STRATUS CONSULTING

Benefit Study of MRPO Candidate Control Options for Electricity Generation

Prepared for:

Lake Michigan Air Directors Consortium
2250 East Devon Avenue, Suite 250
Des Plaines, IL 60018

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Executive Summary

This report describes the methods and results of a health and economic benefits analysis that Stratus Consulting conducted for the Lake Michigan Air Directors Consortium (LADCO). The analysis examines a set of potential candidate control options placing more stringent emission limits for electricity generating units (EGUs). These candidate EGU control options are part of a series of potential programs the Midwest Regional Planning Organization (MRPO) is examining that would improve air quality in the five-state MRPO region in order to meet the National Ambient Air Quality Standards (NAAQS) for ozone and fine particulate matter ($PM_{2.5}$).

The candidate control options examined in this report would require EGUs in the five-state MRPO region to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) by the end of 2012. SO_2 and NO_x are important precursor pollutants to ozone and $PM_{2.5}$; through chemical processes occurring in the atmosphere, these and other air pollutants chemically react to form ozone and $PM_{2.5}$. The candidate control options were described in a series of interim "White Papers" that LADCO produced during 2005. Candidate control options included not only EGUs, but also candidate controls on 15 other emission sources. The specific EGU control options analyzed here are described in "Interim White Paper – Midwest RPO Candidate Control Measures" released December 9, 2005. That paper is available at the LADCO website (LADCO, 2005).

There are four critical analytical components in conducting the health and economic benefits analysis of control options to improve ozone and $PM_{2.5}$ levels: emissions inventory, emission changes, air quality modeling, and health and economic valuation. LADCO provided Stratus Consulting with the results of the EGU emission reduction analyses and the air quality modeling results of the impact of four different emissions scenarios. In addition, LADCO provided the results of a cost analysis produced as an integral part of the emissions analysis. Although Stratus Consulting did not conduct the EGU cost and emissions analysis [which was prepared by LADCO staff and ICF International, Inc. (ICF)], nor the air quality modeling analysis (prepared by LADCO staff), the results of those analyses are summarized in this report.

1. Emissions Inventory

Analytical Baseline The future emissions baseline for this analysis is the complete inventory of all ozone and $PM_{2.5}$ precursor emissions currently predicted to occur in 2012. This analytical baseline reflects reductions from current emissions levels that will occur due to all already promulgated ("on-the-books") federal regulations under the Clean Air Act, as well as anticipated replacement of older model vehicles and existing industrial and commercial equipment. Two federal programs promulgated in 2005 are included in the analytical baseline: the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR). Other federal programs directly affecting EGUs that are included in the 2012 analytical baseline include: the 1997 NO_x SIP call, the OTC NO_x Budget Program, the Acid Rain Program (Title IV), and Title I programs including New Source Review (NSR), New Source Performance Standards (NSPS), and plant-specific requirements adopted under current State Implementation Plans (SIPs).

Emission Reductions from the EGU Candidate Control Measures There are two estimates of the EGU emission reduction changes for each EGU candidate control measure. The first estimate is based on the candidate control option described in the White Paper, where each EGU in the MRPO region must meet a specified emission rate limit (lbs/mmBtu). The EGU1 candidate measure sets the emission limits at the EGU retrofit BACT level, and the EGU2 candidate measure sets the limits at the new plant BACT limit.

The second set of estimates of the emission changes for each candidate control option were developed by considering the potential industry response to additional emission restrictions. LADCO engaged ICF to conduct an Integrated Planning Model (IPM®) analysis of the least-cost method of meeting the candidate emission reductions.

There are two important differences between the White Paper analysis and the IPM analysis of the EGU candidate control options. The White Paper analysis did not allow emission trading; each facility had to meet the candidate emission rates at each unit at all times. The IPM analysis allowed both within MRPO region emissions trading to meet a mass emission cap implied by the BACT limits, and sale of emission reduction credits to out-of-region EGUs under existing federal emission trading programs. A second major difference is the annual mass limit reported for 2012 in the IPM analysis was derived from an average of the mass limits for the years 2010 through 2013. In 2010 and 2011 the IPM analysis assumed Phase 1 of the candidate program was in effect, while in 2012 and 2013 Phase II of the candidate program was assumed. Thus the average mass limit used to represent 2012 is actually the average of the Phase I mass limits and Phase II mass limits. This results in a substantially higher amount of emissions from EGUs in 2012 than were estimated in the White Paper analysis. The subsequent air quality modeling based on the IPM analysis incorporates these higher emission estimates.

Table ES-1 shows the specific emission rate limits for SO_2 in the EGU1 and EGU2 candidate measures, and the associated annual SO_2 emission reductions for all four candidate measures.[1] Table ES-22 shows similar information for NO_x.

1. The emission reductions for EGU1 and EGU2 were based on information reported in the White Paper. Note, however, that the White Paper emissions were adjusted to reflect an earlier (2012) compliance date. These 2012 emission estimates were used in the subsequent air quality modeling.

Table ES-1. SO_2 EGU emission limits and resulting total annual emissions

SO_2 candidate control measure summary	Annual SO_2 EGU emissions (tons/year) in MRPO region	
2002 existing measures (MRPO average SO_2 emission rate is 1.16 lbs/mmBtu)	2002 base	2,799,000
2012 analytical baseline (44% reduction from 2002 base levels due to "on the way" programs)	2012 baseline	1,565,000
EGU1: Emission limits based on "Retrofit SO_2 BACT Level" of 0.15 lbs/mmBtu (71% reduction from the 2012 baseline; total reduction of 84% from 2002)	Reduction in 2012 Remaining	-1,117,000 448,000
EGU2: Emission limits based on "SO_2 BACT Level for New Plants" of 0.10 lbs/mmBtu (81% reduction from 2012 baseline, total 89% reduction from 2002)	Reduction in 2012 Remaining	-1,266,000 299,000
EGU1 with IPM: Annual mass limit with trading (53% reduction from the 2012 baseline; total 74% reduction from 2002)	Reduction in 2012 Remaining	-830,000 735,000
EGU2 with IPM: Annual mass limit with trading (67% reduction from the 2012 baseline; total 82% reduction from 2002)	Reduction in 2012 Remaining	-1,049,000 516,000

Table ES-2. NO_x EGU emission limits and resulting total annual emissions

NO_x candidate control measure summary	Annual NO_x EGU emissions (tons/year) in MRPO region	
2002 existing measures (MRPO average NO_x is 0.43 lbs/mmBtu)	2002 base	1,047,000
2012 analytical baseline (57% reduction from 2002 base levels due to "on the way" programs)	2012 baseline	447,000
EGU1: Emission limits based on "Retrofit NO_x BACT" level of 0.10 lbs/mmBtu (33% reduction from the 2012 baseline; total reduction of 71% from 2002)	Reduction in 2012 Remaining	-148,000 299,000
EGU2: Emission limits based on "NO_x BACT Level for New Plants" of 0.07 lbs/mmBtu (53% reduction from the 2012 baseline; total reduction of 80% from 2002)	Reduction in 2012 Remaining	-238,000 209,000
EGU1 with IPM: Annual mass limit with trading (17% reduction from the 2012 baseline; total 65% reduction from 2002)	Reduction in 2012 Remaining	-76,000 371,000
EGU2 with IPM: Annual mass limit with trading (39% reduction from the 2012 baseline; total 82% reduction from 2002)	Reduction in 2012 Remaining	-173,000 274,000

The required reductions in emissions in the EGU1 and EGU2 candidate programs are confined to the MRPO region. The "EGU1 with IPM" and "EGU2 with IPM" candidate programs, however, allow the reductions in emissions occurring within the five-state region to be sold out-of-region as ERCs. Thus with trading the national totals of SO_2 and NO_x emissions stay essentially constant in the "with IPM" candidate programs, but the spatial distribution of emissions shifts. Fewer emissions occur in the MRPO region due to the program's more stringent emission limits, but emissions in other states increase through the purchase of ERCs. Table ES-3 presents the details of the emissions for the "with IPM" candidate programs.

Table ES 3. SO_2 and NO_x emissions by region (tons/year)

	5 MRPO states		Rest of nation		Total nation	
	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x
2012 baseline	1,565,000	449,000	4,210,000	2,028,000	5,775,000	2,477,000
EGU1 with IPM	735,000	371,000	5,106,000	2,100,000	5,841,000	2,471,000
Change	-830,000	-78,000	+896,000	+72,000	+66,000	-6,000
% change	-53%	-17%	+21%	+4%	+1.1%	-0.2%
EGU2 with IPM	516,000	274,000	5,264,000	2,183,000	5,780,000	2,457,000
Change	-1,049,000	-173,000	+1,054,000	+155,000	+5,000	-20,000
% change	-67%	-39%	+25%	+8%	+0.1%	-0.8%

Note: Regional emissions may not sum to national total due to rounding.

2. Air Quality Modeling

The $PM_{2.5}$ and ozone concentrations were estimated using the Comprehensive Air quality Model (CAMx). The EPA has approved the use of CAMx for developing SIPs for ozone and $PM_{2.5}$, and it has been used by LADCO and the individual states in the MRPO regions for a wide variety of air quality analyses. LADCO staff used CAMx version 4.30 to conduct the air quality analyses for the EGU candidate control options.

Different CAMx configurations were used for modeling ozone and $PM_{2.5}$. $PM_{2.5}$ was estimated at the daily level for the full year, while ozone estimates were prepared at the hourly level for a 90-day ozone season (June 3 through August 30). The $PM_{2.5}$ modeling covered a broader geographic region than the ozone modeling. The estimated $PM_{2.5}$ changes (annual mean $\mu g/m^3$) for each of the four modeled candidate control programs at every location in the $PM_{2.5}$ domain are shown in Figures ES-1 through ES-4. Similar maps for ozone are included in the main report.

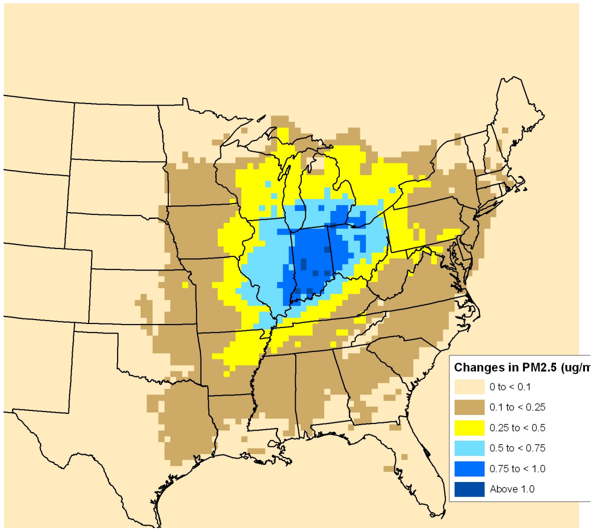

Figure ES-1. Changes in annual mean $PM_{2.5}$ with EGU1 candidate control program.

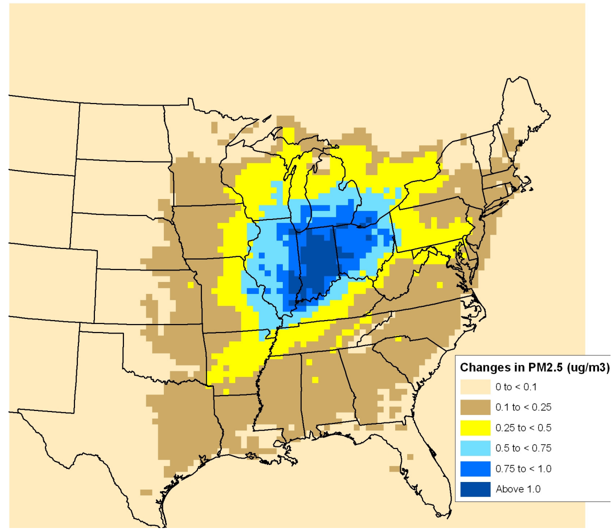

Figure ES-2. Changes in annual mean $PM_{2.5}$ with EGU2 candidate control program.

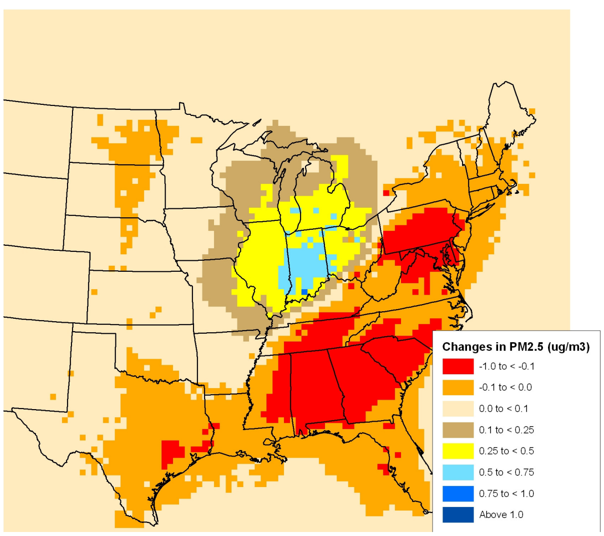

Figure ES-3. Changes in annual mean $PM_{2.5}$ with EGU1 with IPM candidate control program.

Note: Positive values indicate an improvement in $PM_{2.5}$ levels. Negative values indicate a worsening of $PM_{2.5}$ levels.

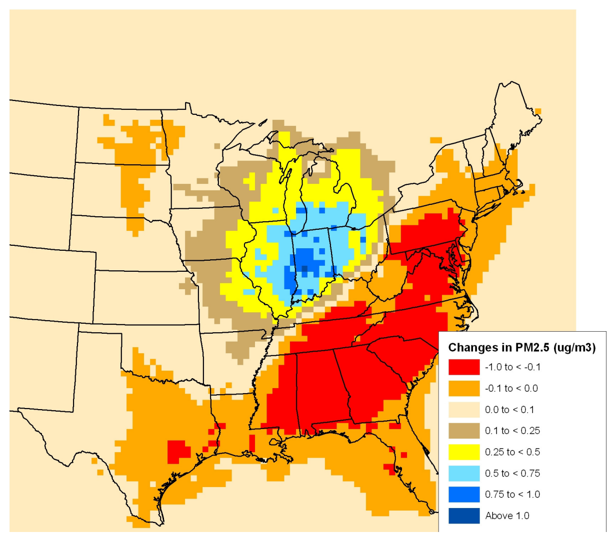

Figure ES-4. Changes in annual mean $PM_{2.5}$ with EGU2 with IPM candidate control program.

3. Health Effects

Changes in the ambient levels of ozone and $PM_{2.5}$ will affect the health of the population exposed to those changes. Quantifiable health effects range from premature mortality and onset of chronic, debilitating respiratory disease to milder symptoms such as school absences and "adult respiratory symptom days" with coughing or wheezing.

While there is scientific uncertainty about the specific magnitude and form of the relationships between changes in exposure and health outcomes, EPA developed a set of analytical methods to quantify many of the important health effects of changes in $PM_{2.5}$ and ozone. The changes in health effects associated with the four air quality change scenarios were estimated using methods and tools developed by the EPA. With one exception, the health effect estimation procedures used in this report are identical to the procedures EPA used in the regulatory analysis of CAIR. The one exception to full consistency with EPA's CAIR analysis is ozone-related premature mortality, which is included in the mortality estimates in this report.

The health and valuation analysis for this report was conducted using EPA's BenMAP version 2.2, a Windows©-based computer model developed for EPA and available from EPA's Technology Transfer Network. BenMAP is the Environmental Benefits Mapping and Analysis Program.

There are ten health effects associated with ozone and $PM_{2.5}$ estimated with BenMAP for this report. In addition, one health-related effect, worker productivity (which is limited to the impact of ozone on outdoor physical labor), is directly measured as the value of the loss of economic output. The estimates of the avoided health effects for each of the four modeled air quality scenarios (EGU1, EGU2, EGU1 with IPM, and EGU2 with IPM) are presented in Table ES-4. The estimates shown in the tables are the number of cases of health effects that are associated with the estimated changes in ozone and $PM_{2.5}$ levels. Air quality improvements result in positive numbers of avoided cases, and worsening air quality results in negative numbers of cases. Table ES-4 show the "national" total (actually the total cases for the modeled areas), as well as the sub-total for the MRPO region.

Table ES-4. Estimated health effects

	EGU1		EGU2		EGU1 w IPM		EGU2 w IPM	
Health Effect	**NATION** (a)	**MRPO Region**	**NATION** (a)	**MRPO Region**	**NATION** (a)	**MRPO Region**	**NATION** (a)	**MRPO Region**
Acute Bronchitis	5,000	2,700	5,900	3,200	260	1,500	920	2,100
Acute Myocardial Infarction	6,100	3,400	7,200	3,900	420	1,800	1,280	2,600
Acute Respiratory Symptoms	2,168,000	1,223,000	2,589,000	1,473,000	19,000	595,000	322,000	912,000
Asthma Exacerbation	131,400	73,300	154,200	86,200	8,000	40,100	25,300	57,900
Chronic Bronchitis	1,900	1,000	2,200	1,200	90	540	330	780
Emergency Room Visits, Respiratory	3,400	2,100	4,000	2,500	400	1,100	900	1,700
Hospital Admissions, Cardiovascular	1,200	600	1,400	700	30	300	170	500
Hospital Admissions, Respiratory	1,900	1,100	2,400	1,400	-650	100	-320	500
Lower Respiratory Symptoms	52,100	29,000	61,100	34,000	3,030	15,900	9,820	22,900
Mortality	3,010	1,570	3,540	1,860	80	810	470	1,200
School Loss Days	33,500	27,600	55,700	45,600	-30,700	-10,600	-18,400	3,800
Work Loss Days	348,300	192,600	408,600	226,200	18,300	105,000	63,600	151,400
Worker Productivity (Thousands $)	$1,100	$800	$1,900	$1,400	-$4,800	-$2,100	-$4,400	-$1,700

a. Benefit estimates for $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are for the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

4. Valuation

In order to better compare the health benefits of the EGU candidate control programs with the costs, it is necessary to estimate the economic value of the estimated avoided cases of health effects. This is a challenging and controversial process. While measuring the direct expenditures for health care (such as the cost of hospitalization for a respiratory illness) can be relatively straightforward, such "resource cost" metrics only reflect one aspect of the full social desirability of improving human health. In an economic benefit-cost study of a potential environmental program, the appropriate economic concept for valuing health effects is to measure a typical individual's willingness to pay (WTP) to reduce the risk of a specific adverse health effect.

Although a WTP-based unit value is the appropriate way to value changes in all health effects, good estimates of WTP are not available at this time for every health effect associated with changes in ambient ozone and PM levels. The unit values used to assign economic values to the health effects in this report are a mix of resource cost and WTP values. These values used in this report are shown in Table ES-5, and are consistent with the values used in the CAIR RIA (U.S. EPA, 2004, 2005). The method used to estimate each unit value is also shown.

Table ES-5. Unit values for health effects

	Unit value (1999$)	Source method of valuation
Premature mortality	$5,320,000	WTP
Chronic bronchitis	$380,000	WTP
Heart attack (MI)	$66,000 to $140,000	Hospital costs + wage loss
Hospital admissions	$6,600 to $18,400	Medical costs
ER visits	$285 to $550	Medical costs
Symptom days	$17 to $65 / day	WTP
Work loss days	$126	Median wage in region
School loss days	$75	Median wage (national)
Acute bronchitis	$350	Medical costs
Asthma attack	$7	Medical costs

Source: Table 4-11, U.S. EPA, 2005.

4.1 Valuation Results

The estimates of the value of the avoided health effects for each of the four modeled air quality scenarios (EGU1, EGU2, EGU1 with IPM, and EGU2 with IPM) are presented in Table ES-6.

The estimates shown in the tables are the aggregate value of the cases of health effects associated with the estimated changes in ozone and $PM_{2.5}$ levels. Air quality improvements result in positive values, and worsening air quality results in negative values. The tables show the "national" total (actually the total value for the modeled areas), as well as the sub-totals for the MRPO region.

Table ES-6. Value of estimated health effects (thousands of $1999)

	EGU1		EGU2		EGU1 w IPM		EGU2 w IPM	
Health Effect	**NATION** (a)	**MRPO Region**	**NATION** (a)	**MRPO Region**	**NATION** (a)	**MRPO Region**	**NATION** (a)	**MRPO Region**
Acute Bronchitis	$1,800	$960	$2,100	$1,120	$100	$520	$300	$760
Acute Myocardial Infarction	$403,000	$222,000	$472,000	$260,000	$28,000	$120,000	$84,000	$173,000
Acute Respiratory Symptoms	$209,000	$117,000	$248,000	$139,800	$5,000	$59,200	$33,000	$88,800
Asthma Exacerbation	$5,600	$3,100	$6,600	$3,700	$300	$1,700	$1,100	$2,500
Chronic Bronchitis	$642,100	$340,200	$753,600	$399,800	$29,300	$184,700	$114,000	$267,000
Emergency Room Visits, Respiratory	$1,000	$660	$1,200	$780	$100	$350	$300	$510
Hospital Admissions, Cardiovascular	$24,600	$12,800	$28,800	$15,000	$500	$6,900	$3,600	$10,000
Hospital Admissions, Respiratory	$26,500	$15,700	$32,400	$19,500	-$3,500	$4,800	$800	$9,200
Lower Respiratory Symptoms	$800	$450	$1,000	$530	$0	$250	$200	$360
Mortality	$16,531,00	$8,637,300	$19,492,00	$10,225,20	$424,000	$4,481,000	$2,603,000	$6,605,400
School Loss Days	$2,500	$2,100	$4,200	$3,400	-$2,300	-$800	-$1,400	$300
Work Loss Days	$46,000	$25,700	$53,000	$30,100	$3,000	$14,100	$9,000	$20,400
Worker Productivity (Thousands $)	$1,100	$800	$1,900	$1,400	-$4,800	-$2,140	-$4,400	-$1,670
Total	$17,894,00	$9,378,000	$21,098,00	$11,100,00	$479,000	$4,871,000	$2,844,000	$7,176,000

a. Benefit estimates for $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are for the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

5. Cost Estimates, Benefit-Cost and Cost-Effectiveness Analyses

While the primary purpose of this report is the health and valuation estimates presented above, it is also possible to make limited comparisons between the estimated value of health benefits and the available cost estimates. Information about the cost estimates for the four candidate control programs were provided to Stratus Consulting by LADCO.

The White Paper presents ranges of average control costs (average $/ton) for the two candidate programs described in the White Paper (EGU1 and EGU2). The White Paper estimates SO_2 emission reductions from EGUs will cost between $800/ton and $1,500/ton, and NO_x emissions will cost between $700/ton and $1,600/ton (LADCO White Paper, Table 1A and 1B). Combining the ranges of control cost estimates with the emission reductions in the EGU1 and EGU2 control programs provides a preliminary control cost estimate for the EGU1 and EGU2 candidate control programs. Table ES-7 presents the preliminary cost estimates. All of these costs will occur within the MRPO region.

