$ at a 7% discount rate for Benefits only)

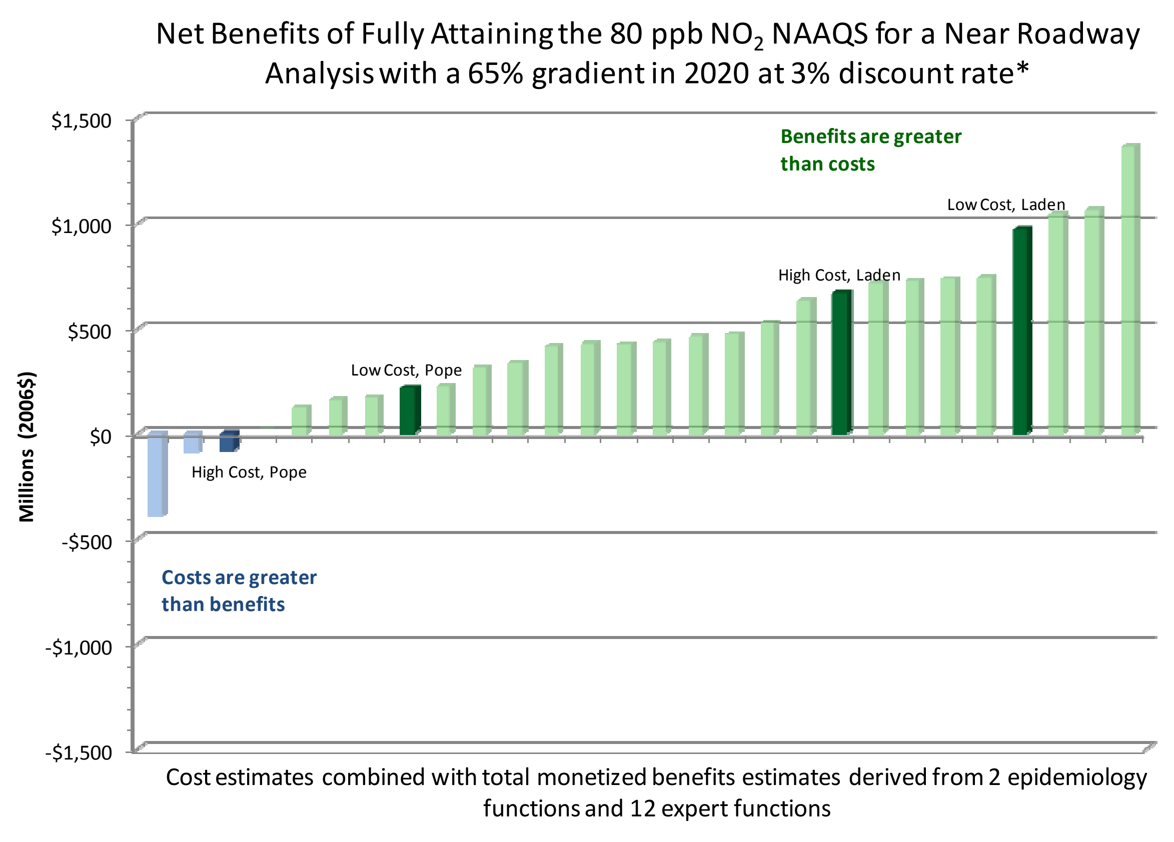
	Standard Level	Total Costs[a, b]			Total Benefits[c]			Net Benefits		
30% Gradient	65 ppb	$170	to	$330	$230	to	$550	-$100	to	$380
	80 ppb	$12	to	$20	$11	to	$27	-$9.0	to	$15
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
65% Gradient	65 ppb	$1,000	to	$2,100	$1,400	to	$3,400	-$700	to	$2,400
	80 ppb	$300	to	$600	$410	to	$1,000	-$190	to	$700
	100 ppb	$17	to	$30	$18	to	$44	-$12	to	$27
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
100% Gradient	65 ppb	$2,400	to	$4,800	$3,300	to	$8,100	-$1,500	to	$5,700
	80 ppb	$1,200	to	$2,300	$1,600	to	$3,900	-$700	to	$2,700
	100 ppb	$270	to	$530	$360	to	$880	-$170	to	$610
	125 ppb	$14	to	$24	$14	to	$34	-$10	to	$20

[a] Total Cost estimates are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[b] Los Angeles and El Paso counties were also included in the area-wide analysis of extrapolated costs. In that analysis a central estimate of $15,000/ton was used to calculate the cost of emission reductions needed beyond identified controls. If that estimate was used for this analysis of 80ppb with the 65% gradient adjustment the total costs would range from $1.1 to $1.2 billion.

[c] Total Benefit estimates are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 7% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

Figure 8.3: Net Benefits for the Near Roadway Analysis of Fully Attaining the 80 ppb NO_2 NAAQS in 2020 – Method 1 (3% Discount Rate)[a]



[a] This graph shows the estimated net benefits in 2020 using the no-threshold model at a discount rate of 3% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies. The results would have the same distribution at a 7% discount rate, but they would be 9% lower.

