Regulatory Impact Analysis (RIA)
for the final Transport Rule
Docket ID No. EPA-HQ-OAR-2009-0491

Regulatory Impact Analysis for the Federal Implementation Plans to Reduce Interstate Transport of Fine Particulate Matter and Ozone in 27 States; Correction of SIP Approvals for 22 States

U.S. EPA
Office of Air and Radiation

June 2011

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CHAPTER 1

EXECUTIVE SUMMARY

This Regulatory Impact Analysis (RIA) presents the health and welfare benefits, costs, and other impacts of the Transport Rule focusing primarily on 2014.

1.1 Key Findings

The final Transport Rule will lower sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions from the electric power industry in 28 eastern states starting in 2012[1]. In 2014, this final rule will have annual benefits (in 2007$) between $120 to $280 billion using a 3% discount rate and $110 and $250 billion using a 7% discount rate. At these respective discount rates, the annual social costs are $0.8 billion and the annual quantified net benefits are $120 to $280 billion or $110 to $270 billion. The benefits outweigh social costs from 150 up to 350 to 1, or from 110 up to 335 to 1. The benefits result primarily from 13,000 to 34,000 fewer $PM_{2.5}$ and ozone-related premature mortalities. There are some costs and important benefits that EPA could not monetize. Upon considering these limitations and uncertainties, it remains clear that the benefits of the Transport Rule are substantial and far outweigh the costs. The annualized private compliance costs to the power industry in 2014 are $0.8 billion. Employment impacts associated with the final rule are estimated to be small. The benefits of the Transport Rule in 2012 are greater than in 2014 due, in part, to the final rule expediting emissions reductions that otherwise would have occurred in 2014.

The benefits and costs in 2014 of the selected remedy (air quality-assured trading) in the final rule are in Table 1-1. This selected remedy covers the electric power industry and allows interstate emissions trading of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) in the covered states as listed in section 2.2 of this RIA.

1 As finalized, the rule requires emission reductions in 27 states. EPA issued a supplemental proposal to request comment on requiring ozone-season NOx reductions in additional states; including the states addressed in the supplemental proposal, the total number of states covered by the Transport Rule would be 28.

Table 1-1. Summary of EPA's Estimates of Benefits, Costs, and Net Benefits of the Selected Remedy in the Transport Rule in 2014[a] (billions of 2007$)

Description	Estimate (3% Discount Rate)	Estimate (7% Discount Rate)
Social costs[b]	$0.81	$0.81
Social benefits[c,d]	$120 to $280 + B	$110 to $250 + B
Health-related benefits:	$110 to $270 + B	$100 to $250 + B
Visibility benefits[e]	$4.1	$4.1
Net benefits (benefits-costs)	$120 to $280	$110 to $250

[a] All estimates are rounded to two significant digits and represent annualized benefits and costs anticipated for the year 2014. For notational purposes, unquantified benefits are indicated with a "B" to represent the sum of additional monetary benefits and disbenefits. Data limitations prevented us from quantifying these endpoints, and as such, these benefits are inherently more uncertain than those benefits that we were able to quantify. A listing of health and welfare effects is provided in Table 1-5. Estimates here are subject to uncertainties discussed further in the body of the document.

[b] Social costs are estimated using the MultiMarket model, the model employed by EPA in this RIA to estimate economic impacts of the industries outside the electric power sector. This model does not estimate indirect impacts associated with a regulation such as this one. Details on the social cost estimates can be found in Chapter 8 and Appendix B of this RIA.

[c] The reduction in premature mortalities account for over 90% of total monetized benefits. Benefit estimates are national except for visibility that covers Class I areas. Valuation assumes discounting over the SAB-recommended 20-year segmented lag structure described in Chapter 5. Results reflect 3 percent and 7 percent discount rates consistent with EPA and OMB guidelines for preparing economic analyses (U.S. EPA, 2010; OMB, 2003). The estimate of social benefits also includes CO_2 related benefits calculated using the social cost of carbon, discussed further in Chapter 5.

[d] Potential benefit categories that have not been quantified and monetized are listed in Table 1-5.

[e] Over 99% of visibility-related benefits occur within Class-1 areas located in the Eastern U.S.

1.1.1 Health Benefits

The final Transport Rule is expected to yield significant health benefits by reducing emissions of two key contributors to fine particle and ozone formation. Sulfur dioxide contributes to the formation of fine particle pollution ($PM_{2.5}$), and nitrogen oxide contributes to the formation of both $PM_{2.5}$ and ground-level ozone.

Our analyses suggest this would yield benefits in 2014 of $120 to $280 billion (based on a 3 percent discount rate) and $110 to $250 billion (based on a 7 percent discount rate). The estimated benefits of this rule are substantial, particularly when viewed within the context of the total public health burden of $PM_{2.5}$ and ozone air pollution. A recent EPA analysis estimated that 2005 levels of $PM_{2.5}$ and ozone were responsible for between 130,000 and 320,000 PM2.5-related and 4,700 ozone-related premature deaths, or about 6.1% of total deaths (based on the lower end of the avoided mortality range) from all causes in the continental U.S. (Fann et al. 2011). This same analysis attributed almost 200,000 non-fatal heart attacks, 90,000 hospital admissions due to respiratory or cardiovascular illness and 2.5 million cases of aggravated asthma among children--among many other impacts. We estimate the Transport Rule to reduce the number of $PM_{2.5}$-related premature deaths in 2014 by between 13,000 and 34,000, 15,000 non-fatal heart attacks, 8,700 fewer hospital admissions and 400,000 fewer cases of aggravated asthma. By 2014, in combination with other federal and state air quality actions, the Transport Rule will address a substantial fraction of the total public health burden of $PM_{2.5}$ and ozone air pollution. However, the benefits and costs reported in this RIA reflect only the incremental costs and benefits of the Transport Rule.

We also estimate substantial additional health improvements for children from reductions in upper and lower respiratory illnesses, acute bronchitis, and asthma attacks. See Table 1-2 for a list of the annual reduction in health effects expected in 2014 and Table 1-3 for the estimated value of those reductions. In these tables we summarize the benefits according to whether they accrue within or beyond the Transport region (Eastern part of the US covered by the final rule). While not analyzed here, we expect the benefits in 2012 (the first compliance year for this final rule) to be significantly larger than those modeled for 2014 because of the much greater incremental SO_2 reductions in 2012 compared to 2014 from the base case. This occurs because the final rule expedites the adoption of SO_2 emissions controls that are planned in the base case to occur after 2012 and be underway by 2014.

Table 1-2: Estimated Reduction in Incidence of Adverse Health Effects of the Selected remedy (95% confidence intervals)[A]

Health Effect		*Within transport region*	*Beyond transport region*	*Total*
PM-Related endpoints				
Premature Mortality				
	Pope et al. (2002) (age >30)	13,000 (5,200—21,000)	33 (5—60)	13,000 (5,200—21,000)
	Laden et al. (2006) (age >25)	34,000 (18,000—49,000)	84 (31—140)	34,000 (18,000—49,000)
	Infant (< 1 year)	59 (-47—160)	0.15 (-0.2—0.5)	59 (-47—160)
Chronic Bronchitis		8,700 (1,600—16,000)	23 (-5—50)	8,700 (1,600—16,000)
Non-fatal heart attacks (age > 18)		15,000 (5,600—24,000)	40 (7—72)	15,000 (5,600—24,000)
Hospital admissions—respiratory (all ages)		2,700 (1,300—4,000)	5 (2—9)	2,700 (1,300—4,000)
Hospital admissions—cardiovascular (age > 18)		5,700 (4,200—6,600)	15 (10—19)	5,800 (4,200—6,600)
Emergency room visits for asthma (age < 18)		9,800 (5,800—14,000)	21 (7—36)	9,800 (5,800—14,000)
Acute bronchitis (age 8-12)		19,000 (-630—37,000)	50 (-29—130)	19,000 (-660—37,000)
Lower respiratory symptoms (age 7-14)		240,000 (120,000—360,000)	630 (130—1,100)	240,000 (120,000—360,000)
Upper respiratory symptoms (asthmatics age 9-18)		180,000 (57,000—310,000)	480 (-25—980)	180,000 (57,000—310,000)
Asthma exacerbation (asthmatics 6-18)		400,000 (45,000—1,100,000)	1,100 (-250—2,900)	400,000 (45,000—1,100,000)
Lost work days (ages 18-65)		1,700,000 (1,500,000—1,900,000)	4,300 (3,500—5,200)	1,700,000 (1,500,000—1,900,000)
Minor restricted-activity days (ages 18-65)		10,000,000 (8,400,000—11,000,000)	26,000 (20,000—32,000)	10,000,000 (8,400,000—12,000,000)

Ozone-related endpoints				
Premature mortality				
Multi-city and NMMAPS	Bell et al. (2004) (all ages)	27 (11—42)	0.1 (0.01—0.3)	27 (11—42)
	Schwartz et al. (2005) (all ages)	41 (17—64)	0.2 (0.1—0.4)	41 (17—65)
	Huang et al. (2005) (all ages)	37 (17—57)	0.2 (0.1—0.4)	37 (17—57)
Meta-analyses	Ito et al. (2005) (all ages)	120 (78—160)	0.6 (0.3—0.9)	120 (79—160)
	Bell et al. (2005) (all ages)	87 (48—130)	0.5 (0.2—0.8)	87 (48—130)
	Levy et al. (2005) (all ages)	120 (89—150)	0.7 (0.4—0.9)	120 (90—160)
Hospital admissions—respiratory causes (ages > 65)		160 (21—280)	1.2 (0.1—2.3)	160 (21—290)
Hospital admissions—respiratory causes (ages <2)		83 (43—120)	0.5 (0.2—0.8)	84 (43—120)
Emergency room visits for asthma (all ages)		86 (-2—260)	0.4 (-0.2—1.4)	86 (-2—260)
Minor restricted-activity days (ages 18-65)		160,000 (80,000—240,000)	910 (240—1,600)	160,000 (80,000—240,000)
School absence days		51,000 (22,000—73,000)	290 (59—490)	51,000 (22,000—74,000)

[A] Estimates rounded to two significant figures; column values will not sum to total value.
[B] The negative estimates for certain endpoints are the result of the weak statistical power of the study used to calculate these health impacts and do not suggest that increases in air pollution exposure result in decreased health impacts.

Table 1-3: Estimated Economic Value of Health and Welfare Benefits (95% confidence intervals, billions of 2007$)[A,B]

Health Effect	*Pollutant*	*Within transport region*	*Beyond transport region*[C]	*Total*
Premature Mortality (Pope et al. 2002 PM mortality and Bell et al. 2004 ozone mortality estimates)				
3% discount rate	$PM_{2.5}$ & O_3	$100 ($8.3—$320)	$0.3 ($0.01—$0.9)	$100 ($8.3—$320)
7% discount rate	$PM_{2.5}$ & O_3	$94 ($7.5—$280)	$0.2 ($0.01—$0.8)	$94 ($7.5—$290)
Premature Mortality (Laden et al. 2006 PM mortality and Levy et al. 2005 ozone mortality estimates)				
3% discount rate	$PM_{2.5}$ & O_3	$270 ($23—$770)	$0.7 ($0.05—$2)	$270 ($23—$770)
7% discount rate	$PM_{2.5}$ & O_3	$240 ($21—$700)	$0.6 ($0.05—$1.8)	$240 ($21—$700)
Chronic Bronchitis	$PM_{2.5}$	$4.2 ($0.2—$19)	$0.01 ($-0.003--$0.06)	$4.2 ($0.2—$19)
Non-fatal heart attacks				
3% discount rate	$PM_{2.5}$	$1.7 ($0.3—$4.2)	$0.004 ($0.003—$0.01)	$1.7 ($0.3—$4.2)
7% discount rate	$PM_{2.5}$	$1.3 ($0.3—$3.1)	$0.004 ($0.002—$0.001)	$1.3 ($0.3—$3.1)
Hospital admissions—respiratory	$PM_{2.5}$ & O_3	$0.04 ($0.02—$0.06)	---	$0.04 ($0.02—$0.06)
Hospital admissions—cardiovascular	$PM_{2.5}$	$0.09 ($0.01—$0.2)	---	$0.09 ($0.01—$0.2)
Emergency room visits for asthma	$PM_{2.5}$ & O_3	$0.003 ($0.002—$0.006)	---	$0.003 ($0.002—$0.006)
Acute bronchitis	$PM_{2.5}$	$0.008 (<$-0.01—$0.02)[D]	---	$0.008 (<$-0.01—$0.02)[c]
Lower respiratory symptoms	$PM_{2.5}$	$0.004 ($0.002—$0.009)	---	$0.004 ($0.002—$0.009)
Upper respiratory symptoms	$PM_{2.5}$	$0.005 (<$0.01—$0.014)	---	$0.005 (<$0.01—$0.014)
Asthma exacerbation	$PM_{2.5}$	$0.02 ($0.002—$0.08)	---	$0.02 ($0.002—$0.08)
Lost work days	$PM_{2.5}$	$0.2 ($0.17—$0.24)	---	$0.2 ($0.17—$0.24)
School loss days	O_3	$0.01 ($0.004—$0.013)	---	$0.01 ($0.004—$0.013)
Minor restricted-activity	$PM_{2.5}$ & O_3	$0.7	---	$0.7

days		($0.3—$1)		($0.3—$1)
Recreational visibility, Class I areas	$PM_{2.5}$			$4.1
Social cost of carbon (3% discount rate, 2014 value)	CO_2			$0.6

Monetized total Benefits (Pope et al. 2002 $PM_{2.5}$ mortality and Bell et al. 2004 ozone mortality estimates)				
3% discount rate	$PM_{2.5}$, O_3	**$110 ($8.8—$340)**	**$0.28 ($0.01—$0.9)**	**$120 ($14—$350)**
7% discount rate	$PM_{2.5}$, O_3	**$100 ($8—$310)**	**$0.03 ($0.01—$0.85)**	**$110 ($13—$320)**
Monetized total Benefits (Laden et al. 2006 $PM_{2.5}$ mortality and Levy et al. 2005 ozone mortality estimates)				
3% discount rate	$PM_{2.5}$, O_3	**$270 ($24—$800)**	**$0.7 ($0.05—$2.1)**	**$280 ($29—$810)**
7% discount rate	$PM_{2.5}$, O_3	**$250 ($22—$720)**	**$0.6 ($0.04—$1.9)**	**$250 ($26—$730)**

[A] Estimates rounded to two significant figures.
[B] States included in transport region may be found in chapter 2.
[C] Monetary value of endpoints marked with dashes are < $100,000. [D] The negative estimates for certain endpoints are the result of the weak statistical power of the study used to calculate these health impacts and do not suggest that increases in air pollution exposure result in decreased health impacts.

1.1.2 Welfare Benefits

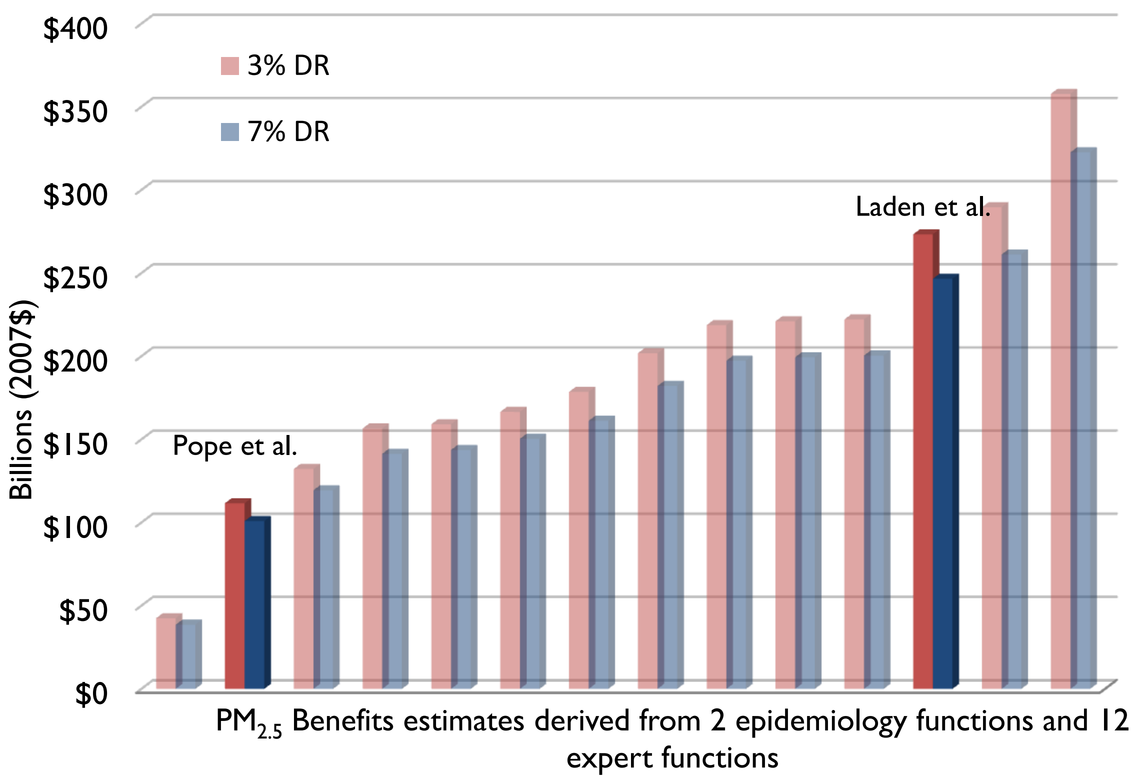
The term *welfare benefits* covers both environmental and societal benefits of reducing pollution, such as reductions in damage to ecosystems, improved visibility and improvements in recreational and commercial fishing, agricultural yields, and forest productivity. Although we are unable to monetize all welfare benefits, EPA estimates the final Transport Rule will yield welfare benefits of $4.1 billion in 2014 (2007$) for visibility improvements in southeastern Class I (national park) areas for a total of $4.1 billion in benefits across southeastern, southwestern and California Class I areas. These benefits are included in the full suite of benefits categories that are accounted for in the monetized benefits for this final rule.

Figure 1-1 summarizes an array of $PM_{2.5}$-related monetized benefits estimates based on alternative epidemiology and expert-derived PM-mortality estimate as well as the sum of ozone-related benefits using the Bell et al. (2004) mortality estimate.

Figure 1-2 summarizes the estimated net benefits for the selected remedy by displaying all possible combinations of PM and ozone-related monetized benefits and costs. The graphic includes one estimate of ozone-related mortality and fourteen different $PM_{2.5}$ related mortality and a single 3% or 7% discounted cost estimate.[2] Each of the 14 bars in each graph represents a separate point estimate of net benefits under a certain combination of cost and benefit estimation methods. Because it is not a distribution, it is not possible to infer the likelihood of any single net benefit estimate.

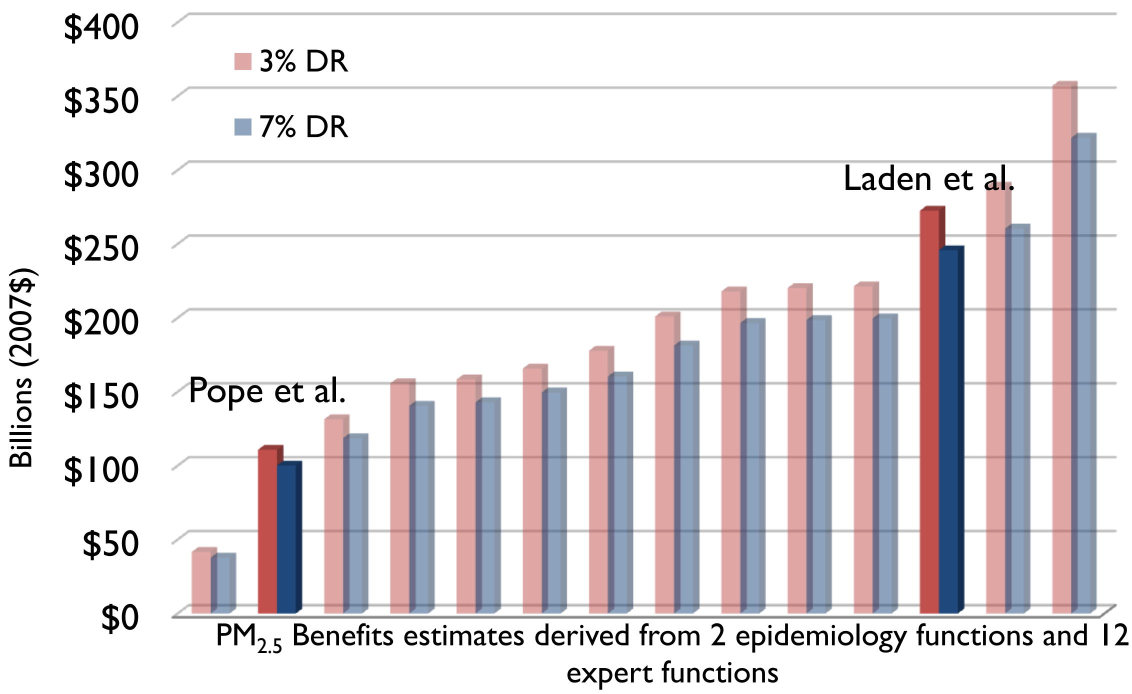
[2] Versions of this figure found in previous EPA RIA's have included the full suite of ozone mortality estimates. Because total benefits are relatively insensitive to the specification of ozone mortality estimate, for simplicity of presentation we have not included this full suite.

Figure 1-1 Estimated Monetized Value of Estimated $PM_{2.5}$- Related Premature Mortalities Avoided According to Epidemiology or Expert-derived Derived PM Mortality Risk Estimate[A]



[A] Column total equals sum of $PM_{2.5}$-related mortality and morbidity benefits and ozone-related morbidity and mortality benefits using the Bell et al. (2004) mortality estimate.

Figure 1-2: Net Benefits of the Transport Rule According to $PM_{2.5}$ Epidemiology or Expert-derived Mortality Risk Estimate[A]



[A] Column total equals sum of $PM_{2.5}$-related mortality and morbidity benefits and ozone-related morbidity and mortality benefits using the Bell et al. (2004) mortality estimate.

1.1.3 Assessment of More and Less Stringent Scenarios

1.1.3.1 Alternatives that Are More or Less Stringent

In accordance with Circular A-4 and EPA's for Guidelines for Preparing Economic Analyses, EPA also analyzed the costs and benefits of two options that differed in their stringency from the selected remedy option – one less stringent, the other more stringent. Both options have the same 2012 requirements and varied in the requirements for SO_2

emissions reductions in 2014. Both options only applied to the Group 1 states; requirements for SO_2 reductions remain the same in Group 2 states in 2014 under each option. Annual and ozone season NOx emissions requirements remain unchanged under these emission caps.