Table ES-7. Preliminary cost estimates for EGU1 and EGU2 (1999$)[a]

	Emission reductions (tons)		Cost/ton estimates		Annual control cost (millions)	
	EGU1	EGU2	Low	High	EGU1	EGU2
SO_2	1,117,000	1,266,000	$800/ton	$1,500/ton	$894-$1,675	$1,013-$1,899
NO_x	148,000	238,000	$700/ton	$1,600/ton	$104-$237	$167-$381
Total					$997-$1,912	$1,180-$2,280

a All cost estimates in this report are in 1999 dollars. The cost estimates from IPM are explicitly stated as being in 1999 dollars. The cost estimates derived from the White Paper are presented in 1999 dollars as well for ease of comparison.

The cost estimates for the EGU1 with IPM and EGU2 with IPM candidate programs were developed using the IPM. IPM is a mathematical programming model that seeks the least-cost solution for the specified set of control options. IPM generates separate estimates of four cost components: annualized capital costs, fuel costs, fixed operating costs and variable operating costs.

Because the IPM analysis of the two candidate control programs permitted ERCs to be sold out of the MRPO region, cost impacts are felt both within the MRPO region and outside the region.

Within the MRPO region the control costs increase to meet the requirements of the candidate control programs. These cost increases will be offset to some extent by the sale of ERCs. Outside of the region control costs decline. By purchasing ERCs from the MRPO regions, EGUs in the non-MRPO region meet their obligations under the existing federal cap-and-trade programs by emitting more than they would in the analytical baseline. Therefore control costs decline outside the MRPO region (partially offset by the purchase of ERCs).

Table ES-8 presents the cost estimates for the EGU1 with IPM and EGU2 with IPM candidate control programs. The costs shown on Table 16 are the changes in the cost of generation for each candidate program compared with the cost of generation in the 2012 analytical baseline.

Table ES-8. Cost estimates for EGU1 with IPM and EGU2 with IPM candidate programs (1999$)

	EGU1 with IPM	EGU2 with IPM
Increase in national total cost of generation	$491,000,000	$1,054,000
% change over analytical baseline	+0.5%	+1.0%
Generation cost increase in MRPO region	$935,000,000	$1,300,000,000
% change over analytical baseline cost	+6.2%	+8.6%
Out of MRPO region	-$444,000,000	$-245,000,000[a]
% change over analytical baseline cost	-0.5%	-0.3%

The control costs estimated by IPM do not reflect the impact of the value of the trading credits. IPM estimates the actual control costs, and where they occur. IPM does not, however, estimate who eventually pays the control costs. The IPM estimates of costs occurring within the MRPO region would be offset to some extent by the value of the ERCs sold by in-region EGUs. Similarly, the control costs occurring outside the MRPO region would be increased by the price paid for the credits.

5.1 Benefit-Cost Analysis

Using the benefit and estimates presented above, it is possible to directly compare the estimated benefits and estimated costs. Table ES-9 shows the comparison of the estimated benefits and costs for the entire modeled region, as well as separately for the five-state MRPO region are presented.

Table ES-9. Estimated benefits and costs of candidate control programs (millions of 1999$)

	National analysis			MRPO region only		
	Benefits	**Costs**	**Net benefits (B - C)**	**Benefits**	**Costs**	**Net benefits (B - C)**
EGU1	$17,894	$1,454	$16,440	$9,378	$1,454	$7,924
EGU2	$21,098	$1,729	$19,369	$11,100	$1,729	$9,371
EGU1 with IPM	$479	$491	-$12	$4,871	$935	$3,936
EGU2 with IPM	$2,844	$1,054	$1,830	$7,176	$1,300	$5,876

As discussed in the section on emissions, the emission reductions are different in the "with IPM" analyses than in the White Paper-based analyses. There is one pair of candidate control program options that provide roughly comparable emissions reductions within the MRPO region. The combined total tons reduced (SO_2 + NO_x) are 3% smaller in the EGU2-with-IPM scenario than in the EGU1 scenario. While this is not an exact match in terms of emissions reduced, this pair of analyses provides the closest available comparison of the effects of allowing in-region and out-of-region trading in a candidate program.

6. Conclusions

Key findings of the benefit-cost analysis presented in this report suggests:

- Costs are lower, if ERCs are sold outside the MRPO region.
- Benefits are slightly greater in the MRPO region (and substantially greater nationally), if ERCs are retired (i.e., not sold outside outside the MRPO region).
- Net benefits are greater in the MRPO region (and nationally), if ERCs are retired.

These findings suggest that further consideration should be given to the use of ERCs from a beyond-CAIR EGU control program. This study shows that retiring these ERCs, rather than selling them to sources outside the MRPO region, will provide much greater net benefits.

Additional IPM analyses including retirement of the MRPO region ERCs, including air quality and health analysis of the full air impact of the candidate control in 2013, is necessary to provide more refined benefit-cost information of the ERC retirement options.

1. Project Objective and Background

This report describes the methods and results of a health and economic benefits analysis that Stratus Consulting conducted for the Lake Michigan Air Directors Consortium (LADCO). The analysis examines a set of candidate control options being considered by the Midwest Region Planning Organization (MRPO). The candidate control options examined in this analysis involve possible more stringent emission limits for electricity generating units (EGUs). These EGU control options are part of a series of potential programs MRPO is examining that would improve air quality in the five-state MRPO region in order to meet the National Ambient Air Quality Standards (NAAQS) for ozone and fine particulate matter ($PM_{2.5}$).

Existing emission control programs, including all existing and recently promulgated federal, state, and local control programs, are not expected to bring all portions of the MRPO region into attainment of the ozone and $PM_{2.5}$ NAAQS by 2012. Under the Clean Air Act, it is the responsibility of each state to develop a comprehensive air quality plan that will achieve attainment of these NAAQS, as well as meet federal goals for reducing regional haze. However, ozone and $PM_{2.5}$ air pollution do not respect state borders; emissions in one state will influence the air pollution levels in states hundreds of miles away. The five member states of MRPO (Wisconsin, Illinois, Indiana, Michigan, and Ohio) asked LADCO to conduct technical analyses of an initial set of possible region-wide measures that could improve ozone and $PM_{2.5}$ levels. The MRPO has not determined which if any of these measures are necessary to achieve attainment, and additional measures will likely be examined in the future.

The control options examined in this memorandum would require EGUs in the five-state MRPO region to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides[1] (NO_x) by the end of 2012. SO_2 and NO_x are important precursor pollutants to ozone and $PM_{2.5}$; through chemical processes occurring in the atmosphere, these and other air pollutants chemically react to form ozone and $PM_{2.5}$. A successful approach to meeting the ozone and $PM_{2.5}$ NAAQS will likely require additional reductions in these precursor pollutants beyond the reductions already required ("on the books") and required but not yet implemented ("on the way"). Such additional emission reductions would not necessarily have to come from EGUs. However, EGUs are the largest emitters of SO_2 in the MRPO region, and an important part of the region's NO_x emissions inventory, making EGUs an important candidate to examine in more depth.

The control options were described in a series of interim "White Papers" that LADCO produced during 2005. Candidate control options included not only EGUs, but also candidate controls on 15 other emission sources. LADCO circulated these interim White Papers for review, discussion,

1. Includes N_2O, NO_2, N_2O_3, N_2O_4, and N_2O_5.

and comment by many stakeholders involved with air quality in the Lake Michigan area, and the individual candidate measures evolved during the process. The specific EGU control options analyzed here are described in "Interim White Paper – Midwest RPO Candidate Control Measures" released December 9, 2005. That paper is available at the LADCO website (LADCO, 2005).

There are four critical analytical components in conducting the health and economic benefits analysis of control options to improve ozone and $PM_{2.5}$ levels:

- **Emissions inventory**: Estimates of all precursor emissions in the year 2012, including emissions from EGUs and from all other sources.

- **Estimates of emission changes**: For this analysis only EGU emissions are changed in each control option; all other emissions are held constant in 2012. This analysis examines two different estimates of the emission changes for each of two candidate control options.

- **Air quality modeling**: The "analytical baseline" is based on estimates of the ambient concentrations of ozone and $PM_{2.5}$ that are expected to exist in 2012 if no additional emission control programs are implemented beyond what is already mandated for 2012 under existing Clean Air Act programs. Additional air quality modeling was used to estimate the ozone and $PM_{2.5}$ concentrations that would result from the aggregate emissions in each candidate control option.

- **Health and economic benefit modeling**: The models estimate the number of adverse health effects (premature mortality, hospital admissions, etc.) that would result from the changes in ozone and $PM_{2.5}$ concentrations, and estimates of the economic value of those health effects.

LADCO provided Stratus Consulting with the results of the EGU emission reduction analyses and the air quality modeling results of the impact of four different emissions scenarios. These are necessary inputs to conducting health and economic benefits modeling. In addition, LADCO provided the results of a cost analysis produced as an integral part of the emissions analysis. Although Stratus Consulting did not conduct the EGU cost and emissions analysis [which was prepared by LADCO staff and ICF International, Inc. (ICF)], nor the air quality modeling analysis (prepared by LADCO staff), the results of those analyses are summarized in this memorandum. Additional details about these analyses are available from LADCO in separate reports.

2. Emissions Inventory

2.1 Analytical Baseline

The future emissions baseline for this analysis is the complete inventory of all ozone and $PM_{2.5}$ precursor emissions currently predicted to occur in 2012. This analytical baseline reflects reductions from current emissions levels that will occur due to all already promulgated ("on-the-books") federal regulations under the Clean Air Act, as well as anticipated replacement of older model vehicles and existing industrial and commercial equipment.

Two federal programs promulgated in 2005 will directly impact emissions from EGUs: the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR). CAIR affects 28 eastern states, including all five states in the MRPO region. The first phase of CAIR will reduce EGU emissions prior to 2012; U.S. Environmental Protection Agency (EPA) estimates SO_2 emissions from EGUs in the 28-state CAIR region will be reduced by 45% (from 2003 levels) by 2010, and NO_x emissions will be reduced 53% by 2009. Phase II of CAIR requires additional EGU emission reductions by 2015.

CAMR requires mercury emissions from EGUs nationwide to be reduced beginning in 2010, with all new coal-fired EGUs built after 2004 meeting tighter mercury emission standards. While mercury is not a major precursor pollutant for either ozone or $PM_{2.5}$, the response by EGU operators to the CAMR may change emissions of precursor pollutants. Controlling mercury emissions will likely lead to reductions in directly emitted $PM_{2.5}$, and fuel switching could lead to reductions in SO_2 and NO_x emissions.

The federal programs directly affecting EGUs that are included in the 2012 analytical baseline include: CAIR, CAMR, the 1997 NO_x SIP call, the OTC NO_x Budget Program, the Acid Rain Program (Title IV), and Title I programs including New Source Review (NSR), New Source Performance Standards (NSPS), and plant-specific requirements adopted under current State Implementation Plans (SIPs). The analytical baseline does not include any reductions necessary to meet any revisions to the current NAAQS, nor passage of any legislation currently pending before Congress, such as the Clear Skies Act.

2.2 Emission Reductions from the Candidate Control Measures

There are two estimates of the EGU emission reduction changes for each EGU candidate control measure. The first estimate is based on the candidate control option described in the White Paper. The White Paper emission reduction estimates are based on an analysis of reductions necessary to meet a specified emission rate limit at every EGU facility in the MRPO region. The desired emission rate limits were specified as an emission-per-quantity-of-heat produced to generate electricity (lbs/mmBtu). This facility-specific emission rate limit approach was used to analyze two different candidate control stringency options, known as EGU1 and EGU2. The EGU1 candidate measure sets the emission limits at the retrofit best available control technology (BACT) limits for EGUs. The EGU2 candidate measure sets the limits at the New Plant BACT limit for EGUs.

The second set of estimates of the emission changes for each candidate control option were developed by considering the potential industry response to additional emission restrictions. LADCO engaged ICF to conduct an analysis of the least-cost method of meeting the candidate emission reductions. ICF used the Integrated Planning Model (IPM®) for this analysis. IPM is a linear programming model that includes a detailed representation of the existing electricity generating infrastructure, emission control options, fuel switching opportunities, transmission grids, all relevant existing EGU emission control requirements, and electricity demand. A detailed description of the IPM analysis for LADCO will be available in a separate report from LADCO.

One important difference between White Paper analysis and the IPM analysis of the EGU candidate control options is the use of emission trading programs. The White Paper analysis did not allow emission trading; each facility had to meet the candidate emission rates at each unit at all times. The IPM analysis allowed two important types of emission trading. First, EGUs within the five-state region were permitted to trade emission reduction credits (ERCs) amongst themselves to meet the in-region emission limits implied by the candidate control options. ERCs generated out-of-region were not allowed to be purchased by in-region generators to meet the in-region candidate control measure requirements. The IPM analysis also allows the emission reductions occurring in the MRPO region to be sold out of the region as ERCs in other emission trading programs. The emission reductions generated in-region could be eligible to be sold under any of several EPA-administered cap-and-trade programs, including the NO_x SIP call, CAIR, and the acid rain (Title IV) trading programs.

There are several important effects of including emissions trading provisions in the IPM analysis:

- **Different total in-region annual emission reductions in the IPM analysis:** The IPM analysis used the targeted BACT emission rate limits from the White Paper candidate programs to develop associated estimates of the total annual emission mass limits (e.g., total tons emitted per year) for SO_2 and NO_x. The IPM analysis also developed a separate summer-only mass limit for NO_x emissions. However, the annual mass limit reported for 2012 in the IPM analysis was derived from an average of the mass limits for the years 2010 through 2013. In 2010 and 2011 the IPM analysis assumed Phase 1 of the candidate program was in effect, while in 2012 and 2013 Phase II of the candidate program was assumed. Thus the average mass limit used to represent 2012 is actually the average of the Phase I mass limits and Phase II mass limits. This results in a substantially higher amount of emissions from EGUs in 2012 than were estimated in the White Paper analysis. The subsequent air quality modeling based on the IPM analysis incorporates these higher emission estimates.

- **Different in-region locations of emission reductions**: Because in the IPM analysis in-region EGUs have the opportunity to sell emission reduction credits to other in-region EGUs, each in-region EGU may reduce a different amount of emissions than in the White Paper analysis. This results in a different spatial and temporal distribution of emission reductions in the two analyses.

- **Emissions increase out-of-region**: In the IPM analysis, out-of-region may purchase ERCs generated in MRPO region as a lower cost way of meeting their obligations under CAIR, the NO_x SIP Call, etc. By purchasing the MRPO-region ERCs, out-of-region EGUs can then pursue less aggressive emission reductions than they otherwise would have adopted. While the overall mass emission caps of CAIR and the NO_x SIP Call continue to be met, trading of MRPO-region credits effectively redistributes emissions from the MRPO region to other states. In the IPM analysis, all five MRPO region states reduce emissions. However, most other states increase their emissions from EGUs relative to what they would have done without the candidate programs.

- **Different air quality impacts**: The combination of differences in emission reductions in the MRPO region and the increase in emissions out of the MRPO region due to emissions trading results in substantially different air quality impacts in the White Paper candidate programs versus the IPM analysis.

Because of these important differences between the White Paper and IPM analyses of the EGU candidate control measures, the remainder of this paper will present the results of essentially four different candidate control programs. The four candidate programs will be referred to as EGU1, EGU2, EGU1-with-IPM, and EGU2-with-IPM. The EGU1 and EGU2 candidate programs are as described in the White Paper. The EGU1-with-IPM and EGU2-with-IPM programs are the with-trading programs analyzed using IPM, using the higher 2012 mass emission limits described above.

Table 1 shows the specific emission rate limits for SO_2 in the EGU1 and EGU2 candidate measures, and the associated annual SO_2 emission reductions for all four candidate measures.[2] Table 2 shows similar information for NO_x.

2. The emission reductions for EGU1 and EGU2 were based on information reported in the White Paper. Note, however, that the White Paper emissions were adjusted to reflect an earlier (2012) compliance date. These 2012 emission estimates were used in the subsequent air quality modeling.

Table 1. SO_2 EGU emission limits and resulting total annual emissions

SO_2 candidate control measure summary	Annual SO_2 EGU emissions (tons/year) in MRPO region	
2002 existing measures (MRPO average SO_2 emission rate is 1.16 lbs/mmBtu)	2002 base	2,799,000
2012 analytical baseline (44% reduction from 2002 base levels due to "on the way" programs)	2012 baseline	1,565,000
EGU1: Emission limits based on "Retrofit SO_2 BACT Level" of 0.15 lbs/mmBtu (71% reduction from the 2012 baseline; total reduction of 84% from 2002)	Reduction in 2012 Remaining	-1,117,000 448,000
EGU2: Emission limits based on "SO_2 BACT Level for New Plants" of 0.10 lbs/mmBtu (81% reduction from 2012 baseline, total 89% reduction from 2002)	Reduction in 2012 Remaining	-1,266,000 299,000
EGU1 with IPM: Annual mass limit with trading (53% reduction from the 2012 baseline; total 74% reduction from 2002)	Reduction in 2012 Remaining	-830,000 735,000
EGU2 with IPM: Annual mass limit with trading (67% reduction from the 2012 baseline; total 82% reduction from 2002)	Reduction in 2012 Remaining	-1,049,000 516,000

Table 2. NO_x EGU emission limits and resulting total annual emissions

NO_x candidate control measure summary	Annual NO_x EGU emissions (tons/year) in MRPO region	
2002 existing measures (MRPO average NO_x is 0.43 lbs/mmBtu)	2002 base	1,047,000
2012 analytical baseline (57% reduction from 2002 base levels due to "on the way" programs)	2012 baseline	447,000
EGU1: Emission limits based on "Retrofit NO_x BACT" level of 0.10 lbs/mmBtu (33% reduction from the 2012 baseline; total reduction of 71% from 2002)	Reduction in 2012 Remaining	-148,000 299,000
EGU2: Emission limits based on "NO_x BACT Level for New Plants" of 0.07 lbs/mmBtu (53% reduction from the 2012 baseline; total reduction of 80% from 2002)	Reduction in 2012 Remaining	-238,000 209,000
EGU1 with IPM: Annual mass limit with trading (17% reduction from the 2012 baseline; total 65% reduction from 2002)	Reduction in 2012 Remaining	-76,000 371,000
EGU2 with IPM: Annual mass limit with trading (39% reduction from the 2012 baseline; total 82% reduction from 2002)	Reduction in 2012 Remaining	-173,000 274,000

Note that the emission reductions in similarly named programs are not the same; the "with IPM" programs, which include trading, have significantly smaller in-region emission reductions than the direct control (no trading) counterparts. Examining the emission reductions for the four different candidate programs shows that in terms of emission reductions within the MRPO region, the two most comparable programs are EGU1 and EGU2 with IPM. The cumulative in-region annual SO_2 emission reductions are 6% smaller in the EGU2 with IPM program than in the EGU1 program, while NO_x emission reductions are 17% larger in EGU2 with IPM. The combined total tons reduced (SO_2 + NO_x) are 3% smaller in EGU2 with IPM than in EGU1. While this is not an exact match in terms of emissions reduced, this pair of analyses provides the closest available comparison of the effects of allowing in-region and out-of-region trading in a candidate program.

The required reductions in emissions in the EGU1 and EGU2 candidate programs are confined to the MRPO region; no change is assumed outside the region. The "with IPM" candidate programs, however, allow the reductions in emissions occurring within the five-state region to be sold out-of-region as ERCs. Thus with trading the national totals of SO_2 and NO_x emissions stay essentially constant in the "with IPM" candidate programs, but the spatial distribution of emissions shifts. Fewer emissions occur in the MRPO region due to the program's more stringent emission limits, but emissions in other states increase through the purchase of ERCs. Table 3 presents the details of the emissions for the "with IPM" candidate programs.

Table 3. SO_2 and NO_x emissions by region (tons/year)

	5 MRPO states		**Rest of nation**		**Total nation**	
	SO_2	**NO_x**	**SO_2**	**NO_x**	**SO_2**	**NO_x**
2012 baseline	1,565,000	449,000	4,210,000	2,028,000	5,775,000	2,477,000
EGU1 with IPM	735,000	371,000	5,106,000	2,100,000	5,841,000	2,471,000
Change	-830,000	-78,000	+896,000	+72,000	+66,000	-6,000
% change	-53%	-17%	+21%	+4%	+1.1%	-0.2%
EGU2 with IPM	516,000	274,000	5,264,000	2,183,000	5,780,000	2,457,000
Change	-1,049,000	-173,000	+1,054,000	+155,000	+5,000	-20,000
% change	-67%	-39%	+25%	+8%	+0.1%	-0.8%

Note: Regional emissions may not sum to national total due to rounding.

3. Air Quality Modeling

3.1 Air Quality Model

The $PM_{2.5}$ and ozone concentrations were estimated using the Comprehensive Air quality Model (CAMx). CAMx is an open-sourced (publicly available) computer model supported by the EPA for use in regional analysis of ozone and $PM_{2.5}$ concentrations. The EPA has approved the use of CAMx for developing SIPs for ozone and $PM_{2.5}$, and it has been used by LADCO and the individual states in the MRPO regions for a wide variety of air quality analyses. LADCO staff used CAMx version 4.30 to conduct the air quality analyses for the EGU candidate control options. A brief technical description of CAMx (Environ, 2005) is:

> CAMx is an Eulerian photochemical dispersion model that allows for integrated "one-atmosphere" assessments of gaseous and particulate air pollution (ozone, $PM_{2.5}$, PM10, air toxics) over many scales ranging from sub-urban to continental. It is designed to unify all of the technical features required of "state-of-the-science" air quality models into a single system that is computationally efficient, easy to use, and publicly available. CAMx can be provided environmental input fields from any meteorological model (e.g., MM5, RAMS, and WRF) and emission inputs from any emissions processor (SMOKE, CONCEPT, EPS, EMS).

Additional information, including full technical documentation and the downloadable computer code for CAMx, is available from the CAMx website at www.camx.com.

LADCO staff used different CAMx configurations for ozone and $PM_{2.5}$. $PM_{2.5}$ was estimated at the daily level for the full year, while ozone estimates were prepared at the hourly level for a 90-day ozone season (June 3 through August 30). For both the $PM_{2.5}$ and ozone modeling CAMx was configured to cover a wider region than just the MRPO region, because regional transport of precursor emissions from outside the MRPO region affect air quality within the MRPO region, and emissions within the region affect air quality outside the region.

The $PM_{2.5}$ modeling covered a broader geographic region than the ozone modeling. Figure 1 shows the region modeled for $PM_{2.5}$. The $PM_{2.5}$ modeling used a grid size of approximately 36 km × 36 km. There are 8,730 individual cells modeled in the $PM_{2.5}$ domain (97 columns × 90 rows). The estimated 2012 population in the $PM_{2.5}$ region is 249.9 million people.

Figure 2 shows the modeled ozone region. The ozone modeling used a grid size of approximately 12 km × 12 km. There are 17,161 individual cells in the ozone domain (131 columns × 131 rows), and the estimated 2012 population is 97.7 million.