Table 8.6: Benefit Cost Comparison for Near Roadway Analysis – Method 2 (in millions of 2006$ at a 3% discount rate for Benefits only)

	Standard Level	Total Costs [a]			Total Benefits [b]			Net Benefits		
30% Gradient	65 ppb	$12	to	$21	$15	to	$36	-$6.0	to	$24
	80 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
65% Gradient	65 ppb	$260	to	$510	$440	to	$1,100	-$70	to	$840
	80 ppb	$23	to	$42	$33	to	$81	-$9.0	to	$58
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
100% Gradient	65 ppb	$910	to	$1,800	$1,600	to	$3,800	-$200	to	$2,900
	80 ppb	$280	to	$560	$480	to	$1,200	-$80	to	$920
	100 ppb	$17	to	$31	$24	to	$59	-$7.0	to	$42
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6

[a] Total Cost estimates are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m.

[b] Total Benefit estimates are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 3% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector. These benefits estimates do not include several important benefits categories, including NO_2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

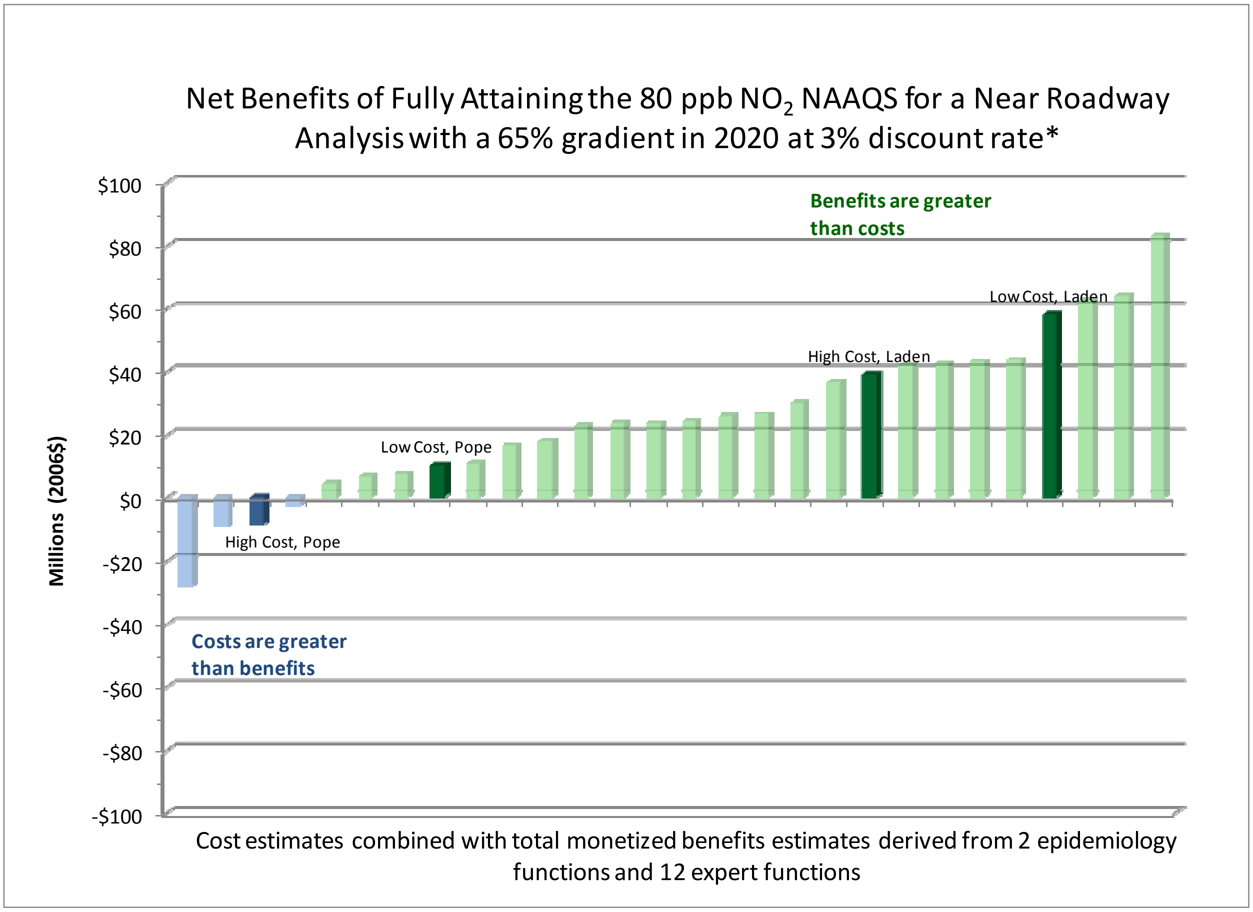
Table 8.7: Benefit Cost Comparison for Near Roadway Analysis – Method 2 (in millions of 2006$ at a 7% discount rate for Benefits only)

	Standard Level	Total Costs *			Total Benefits **			Net Benefits		
30% Gradient	65 ppb	$12	to	$21	$12	to	$29	-$9.0	to	$17
	80 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
65% Gradient	65 ppb	$260	to	$510	$350	to	$850	-$160	to	$590
	80 ppb	$23	to	$42	$26	to	$64	-$16	to	$41
	100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
100% Gradient	65 ppb	$910	to	$1,800	$1,300	to	$3,000	-$500	to	$2,100
	80 ppb	$280	to	$560	$380	to	$930	-$180	to	$650
	100 ppb	$17	to	$31	$19	to	$46	-$12.0	to	$29
	125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6

[a] Total Cost estimates are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[b] Total Benefit estimates are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 7% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector. These benefits estimates do not include several important benefits categories, including NO_2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

Figure 8.4: Net Benefits for the Near Roadway Analysis of Fully Attaining the 80 ppb NO_2 NAAQS in 2020 – Method 2 (3% Discount Rate)[a]



[a] This graph shows the estimated net benefits in 2020 using the no-threshold model at a discount rate of 3% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies. The results would have the same distribution at a 7% discount rate, but they would be 9% lower.