Unlike the selected remedy, which requires greater SO_2 reductions, reductions of up to $2,300/ton in marginal cost in 16 states (Group 1) beginning in 2014 from 2012 emissions levels, the less stringent option only requires SO_2 reductions in 2014 of up to $1,600/ton in marginal cost in Group 1 states. The more stringent option requires SO_2 reductions in 2014 of up to $10,000/ton in marginal cost in Group 1 states.

Table 1-4 provides a summary of the benefits, costs, and net benefits for the two alternatives considered to the selected remedy along with those for the selected remedy.

Table 1-4. Summary of Annual Benefits, Costs, and Net Benefits of Versions of the Selected Remedy Option in 2014[a] (billions of 2007 dollars)

Description	*Preferred Remedy*	*Less Stringent Scenario*	*More Stringent Scenario*
Social costs[b]			
3 % discount rate	$0.81	$0.43	$3.6
7 % discount rate	$0.81	$0.43	$3.6
Health-related benefits[c,d]			
3 % discount rate	$110 to $270 + B	$98 to $240 + B	$130 to $320 + B
7 % discount rate	$100 to $250 + B	$89 to $220 + B	$120 to $290 + B
Net benefits (benefits-costs)[e]			
3 % discount rate	$110 to $270	$98 to $240 + B	$130 to $320 + B
7 % discount rate	$100 to $250	$88 to $220 + B	$120 to $290 + B

[a] When presenting benefits and net benefits, EPA traditionally rounds all estimates to two significant figures. In this case we have rounded to three significant digits to facilitate comparison of the benefits and costs among the preferred remedy and the less and more stringent scenarios.

[b] The social costs are estimated using the MultiMarket model, the model employed by EPA in this RIA to estimate economic impacts of industries outside the electric power sector. This model does not estimate indirect impacts associated with a regulation such as this one. More information on the social costs can be found in Chapter 8 and Appendix B of this RIA.

[c] Due to methodological limitations, the health benefits of the two A-4 alternative remedies include $PM_{2.5}$ –related benefits but omit visibility, ozone, and CO_2-related benefits. We present the $PM_{2.5}$ –related benefits of the selected remedy, omitting these other important benefits, so that readers may compare directly the benefits of the selected and alternate remedies. Total benefits are primarily of the value of PM-related avoided premature mortalities. The reduction in these premature mortalities in each year account for over 90 percent of total $PM_{2.5}$ –related monetized benefits. Benefits in this table are nationwide and are associated with NO_x and SO_2 reductions. Visibility and ozone-related benefits not calculated for the more and less stringent scenarios because these impacts were estimated using $PM_{2.5}$-related benefit per ton estimates.

[d] Not all possible benefits or disbenefits are monetized in this analysis. These are listed in Table 1-5.

[e] Valuation assumes discounting over the SAB-recommended 20-year segmented lag structure. Results reflect the use of 3 % and 7 % discount rates consistent with EPA and OMB guidelines.

1.2 Not All Benefits Quantified

EPA was unable to quantify or monetize all of the health and environmental benefits associated with the Transport Rule. EPA believes these unquantified benefits are substantial, including the value of increased agricultural crop and commercial forest yields, visibility improvements, reductions in nitrogen and acid deposition and the resulting changes in ecosystem functions, and health and welfare benefits associated with reduced mercury emissions. Table 1-5 provides a list of these benefits.

Table 1-5: Human Health and Welfare Effects of Pollutants Affected by the Transport Rule

Pollutant/ Effect	*Quantified and monetized in base estimate*	*Unquantified*
PM: health[a]	Premature mortality based on cohort study estimates[b] Premature mortality based on expert elicitation estimates Hospital admissions: respiratory and cardiovascular Emergency room visits for asthma Nonfatal heart attacks (myocardial infarctions) Lower and upper respiratory illness Minor restricted activity days **Work loss days** Asthma exacerbations (among asthmatic populations Respiratory symptoms (among asthmatic populations) Infant mortality	Low birth weight Pulmonary function Chronic respiratory diseases other than chronic bronchitis Non-asthma respiratory emergency room visits UVb exposure (+/-)[c]
PM: welfare	Visibility in Class I areas	Household soiling Visibility in residential and non-class I areas UVb exposure (+/-)[c] Global climate impacts[c]
Ozone: health	Premature mortality based on short-term study estimates Hospital admissions: respiratory Emergency room visits for asthma Minor restricted activity days School loss days	Chronic respiratory damage Premature aging of the lungs Non-asthma respiratory emergency room visits UVb exposure (+/-)[c]
Ozone: welfare	Decreased outdoor worker productivity	Yields for: --Commercial forests --Fruits and vegetables, and --Other commercial and noncommercial crops Damage to urban ornamental plants Recreational demand from damaged forest

	aesthetics Ecosystem functions UVb exposure (+/-)[c]
NO_2: health	Respiratory hospital admissions Respiratory emergency department visits Asthma exacerbation Acute respiratory symptoms Premature mortality Pulmonary function
NO_2: welfare	Commercial fishing and forestry from acidic deposition Commercial fishing, agriculture and forestry from nutrient deposition Recreation in terrestrial and estuarine ecosystems from nutrient deposition Other ecosystem services and existence values for currently healthy ecosystems Coastal eutrophication from nitrogen deposition
SO_2: health	Respiratory hospital admissions Asthma emergency room visits Asthma exacerbation Acute respiratory symptoms Premature mortality Pulmonary function
SO_2: welfare	Commercial fishing and forestry from acidic deposition Recreation in terrestrial and aquatic ecosystems from acid deposition Increased mercury methylation
Mercury: health	Incidence of neurological disorders Incidence of learning disabilities Incidences in developmental delays Potential cardiovascular effects including: --Altered blood pressure regulation --Increased heart rate variability --Incidences of heart attack Potential reproductive effects
Mercury: environment	Impact on birds and mammals (e.g. reproductive effects)
Mercury: welfare	Impacts to commercial., subsistence and recreational fishing

[a] In addition to primary economic endpoints, there are a number of biological responses that have been associated with PM health effects including morphological changes and altered host defense mechanisms. The public health impact of these biological responses may be partly represented by our quantified endpoints.

[b] Cohort estimates are designed to examine the effects of long term exposures to ambient pollution, but relative risk estimates may also incorporate some effects due to shorter term exposures (see Kunzli et al., 2001 for a discussion of this issue). While some of the effects of short term exposure are likely to be captured by the cohort estimates, there may be additional premature mortality from short term PM exposure not captured in the cohort estimates included in the primary analysis.

[c] May result in benefits or disbenefits.

1.3 Costs and Economic Impacts

For the affected region, the projected annual incremental private costs of the selected remedy option (air quality-assured trading) to the power industry are $1.4 billion in 2012 and $0.8 billion in 2014 (in 2007 dollars). Costs are lower in 2014 than in 2012 as the rule becomes more stringent because there are larger amounts of State and Federally enforceable controls that happen between 2012 and 2014 in the baseline. These costs represent the total cost to the electricity-generating industry of reducing NO_x and SO_2 emissions to meet the emissions caps set out in the rule. Estimates are in 2007 dollars. These costs of the rule are estimated using the Integrated Planning Model (IPM). It should be noted that the rule modeled for this analysis differs from the final rule in that it includes reductions that would be required by the supplemental proposal for six states (Iowa, Kansas, Michigan, Missouri, Oklahoma, and Wisconsin). These reductions are included in the cost and impacts estimates described in this RIA, and therefore are accounted for in the benefits estimates.

In estimating the net benefits of regulation presented above, the appropriate cost measure is "social costs." Social costs represent the changes in social welfare from the rule measured as the change in total surplus (consumer and producer) in the macroeconomic analysis of this rule.

There are several national changes in energy prices that result from the Transport Rule. Retail electricity prices are projected to increase nationally by an average of 1.3 % in 2012 and 0.8 % in 2014 with the final Transport Rule. The average delivered coal price decreases by about 1.4 percent in 2012 and 0.5 percent in 2014 relative to the base case as a result of decreased coal demand and shifts in the type of coal demanded. EPA also projects that delivered natural gas prices for the electric power sector will increase by about 0.3% over the 2012-2030 timeframe and that natural gas use for electricity generation will increase by approximately 200 billion cubic feet (BCF) by 2014, or roughly 4%. This impact is well within the range of price variability that is regularly experienced in natural gas markets. Finally, under the Transport Rule, EPA projects coal production for use by the power sector will increase above 2009 levels by 40 million tons in 2012 and 54 million tons in 2014 (compared to roughly one billion tons of total coal produced for the power sector in 2009). This increase in production is 16% less in 2012 and 27% less in 2014 than the increase projected in the base case. The Transport Rule is not projected to impact production of coal for uses outside the power sector (e.g., export, industrial sources), which represent approximately 6% of total coal production in 2009. More detail and background for these results can be found in Chapter 7 of the RIA.

There are several other types of energy impacts from the Transport Rule. A relatively small amount of coal-fired capacity, about 4.8 GW (1 percent of all coal-fired capacity and 0.5% of total generating capacity), is projected to be uneconomic to maintain and EPA forecast that 1 GW of that capacity was likely to be unprofitable to operate in the 2020 in the base case. In practice units projected to be uneconomic to maintain may be "mothballed," retired, or kept in service to ensure transmission reliability in certain parts of the grid. For the most part, these units are small and infrequently used generating units that are dispersed throughout the Transport Rule region.

In addition to addressing the costs, benefits, and economic impacts of the Transport Rule, EPA has estimated a portion of the employment impacts of this rulemaking. We have estimated three types of impacts. One provides an estimate of the employment impacts on the regulated industry over time. The second covers the short-term employment impacts associated with the construction of needed pollution control equipment until the compliance date of the regulation. The third is to estimate short-term employment impacts extending outside of the power sector, as described in Appendix D. We expect that the rule's impact on employment will be small.

In Table 1-6, we show the employment impacts of the Transport Rule as estimated by the environmental protection sector approach and by the Morgenstern approach. The estimated employment changes due to changes in fuel use are reported in Chapter 8.

Table 1-6. Estimated Employment Impact Table

	Annual (reoccurring)	**One time (construction during compliance period)**
Environmental Protection Sector approach*	Not Applicable	2,230
Net Effect on Electric Utility Sector Employment from Morgenstern et al. approach***	700** -1, 000 to +3,000****	Not Applicable

*These one-time impacts on employment are estimated in terms of job-years.

**This estimate is not statistically different from zero.

**These annual or reoccurring employment impacts are estimated in terms of production workers as defined by the US Census Bureau's Annual Survey of Manufacturers (ASM).

**** 95% confidence interval

Overall, the impacts of the final rule are modest, particularly in light of the large projected benefits mentioned earlier.

1.4 Small Entity and Unfunded Mandates Impacts

After preparing an analysis of small entity impacts, EPA has certified that this final rule will have no SISNOSE (significant economic impacts on a substantial number of small entities). First, of the small entities projected to have costs greater than 1 percent of revenues (24 out of 108 affected), around 70 percent of them operate in cost of service regions and would generally be able to pass any increased costs along to rate-payers. In EPA's modeling, most of the cost impacts for these small entities and their associated units are driven by lower electricity generation relative to the base case. Specifically, two units reduce their generation by significant amounts, driving the bulk of the costs for all small entities. Excluding these two units, another driver of small entity impacts for sub-divisions and private small entities is higher fuel costs, which the affected units would be expected to use irrespective of whether they had to comply with this rule. Further, increased fuel costs are often passed through to rate-payers as common practice in many areas of the U.S. due to fuel adder arrangements instituted by state public utility commissions. Finally, EPA's decision to exclude units smaller than 25 Megawatt capacity (MW) has already significantly reduced the burden on small entities by reducing the number of affected small entity-owned units by about 390.

EPA examined the potential economic impacts on state and municipality-owned entities associated with this rulemaking based on assumptions of how the affected states will implement control measures to meet their emissions. These impacts have been calculated to provide additional understanding of the nature of potential impacts and additional information.

According to EPA's analysis, of the 98 government entities considered in this analysis and the 365 government entities in the Transport Rule region that are included in EPA's modeling, 26 may experience compliance costs in excess of 1 percent of revenues in 2014, based on our assumptions of how the affected states implement control measures to meet their emissions budgets as set forth in this rulemaking.

Government entities projected to experience compliance costs in excess of 1 percent of revenues may have some potential for significant impact resulting from implementation of the Transport Rule. However, it is EPA's position that because these government entities can pass on their costs of compliance to rate-payers, they will not be significantly affected. Furthermore, the decision to include only units greater than 25 MW in size exempts 354 government entities that would otherwise be potentially affected by the Transport Rule.

1.5 Limitations and Uncertainties

Every analysis examining the potential benefits and costs of a change in environmental protection requirements is limited to some extent by data gaps, limitations in model capabilities (such as geographic coverage), and variability or uncertainties in the underlying scientific and economic studies used to configure the benefit and cost models. Despite the uncertainties, we believe this benefit-cost analysis provides a reasonable indication of the expected economic benefits and costs of the final Transport Rule.

For this analysis, such uncertainties include possible errors in measurement and projection for variables such as population growth and baseline incidence rates; uncertainties associated with estimates of future-year emissions inventories and air quality; variability in the estimated relationships between changes in pollutant concentrations and the resulting changes in health and welfare effects; and uncertainties in exposure estimation.

EPA's cost estimates assume that all states in the final Transport Rule region participate in the programs that reduce SO_2 and NO_x emissions from the power industry, rather than complying with state-level requirements through other regulatory means.

Below is a summary of the key uncertainties of the analysis:

Costs

- Analysis does not capture employment shifts as workers are retrained at the same company or re-employed elsewhere in the economy.

- We do not include the costs of certain relatively small permitting costs associated with Title V that new program entrants face.
- Technological innovation is not incorporated into these cost estimates.
- Economic impacts do not take into response of electric power consumers to changes in electricity prices. While this response is likely to be of small magnitude, it may have some impact on the final estimate of private compliance costs.

Benefits

- Most of the estimated PM-related benefits in this rule accrue to populations exposed to higher levels of $PM_{2.5}$. Of these estimated PM-related mortalities avoided, about 69% occur among populations initially exposed to annual mean $PM_{2.5}$ level of 10 $\mu g/m^3$ and about 96% occur among those initially exposed to annual mean $PM_{2.5}$ level of 7.5 $\mu g/m^3$; these are the lowest air quality levels considered in the Laden et al. (2006) and Pope et al. (2002) studies, respectively. This fact is important, because as we estimate PM-related mortality among populations exposed to levels of $PM_{2.5}$ that are successively lower, our confidence in the results diminishes. However, our analysis shows that the great majority of the impacts occur at higher exposures.

- There are uncertainties related to the health impact functions used in the analysis. These include: within study variability; across study variation; the application of concentration-response (C-R) functions nationwide; extrapolation of impact functions across population; and various uncertainties in the C-R function, including causality and thresholds. Therefore, benefits may be under- or over-estimates.

- Analysis is for 2014, and projecting key variables introduces uncertainty. Inherent in any analysis of future regulatory programs are uncertainties in projecting atmospheric conditions and source level emissions, as well as population, health baselines, incomes, technology, and other factors.

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

- $PM_{2.5}$ mortality benefits represent a substantial proportion of total monetized benefits (over 90%), and these estimates have following key assumptions and uncertainties.

    1. The $PM_{2.5}$ -related benefits of the alternative scenarios were derived through a benefit per-ton approach, which does not fully reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual benefits of controlling SO_2.

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

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

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

These projected impacts of this final rule do not reflect minor technical corrections to SO_2 budgets in three states (KY, MI, and NY). These projections also assumed preliminary variability limits that were smaller than the variability limits finalized in this rule. EPA conducted sensitivity analysis confirming that these differences do not meaningfully alter any of the Agency's findings or conclusions based on the projected cost, benefit, and air quality impacts presented for the final Transport Rule. The results of this sensitivity analysis are presented in Appendix F in the final Transport Rule RIA.

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CHAPTER 2

INTRODUCTION AND BACKGROUND

2.1 Introduction

EPA is addressing in this action the interstate transport of emissions of nitrogen oxides (NO_x) and sulfur dioxide (SO_2) that contribute significantly to nonattainment and maintenance problems with respect to the national ambient air quality standards (NAAQS) for fine particulate matter ($PM_{2.5}$) that EPA promulgated in 1997 and 2006 and for 8-hour ozone that were promulgated in 1997. In this action, EPA will both identify and eliminate emissions within states in the eastern United States that significantly contribute to nonattainment and interfere with maintenance of the ozone and $PM_{2.5}$ NAAQS in other downwind states. This document presents the health and welfare benefits of the Transport Rule and compares the benefits of this rule to the estimated costs of implementing the rule in 2012 and 2014. This chapter contains background information relative to the rule and an outline of the chapters of the report.

2.2 Background

Clean Air Act (CAA) section 110(a)(2)(D)(i)(I) requires states to prohibit emissions that contribute significantly to nonattainment in, or interfere with maintenance by, any other state with respect to the National Ambient Air Quality Standards (NAAQS). In this final rule, the Environmental Protection Agency (EPA) will partially or fully address the interstate transport of emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and the fine particulate that they form in the atmosphere, that contribute significantly to nonattainment and interfere with maintenance with respect to the fine particulate matter ($PM_{2.5}$) NAAQS promulgated in 1997 and 2006. This final rule includes actions to partially or fully address the interstate transport of NO_x and the ozone that it forms in the atmosphere that contribute significantly to nonattainment and interfere with maintenance with respect to the 8-hour ozone NAAQS promulgated in 1997.

With this final rule, EPA is responding to the remand of the Clean Air Interstate Rule (CAIR) by the U.S. Court of Appeals for the D.C. Circuit in 2008. CAIR, promulgated May 12, 2005 (70 FR 25162) and the CAIR federal implementation plans (FIPs), promulgated April 26, 2006 (71 FR 25328), aimed to address the interstate transport of pollutants that contributed significantly to downwind nonattainment of the $PM_{2.5}$ and 8-hour ozone NAAQS promulgated in July 1997. In July 2008, the D.C. Circuit Court found CAIR and the CAIR FIPs unlawful. *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008). The Court's original decision vacated CAIR. Id. at 929-30. However, the Court subsequently remanded CAIR to EPA without vacatur because it found that "allowing CAIR to remain in effect until it is replaced by a rule consistent with our opinion would at least temporarily preserve the environmental values covered by CAIR." *North Carolina v. EPA*, 550 F.3d 1176, 1178 (D.C. Cir. 2008).

2.2.1 Methodology for Identifying Needed Reductions

As described in the preamble for this rule, EPA applies a state-specific methodology to identify specific reductions that states in the eastern United States must make to satisfy the CAA section 110(a)(2)(D)(i)(I) prohibition on emissions that significantly contribute to nonattainment or interfere with maintenance in a downwind state. To facilitate implementation of the requirement that significant contribution and interference with maintenance be eliminated, EPA developed state emissions budgets. These are new emissions budgets which are based on the Agency's state-by-state analysis of each upwind state's significant contribution to nonattainment and interference with maintenance downwind. A state's emissions budget is the quantity of emissions that would remain after elimination of significant contribution and interference with maintenance in an average year, assuming no abnormal meteorology or disruptions in electricity supply. EPA establishes SO_2 and NO_x budgets for each state covered for the 24-hour and/or annual $PM_{2.5}$ NAAQS. EPA also establishes an ozone season[3] NO_x budget for each state covered for the 8-hour ozone NAAQS.

2.2.2 How Reductions Will Be Achieved, and Different Options to Do So

EPA is finalizing federal implementation plans (FIPs) to immediately implement the emissions reduction requirements. The FIPs regulate electric generating units (EGUs) in the 27 covered states in the final rule[4]. EPA will regulate these sources through a program that uses state-specific budgets and allows interstate trading.

2.2.3 States Covered by the Final Rule

In the final rule, EPA requires SO_2 and NO_x emissions controls in the following 21 jurisdictions that contribute significantly to nonattainment in, or interfere with maintenance by, a downwind area with respect to the 24-hour $PM_{2.5}$ NAAQS promulgated in September 2006: Alabama, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin.

EPA requires SO_2 and NO_x emissions controls in the following 18 jurisdictions that contribute significantly to nonattainment in, or interfere with maintenance by, a downwind area with respect to the annual $PM_{2.5}$ NAAQS promulgated in July 1997: Alabama, Georgia, Illinois, Indiana, Iowa, Kentucky, Maryland, Michigan, Missouri, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, West Virginia, and Wisconsin.

The final rule requires ozone season NO_x emissions controls in 20 states. As discussed in the preamble, EPA issued a supplemental proposal addressing ozone-season NO_X controls in 6 additional states. In total, EPA identified 26 states that contribute significantly to nonattainment in, or interfere with maintenance by, a downwind area with

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[3] Consistent with the approach taken by the Ozone Transport Assessment Group (OTAG), the NO_X SIP call, and the CAIR, we define the ozone season, for purposes of emissions reduction requirements in this rule, as May through September. We recognize that this ozone season for regulatory requirements will have differences from the official state-specific monitoring season.

4 As finalized, the rule requires emission reductions in 27 states. EPA issued a supplemental proposal to request comment on requiring ozone-season NOx reductions in additional states; including the states addressed in the supplemental proposal, the total number of states covered by the Transport Rule would be 28.

respect to the 8-hour ozone NAAQS promulgated in July 1997: Alabama, Arkansas, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin. This group of jurisdictions includes 20 states covered by the final rule and 6 proposed states (Iowa, Kansas, Michigan, Missouri, Oklahoma, and Wisconsin) in the supplemental proposed rule. EPA is reporting on all 26 states in this RIA.

As discussed, EPA is finalizing FIPs to directly regulate EGU SO_2 and/or NO_x emissions in the covered states. The FIPs require the states covered for purposes of the 24-hour and/or annual $PM_{2.5}$ NAAQS to reduce SO_2 and NO_x emissions by specified amounts. The FIPs require the states covered for purposes of the 8-hour ozone NAAQS to reduce ozone season NO_x emissions by specified amounts. For the $PM_{2.5}$ NAAQS, EPA would require two phases with an initial phase in 2012 and subsequent phase in 2014. For 8-hour ozone, EPA would require a single phase that would start in 2012.

As discussed in detail in the preamble, the approach to significant contribution and interference with maintenance groups the 23 states covered for 24-hour and/or annual $PM_{2.5}$ NAAQS in two tiers reflecting the stringency of SO_2 reductions required to eliminate that state's significant contribution and interference with maintenance. There is a more stringent SO_2 tier comprising 16 states ("group 1") and a moderately stringent SO_2 tier comprising 7 states ("group 2") with uniform stringency within each tier.[5] For these same 23 states, there is one annual NO_x tier with uniform stringency of NO_x reductions across all states. Similarly, for the states covered for the 8-hour ozone NAAQS there is one ozone season NO_x tier with uniform stringency across all of these states.