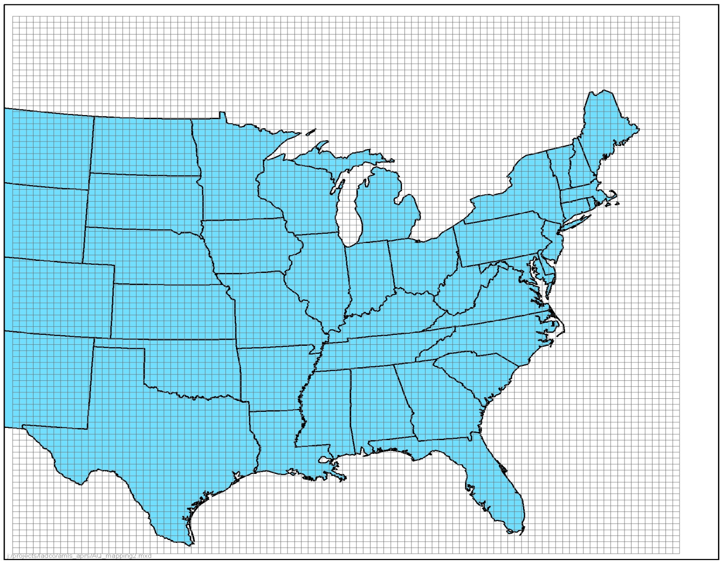

Figure 1. Geographic domain for $PM_{2.5}$ modeling.

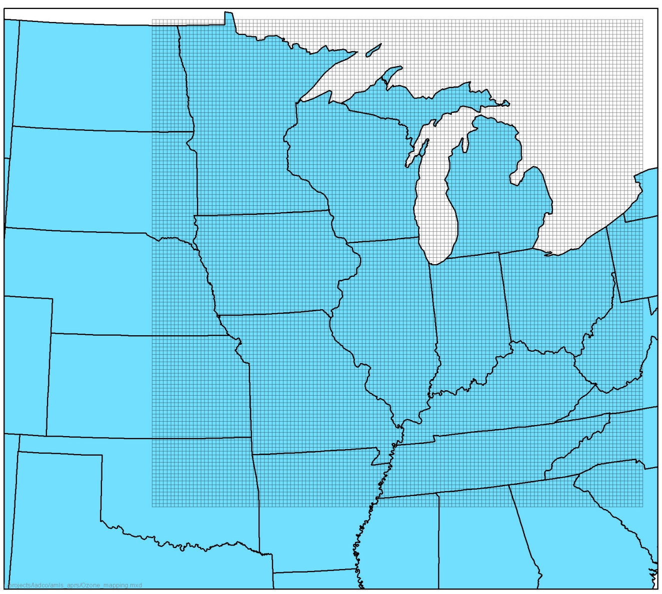

Figure 2. Geographic domain for ozone modeling.

The differences between the two modeling domains call for careful interpretation of the health benefits. Due to both the larger domain and the full year of modeling, the $PM_{2.5}$ benefits estimates will necessarily be more comprehensive than the ozone benefits. While there may be some changes in $PM_{2.5}$ concentrations outside of the modeled $PM_{2.5}$ domain, there will almost certainly be ozone changes in locations outside the modeled ozone domain.

The health benefits analysis does not use the CAMx ozone and $PM_{2.5}$ estimates directly. The model estimates were calibrated to monitor measurements to adjust for potential errors in the modeling process. This calibration step is used to estimate the future air quality levels for the health analysis. The overall benefits estimation procedure closely follows the procedures the EPA used in conducting the benefits analysis included in the Regulatory Impact Analysis (RIA) for the CAIR (U.S. EPA, 2004, 2005). EPA's standard procedure for health analyses is to combine air quality modeling results with data from air quality monitors data to prepare estimates of future air quality conditions. This procedure adjusts the future year air quality modeling results by combining observed monitor data (from 2002 for this analysis) with air quality modeling for 2002 and the future year. A relative temporal and spatial adjustment method known as Enhanced Veronoi Neighbor Averaging (VNA) available in the benefits model (BenMAP) produced the actual 2012 air quality estimates used in this analysis.[3] Details on the Enhanced VNA method are available in the CAIR RIA and the BenMap Users Manual (Abt Associates, 2005). In order to use the Enhanced VNA adjustment method, LADCO staff used CAMx to prepare ozone and $PM_{2.5}$ air quality estimates for 2002.

3.2 Air Quality Modeling Results

The most important results from the air quality modeling are the estimates of the changes in $PM_{2.5}$ and ozone concentrations. The estimated $PM_{2.5}$ changes (annual mean $\mu g/m^3$) for each of the four modeled candidate control programs at every location in the $PM_{2.5}$ domain are shown in Figures 3 through 6. PM-related health effects are calculated from either the change in annual mean $PM_{2.5}$, or the change in the daily estimates of $PM_{2.5}$ on each of the 365 days in a year. As one of the $PM_{2.5}$ NAAQS is defined in terms of the annual mean, the maps showing the changes in $PM_{2.5}$ annual mean can be readily interpreted by individuals familiar with $PM_{2.5}$ NAAQS attainment issues. The current annual mean $PM_{2.5}$ standard is 15 $\mu g/m^3$. The maximum estimated change in $PM_{2.5}$ was 1.3 $\mu g/m^3$.

3. In this analysis, the Enhanced VNA adjustment procedure is used on the total $PM_{2.5}$ concentrations. In EPA's analysis of the CAIR rule, the Enhanced VNA procedure was separately used on each major chemical component of total $PM_{2.5}$, with the speciated $PM_{2.5}$ components summed to estimate total adjusted $PM_{2.5}$.

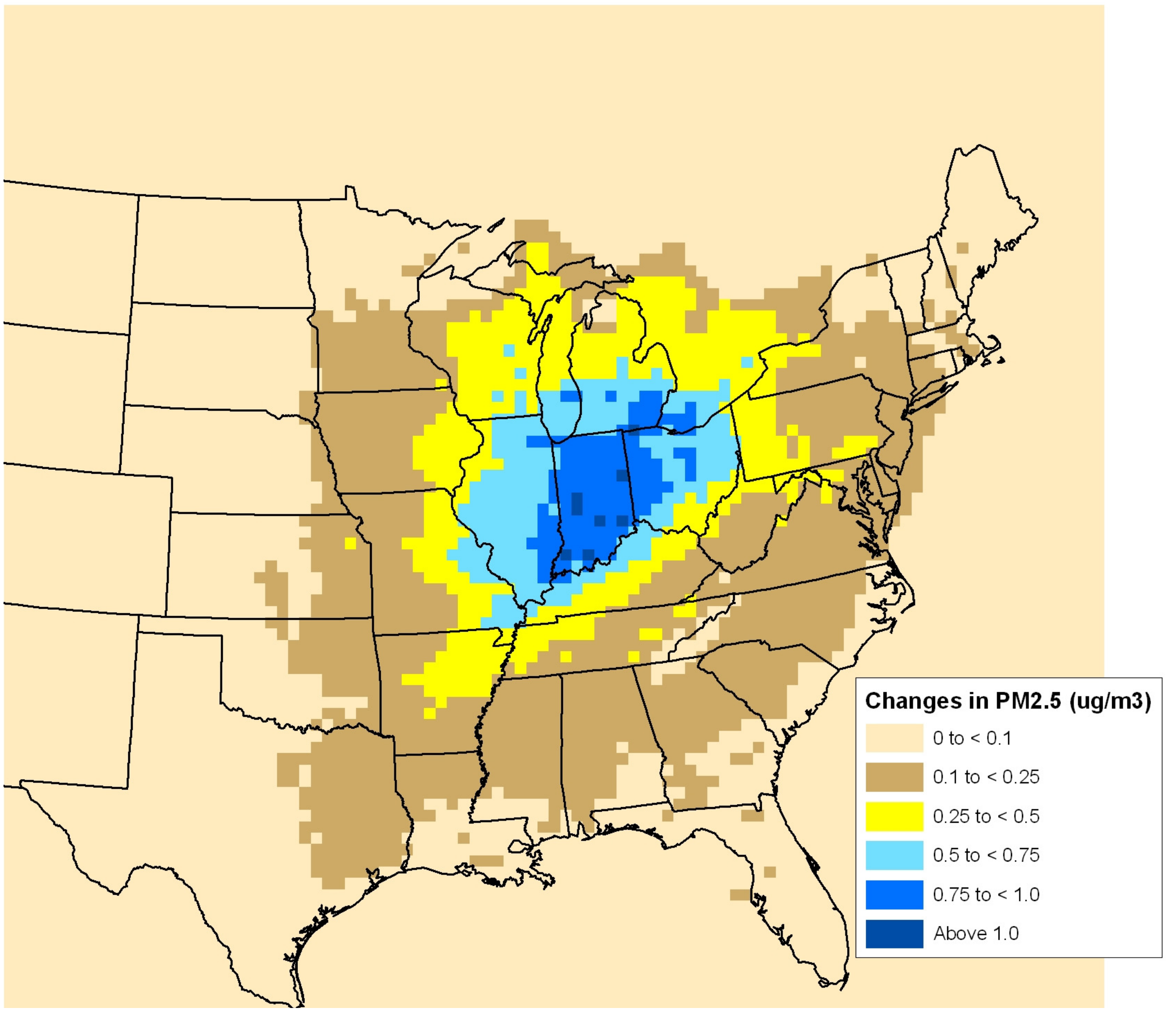

Figure 3. Changes in annual mean $PM_{2.5}$ with EGU1 candidate control program.

Note: Positive values indicate an improvement in $PM_{2.5}$ levels. Negative values indicate a worsening of $PM_{2.5}$ levels.

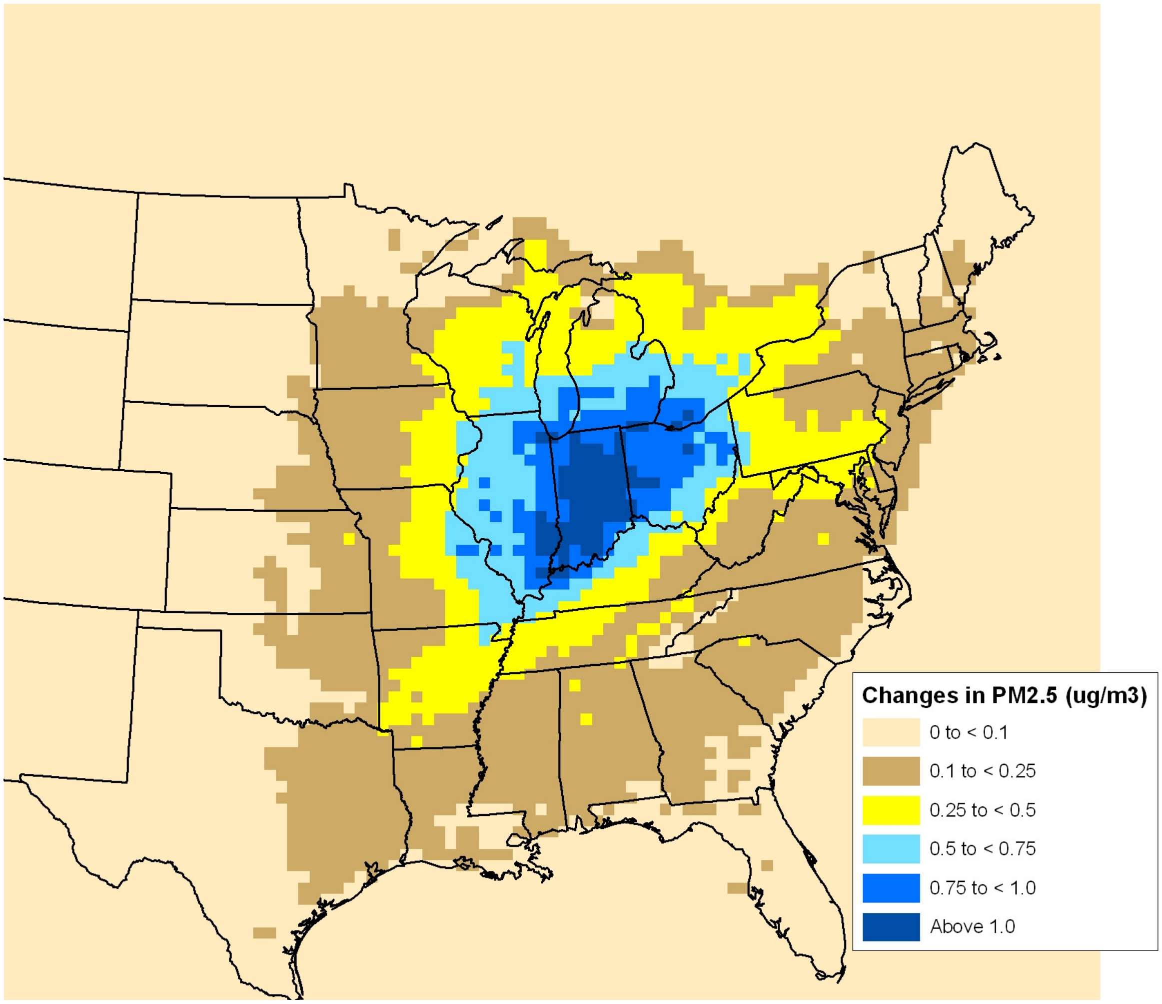

Figure 4. Changes in annual mean $PM_{2.5}$ with EGU2 candidate control program.

Note: Positive values indicate an improvement in $PM_{2.5}$ levels. Negative values indicate a worsening of $PM_{2.5}$ levels.

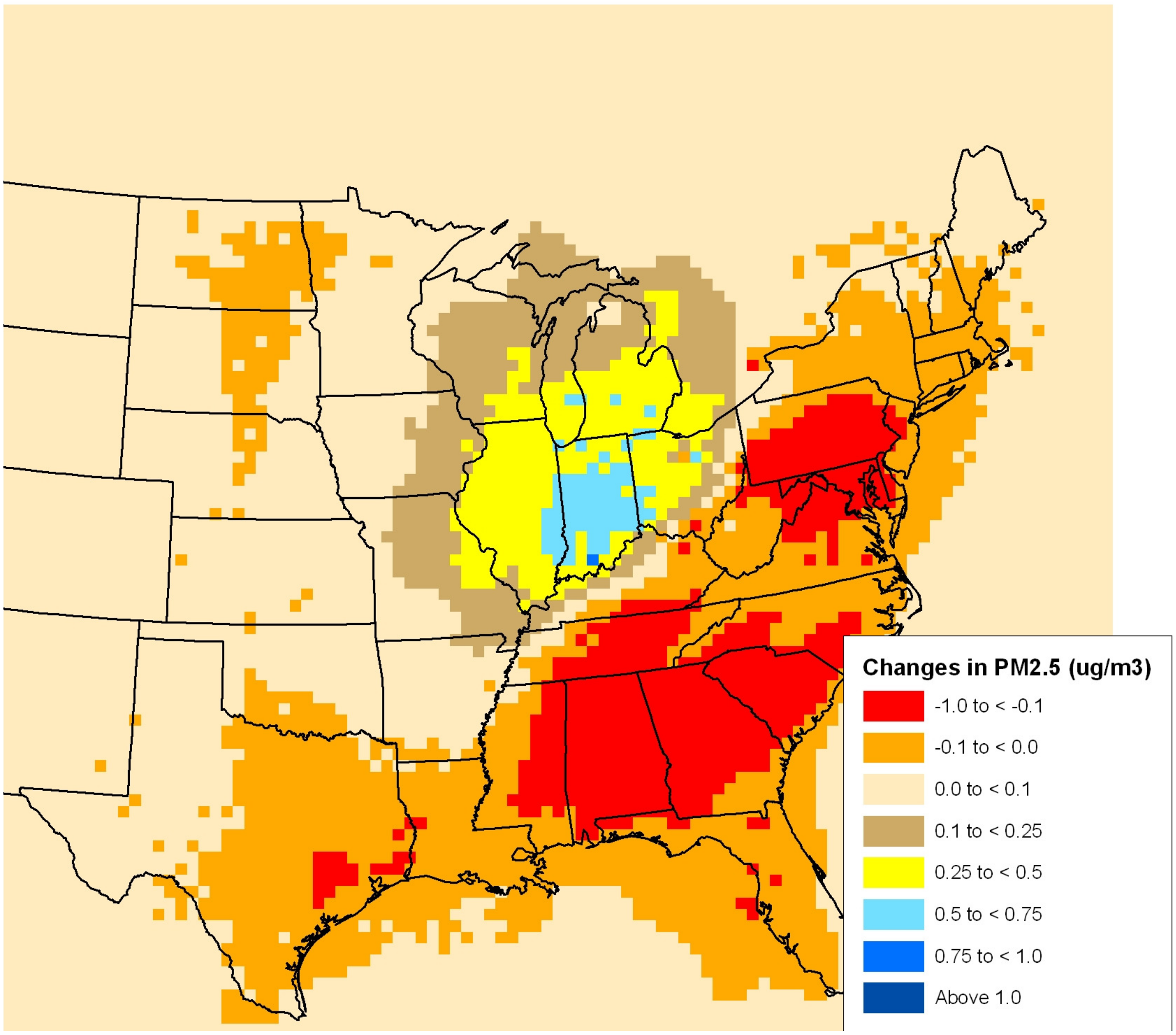

Figure 5. Changes in annual mean $PM_{2.5}$ with EGU1 with IPM candidate control program.

Note: Positive values indicate an improvement in $PM_{2.5}$ levels. Negative values indicate a worsening of $PM_{2.5}$ levels.

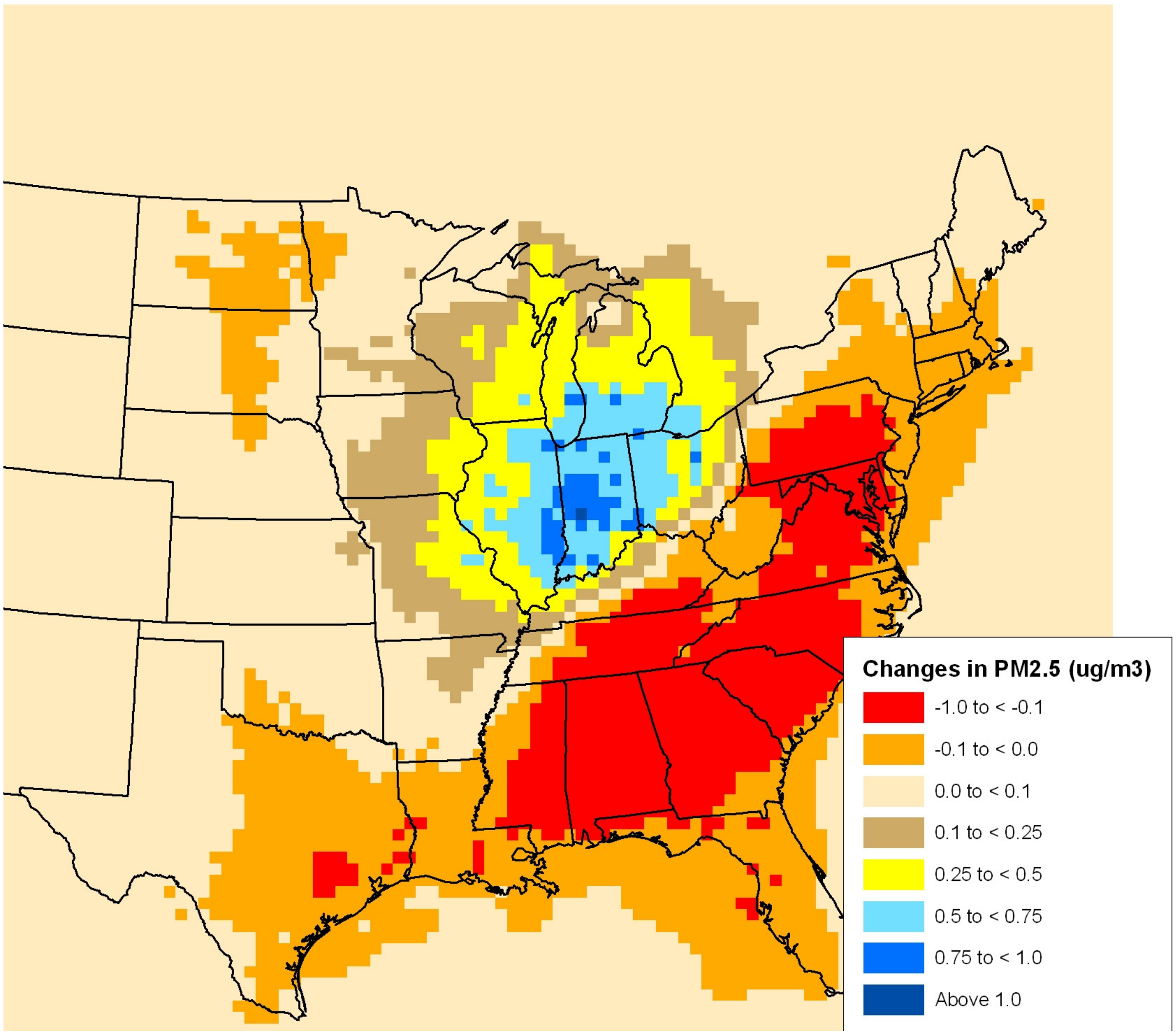

Figure 6. Changes in annual mean $PM_{2.5}$ with EGU2 with IPM candidate control program.

Note: Positive values indicate an improvement in $PM_{2.5}$ levels. Negative values indicate a worsening of $PM_{2.5}$ levels.

The health effects associated with changes in ozone levels are calculated from either the change in each hour of each day, or the change in the peak 8-hour level or 1-hour level on each day. Changes in ozone levels on each modeled day contribute to the overall health effects from ozone. Maps showing the seasonal (90 modeled days) average change in the daily peak 8-hour ozone level give the clearest information about the location and magnitude of the ozone changes relevant to human health. Figures 7 through 10 present maps of the seasonal average change in the 8-hour ozone levels. The seasonal 8-hour average for each CAMx ozone grid cell is calculated by first determining the 8-hour average of modeled ozone values for every possible 8-hour block within a modeled 24-hour period. The maximum 8-hour value is then identified for that day. This is repeated for each of the 90 modeled days. Then, the seasonal average of the 90 estimated 8-hour maximum values is calculated for each CAMx ozone grid cell.

The seasonal average ozone level is not readily familiar to individuals working with ozone attainment issues. The form of the 8-hour ozone NAAQS is defined in terms of the maximum ozone levels seen in a year (specifically, the current ozone standard is defined by the fourth highest daily 8-hour value, averaged over a three-year period). Presenting maps of the location and magnitudes of the changes on only the worst day in each grid cell would give an incorrect representation about the changes relevant to health effects. Health is affected by changes in ozone levels on every day, not only on the changes on the worst ozone days. To help put the ozone changes in context, the seasonal average 8-hour ozone levels in the MRPO region are typically between 45 ppb and 70 ppb. The estimated changes in ozone concentrations from the candidate control measures in the five-state region are generally in the range of $\pm$ 0.2 ppb.