8.3 Combined Results of the Area-wide and Near-roadway Analyses

Tables 8.8 and 8.9 present the combined results of the area-wide and near-road analyses.

Table 8.8: Benefit Cost Comparison for Area-wide and Near Roadway Analyses (in millions of 2006$, 3% Discount Rate)[a]

			Standard Level	Total Costs[b, c]			Total Benefits[d, e]			Net Benefits		
Area-wide Analysis			50 ppb	$390			$270	to	$660	$(120)	to	$270
Near Roadway Analysis	**Method 1**	30% Gradient	65 ppb	$170	to	$330	$290	to	$700	-$40	to	$530
			80 ppb	$12	to	$20	$14	to	$34	-$6.0	to	$22
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		65% Gradient	65 ppb	$1,000	to	$2,100	$1,800	to	$4,400	-$300	to	$3,400
			80 ppb	$300	to	$600	$520	to	$1,300	-$80	to	$1,000
			100 ppb	$17	to	$30	$23	to	$56	-$7.0	to	$39
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		100% Gradient	65 ppb	$2,400	to	$4,800	$4,200	to	$10,000	-$600	to	$7,600
			80 ppb	$1,200	to	$2,300	$2,000	to	$5,000	-$300	to	$3,800
			100 ppb	$270	to	$530	$460	to	$1,100	-$70	to	$830
			125 ppb	$14	to	$24	$18	to	$43	-$6.0	to	$29
	Method 2	30% Gradient	65 ppb	$12	to	$21	$15	to	$36	-$6.0	to	$24
			80 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		65% Gradient	65 ppb	$260	to	$510	$440	to	$1,100	-$70	to	$840
			80 ppb	$23	to	$42	$33	to	$81	-$9.0	to	$58
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		100% Gradient	65 ppb	$910	to	$1,800	$1,600	to	$3,800	-$200	to	$2,900
			80 ppb	$280	to	$560	$480	to	$1,200	-$80	to	$920
			100 ppb	$17	to	$31	$24	to	$59	-$7.0	to	$42
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6

[a] All estimates are for the analysis year (2020) and are rounded to two significant figures.

[b] Costs are estimated at a 3% discount rate in the Area-wide analysis for sources where there is a capital component and O&M component.

[c] Total Cost estimates for Near roadway analysis are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[d] These benefits estimates do not include several important benefits categories, including NO_2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

[e] Total Benefit estimates for the Near-roadway analysis are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 3% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

Table 8.9: Benefit Cost Comparison for Area-wide and Near Roadway Analyses (in millions of 2006$, 7% Discount Rate)[a]

			Standard Level	Total Costs[b]			Total Benefits[c, d]			Net Benefits		
Area-wide Analysis			50 ppb	$400			$250	to	$600	($150)	to	$200
Near Roadway Analysis	Method 1	30% Gradient	65 ppb	$170	to	$330	$230	to	$550	-$100	to	$380
			80 ppb	$12	to	$20	$11	to	$27	-$9.0	to	$15
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		65% Gradient	65 ppb	$1,000	to	$2,100	$1,400	to	$3,400	-$700	to	$2,400
			80 ppb	$300	to	$600	$410	to	$1,000	-$190	to	$700
			100 ppb	$17	to	$30	$18	to	$44	-$12	to	$27
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		100% Gradient	65 ppb	$2,400	to	$4,800	$3,300	to	$8,100	-$1,500	to	$5,700
			80 ppb	$1,200	to	$2,300	$1,600	to	$3,900	-$700	to	$2,700
			100 ppb	$270	to	$530	$360	to	$880	-$170	to	$610
			125 ppb	$14	to	$24	$14	to	$34	-$10	to	$20
	Method 2	30% Gradient	65 ppb	$12	to	$21	$12	to	$29	-$9.0	to	$17
			80 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		65% Gradient	65 ppb	$260	to	$510	$350	to	$850	-$160	to	$590
			80 ppb	$23	to	$42	$26	to	$64	-$16	to	$41
			100 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6
		100% Gradient	65 ppb	$910	to	$1,800	$1,300	to	$3,000	-$500	to	$2,100
			80 ppb	$280	to	$560	$380	to	$930	-$180	to	$650
			100 ppb	$17	to	$31	$19	to	$46	-$12.0	to	$29
			125 ppb	$3.6	to	$3.6	$0	to	$0	-$3.6	to	-$3.6

[a] All estimates are for the analysis year (2020) and are rounded to two significant figures.

[b] Total Cost estimates for Near roadway analysis are shown as a range of annualized costs from $3,000/ton to $6,000/ton. Results include monitoring costs of $3.6m. Costs estimates were only available for a 3% discount rate.

[c] These benefits estimates do not include several important benefits categories, including NO_2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

[d] Total Benefit estimates for the Near-roadway analysis are actually $PM_{2.5}$ co-benefits, shown as a range from Pope et al to Laden et al, at a 7% discount rate, using no-threshold functions, assuming NOx emission reductions from the mobile sector.

8.4 Discussion of Uncertainties and Limitations

As with other NAAQS RIAs, 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 of the NO_2 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 NO_2 levels, as well as coincident reductions in ambient fine particulates.

In the remainder of this section we re-state the most important limitations and uncertainties in the cost and benefit estimates.