The more stringent SO_2 tier ("group 1") includes Illinois, Indiana, Iowa, Kentucky, Maryland, Michigan, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin. The moderately stringent SO_2 tier ("group 2") includes Alabama, Georgia, Kansas, Minnesota, Nebraska, South Carolina, and Texas.

For the 16 states in the more stringent SO_2 tier ("group 1"), the 2014 phase increases

[5] With regard to interstate trading, the two SO_2 stringency tiers lead to two exclusive SO_2 trading groups.

the SO_2 reduction requirements (i.e., these states would have smaller SO_2 emissions budgets starting in 2014), reflecting the greater reductions needed to eliminate significant contribution and interference with maintenance from these states with respect to the 24-hour $PM_{2.5}$ NAAQS. The 2014 annual NO_x emissions budgets for all 23 states covered for the 24-hour and/or annual $PM_{2.5}$ NAAQS remain the same as the 2012 annual NO_x.

For the 7 states in the moderately stringent SO_2 tier ("group 2"), the 2014 SO_2 emission reduction requirements remain the same as the 2012 SO_2 emission reduction requirements for these states. See Table 2-1 for lists of covered states, which includes the 6 states addressed in the supplemental proposal for ozone-season NO_X.

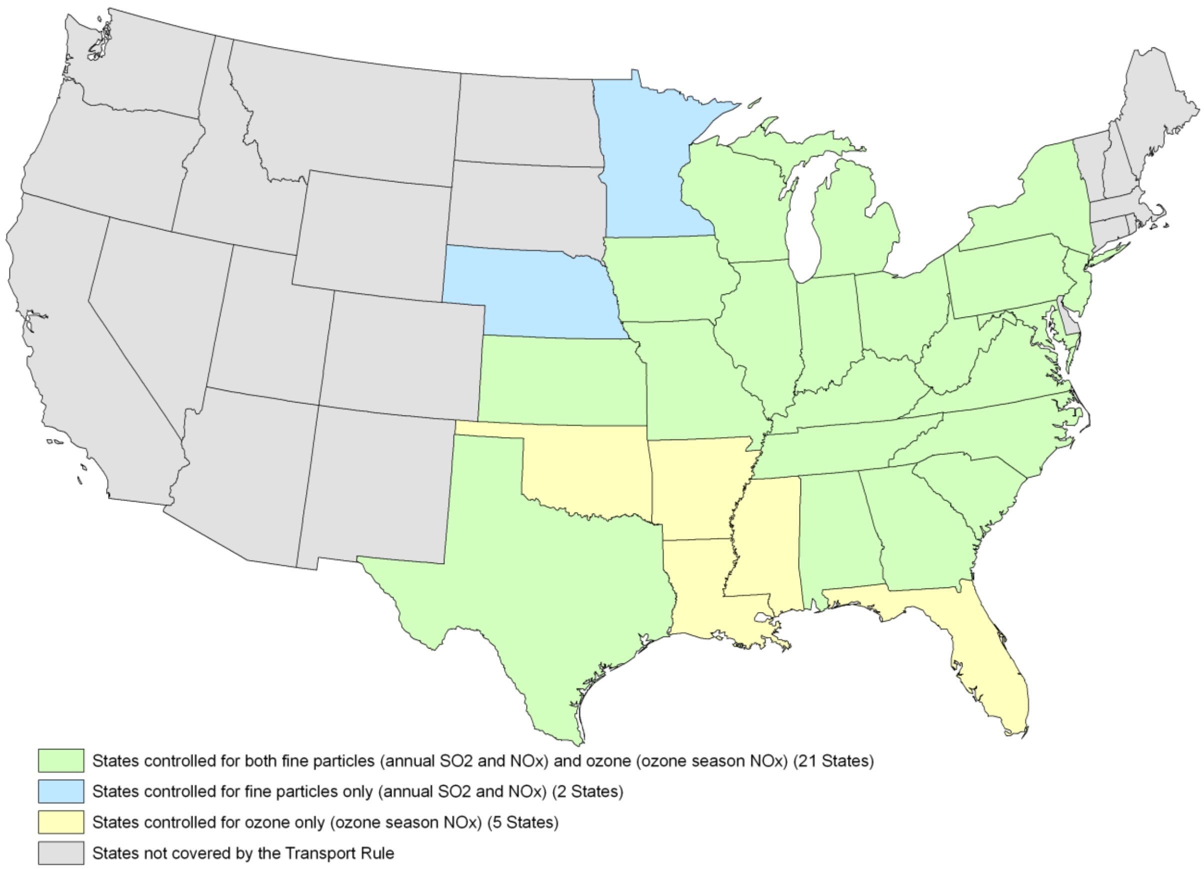
Table 2-1 -- Lists of Covered States for $PM_{2.5}$ and 8-Hour Ozone NAAQS

State	Covered for 24-hour and/or annual $PM_{2.5}$	Covered for 8-hour ozone
	Required to reduce SO_2 and NO_x	Required to reduce ozone season NO_x
Alabama	X	X
Arkansas		X
Florida		X
Georgia	X	X
Illinois	X	X
Indiana	X	X
Iowa	X	X
Kansas	X	X
Kentucky	X	X
Louisiana		X
Maryland	X	X
Michigan	X	X
Minnesota	X	
Mississippi		X

Missouri	X	X
Nebraska	X	
New Jersey	X	X
New York	X	X
North Carolina	X	X
Ohio	X	X
Oklahoma		X
Pennsylvania	X	X
South Carolina	X	X
Tennessee	X	X
Texas	X	X
Virginia	X	X
West Virginia	X	X
Wisconsin	X	X
TOTALS	23	26

The relevant regions for $PM_{2.5}$ and ozone significant contribution are also depicted in the graphic in Figure 2-1. Maps are also available in Chapter 7 of this RIA.

Figure 2-1 – States Covered Under the Final Transport Rule



2.3 Regulated Entities

This action will directly regulate emissions of NO_x and SO_2 from electric generating units (EGUs) with capacity greater than 25 MW in the covered states.

2.4 Baseline and Years of Analysis

The rule on which this analysis is based sets forth the requirements for states to address their significant contribution to downwind nonattainment of ozone and $PM_{2.5}$ NAAQS and interference with maintenance. To address this significant contribution and interference with maintenance, EPA requires that certain states reduce their emissions of SO_2 and NO_x. The Agency considered all promulgated CAA requirements and known state actions in the baseline used to develop the estimates of benefits and costs for this rule. This baseline analysis takes into account emissions reductions associated with the implementation of all federal rules promulgated by December 2010 and assumes that the CAIR is not in effect. However, this baseline presents a unique situation. EPA has been directed to replace the CAIR; yet the CAIR remains in place and has led to significant emissions reductions in many states.

A key step in the process of developing a 110(a)(2)(D)(i)(I) rule involves analyzing existing (base case) emissions to determine which states significantly contribute to downwind nonattainment and maintenance areas. It should be noted that a state affected by CAIR may not be affected by the new rule and after the new rule goes into effect, the CAIR requirements will no longer apply. For a state covered by CAIR but not covered by the new rule, the CAIR requirements would not be replaced with new requirements, and therefore an increase in emissions relative to present levels could occur in that state. More fundamentally, the court has made clear that, due to legal flaws, the CAIR rule cannot remain in place and must be replaced. If EPA's base case analysis were to ignore this fact and assume that reductions from CAIR would continue indefinitely, areas that are in attainment solely due to controls required by CAIR would again face nonattainment problems, because the existing protection from upwind pollution would not be replaced. For these reasons, EPA cannot assume in its base case analysis, that the reductions required by CAIR will continue to be achieved.

Following this logic, the 2012 base case shows emissions higher than current levels in some states. Because EPA has been directed to replace CAIR, EPA believes that for many states, the absence of the CAIR NO_x program will lead to the status quo of the NO_x Budget Trading Program (NBP), which substantially limits ozone-season NO_x emissions from electric power generation in a major part of the Eastern US and ensures the operation of NO_x controls in 20 covered states and the District of Columbia. The base case contains the NBP. Also, without the CAIR SO_2 program, there would remain the broad federal SO_2 emissions requirements for electric generation from fossil fuels in the lower 48 states for the comparatively less stringent CAA Title IV Acid Rain Program (ARP). As a result, SO_2 emissions in many states would increase markedly in the 2012 base case relative to the present. Efforts to comply with ARP rules at the least-cost would occur in many cases solely through use of currently readily available, inexpensive Title IV allowances and without the operation of some existing scrubbers that do not have other binding enforceable requirements. Notably, all known controls for both SO_2 and NO_x that are required under state laws, NSPS, consent decrees, and other enforceable, binding commitments through 2014 are accounted for in the base case. These requirements are quite substantial in maintaining the operation of much of the existing advanced controls in place. It is against this backdrop that the Transport Rule is analyzed and that significant contribution to nonattainment and interference with maintenance must be addressed.

The model's base case features an updated Title IV SO_2 allowance bank assumption and incorporates updates related to the Energy Independence and Security Act of 2007. Many key assumptions, notably demand for electricity, reflect the 2010 Annual Energy Outlook from the Energy Information Administration (EIA). In addition, the model includes policies affecting the power sector: the Title IV of the Clean Air Act (the Acid Rain Program); the NO_x SIP Call; various New Source Review (NSR) settlements[6]; and several

[6] The NSR settlements include agreements between EPA and Southern Indiana Gas and Electric Company (Vectren), Public Service Enterprise Group, Tampa Electric Company, We Energies (WEPCO), Virginia Electric & Power Company (Dominion), Santee Cooper, Minnkota Power Coop, American Electric Power (AEP), East Kentucky Power Cooperative (EKPC), Nevada Power Company, Illinois Power, Mirant, Ohio Edison, and Kentucky Utilities. These agreements lay out specific NO_x, SO_2, and other emissions controls for the fleets of these major Eastern companies by specified dates. Many of the pollution controls are required between 2010 and 2014.

state rules[7] affecting emissions of SO_2 and NO_x , that were finalized through December, 2010. IPM includes state rules that have been finalized and/or approved by a state's legislature or environmental agency. The IPM documentation TSD contains details on all of these other legally binding and enforceable commitments for installation and operation of advanced NO_X and SO_2 pollution controls.

The years 2012 and 2014 are the compliance years for the final rule, though as we explain in Chapters 5 and 7 we use 2015 (which covers 2014, 2015, 2016, and 2017) as a proxy for compliance in 2014 for our benefits and economic impact analysis due to availability of modeling impacts in that year. All estimates presented in this report represent annualized estimates of the benefits and costs of the final Transport Rule in 2012 and 2015 rather than the net present value of a stream of benefits and costs in these particular years of analysis.

2.5 Control Scenarios

The Transport Rule includes FIPs that would utilize state-specific control budgets and allow for interstate trading. This approach would assure environmental results while providing some limited flexibility for covered sources. The approach would also facilitate the transition from CAIR to the Transport Rule for implementing agencies and covered sources. The preferred remedy would use new allowance allocations developed on a different basis from CAIR. Fossil-fuel electric generating units (EGUs) over 25 megawatt (MW) capacity within the Transport Rule region would be covered by this action.

At proposal, EPA looked at two other alternatives of direct control and intrastate trading and fully analyzed their implications. The results of that analysis can be found in the proposal's RIA. We also considered a more and less stringent option in accordance with OMB Circular A-4 in that RIA. We have re-done our A-4 analysis in this final RIA and the results are found in Chapter 10.

[7] These include current and future state programs in Alabama, Connecticut, Delaware, Georgia, Illinois, Kansas, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, North Carolina, New Jersey, New York, Oregon, Pennsylvania, Tennessee, Texas, West Virginia, and Wisconsin.

2.6 Benefits of Emission Controls

The benefits of the Transport Rule are discussed in Chapter 5 of this report. Annual monetized benefits of $120 to 280 billion (3 percent discount rate) or $110 to $250 billion (7 percent discount rate) are expected for the final rule in 2014.

2.7 Costs of Emission Controls

EPA analyzed the costs to private industry of the Transport Rule using the Integrated Planning Model (IPM). EPA has used this model in the past to analyze the impacts of regulations on the power sector and used an earlier version of this model to analyze the impacts of the CAIR rule. The social cost is estimated using the Multimarket Model. IPM results are incorporated into the Multimarket Model when calculating the social cost of the Transport Rule. EPA estimates the private industry costs of the rule to the power sector to be $1.4 billion in 2012 and $0.8 billion in 2014 (2007 dollars). In estimating the net benefits (benefits – costs) of the rule, EPA uses social costs of the rule that represent the costs to society. These social costs include to the impact to industries affected by changes to electricity prices resulting from implementation of the Transport Rule. The social costs of the rule are estimated to be $0.8 billion in 2014.

A description of the methodologies used to model the costs and economic impacts to the power sector is discussed in Chapter 7 of this report, and a description of the methodology used to estimate the social cost of the rule, the employment impacts of the rule, and model economic impacts outside of the power sector are discussed in Chapter 8 of this report.

2.8 Organization of the Regulatory Impact Analysis

This report presents EPA's analysis of the benefits, costs, and other economic effects of the final Transport Rule to fulfill the requirements of a Regulatory Impact Analysis (RIA). This RIA includes the following chapters:

- Chapter 3, Emissions Impacts, describes the emission inventories and modeling that are essential inputs into the cost and benefit assessments.
- Chapter 4, Air Quality Impacts, describes the air quality data and modeling that are important for assessing the effect on contributions to air quality from the remedy option applied in this rule, and as inputs to the benefits assessment.
- Chapter 5, Benefits Analysis and Results, describes the methodology and results of the benefits analysis
- Chapter 6, Electric Power Sector Profile, describes the industry affected by the rule.
- Chapter 7, Cost, Economic, and Energy Impacts, describes the modeling conducted to estimate the cost, economic, and energy impacts to the power sector.
- Chapter 8, Macroeconomic and Employment Impacts, describes the describes the analysis to estimate the impacts on employment associated with the final rule, the modeling conducted to estimate the social cost of the rule and the economic impacts to industries outside of the power sector.
- Chapter 9, Statutory and Executive Order Impact Analyses, describes the small business, unfunded mandates, paperwork reduction act, environmental justice, and other analyses conducted for the rule to meet statutory and Executive Order requirements.
- Chapter 10, Comparison of Benefits and Costs, shows a comparison of the social benefits to social costs of the rule.
- Appendix A, Distribution of the $PM_{2.5}$-Related Benefits Among Vulnerable and Susceptible Populations
- Appendix B, OAQPS Multimarket Model to Assess the Economic Impact of Environmental Regulation
- Appendix C, State Benefits Results

CHAPTER 3
EMISSIONS IMPACTS

This chapter summarizes the emissions inventories that are used to create emissions inputs to the air quality modeling that is described in Chapter 4. This chapter provides a summary of the baseline emissions inventories and the emissions reductions that were modeled for this rule. The emissions inventories are processed into a form that is required by the Comprehensive Air Quality Model with extensions (CAMx). CAMx simulates the numerous physical and chemical processes involved in the formation, transport, and destruction of ozone and particulate matter (PM). Separate runs of CAMx were performed for the base year, future baseline, and post-control scenarios. As part of the analysis for this rulemaking, CAMx outputs were used to calculate 8-hr maximum ozone concentrations; daily and annual concentrations of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). In the remainder of this Chapter we provide an overview of (1) the emissions components of the modeling platform, (2) the development of the 2005 base-year emissions, (3) the development of the 2012 and 2014 future-year base case emissions, and (4) the development of the 2014 future year-control case (policy case) emissions. It should be noted that the projected future year inventory used for this analysis is generally representative of several years around 2014 such as 2015.

3.1 Overview of Modeling Platform and Emissions Processing Performed

The inputs to the air quality model; including emissions, meteorology, initial conditions, boundary conditions; along with the methods used to produce the inputs and the configuration of the air quality model are collectively known as a 'modeling platform'. The 2005-based air quality modeling platform used for the Transport Rule includes 2005 base-year emissions and 2005 meteorology for modeling ozone and $PM_{2.5}$ with CAMx (see http://www.camx.com/). Version 4.2 of the 2005-based platform (2005 v4.2 platform) was used for the Transport Rule, and it is described in the document: "Emissions Inventory Technical Support Document (TSD) for the Transport Rule NFR", posted at http://www.epa.gov/ttn/chief/emch/. The Emissions Inventory TSD provides more detail on (1) the development of the emissions inventories for all sectors and (2) the procedures followed to create emissions inputs to CAMx. For additional details on EPA's projected emissions for the EGU sector, see Chapter 7 of this RIA.

Emissions estimates were made for a 2005 base year and for 2012 and 2014 future-year scenarios. All inventories include emissions from EGUs, non-EGU point sources, stationary nonpoint sources (previously referred to as stationary area sources), onroad mobile sources, nonroad mobile sources and natural, biogenic emissions. In support of this rule, EPA processed the emissions in support of air quality modeling for two domains, covering the East and the West (2 separate model runs) of the U.S. and parts of Canada and Mexico using a horizontal grid resolution of 12 x 12 kilometers (km). These 12 km modeling domains were "nested" within a modeling domain covering the lower 48 states using a grid resolution of 36 x 36 km[8], therefore the tables of emissions in this section cover the contiguous 48 states.

For each of the modeling scenarios conducted: 2005 base year, 2012 base case, 2014 base case, and 2014 control case, the emissions inventory files were processed using the Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System version 2.6 to produce the gridded model-ready emissions for input to CAMx. SMOKE was used to create the hourly, gridded emissions data for the species required by CAMx species to perform air quality modeling for all sectors, including biogenic emissions. Details on the non-emissions portion of the modeling platform used for the RIA are provided in Chapter 4.

3.2 Development of 2005 Base Year Emissions

Emissions inventory inputs representing the year 2005 were developed to provide a base year for forecasting future air quality. These inventories include criteria air pollutants and some hazardous air pollutants. For some sectors, benzene, formaldehyde, acetaldehyde and methanol (sometimes abbreviated "BAFM") are used from the inventory for chemical speciation of volatile organic compounds (VOC). The emission source sectors and the basis

[8] The air quality predictions from the 36 km Continental US (CONUS) domain were used to provide incoming "boundary" concentrations for the 12 km domains.

for current and future-year inventories are listed and defined in Table 3-1. These are the same sectors as were used in the 2005-based version 4 (v4) platform (www.epa.gov/ttn/chief/emch/index.html#2005), from which the v4.2 platform was derived. The starting point for both the v4 and v4.2 platforms was the 2005 National Emission Inventory (NEI), version 2 (v2) from October 6, 2008 (http://www.epa.gov/ttn/chief/net/2005inventory.html). The v4.2 platform utilizes the same 2006 Canadian inventory and a 1999 Mexican inventory as were used in the v4 platform; as these were the latest available data from these countries and were used for the portions of Canada and Mexico within the modeling domains.

Table 3-1. Emissions Source Sectors for Current and Future-Year Inventories, 2005-based Platform, Version 4.2

Platform Sector, modeling abbrev. (and corresponding 2005 NEI sector)	Description and resolution of the data input to SMOKE, 2005 v4.2 platform
EGU sector: *ptipm (point)*	2005 NEI v2 point source EGUs mapped to the Integrated Planning Model (IPM) model using the National Electric Energy Database System (NEEDS) 2006 version 4.10 database. Daily emissions input into SMOKE. Annual emissions allocated to months using 3 years of continuous emissions monitor (CEM) data, and allocated to days using month-to day allocations from the 2005 CEM data. Includes updates such as removing duplicates and reflecting comments received on the proposed Transport Rule.
Non-EGU sector: *ptnonipm (point)*	All 2005 NEI v2 point source records not matched to the ptipm sector. Includes all aircraft emissions. Includes updates to remove duplicates, improve estimates from ethanol plants, reflect new information collected from industry from the ICR for the Boiler MACT, and to reflect comments received on the proposed Transport Rule. Includes point source fugitive dust emissions for which county-specific PM transportable fractions were applied. Annual resolution.
Average-fire sector: *avefire*	Average-year wildfire and prescribed fire emissions; county and annual resolution.
Agricultural sector: *ag (nonpoint)*	NH_3 emissions from 2002 NEI nonpoint livestock and fertilizer application, county and annual resolution.
Area fugitive dust sector: *afdust (nonpoint)*	PM_{10} and $PM_{2.5}$ from fugitive dust sources (e.g., building construction, road construction, paved roads, unpaved roads, agricultural dust) from the NEI nonpoint inventory (which used 2002 emissions for this sector) after application of county-specific PM transportable fractions. Includes county and annual resolution.
Remaining nonpoint sector: *nonpt (nonpoint)*	Primarily 2002 NEI nonpoint sources not otherwise included in other SMOKE sectors, county and annual resolution. Includes updated residential wood combustion emissions, year 2005 non-California WRAP oil and gas Phase II inventory, and year 2005 Texas and Oklahoma oil and gas emissions. Includes updates based on comments received on the proposed Transport Rule.
Nonroad sector:	Monthly nonroad emissions from the National Mobile Inventory Model (NMIM)

Platform Sector, modeling abbrev. (and corresponding 2005 NEI sector)	**Description and resolution of the data input to SMOKE, 2005 v4.2 platform**
nonroad (nonroad)	using NONROAD2005 version nr05c-BondBase, which is equivalent to NONROAD2008a, since it incorporated Bond rule revisions to some of the base case inputs and the Bond rule controls did not take effect until later. NMIM was used for all states except California. Monthly emissions for California created from annual emissions submitted by the California Air Resources Board (CARB) for the 2005v2 NEI**.**
Locomotive, and non-C3 commercial marine vessel (CMV): ***alm_no_c3 (nonroad)***	2002 NEI non-rail maintenance locomotives, and category 1 and category 2 commercial marine vessel (CMV) emissions sources, county and annual resolution. Aircraft emissions are included in the Non-EGU sector (as point sources) and category 3 CMV emissions are contained in the seca_c3 sector.
C3 commercial marine: ***seca_c3 (nonroad)***	Annual point source-formatted, year 2005 category 3 (C3) CMV emissions, developed for the rule called "Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder", usually described as the Emissions Control Area (ECA) study (http://www.epa.gov/otaq/oceanvessels.htm). Uses final projections from 2002, developed for the C3 ECA proposal to the International Maritime Organization (EPA-420-F-10-041, August 2010) and a state/federal water boundary of 3-10 nautical miles. Includes other updates reflecting comments received on the proposed Transport Rule.
Onroad California, NMIM-based, and Motor Vehicle Emissions Simulator (MOVES) sources not subject to temperature adjustments: ***on_noadj (onroad)***	Three, monthly, county-level components: 1) California onroad, created using annual emissions submitted by CARB for the 2005 NEI version 2. NH_3 (not submitted by CARB) from MOVES2010. 2) Onroad gasoline and diesel vehicle emissions from MOVES2010 not subject to temperature adjustments: exhaust carbon monoxide (CO), nitrogen oxides (NO_X), sulfur dioxide (SO_2), VOC, ammonia (NH_3), benzene, formaldehyde, acetaldehyde, 1,3-butadiene, acrolein, naphthalene, brake and tire wear PM, and evaporative VOC, benzene, and naphthalene.
Onroad cold-start gasoline exhaust mode vehicle from MOVES subject to temperature adjustments: ***on_moves_startpm (onroad)***	2005 monthly, county-level MOVES2010 onroad gasoline vehicle emissions subject to temperature adjustments. Pollutants that are included are limited to PM species and Naphthalene for exhaust mode only. California emissions are not included (covered by on_noadj). This sector is limited to cold start mode emissions that contain different temperature adjustment curves from running exhaust (see on_moves_runpm sector).
Onroad running gasoline exhaust mode vehicle from MOVES subject to temperature adjustments: ***on_moves_runpm (onroad)***	2005 monthly, county-level MOVES2010 onroad gasoline vehicle emissions subject to temperature adjustments. Pollutants that are included are limited to PM species and Naphthalene for exhaust mode only. California emissions are not included. This sector is limited to running mode emissions that contain different temperature adjustment curves from cold start exhaust (see on_moves_startpm sector).