The maps clearly indicate two important issues that will significantly influence the health benefits analysis:

- Reducing emissions within the MRPO region (with no change elsewhere) will improve air quality not only within the region, but also across much of the eastern United States. Therefore health benefits will occur not only within the region, but also throughout the eastern United States.

- The eligibility of in-region emission reductions to be used as tradable credits in any of the EPA-administered cap-and-trade programs results in the emissions effectively being "exported" from the five-state region to other parts of the country. The purchasing out-of-region EGUs will then increase their emissions relative to what they would have done in the 2012 analytical baseline. The IPM results suggest that a portion of the emission credits will be purchased by EGUs at a considerable distance from the five-state region. Those distant emission increases would not have a significant impact on the air quality in the MRPO region, although they would adversely impact the air quality outside of the MRPO region. Other emission credits, however, would be sold to nearby states. The increases in emissions in those neighboring states will adversely impact the air quality in the MRPO states, leading to smaller in-region health effects than the benefits estimated for the candidate programs without trading provisions.

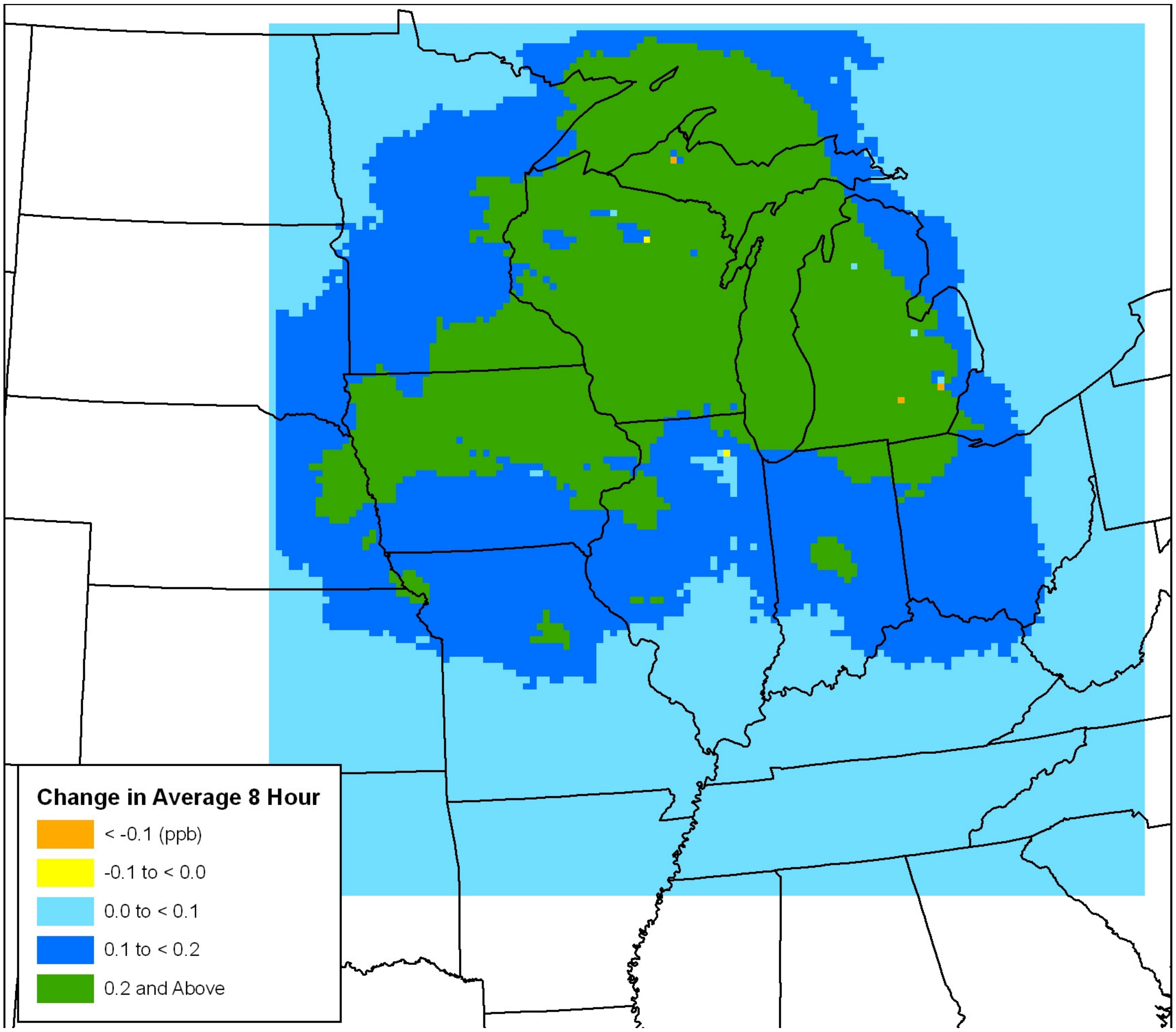

Figure 7. Changes in seasonal mean 8-hour ozone with EGU1 candidate control program.

Note: Positive values indicate an improvement in ozone levels. Negative values indicate a worsening of ozone levels.

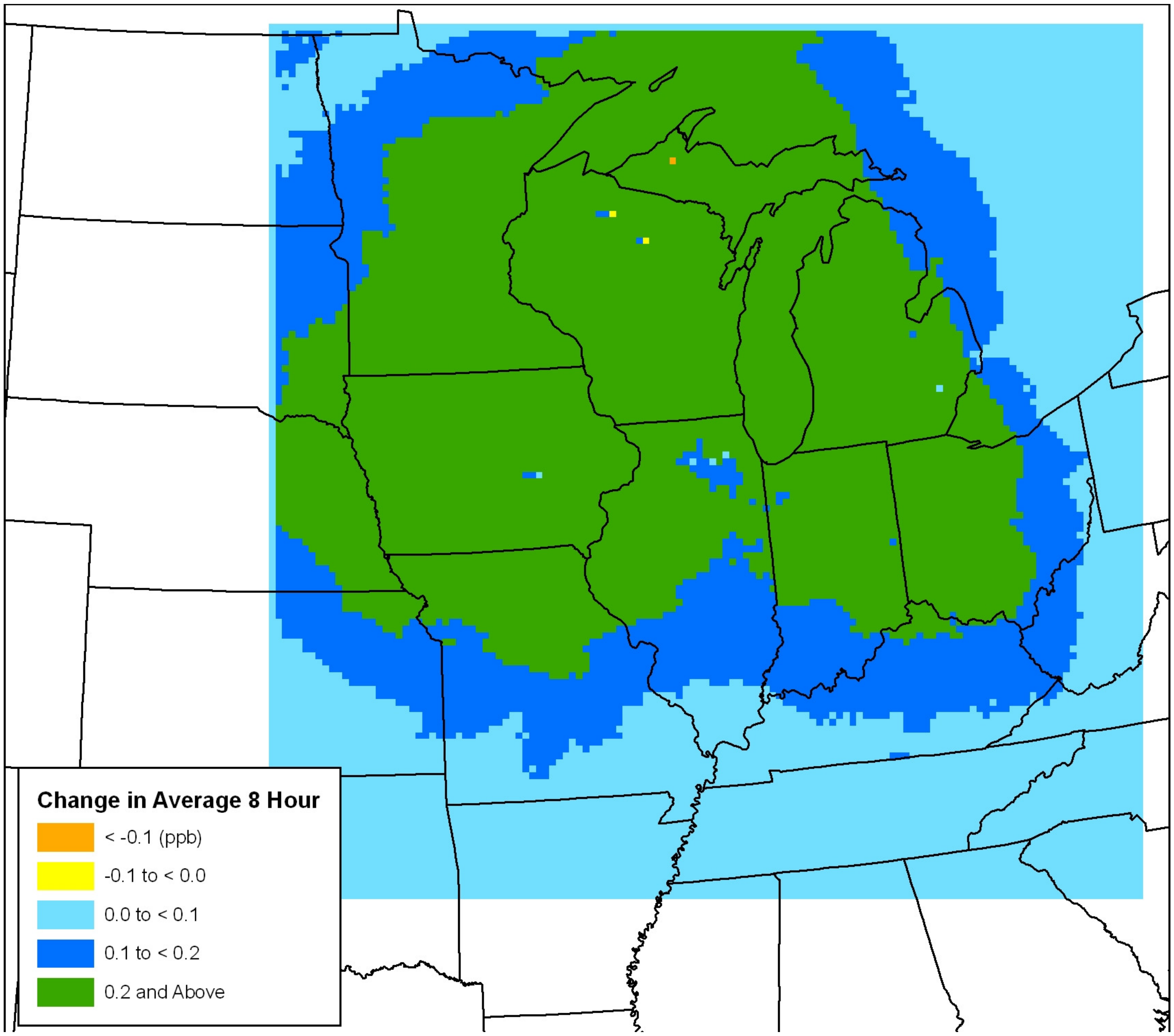

Figure 8. Changes in seasonal mean 8-hour ozone with EGU2 candidate control program.

Note: Positive values indicate an improvement in ozone levels. Negative values indicate a worsening of ozone levels.

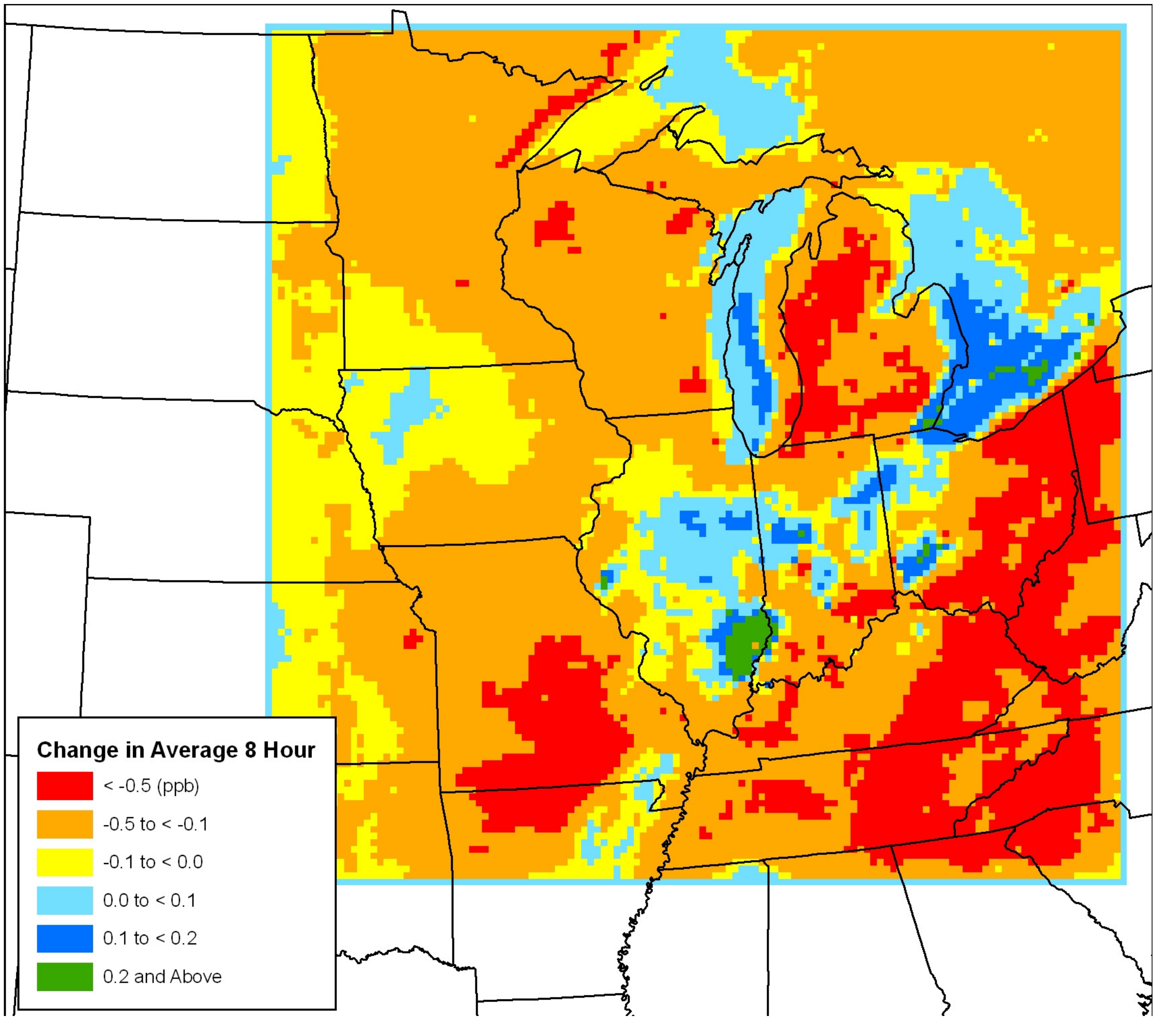

Figure 9. Changes in seasonal mean 8-hour ozone with EGU1 with IPM candidate control program.

Note: Positive values indicate an improvement in ozone levels. Negative values indicate a worsening of ozone levels.

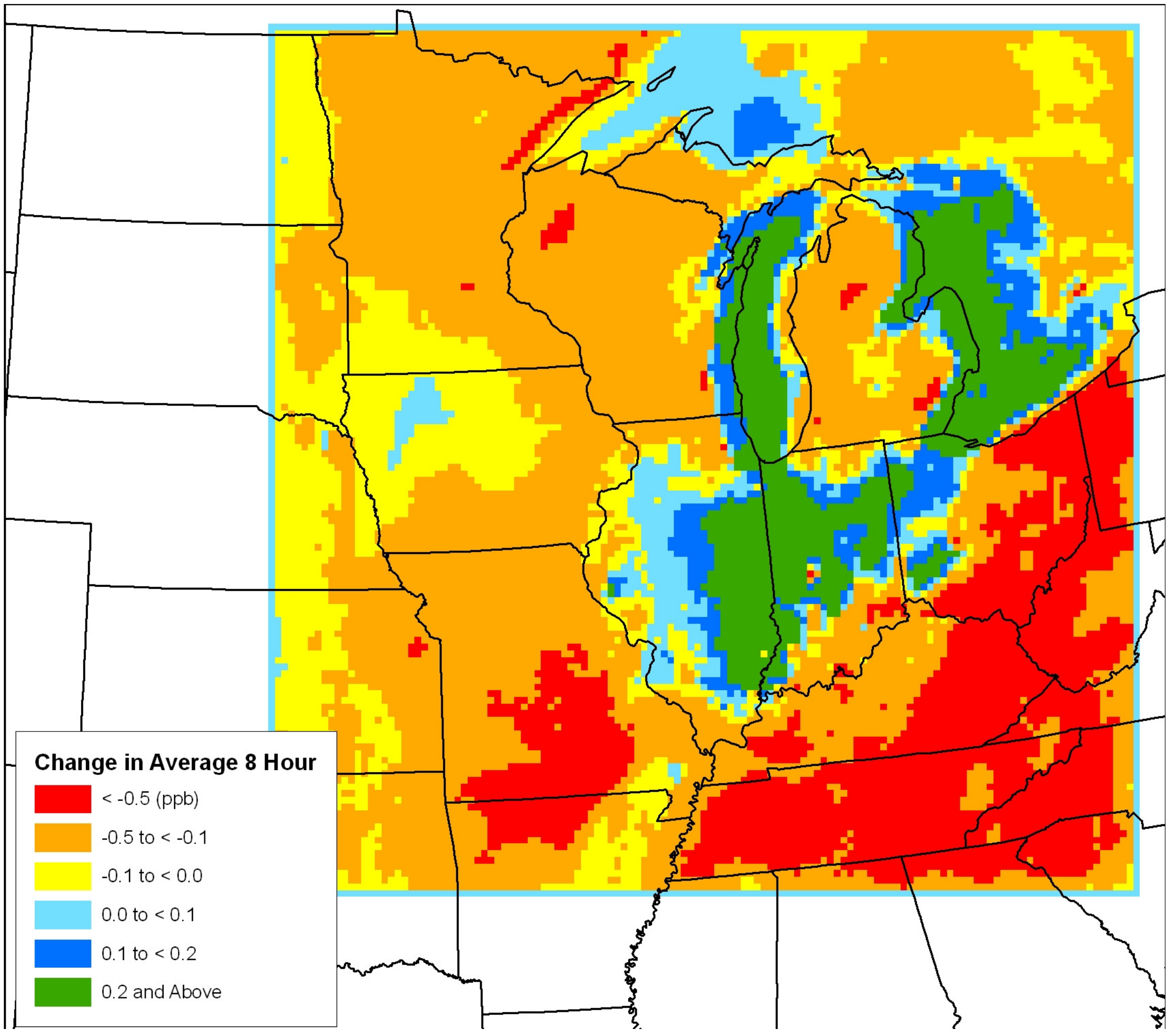

Figure 10. Changes in seasonal mean 8-hour ozone with EGU2 with IPM candidate control program.

Note: Positive values indicate an improvement in ozone levels. Negative values indicate a worsening of ozone levels.

4. Health Effects

Changes in the ambient levels of ozone and $PM_{2.5}$ will affect the health of the population exposed to those changes. There are a wide range of adverse health effects associated with exposure to elevated ozone and $PM_{2.5}$. Quantifiable health effects range from premature mortality and onset of chronic, debilitating respiratory disease to milder symptoms such as school absences and "adult respiratory symptom days" with coughing or wheezing.

While there is scientific uncertainty about the specific magnitude and form of the relationships between changes in exposure and health outcomes, EPA developed a set of analytical methods to quantify many of the important health effects of changes in $PM_{2.5}$ and ozone. EPA regularly uses these methods in regulatory and policy analyses of all major air pollution programs. EPA's analytical method uses a damage function approach, combining air quality modeling results with concentration-response relationships from published health research, population projections, and health status information (e.g., baseline incidence) to estimate the changes in health effects from air pollution policies. All aspects of EPA's overall analytical methods used in this report have been peer reviewed by both EPA's Science Advisory Board (SAB) and (for $PM_{2.5}$) by the National Research Council (NRC, 2002).

The changes in health effects associated with the four air quality change scenarios were estimated using methods and tools developed by the EPA. With one exception, the health effect estimation procedures used in this report are identical to the procedures EPA used in the regulatory analysis of CAIR, which was published by EPA in 2005 (Environ, 2005; U.S. EPA, 2005).

The one exception to full consistency with EPA's CAIR analysis is ozone-related premature mortality, which is included in the mortality estimates in this report. The magnitude and extent to which ozone has a separate and additive effect to the PM-related premature mortality impacts is currently the subject of considerable scientific and policy-related research. In the EPA CAIR analysis, ozone mortality was included as a sensitivity analysis, but not included in the primary results total. The introduction to the RIA for CAIR included the following discussion:

> "Premature mortality associated with ozone is not currently included in the primary analysis. Recent evidence suggests that short-term exposures to ozone may have a significant effect on daily mortality rates, independent of exposure to PM. EPA is currently conducting a series of meta-analyses of the ozone mortality epidemiology literature. EPA will consider including ozone mortality in primary benefits analyses once a peer-reviewed methodology is available." (p. 1-1)

The CAIR RIA provided further discussion of this important issue:

> "However, there is one category where new studies suggest the possibility of significant additional economic benefits. Over the past several years, EPA's SAB has expressed the view that there were not sufficient data to show a separate ozone mortality effect, in essence, saying that any ozone benefits are captured in the PM-related mortality benefit estimates. However, in their most recent advice, the SAB recommended that EPA reconsider the evidence on ozone-related mortality based on the publication of several recent analyses that found statistically significant associations between ozone and mortality. Based on these studies and the recommendations from the SAB, EPA has sponsored three independent meta-analyses of the ozone-mortality epidemiology literature to inform a determination on including this important health endpoint. The studies are complete and have been accepted for publication in the journal Epidemiology in July 2005 [see Bell et al., in press; Ito et al., in press; Levy et al., in press].
>
> The Agency believes that publication of these meta-analyses will significantly enhance the scientific defensibility of benefits estimates for ozone, that include the benefits of premature mortality reductions. In addition, a study published in JAMA in November 2004 also confirmed that ozone mortality impacts can be calculated separately from PM mortality impacts (Bell et al., 2004). EPA believes that there is sufficient evidence to return to the SAB to confirm that these studies address their previous concerns. Using effect estimates similar to those found in these new studies, EPA estimates the monetary value of the ozone-related premature mortality benefits could be substantial."

[Note: the meta-analyses cited were subsequently published in 2004 and 2005 (Bell et al., 2004, 2005; Ito et al., 2005; Levy et al., 2005).]

The most recent EPA Ozone Criteria Document (U.S. EPA, 2006; published in March, 2006) extensively reviewed all the available evidence about the relationship between short-term ozone exposure and premature mortality. In Chapter 8, "Integrative Synthesis: Ozone Exposure and Health Effects," in the section "Summary and Conclusions for Ozone Health Effect," the Criteria Document makes the following statement:

> "This overall body of evidence is highly suggestive that O_3 directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality, but additional research is needed to more fully establish underlying mechanisms by which such effects occur." (p. 8-78)

EPA's SAB is currently formally reviewing the Ozone Criteria Document. In addition to this peer review, EPA is reported to be in the process of formally requesting the National Academy of Sciences review the evidence linking ozone exposure and premature mortality, and recommend appropriate procedures for including ozone mortality in regulatory and policy analyses (Inside EPA.com, 2006).

Although there is remaining scientific uncertainty about the ozone/mortality relationship, ozone-related premature mortality is included in this report. This provides a modest increase to the total amount of premature mortality estimated for each modeled air quality regime. For the modeled ozone air quality scenarios, the largest amount of ozone-related mortality is associated with the EGU2 scenario, where ozone increases the total mortality effects by 1.5%.

4.1 Health Effects

The majority of the health effect concentration-response functions used in this analysis are non-threshold, log-linear relative risk functions. With this type of function, health effects are associated with any change in the ambient pollutant level, regardless of the pollution level. Hence even small air quality changes in locations estimated to already meet the NAAQS by 2012 will produce quantifiable health effects. The exact form of the actual health effect relationships, and whether there is a threshold within the predicted range of pollution levels, are important scientific questions and are key sources of uncertainty. Different assumptions could substantially impact the estimates of the changes in health effects and their values.

The health and valuation analysis for this report was conducted using EPA's BenMAP version 2.2, a Windows©-based computer model developed for EPA and available from EPA's Technology Transfer Network.[4] BenMAP is the Environmental Benefits Mapping and Analysis Program.

There are ten health effects associated with ozone and $PM_{2.5}$ that were estimated with BenMAP for this report. In addition, one health-related effect, worker productivity (which is limited to the impact of ozone on outdoor physical labor), is directly measured as the value of the loss of economic output. Table 4 identifies the health effects, which pollutants each effect is associated with, and the authors of the health effects studies used. For some health effects there are multiple studies used, which helps expand the range of ages covered, specific disease categories, and to reflect the diversity of results in the literature. Full specifications of each concentration-response function used in the analysis, including the methods used for combining multiple studies and

4. Model downloaded from EPA's BenMAP website, http://www.epa.gov/ttn/ecas/benmodels.html. Additional BenMAP population datasets for the United States used in the CAIR analysis were obtained from Dr. Bryan Hubbell, Office of Air Quality Planning and Standards.