Uncertainties related to the control strategy and costs estimates include the following:

- Actual State Implementation Plans May Differ from our Simulation: In order to reach attainment with the proposed NAAQS, each state will develop its own implementation plan implementing a combination of emissions controls that may differ from those simulated in this analysis. This analysis therefore represents an approximation of the emissions reductions that would be required to reach attainment and should not be treated as a precise estimate.

- Current $PM_{2.5}$ and Ozone Controls in Baseline: Our 2020 analysis year baseline assumes that States will put in place the necessary control strategies to attain the current $PM_{2.5}$ and ozone standards. Some of the control strategies employed as part of the ozone RIA, in particular, were of necessity highly uncertain. As States develop their plans for attaining these standards, their NOx control strategies may differ significantly from our analysis.

- Use of Existing CMAQ Model Runs: This analysis represents a screening level analysis. We did not conduct new regional scale modeling specifically targets to NO_2; instead we relied upon impact ratios developed from model runs used in the analysis underlying the ozone NAAQS.

- Analysis Year of 2020: Data limitations necessitated the choice of an analysis year of 2020, as opposed to the presumptive implementation year of 2017. Emission inventory projections are available for 5-year increments; i.e. we have inventories for 2015 and 2020, but not 2017. In addition, the CMAQ model runs upon which we relied were also based on an analysis year of 2020.

- Unknown controls: We have limited information on available controls for some of the monitor areas included in this analysis. For example, a full set of identified controls were applied to Los Angeles County in the Ozone NAAQS RIA; because this analysis is incremental, this left no additional identified control measures to be applied, particularly because we do not have emission reduction estimates for the Port of Long Beach in our analysis.

- We do not have sufficient information for all of our known control measures to calculate cost estimates that vary with an interest rate. We are able to calculate annualized costs at an interest rate other than 7% (e.g., 3% interest rate) where there is sufficient information—available capital cost data, and equipment life—to annualize the costs for individual control measures. For the vast majority of nonEGU point source control measures, we do have sufficient capital cost and equipment life data for individual control measures to prepare annualized capital costs using the standard capital recovery factor. Hence, we are able to provide annualized cost estimates at different interest rates for the point source control measures.

- 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 “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.

Uncertainties related to the benefits estimates include the following:

- Benefits are most uncertain for the Los Angeles and El Paso areas because a large proportion of the $PM_{2.5}$-related benefits are based on emission reductions attributable to unidentified emission controls. 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.

- The gradient of ambient NO_2 concentrations is difficult to estimate due to the sparsity of the monitoring network. The 12km CMAQ grid, which is the air quality modeling resolution, may be too coarse to accurately estimate the potential near-field health benefits of reducing NO_2 emissions. These uncertainties may under- or over-estimate benefits.

- The interpolation techniques used to estimate the full attainment benefits of the alternative standards contributed some uncertainty to the analysis. The great majority of benefits estimated for the 50 ppb standard alternative were derived through interpolation. As noted previously in this chapter, these benefits are likely to be more uncertain than if we had modeled the air quality scenario for both NO_2 and $PM_{2.5}$. In general, the VNA interpolation approach will under-estimate benefits because it does not account for the broader spatial distribution of air quality changes that may occur due to the implementation of a regional emission control program.

- There are many uncertainties associated with the health impact functions used in this modeling effort. These include: within study variability (the precision with which a given study estimates the relationship between air quality changes and health effects); across study variation (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 (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 (we assumed that certain health impact functions applied to age ranges broader than that considered in the original epidemiological study); and various uncertainties in the C-R function, including causality and thresholds. These uncertainties may under- or over-estimate benefits.

- Co-pollutants present in the ambient air may have contributed to the health effects attributed to NO_2 in single pollutant models. Risks attributed to NO_2 might be overestimated where concentration-response functions are based on single pollutant models. If co-pollutants are highly correlated with NO_2, their inclusion in an NO_2 health effects model can lead to misleading conclusions in identifying a specific causal pollutant. Because this colinearity exists, many of the studies reported statistically insignificant effect estimates for both NO_2 and the co-pollutants. Where available, we have selected multipollutant effect estimates to control for the potential confounding effects of co-pollutants; these include NYDOH (2006), Schwartz et al. (1994) and O'Conner et al. (2007). The remaining studies include single pollutant models.

- This analysis is for the year 2020, and projecting key variables introduces uncertainty. 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.

- This analysis omits certain unquantified effects due to lack of data, time and resources. These unquantified endpoints include other health effects, ecosystem effects, and visibility. EPA will continue to evaluate new methods and models and select those most appropriate for estimating the benefits of reductions in air pollution. Enhanced collaboration between air quality modelers, epidemiologists, toxicologists, ecologists, and economists should result in a more tightly integrated analytical framework for measuring benefits of air pollution policies.

- $PM_{2.5}$ co-benefits represent a substantial proportion of total monetized benefits (97% to 99% of total benefits for the 50 ppb standard), and these estimates are subject to a number of assumptions and uncertainties.

- $PM_{2.5}$ co-benefits were derived through benefit per-ton estimates, which do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual benefits of controlling directly emitted fine particulates.

- We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ produced via transported precursors emitted from EGUs may differ significantly from direct $PM_{2.5}$ released from diesel engines and other industrial sources, but no clear scientific grounds exist for supporting differential effects estimates by particle type.

- We assume that the health impact function for fine particles is linear within the range of ambient concentrations under consideration. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5,}$ including both regions that are in attainment with fine particle standard and those that do not meet the standard down to the lowest modeled concentrations.