Platform Sector, modeling abbrev. (and corresponding 2005 NEI sector)	Description and resolution of the data input to SMOKE, 2005 v4.2 platform
Biogenic: ***biog***	Hour-specific, grid cell-specific emissions generated from the BEIS3.14 model - includes emissions in Canada and Mexico.
Other point sources not from the NEI: ***othpt***	Point sources from Canada's 2006 inventory and Mexico's Phase III 1999 inventory, annual resolution. Also includes annual U.S. offshore oil 2005 NEI v2 point source emissions.
Other nonpoint and nonroad not from the NEI: ***othar***	Year 2006 Canada (province resolution) and year 1999 Mexico Phase III (municipio resolution) nonpoint and nonroad mobile inventories, annual resolution.
Other onroad sources not from the NEI: ***othon***	Year 2006 Canada (province resolution) and year 1999 Mexico Phase III (municipio resolution) onroad mobile inventories, annual resolution.

The onroad emissions were primarily based on the 12/21/2009 version of the Motor Vehicle Emissions Simulator (MOVES2010) (http://www.epa.gov/otaq/models/moves/) with database corrections for diesel toxics. MOVES was run with a State/month aggregation using average fuels for each state, state/month-average temperatures, and national default vehicle age distributions. The MOVES data were allocated to counties using state-county distributions from the 2005 National Mobile Inventory model (NMIM) results that are part of the 2005 NEI v2. MOVES2010 was used for onroad sources other than in California[9] for carbon monoxide (CO), nitrogen oxides (NO_X), VOC, $PM_{2.5}$, particulate matter less than ten microns (PM_{10}), sulfur dioxide (SO_2), ammonia (NH_3), naphthalene,[10] and some VOC HAPs.[11] To account for the temperature dependence of $PM_{2.5}$, MOVES-based temperature adjustment factors were applied to gridded, hourly emissions using the same 2005 gridded, hourly 2 meter temperature data used in CAMx. Additional information on this approach is available in the Emissions Inventory TSD.

[9] California onroad emissions were taken from the California Air Resources Board submission of 2005 data to the NEI. The inventory included all criteria air pollutants other than ammonia and hazardous air pollutants.

[10] Naphthalene emissions were not used in the modeling.

[11] 1,3 Butadiene, Acrolein, Formaldehyde, Benzene and Acetaldehyde. Of these, the latter 3 are used in the modeling.

The nonroad emissions utilized the NMIM model (other than California) to create county/month emissions, which are consistent with the annual emissions from the 2005 NEI v2. For California, state-submitted emissions were used.

Emissions from the point source NEI were primarily from the 2005 NEI v2 inventory, consisting primarily of 2005 values with some 2002 emissions values where 2005 data were not available. The point sources are split into "EGU" (aka "ptipm") and "Non-EGU" (aka "ptnonipm") sectors for modeling purposes, based on the matching of the unit level data in the NEI units in the National Electric Energy Database System (NEEDS) version 4.10 database. All units that matched NEEDS were included in the EGU sector so that the future year emissions could easily be taken from the Integrated Planning Model (IPM) emissions that are based on the NEEDS units. Effort were made to ensure that there were not duplicate emissions in the 2005 data (e.g., from 2002 and 2005), to properly account for plants or units that shutdown prior to 2005, add estimates for ethanol plants, and to revise some of the 2002 data to reflect 2005 emissions based on controls put in place between 2002 and 2005.

The 2005 annual NO_X and SO_2 emissions for sources in the EGU sector as defined in Table 3-1 are based primarily on data from EPA's Clean Air Markets Division's Continuous Emissions Monitoring (CEM) program, with other pollutants estimated using emission factors and the CEM annual heat input. For EGUs without CEMs, emissions were obtained from the state-submitted data in the NEI. Additional ORIS12 plant and unit code matches were implemented in version 4.2 of the platform, and for a subset of these units, annual emissions were recomputed13 to reflect the newly matched CEM data.

For the 2005 base year, the annual EGU NEI emissions were allocated to hourly emissions values needed for modeling based on the 2004, 2005, and 2006 CEM data. The NO_X CEM data were used to create NO_X-specific profiles, the SO_2 data were used to create SO_2-specific profiles, and the heat input data were used to allocate all other pollutants. The three years of data were used to create monthly profiles by state, while the 2005 data were used to create state-averaged profiles for allocating monthly emissions to daily. These daily values were input into SMOKE, which utilized state-averaged 2005-based hourly profiles to

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[12] An Oris code is a 4 digit number assigned by the Energy Information Administration (EIA) at the U.S. Department of Energy that is used to track emission generating units under numerous other data systems including the Clean Air Markets Divisions CEM data.

[13] Net change was a decrease in NO_X by 1700 tons and a decrease in SO_2 by 600 tons.

allocate to hourly values. This approach to temporal allocation was used for all base and control cases modeled to provide a temporal consistency between the years modeled without tying the temporalization to the events of a single year.

The 2002 NEI v2 nonpoint inventory was augmented with updated oil and gas exploration emissions from Texas and Oklahoma (CO, NO_X, PM, SO_2, VOC). These oil and gas exploration emissions were in addition to oil and gas data previously available to the 2005 v4 platform that includes emissions within the following states: Arizona, Colorado, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, and Wyoming.

The commercial marine category 3 (C3) vessel emissions (seca_c3 sector) used gridded 2005 emissions that reflect the final projections from 2002 developed for the category 3 commercial marine Emissions Control Area (ECA) proposal to the International Maritime Organization (EPA-420-F-10-041, August 2010). These emissions include Canada as part of the ECA, and were updated using region-specific growth rates; thus the v4.2 seca_c3 sector inventories contain Canadian province codes. The state/federal water boundaries were based on a file available from the Mineral Management Service (MMS) that specify boundaries from three to ten nautical miles from the coast.

Other emissions inventories included average-year county-based inventories for emissions from wildfires and prescribed burning. These emissions are intended to be representative for both base and future years and are held constant for each, which minimizes their impact on the modeling results because of post-processing techniques.

Once developed, the emissions inventories were processed to provide the hourly, gridded emissions for the model-species needed by CAMx. Details on this processing are further described in the Emissions Inventory TSD. Table 3-2 provides summaries of the 2005 emissions inventories by sector for the final Transport Rule. Tables 3-3 through 3-4 provide state-level summaries for SO_2, and NO_X. In these tables, “Nonpoint” represents the nonpt sector; “Area Fugitive Dust” (which contains only PM_{10} and $PM_{2.5}$) represents the afdust sector; on_noadj, on_startpm and on_runpm sectors are summed into “Onroad”; nonroad, alm_no_c3 (locomotives and category 1 and 2 marine vessels) and seca_c3 (category 3 marine vessels) sectors are summed into “Nonroad”; and “Fires” represent the average-year fire (avefire) emissions for wildfires and prescribed burning mentioned above.

Table 3-2. 2005 Emissions by Sector

Sector Abbrev.	2005 NOX [tons/yr]	2005 SO2 [tons/yr]	2005 PM2_5 [tons/yr]	2005 PM10 [tons/yr]	2005 NH3 [tons/yr]	2005 CO [tons/yr]	2005 VOC [tons/yr]
Area fugitive dust	0	0	1,030,391	8,858,992	0	0	0
Agriculture	0	0	0	0	3,251,990	0	0
Locomotive/marine	1,922,723	153,068	56,666	59,342	773	270,007	67,690
Commercial marine Category 3 (US only)	130,164	97,485	10,673	11,628	0	11,862	4,570
Nonpoint	1,696,902	1,216,362	1,079,906	1,349,639	133,962	7,410,946	7,530,578
Nonroad	2,115,408	197,341	201,138	211,807	1,972	19,502,718	2,691,844
Onroad running PM	0	0	49,789	54,071	0	0	0
Onroad start PM	0	0	20,929	22,729	0	0	0
Onroad other	9,142,274	177,977	236,927	308,497	156,528	43,356,130	3,949,362
EGU	3,729,161	10,380,883	496,877	602,236	21,995	603,788	41,089
Non-EGU	2,226,250	2,082,159	433,381	646,373	158,524	3,214,833	1,309,895
Average fires	189,428	49,094	684,035	796,229	36,777	8,554,551	1,958,992
Commercial marine Category 3 (non-US)	1,801,699	1,085,894	134,604	146,312	0	146,027	62,132
Canada area[1]	734,587	95,086	432,402	1,666,188	546,034	3,789,362	1,281,095
Canada onroad	524,837	5,309	10,395	14,665	21,312	4,403,745	270,872
Canada point	857,977	1,664,040	68,689	117,669	21,268	1,270,438	447,313
Mexico area	249,045	101,047	92,861	143,816	486,484	644,733	586,842
Mexico onroad	147,419	8,270	6,372	6,955	2,547	1,455,121	183,429
Mexico point	258,510	980,359	88,132	125,385	0	88,957	113,044
Off-shore point	82,581	1,961	837	839	0	89,812	51,240

Table 3-3. 2005 Base Year SO2 Emissions (tons/year) for States by Sector

State	EGU	NonEGU	Nonpoint	Nonroad	Onroad	Fires	Total
Alabama	460,123	66,373	52,325	5,622	3,983	983	589,408
Arizona	52,733	23,966	2,571	6,154	3,919	2,888	92,231
Arkansas	66,384	13,039	27,260	5,678	1,998	728	115,087
California	601	33,136	77,672	41,140	4,935	6,735	164,217
Colorado	64,174	1,549	6,810	4,897	3,064	1,719	82,213
Connecticut	10,356	1,831	18,455	2,556	1,375	4	34,576
Delaware	32,378	34,859	1,030	2,657	519	6	71,449
District of Columbia	1,082	686	1,559	414	218	0	3,961
Florida	417,321	57,429	70,490	31,191	13,280	7,018	596,729
Georgia	616,063	52,830	56,829	9,223	7,163	2,010	744,119

State	EGU	NonEGU	Nonpoint	Nonroad	Onroad	Fires	Total
Idaho	0	17,151	2,915	2,304	951	3,845	27,166
Illinois	330,382	156,154	5,395	19,303	7,279	20	518,531
Indiana	878,979	87,795	59,775	9,437	4,937	24	1,040,947
Iowa	130,264	64,448	19,832	8,838	2,045	25	225,451
Kansas	136,520	13,234	36,381	8,035	2,241	103	196,515
Kentucky	502,731	25,962	34,229	6,942	3,377	364	573,604
Louisiana	109,875	165,705	2,378	25,447	3,043	892	307,340
Maine	3,887	18,512	9,969	1,625	986	150	35,129
Maryland	283,205	34,988	40,864	9,372	2,706	32	371,166
Massachusetts	84,234	19,620	25,261	6,524	2,819	93	138,551
Michigan	349,877	76,509	42,066	14,597	8,966	91	492,106
Minnesota	101,678	25,158	14,747	10,412	3,111	631	155,736
Mississippi	75,047	29,892	6,796	5,930	2,681	1,051	121,397
Missouri	284,384	78,307	44,573	10,464	5,339	186	423,253
Montana	19,715	11,056	2,600	3,813	912	1,422	39,518
Nebraska	74,955	6,469	7,659	9,199	1,640	105	100,026
Nevada	53,363	2,253	12,477	2,877	702	1,346	73,018
New Hampshire	51,445	3,155	7,408	789	780	38	63,614
New Jersey	57,044	7,639	10,726	13,315	3,112	61	91,898
New Mexico	30,628	8,062	3,193	3,541	1,879	3,450	50,755
New York	180,847	58,426	125,158	15,663	6,500	113	386,707
North Carolina	512,231	59,433	22,020	8,766	6,506	696	609,652
North Dakota	137,371	9,678	6,455	5,986	525	66	160,082
Ohio	1,116,095	115,154	19,810	15,630	7,715	22	1,274,427
Oklahoma	110,081	40,482	8,556	5,015	3,316	469	167,918
Oregon	12,304	9,825	9,845	5,697	1,872	4,896	44,438
Pennsylvania	1,002,203	83,375	68,349	11,999	6,597	32	1,172,555
Rhode Island	176	2,743	3,365	816	265	1	7,366
South Carolina	218,781	31,495	13,489	7,719	3,741	646	275,871
South Dakota	12,215	1,999	10,347	3,412	612	498	29,083
Tennessee	266,148	67,160	32,714	6,288	6,088	277	378,676
Texas	534,949	223,625	115,192	34,943	17,970	1,178	927,857
Tribal	3	1,511	0	0	0	0	1,515
Utah	34,813	9,132	3,577	2,439	1,999	1,934	53,893
Vermont	9	902	5,385	385	346	49	7,078
Virginia	220,287	69,401	32,923	10,094	4,647	399	337,752
Washington	3,409	24,211	7,254	18,810	3,490	407	57,580
West Virginia	469,456	46,710	14,589	2,133	1,289	215	534,392
Wisconsin	180,200	66,807	6,369	7,134	3,735	70	264,315
Wyoming	89,874	22,321	6,721	2,674	807	1,106	123,503
Total	**10,380,883**	**2,082,159**	**1,216,362**	**447,895**	**177,977**	**49,094**	**14,354,370**

Table 3-4. 2005 Base Year NO_X Emissions (tons/year) for States by Sector

State	EGU	NonEGU	Nonpoint	Nonroad	Onroad	Fires	Total
Alabama	133,051	72,795	32,024	60,373	182,224	3,814	484,282
Arizona	79,776	15,975	8,650	62,711	223,130	10,532	400,774
Arkansas	35,407	35,846	21,453	63,493	106,127	2,654	264,979
California	6,925	90,708	121,882	424,268	665,225	24,563	1,333,571
Colorado	73,909	20,971	43,652	50,856	138,976	6,271	334,635
Connecticut	6,865	5,824	12,554	21,802	82,677	14	129,736
Delaware	11,917	5,567	2,274	10,617	28,088	23	58,486
District of Columbia	492	501	1,740	3,494	10,575	0	16,802
Florida	217,282	53,757	29,533	176,468	553,534	25,600	1,056,174
Georgia	111,281	50,434	38,919	89,708	364,376	7,955	662,673
Idaho	19	10,354	30,317	22,087	45,427	14,024	122,228
Illinois	127,940	97,409	47,645	223,696	368,378	71	865,139
Indiana	213,588	67,479	30,185	110,100	252,229	88	673,669
Iowa	72,806	41,818	15,150	92,965	108,205	90	331,034
Kansas	90,220	70,858	42,286	86,553	97,259	378	387,554
Kentucky	164,783	35,425	17,557	90,669	172,502	1,326	482,262
Louisiana	64,987	162,770	27,559	222,575	145,398	3,254	626,542
Maine	1,100	17,949	7,423	9,928	49,128	566	86,094
Maryland	62,574	24,621	21,715	41,889	161,294	137	312,230
Massachusetts	25,134	18,429	34,373	43,494	161,867	341	283,638
Michigan	120,026	94,118	43,499	101,060	359,421	330	718,454
Minnesota	84,304	63,971	56,700	115,872	183,758	2,300	506,905
Mississippi	45,166	53,985	12,212	79,288	130,111	3,833	324,595
Missouri	127,431	38,604	32,910	123,228	240,506	678	563,356
Montana	39,858	5,356	14,415	40,687	43,926	5,187	149,429
Nebraska	52,426	12,187	14,749	107,180	76,791	381	263,714
Nevada	47,297	17,191	5,379	27,747	49,381	4,910	151,905
New Hampshire	8,827	2,805	11,235	9,220	41,101	137	73,325
New Jersey	30,142	20,570	26,393	71,738	192,310	223	341,376
New Mexico	75,483	44,107	69,175	45,552	96,239	12,582	343,139
New York	63,315	55,122	87,608	112,441	369,210	412	688,109
North Carolina	111,576	44,502	18,869	79,893	287,918	11,424	554,183
North Dakota	76,381	7,672	10,046	59,635	28,313	240	182,289
Ohio	258,944	71,090	41,466	173,981	360,765	81	906,327
Oklahoma	86,204	73,465	67,762	55,424	149,720	1,709	434,284
Oregon	9,383	22,927	17,059	65,058	107,934	17,857	240,218
Pennsylvania	176,891	89,287	53,435	118,796	343,120	117	781,647
Rhode Island	545	2,164	2,964	5,028	17,676	4	28,381
South Carolina	52,657	29,069	17,706	49,026	163,461	2,357	314,276
South Dakota	15,650	5,271	5,766	30,324	32,508	1,817	91,336
Tennessee	102,934	54,255	18,676	82,331	267,818	1,012	527,027
Texas	176,170	292,806	317,192	348,014	867,843	4,890	2,006,916
Tribal	78	13,322	0	0	0	0	13,400

State	EGU	NonEGU	Nonpoint	Nonroad	Onroad	Fires	Total
Utah	65,261	19,466	13,844	26,985	84,202	7,052	216,810
Vermont	297	799	3,438	3,951	17,032	179	25,696
Virginia	62,793	59,820	53,605	77,661	232,928	1,456	488,263
Washington	17,634	25,427	16,911	106,226	189,992	1,484	357,674
West Virginia	159,947	36,196	14,519	32,739	64,469	785	308,655
Wisconsin	72,170	40,688	21,994	75,979	190,138	256	401,226
Wyoming	89,315	30,516	40,480	35,482	37,065	4,035	236,894
Total	**3,729,161**	**2,226,250**	**1,696,902**	**4,168,294**	**9,142,274**	**189,428**	**21,152,309**

3.3 Development of Future Year Base Case Emissions

The 2012 and 2014 base case scenarios represent predicted emissions including known federal measures for all sectors. They reflect projected economic changes and fuel usage for the EGU and mobile sectors. Emissions from non-EGU stationary sectors have previously been shown to not be well correlated with economic forecasts, and therefore economic impacts were not included for non-EGU stationary sources. Like the 2005 base case, these emissions cases include criteria pollutants and for some sectors, benzene, formaldehyde, acetaldehyde and methanol from the inventory is used in VOC speciation.

The 2012 and 2014 base case EGU emissions projections of SO_2, and NO_X were obtained using Version 4.10 Final of the Integrated Planning Model (IPM) (http://www.epa.gov/airmarkt/progsregs/epa-ipm/index.html). The IPM is a multiregional, dynamic, deterministic linear programming model of the U.S. electric power sector. Version 4.10 Final reflects state rules and consent decrees through December 1, 2010, information obtained from the 2010 Information Collection Request (ICR), and information from comments received on the IPM-related Notice of Data Availability (NODA) published on September 1, 2010. Notably, IPM 4.1 Final included the addition of over 20 GW of existing Activated Carbon Injection (ACI) for coal-fired EGUs reported to EPA via the ICR. Additional unit-level updates that identified existing pollution controls (such as scrubbers) were also made based on the ICR and on comments from the IPM NODA. Units with SO_2 or NO_X advanced controls (e.g., scrubber, SCR) that were not required to run for compliance with Title IV, New Source Review (NSR), state settlements, or state-specific rules were modeled by IPM to either operate those controls or not based on economic efficiency parameters.

Additionally, IPM v4.1 Final corrected a natural gas emission factor responsible for an over-prediction in $PM_{2.5}$ emissions of 85 thousand tons from the EGU sector. Other updates includes adjustments to assumptions regarding the performance of acid gas control technologies, new costs imposed on fuel-switching (e.g., bituminous to sub-bituminous), correction of lignite availability to some plants, incorporation of additional planned retirements, a more inclusive implementation of the scrubber upgrade option, and the availability of a scrubber retrofit to waste-coal fired fluidized bed combustion units without an existing scrubber. Further details on the future year EGU emissions inventory used for this rule can be found in the IPM v.4.10 Documentation, available at http://www.epa.gov/airmarkt/progsregs/epa-ipm/index.html. Note that the Transport Rule future year base cases do not include the Toxics Rule, which was proposed on March 16, 2011. In addition, the Boiler MACT was not represented in the final Transport Rule modeling because the rule was not final at the time the modeling was performed.

Mobile source inventories of onroad and nonroad mobile emissions were created for 2012 and 2014 using a combination of the NMIM and MOVES models in a consistent approach with the 2005 base year. As with the 2005 emissions, the 2012 and 2014 onroad emissions were based on MOVES2010 emissions provided at the state-month resolution that were then allocated to counties using NMIM emissions values. Future-year vehicle miles travelled (VMT) were projected from the 2005 NEI v2 VMT using growth rates from the 2009 Annual Energy Outlook (AEO) data. The same MOVES-based $PM_{2.5}$ temperature adjustment factors were applied as in 2005 for running mode emissions because these are not dependent on year; however, cold start emissions used year-specific temperature adjustment factors. The 2012 and 2014 onroad emissions reflect control program implementation through 2012 and 2014 and include the Light-Duty Vehicle Tier 2 Rule, the Onroad Heavy-Duty Rule, and the Mobile Source Air Toxics (MSAT) final rule. Emission reductions and increases from the Renewable Fuel Standard version 2 (RFS2) are not reflected because they do not take effect until later years.

Nonroad mobile emissions were created only with NMIM using a consistent approach as was used for 2005, but using NMIM future-year equipment population estimates and control programs for 2015 and 2012 using national level inputs. Year 2014 emissions were created by interpolating 2012 and 2015 emissions. Emissions for locomotives and category 1 and 2 (C1 and C2) commercial marine vessels were derived for 2012 and 2014 based on emissions published in the Final Locomotive Marine Rule, Regulatory Impact Assessment, Chapter 3 (see http://www.epa.gov/otaq/locomotives.htm#2008final).