Table 4. Health effects included in analysis

Health effect	Pollutant	Affected population	Key studies used in analysis
Premature mortality	$PM_{2.5}$ and ozone	PM: Adults 30 and older PM: Infants < 1 Ozone: All ages	PM: adult: Pope et al., 2002 Infants: Woodruff et al., 1997 Ozone: 5 studies
Chronic bronchitis	$PM_{2.5}$	Adults 27 and older	Abbey et al., 1995
Heart attacks (myocardial infarctions)	$PM_{2.5}$	Adults 18 and older	Peters et al., 2001
Hospital admissions	$PM_{2.5}$ and ozone	Adults 18 and older	PM: 9 studies (various ages) Ozone: 8 studies (various ages)
Emergency room visits for asthma	$PM_{2.5}$ and ozone	Children 17 and under	PM: Norris et al., 1999 Ozone: 5 studies
Acute bronchitis and other symptom days	$PM_{2.5}$ and ozone	Adults 18 and over	PM and ozone: Ostro and Rothschild, 1989 Acute bronchitis (PM): Dockery et al., 1996
Asthma "attack" days	$PM_{2.5}$	Children ages 6 to 18	4 studies
Work loss days	$PM_{2.5}$	Adults 18 to 64	Ostro, 1987
School loss days	Ozone	Children ages 5 to 17	2 studies
Worker productivity	Ozone	Adults 18 to 64	Crocker and Horst, 1981

valuing each health effect, are presented in the BenMAP audit reports in Appendix A (PM related health effects) and Appendix B (ozone related health effects). The appendices include citations for each concentration-response function.

In addition to the health effects that are quantified in this report, ozone and $PM_{2.5}$ are believed to have a wide range of other impacts on human health, agriculture, forest yields, nitrogen and acid deposition into water bodies, and other ecological impacts. It is not possible at this time to quantify all the impacts of changes in ambient ozone and $PM_{2.5}$ concentrations with a satisfactory level of scientific confidence. EPA believes that these omitted effects are substantial, and their omissions leads to an underestimate of the benefits from improving ozone and $PM_{2.5}$ levels. Table 5 is from the CAIR RIA (U.S. EPA, 2005), and shows some of the important health and ecological impacts omitted from this analysis.

Table 5. Unquantified and nonmonetized effects

Pollutant effects not included in primary estimates
Ozone – health
Chronic respiratory damage
Premature aging of the lungs
Nonasthma respiratory emergency room visits
Increased exposure to UVb
Ozone – welfare
Yield changes for:
Commercial forests,
Fruits and vegetables, and
Commercial and noncommercial crops
Damage to urban ornamental plants
Recreational demand from damaged forest aesthetics
Ecosystem functions
Increased exposure to UVb
PM – health
Premature mortality: short-term exposures
Low birth weight
Pulmonary function
Chronic respiratory diseases other than chronic bronchitis
Nonasthma respiratory emergency room visits
Exposure to UVb (+/-)
PM – welfare
Visibility in many Class I areas
Residential and recreational visibility in non-Class I areas
Soiling and materials damage
Ecosystem functions
Exposure to UVb (+/-)
Nitrogen and sulfate deposition – welfare
Commercial forests due to acidic sulfate and nitrate deposition
Commercial freshwater fishing due to acidic deposition
Recreation in terrestrial ecosystems due to acidic deposition
Existence values for currently healthy ecosystems
Commercial fishing, agriculture, and forests due to nitrogen deposition
Recreation in estuarine ecosystems due to nitrogen deposition
Ecosystem functions
Passive fertilization due to nitrogen deposition
Source: U.S. EPA, 2005.

4.2 Health Effect Estimates

The estimates of the avoided health effects for each of the four modeled air quality scenarios (EGU1, EGU2, EGU1 with IPM, and EGU2 with IPM) are presented in Tables 6 through 9. The estimates shown in the tables are the number of cases of health effects that are associated with the estimated changes in ozone and $PM_{2.5}$ levels. Air quality improvements result in positive numbers of avoided cases, and worsening air quality results in negative numbers of cases. The tables show the "national" total (actually the total cases for the modeled areas), as well as subtotals for the MRPO region and the rest of the country (non-MRPO region). The tables also present the estimated number of cases in each state within the MRPO region.

Table 6. Estimated health effects for EGU1

Health effect	National total[a]	MRPO region total	Regional detail: Illinois	Indiana	Michigan	Ohio	Wisconsin	Rest of country
Acute bronchitis	5,000	2,700	760	530	540	650	200	2,300
Acute myocardial infarction	6,100	3,400	930	660	680	890	200	2,800
Acute respiratory symptoms	2,168,000	1,223,000	339,000	243,000	252,000	313,000	76,000	946,000
Asthma exacerbation	131,400	73,300	21,500	14,800	14,700	18,200	4,200	58,100
Chronic bronchitis	1,900	1,000	270	190	210	250	80	890
Emergency room visits, respiratory	3,400	2,100	610	420	430	520	120	1,250
Hospital admissions, cardiovascular	1,200	600	170	120	120	160	40	550
Hospital admissions, respiratory	1,900	1,100	300	230	230	300	80	770
Lower respiratory symptoms	52,100	29,000	8,400	5,800	5,800	7,200	1,700	23,100
Mortality	3,010	1,570	420	310	310	420	120	1,440
School loss days	33,500	27,600	5,100	6,800	5,700	7,700	2,200	5,900
Work loss days	348,300	192,600	54,800	37,700	39,600	48,800	11,600	155,700
Worker productivity (thousands)	$1,100	$800	$120	$160	$180	$170	$170	$300

Note: Regional avoided cases may not sum to national total due to rounding.

a. Benefit estimates for $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are for the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

Table 7. Estimated health effects for EGU2

Health effect	National total[a]	MRPO region total	Regional detail					Rest of country
			Illinois	Indiana	Michigan	Ohio	Wisconsin	
Acute bronchitis	5,900	3,200	910	620	620	770	230	2,700
Acute myocardial infarction	7,200	3,900	1,110	770	770	1,050	230	3,200
Acute respiratory symptoms	2,589,000	1,473,000	414,000	294,000	297,000	377,000	91,000	1,116,000
Asthma exacerbation	154,200	86,200	25,600	17,400	16,800	21,500	4,800	68,000
Chronic bronchitis	2,200	1,200	330	230	240	300	90	1,040
Emergency room visits, respiratory	4,000	2,500	740	500	490	620	140	1,470
Hospital admissions, cardiovascular	1,400	700	200	140	140	190	40	650
Hospital admissions, respiratory	2,400	1,400	380	290	280	380	100	930
Lower respiratory symptoms	61,100	34,000	10,100	6,800	6,700	8,500	1,900	27,000
Mortality	3,540	1,860	500	360	360	490	140	1,680
School loss days	55,700	45,600	9,300	10,800	9,600	11,800	4,100	10,200
Work loss days	408,600	226,200	65,500	44,500	45,300	57,600	13,400	182,300
Worker productivity (thousands)	$1,900	$1,400	$230	$260	$330	$260	$320	$500

Note: Regional avoided cases may not sum to national total due to rounding.

a. Benefit estimates for $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are for the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

Table 8. Estimated health effects for EGU1 with IPM

Health effect	National total[a]	MRPO region total	Regional detail: Illinois	Indiana	Michigan	Ohio	Wisconsin	Rest of country
Acute bronchitis	260	1,500	440	300	350	270	110	-1,200
Acute myocardial infarction	420	1,800	540	370	430	360	120	-1,400
Acute respiratory symptoms	19,000	595,000	187,000	126,000	139,000	106,000	37,000	-576,000
Asthma exacerbation	8,000	40,100	12,400	8,400	9,400	7,600	2,500	-32,200
Chronic bronchitis	90	540	160	110	130	100	40	-460
Emergency room visits, respiratory	400	1,100	350	240	270	210	70	-690
Hospital admissions, cardiovascular	30	300	100	70	80	60	20	-300
Hospital admissions, respiratory	-650	100	110	50	30	-60	-10	-780
Lower respiratory symptoms	3,030	15,900	4,900	3,300	3,700	3,000	1,000	-12,800
Mortality	80	810	240	170	190	160	60	-740
School loss days	-30,700	-10,600	-200	-300	-3,900	-5,000	-1,300	-20,100
Work loss days	18,300	105,000	31,500	21,300	25,100	20,200	6,900	-86,600
Worker productivity (thousands)	-$4,800	-$2,100	-$220	-$290	-$570	-$590	-$470	-$2,600

Note: Regional avoided cases may not sum to national total due to rounding.

a. Benefit estimates for $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are for the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

Table 9. Estimated health effects for EGU2 with IPM

Health effect	National total[a]	MRPO region total	Regional detail					Rest of country
			Illinois	Indiana	Michigan	Ohio	Wisconsin	
Acute bronchitis	920	2,100	670	420	470	390	170	-1,200
Acute myocardial infarction	1,280	2,600	810	520	580	530	180	-1,300
Acute respiratory symptoms	322,000	912,000	295,000	188,000	205,000	163,000	61,000	-590,000
Asthma exacerbation	25,300	57,900	18,700	11,700	12,700	10,900	3,700	-32,600
Chronic bronchitis	330	780	240	150	180	150	70	-450
Emergency room visits, respiratory	900	1,700	540	330	370	310	110	-720
Hospital admissions, cardiovascular	170	500	140	90	100	90	30	-300
Hospital admissions, respiratory	-320	500	220	120	110	0	20	-790
Lower respiratory symptoms	9,820	22,900	7,400	4,600	5,000	4,400	1,500	-13,100
Mortality	470	1,200	360	240	270	230	100	-730
School loss days	-18,400	3,800	3,700	3,500	300	-3,500	-200	-22,200
Work loss days	63,600	151,400	47,800	29,800	34,200	29,200	10,400	-87,700
Worker productivity (thousands)	-$4,400	-$1,700	-$120	-$200	-$400	-$550	-$400	-$2,700

Note: Regional avoided cases may not sum to national total due to rounding.

a. Benefit estimates for $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are for the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

5. Valuation

In order to better compare the health benefits of the EGU candidate control programs with the costs, it is necessary to estimate the economic value of the estimated avoided cases of health effects. This is a challenging and controversial process. While measuring the direct expenditures for health care (such as the cost of hospitalization for a respiratory illness) can be relatively straightforward, such "resource cost" metrics only reflect one aspect of the full social desirability of improving human health. Including other direct expenditures (e.g., lost time from work, time spent by family caregivers, non-hospital health costs and transportation) make a more complete estimate of the resource costs, but still omit important concepts properly included in a comprehensive measure of the social benefit. In addition to direct costs, the full social benefit of avoiding a hospitalization includes avoiding all aspects of the pain and suffering, and reduced quality of life, associated with a health effect.

In an economic benefit-cost study of a potential environmental program, the appropriate economic concept for valuing health effects is to measure a typical individual's willingness to pay (WTP) to reduce the risk of a specific adverse health effect. WTP can include all aspects of a person's desire to reduce a particular risk, and includes both resource costs and pain and suffering. A properly estimated WTP measure can be very specific, such as the WTP for avoiding a one-in-1-million (10^{-6}) risk of a having a day with a PM-induced "asthma attack."

The most challenging health effect to value is premature mortality; many people find the concept of "valuing a human life" to be unacceptable, especially if measured by only the avoided medical costs. Yet premature mortality is a very important and well-established health effect associated with changes in air pollution exposures. Assessing the economic benefits of candidate control measures that lead to reduced risks of premature mortality requires a method to estimate the economic value of this important health effect. Economic theory identifies WTP to reduce the risk of premature mortality as the appropriate way to value estimates of premature mortality avoided.

In practice, WTP estimates of the value of reducing risks are often presented as *unit values*. Unit values are calculated from the WTP estimates for a small change in risk, which is then applied to a large exposed population. For example, consider a candidate control program where 1,000,000 people live where the improvement in air quality will reduce their risk of premature mortality by 1×10^{-6} in a year. With this reduction in mortal risk for this population, one person is estimated to avoid dying prematurely each year (this is known as one "statistical life lost"). If the typical individual's WTP for a 1×10^{-6} reduction in mortal risk is $6.00, then each member of that 1,000,000 exposed population is willing to pay $6.00 for that risk reduction. Hence the sum of all the individual WTPs for that exposed population is $6,000,000. A number calculated in this manner is referred to as the "value of a statistical life."

Although a WTP-based unit value is the appropriate way to value changes in all health effects, good estimates of WTP are not available at this time for all the health effects associated with changes in ambient ozone and PM levels. The premature mortality unit value is a WTP-based value, reflecting combination of wage-risk tradeoff and "stated preference" studies based on survey responses. Where acceptable WTP measures are not available, unit values must be based an alternative method. Some other health effects use a resource cost estimate for the unit value. The resource cost estimate will underestimate the appropriate social value of avoiding adverse health effects.

The unit values used to assign economic values to the health effects for the candidate control measures are presented in Table 10. These values are consistent with the values used in the CAIR RIA (U.S. EPA, 2004, 2005). The method used to estimate each unit value is also shown.

Table 10. Unit values for health effects

	Unit value (1999$)	Source method of valuation
Premature mortality	$5,320,000	WTP
Chronic bronchitis	$380,000	WTP
Heart attack (MI)	$66,000 to $140,000	Hospital costs + wage loss
Hospital admissions	$6,600 to $18,400	Medical costs
ER visits	$285 to $550	Medical costs
Symptom days	$17 to $65 / day	WTP
Work loss days	$126	Median wage in region
School loss days	$75	Median wage (national)
Acute bronchitis	$350	Medical costs
Asthma attack	$7	Medical costs

Source: Table 4-11, U.S. EPA, 2005.

5.1 Valuation Results

The estimates of the value of the avoided health effects for each of the four modeled air quality scenarios (EGU1, EGU2, EGU1 with IPM, and EGU2 with IPM) are presented in Tables 11 through 14. The estimates shown in the tables are the aggregate value of the cases of health effects associated with the estimated changes in ozone and $PM_{2.5}$ levels. Air quality improvements result in positive values, and worsening air quality results in negative values. The tables show the "national" total (actually the total value for the modeled areas), as well as sub-totals for the MRPO region and the rest of the country (non-MRPO region). The tables also present the values in each state within the MRPO region.

Table 11. Estimated economic benefits for EGU1 (thousands of 1999$)

Health effect	National total[a]	LADCO region total	Regional detail: Illinois	Indiana	Michigan	Ohio	Wisconsin	Rest of country[a]
Acute bronchitis	$1,800	$960	$270	$190	$190	$230	$70	$830
Acute myocardial infarction	$403,000	$222,000	$61,400	$43,300	$44,700	$58,900	$13,300	$181,500
Acute respiratory symptoms	$209,000	$117,000	$32,700	$23,200	$24,100	$29,900	$7,200	$91,900
Asthma exacerbation	$5,600	$3,100	$900	$600	$600	$800	$200	$2,500
Chronic bronchitis	$642,100	$340,200	$92,800	$65,300	$70,000	$85,600	$26,500	$301,900
Emergency room visits, respiratory	$1,000	$660	$190	$130	$130	$160	$40	$390
Hospital admissions, cardiovascular	$24,600	$12,800	$3,500	$2,500	$2,600	$3,400	$800	$11,800
Hospital admissions, respiratory	$26,500	$15,700	$4,200	$3,100	$3,200	$4,200	$1,000	$10,800
Lower respiratory symptoms	$800	$450	$130	$90	$90	$110	$30	$360
Mortality	$16,531,000	$8,637,300	$2,307,000	$1,685,000	$1,722,000	$2,286,000	$637,000	$7,893,000
School loss days	$2,500	$2,100	$380	$510	$420	$580	$170	$400
Work loss days	$46,000	$25,700	$7,600	$4,700	$5,700	$6,100	$1,500	$19,900
Worker productivity	$1,100	$800	$120	$160	$180	$170	$170	$300
Total	$17,894,000	$9,378,000	$2,511,000	$1,829,000	$1,874,000	$2,477,000	$688,000	$8,516,000

Note: Regional benefit values may not sum to national total due to rounding.

a. Benefits from $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are limited to the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

Table 12. Estimated economic benefits for EGU2 (thousands of 1999$)

Health effect	National total[a]	LADCO region total	Regional Detail: Illinois	Indiana	Michigan	Ohio	Wisconsin	Rest of country[a]
Acute bronchitis	$2,100	$1,120	$320	$220	$220	$270	$80	$970
Acute myocardial infarction	$472,000	$260,000	$73,200	$51,000	$51,000	$69,400	$15,200	$212,400
Acute respiratory symptoms	$248,000	$139,800	$39,600	$27,800	$28,100	$35,700	$8,500	$108,200
Asthma exacerbation	$6,600	$3,700	$1,100	$700	$700	$900	$200	$2,900
Chronic bronchitis	$753,600	$399,800	$110,800	$77,000	$80,300	$100,900	$30,800	$353,800
Emergency room visits, respiratory	$1,200	$780	$230	$160	$150	$190	$40	$460
Hospital admissions, cardiovascular	$28,800	$15,000	$4,200	$3,000	$3,000	$4,000	$900	$13,800
Hospital admissions, respiratory	$32,400	$19,500	$5,300	$3,900	$3,800	$5,200	$1,300	$12,900
Lower respiratory symptoms	$1,000	$530	$160	$110	$100	$130	$30	$420
Mortality	$19,492,000	$10,225,200	$2,772,000	$2,000,000	$1,989,000	$2,713,000	$750,000	$9,267,000
School loss days	$4,200	$3,400	$700	$810	$720	$880	$310	$800
Work loss days	$53,000	$30,100	$9,100	$5,500	$6,500	$7,200	$1,800	$23,300
Worker productivity	$1,900	$1,400	$230	$260	$330	$260	$320	$520
Total	$21,098,000	$11,100,000	$3,017,000	$2,171,000	$2,164,000	$2,939,000	$809,000	$9,997,000

Note: Regional benefit values may not sum to national total due to rounding.

a. Benefits from $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are limited to the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

Table 13. Estimated economic benefits for EGU1 with IPM (thousands of 1999$)

Health effect	National total[a]	LADCO region total	Regional detail					Rest of country[a]
			Illinois	Indiana	Michigan	Ohio	Wisconsin	
Acute bronchitis	$100	$520	$160	$110	$120	$100	$40	-$430
Acute myocardial infarction	$28,000	$120,000	$35,400	$24,500	$28,400	$23,900	$7,900	-$92,500
Acute respiratory symptoms	$5,000	$59,200	$18,300	$12,400	$13,900	$10,800	$3,700	-$54,300
Asthma exacerbation	$300	$1,700	$500	$400	$400	$300	$100	-$1,400
Chronic bronchitis	$29,300	$184,700	$53,300	$36,800	$44,500	$35,000	$15,000	-$155,300
Emergency room visits, respiratory	$100	$350	$110	$70	$80	$70	$20	-$210
Hospital admissions, cardiovascular	$500	$6,900	$2,000	$1,400	$1,600	$1,400	$400	-$6,400
Hospital admissions, respiratory	-$3,500	$4,800	$2,000	$1,200	$1,100	$400	$200	-$8,300
Lower respiratory symptoms	$0	$250	$80	$50	$60	$50	$20	-$200
Mortality	$424,000	$4,481,000	$1,309,000	$923,000	$1,048,000	$854,000	$346,000	-$4,057,000
School loss days	-$2,300	-$800	-$20	-$20	-$290	-$370	-$100	-$1,500
Work loss days	$3,000	$14,100	$4,400	$2,600	$3,600	$2,600	$900	-$11,300
Worker productivity	-$4,800	-$2,140	-$220	-$290	-$570	-$590	-$470	-$2,610
Total	$479,000	$4,871,000	$1,425,000	$1,003,000	$1,141,000	$928,000	$374,000	-$4,392,000

Note: Regional benefit values may not sum to national total due to rounding.

a. Benefits from $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are limited to the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs.

Table 14. Estimated economic benefits for EGU2 with IPM (thousands of 1999$)

Health effect	National total[a]	LADCO region total	Regional detail					Rest of country[a]
			Illinois	Indiana	Michigan	Ohio	Wisconsin	
Acute bronchitis	$300	$760	$240	$150	$170	$140	$60	-$430
Acute myocardial infarction	$84,000	$173,000	$53,400	$34,300	$38,500	$34,700	$11,900	-$88,600
Acute respiratory symptoms	$33,000	$88,800	$28,500	$18,100	$20,000	$16,300	$6,000	-$55,500
Asthma exacerbation	$1,100	$2,500	$800	$500	$500	$500	$200	-$1,400
Chronic bronchitis	$114,000	$267,000	$80,800	$51,600	$60,600	$50,800	$23,100	-$153,000
Emergency room visits, respiratory	$300	$510	$170	$100	$110	$100	$30	-$220
Hospital admissions, cardiovascular	$3,600	$10,000	$3,100	$2,000	$2,200	$2,000	$700	-$6,300
Hospital admissions, respiratory	$800	$9,200	$3,400	$2,000	$2,000	$1,100	$600	-$8,400
Lower respiratory symptoms	$200	$360	$110	$70	$80	$70	$20	-$200
Mortality	$2,603,000	$6,605,400	$2,002,000	$1,321,000	$1,463,000	$1,277,000	$542,000	-$4,003,000
School loss days	-$1,400	$300	$280	$270	$20	-$260	-$20	-$1,700
Work loss days	$9,000	$20,400	$6,700	$3,700	$4,900	$3,700	$1,400	-$11,200
Worker productivity	-$4,400	-$1,670	-$120	-$200	-$400	-$550	-$400	-$2,740
Total	$2,844,000	$7,176,000	$2,180,000	$1,433,000	$1,592,000	$1,386,000	$585,000	-$4,332,000

Note: Regional benefit values may not sum to national total due to rounding.

a. Benefits from $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are limited to the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control program

6. Cost Estimates, Benefit-Cost and Cost-Effectiveness Analyses

While the primary purpose of this report is the health and valuation estimates presented above, it is also possible to make limited comparisons between the estimated value of health benefits and the available cost estimates. Information about the cost estimates for the four candidate control programs were provided to Stratus Consulting by LADCO.

6.1 Cost Estimates for the EGU1 and EGU2 Candidate Control Programs

The White Paper presents ranges of average control costs (average $/ton) for the two candidate programs described in the White Paper (EGU1 and EGU2). The White Paper estimates SO_2 emission reductions from EGUs will cost between $800/ton and $1,500/ton, and NO_x emissions will cost between $700/ton and $1,600/ton (LADCO White Paper, Table 1A and 1B). As described in the White Paper, LADCO's contractor developed these preliminary abatement cost ranges from various published sources, and recommended that more refined cost estimates would be needed.

Combining the ranges of control cost estimates with the emission reductions in the EGU1 and EGU2 control programs provides a preliminary control cost estimate for the EGU1 and EGU2 candidate control programs. Table 15 presents the preliminary cost estimates. All of these costs will occur within the MRPO region.