- To characterize the uncertainty in the relationship between $PM_{2.5}$ and premature mortality (which typically accounts for 85% to 95% of total monetized benefits), we include a set of twelve estimates based on results of the expert elicitation study in addition to our core estimates. Even these multiple characterizations, omit the uncertainty in air quality estimates, baseline incidence rates, populations exposed and transferability of the effect estimate to diverse locations. As a result, the reported confidence intervals and range of estimates give an incomplete picture about the overall uncertainty in the $PM_{2.5}$ estimates. This information should be interpreted within the context of the larger uncertainty surrounding the entire analysis. For more information on the uncertainties associated with $PM_{2.5}$ benefits, please consult the $PM_{2.5}$ NAAQS RIA.

Uncertainties related to the screening level near-roadway analysis include:

- Due to the absence of a near-roadway monitoring network, this is a screening level analysis with several simplifying assumptions. It is provided to give a rough projection of the costs and benefits of attaining a revised NO_2 standard based on a yet to be established monitoring network.

- This analysis does not take into account a large variety of localized conditions specific to individual monitors; instead, the analysis attempts to account for some local parameters by adjusting future design values based on average localized impacts near roads from onroad emissions.

- The process of adjusting from a specific 12 km CMAQ receptor to a near-road air quality estimate represents an uncertain approximation at the specific monitor level.

- This analysis is an approximation in that it derives future year (2020) **peak** air quality concentrations in specific locations by relying on CMAQ estimates that are averages over a 12 km grid square.

- This analysis cannot predict air quality in locations for which there is no current NO_2 monitor, or where current monitoring data is incomplete. There are 142 CBSAs for which we are proposing to add new near-road monitors. Of these, 73 either have no existing monitor in the CBSA, or have a monitor with data not complete enough to include in the near-roadway analysis. In these CBSAs, extrapolation to near-roadway levels is not possible.

- This analysis assumes area-wide monitors remain in the same location; however concentrations are adjusted to reflect near-roadway conditions.

- Because the emission reductions in this analysis are solely reductions from mobile sources, this analysis uses an estimated cost per ton for NOx emission reductions that is different from the estimated cost per ton for NOx emission reductions used in the main body of the RIA.

- This analysis omits certain unquantified effects due to lack of data, time and resources. These unquantified endpoints include NO_2 health effects, ozone co-benefits, ecosystem effects, and visibility.

Appendix 8a: Sensitivity Analysis for Alternative Standard of 65 ppb

Synopsis

This appendix presents the sensitivity analysis for an alternative standard of 65 ppb. Because the proposal requests comments on alternative NAAQS levels from 65 ppb to 125 ppb, we included an analysis of the costs of benefits of attaining 65 ppb as a sensitivity.

8a.1 Identified Control Strategy Analysis

As shown in Table 8a.1, only one county is projected to exceed an alternative standard of 65 ppb using the air quality estimation technique presented in Chapter 3. Adams County, CO exceeds the alternative standard by 1 ppb, and is projected to need to control approximately 460 tons of emissions to attain 65 ppb.

Table 8a.1: Projected Ambient Concentration of NO_2 in 2020 and Emission Reductions Needed for Attainment of an Alternative Standard of 65 ppb[a]

State	County	Ambient Concentration in 2020 (ppb)	NOx Emission Reductions Needed in 2020 (tons/year)
CO	Adams	66.4	460

[a] All estimates rounded to two significant figures.

As discussed in Chapter 4, the controls analyzed for Adams County consisted of point source controls for a local EGU facility. To illustrate attainment with an alternative standard of 65 ppb, only one control was applied to the facility. This one control yielded emission reductions of 1,400 tons (Table 8a.2). This is greater than the emission reductions needed for this county, but after looking at the other available control options for this geographic area, it appeared this was still the most cost-effective option. Table 8a.3 shows the ambient concentration of NO_2 post the application of identified controls.

Table 8a.2: Emission Reductions by County in 2020 for Alternative Standard 65 ppb[a]

State	County	NOx Emission Reductions in 2020 (tons/year)
CO	Adams	1,400

[a] All estimates rounded to two significant figures.

Table 8a.3: Projected Ambient NO_2 Concentration in 2020 Achieved with Identified Controls for the Alternative Standard of 65 ppb

State	County	2020 NO_2 Concentration (ppb)
CO	Adams	63.4

8a.2 Cost Analysis

The identified control costs for Adams County are presented in Table 8a.4. The total engineering costs of an alternative standard of 65 ppb is three million dollars using a seven percent discount rate.

Table 8a.4: Annual Control Costs of Identified Controls applied for the Alternative Standard Analysis of 65 ppb (Millions of 2006$) [a, b]

State	County	3% Discount Rate[c]	7% Discount Rate
CO	Adams	$2.3	$3.0
	Total	**$2.3**	**$3.0**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] All estimates provided reflect the engineering cost of the modeled control strategy, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.

8a.3 Benefits Analysis

In order to calculate the benefits of attaining an alternative standard level of 65 ppb, we used the same benefits methodology as described in Chapter 5 with one minor adjustment. To calculate the NO_2 benefits of attaining 65 ppb, we interpolated from the benefits estimates for 50 ppb. The interpolation factor is the ratio between the concentration reduction each non-attaining area needed to get to 65 ppb and the concentration reduction each non-attaining area needed to get to 50 ppb. We believe this is a reasonable approximation because of the magnitude of NO_2 benefits relative to $PM_{2.5}$ co-benefits and the minimal non-attainment problem at these levels. These estimates reflect EPA's most current interpretation of the scientific literature on $PM_{2.5}$ and mortality, including our updated benefits methodology (i.e., a no-threshold model that calculates incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels and incorporates two technical updates) compared to the estimates in previous RIAs that did not include these changes.