The future baseline nonroad mobile emissions reductions include reductions to locomotives, various nonroad engines including diesel engines and various marine engine types, fuel sulfur content, and evaporative emissions standards, including the category 3 marine diesel engines and International Maritime Organization standards which include the establishment of emission control areas for these ships. A summary of the mobile source control programs included in the projected future year baseline is shown in Table 3-5.

Table 3-5. Summary of Mobile Source Control Programs Included in 2014 Baseline

National Onroad Rules:
Tier 2 Rule (*Signature date:* February 28, 2000)
Onroad Heavy-Duty Rule (February 24, 2009)
Final Mobile Source Air Toxics Rule (MSAT2) (February 9, 2007)
Renewable Fuel Standard (March 26, 2010)
Local Onroad Programs:
National Low Emission Vehicle Program (NLEV) (March 2, 1998)
Ozone Transport Commission (OTC) LEV Program (January, 1995)
National Nonroad Controls:
Tier 1 nonroad diesel rule (June 17, 2004)
Phase 1 nonroad SI rule (July 3, 1995)
Marine SI rule (October 4, 1996)
Nonroad diesel rule (October 23, 1998)
Phase 2 nonroad nonhandheld SI rule (March 30, 1999)
Phase 2 nonroad handheld SI rule (April 25, 2000)
Nonroad large SI and recreational engine rule (November 8, 2002)
Clean Air Nonroad Diesel Rule - Tier 4 (June 29, 2004)
Locomotive and marine rule (May 6, 2008)
Nonroad SI rule (October 8, 2008)
Aircraft:
Itinerant (ITN) operations at airports adjusted to years 2012 and 2014
Locomotives:
Clean Air Nonroad Diesel Final Rule – Tier 4 (June 29, 2004)
Locomotive rule (April 16, 2008)
Locomotive and marine rule (May 6, 2008)
Commercial Marine:
Locomotive and marine rule (May 6, 2008)
Category 3 marine diesel engines Clean Air Act and International Maritime Organization standards (April, 30, 2010)

For non-EGU point sources, emissions were projected by including emissions reductions and increases from a variety of source data.[14] For non-EGU point sources, other than for certain large municipal waste combustors and airports, emissions were not grown using economic growth projections, but rather were held constant at the emissions levels in 2005. Emissions reductions were applied to non-EGU point source to reflect final federal measures, known plant closures, refinery and other consent decrees. The starting point was the emission projections done for the 2005v4 platform for the proposed Transport Rule. The 2012 and 2014 projection factors developed for the Transport Rule proposal (see http://www.epa.gov/ttn/chief/emch/index.html#transport) were updated for these 2012 and 2014 baseline projections. Several additional NESHAP were promulgated since emission projections were done for the proposed Transport Rule, and these were included for the 2012 and 2014 base cases. Emission reductions were also applied to include local controls for NO_X and VOC from the New York State Implementation Plan (SIP) as part of another effort; we do not anticipate that this change significantly impacts the results of this RIA, which are primarily resulting from changes to SO_2 and $PM_{2.5}$.

Since aircraft at airports were treated as point emissions sources in the 2005 NEI v2, we applied projection factors based on activity growth projected by the Federal Aviation Administration Terminal Area Forecast (TAF) system, published December 2008 for these sources.

Emissions from stationary nonpoint sources were projected using procedures specific to individual source categories. Refueling emissions were projected using the refueling results from the NMIM runs performed for the onroad mobile sector. Portable fuel container emissions were projected using estimates from previous rulemaking inventories compiled by the Office of Transportation and Air Quality (OTAQ). Emissions of ammonia and dust from animal operations were projected based on animal population data from the Department of Agriculture and EPA. Residential wood combustion was projected by replacement of obsolete woodstoves with new woodstoves and a 1 percent annual increase in fireplaces. Landfill emissions were projected using MACT controls. In addition, many of the NY SIP controls applied to nonpoint categories and were included in the projection. All other nonpoint sources were held constant between 2005 and the 2014 future year scenarios.

[14] Controls from the NO_X SIP call were assumed to have been in place by 2005 and captured in the 2005 NEI v2.

A summary of all rules and growth assumptions impacting non-EGU stationary sources is provided in Table 3-6. The table is broken out into two sections: (1) the approaches used to project emissions for the proposed Transport Rule that were carried forward for the final Transport Rule and (2) the added controls/reductions used for the final Transport rule that had not been used for the proposed Transport rule.

Table 3-6. Control Strategies and/or Growth Assumptions Included in the 2012 and 2014 Projection for Non EGU Stationary Sources

Control Strategies and/or Growth Assumptions Applied to 2005 emissions for the 2014 projection	
Projection Approaches Carried Forward from the Proposed Transport Rule	
MACT rules, national, VOC: national applied by SCC, MACT	VOC
Consent Decrees and Settlements, including refinery consent decrees, and settlements for: Alcoa, TX and Premcor (formerly MOTIVA), DE	All
Municipal Waste Combustor Reductions –plant level	PM
Hazardous Waste Combustion	PM
Hospital/Medical/Infectious Waste Incinerator Regulations	NOx, PM, SO_2
Large Municipal Waste Combustors – growth applied to specific plants	All
MACT rules, plant-level, VOC: Auto Plants	VOC
MACT rules, plant-level, PM & SO2: Lime Manufacturing	PM, SO_2
MACT rules, plant-level, PM: Taconite Ore	PM
Municipal Waste Landfills: project factor of 0.25 applied	All
Livestock Emissions Growth from year 2002 to years 2012 and 2014	NH3, PM
Residential Wood Combustion Growth and Change-outs from years 2005 to years 2012 and 2014	All
Gasoline Stage II growth and control from year 2005 to year 2014	VOC
Portable Fuel Container Mobile Source Air Toxics Rule 2: inventory growth and control from year 2005 to years 2012 and 2014	VOC
Additional Projection Approaches For the Final Transport Rule	
NESHAP: Portland Cement (09/09/10) – plant level based **on Industrial Sector Integrated Solutions (ISIS)** policy emissions in 2013. The ISIS results are from the ISIS-Cement model runs for the NESHAP and NSPS analysis of July 28, 2010 and include closures. For year 2012, only known closures and new units through year 2009 were included; ISIS-based future year projections were not included.	Hg, NO_X, SO2, PM, HCL
NESHAP: Industrial, Commercial, Institutional (ICI) Boilers, aka “Boiler MACT” (signed 02/21/2011)	Hg, SO_2, HCL, PM
New York ozone SIP standards	VOC, HAP VOC, NO_X
Additional Plant and Unit closures provided by state, regional, and EPA agencies	All
Emission Reductions resulting from controls put on specific boiler units (not due to MACT) after 2005, identified through analysis of the control data gathered from the ICR from the ICI Boiler NESHAP.	NO_X, SO_2, HCL
NESHAP: Reciprocating Internal Combustion Engines (RICE). SO2 controls for RICE were not effective until after 2012, but are applied in 2014.	NO_X, CO, PM, SO2
Use Phase II WRAP 2018 Oil and Gas, and apply RICE controls to these emissions	VOC, SO_2, NO_X, CO
Use 2008 Oklahoma and Texas Oil and Gas, and apply RICE controls to these emissions	VOC, SO_2, NO_X, CO, PM
State fuel sulfur content rules for fuel oil –effective in 2014 only in Maine and New York	SO2

In all future year cases, we used the 2005 base year emissions for Canada and Mexico because appropriate future-year emissions for sources in these countries were not available. The future-year emissions need to reflect expected percent reductions or increases between the base year and the future year to be considered appropriate for this type of modeling.

Table 3-7 shows a summary of the 2005 and 2014 modeled base case emissions for the sum of the lower 48 states. Tables 3-8 and 3-9 below provide summaries of SO_2 and NO_X in the 2014 base case for each sector by state. The 2012 emissions are not presented here because they were not considered as part of the RIA. For details on the 2012 emissions, see the Emissions Inventory TSD.

Table 3-7. Summary of Modeled Base Case Annual Emissions (tons/year) for 48 States by Sector: SO_2 and NO_X

Source Sector SO_2 Emissions	**2005**	**2014**
EGU Point	10,380,883	7,159,569
Non-EGU Point	2,082,159	1,643,061
Nonpoint	1,216,362	1,126,861
Nonroad	447,895	74,180
On-road	177,977	26,022
Average Fire	49,094	49,094
Total SO_2, All Sources	**14,354,370**	**10,078,786**
Source Sector NO_X Emissions	**2005**	**2014**
EGU Point	3,729,161	2,089,422
Non-EGU Point	2,226,250	2,021,334
Nonpoint	1,696,902	1,628,712
Nonroad	4,168,294	3,049,397
On-road	9,142,274	4,946,217
Average Fire	189,428	189,428
Total NO_X, All Sources	**21,152,309**	**13,924,510**

Table 3-8. 2014 Base Case SO_2 Emissions (tons/year) for States by Sector

State	EGU*	NonEGU	Nonpoint	Nonroad	Onroad	Fires	Total
Alabama	417,340	63,152	52,200	523	502	983	534,700
Arizona	35,601	24,180	2,478	51	593	2,888	65,792
Arkansas	99,411	12,163	26,723	296	279	728	139,599
California	7,350	21,979	67,943	13,111	2,150	6,735	119,268
Colorado	62,105	1,403	6,446	47	507	1,719	72,227
Connecticut	3,774	1,831	18,200	538	271	4	24,618
Delaware	2,172	4,917	1,024	1,116	77	6	9,311
District of Columbia	0	686	1,505	3	35	0	2,230
Florida	143,601	49,057	69,968	8,754	1,835	7,018	280,233
Georgia	170,288	44,228	55,848	886	1,071	2,010	274,332
Idaho	182	17,132	2,906	21	162	3,845	24,248
Illinois	141,606	111,567	5,231	600	1,008	20	260,031
Indiana	727,786	75,715	59,453	288	656	24	863,923
Iowa	133,083	45,804	19,437	115	283	25	198,747
Kansas	69,819	10,749	36,072	56	251	103	117,050
Kentucky	488,005	23,838	33,873	580	426	364	547,085
Louisiana	118,230	131,620	2,372	8,073	391	892	261,579
Maine	2,355	14,345	3,234	429	128	150	20,642
Maryland	42,926	33,557	40,688	2,386	500	32	120,089
Massachusetts	13,364	17,350	24,990	1,631	485	93	57,914
Michigan	269,434	48,697	42,028	2,887	899	91	364,035
Minnesota	70,937	25,048	14,433	563	488	631	112,099
Mississippi	30,972	24,405	6,593	812	323	1,051	64,156
Missouri	390,287	75,587	44,543	425	636	186	511,664
Montana	15,447	7,505	2,179	24	102	1,422	26,678
Nebraska	73,073	4,776	7,615	55	176	105	85,799
Nevada	14,416	2,120	12,027	25	177	1,346	30,112
New Hampshire	6,453	2,470	7,282	32	117	38	16,391
New Jersey	38,856	6,740	10,574	4,576	648	61	61,455
New Mexico	11,857	8,042	2,905	23	229	3,450	26,507
New York	42,887	45,206	71,141	2,677	1,277	113	163,302
North Carolina	126,048	58,499	21,675	948	786	696	208,652
North Dakota	103,633	9,678	5,912	34	61	66	119,385
Ohio	851,199	93,846	19,591	1,334	946	22	966,938
Oklahoma	137,981	29,033	7,503	50	423	469	175,459
Oregon	11,336	9,792	9,710	1,081	359	4,896	37,175
Pennsylvania	509,649	64,926	67,696	2,013	961	32	645,278
Rhode Island	0	2,743	3,340	230	70	1	6,385
South Carolina	213,281	28,534	13,275	2,044	451	646	258,231
South Dakota	29,711	1,947	10,201	22	75	498	42,453
Tennessee	284,468	60,476	32,634	349	674	277	378,878
Texas	453,332	133,219	108,505	6,061	2,016	1,178	704,311
Tribal	0	677	0	0	0	0	677
Utah	33,498	6,757	3,449	25	285	1,934	45,947
Vermont	263	901	5,307	7	86	49	6,614
Virginia	77,256	50,378	32,434	1,407	737	399	162,611
Washington	3,430	20,157	6,976	6,463	630	407	38,062
West Virginia	498,507	33,356	14,294	169	159	215	546,702

State	EGU*	NonEGU	Nonpoint	Nonroad	Onroad	Fires	Total
Wisconsin	130,538	61,097	6,226	327	537	70	198,795
Wyoming	51,817	21,174	6,221	17	85	1,106	80,419
Total	**7,159,569**	**1,643,061**	**1,126,861**	**74,180**	**26,022**	**49,094**	**10,078,786**

* Emission estimates apply to all fossil Electric Generating Units, including those with capacity < 25MW

Table 3-9. 2014 Base Case NO_X Emissions (tons/year) for States by Sector

State	EGU	NonEGU	Nonpoint	Nonroad	Onroad	Fires	Total
Alabama	76,012	72,271	31,836	44,834	93,207	3,814	321,975
Arizona	35,616	13,283	8,476	43,525	137,141	10,532	248,574
Arkansas	36,347	32,253	20,464	45,075	56,878	2,654	193,670
California	26,874	84,169	116,422	303,640	386,587	24,563	942,254
Colorado	49,381	19,256	41,872	35,819	84,697	6,271	237,296
Connecticut	2,854	5,823	12,264	14,257	45,574	14	80,787
Delaware	1,701	3,675	2,194	10,177	13,959	23	31,729
District of Columbia	0	501	1,687	2,402	5,183	0	9,773
Florida	100,581	50,044	28,826	143,368	289,809	25,600	638,227
Georgia	49,411	48,274	37,840	63,607	196,604	7,955	403,691
Idaho	608	9,687	30,152	15,964	31,275	14,024	101,710
Illinois	55,269	79,963	46,835	153,821	210,508	71	546,467
Indiana	117,832	63,444	29,359	76,941	143,678	88	431,342
Iowa	48,400	35,331	14,679	66,475	58,415	90	223,390
Kansas	32,637	62,469	41,859	62,453	48,897	378	248,692
Kentucky	83,544	33,996	17,084	67,238	91,074	1,326	294,262
Louisiana	31,573	150,460	26,054	179,194	75,553	3,254	466,089
Maine	5,402	15,199	7,236	8,117	25,137	566	61,657
Maryland	17,566	23,288	21,396	32,179	87,342	137	181,909
Massachusetts	6,992	17,789	33,333	31,258	85,562	341	175,275
Michigan	67,705	78,719	42,524	73,231	186,832	330	449,343
Minnesota	41,474	63,653	56,230	85,182	96,643	2,300	345,483
Mississippi	26,294	49,191	11,818	59,663	65,639	3,833	216,438
Missouri	57,318	43,918	32,195	89,795	133,942	678	357,846
Montana	19,399	5,253	13,619	28,847	20,418	5,187	92,723
Nebraska	45,047	10,719	14,117	76,764	39,379	381	186,408
Nevada	14,074	15,149	5,295	19,478	22,135	4,910	81,041
New Hampshire	5,126	1,939	11,072	6,587	22,776	137	47,637
New Jersey	8,006	18,996	25,749	54,659	102,495	223	210,127
New Mexico	64,745	40,746	63,420	32,645	50,276	12,582	264,414
New York	21,689	52,969	86,472	82,154	215,392	412	459,087
North Carolina	49,322	44,759	18,341	53,665	144,033	11,424	321,544
North Dakota	53,265	7,328	9,237	43,482	13,573	240	127,125
Ohio	104,149	62,913	40,188	122,508	192,610	81	522,450
Oklahoma	66,966	68,904	70,100	40,079	80,924	1,709	328,683
Oregon	9,584	22,516	16,786	49,681	62,899	17,857	179,324
Pennsylvania	134,092	76,430	52,492	84,800	181,742	117	529,673
Rhode Island	442	2,179	2,923	3,408	9,853	4	18,808

State	EGU	NonEGU	Nonpoint	Nonroad	Onroad	Fires	Total
South Carolina	39,018	26,467	17,433	35,050	84,063	2,357	204,389
South Dakota	14,270	4,862	5,623	22,105	16,820	1,817	65,498
Tennessee	29,276	49,126	18,184	60,111	144,394	1,012	302,103
Texas	142,087	249,562	286,315	256,684	433,197	4,890	1,372,735
Tribal	11	13,126	0	0	0	0	13,137
Utah	67,434	18,314	13,321	18,845	45,873	7,052	170,840
Vermont	455	802	3,383	2,771	15,234	179	22,824
Virginia	40,469	50,895	52,600	56,304	132,997	1,456	334,720
Washington	13,322	22,726	16,303	86,529	108,957	1,484	249,322
West Virginia	64,824	30,195	13,847	24,369	32,074	785	166,094
Wisconsin	40,750	39,141	21,569	54,245	106,241	256	262,201
Wyoming	70,207	28,659	37,687	25,412	17,725	4,035	183,726
Total	**2,089,422**	**2,021,334**	**1,628,712**	**3,049,397**	**4,946,217**	**189,428**	**13,924,510**

3.4 Development of Future Year Control Case Emissions for Air Quality Modeling

For the future year control case (policy case) air quality modeling, the emissions for all sectors were unchanged from the base case modeling except for those from EGUs. The IPM model was used to prepare the 2014 policy case (i.e., the final Transport Rule) for EGU emissions as described in the IPM v.4.10 Documentation, available at http://www.epa.gov/airmarkt/progsregs/epa-ipm/index.html. As with the base case projections, photochemical modeling of the policy case is based on IPM v.4.10 Final. The changes in EGU SO_2, and NOx emissions as a result of the policy case for the lower 48 states are summarized in Table 3-10. State-specific summaries of EGU SO_2 and NO_X for the sum of the lower 48 states are shown in Tables 3-11 and 3-12, respectively.

Table 3-10. Summary of Emissions Changes for the Transport Rule in the Lower 48 States

2014 EGU Emissions	**SO2**	**NO_X**
Base Case EGU Emissions (tons)	7,159,569	2,089,422
Control EGU Emissions (tons)	3,356,577	1,890,590
Reductions to Base Case in Control Case (tons)	3,802,991	198,832
Percentage Reduction of Base EGU Emissions	53%	10%
Total 2014 Man-made Emissions*		
Total Base Case Emissions (tons)	10,078,786	13,924,510
Total Control Case Emissions (tons)	6,275,795	13,725,678
Percentage Reduction of All Man-made Emissions	37.7%	1.4%
* In this table, man-made emissions includes average fires.		

Table 3-11. State Specific Changes in Annual EGU SO_2 for the Lower 48 States

State	2014 Base Case SO2 (tons)	2014 Policy Case SO2 (tons)	EGU SO2 reduction (tons)	EGU SO2 reduction (%)
Alabama	417,340	173,566	243,775	58%
Arizona	35,601	35,601	0	0%
Arkansas	99,411	106,685	-7,274	-7%
California	7,350	7,350	0	0%
Colorado	62,105	73,858	-11,753	-19%
Connecticut	3,774	3,883	-109	-3%
Delaware	2,172	2,172	0	0%
District of Columbia	0	0	0	-
Florida	143,601	148,069	-4,468	-3%
Georgia	170,288	93,208	77,080	45%
Idaho	182	182	0	0%
Illinois	141,606	132,647	8,959	6%
Indiana	727,786	195,046	532,740	73%
Iowa	133,083	83,827	49,256	37%
Kansas	69,819	45,740	24,078	34%
Kentucky	488,005	116,927	371,078	76%
Louisiana	118,230	139,204	-20,973	-18%
Maine	2,355	2,355	0	0%
Maryland	42,926	30,368	12,558	29%
Massachusetts	13,364	13,363	1	0%
Michigan	269,434	162,632	106,802	40%
Minnesota	70,937	49,622	21,315	30%
Mississippi	30,972	32,109	-1,137	-4%
Missouri	390,287	186,899	203,388	52%
Montana	15,447	22,826	-7,379	-48%
Nebraska	73,073	71,339	1,734	2%
Nevada	14,416	14,416	0	0%
New Hampshire	6,453	6,742	-289	-4%
New Jersey	38,856	6,243	32,614	84%
New Mexico	11,857	13,926	-2,068	-17%
New York	42,887	15,160	27,727	65%

State	2014 Base Case SO2 (tons)	2014 Policy Case SO2 (tons)	EGU SO2 reduction (tons)	EGU SO2 reduction (%)
North Carolina	126,048	69,377	56,670	45%
North Dakota	103,633	103,624	9	0%
Ohio	851,199	178,975	672,224	79%
Oklahoma	137,981	138,072	-91	0%
Oregon	11,336	11,336	0	0%
Pennsylvania	509,649	125,545	384,105	75%
Rhode Island	0	0	0	-
South Carolina	213,281	100,788	112,494	53%
South Dakota	29,711	29,711	0	0%
Tennessee	284,468	64,721	219,747	77%
Texas	453,332	266,648	186,685	41%
Tribal	0	0	0	-
Utah	33,498	33,968	-469	-1%
Vermont	263	263	0	0%
Virginia	77,256	51,144	26,112	34%
Washington	3,430	3,430	0	0%
West Virginia	498,507	84,344	414,163	83%
Wisconsin	130,538	50,137	80,401	62%
Wyoming	51,817	58,530	-6,714	-13%
Total	**7,159,569**	**3,356,577**	**3,802,991**	**53%**

Table 3-12. State Specific Changes in Annual EGU NO_X for the Lower 48 States

State	2014 Base Case NO_X (tons)	2014 Policy Case NO_X (tons)	EGU NO_X reduction (tons)	EGU NO_X reduction (%)
Alabama	76,012	69,192	6,820	9%
Arizona	35,616	35,613	4	0%
Arkansas	36,347	37,640	-1,293	-4%
California	26,874	26,776	97	0%
Colorado	49,381	49,331	50	0%
Connecticut	2,854	2,860	-6	0%
Delaware	1,701	1,717	-15	-1%
District of Columbia	0	0	0	-
Florida	100,581	78,508	22,073	22%
Georgia	49,411	41,484	7,927	16%
Idaho	608	608	0	0%
Illinois	55,269	49,162	6,107	11%
Indiana	117,832	110,740	7,092	6%
Iowa	48,400	42,231	6,169	13%

State	2014 Base Case NO_X (tons)	2014 Policy Case NO_X (tons)	EGU NO_X reduction (tons)	EGU NO_X reduction (%)
Kansas	32,637	24,328	8,308	25%
Kentucky	83,544	76,088	7,456	9%
Louisiana	31,573	31,582	-9	0%
Maine	5,402	5,402	0	0%
Maryland	17,566	17,190	375	2%
Massachusetts	6,992	7,033	-41	-1%
Michigan	67,705	60,907	6,798	10%
Minnesota	41,474	34,429	7,045	17%
Mississippi	26,294	26,080	214	1%
Missouri	57,318	52,103	5,216	9%
Montana	19,399	19,303	96	0%
Nebraska	45,047	28,211	16,836	37%
Nevada	14,074	14,050	24	0%
New Hampshire	5,126	4,971	156	3%
New Jersey	8,006	7,720	286	4%
New Mexico	64,745	64,833	-88	0%
New York	21,689	20,528	1,160	5%
North Carolina	49,322	45,008	4,314	9%
North Dakota	53,265	53,267	-2	0%
Ohio	104,149	89,753	14,396	14%
Oklahoma	66,966	44,143	22,823	34%
Oregon	9,584	9,632	-48	0%
Pennsylvania	134,092	118,981	15,110	11%
Rhode Island	442	442	0	0%
South Carolina	39,018	36,747	2,271	6%
South Dakota	14,270	14,273	-3	0%
Tennessee	29,276	20,512	8,764	30%
Texas	142,087	137,964	4,123	3%
Tribal	11	11	0	0%
Utah	67,434	67,434	0	0%
Vermont	455	455	0	0%
Virginia	40,469	39,734	735	2%
Washington	13,322	13,322	0	0%
West Virginia	64,824	53,975	10,849	17%
Wisconsin	40,750	33,537	7,212	18%
Wyoming	70,207	70,778	-571	-1%
Total	**2,089,422**	**1,890,590**	**198,832**	**10%**

CHAPTER 4

AIR QUALITY MODELING AND IMPACTS

4.1 Air Quality Impacts

This section summarizes the methods for and results of estimating air quality for the 2014 base case and control scenario for the purposes of the benefit analysis. EPA has focused on the health, welfare, and ecological effects that have been linked to air quality changes. These air quality changes include the following:

1. Ambient fine particulate matter ($PM_{2.5}$) and ground-level ozone (O_3)–as estimated using a national-scale applications of the Comprehensive Air Quality Model with Extensions (CAMx; Environ, 2010);

2. Visibility degradation (i.e., regional haze), as developed using empirical estimates of light extinction coefficients and efficiencies in combination with CAMx modeled reductions in pollutant concentrations.