Table 15. Preliminary cost estimates for EGU1 and EGU2 (1999$)[a]

	Emission reductions (tons)		Cost/ton estimates		Annual control cost (millions)	
	EGU1	EGU2	Low	High	EGU1	EGU2
SO_2	1,117,000	1,266,000	$800/ton	$1,500/ton	$894-$1,675	$1,013-$1,899
NO_x	148,000	238,000	$700/ton	$1,600/ton	$104-$237	$167-$381
Total					$997-$1,912	$1,180-$2,280

a All cost estimates in this report are in 1999 dollars. The cost estimates from IPM are explicitly stated as being in 1999 dollars. The cost estimates derived from the White Paper are presented in 1999 dollars as well for ease of comparison.

6.2 Cost Estimates for the EGU1 with IPM and EGU2 with IPM Candidate Control Programs

The cost estimates for the EGU1 with IPM and EGU2 with IPM candidate programs were developed using the IPM. IPM is a mathematical programming model that seeks the least-cost solution for the specified set of control options. IPM generates separate estimates of four cost components: annualized capital costs, fuel costs, fixed operating costs and variable operating costs.

Because the IPM analysis of the two candidate control programs permitted ERCs to be sold out of the MRPO region, cost impacts are felt both within the MRPO region and outside the region. Within the MRPO region the control costs increase to meet the requirements of the candidate control programs. These cost increases will be offset to some extent by the sale of ERCs. Outside of the region control costs decline. By purchasing ERCs from the MRPO regions, EGUs in the non-MRPO region meet their obligations under the existing federal cap-and-trade programs by emitting more than they would in the analytical baseline. Therefore control costs decline outside the MRPO region (partially offset by the purchase of ERCs).

Table 16 presents the cost estimates for the EGU1 with IPM and EGU2 with IPM candidate control programs. The costs shown on Table 16 are the changes in the cost of generation for each candidate program compared with the cost of generation in the 2012 analytical baseline.

Table 16. Cost estimates for EGU1 with IPM and EGU2 with IPM candidate programs (1999$)

	EGU1 with IPM	**EGU2 with IPM**
Increase in national total cost of generation	$491,000,000	$1,054,000
% change over analytical baseline	+0.5%	+1.0%
Generation cost increase in MRPO region	$935,000,000	$1,300,000,000
% change over analytical baseline cost	+6.2%	+8.6%
Out of MRPO region	-$444,000,000	$-245,000,000[a]
% change over analytical baseline cost	-0.5%	-0.3%

a. The IPM analysis estimates the amount of electricity generated in the MRPO region declines with both programs: in-region generation declines by 1.6% in the EGU1 with IPM program, and by 3.0% in the EGU2 with IPM program. As the 2012 national demand for electricity is assumed to remain constant, non-MRPO generation increases by roughly the same amount that MRPO generation declines (IPM does estimate the impact of transmission loss). In the EGU2 with IPM candidate program, the increasing fuel costs in the non-MRPO region partially offset the reduced costs of abatement possible through purchasing the credits, resulting in a smaller decrease in non-MRPO region control costs with EGU2 with IPM than in the EGU1 with IPM program.

The control costs estimated by IPM do not reflect the impact of the value of the trading credits. IPM estimates the actual control costs, and where they occur. IPM does not, however, estimate who eventually pays the control costs. The IPM estimates of costs occurring within the MRPO region would be offset to some extent by the value of the ERCs sold by in-region EGUs. Similarly, the control costs occurring outside the MRPO region would be increased by the price paid for the credits.

The amount actually paid for the credits would be determined through the trading market, with buyers and sellers agreeing to a price for each sale. It is possible that different trades would occur at different prices. The prices of credits would be influenced by details about how the trading program would be set up, the initial distribution (allocation) of emission caps within the MRPO region, and other factors.

Although IPM does not attempt to estimate the prices of ERCs that would be traded out of the MRPO region, it does provide enough information to bound the total amount the MRPO EGUs may receive for the credits they sell.

An upper bound on the total value of the credits is the estimated total cost savings for the non-MRPO region EGUs. For example, under the EGU1 with IPM candidate program the non-MRPO region EGUs reduce their costs of generation by $444 million. They could pay up to that amount for the ERCs purchased from the MRPO region and be just as financially well off as in the baseline. If the in-region EGUs were able to sell the ERCs for this upper bound amount, the total in-region cost of the EGU1 with IPM candidate program would decline by 47%.

6.3 Benefit-Cost Analysis

Using the benefit estimates presented in Section V, and the cost estimates presented in Section VI, it is possible to directly compare the estimated benefits and estimated costs. Table 17 shows the comparison of the estimated benefits and costs for the entire modeled region, as well as separately for the five-state MRPO region are presented.

The air quality pollution concentration increases (worsens) in some sections of the non-MRPO region in the two "with IPM" candidate programs, producing negative health impacts (dis-benefits) in those locations. In the two "with IPM" programs the air quality is estimated to be worse in some locations relative to the analytical base case, so there will be increased incidence of air pollution-related illness and mortality in those areas. This results in a negative benefit value in some locations.

Table 17. Estimated benefits and costs of candidate control programs (millions of 1999$)

	National analysis[a]			MRPO region only		
	Benefits	**Costs[b]**	**Net benefits (B - C)**	**Benefits**	**Costs[b]**	**Net benefits (B - C)**
EGU1	$17,894	$1,454	$16,440	$9,378	$1,454	$7,924
EGU2	$21,098	$1,729	$19,369	$11,100	$1,729	$9,371
EGU1 with IPM	$479	$491	-$12	$4,871	$935	$3,936
EGU2 with IPM	$2,844	$1,054	$1,830	$7,176	$1,300	$5,876

a. Benefits from $PM_{2.5}$ are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are limited to the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs. The cost estimates are for the contiguous 48 states plus the District of Columbia. Most of the emission changes occur within the eastern United States.
b. Costs for EGU1 and EGU2 shown here are the average of the low and high cost estimates shown in Table 15.

6.4 Cost-Effectiveness Analysis

An alternative method of comparing the benefits and costs of the candidate programs is to examine the cost per life saved. This is known as cost-effectiveness analysis. In recent policy analyses of national air programs, including the analysis of CAIR, EPA included a cost-effectiveness analysis as a supplement to benefit-cost analysis.

Estimating the cost-effectiveness of environmental programs is relatively new, and the methods are not as standardized as those used in benefit-cost analysis. In 2006, the Institute of Medicine (IOM, a part of the National Academies) published *Valuing Health for Regulatory Cost-Effectiveness Analysis* (Miller et al., 2006), which reviewed the conceptual basis of cost-effectiveness analysis. The book also made a series of recommendations about how cost-effectiveness analysis should be conducted and presented.

Three of the recommended methods of presenting cost-effectiveness revolve around the concepts of life-years lost (rather than number of lives lost) or changes in the quality of life. These cost-effectiveness measures go beyond the estimates of health effects presented in this report. The fourth method recommended by the IOM can be used with the information developed for this report, and is presented in this section.

One of the IOM-recommended measures of cost-effectiveness calculates the net cost per life saved (premature death avoided). This measure is calculated by subtracting from the cost estimates the estimated value of the health benefits for all of the health effects *except* for the value of avoided premature mortality. Dividing this net cost of the program by the number of lives saved (premature mortality avoided) produces an estimate of the cost per life saved.

The concept of the net cost per life saved measure stems in part from concerns that traditional economic benefit-cost analysis results are typically dominated by the value of a statistical life, and the appropriate value of a statistical life is both controversial and uncertain. The value of non-fatal health effects is largely based on resource cost estimated values, such as the cost of hospital admissions. There is less uncertainty about resource cost estimates, and considerably less controversy. The calculated net cost of a program is thus seen by some as a more certain and less controversial measure of the net costs of a candidate program. Dividing this relatively more certain net cost estimate by the number of lives saved provides a measure of each candidate program's average cost of saving an additional life after accounting for the other, non-fatal, health effects. Cost-effectiveness measures do not provide guidance as to what is an "acceptable" cost per life saved. They do facilitate comparisons between candidate programs, and encourage each reader to consider whether the estimated net cost per life saved is acceptable. When comparing alternative programs with similar environmental impacts, alternatives with lower cost per life saved are preferred to higher cost alternatives.

Table 18 presents the results of the net cost per life saved cost-effectiveness measure for the four candidate programs examined in this report. Using information presented in previous tables, this cost-effectiveness measure is calculated for the entire nation, and separately for the MRPO region alone.

Table 18. Cost-effectiveness analysis: Net costs per life saved of candidate control programs (millions of 1999$)

	National analysis[a]			MRPO region only		
	Net cost	**Lives saved**	**Net cost per life saved**	**Net cost**	**Lives saved**	**Net cost per life saved**
EGU1	< 0[b]	3,000	< 0[b]	< 0[b]	1,600	< 0[b]
EGU2	< 0[b]	3,500	< 0[b]	$664	1,900	$0.36
EGU1 with IPM	$435	77	$5.66	$60	810	$0.07
EGU2 with IPM	$2,642	470	$5.58	$728	1,200	$0.61

a. Benefits are from the $PM_{2.5}$ CAMx domain, which includes the eastern United States. Most of the PM impacts are likely included in this domain. Ozone benefits are from the CAMx ozone domain, which is limited to the five MRPO states and portions of the surrounding states. Ozone-related health effects are not included for the remaining population in the eastern United States, which is likely to experience changes in ozone levels as well due to the candidate control programs. The cost estimates are for the contiguous 48 states plus the District of Columbia. Most of the emission changes occur within the eastern United States.
b. Net costs (program costs minus non-fatal benefits) are negative for some candidate program/region combinations. In these situation the value of the non-fatal benefits exceeds the total costs, making calculation of net cost/life saved meaningless.

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Appendix A. BenMAP Audit Report for $PM_{2.5}$ Health Analysis

C:\Program Files\Abt Associates Inc\BenMAP 2.2 US Version\Configuration Results\LADCO PM EGU2 w IPM Relative Incidence & Valuation county.apvr

Configuration Results: C:\Program Files\Abt Associates Inc\BenMAP 2.2 US Version\Configuration Results\Full CAIR PM EGU2 w IPM Relative 02 mons.cfgr

Latin Hypercube Points: 50
Year: 2012
Threshold: 0
Grid Definition

Name: CAMx LADCO 36km PM as shape
ID: 9
Columns: 97
Rows: 90
Grid Type: Shapefile
Shapefile Name: CAMxPM25

Selected Studies

CR Function 0

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Seasonal Metric: QuarterlyMean
Metric Statistic: Mean
Author: Pope et al.
Year: 2002
Location: 51 cities
Qualifier: Pollution data averaged from: 1979-1983; 1999-2000. Long-Term Mo
Reference: Pope, C.A., 3rd, 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. Jama. Vol. 287 (9): 1132-41.
Start Age: 30
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.00582689081239758
Beta Distribution: Normal
P1Beta: 0.00215707622520569

P2Beta: 0
A: 0
B: 0
C: 7.5
Name C: Long-term cutpoint

CR Function 1

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Seasonal Metric: QuarterlyMean
Metric Statistic: Mean
Author: Woodruff et al.
Year: 1997
Location: 86 cities
Qualifier: Infant Mortality Function
Reference: Woodruff, T.J., J. Grillo and K.C. Schoendorf. 1997. The relationship between selected causes of postneonatal infant mortality and particulate air pollution in the United States. Environmental Health Perspectives. Vol. 105 (6): 608-612.
Start Age: 0
End Age: 0
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/((1-Incidence)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+Incidence)))*Incidence*POP
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.00392207131532813
Beta Distribution: Normal
P1Beta: 0.00122081686677641
P2Beta: 0
A: 0
B: 0
C: 7.5
Name C: Long-term cutpoint

CR Function 2

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Chronic Bronchitis
Endpoint: Chronic Bronchitis
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Seasonal Metric: QuarterlyMean
Metric Statistic: Mean
Author: Abbey et al.
Year: 1995
Location: SF, SD, South Coast Air Basin

Reference: Abbey, D.E., B.E. Ostro, F. Petersen and R.J. Burchette. 1995. Chronic Respiratory Symptoms Associated with Estimated Long-Term Ambient Concentrations of Fine Particulates Less Than 2.5 Microns in Aerodynamic Diameter ($PM_{2.5}$) and Other Air Pollutants. J E
Start Age: 27
End Age: 99
Baseline Functional Form: Incidence*POP*(1-Prevalence)
Functional Form: (1-(1/((1-Incidence)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+Incidence)))*Incidence*POP*(1-Prevalence)
Incidence DataSet: 2000 Incidence and Prevalence
Prevalence DataSet: 2000 Incidence and Prevalence
Beta: 0.0137
Beta Distribution: Normal
P1Beta: 0.00679624548559618
P2Beta: 0
A: 0
B: 0
C: 7.5
Name C: Long-term cutpoint

CR Function 3

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Acute Myocardial Infarction
Endpoint: Acute Myocardial Infarction, Nonfatal
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Peters et al.
Year: 2001
Location: Boston, MA
Reference: Peters, A., D.W. Dockery, J.E. Muller and M.A. Mittleman. 2001. Increased particulate air pollution and the triggering of myocardial infarction. Circulation. Vol. 103 (23): 2810-5.
Start Age: 18
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/((1-Incidence*A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+Incidence*A)))*Incidence*A*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.033201
Beta Distribution: Normal
P1Beta: 0.0092848634776194
P2Beta: 0
A: 0.93
Name A: % of hospMI surviving 28 days
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 4

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Chronic Lung Disease
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Moolgavkar
Year: 2003
Location: Los Angeles, CA
Qualifier: Los Angeles County
Reference: Moolgavkar, S.H. 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. 2003, Health Effects Institute: Boston, MA. p. 183-198.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.001974
Beta Distribution: Normal
P1Beta: 0.00056
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 5

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Chronic Lung Disease
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Ito
Year: 2003
Location: Detroit, MI
Qualifier: Detroit, MI
Reference: Ito, K. Associations of Particulate Matter Components with Daily Mortality and Morbidity in Detroit, Michigan. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. 2003, Health Effects Institute: Boston, MA. p. 143-156.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP

Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00132
Beta Distribution: Normal
P1Beta: 0.00206404975223149
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 6

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Chronic Lung Disease (less Asthma)
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Moolgavkar
Year: 2000
Location: Los Angeles, CA
Qualifier: Los Angeles County
Reference: Moolgavkar, S.H. Air Pollution and Hospital Admissions for Chronic Obstructive Pulmonary Disease in Three Metropolitan Areas in the United States. Inhalation Toxicology, 2000. 12(Supplement 4): p. 75-90.
Start Age: 18
End Age: 64
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.002352
Beta Distribution: Normal
P1Beta: 0.000782
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 7

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Pneumonia
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Ito
Year: 2003

Location: Detroit, MI
Qualifier: Detroit, MI
Reference: Ito, K. Associations of Particulate Matter Components with Daily Mortality and Morbidity in Detroit, Michigan. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. 2003, Health Effects Institute: Boston, MA. p. 143-156.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.004478
Beta Distribution: Normal
P1Beta: 0.001868
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 8

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Asthma
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Sheppard
Year: 2003
Location: Seattle, WA
Qualifier: Seattle, Washington
Reference: Sheppard, L. Ambient Air Pollution and Nonelderly Asthma Hospital Admissions in Seattle, Washington, 1987-1994. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. 2003, Health Effects Institute: Boston, MA. p. 227-230.
Start Age: 0
End Age: 64
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.003924
Beta Distribution: Normal
P1Beta: 0.001229
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 9

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Hospital Admissions, Cardiovascular
Endpoint: HA, All Cardiovascular (less Myocardial Infarctions)
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Moolgavkar
Year: 2003
Location: Los Angeles, CA
Qualifier: Los Angeles County
Reference: Moolgavkar, S.H. 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. 2003, Health Effects Institute: Boston, MA. p. 183-198.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.001694
Beta Distribution: Normal
P1Beta: 0.000369
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 10

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Hospital Admissions, Cardiovascular
Endpoint: HA, Ischemic Heart Disease (less Myocardial Infarctions)
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Ito
Year: 2003
Location: Detroit, MI
Qualifier: Detroit, MI
Reference: Ito, K. Associations of Particulate Matter Components with Daily Mortality and Morbidity in Detroit, Michigan. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. 2003, Health Effects Institute: Boston, MA. p. 143-156.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence

Beta: 0.001609
Beta Distribution: Normal
P1Beta: 0.001305
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 11

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Hospital Admissions, Cardiovascular
Endpoint: HA, All Cardiovascular (less Myocardial Infarctions)
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Moolgavkar
Year: 2000
Location: Los Angeles, CA
Qualifier: Los Angeles County
Reference: Moolgavkar, S.H. Air pollution and hospital admissions for diseases of the circulatory system in three U.S. metropolitan areas. J Air Waste Manag Assoc, 2000. 50(7): p. 1199-206.
Start Age: 18
End Age: 64
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.0015
Beta Distribution: Normal
P1Beta: 0.000369
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 12

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Emergency Room Visits, Respiratory
Endpoint: Emergency Room Visits, Asthma
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Norris et al.
Year: 1999
Location: Seattle, WA

Other Pollutants: NO2, SO2
Qualifier: Seattle, Washington
Reference: Norris, G., et al. An association between fine particles and asthma emergency department visits for children in Seattle. Environ Health Perspect, 1999. 107(6): p. 489-93.
Start Age: 0
End Age: 17
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.018512
Beta Distribution: Normal
P1Beta: 0.004645
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 13

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Acute Bronchitis
Endpoint: Acute Bronchitis
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Seasonal Metric: QuarterlyMean
Metric Statistic: Mean
Author: Dockery et al.
Year: 1996
Location: 24 communities
Reference: Dockery, D.W., J. Cunningham, A.I. Damokosh, L.M. Neas, J.D. Spengler, P. Koutrakis, J.H. Ware, M. Raizenne and F.E. Speizer. 1996. Health Effects of Acid Aerosols On North American Children - Respiratory Symptoms. Environmental Health Perspectives. Vol.
Start Age: 8
End Age: 12
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/((1-Incidence)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+Incidence)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.030703
Beta Distribution: Normal
P1Beta: 0.019302
P2Beta: 0
A: 0
B: 0
C: 7.5
Name C: Long-term cutpoint

CR Function 14

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Lower Respiratory Symptoms
Endpoint: Lower Respiratory Symptoms
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Schwartz and Neas
Year: 2000
Location: 6 U.S. cities
Reference: Schwartz, J. and L.M. Neas. 2000. Fine particles are more strongly associated than coarse particles with acute respiratory health effects in schoolchildren. Epidemiology. Vol. 11 (1): 6-10.
Start Age: 7
End Age: 14
Baseline Functional Form: A*POP
Functional Form: (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP
Beta: 0.0197
Beta Distribution: Normal
P1Beta: 0.006221
P2Beta: 0
A: 0.0012
Name A: lowerRespSymp7to14; Schwartz et al., 1994, Table 2.
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 15

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Asthma Exacerbation
Endpoint: Asthma Exacerbation, Cough
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Ostro et al.
Year: 2001
Location: Los Angeles, CA
Qualifier: African-American children 8-13. Uses 12-Hour Mean $PM_{2.5}$.
Reference: 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.
Start Age: 6
End Age: 18
Baseline Functional Form: A*POP*B
Functional Form: (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP*B
Beta: 0.001012
Beta Distribution: Normal

P1Beta: 0.000768
P2Beta: 0
A: 0.145
Name A: cough8to13Black; Ostro et al., 2001, p 202, weighted avg.
B: 0.0567
Name B: Asthmatic population ages 6 to 18
C: 10
Name C: Short-term cutpoint

CR Function 16

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Asthma Exacerbation
Endpoint: Asthma Exacerbation, Cough
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Vedal et al.
Year: 1998
Location: Vancouver, CAN
Qualifier: Pollutant listed as $PM_{2.5}$, but study actually used PM10.
Reference: Vedal, S., et al., Acute effects of ambient inhalable particles in asthmatic and nonasthmatic children. American Journal of Respiratory and Critical Care Medicine, 1998. 157(4): p. 1034-1043.
Start Age: 6
End Age: 18
Baseline Functional Form: A*POP*B
Functional Form: (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP*B
Beta: 0.008062
Beta Distribution: Normal
P1Beta: 0.003968
P2Beta: 0
A: 0.086
Name A: cough6to13; Vedal et al., 1998, Table 1.
B: 0.0567
Name B: Asthmatic population ages 6 to 18
C: 10
Name C: Short-term cutpoint

CR Function 17

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Asthma Exacerbation
Endpoint: Asthma Exacerbation, Shortness of Breath
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Ostro et al.
Year: 2001

Location: Los Angeles, CA
Qualifier: African-American children 8-13. Uses 12-Hour Mean $PM_{2.5}$.
Reference: 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.
Start Age: 6
End Age: 18
Baseline Functional Form: A*POP*B
Functional Form: (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP*B
Beta: 0.00264
Beta Distribution: Normal
P1Beta: 0.001377
P2Beta: 0
A: 0.074
Name A: shortBreath8to13Black; Ostro et al., 2001, p 202, weighted avg.
B: 0.0567
Name B: Asthmatic population ages 6 to 18
C: 10
Name C: Short-term cutpoint

CR Function 18

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Asthma Exacerbation
Endpoint: Asthma Exacerbation, Wheeze
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Ostro et al.
Year: 2001
Location: Los Angeles, CA
Qualifier: African-American children 8-13. Uses 12-Hour Mean $PM_{2.5}$.
Reference: 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.
Start Age: 6
End Age: 18
Baseline Functional Form: A*POP*B
Functional Form: (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP*B
Beta: 0.001994
Beta Distribution: Normal
P1Beta: 0.000824
P2Beta: 0
A: 0.173
Name A: wheeze8to13Black; Ostro et al., 2001, p 202, weighted avg.
B: 0.0567
Name B: Asthmatic population ages 6 to 18
C: 10
Name C: Short-term cutpoint

CR Function 19

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Work Loss Days
Endpoint: Work Loss Days
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Ostro
Year: 1987
Location: Nationwide
Reference: Ostro, B.D. Air Pollution and Morbidity Revisited: A Specification Test. Journal of Environmental Economics and Management, 1987. 14: p. 87-98.
Start Age: 18
End Age: 64
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.0046
Beta Distribution: Normal
P1Beta: 0.00036
P2Beta: 0
A: 0
B: 0
C: 10
Name C: Short-term cutpoint

CR Function 20

CRFunction DataSet: EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds
Endpoint Group: Acute Respiratory Symptoms
Endpoint: Minor Restricted Activity Days
Pollutant: $PM_{2.5}$
Metric: D24HourMean
Metric Statistic: None
Author: Ostro and Rothschild
Year: 1989
Location: Nationwide
Other Pollutants: Ozone
Reference: Ostro, B.D. and S. Rothschild. Air Pollution and Acute Respiratory Morbidity - an Observational Study of Multiple Pollutants. Environ Res, 1989. 50(2): p. 238-247.
Start Age: 18
End Age: 64
Baseline Functional Form: A*POP
Functional Form: (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*A*POP
Beta: 0.00741
Beta Distribution: Normal
P1Beta: 0.0007
P2Beta: 0