Table 8a.5: Total NO_2 and $PM_{2.5}$ Benefits to attain 65 ppm at discount rates of 3% and 7% (millions of 2006$)*

	3% Full Attainment	**7% Full Attainment**
NO_2	$0.67	$0.67
$PM_{2.5}$		
Pope et al	$11	$9.7
Laden et al	$26	$24
TOTAL with Pope	**$11**	**$10**
TOTAL with Laden	**$27**	**$24**

*Numbers have been rounded to two significant figures and therefore summation may not match table estimates. All estimates are for the analysis year (2020) and are rounded to two significant figures. These benefits estimates do not include several important benefits categories, including NO2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

8a.4 Net Benefits

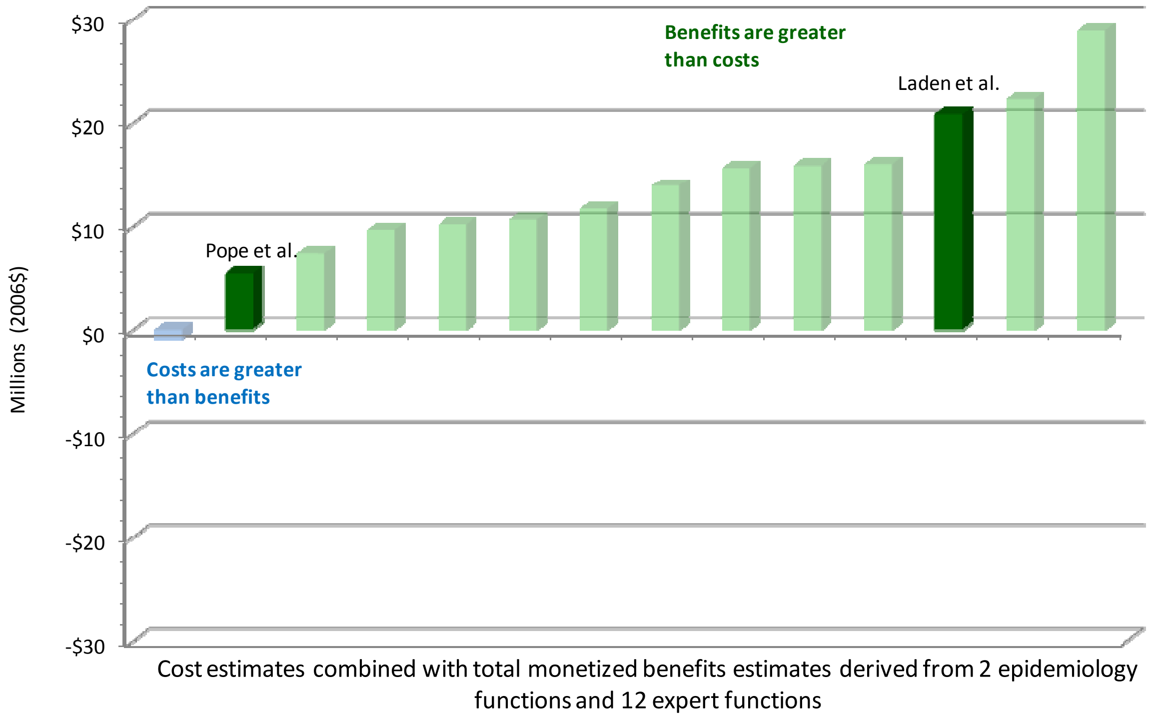
The net benefits of the alternative standard of 65 ppb are presented in Table 8a.6 and shown in graphical form in Figures 8a.1 and 8a.2. For both discount rates the benefits of attaining the alternative standard exceed the costs by an order of magnitude.

Table 8a.6: Summary of Net Benefits for Alternative Standard 65 ppb (Millions of 2006$)*

	3% Discount Rate	7% Discount Rate
Total Costs + Monitoring	$2.3 + 3.6	$3.0 + 3.6
Total Benefits	$11 to $27	$10 to $24
Total	**$5.1 to $21**	**$3.4 to $17**