The air quality estimates in this section are based on the emission changes summarized in the preceding section. These air quality results are in turn associated with human populations and ecosystems to estimate changes in health and welfare effects. In Section 4.1.1, we describe the air quality modeling platform and in Section 4.2, we cover the impacts on $PM_{2.5}$ and ozone. Lastly, in Section 4.3, we discuss the estimation of visibility degradation.

4.1.1 Air Quality Modeling Platform

We use the emissions inputs summarized above with national scale and regional scale application of the CAMx modeling system to estimate $PM_{2.5}$ and ozone air quality in the contiguous U.S. CAMx is a three-dimensional grid-based Eulerian photochemical model designed to estimate $PM_{2.5}$ and ozone concentrations over annual time periods. Consideration of the different processes that affect primary (directly emitted) and secondary (formed by atmospheric processes) $PM_{2.5}$ in different locations is fundamental to understanding and assessing the effects of pollution control measures that affect $PM_{2.5}$ and ozone concentrations at the surface.[15] Because it accounts for spatial and temporal variations as well as differences in the reactivity of emissions, CAMx is useful for evaluating the impacts of the rule on $PM_{2.5}$ and ozone concentrations. Version 5.3 of CAMx was employed for this Transport Rule modeling, as described in the Air Quality Modeling Technical Support Document (EPA, 2011).

For this analysis we used CAMx to simulate air quality for every hour of every day of the year. These model applications required a variety of input files that contain information pertaining to the modeling domain and simulation period. In addition to the CAMx model, our modeling system includes (1) emissions for a 2005 base year and emissions for the 2014 base case and control scenario, (2) meteorology for the year 2005, and (3) estimates of intercontinental transport (i.e., boundary concentrations) from a global photochemical model. Using these data, CAMx generates hourly predictions of ozone and $PM_{2.5}$ component species concentrations. As discussed in the Air Quality Modeling TSD, we use the relative predictions from the model by combining the 2005 base-year and each future-year scenario with speciated ambient air quality observations to determine the expected change in 2014 concentrations due to the rule. After completing this process, we then calculated annual mean $PM_{2.5}$ and seasonal mean ozone air quality metrics as inputs to the health and welfare C-R functions of the benefits analysis.

4.1.1.1 Simulation Periods

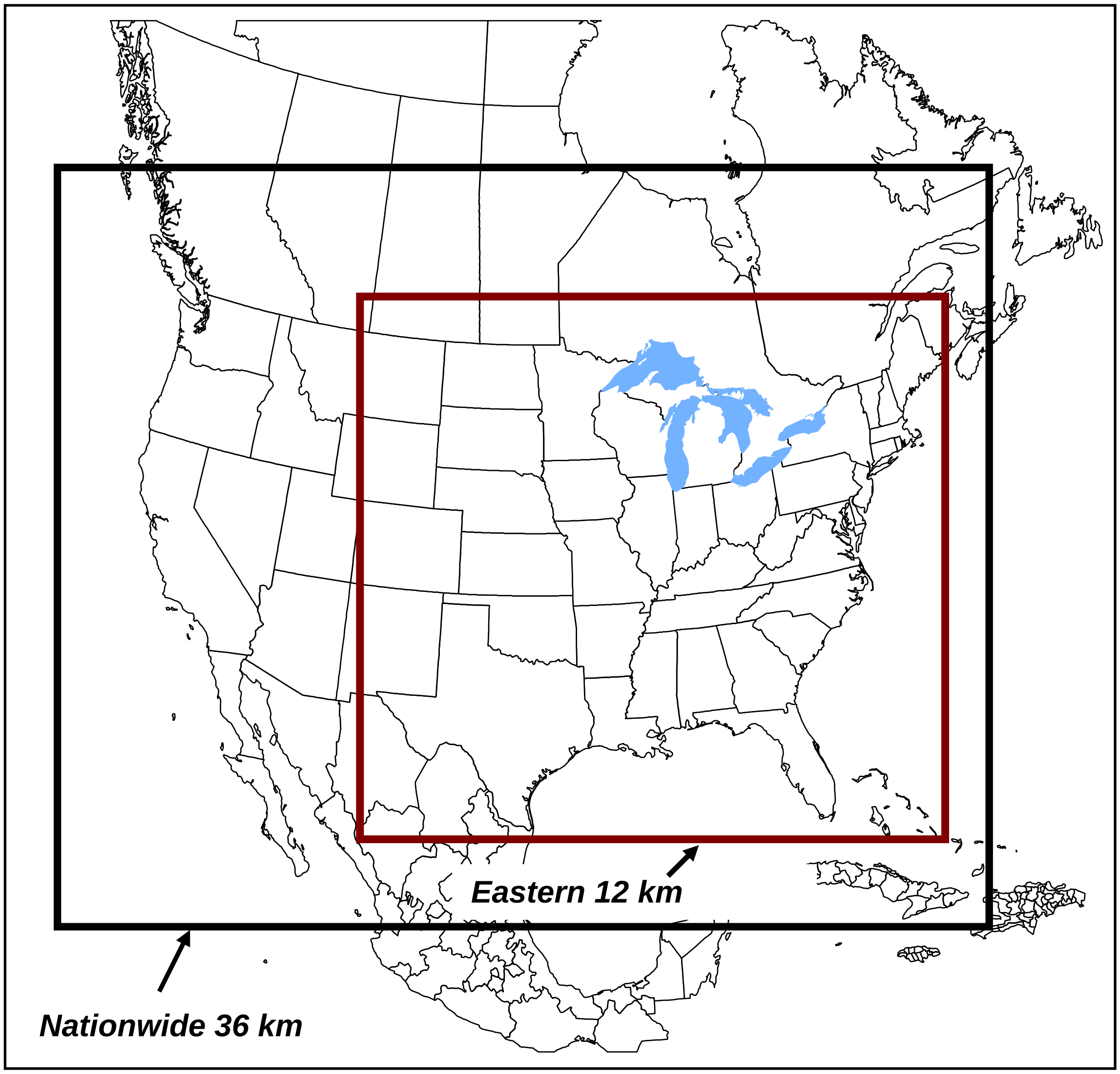
For use in this benefits analysis, the simulation period modeled by CAMx included separate full-year application for each of the three emissions scenarios (i.e., 2005 base year and the 2014 base case and 2014 control scenario).

4.1.1.2 Air Quality Modeling Domain

[15]Given the focus of this rule on secondarily formed particles it is important to employ a Eulerian model such as CAMx. The impact of secondarily formed pollutants typically involves primary precursor emissions from a multitude of widely dispersed sources, and chemical and physical processes of pollutants are best addressed using an air quality model that employs an Eulerian grid model design.

Although air quality estimate are provided for the entire U.S., the focus of our analysis is on the Eastern U.S. since this is the geographic area of importance for this rule. The areas modeled (i.e., modeling domains) are segmented into rectangular blocks referred to as grid cells. The model actually predicts pollutant concentrations for each of these grid cells. Our modeling for the East (referred to as the Eastern regional scale domain) was performed at a horizontal resolution of 12 x 12 km. Modeling for the remainder of the U.S. (referred to as the national scale domain) was performed at a resolution of 36 x 36 km. The national and regional scale modeling domains contain 14 vertical layers with the top of the modeling domain at about 16,200 meters, or approximately 100 mb. The Eastern domain is nested within the National domain, as shown in Figure 4-1.

Figure 4-1. National and Eastern U.S. air quality modeling domains.



4.1.1.3 Air Quality Model Inputs

CAMx requires a variety of input files that contain information pertaining to the modeling domain and simulation period. These include gridded, hourly emissions estimates and meteorological data, and initial and boundary conditions. Separate emissions inventories were prepared for the 2005 base year and each future-year scenario. All other inputs were specified for the 2005 base year model application and remained unchanged for each future-year modeling scenario.

CAMx requires detailed emissions inventories containing temporally allocated emissions for each grid-cell in the modeling domain for each species being simulated. The previously described annual emission inventories were preprocessed into model-ready inputs through the SMOKE emissions preprocessing system. Meteorological inputs reflecting 2005 conditions across the contiguous U.S. were derived from Version 5 of the Mesoscale Model (MM5). These inputs included horizontal wind components (i.e., speed and direction), temperature, moisture, vertical diffusion rates, and rainfall rates for each grid cell in each vertical layer. Details of the annual 2005 MM5 modeling are provided in the Air Quality Modeling TSD.

The lateral boundary and initial species concentrations are provided by a three-dimensional global atmospheric chemistry and transport model (GEOS-CHEM). The lateral boundary species concentrations varied with height and time (every 3 hours). Terrain elevations and land use information were obtained from the U.S. Geological Survey database at 10 km resolution and aggregated to the roughly 36 km horizontal resolution used for this CAMx application. The development of model inputs is discussed in greater detail in the Air Quality Modeling TSD, which is available in the docket for this rule.

4.2 Results for $PM_{2.5}$ and Ozone

4.2.1 Converting CAMx $PM_{2.5}$ Outputs to Benefits Inputs

CAMx generates predictions of hourly $PM_{2.5}$ species concentrations for every grid. The species include a primary fraction and several secondary particles (e.g., sulfates, nitrates, and organics). $PM_{2.5}$ is calculated as the sum of the primary and the secondary formed particles. Future-year estimates of $PM_{2.5}$ were calculated using relative reduction factors (RRFs) applied to 2005 ambient $PM_{2.5}$ species concentrations. Gridded fields of species concentrations were created by interpolating ambient data from the $PM_{2.5}$ speciation network and IMPROVE data. The ambient data were interpolated to the 36 km and 12 km grid resolutions.

The procedures for determining the RRFs are similar to those in EPA guidance for modeling the $PM_{2.5}$ standard (EPA, 2007). This guidance recommends that model predictions be used in a relative sense to estimate changes expected to occur in each $PM_{2.5}$ species. The procedure for calculating future year $PM_{2.5}$ values is called the Modeled Attainment Test Software (MATS). EPA used this procedure to estimate the ambient impacts of the Transport Rule emissions controls. For the purposes of projecting future $PM_{2.5}$ concentrations for input to the benefits calculations, we applied the MATS procedure using the base year 2005 modeling results and each of the results from each of the 2014 base case and 2014 control scenario.   In our application of MATS for $PM_{2.5}$ we used temporally scaled speciated $PM_{2.5}$ monitoring data from 2005 as the set of base-year measured concentrations. Temporal scaling is based on the ratios of model-predicted future case $PM_{2.5}$ species concentrations to the corresponding model-predicted 2005 concentrations. Output files from this process include both quarterly and annual mean $PM_{2.5}$ mass concentrations which are then manipulated within SAS to produce a BenMAP input file containing 364 daily values (created by replicating the quarterly mean values for each day of the appropriate season).

The MATS procedures documented in the Air Quality Modeling TSD are applicable for projecting future nonattainment and maintenance sites and downwind receptor areas for the transport analysis. Those procedures are similar as those performed for the PM benefits analysis in Chapter 5 with the following exceptions:

1) The benefits analysis uses interpolated $PM_{2.5}$ data that cover all of the grid cells in the modeling domain, whereas the nonattainment analysis is performed at each ambient monitoring site using measured $PM_{2.5}$ data (only the species data are interpolated).

2) The benefits analysis is anchored by the interpolated $PM_{2.5}$ data from the single year of 2005, whereas the nonattainment analysis uses design values from three, 3-year periods (i.e., 2003-2005, 2004-2006, and 2005-2007) at individual monitoring sites.

4.2.2 $PM_{2.5}$ Air Quality Results

Table 4-1 summaries the projected ambient $PM_{2.5}$ concentrations for the 2014 base case and 2014 impacts associated with rule. This table includes the annual mean concentrations averaged across all model grid cells in the East along with the average change between the 2014 base and control concentrations. We also provide the population-weighted average that better reflects the baseline levels and predicted changes for more populated areas of the East. This measure, therefore better reflects the potential benefits of these predicted changes through exposure changes to the affected populations. As shown, the average annual mean concentrations of $PM_{2.5}$ across populated areas of the East declines by roughly 9 percent (or 0.6 μg/m^3) in 2014. The population-weighted average mean concentration declined by 9 percent (or 0.87 μg/m^3) in 2014. This indicates the rule generates greater absolute air quality improvements in more populated, urban areas.

Table 4-1. Summary of Base Case $PM_{2.5}$ Air Quality and Changes Due to the Transport Rule.

Statistic	2014 Base Case	2014 Control Case	2014 Percent Change[a]
$PM_{2.5}$ (μg/m^3)			
Minimum Annual Mean	1.84	1.84	0%
Maximum Annual Mean	19	19	0%
Average Annual Mean	7.3	6.7	9%
Pop-Weighted Average Annual Mean [b]	9.95	9.08	9%

[a] The percent change is defined as the control case value minus the base case value multiplied by 100. A negative value denotes an increase in $PM_{2.5}$ concentration.

[b] Calculated by summing the product of the projected CAMx grid-cell population and the estimated concentration, for that grid-cell and then dividing by the total population.

Table 4-2 provides information on the populations in 2014 that will experience improved PM air quality. Significant populations that live in areas with meaningful reductions in annual mean $PM_{2.5}$ concentrations resulting from the rule. As shown, in 2014, about 12percent of the U.S. population located in the modeling domain are predicted to experience reductions of greater than 1.75 µg/m^3. Furthermore, nearly 30 percent of this population will benefit from reductions in annual mean $PM_{2.5}$ concentrations of greater than 1.25 µg/m^3 and 68 percent will live in areas with reductions of greater than 0.5µg/m^3**.**

Table 4-2. Distribution of $PM_{2.5}$ Air Quality Improvements Over Population in 2014 Due to the Transport Rule for the Eastern U.S.

Change in Annual Mean $PM_{2.5}$ Concentrations (µg/m^3)	**2014 Population[b]**	
	Number (millions)	**Percent (%)**
$-0.25 > \Delta$ $PM_{2.5}$ Conc < 0	6,594,134	2%
$0 = \Delta$ $PM_{2.5}$ Conc	34,315,378	11%
$0 > \Delta$ $PM_{2.5}$ Conc ≤ 0.25	36,670,522	11%
$0.25 > \Delta$ $PM_{2.5}$ Conc ≤ 0.5	27,463,668	9%
$0.5 > \Delta$ $PM_{2.5}$ Conc ≤ 0.75	43,099,722	13%
$0.75 > \Delta$ $PM_{2.5}$ Conc ≤ 1.0	53,403,287	17%
$1.0 > \Delta$ $PM_{2.5}$ Conc ≤ 1.25	28,161,111	9%
$1.25 > \Delta$ $PM_{2.5}$ Conc ≤ 1.5	30,602,368	10%
$1.5 > \Delta$ $PM_{2.5}$ Conc ≤ 1.75	21,163,369	7%
Δ $PM_{2.5}$ Conc > 1.75	39,290,133	12%

[a] The change is defined as the control case value minus the base case value.

[b] Population counts and percentages are for the fraction of the national population located in the eastern 37 state modeling domain (as shown in Figure 4-1) considered in modeling health benefits for the rule.

4.2.3 Converting CAMx Outputs to Full-Season Profiles for Benefits Analysis

This study extracted hourly, surface-layer ozone concentrations for each grid-cell from the standard CAMx output file containing hourly average ozone values. These model predictions are used in conjunction with the observed concentrations obtained from the Aerometric Information Retrieval System (AIRS) to generate ozone concentrations for the entire ozone season.[16,17] The predicted changes in ozone concentrations from the future-year base case to future-year control scenario serve as inputs to the health and welfare C-R functions of the benefits analysis (i.e., BenMAP).

To estimate ozone-related health and welfare effects, full-season ozone data are required for every grid cell. Given available ozone monitoring data, we generated full-season ozone profiles for each location in the contiguous 48 States in two steps: (1) we combine monitored observations and modeled ozone predictions to interpolate hourly ozone concentrations to a grid of 8 km by 8 km population grid-cells, and (2) we converted these full-season hourly ozone profiles to an ozone measure of interest, such as the daily average.[18,19]

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[16] The ozone season for this analysis is defined as the 5-month period from May to September; however, to estimate certain crop yield benefits, the modeling results were extended to include months outside the 5-month ozone season.

[17] Based on AIRS, there were 961 ozone monitors with sufficient data, i.e., 50 percent or more days reporting at least 9 hourly observations per day (8 am to 8 pm) during the ozone season.

[18] The 12 km grid squares contain the population data used in the health benefits analysis model, BenMAP. See Chapter 5 for a discussion of this model.

[19] This approach is a generalization of planar interpolation that is technically referred to as enhanced Voronoi Neighbor Averaging (EVNA) spatial interpolation.

4.2.4 Ozone Air Quality Results

This section provides a summary of the predicted ambient ozone concentrations from the CAMx model for the 2014 base case and changes associated with the rule. Table 4-3 provides those ozone metrics for grid cells in the Eastern U.S. that enter the C-R functions for health benefits endpoints. The population-weighted average reflects the baseline levels and predicted changes for more populated areas of the nation. This measure, therefore, will better reflect the potential benefits of these predicted changes through exposure changes to these populations.

Table 4-3. Summary of CAMx Derived Population-Weighted Ozone Season Air Quality Metrics for Health Benefits Endpoints Due to the Transport Rule for the Eastern U.S.

Statistic[a]	2014		
	Base Case	Change [b]	Percent Change [b]
Population-Weighted Average (ppb) [c]			
Daily 8-Hour Average Concentration	44.85	0.09	0.2%

[a] This ozone metric is calculated at the CAMx grid-cell level for use in health effects estimates based on the results of spatial and temporal Voronoi Neighbor Averaging.

[b] The change is defined as the control case value minus the base case value. The percent change is the "Change" divided by the "Base Case," and then multiplied by 100 to convert the value to a percentage.

[c] Calculated by summing the product of the projected CAMx grid-cell population and the estimated CAMx grid-cell seasonal ozone concentration, and then dividing by the total population.

4.3 Visibility Degradation Estimates

Visibility degradation is often directly proportional to decreases in light transmittal in the atmosphere. Scattering and absorption by both gases and particles decrease light transmittance. To quantify changes in visibility, our analysis computes a light-extinction coefficient, based on the work of Sisler (1996), which shows the total fraction of light that is decreased per unit distance. This coefficient accounts for the scattering and absorption of light by both particles and gases, and accounts for the higher extinction efficiency of fine particles compared to coarse particles. Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon (soot), and soil (Sisler, 1996).

Based upon the light-extinction coefficient, we also calculated a unitless visibility index, called a "deciview," which is used in the valuation of visibility. The deciview metric provides a scale for perceived visual changes over the entire range of conditions, from clear to hazy. Under many scenic conditions, the average person can generally perceive a change of one deciview. The higher the deciview value, the worse the visibility. Thus, an improvement in visibility is a decrease in deciview value.

Table 4-4 provides the visibility improvements, measured in annual average deciviews, expected to occur in the Eastern and Western U.S. As shown, Class I visibility regions in the Eastern U.S., including such regions as the Great Smoky Mountains and Shenandoah, are expected to see significant improvements in visibility. By 2014, such regions in the Eastern U.S. are expected to see improvements of over 1.5 deciview (11 percent), and such regions in the Western U.S. are expected to see improvements of over 0.02 deciviews (or less than 1 percent).

Table 4-4. Summary of Basecase Recreational Visibility and Changes by Region: (annual average deciviews)

	2014		
Class I Visibility Regions	**Base Case (Deciviews)**	**Change in Annual Average (Deciviews)**	**Percent Change in Annual Average (%)**
Eastern US	14.84	1.57	11.0
Western US	9.09	0.02	<1

4.4 References

Environ, 2010. Comprehensive Air Quality Model with Extensions Version 5.3 User's Guide. Environ International Corporation. Novato, CA. December 2010.

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

U.S. Environmental Protection Agency (EPA). 2007. Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze. Office of Air Quality Planning and Standards, Research Triangle Park, NC.

U.S. Environmental Protection Agency (EPA). 2011. Air Quality Modeling Technical Support Document for the Transport Rule. Office of Air Quality Planning and Standards, Research Triangle Park, NC.

Chapter 5

Benefits Analysis and Results

Synopsis

This chapter contains a subset of the estimated health and welfare benefits of the Transport Rule remedy in 2014. This rule is expected to yield significant reductions in SO_2 and NO_x from EGUs, which in turn would lower overall ambient levels of $PM_{2.5}$ and ozone across much of the eastern U.S. In this chapter we quantify the health and welfare benefits resulting from these air quality improvements.