A: 0.02137
Name A: mRAD18to64; Ostro and Rothschild, 1989, p 243.
B: 0
C: 10
Name C: Short-term cutpoint

Baseline Air Quality Grid: C:\Program Files\Abt Associates Inc\BenMAP 2.2 US Version\Air Quality Grids\LADCO 2012 PM base Relative.aqg

Pollutant: $PM_{2.5}$
Interpolation Type: Voronoi Neighborhood Averaging
Library Monitors: True
Monitor Year: 2002
Scaling Type: Both
Grid Definition

Name: CAMx LADCO 36km PM as shape
ID: 9
Columns: 97
Rows: 90
Grid Type: Shapefile
Shapefile Name: CAMxPM25

Advanced

Neighbor Scaling Type: Inverse Distance

Monitor Filtering

Methods: 116, 117, 118, 119, 120, 123
Objectives: EXTREME DOWNWIND, GENERAL/BACKGROUND, HIGHEST CONCENTRATION, OTHER, POPULATION EXPOSURE, REGIONAL TRANSPORT, SOURCE ORIENTED, UNKNOWN, UPWIND BACKGROUND, WELFARE RELATED IMPACTS, ZZ
Maximum POC: 4
POC Preferences: 1, 2, 3, 4
Minimum Lat, Long: 20, -130
Maximum Lat, Long: 55, -65
Number Required per Quarter: 11
Types Used: Local
Type Preferred: Local
Type Output: Local

Control Air Quality Grid: C:\Program Files\Abt Associates Inc\BenMAP 2.2 US Version\Air Quality Grids\LADCO 2012 PM relative EGU2 w IPM.aqg

Pollutant: $PM_{2.5}$
Interpolation Type: Voronoi Neighborhood Averaging
Library Monitors: True

Monitor Year: 2002
Scaling Type: Both
Grid Definition

Name: CAMx LADCO 36km PM as shape
ID: 9
Columns: 97
Rows: 90
Grid Type: Shapefile
Shapefile Name: CAMxPM25

Advanced

Neighbor Scaling Type: Inverse Distance

Monitor Filtering

Methods: 116, 117, 118, 119, 120, 123
Objectives: EXTREME DOWNWIND, GENERAL/BACKGROUND, HIGHEST CONCENTRATION, OTHER, POPULATION EXPOSURE, REGIONAL TRANSPORT, SOURCE ORIENTED, UNKNOWN, UPWIND BACKGROUND, WELFARE RELATED IMPACTS, ZZ
Maximum POC: 4
POC Preferences: 1, 2, 3, 4
Minimum Lat, Long: 20, -130
Maximum Lat, Long: 55, -65
Number Required per Quarter: 11
Types Used: Local
Type Preferred: Local
Type Output: Local

Advanced

Default Advanced Pooling Method: Round Weights to Two Digits
Default Monte Carlo Iterations: 5000
Random Seed: -1
Incidence Aggregation

Name: County
ID: 0
Columns: 56
Rows: 840
Grid Type: Shapefile
Shapefile Name: County

Valuation Aggregation

Name: County
ID: 0
Columns: 56
Rows: 840
Grid Type: Shapefile
Shapefile Name: County

Incidence Pooling Windows

Incidence Pooling Window: mortality 30+

Mortality, Mortality, All Cause, Pope et al., Pollution data averaged from: 1979-1983; 1999-2000. Long-Term Mo, 51 cities, 30, 99, 2002, , Pope, C.A., 3rd, 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. Jama. Vol. 287 (9): 1132-41., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, QuarterlyMean, Mean, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 1: []

Incidence Pooling Window: Mortality - infants

Mortality, Mortality, All Cause, Woodruff et al., Infant Mortality Function, 86 cities, 0, 0, 1997, , Woodruff, T.J., J. Grillo and K.C. Schoendorf. 1997. The relationship between selected causes of postneonatal infant mortality and particulate air pollution in the United States. Environmental Health Perspectives. Vol. 105 (6): 608-612., , , (1-(1/((1-Incidence)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+Incidence)))*Incidence*POP, $PM_{2.5}$, D24HourMean, QuarterlyMean, Mean, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 1: []

Incidence Pooling Window: chronic bronchitis 26+

Chronic Bronchitis, Chronic Bronchitis, Abbey et al., , SF, SD, South Coast Air Basin, 27, 99, 1995, , Abbey, D.E., B.E. Ostro, F. Petersen and R.J. Burchette. 1995. Chronic Respiratory Symptoms Associated with Estimated Long-Term Ambient Concentrations of Fine Particulates Less Than 2.5 Microns in Aerodynamic Diameter ($PM_{2.5}$) and Other Air Pollutants. J E, , , (1-(1/((1-Incidence)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+Incidence)))*Incidence*POP*(1-Prevalence), $PM_{2.5}$, D24HourMean, QuarterlyMean, Mean, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: AMI-adults

Acute Myocardial Infarction, Acute Myocardial Infarction, Nonfatal, Peters et al., , Boston, MA, 18, 99, 2001, , Peters, A., D.W. Dockery, J.E. Muller and M.A. Mittleman. 2001. Increased particulate air pollution and the triggering of myocardial infarction. Circulation. Vol. 103 (23): 2810-5., , , (1-(1/((1-Incidence*A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+Incidence*A)))*Incidence*A*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Resp Hospital - COPD 65+

Hospital Admissions, Respiratory, HA, Chronic Lung Disease [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Moolgavkar, Los Angeles County, Los Angeles, CA, 65, 99, 2003, , Moolgavkar, S.H. 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. 2003, Health Effects Institute: Boston, MA. p. 183-198., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: [Weight: 0.93, Mean: 53.35, StdDev: 14.92]
Ito, Detroit, MI, Detroit, MI, 65, 99, 2003, , Ito, K. Associations of Particulate Matter Components with Daily Mortality and Morbidity in Detroit, Michigan. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. 2003, Health Effects Institute: Boston, MA. p. 143-156., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: [Weight: 0.07, Mean: 35.60, StdDev: 55.05]

Incidence Pooling Window: Resp Hospital - COPD 20 to 64

Hospital Admissions, Respiratory, HA, Chronic Lung Disease (less Asthma), Moolgavkar, Los Angeles County, Los Angeles, CA, 18, 64, 2000, , Moolgavkar, S.H. Air Pollution and Hospital Admissions for Chronic Obstructive Pulmonary Disease in Three Metropolitan Areas in the United States. Inhalation Toxicology, 2000. 12(Supplement 4): p. 75-90., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Resp Hosp - Pneu 65+

Hospital Admissions, Respiratory, HA, Pneumonia, Ito, Detroit, MI, Detroit, MI, 65, 99, 2003, , Ito, K. Associations of Particulate Matter Components with Daily Mortality and Morbidity in Detroit, Michigan. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. 2003, Health Effects Institute: Boston, MA. p. 143-156., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Resp Hosp - Asthma 0-65

Hospital Admissions, Respiratory, HA, Asthma, Sheppard, Seattle, Washington, Seattle, WA, 0, 64, 2003, , Sheppard, L. Ambient Air Pollution and Nonelderly Asthma Hospital Admissions in Seattle, Washington, 1987-1994. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. 2003, Health Effects Institute: Boston, MA. p. 227-230., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Cardio Hosp - 65+ pooled

Hospital Admissions, Cardiovascular [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

HA, All Cardiovascular (less Myocardial Infarctions), Moolgavkar, Los Angeles County, Los Angeles, CA, 65, 99, 2003, ,c , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: [Weight: 0.51, Mean: 180.83, StdDev: 38.84]
HA, Ischemic Heart Disease (less Myocardial Infarctions), Ito, Detroit, MI, Detroit, MI, 65, 99, 2003, , Ito, K. Associations of Particulate Matter Components with Daily Mortality and Morbidity in Detroit, Michigan. In: Revised Analyses of Time-Series Studies of Air Pollution and Health. 2003, Health Effects Institute: Boston, MA. p. 143-156., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: [Weight: 0.49, Mean: 53.00, StdDev: 42.42]

Incidence Pooling Window: Cardio Hosp - 20 to 64

Hospital Admissions, Cardiovascular, HA, All Cardiovascular (less Myocardial Infarctions), Moolgavkar, Los Angeles County, Los Angeles, CA, 18, 64, 2000, , Moolgavkar, S.H. Air pollution and hospital admissions for diseases of the circulatory system in three U.S. metropolitan areas. J Air Waste Manag Assoc, 2000. 50(7): p. 1199-206., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Asthma ERVs

Emergency Room Visits, Respiratory, Emergency Room Visits, Asthma, Norris et al., Seattle, Washington, Seattle, WA, 0, 17, 1999, NO2, SO2, Norris, G., et al. An association between fine particles and asthma emergency department visits for children in Seattle. Environ Health Perspect, 1999. 107(6): p. 489-93., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Acute Bronchitis

Acute Bronchitis, Acute Bronchitis, Dockery et al., , 24 communities, 8, 12, 1996, , Dockery, D.W., J. Cunningham, A.I. Damokosh, L.M. Neas, J.D. Spengler, P. Koutrakis, J.H. Ware, M. Raizenne and F.E. Speizer. 1996. Health Effects of Acid Aerosols On North American Children - Respiratory Symptoms. Environmental Health Perspectives. Vol. , , , (1-(1/((1-Incidence)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+Incidence)))*Incidence*POP, $PM_{2.5}$, D24HourMean, QuarterlyMean, Mean, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Lower Resp Symptoms

Lower Respiratory Symptoms, Lower Respiratory Symptoms, Schwartz and Neas, , 6 U.S. cities, 7, 14, 2000, , Schwartz, J. and L.M. Neas. 2000. Fine particles are more strongly associated than coarse particles with acute respiratory health effects in schoolchildren. Epidemiology. Vol. 11 (1): 6-10., , , (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Asthma Exacerbations

Asthma Exacerbation [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Asthma Exacerbation, Wheeze, Ostro et al., African-American children 8-13. Uses 12-Hour Mean $PM_{2.5}$., Los Angeles, CA, 6, 18, 2001, , 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., , , (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP*B, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: [Weight: 0.24, Mean: 11,348.49, StdDev: 4,625.69]
Asthma Exacerbation, Shortness of Breath, Ostro et al., African-American children 8-13. Uses 12-Hour Mean $PM_{2.5}$., Los Angeles, CA, 6, 18, 2001, , 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., , , (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP*B, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: [Weight: 0.37, Mean: 7,187.28, StdDev: 3,695.71]
Asthma Exacerbation, Cough

Vedal et al., Pollutant listed as $PM_{2.5}$, but study actually used PM10. , Vancouver, CAN, 6, 18, 1998, , Vedal, S., et al., Acute effects of ambient inhalable particles in asthmatic and nonasthmatic children. American Journal of Respiratory and Critical Care Medicine, 1998. 157(4): p. 1034-1043., , , (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP*B, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: [Weight: 0.03, Mean: 25,048.51, StdDev: 12,114.07]
Ostro et al., African-American children 8-13. Uses 12-Hour Mean $PM_{2.5}$., Los Angeles, CA, 6, 18, 2001, , 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., , , (1-(1/((1-A)*EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))+A)))*A*POP*B, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: [Weight: 0.36, Mean: 4,992.75, StdDev: 3,740.02]

Incidence Pooling Window: Work Loss Days

Work Loss Days, Work Loss Days, Ostro, , Nationwide, 18, 64, 1987, , Ostro, B.D. Air Pollution and Morbidity Revisited: A Specification Test. Journal of Environmental Economics and Management, 1987. 14: p. 87-98., , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*Incidence*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Incidence Pooling Window: Minor Restricted Activity Days

Acute Respiratory Symptoms, Minor Restricted Activity Days, Ostro and Rothschild, , Nationwide, 18, 64, 1989, Ozone, Ostro, B.D. and S. Rothschild. Air Pollution and Acute

Respiratory Morbidity - an Observational Study of Multiple Pollutants. Environ Res, 1989. 50(2): p. 238-247.

, , , (1-(1/EXP(Beta*(MAX(Q1,C)-MAX(Q0,C)))))*A*POP, $PM_{2.5}$, D24HourMean, , None, EPA $PM_{2.5}$ C-R Functions - Adjusted Coefficients With Thresholds, 0: []

Valuation Pooling Windows

Valuation Pooling Window: mortality 30+

Mortality, VSL, based on range from $1 to $10 million, normal distribution,: []

Valuation Pooling Window: Mortality - infants

Mortality, VSL, based on range from $1 to $10 million, normal distribution,: []

Valuation Pooling Window: chronic bronchitis 26+

Chronic Bronchitis, WTP: average severity: []

Valuation Pooling Window: AMI-adults

Acute Myocardial Infarction

COI: 5 yrs med, 5 yrs wages, 3% DR, Wittels (1990): []
COI: 5 yrs med, 5 yrs wages, 3% DR, Russell (1998): []

Valuation Pooling Window: Resp Hospital - COPD 65+

Hospital Admissions, Respiratory, COI: med costs + wage loss: []

Valuation Pooling Window: Resp Hospital - COPD 20 to 64
Valuation Pooling Window: Resp Hosp - Pneu 65+

Hospital Admissions, Respiratory, COI: med costs + wage loss: []

Valuation Pooling Window: Resp Hosp - Asthma 0-65

Hospital Admissions, Respiratory, COI: med costs + wage loss: []

Valuation Pooling Window: Cardio Hosp - 65+ pooled

Hospital Admissions, Cardiovascular, COI: med costs + wage loss: []

Valuation Pooling Window: Cardio Hosp - 20 to 64

Hospital Admissions, Cardiovascular, COI: med costs + wage loss: []

Valuation Pooling Window: Asthma ERVs

Emergency Room Visits, Respiratory

COI: Standford et al. (1999): []
COI: Smith et al. (1997): []

Valuation Pooling Window: Acute Bronchitis

Acute Bronchitis, WTP: 6 day illness, CV studies: []

Valuation Pooling Window: Lower Resp Symptoms

Lower Respiratory Symptoms, WTP: 1 day, CV studies: []

Valuation Pooling Window: Asthma Exacerbations

Asthma Exacerbation, WTP: bad asthma day, Rowe and Chestnut (1986): []

Valuation Pooling Window: Work Loss Days

Work Loss Days, Median daily wage, county-specific: []

Valuation Pooling Window: Minor Restricted Activity Days

Appendix B. BenMAP Audit Report for Ozone Health Analysis

C:\Program Files\Abt Associates Inc\BenMAP 2.2 US Version\Configuration Results\LADCO ozone EGU1 w IPM Relative Incidence & Valuation county.apvr

Configuration Results: C:\Program Files\Abt Associates Inc\BenMAP 2.2 US Version\Configuration Results\2012 ozone EGU1 w IPM Relative 02 mons.cfgr

Latin Hypercube Points: 50
Year: 2012
Threshold: 0
Grid Definition

Name: LADCO Ozone CAMx
ID: 12
Columns: 131
Rows: 131
Grid Type: Shapefile
Shapefile Name: CAMxOzone

Selected Studies

CR Function 0

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, All Respiratory
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Schwartz
Year: 1995
Location: New Haven, CT
Other Pollutants: PM10
Qualifier: New Haven, CT
Reference: Schwartz, J. Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. Thorax, 1995. 50(5): p. 531-538.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00265221944452865
Beta Distribution: Normal
P1Beta: 0.00139761964737073
P2Beta: 0

A: 0
B: 0
C: 0

CR Function 1

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, All Respiratory
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Burnett et al.
Year: 2001
Location: Toronto, CAN
Other Pollutants: $PM_{2.5}$
Qualifier: May-August
Reference: Burnett, R.T., et al. Association between ozone and hospitalization for acute respiratory diseases in children less than 2 years of age. Am J Epidemiol, 2001. 153(5): p. 444-52.
Start Age: 0
End Age: 1
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00630926863348811
Beta Distribution: Normal
P1Beta: 0.00183409
P2Beta: 0
A: 0
B: 0
C: 0

CR Function 2

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, All Respiratory
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Schwartz
Year: 1995
Location: Tacoma, WA
Other Pollutants: PM10
Qualifier: Tacoma, WA
Reference: Schwartz, J. Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. Thorax, 1995. 50(5): p. 531-538.
Start Age: 65

End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00714700616984401
Beta Distribution: Normal
P1Beta: 0.002565418728
P2Beta: 0
A: 0
B: 0
C: 0

CR Function 3

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Pneumonia
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Moolgavkar et al.
Year: 1997
Location: Minneapolis, MN
Other Pollutants: PM10, SO2, NO2
Qualifier: Minneapolis-St. Paul, MN
Reference: Moolgavkar, S.H., E.G. Luebeck, and E.L. Anderson. Air pollution and hospital admissions for respiratory causes in Minneapolis St. Paul and Birmingham. Epidemiology, 1997. 8(4): p. 364-370.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00369564712587337
Beta Distribution: Normal
P1Beta: 0.00103005495510973
P2Beta: 0
A: 0
B: 0
C: 0

CR Function 4

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Pneumonia
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None

Author: Schwartz
Year: 1994
Location: Detroit, MI
Other Pollutants: PM10
Qualifier: Detroit, MI
Reference: Schwartz, J. Air Pollution and Hospital Admissions For the Elderly in Detroit, Michigan. American Journal of Respiratory and Critical Care Medicine, 1994 150(3): p. 648-655.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00521
Beta Distribution: Normal
P1Beta: 0.0013
P2Beta: 0
A: 0
B: 0
C: 0

CR Function 5

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Pneumonia
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Schwartz
Year: 1994
Location: Minneapolis, MN
Other Pollutants: PM10
Qualifier: Minneapolis-St. Paul, MN
Reference: Schwartz, J. PM(10) Ozone, and Hospital Admissions For the Elderly in Minneapolis St Paul, Minnesota. Archives of Environmental Health, 1994. 49(5): p. 366-374.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.0039770171749033
Beta Distribution: Normal
P1Beta: 0.00186459068109421
P2Beta: 0
A: 0
B: 0
C: 0

CR Function 6

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Chronic Lung Disease
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Moolgavkar et al.
Year: 1997
Location: Minneapolis, MN
Other Pollutants: PM10, CO
Qualifier: Minneapolis-St. Paul, MN
Reference: Moolgavkar, S.H., E.G. Luebeck, and E.L. Anderson. Air pollution and hospital admissions for respiratory causes in Minneapolis St. Paul and Birmingham. Epidemiology, 1997. 8(4): p. 364-370.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00274279622207835
Beta Distribution: Normal
P1Beta: 0.0016988272083893
P2Beta: 0
A: 0
B: 0
C: 0

CR Function 7

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Hospital Admissions, Respiratory
Endpoint: HA, Chronic Lung Disease (less Asthma)
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Schwartz
Year: 1994
Location: Detroit, MI
Other Pollutants: PM10
Qualifier: Detroit, MI
Reference: Schwartz, J. Air Pollution and Hospital Admissions For the Elderly in Detroit, Michigan. American Journal of Respiratory and Critical Care Medicine, 1994 150(3): p. 648-655.
Start Age: 65
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP

Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00549
Beta Distribution: Normal
P1Beta: 0.00205
P2Beta: 0
A: 0
B: 0
C: 0

CR Function 8

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Emergency Room Visits, Respiratory
Endpoint: Emergency Room Visits, Asthma
Pollutant: Ozone
Metric: D5HourMean
Metric Statistic: None
Author: Cody et al.
Year: 1992
Location: New Jersey (Northern)
Other Pollutants: SO2
Qualifier: New Jersey (Northern), May-August
Reference: Cody, R.P., et al. The effect of ozone associated with summertime photochemical smog on the frequency of asthma visits to hospital emergency departments. Environ Res, 1992. 58(2): p. 184-94.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (Beta/A)*DELTAQ*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.0203
Beta Distribution: Normal
P1Beta: 0.00717
P2Beta: 0
A: 4436976
Name A: CentNJ Baseline POP
B: 0
C: 0

CR Function 9

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Emergency Room Visits, Respiratory
Endpoint: Emergency Room Visits, Asthma
Pollutant: Ozone
Metric: D5HourMean
Metric Statistic: None
Author: Weisel et al.
Year: 1995

Location: New Jersey (Northern and Central)
Qualifier: New Jersey (Northern and Central), May-August
Reference: Weisel, C.P., R.P. Cody, and P.J. Lioy. Relationship between summertime ambient ozone levels and emergency department visits for asthma in central New Jersey. Environ Health Perspect, 1995. 103 Suppl 2: p. 97-102.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: (Beta/A)*DELTAQ*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.0443
Beta Distribution: Normal
P1Beta: 0.00723
P2Beta: 0
A: 4436976
Name A: CentNJ Baseline POP
B: 0
C: 0

CR Function 10

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Emergency Room Visits, Respiratory
Endpoint: Emergency Room Visits, Asthma
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Stieb et al.
Year: 1996
Location: New Brunswick, CAN
Qualifier: May-September
Reference: Stieb, D.M., et al. Association between ozone and asthma emergency department visits in Saint John, New Brunswick, Canada. Environmental Health Perspectives, 1996. 104(12): p. 1354-1360.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: ((Beta)*(sqr(Q1)-sqr(Q0))*POP)/A
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 4E-5
Beta Distribution: Normal
P1Beta: 2E-5
P2Beta: 0
A: 125000
Name A: St. John Base Pop
B: 0
C: 0

CR Function 11

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Emergency Room Visits, Respiratory
Endpoint: Emergency Room Visits, Asthma
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Stieb et al.
Year: 1996
Location: New Brunswick, CAN
Qualifier: May-September
Reference: Stieb, D.M., et al. Association between ozone and asthma emergency department visits in Saint John, New Brunswick, Canada. Environmental Health Perspectives, 1996. 104(12): p. 1354-1360.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP
Functional Form: ((Beta)*(sqr(Q1)-sqr(Q0))*POP)/A
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.0001
Beta Distribution: Normal
P1Beta: 4E-5
P2Beta: 0
A: 125000
Name A: St. John Base Pop
B: 0
C: 0

CR Function 12

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Emergency Room Visits, Respiratory
Endpoint: Emergency Room Visits, Asthma
Pollutant: Ozone
Metric: D8HourMax
Metric Statistic: None
Author: Jaffe et al.
Year: 2003
Location: Ohio cities
Reference: Jaffe, D.H., M.E. Singer, and A.A. Rimm. Air pollution and emergency department visits for asthma among Ohio Medicaid recipients, 1991-1996. Environ Res, 2003. 91(1): p. 21-8.
Start Age: 5
End Age: 34
Baseline Functional Form: Incidence*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00295588022415444

Beta Distribution: Normal
P1Beta: 0.00148645173785653
P2Beta: 0
A: 0
B: 0
C: 0

CR Function 13

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, Non-Accidental
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Samet et al.
Year: 1997
Location: Philadelphia, PA
Other Pollutants: CO,NO2,SO2,TSP
Reference: Samet, J.M., et al. Air Pollution, Weather, and Mortality in Philadelphia 1973-1988. 1997, Health Effects Institute: Cambridge, MA.
Start Age: 18
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000935748
Beta Distribution: Normal
P1Beta: 0.000311916
P2Beta: 0
A: 0.002739726
Name A: Scale annual mortality rate to daily rate
B: 0
C: 0

CR Function 14

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, Non-Accidental
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Moolgavkar et al.
Year: 1995
Location: Philadelphia, PA
Other Pollutants: SO2,TSP
Reference: Moolgavkar, S.H., et al. Air Pollution and Daily Mortality in Philadelphia. Epidemiology, 1995. 6(5): p. 476-484.