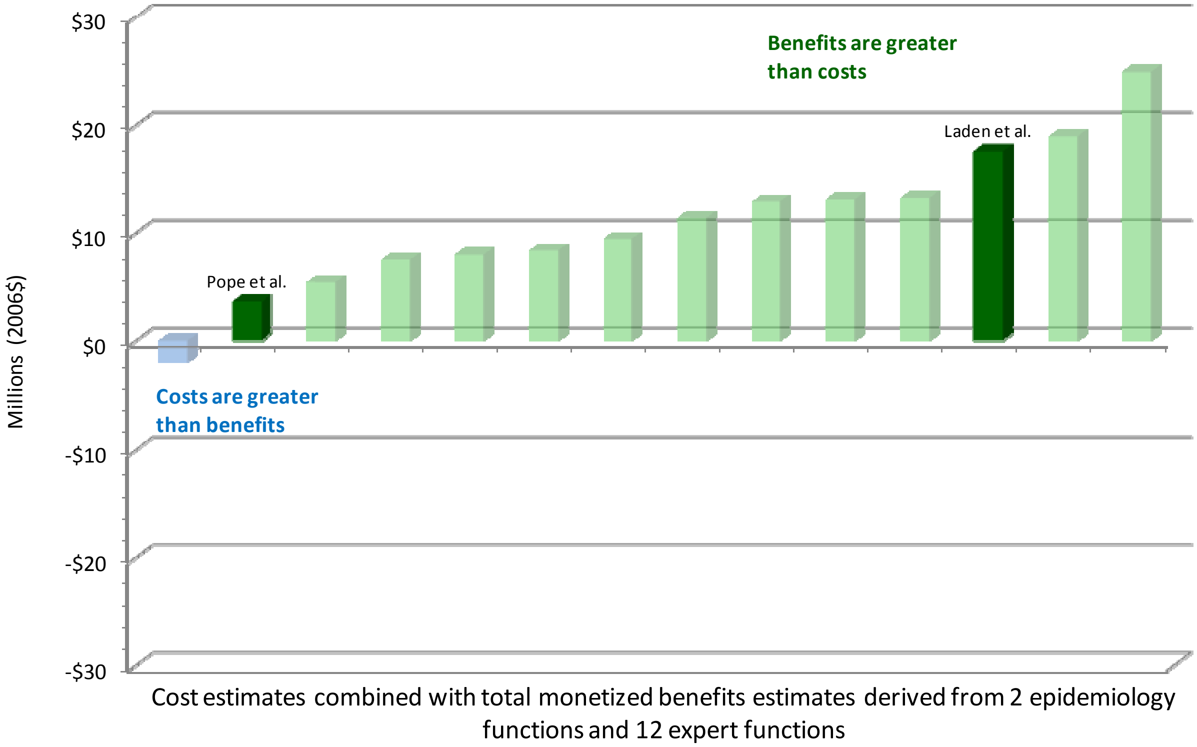
*Numbers have been rounded to two significant figures and therefore summation may not match table estimates. These benefits estimates do not include several important benefits categories, including NO_2-related premature mortality, ecosystem effects from nitrogen deposition, ozone-related health effects, or improvements in visibility.

Figure 8a.1: Net Benefits of Fully Attaining an Alternative Standard of 65 ppb in 2020 (3% Discount Rate)



*This graph shows the estimated net benefits in 2020 using the no-threshold model at a discount rates of 3% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

Figure 8a.1: Net Benefits of Fully Attaining an Alternative Standard of 65 ppb in 2020 (7% Discount Rate)



*This graph shows the estimated net benefits in 2020 using the no-threshold model at a discount rate of 7% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

Chapter 9: Statutory and Executive Order Reviews

A. *Executive Order 12866: Regulatory Planning and Review*

Under section 3(f)(1) of Executive Order (EO) 12866 (58 FR 51735, October 4, 1993), this action is not an "economically significant regulatory action" because it is not likely to have an annual effect on the economy of $100 million or more. Nevertheless, EPA has submitted this action to the Office of Management and Budget (OMB) for review under EO 12866 and any changes made in response to OMB recommendations have been documented in the docket for this action (). In addition, EPA prepared this Regulatory Impact Analysis (RIA) of the potential costs and benefits associated with this action. However, the 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 developing this proposed rule.

B. *Paperwork Reduction Act*

The information collection requirements in this final rule will be submitted for approval to the Office of Management and Budget (OMB) under the Paperwork Reduction Act, 44 U.S.C. 3501 et seq. The information collection requirements are not enforceable until OMB approves them.

The information collected under 40 CFR part 53 (e.g., test results, monitoring records, instruction manual, and other associated information) is needed to determine whether a candidate method intended for use in determining attainment of the National Ambient Air Quality Standards (NAAQS) in 40 CFR part 50 will meet the design, performance, and/or comparability requirements for designation as a Federal reference method (FRM) or Federal equivalent method (FEM).

The information collected and reported under 40 CFR part 58 is needed to determine compliance with the NAAQS, to characterize air quality and associated health and ecosystem impacts, to develop emissions control strategies, and to measure progress for the air pollution program. The proposed amendments would revise the technical requirements for NO2 monitoring sites, require the siting and operation of additional NO2 ambient air monitors, and the reporting of the collected ambient NO_2 monitoring data to EPA's Air Quality System (AQS). We have estimated the burden based on the proposed monitoring requirements of this rule. Based on these requirements, the annual average reporting burden for the collection under 40 CFR part 58 (averaged over the first 3 years of this ICR) for 142 respondents is estimated to increase by a total of 38,077 labor hours per year with an increase of $3,616,487 per year. Burden is defined at 5 CFR 1320.3(b).

C. Regulatory Flexibility Act

The Regulatory Flexibility Act (RFA) generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions.

For purposes of assessing the impacts of this 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 this final rule on small entities, the Administrator certified this action will not have a significant economic impact on a substantial number of small entities. This final rule will not impose any requirements on small entities. Rather, this rule establishes national standards for allowable concentrations of NO_2 in ambient air as required by section 109 of the CAA. *American Trucking Ass'ns v. EPA,* 175 F. 3d 1027, 1044-45 (D.C. cir. 1999) (NAAQS do not have significant impacts upon small entities because NAAQS themselves impose no regulations upon small entities). Similarly, the amendments to 40 CFR part 58 address the requirements for States to collect information and report compliance with the NAAQS and will not impose any requirements on small entities.