We estimate the monetized benefits of the selected remedy to be $120 billion to $280 billion at a 3% discount rate and $110 billion to $250 billion at a 7% discount rate in 2014. The benefits of the more and less stringent alternatives may be found in the benefit-cost comparison chapter. All estimates are in 2007$. We estimate the benefits of the selected remedy using modeled changes in ambient pollution concentrations while the benefits of the more and less stringent remedies are based on a benefit per ton approach described below. This benefits analysis accounts for both decreases and increases in emissions across the country. These estimates omit the benefits from several important categories, including ecosystem benefits, mercury benefits, and the direct health benefits from reducing exposure to NO_2 and SO_2 due to time constraints.

The estimated benefits of this rule are substantial, particularly when viewed within the context of the total public health burden of $PM_{2.5}$ and ozone air pollution. A recent EPA analysis estimated that 2005 levels of $PM_{2.5}$ and ozone were responsible for between 130,000 and 320,000 $PM_{2.5}$-related and 4,700 ozone-related premature deaths, or about 6.1% of total deaths from all causes in the continental U.S. (Fann et al. 2011). This same analysis attributed almost 200,000 non-fatal heart attacks, 90,000 hospital admissions due to respiratory or cardiovascular illness and 2.5 million cases of aggravated asthma among children--among many other impacts. We estimate the Transport Rule to reduce the number of $PM_{2.5}$-related premature deaths in 2014 by between 13,000 and 34,000, 15,000 non-fatal heart attacks, 8,700 fewer hospital admissions and 400,000 fewer cases of aggravated asthma. By 2014, in combination with other federal and state air quality actions, the Transport Rule will address a substantial fraction of the total public health burden of $PM_{2.5}$ and ozone air pollution.

EPA expects greater emission reductions due to this rule in 2012 than in 2014, due to substantial emission reductions expected to occur in the baseline (i.e., unrelated to the Transport Rule) between those years. As a result, we anticipate that the avoided health impacts and monetized benefits would also be greater in 2012, though we have not calculated these estimates for this analysis.

Appendix A to this RIA contains an assessment of the distribution of health benefits among different populations. In this analysis, we considered the level of $PM_{2.5}$ mortality risk according to the race, income and educational attainment of the population before and after the implementation of the Transport Rule. We found those populations whose $PM_{2.5}$ mortality risk was before the implementation of the rule received the greatest risk reduction from the Transport Rule—irrespective of the race of the population. We also found that populations with lower levels of educational attainment, an attribute that may be associated with increased vulnerability to PM2.5 mortality risk, also received a significant reduction in risk.

Finally, Appendix E provides an alternate presentation of the benefits as an attempt to incorporate the recommendations from EPA's recently published Guidelines for Preparing Economic Analyses (U.S. EPA, 2010).

5.1 Overview

This chapter contains a subset of the estimated health and welfare benefits of the selected and alternate rule remedies for the Transport Rule in 2014. The Transport Rule is expected to yield significant aggregate reductions in SO_2 and NO_x from EGUs, which in turn would lower overall ambient levels of $PM_{2.5}$ and ozone across much of the eastern U.S. To perform this analysis, EPA followed an approach that is generally consistent with the proposal Transport Rule analysis, with the exception of the baseline incidence rates that are an input into the health impact calculation for $PM_{2.5}$ and ozone health outcomes. These updated rates are both more current and provide better spatial resolution in many areas of the U.S. As we describe in section 5.4 below, these updated data are likely to yield a better overall estimate of PM and ozone-related health impacts.

The analysis in this chapter aims to characterize the benefits of the selected remedy by answering two key questions:

1. What are the health and welfare effects of changes in ambient particulate matter ($PM_{2.5}$) and ozone air quality resulting from reductions in precursors including NO_x and SO_2?
2. What is the economic value of these effects?

In this analysis we consider an array of health and welfare impacts attributable to changes in $PM_{2.5}$ and ozone air quality. The 2009 $PM_{2.5}$ Integrated Science Assessment (U.S. EPA, 2009d) and the 2006 ozone criteria document (U.S. EPA, 2006a) identify the human health effects associated with these ambient pollutants, which include premature mortality and a variety of morbidity effects associated with acute and chronic exposures. PM welfare effects include visibility impairment and materials damage. Ozone welfare effects include damages to agricultural and forestry sectors. NO_x welfare effects include aquatic and terrestrial acidification and nutrient enrichment (U.S. EPA, 2008f). SO_2 welfare effects include aquatic and terrestrial acidification and increased mercury methylation (U.S. EPA, 2008f). Though models exist for quantifying these ecosystem impacts, time and resource constraints precluded us from quantifying most of those effects in this analysis.

Table 5-1 summarizes the total monetized benefits of the final Transport Rule remedy in 2014. This table reflects the economic value of the change in $PM_{2.5}$ and ozone-related human health impacts occurring as a result of the Transport Rule.

Table 5-2 summarizes the human health and welfare benefits categories contained within the primary benefits estimate, those categories that were unquantified due to limited data or time.

Table 5-1: Estimated monetized benefits of the final Transport Rule remedy (billions of 2007$)[A]

Benefits Estimate	*Within Transport Region[B]*	*Outside Transport Region*	*Total*
Pope et al. (2002) $PM_{2.5}$ mortality and Bell et al. (2004) ozone mortality estimates			
Using a 3% discount rate	\$110 +B (\$8.8—\$340)	\$0.28 +B (\$0.01—\$0.9)	\$120 +B (\$14—\$350)
Using a 7% discount rate	\$100 +B (\$8—\$310)	\$0.25 +B (\$0.01—\$0.85)	\$110 +B (\$13—\$320)
Laden et al. (2006) $PM_{2.5}$ mortality and Levy et al. (2005) ozone mortality estimates			
Using a 3% discount rate	\$270 +B (\$24—\$800)	\$0.7 +B (\$0.05—\$0.21)	\$280 +B (\$29—\$810)
Using a 7% discount rate	\$250 +B (\$22—\$720)	\$0.6 +B (\$0.04—\$1.9)	\$250 +B (\$26—\$730)

[A] For notational purposes, unquantified benefits are indicated with a "B" to represent the sum of additional monetary benefits and disbenefits. Data limitations prevented us from quantifying these endpoints, and as such, these benefits are inherently more uncertain than those benefits that we were able to quantify. A detailed listing of unquantified health and welfare effects is provided in Table 5-2. Estimates here are subject to uncertainties discussed further in the body of the document. Estimates include the value of CO_2-related benefits and the monetized benefits of visibility improvements in Class I areas.

[B] Rounded to two significant figures.

The benefits analysis in this chapter relies on an array of data inputs—including air quality modeling, health impact functions and valuation estimates among others—which are themselves subject to uncertainty and may also in turn contribute to the overall uncertainty in this analysis. As a means of characterizing this uncertainty we employ two primary techniques. First, we use Monte Carlo methods for characterizing random sampling error associated with the concentration response functions from epidemiological studies and economic valuation functions. Second, because this characterization of random statistical error may omit important sources of uncertainty we also employ the results of an expert elicitation on the relationship between premature mortality and ambient $PM_{2.5}$ concentration (Roman et al., 2008); this provides additional insight into the likelihood of different outcomes and about the state of knowledge regarding the benefits estimates. Both approaches have different strengths and weaknesses, which are fully described in Chapter 5 of the PM NAAQS RIA (U.S. EPA, 2006).

Given that reductions in premature mortality dominate the size of the overall monetized benefits, more focus on uncertainty in mortality-related benefits gives us greater confidence in our uncertainty characterization surrounding total benefits. Certain EPA RIA's including the 2008 Ozone NAAQS RIA (U.S. EPA, 2008a) contained a suite of sensitivity analyses, only some of which we include here due in part to time constraints. In particular, these analyses characterized the sensitivity of the monetized benefits to the specification of alternate cessation lags and income growth adjustment factors. The estimated benefits increased or decreased in proportion to the specification of alternate income growth adjustments and cessation lags, making it possible for readers to infer the sensitivity of the results in this RIA to these parameters by referring to the PM NAAQS RIA (2006d) and Ozone NAAQS RIA (2008a).

For example, the use of an alternate lag structure would change the $PM_{2.5}$-related mortality benefits discounted at 3% discounted by between 10.4% and –27%; when discounted at 7%, these benefits change by between 31% and -49%. When applying higher and lower income growth adjustments, the monetary value of $PM_{2.5}$ and ozone-related premature changes between 30% and -10%; the value of chronic endpoints change between 5% and -2% and the value of acute endpoints change between 6% and -7%.

Below we include a new analysis (Figures 5-19 and 5-20) in which we bin the estimated number of avoided $PM_{2.5}$-related premature mortalities resulting from the implementation of the Transport Rule according to the projected 2014 baseline $PM_{2.5}$ air quality levels. This presentation is consistent with our approach to applying $PM_{2.5}$ mortality risk coefficients that have not been adjusted to incorporate an assumed threshold. The very large proportion of the avoided PM-related impacts we estimate in this analysis occur among populations exposed at or above the LML of each study, increasing our confidence in the PM mortality analysis. Approximately 69% of the avoided impacts occur at or above an annual mean $PM_{2.5}$ level of 10 μg/m^3 (the LML of the Laden et al. 2006 study); about 96% occur at or above an annual mean $PM_{2.5}$ level of 7.5 μg/m^3 (the LML of the Pope et al. 2002 study). As we model mortality impacts among populations exposed to levels of $PM_{2.5}$ that are successively lower than the LML of each study our confidence in the results diminishes. However, the analysis below confirms that the great majority of the impacts occur at or above each study's LML.

Table 5-2: Human Health and Welfare Effects of Pollutants Affected by the Transport Rule

Pollutant/ Effect	*Quantified and monetized in base estimate*	*Unquantified*
PM: health[a]	Premature mortality based on cohort study estimates[b] and expert elicitation estimates Hospital admissions: respiratory and cardiovascular Emergency room visits for asthma Nonfatal heart attacks (myocardial infarctions) Lower and upper respiratory illness Minor restricted activity days Work loss days Asthma exacerbations (among asthmatic populations) Respiratory symptoms (among asthmatic populations) Infant mortality	Low birth weight, pre-term birth and other reproductive outcomes Pulmonary function Chronic respiratory diseases other than chronic bronchitis Non-asthma respiratory emergency room visits UVb exposure (+/-)[c]
PM: welfare	Visibility in Class I areas in SE, SW, and CA regions	Household soiling Visibility in residential areas Visibility in non-class I areas and class 1 areas in NW, NE, and Central regions UVb exposure (+/-)[c] Global climate impacts[c]
Ozone: health	Premature mortality based on short-term study estimates Hospital admissions: respiratory Emergency room visits for asthma Minor restricted activity days School loss days	Chronic respiratory damage Premature aging of the lungs Non-asthma respiratory emergency room visits UVb exposure (+/-)[c]
Ozone: welfare	Decreased outdoor worker productivity	Yields for: --Commercial forests --Fruits and vegetables, and --Other commercial and noncommercial crops Damage to urban ornamental plants Recreational demand from damaged forest aesthetics Ecosystem functions UVb exposure (+/-)[c] Climate impacts
NO_2: health		Respiratory hospital admissions Respiratory emergency department visits Asthma exacerbation Acute respiratory symptoms Premature mortality Pulmonary function
NO_X: welfare		Commercial fishing and forestry from acidic deposition effects Commercial fishing, agriculture and forestry from nutrient deposition effects Recreation in terrestrial and estuarine ecosystems from nutrient deposition effects Other ecosystem services and existence values for

	currently healthy ecosystems Coastal eutrophication from nitrogen deposition effects
SO_2: health	Respiratory hospital admissions Asthma emergency room visits Asthma exacerbation Acute respiratory symptoms Premature mortality Pulmonary function
SO_X: welfare	Commercial fishing and forestry from acidic deposition effects Recreation in terrestrial and aquatic ecosystems from acid deposition effects Increased mercury methylation
Mercury: health	Incidence of neurological disorders Incidence of learning disabilities Incidences in developmental delays
Mercury: welfare	Impact on birds and mammals (e.g. reproductive effects) Impacts to commercial, subsistence and recreational fishing

[A] In addition to primary economic endpoints, there are a number of biological responses that have been associated with PM health effects including morphological changes and altered host defense mechanisms. The public health impact of these biological responses may be partly represented by our quantified endpoints.

[B] Cohort estimates are designed to examine the effects of long term exposures to ambient pollution, but relative risk estimates may also incorporate some effects due to shorter term exposures (see Kunzli et al., 2001 for a discussion of this issue). While some of the effects of short term exposure are likely to be captured by the cohort estimates, there may be additional premature mortality from short term PM exposure not captured in the cohort estimates included in the primary analysis.

[C] May result in benefits or disbenefits.

5.2 Benefits Analysis Methods

We follow a "damage-function" approach in calculating total benefits of the modeled changes in environmental quality. This approach estimates changes in individual health and welfare endpoints (specific effects that can be associated with changes in air quality) and assigns values to those changes assuming independence of the individual values. Total benefits are calculated simply as the sum of the values for all non-overlapping health and welfare endpoints. The "damage-function" approach is the standard method for assessing costs and benefits of environmental quality programs and has been used in several recent published analyses (Levy et al., 2009; Hubbell et al., 2009; Tagaris et al., 2009).

To assess economic value in a damage-function framework, the changes in environmental quality must be translated into effects on people or on the things that people value. In some cases, the changes in environmental quality can be directly valued, as is the case for changes in visibility. In other cases, such as for changes in ozone and PM, a health and welfare impact analysis must first be conducted to convert air quality changes into effects that can be assigned dollar values.

For the purposes of this RIA, the health impacts analysis (HIA) is limited to those health effects that are directly linked to ambient levels of air pollution and specifically to those linked to ozone and PM. There may be other, indirect health impacts associated with implementing emissions controls, such as occupational health impacts for coal miners.

The welfare impacts analysis is limited to changes in the environment that have a direct impact on human welfare. For this analysis, we are limited by the available data to examine impacts of changes in visibility in Class 1 areas. We also provide qualitative discussions of the impact of changes in other environmental and ecological effects, for example, changes in deposition of nitrogen and sulfur to terrestrial and aquatic ecosystems, but we are unable to place an economic value on these changes due to time and resource limitations.

We note at the outset that EPA rarely has the time or resources to perform extensive new research to measure directly either the health outcomes or their values for regulatory analyses. Thus, similar to Kunzli et al. (2000) and other recent health impact analyses, our estimates are based on the best available methods of benefits transfer. Benefits transfer is the science and art of adapting primary research from similar contexts to obtain the most accurate measure of benefits for the environmental quality change under analysis. Adjustments are made for the level of environmental quality change, the socio-demographic and economic characteristics of the affected population, and other factors to improve the accuracy and robustness of benefits estimates.

5.2.1 Health Impact Assessment

The Health Impact Assessment (HIA) quantifies the changes in the incidence of adverse health impacts resulting from changes in human exposure to $PM_{2.5}$ and ozone air quality. HIAs are a well-established approach for estimating the retrospective or prospective change in adverse health impacts expected to result from population-level changes in exposure to pollutants (Levy et al. 2009). PC-based tools such as the environmental Benefits Mapping and Analysis Program (BenMAP) can systematize health impact analyses by applying a database of key input parameters, including health impact functions and population projections. Analysts have applied the HIA approach to estimate human health impacts resulting from hypothetical changes in pollutant levels (Hubbell et al. 2005; Davidson et al. 2007, Tagaris et al. 2009). EPA and others have relied upon this method to predict future changes in health impacts expected to result from the implementation of regulations affecting air quality (U.S. EPA, 2008a).

The HIA approach used in this analysis involves three basic steps: (1) utilizing CAMx-generated projections of $PM_{2.5}$ and ozone air quality and estimating the change in the spatial distribution of the ambient air quality; (2) determining the subsequent change in population-level exposure; (3) calculating health impacts by applying concentration-response relationships drawn from the epidemiological literature (Hubbell et al. 2009) to this change in population exposure.

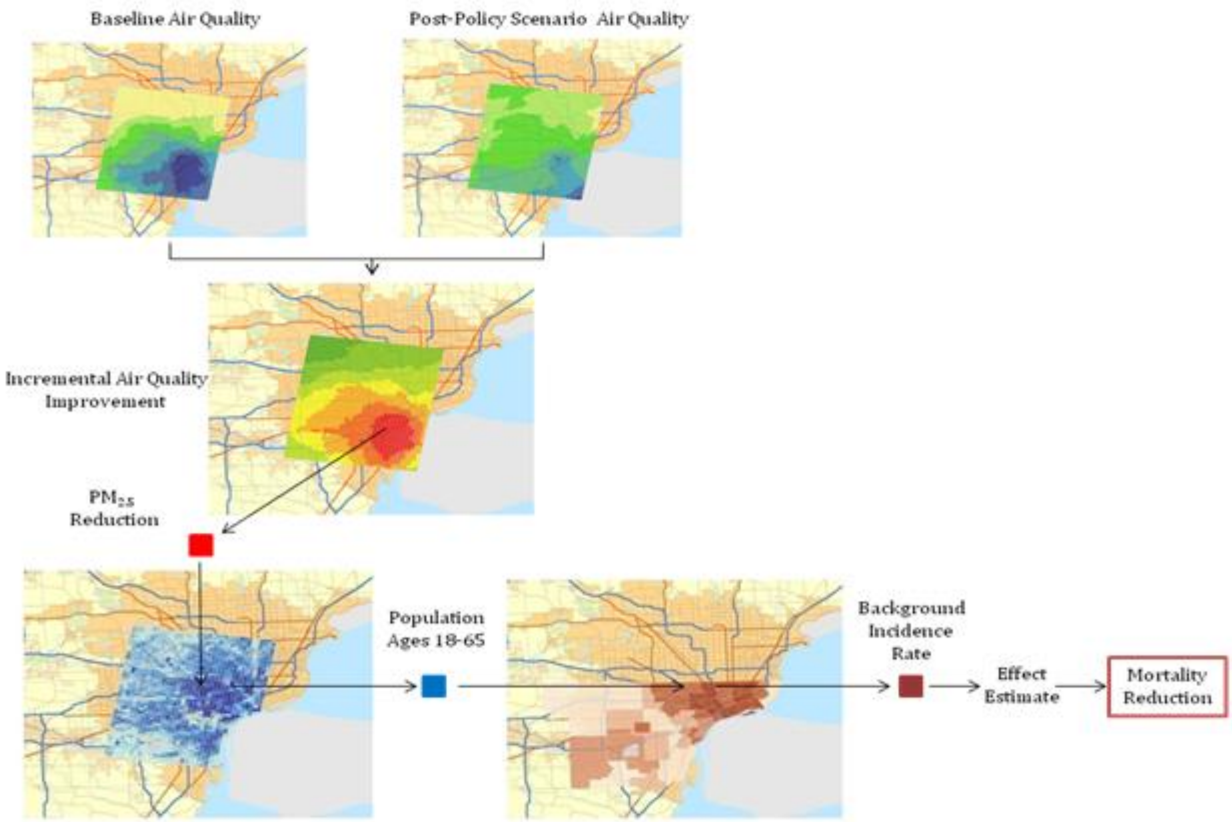
A typical health impact function might look as follows:

$$\Delta y = y_o \cdot \left(e^{\beta \cdot \Delta x} - 1\right) \cdot Pop$$

where y_0 is the baseline incidence rate for the health endpoint being quantified (for example, a health impact function quantifying changes in mortality would use the baseline, or background, mortality rate for the given population of interest); *Pop* is the population affected by the change in air quality; Δx is the change in air quality; and β is the effect coefficient drawn from the epidemiological study. Tools such as BenMAP can systematize the HIA calculation process, allowing users to draw upon a library of existing air quality monitoring data, population data and health impact functions.

Figure 5-1 provides a simplified overview of this approach.

Figure 5-1: Illustration of BenMAP Approach



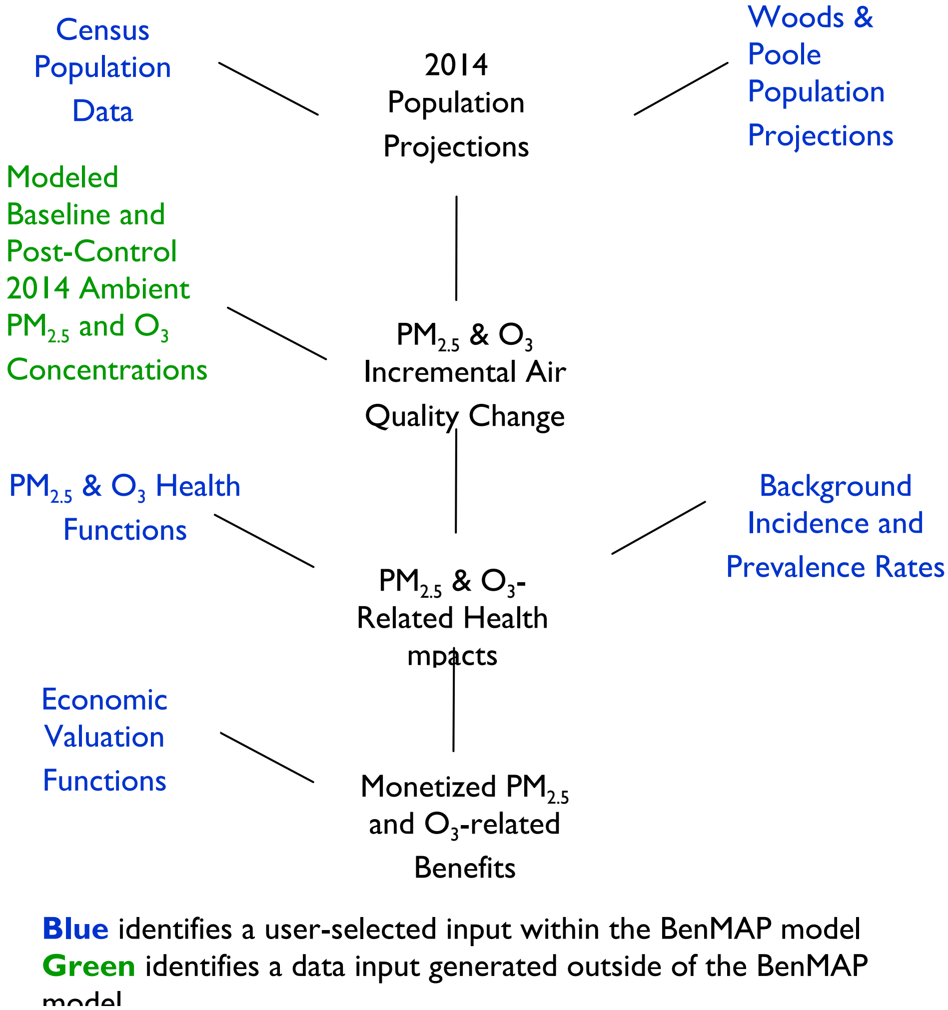
5.2.2 Economic Valuation of Health Impacts

After quantifying the change in adverse health impacts, the final step is to estimate the economic value of these avoided impacts. The appropriate economic value for a change in a health effect depends on whether the health effect is viewed *ex ante* (before the effect has occurred) or *ex post* (after the effect has occurred). Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects by a small amount for a large population. The appropriate economic measure is therefore *ex ante* Willingness to Pay (WTP) for changes in risk. However, epidemiological studies generally provide estimates of the relative risks of a particular health effect avoided due to a reduction in air pollution. A convenient way to use this data in a consistent framework is to convert probabilities to units of avoided statistical incidences. This measure is calculated by dividing individual WTP for a risk reduction by the related observed change in risk. For example, suppose a measure is able to reduce the risk of premature mortality from 2 in 10,000 to 1 in 10,000 (a reduction of 1 in 10,000). If individual WTP for this risk reduction is $100, then the WTP for an avoided statistical premature mortality amounts to $1 million ($100/0.0001 change in risk). Using this approach, the size of the affected population is automatically taken into account by the number of incidences predicted by epidemiological studies applied to the relevant population. The same type of calculation can produce values for statistical incidences of other health endpoints.