Start Age: 18
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000610951
Beta Distribution: Normal
P1Beta: 0.000216114
P2Beta: 0
A: 0.002739726
Name A: Scale annual mortality rate to daily rate
B: 0
C: 0

CR Function 15

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, Non-Accidental
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Ito and Thurston
Year: 1996
Location: Chicago, IL
Other Pollutants: PM10
Reference: Ito, K. and G.D. Thurston. 1996. Daily PM10/mortality associations: an investigations of at-risk subpopulations. Journal of Exposure Analysis and Environmental Epidemiology. Vol. 6 (1): 79-95.
Start Age: 18
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000634
Beta Distribution: Normal
P1Beta: 0.000251
P2Beta: 0
A: 0.002739726
Name A: Scale annual mortality rate to daily rate
B: 0
C: 0

CR Function 16

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: Ozone

Metric: D24HourMean
Metric Statistic: None
Author: Bell et al.
Year: 2005
Location: U.S.
Qualifier: U.S. Only Meta-Analysis
Reference: Bell, M.L., F. Dominici, and J.M. Samet. A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study. Epidemiology, 2005. 16(4): p. 436-45.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000836491633162767
Beta Distribution: Normal
P1Beta: 0.000427044078124895
P2Beta: 0
A: 0.0027397
Name A: Scalar to convert annual mortality rate to daily rate
B: 0
C: 0

CR Function 17

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Bell et al.
Year: 2005
Location: U.S.
Other Pollutants: PM
Qualifier: U.S. Only Meta-Analysis
Reference: Bell, M.L., F. Dominici, and J.M. Samet. A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study. Epidemiology, 2005. 16(4): p. 436-45.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000737275432941316
Beta Distribution: Normal
P1Beta: 0.000346910697138913
P2Beta: 0
A: 0.0027397

Name A: Scalar to convert annual mortality rate to daily rate
B: 0
C: 0

CR Function 18

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Bell et al.
Year: 2004
Location: 95 U.S. cities
Reference: Bell, M.L., et al. Ozone and short-term mortality in 95 US urban communities, 1987-2000. Jama, 2004. 292(19): p. 2372-8.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000518652668730015
Beta Distribution: Normal
P1Beta: 0.000126891447869316
P2Beta: 0
A: 0.0027397
Name A: Scalar to convert annual mortality rate to daily rate
B: 0
C: 0

CR Function 19

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Ito et al.
Year: 2005
Reference: Ito, K., S.F. De Leon, and M. Lippmann. Associations between ozone and daily mortality: analysis and meta-analysis. Epidemiology, 2005. 16(4): p. 446-57.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000399202126953746

Beta Distribution: Normal
P1Beta: 6.60623184054822E-5
P2Beta: 0
A: 0.0027397
Name A: Scalar to convert annual mortality rate to daily rate
B: 0
C: 0

CR Function 20

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Ito et al.
Year: 2005
Other Pollutants: PM
Reference: Ito, K., S.F. De Leon, and M. Lippmann. Associations between ozone and daily mortality: analysis and meta-analysis. Epidemiology, 2005. 16(4): p. 446-57.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000369317183761761
Beta Distribution: Normal
P1Beta: 8.64150411649191E-5
P2Beta: 0
A: 0.0027397
Name A: Scalar to convert annual mortality rate to daily rate
B: 0
C: 0

CR Function 21

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Levy et al.
Year: 2005
Reference: Levy, J.I., S.M. Chemerynski, and J.A. Sarnat. Ozone exposure and mortality: an empiric bayes metaregression analysis. Epidemiology, 2005. 16(4): p. 458-68.
Start Age: 0
End Age: 99

Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000409161790325356
Beta Distribution: Normal
P1Beta: 5.08120954401706E-5
P2Beta: 0
A: 0.0027397
Name A: Scalar to convert annual mortality rate to daily rate
B: 0
C: 0

CR Function 22

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Mortality
Endpoint: Mortality, All Cause
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Levy et al.
Year: 2005
Qualifier: Summer season only
Reference: Levy, J.I., S.M. Chemerynski, and J.A. Sarnat. Ozone exposure and mortality: an empiric bayes metaregression analysis. Epidemiology, 2005. 16(4): p. 458-68.
Start Age: 0
End Age: 99
Baseline Functional Form: Incidence*POP*A
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A
Incidence DataSet: 2010 Mortality Incidence
Beta: 0.000836491633162767
Beta Distribution: Normal
P1Beta: 0.000131561395652476
P2Beta: 0
A: 0.0027397
Name A: Scalar to convert annual mortality rate to daily rate
B: 0
C: 0

CR Function 23

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: School Loss Days
Endpoint: School Loss Days, All Cause
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Chen et al.
Year: 2000

Location: Washoe Co, NV
Other Pollutants: PM10, CO
Qualifier: Study actually looked at children 6-11.
Reference: Chen, L., B.L. Jennison, W. Yang and S.T. Omaye. 2000a. Elementary school absenteeism and air pollution. Inhal Toxicol. Vol. 12 (11): 997-1016.
Start Age: 5
End Age: 17
Baseline Functional Form: Incidence/B*POP*A
Functional Form: Beta*C*DELTAQ*Incidence/B*POP*A
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.0132466
Beta Distribution: Normal
P1Beta: 0.0049851
P2Beta: 0
A: 0.3929
Name A: Scalar for % of school days in ozone season
B: 0.0509
Name B: Study-specific school absence rate
C: 0.01
Name C: Convert beta to proportion

CR Function 24

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: School Loss Days
Endpoint: School Loss Days, All Cause
Pollutant: Ozone
Metric: D8HourMean
Metric Statistic: None
Author: Gilliland et al.
Year: 2001
Location: Southern California
Qualifier: Study actually looked at children 9-10.
Reference: Gilliland, F.D., K. Berhane, E.B. Rappaport, D.C. Thomas, E. Avol, W.J. Gauderman, S.J. London, H.G. Margolis, R. McConnell, K.T. Islam and J.M. Peters. 2001. The effects of ambient air pollution on school absenteeism due to respiratory illnesses. Epidemi
Start Age: 5
End Age: 17
Baseline Functional Form: Incidence*POP*A*B
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A*B
Incidence DataSet: 2000 Incidence and Prevalence
Beta: 0.00755014367682637
Beta Distribution: Normal
P1Beta: 0.00452714335601797
P2Beta: 0
A: 0.3929
Name A: Scalar for % school days in ozone season
B: 0.945

Name B: Population of school children at-risk for a new absence
C: 0

CR Function 25

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Acute Respiratory Symptoms
Endpoint: Minor Restricted Activity Days
Pollutant: Ozone
Metric: D1HourMax
Metric Statistic: None
Author: Ostro and Rothschild
Year: 1989
Location: Nationwide
Other Pollutants: $PM_{2.5}$
Reference: Ostro, B.D. and S. Rothschild. Air Pollution and Acute Respiratory Morbidity - an Observational Study of Multiple Pollutants. Environ Res, 1989. 50(2): p. 238-247.

Start Age: 18
End Age: 64
Baseline Functional Form: A*POP
Functional Form: (1-(1/EXP(Beta*DELTAQ)))*A*POP
Beta: 0.0022
Beta Distribution: Normal
P1Beta: 0.000658
P2Beta: 0
A: 0.02137
Name A: mRAD18to64; Ostro and Rothschild, 1989, p 243.
B: 0
C: 0

CR Function 26

CRFunction DataSet: EPA Standard C-R Functions
Endpoint Group: Worker Productivity
Endpoint: Worker Productivity
Pollutant: Ozone
Metric: D24HourMean
Metric Statistic: None
Author: Crocker and Horst
Year: 1981
Location: Nationwide
Reference: Crocker, T.D. and R.L. Horst, Jr. Hours of Work, Labor Productivity, and Environmental Conditions: A Case Study. The Review of Economics and Statistics, 1981. 63: p. 361-368.
Start Age: 18
End Age: 64

Baseline Functional Form:
DAILYWAGEOUTDOOR*(MEDIAN_INCOME/NATL_MEDIAN_INCOME)*POP*(COUNT_FARM_EMPLOYED/POPULATION18TO64)
Functional Form: if (Q1 <> 0) then Result := Beta*((Q1-Q0)/Q1)*DAILYWAGEOUTDOOR*(MEDIAN_INCOME/NATL_MEDIAN_INCOME)*POP*(COUNT_FARM_EMPLOYED/POPULATION18TO64)
Variable DataSet: EPA Standard Variables
Beta: 0.1427
Beta Distribution: None
P1Beta: 0
P2Beta: 0
A: 0
B: 0
C: 0

Baseline Air Quality Grid: C:\Program Files\Abt Associates Inc\BenMAP 2.2 US Version\Air Quality Grids\LADCO 2012 ozone base relative.aqg

Pollutant: Ozone
Interpolation Type: Voronoi Neighborhood Averaging
Library Monitors: True
Monitor Year: 2002
Scaling Type: Both
Grid Definition

Name: LADCO Ozone CAMx
ID: 12
Columns: 131
Rows: 131
Grid Type: Shapefile
Shapefile Name: CAMxOzone

Advanced

Neighbor Scaling Type: Inverse Distance

Monitor Filtering

Methods: 3, 11, 14, 19, 47, 53, 55, 56, 78, 87, 91, 103, 112, 134
Objectives: EXTREME DOWNWIND, GENERAL/BACKGROUND, HIGHEST CONCENTRATION, MAX OZONE CONCENTRATION, MAX PRECURSOR EMISSIONS IMPACT, OTHER, POPULATION EXPOSURE, REGIONAL TRANSPORT, SOURCE ORIENTED, UNKNOWN, UPWIND BACKGROUND
Maximum POC: 4
POC Preferences: 1, 2, 3, 4
Minimum Lat, Long: 20, -130
Maximum Lat, Long: 55, -65
Start Hour: 8
End Hour: 19

Observations Required Per Day: 9
Start Day: 0
End Day: 364
Valid Days Required Per Year: 76

Control Air Quality Grid: C:\Program Files\Abt Associates Inc\BenMAP 2.2 US Version\Air Quality Grids\LADCO 2012 ozone EGU1 w IPM relative with 2002 mon.aqg

Pollutant: Ozone
Interpolation Type: Voronoi Neighborhood Averaging
Library Monitors: True
Monitor Year: 2002
Scaling Type: Both
Grid Definition

Name: LADCO Ozone CAMx
ID: 12
Columns: 131
Rows: 131
Grid Type: Shapefile
Shapefile Name: CAMxOzone

Advanced

Neighbor Scaling Type: Inverse Distance

Monitor Filtering

Methods: 3, 11, 14, 19, 47, 53, 55, 56, 78, 87, 91, 103, 112, 134
Objectives: EXTREME DOWNWIND, GENERAL/BACKGROUND, HIGHEST CONCENTRATION, MAX OZONE CONCENTRATION, MAX PRECURSOR EMISSIONS IMPACT, OTHER, POPULATION EXPOSURE, REGIONAL TRANSPORT, SOURCE ORIENTED, UNKNOWN, UPWIND BACKGROUND
Maximum POC: 4
POC Preferences: 1, 2, 3, 4
Minimum Lat, Long: 20, -130
Maximum Lat, Long: 55, -65
Start Hour: 8
End Hour: 19
Observations Required Per Day: 9
Start Day: 0
End Day: 364
Valid Days Required Per Year: 76

Advanced

Default Advanced Pooling Method: Round Weights to Two Digits
Default Monte Carlo Iterations: 1000
Random Seed: -1

Incidence Aggregation

Name: County
ID: 0
Columns: 56
Rows: 840
Grid Type: Shapefile
Shapefile Name: County

Valuation Aggregation

Name: County
ID: 0
Columns: 56
Rows: 840
Grid Type: Shapefile
Shapefile Name: County

Incidence Pooling Windows

Incidence Pooling Window: HA, all Resp

Hospital Admissions, Respiratory, HA, All Respiratory

Burnett et al., May-August, Toronto, CAN, 0, 1, 2001, $PM_{2.5}$, Burnett, R.T., et al. Association between ozone and hospitalization for acute respiratory diseases in children less than 2 years of age. Am J Epidemiol, 2001. 153(5): p. 444-52., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP, Ozone, D1HourMax, , None, EPA Standard C-R Functions, 0: []
Schwartz [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Tacoma, WA, Tacoma, WA, 65, 99, 1995, PM10, Schwartz, J. Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. Thorax, 1995. 50(5): p. 531-538., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP, Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.23, Mean: -914.99, StdDev: 324.92]
New Haven, CT, New Haven, CT, 65, 99, 1995, PM10, Schwartz, J. Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. Thorax, 1995. 50(5): p. 531-538., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP, Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.77, Mean: -339.06, StdDev: 176.52]

Incidence Pooling Window: HA, Pneumonia

Hospital Admissions, Respiratory, HA, Pneumonia [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Moolgavkar et al., Minneapolis-St. Paul, MN, Minneapolis, MN, 65, 99, 1997, PM10, SO2, NO2, Moolgavkar, S.H., E.G. Luebeck, and E.L. Anderson. Air pollution and hospital admissions for respiratory causes in Minneapolis St. Paul and Birmingham. Epidemiology, 1997. 8(4): p. 364-370., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP, Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.71, Mean: -223.20, StdDev: 61.49]
Schwartz [Weight: 0.29, Mean: -290.34, StdDev: 96.40] [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Minneapolis-St. Paul, MN, Minneapolis, MN, 65, 99, 1994, PM10, Schwartz, J. PM(10) Ozone, and Hospital Admissions For the Elderly in Minneapolis St Paul, Minnesota. Archives of Environmental Health, 1994. 49(5): p. 366-374., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP, Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.33, Mean: -240.26, StdDev: 111.33]
Detroit, MI, Detroit, MI, 65, 99, 1994, PM10, Schwartz, J. Air Pollution and Hospital Admissions For the Elderly in Detroit, Michigan. American Journal of Respiratory and Critical Care Medicine, 1994 150(3): p. 648-655., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP, Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.67, Mean: -314.81, StdDev: 77.68]

Incidence Pooling Window: ER, asthma

Emergency Room Visits, Respiratory, Emergency Room Visits, Asthma [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Jaffe et al. , , Ohio cities, 5, 34, 2003, , Jaffe, D.H., M.E. Singer, and A.A. Rimm. Air pollution and emergency department visits for asthma among Ohio Medicaid recipients, 1991-1996. Environ Res, 2003. 91(1): p. 21-8.

, , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP, Ozone, D8HourMax, , None, EPA Standard C-R Functions, 0: [Weight: 0.03, Mean: -154.51, StdDev: 76.76]
Weisel et al. , New Jersey (Northern and Central), May-August, New Jersey (Northern and Central), 0, 99, 1995, , Weisel, C.P., R.P. Cody, and P.J. Lioy. Relationship between summertime ambient ozone levels and emergency department visits for asthma in central New Jersey. Environ Health Perspect, 1995. 103 Suppl 2: p. 97-102., , , (Beta/A)*DELTAQ*POP, Ozone, D5HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.48, Mean: -41.94, StdDev: 6.76]
Cody et al. , New Jersey (Northern), May-August, New Jersey (Northern), 0, 99, 1992, SO2, Cody, R.P., et al. The effect of ozone associated with summertime photochemical smog on the frequency of asthma visits to hospital emergency departments. Environ Res, 1992. 58(2): p. 184-94., , , (Beta/A)*DELTAQ*POP, Ozone, D5HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.48, Mean: -19.22, StdDev: 6.70]
Stieb et al., May-September, New Brunswick, CAN, 0, 99, 1996, , Stieb, D.M., et al. Association between ozone and asthma emergency department visits in Saint John, New Brunswick, Canada. Environmental Health Perspectives, 1996. 104(12): p. 1354-1360., , , ((Beta)*(sqr(Q1)-sqr(Q0))*POP)/A, Ozone [Weight: 0.02, Mean: -119.84, StdDev: 89.00] [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.14, Mean: -286.33, StdDev: 113.08]
D1HourMax, , None, EPA Standard C-R Functions, 0: [Weight: 0.86, Mean: -93.48, StdDev: 46.15]

Incidence Pooling Window: Mortality

Mortality, Mortality, All Cause [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Levy et al.

Summer season only, , 0, 99, 2005, , Levy, J.I., S.M. Chemerynski, and J.A. Sarnat. Ozone exposure and mortality: an empiric bayes metaregression analysis. Epidemiology, 2005. 16(4): p. 458-68., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A, Ozone, D1HourMax, , None, EPA Standard C-R Functions, 0: [Weight: 0.17, Mean: -65.01, StdDev: 10.10]
0, 99, 2005, , Levy, J.I., S.M. Chemerynski, and J.A. Sarnat. Ozone exposure and mortality: an empiric bayes metaregression analysis. Epidemiology, 2005. 16(4): p. 458-68., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A, Ozone, D1HourMax, , None, EPA Standard C-R Functions, 0: [Weight: 0.26, Mean: -31.80, StdDev: 3.90]

Ito et al., , , 0, 99, 2005

PM, Ito, K., S.F. De Leon, and M. Lippmann. Associations between ozone and daily mortality: analysis and meta-analysis. Epidemiology, 2005. 16(4): p. 446-57., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A, Ozone, D1HourMax, , None, EPA Standard C-R Functions, 0: [Weight: 0.22, Mean: -28.70, StdDev: 6.63]
Ito, K., S.F. De Leon, and M. Lippmann. Associations between ozone and daily mortality: analysis and meta-analysis. Epidemiology, 2005. 16(4): p. 446-57., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A, Ozone, D1HourMax, , None, EPA Standard C-R Functions, 0: [Weight: 0.24, Mean: -31.02, StdDev: 5.07]

Bell et al.

95 U.S. cities, 0, 99, 2004, , Bell, M.L., et al. Ozone and short-term mortality in 95 US urban communities, 1987-2000. Jama, 2004. 292(19): p. 2372-8., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A, Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.09, Mean: -76.50, StdDev: 18.48]
U.S. Only Meta-Analysis, U.S., 0, 99, 2005

PM, Bell, M.L., F. Dominici, and J.M. Samet. A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study. Epidemiology, 2005. 16(4): p. 436-45., , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A, Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.02, Mean: -108.75, StdDev: 50.54]
Bell, M.L., F. Dominici, and J.M. Samet. A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study. Epidemiology, 2005. 16(4): p. 436-45., , , (1-

(1/EXP(Beta*DELTAQ)))*Incidence*POP*A, Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.01, Mean: -123.40, StdDev: 62.21]

Incidence Pooling Window: School Loss Days

School Loss Days, School Loss Days, All Cause [Pooling Method: Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Gilliland et al., Study actually looked at children 9-10., Southern California, 5, 17, 2001, , Gilliland, F.D., K. Berhane, E.B. Rappaport, D.C. Thomas, E. Avol, W.J. Gauderman, S.J. London, H.G. Margolis, R. McConnell, K.T. Islam and J.M. Peters. 2001. The effects of ambient air pollution on school absenteeism due to respiratory illnesses. Epidemi, , , (1-(1/EXP(Beta*DELTAQ)))*Incidence*POP*A*B, Ozone, D8HourMean, , None, EPA Standard C-R Functions, 0: [Weight: 0.02, Mean: -113,852.04, StdDev: 67,496.92]
Chen et al., Study actually looked at children 6-11., Washoe Co, NV, 5, 17, 2000, PM10, CO, Chen, L., B.L. Jennison, W. Yang and S.T. Omaye. 2000a. Elementary school absenteeism and air pollution. Inhal Toxicol. Vol. 12 (11): 997-1016., , , Beta*C*DELTAQ*Incidence/B*POP*A, Ozone, D1HourMax, , None, EPA Standard C-R Functions, 0: [Weight: 0.98, Mean: -28,650.71, StdDev: 10,646.02]

Incidence Pooling Window: Acute Resp Symptom Days

Acute Respiratory Symptoms, Minor Restricted Activity Days, Ostro and Rothschild, , Nationwide, 18, 64, 1989, $PM_{2.5}$, Ostro, B.D. and S. Rothschild. Air Pollution and Acute Respiratory Morbidity - an Observational Study of Multiple Pollutants. Environ Res, 1989. 50(2): p. 238-247.

, , , (1-(1/EXP(Beta*DELTAQ)))*A*POP, Ozone, D1HourMax, , None, EPA Standard C-R Functions, 0: []

Incidence Pooling Window: Worker Productivity

Worker Productivity, Worker Productivity, Crocker and Horst, , Nationwide, 18, 64, 1981, , Crocker, T.D. and R.L. Horst, Jr. Hours of Work, Labor Productivity, and Environmental Conditions: A Case Study. The Review of Economics and Statistics, 1981. 63: p. 361-368., , , if (Q1 <> 0) then Result :: Beta*((Q1-Q0)/Q1)*DAILYWAGEOUTDOOR*(MEDIAN_INCOME/NATL_MEDIAN_INCOME)*POP*(COUNT_FARM_EMPLOYED/POPULATION18TO64), Ozone, D24HourMean, , None, EPA Standard C-R Functions, 0=[]

Valuation Pooling Windows

Valuation Pooling Window: HA, all Resp

Hospital Admissions, Respiratory, HA, All Respiratory [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

Burnett et al., COI: med costs + wage loss: [Weight: 0.99, Mean: -1,307,777.00, StdDev: 459,633.69]

Schwartz, COI: med costs + wage loss: [Weight: 0.01, Mean: -8,674,829.00, StdDev: 5,988,157.50]

Valuation Pooling Window: HA, Pneumonia

Hospital Admissions, Respiratory, COI: med costs + wage loss: []

Valuation Pooling Window: ER, asthma

Emergency Room Visits, Respiratory [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

COI: Standford et al. (1999): [Weight: 0.59, Mean: -9,302.96, StdDev: 8,243.59]
COI: Smith et al. (1997): [Weight: 0.41, Mean: -11,102.94, StdDev: 9,957.27]

Valuation Pooling Window: Mortality

Mortality, VSL, based on 26 value-of-life studies.: []

Valuation Pooling Window: School Loss Days

School Loss Days, : [ ]

Valuation Pooling Window: Acute Resp Symptom Days

Acute Respiratory Symptoms [Pooling Method: Random / Fixed Effects] [Advanced Pooling Method: Round Weights to Two Digits]

WTP: 3 symptoms 1 day, Dickie and Ulery (2002).: [Weight: 0.30, Mean: -8,733,846.00, StdDev: 3,216,866.50]
WTP: 1 day, CV studies: [Weight: 0.70, Mean: -4,506,796.00, StdDev: 2,112,471.00]

Valuation Pooling Window: Worker Productivity

Worker Productivity, : [ ]