D. 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. Unless otherwise prohibited by law, 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 one year. Before promulgating an EPA rule for which a written statement is required under section 202, section 205 of the UMRA generally requires EPA to identify and consider a reasonable number of regulatory alternatives and to 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 action is not subject to the requirements of sections 202 and 205 of the UMRA. EPA has determined that this final rule does not contain a Federal mandate that may result in expenditures of $100 million or more for State, local, and tribal governments, in the aggregate, or the private sector in any one year. The revisions to the NO_2 NAAQS impose no enforceable duty on any State, local or Tribal governments or the private sector. The expected costs associated with the increased monitoring requirements are described in EPA’s ICR document, but those costs are not expected to exceed $100 million in the aggregate for any year. Furthermore, as indicated previously, in setting a NAAQS EPA cannot consider the economic or technological feasibility of attaining ambient air quality standards. Because the Clean Air Act prohibits EPA from considering the types of estimates and assessments described in section 202 when setting the NAAQS, the UMRA does not require EPA to prepare a written statement under section 202 for the revisions to the NO_2 NAAQS.

With regard to implementation guidance, the CAA imposes the obligation for States to submit SIPs to implement the NO_2 NAAQS. In this proposed rule, EPA is merely providing an interpretation of those requirements. However, even if this rule did establish an independent obligation for States to submit SIPs, it is questionable whether an obligation to submit a SIP revision would constitute a Federal mandate in any case. The obligation for a State to submit a SIP that arises out of section 110 and section 191 of the CAA is not legally enforceable by a court of law, and at most is a condition for continued receipt of highway funds. Therefore, it is possible to view an action requiring such a submittal as not creating any enforceable duty within the meaning of 2 U.S.C. 658 for purposes of the UMRA. Even if it did, the duty could be viewed as falling within the exception for a condition of Federal assistance under 2 U.S.C. 658.

EPA has determined that this final rule contains no regulatory requirements that might significantly or uniquely affect small governments because it imposes no enforceable duty on any small governments. Therefore, this rule is not subject to the requirements of section 203 of the UMRA.

E. 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.”

This proposed rule does not have federalism implications. It will 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. The rule does not alter the relationship between the Federal government and the States regarding the establishment and implementation of air quality improvement programs as codified in the CAA. Under section 109 of the CAA, EPA is mandated to establish NAAQS; however, CAA section 116 preserves the rights of States to establish more stringent requirements if deemed necessary by a State. Furthermore, this rule does not impact CAA section 107 which establishes that the States have primary responsibility for implementation of the NAAQS. Finally, as noted in section E (above) on UMRA, this rule does not impose significant costs on State, local, or tribal governments or the private sector. Thus, Executive Order 13132 does not apply to this rule.

However, EPA recognizes that States will have a substantial interest in this rule and any corresponding revisions to associated air quality surveillance requirements, 40 CFR part 58. Therefore, in the spirit of Executive Order 13132, and consistent with EPA policy to promote communications between EPA and State and local governments, EPA is specifically soliciting comment on this proposed rule from State and local officials as noted in the preamble.

F. 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 proposed rule does not have tribal implications, as specified in Executive Order 13175 (65 FR 67249, November 9, 2000). 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 or monitoring requirements for NAAQS. Thus, Executive Order 13175 does not apply to this action. However, EPA has specifically solicited additional comment on this proposed rule from tribal officials.

G. Executive Order 13045: Protection of Children from Environmental Health & Safety Risks

This action is not subject to Executive Order (62 FR 19885, April 23, 1997) because it is not an economically significant regulatory action as defined by Executive Order 12866. However, we believe that the environmental health risk addressed by this action could have a disproportionate effect on children. The proposed rule will establish uniform national ambient air quality standards for NO_2; these standards are designed to protect public health with an adequate margin of safety, as required by CAA section 109. The protection offered by these standards may be especially important for asthmatics, including asthmatic children, because respiratory effects in asthmatics are among the most sensitive health endpoints for NO_2 exposure. Because asthmatic children are considered a sensitive population, we have evaluated the potential health effects of exposure to NO_2 pollution among asthmatic children. These effects and the size of the population affected are discussed in chapters 3 and 4 of the ISA; chapters 3, 4, and 8 of the REA, and sections II.A through II.E of the preamble.

H. Executive Order 13211: Actions that Significantly Affect Energy Supply, Distribution or Use

This 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 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 NO_2. The rule does not prescribe specific 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.

I. National Technology Transfer and Advancement Act

Section 12(d) of the National Technology Transfer and Advancement Act of 1995 (NTTAA), Public Law 104-113, section 12(d) (15 U.S.C. 27_2 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.

This proposed rulemaking involves technical standards with regard to ambient monitoring of NO_2. The use of this voluntary consensus standard would be impractical because the analysis method does not provide for the method detection limits necessary to adequately characterize ambient NO_2 concentrations for the purpose of determining compliance with the proposed revisions to the NO_2 NAAQS.

EPA is welcoming comments on this aspect of the proposed rule, and has specifically invited the public to identify potentially applicable voluntary consensus standards and to explain why such standards should be used in the regulation.

J. Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations

Executive Order 12898 (59 FR 7629; Feb. 16, 1994) establishes federal executive policy on environmental justice. Its main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States.

EPA has determined that this proposed rule will not have disproportionately high and adverse human health or environmental effects on minority or low-income populations because it increases the level of environmental protection for all affected populations without having any disproportionately high and adverse human health effects on any population, including any minority or low-income population. The proposed rule will establish uniform national standards for NO_2 in ambient air. EPA has requested comment on environmental justice issues related to the proposed revision of the NO_2 NAAQS.