For some health effects, such as hospital admissions, WTP estimates are generally not available. In these cases, we use the cost of treating or mitigating the effect as a primary estimate. For example, for the valuation of hospital admissions we use the avoided medical costs as an estimate of the value of avoiding the health effects causing the admission. These cost of illness (COI) estimates generally (although not in every case) understate the true value of reductions in risk of a health effect. They tend to reflect the direct expenditures related to treatment but not the value of avoided pain and suffering from the health effect.

We use the BenMAP model (Abt Associates, 2008) to estimate the health impacts and monetized health benefits for the preferred remedy. Figure 5-2 below shows the data inputs and outputs for the BenMAP model.

Figure 5-2: Data inputs and outputs for the BenMAP model



5.2.3 Benefit Per-Ton Estimates

Benefit per-ton (BPT) estimates quantify the health impacts and monetized human health benefits of an incremental change in air pollution precursor emissions. In situations when we are unable to perform air quality modeling because of resource or time constraints, this approach can provide a reliable estimate of the benefits of emission reduction scenarios. EPA has used the benefit per-ton technique in previous RIAs, including the recent Ozone NAAQS RIA (U.S. EPA, 2008) and NO_2 NAAQS RIA (U.S. EPA, 2010b). Time constraints prevented the Agency from modeling the air quality changes resulting from e the more and less stringent SO_2 caps and so we estimate a subset of these health benefits using $PM_{2.5}$ benefit per-ton estimates. The assessment of the alternate scenarios omits ozone-related benefits for two reasons. First, the overall level of ozone-related benefits in the modeled case is relatively small compared to those associated with $PM_{2.5}$ reductions (see table 5-17 below), due in part to the fairly modest summer time NO_x

emission reductions under this scenario. The level of summertime NO_x emission reductions of the alternate scenarios are very similar to the modeled scenario, suggesting that the omission of ozone-related impacts would not greatly influence the overall level of benefits. Second, the complex non-linear chemistry of ozone formation introduces uncertainty to the development and application of a benefit per ton estimate. Taken together, these factors argued against developing an ozone benefit per ton estimate for this RIA.

For this analysis, EPA applies $PM_{2.5}$ BPT estimates that are methodologically consistent with those reported in Fann et al. (2009), but have been adjusted for this analysis to better match the spatial distribution of air quality changes projected for the Transport Rule. To derive the BPT estimates for this analysis, we:

1. *Quantified the $PM_{2.5}$-related human and monetized health benefits of the SO_2 emission reductions of the proposed remedy*. We first quantified the health impacts and monetized benefits of total $PM_{2.5}$ mass formed from the SO_2 reductions of the proposed remedy, allowing us to isolate the PM air quality impacts from SO_2 reductions alone.[20] This procedure allowed us to develop $PM_{2.5}$ BPT estimates that quantified the $PM_{2.5}$-related benefits of incremental changes in SO_2 emissions. Because reductions in NO_x emissions are relatively small in each scenario, and previous EPA modeling indicates that $PM_{2.5}$ formation is less sensitive to NO_x emission reductions on a per-µg/m^3 basis (Fann et al, 2009), we did not quantify the NO_x-related $PM_{2.5}$ changes.

2. *Divided the health impacts and monetized benefits by the emission reduction.* This calculation yields BPT estimates for PM-related SO_2.

The resulting BPT estimates were then multiplied by the projected SO_2 emission reductions for the more and less stringent scenarios to produce an estimate of the PM- and ozone-related health impacts and monetized benefits. There is no analogous approach for estimating a BPT for

[20] The Transport Rule includes both SO_2 and NOx emissions reductions. In general SO_2 is a precursor to particulate sulfate and NOx is a precursor to particulate nitrate. However, there are also several interactions between the $PM_{2.5}$ precursors which cannot be easily quantified. For example, under conditions in which SO_2 levels are reduced by a substantial margin, "nitrate replacement" may occur. This occurs when particulate ammonium sulfate concentrations are reduced, thereby freeing up excess gaseous ammonia. The excess ammonia is then available to react with gaseous nitric acid to form particulate nitrate. The impact of nitrate replacement is also affected by concurrent NOx reductions. NOx reductions can lead to decreases in nitrate, which competes with the process of nitrate replacement. NOx reductions can also lead to reductions in photochemical by-products which can reduce both particulate sulfate and secondary organic carbon PM concentrations. Due to the complex nature of these interactions, EPA performed a sensitivity modeling analysis in which only SO_2 emissions were reduced at levels that approximated those of the selected remedy. We calculated benefits from this air quality modeling run to generate an SO_2-only benefit per ton estimate. The results of the SO_2-only sensitivity run may be found in the EPA Benefits TSD [Docket No. EPA-HQ-OAR-2010-0491]

visibility, and so the benefits of the alternative remedies omit this important monetized benefit.

5.3 Uncertainty Characterization

In any complex analysis using estimated parameters and inputs from numerous models, there are likely to be many sources of uncertainty and this analysis is no exception. As outlined both in this and preceding chapters, many inputs were used to derive the estimate of benefits for the proposed remedy, including emission inventories, air quality models (with their associated parameters and inputs), epidemiological health effect estimates, estimates of values (both from WTP and COI studies), population estimates, income estimates, and estimates of the future state of the world (i.e., regulations, technology, and human behavior). Each of these inputs may be uncertain and, depending on its role in the benefits analysis, may have a disproportionately large impact on estimates of total benefits. For example, emissions estimates are used in the first stage of the analysis. As such, any uncertainty in emissions estimates will be propagated through the entire analysis. When compounded with uncertainty in later stages, small uncertainties in emission levels can lead to large impacts on total benefits.

The National Research Council (NRC) (2002, 2008) highlighted the need for EPA to conduct rigorous quantitative analysis of uncertainty in its benefits estimates and to present these estimates to decision makers in ways that foster an appropriate appreciation of their inherent uncertainty. In general, the NRC concluded that EPA's general methodology for calculating the benefits of reducing air pollution is reasonable and informative in spite of inherent uncertainties. Since the publication of these reports, EPA's Office of Air and Radiation (OAR) continues to make progress toward the goal of characterizing the aggregate impact of uncertainty in key modeling elements on both health incidence and benefits estimates in two key ways: Monte Carlo analysis and expert-derived concentration-response functions. In this analysis, we use both of these two methods to assess uncertainty quantitatively, as well as provide a qualitative assessment for those aspects that we are unable to address quantitatively.

First, we used Monte Carlo methods for characterizing random sampling error associated with the concentration response functions from epidemiological studies and random effects modeling to characterize both sampling error and variability across the economic valuation functions. Monte Carlo simulation uses random sampling from distributions of parameters to characterize the effects of uncertainty on output variables, such as incidence of premature mortality. Specifically, we used Monte Carlo methods to generate confidence intervals around the estimated health impact and dollar benefits. The reported standard errors in the epidemiological studies determined the distributions for individual effect estimates.

Second, because characterization of random statistical error omits important sources of uncertainty (e.g., in the functional form of the model—e.g., whether or not a threshold may exist), we also incorporate the results of an expert elicitation on the relationship between premature mortality and ambient $PM_{2.5}$ concentration (Roman et al., 2008). Use of the expert elicitation and incorporation of the standard errors approaches provide insights into the likelihood of different outcomes and about the state of knowledge regarding the benefits estimates. However, there are significant unquantified uncertainties present in upstream inputs including emission and air quality. Both approaches have different strengths and weaknesses, which are fully described in Chapter 5 of the PM NAAQS RIA (U.S. EPA, 2006).

In benefit analyses of air pollution regulations conducted to date, the estimated impact of reductions in premature mortality has accounted for 85% to 95% of total monetized benefits. Therefore, it is particularly important to attempt to characterize the uncertainties associated with reductions in premature mortality. The health impact functions used to estimate avoided premature deaths associated with reductions in ozone have associated standard errors that represent the statistical errors around the effect estimates in the underlying epidemiological studies. In our results, we report credible intervals based on these standard errors, reflecting the uncertainty in the estimated change in incidence of avoided premature deaths. We also provide multiple estimates, to reflect model uncertainty between alternative study designs.

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

In 2006 the EPA requested an NAS study to evaluate the extent to which the epidemiological literature to that point improved the understanding of ozone-related mortality. The NAS found that short-term ozone exposure was likely to contribute to ozone-related mortality (NRC, 2008) and issued a series of recommendations to EPA, including that the Agency should:

1. Present multiple short-term ozone mortality estimates, including those based on multi-city analyses such as the National Morbidity, Mortality and Air Pollution Study (NMMAPS) as well as meta-analytic studies.
2. Report additional risk metrics, including the percentage of baseline mortality attributable to short-term exposure.
3. Remove reference to a no-causal relationship between ozone exposure and premature mortality.

The quantification and presentation of ozone-related premature mortality in this chapter is responsive to these NRC recommendations and generally consistent with EPA's recent ozone reconsideration analysis (U.S. EPA, 2010a).

Some key sources of uncertainty in each stage of both the PM and ozone health impact assessment are the following:

- gaps in scientific data and inquiry;
- variability in estimated relationships, such as epidemiological effect estimates, introduced through differences in study design and statistical modeling;
- errors in measurement and projection for variables such as population growth rates;
- errors due to misspecification of model structures, including the use of surrogate variables, such as using PM_{10} when $PM_{2.5}$ is not available, excluded variables, and simplification of complex functions; and
- biases due to omissions or other research limitations.

In Table 5-3 we summarize some of the key uncertainties in the benefits analysis.

Table 5-3. Primary Sources of Uncertainty in the Benefits Analysis

1. Uncertainties Associated with Impact Functions
- The value of the ozone or PM effect estimate in each impact function. - Application of a single impact function to pollutant changes and populations in all locations. - Similarity of future-year impact functions to current impact functions. - Correct functional form of each impact function. - Extrapolation of effect estimates beyond the range of ozone or PM concentrations observed in the source epidemiological study. - Application of impact functions only to those subpopulations matching the original study population.
2. Uncertainties Associated with CAMx-Modeled Ozone and PM Concentrations
- Responsiveness of the models to changes in precursor emissions from the control policy. - Projections of future levels of precursor emissions, especially ammonia and crustal materials. - Lack of ozone and $PM_{2.5}$ monitors in all rural areas requires extrapolation of observed ozone data from urban to rural areas.
3. Uncertainties Associated with PM Mortality Risk
- Limited scientific literature supporting a direct biological mechanism for observed epidemiological evidence. - Direct causal agents within the complex mixture of PM have not been identified. - The extent to which adverse health effects are associated with low-level exposures that occur many times in the year versus peak exposures. - The extent to which effects reported in the long-term exposure studies are associated with historically higher levels of PM rather than the levels occurring during the period of study. - Reliability of the $PM_{2.5}$ monitoring data in reflecting actual $PM_{2.5}$ exposures.
4. Uncertainties Associated with Possible Lagged Effects
- The portion of the PM-related long-term exposure mortality effects associated with changes in annual PM levels that would occur in a single year is uncertain as well as the portion that might occur in subsequent years.
5. Uncertainties Associated with Baseline Incidence Rates
- Some baseline incidence rates are not location specific (e.g., those taken from studies) and therefore may not accurately represent the actual location-specific rates. - Current baseline incidence rates may not approximate well baseline incidence rates in 2014. - Projected population and demographics may not represent well future-year population and demographics.
6. Uncertainties Associated with Economic Valuation
- Unit dollar values associated with health and welfare endpoints are only estimates of mean WTP and therefore have uncertainty surrounding them. - Mean WTP (in constant dollars) for each type of risk reduction may differ from current estimates because of differences in income or other factors.
7. Uncertainties Associated with Aggregation of Monetized Benefits
- Health and welfare benefits estimates are limited to the available impact functions. Thus, unquantified or unmonetized benefits are not included.

5.4 Benefits Analysis Data Inputs

In Figure 5-2, we summarized the key data inputs to the health impact and economic valuation estimate. Below we summarize the data sources for each of these inputs, including demographic projections, effect coefficients, incidence rates and economic valuation. We indicate where we have updated key data inputs since the 2005 CAIR benefits analysis.

5.4.1 Demographic Data

Quantified and monetized human health impacts depend on the demographic characteristics of the population, including age, location, and income. We use projections based on economic forecasting models developed by Woods and Poole, Inc (Woods and Poole, 2008). The Woods and Poole (WP) database contains county-level projections of population by age, sex, and race out to 2030. Projections in each county are determined simultaneously with every other county in the United States to take into account patterns of economic growth and migration. The sum of growth in county-level populations is constrained to equal a previously determined national population growth, based on Bureau of Census estimates (Hollman et al., 2000). According to WP, linking county-level growth projections together and constraining to a national-level total growth avoids potential errors introduced by forecasting each county independently. County projections are developed in a four-stage process:

1. First, national-level variables such as income, employment, and populations are forecasted.

2. Second, employment projections are made for 172 economic areas defined by the Bureau of Economic Analysis, using an "export-base" approach, which relies on linking industrial-sector production of non-locally consumed production items, such as outputs from mining, agriculture, and manufacturing with the national economy. The export-based approach requires estimation of demand equations or calculation of historical growth rates for output and employment by sector.

3. Third, population is projected for each economic area based on net migration rates derived from employment opportunities and following a cohort-component method based on fertility and mortality in each area.

4. Fourth, employment and population projections are repeated for counties, using the economic region totals as bounds. The age, sex, and race distributions for each region or

county are determined by aging the population by single year of age by sex and race for each year through 2014 based on historical rates of mortality, fertility, and migration.

5.4.2 Effect Coefficients

The first step in selecting effect coefficients is to identify the health endpoints to be quantified. We base our selection of health endpoints on consistency with EPA's Integrated Science Assessments (which replace the Criteria Document), with input and advice from the EPA Science Advisory Board - Health Effects Subcommittee (SAB-HES), a scientific review panel specifically established to provide advice on the use of the scientific literature in developing benefits analyses for air pollution regulations (http://www.epa.gov/sab/). In general, we follow a weight of evidence approach, based on the biological plausibility of effects, availability of concentration-response functions from well conducted peer-reviewed epidemiological studies, cohesiveness of results across studies, and a focus on endpoints reflecting public health impacts (like hospital admissions) rather than physiological responses (such as changes in clinical measures like Forced Expiratory Volume (FEV1)).

There are several types of data that can support the determination of types and magnitude of health effects associated with air pollution exposures. These sources of data include toxicological studies (including animal and cellular studies), human clinical trials, and observational epidemiology studies. All of these data sources provide important contributions to the weight of evidence surrounding a particular health impact. However, only epidemiology studies provide direct concentration-response relationships which can be used to evaluate population-level impacts of reductions in ambient pollution levels in a health impact assessment.

For the data-derived estimates, we relied on the published scientific literature to ascertain the relationship between PM and adverse human health effects. We evaluated epidemiological studies using the selection criteria summarized in Table 5-4. These criteria include consideration of whether the study was peer-reviewed, the match between the pollutant studied and the pollutant of interest, the study design and location, and characteristics of the study population, among other considerations. The selection of C-R functions for the benefits analysis is guided by the goal of achieving a balance between comprehensiveness and scientific defensibility. In general, the use of results from more than a single study can provide a more robust estimate of the relationship between a pollutant and a given health effect. However, there are often differences between studies examining the same endpoint, making it difficult to pool the results in a consistent manner. For example, studies may examine different pollutants or different age groups. For this reason, we consider very carefully the set of studies available examining each endpoint and select a consistent subset that provides a good balance of population coverage and match with the pollutant of interest. In many cases, either because of a lack of multiple studies, consistency problems, or clear superiority in the quality or comprehensiveness of one study over others, a single published study is selected as the basis of the effect estimate.

Table 5-4. Criteria Used when Selecting C-R functions

Consideration	*Comments*
Peer-Reviewed Research	Peer-reviewed research is preferred to research that has not undergone the peer-review process.
Study Type	Among studies that consider chronic exposure (e.g., over a year or longer), prospective cohort studies are preferred over ecological studies because they control for important individual-level confounding variables that cannot be controlled for in ecological studies.
Study Period	Studies examining a relatively longer period of time (and therefore having more data) are preferred, because they have greater statistical power to detect effects. More recent studies are also preferred because of possible changes in pollution mixes, medical care, and lifestyle over time. However, when there are only a few studies available, studies from all years will be included.
Population Attributes	The most technically appropriate measures of benefits would be based on impact functions that cover the entire sensitive population but allow for heterogeneity across age or other relevant demographic factors. In the absence of effect estimates specific to age, sex, preexisting condition status, or other relevant factors, it may be appropriate to select effect estimates that cover the broadest population to match with the desired outcome of the analysis, which is total national-level health impacts. When available, multi-city studies are preferred to single city studies because they provide a more generalizable representation of the C-R function.
Study Size	Studies examining a relatively large sample are preferred because they generally have more power to detect small magnitude effects. A large sample can be obtained in several ways, either through a large population or through repeated observations on a smaller population (e.g., through a symptom diary recorded for a panel of asthmatic children).
Study Location	U.S. studies are more desirable than non-U.S. studies because of potential differences in pollution characteristics, exposure patterns, medical care system, population behavior, and lifestyle.
Pollutants Included in Model	When modeling the effects of ozone and PM (or other pollutant combinations) jointly, it is important to use properly specified impact functions that include both pollutants. Using single-pollutant models in cases where both pollutants are expected to affect a health outcome can lead to double-counting when pollutants are correlated.
Measure of PM	For this analysis, impact functions based on $PM_{2.5}$ are preferred to PM_{10} because of the focus on reducing emissions of $PM_{2.5}$ precursors, and because air quality modeling was conducted for this size fraction of PM. Where $PM_{2.5}$ functions are not available, PM_{10} functions are used as surrogates, recognizing that there will be potential downward (upward) biases if the fine fraction of PM_{10} is more (less) toxic than the coarse fraction.
Economically Valuable Health Effects	Some health effects, such as forced expiratory volume and other technical measurements of lung function, are difficult to value in monetary terms. These health effects are not quantified in this analysis.
Non-overlapping Endpoints	Although the benefits associated with each individual health endpoint may be analyzed separately, care must be exercised in selecting health endpoints to include in the overall benefits analysis because of the possibility of double-counting of benefits.

When several effect estimates for a pollutant and a given health endpoint have been selected, they are quantitatively combined or pooled to derive a more robust estimate of the relationship. The BenMAP Technical Appendices provides details of the procedures used to combine multiple impact functions (Abt Associates, 2008). In general, we used fixed or random effects models to pool estimates from different studies of the same endpoint. Fixed effects pooling simply weights each study's estimate by the inverse variance, giving more weight to studies with greater statistical power (lower variance). Random effects pooling accounts for both within-study variance and between-study variability, due, for example, to differences in population susceptibility. We used the fixed effects model as our null hypothesis and then determined whether the data suggest that we should reject this null hypothesis, in which case we would use the random effects model. Pooled impact functions are used to estimate hospital admissions and asthma exacerbations. For more details on methods used to pool incidence estimates, see the BenMAP Manual Appendices (Abt Associates, 2008), which are available with the BenMAP software at http://www.epa.gov/benmap.html.

Effect estimates selected for a given health endpoint were applied consistently across all locations nationwide. This applies to both impact functions defined by a single effect estimate and those defined by a pooling of multiple effect estimates. Although the effect estimate may, in fact, vary from one location to another (e.g., because of differences in population susceptibilities or differences in the composition of PM), location-specific effect estimates are generally not available.

The specific studies from which effect estimates for the primary analysis are drawn are included in Table 5-5. We highlight in blue those studies that have been added since the 2005 CAIR benefits analysis and incorporated into the central benefits estimate. In all cases where effect estimates are drawn directly from epidemiological studies, standard errors are used as a partial representation of the uncertainty in the size of the effect estimate. Below we provide the basis for selecting these studies.

Table 5-5. Health Endpoints and Epidemiological Studies Used to Quantify Health Impacts

Endpoint	Pollutant	Study	Study Population
Premature Mortality			
Premature mortality—daily time series	O3 (8-hour max)	Bell et al.(2004) (NMMAPS study) Huang et al. (2004) (multi-city) Schwartz (2005) (multi-city) Meta-analyses: Bell et al. (2005) Ito et al. (2005) Levy et al. (2005)	All ages
Premature mortality—cohort study, all-cause	$PM_{2.5}$ (annual avg)	Pope et al. (2002) Laden et al. (2006)	>29 years >25 years
Premature mortality, total exposures	$PM_{2.5}$ (annual avg)	Expert Elicitation (Roman et al., 2008)	>24 years
Premature mortality—all-cause	$PM_{2.5}$ (annual avg)	Woodruff et al. (2006)	Infant (<1 year)
Chronic Illness			
Chronic bronchitis	$PM_{2.5}$ (annual avg)	Abbey et al. (1995)	>26 years
Nonfatal heart attacks	$PM_{2.5}$ (24-hour avg)	Peters et al. (2001)	Adults (>18 years)
Hospital Admissions			
Respiratory	O_3 (8-hour max)	*Pooled estimate:* Schwartz (1995)—ICD 460–519 (all resp) Schwartz (1994a; 1994b)—ICD 480–486 (pneumonia) Moolgavkar et al. (1997)—ICD 480–487 (pneumonia) Schwartz (1994b)—ICD 491–492, 494–496 (COPD) Moolgavkar et al. (1997)—ICD 490–496 (COPD)	>64 years
		Burnett et al. (2001)	<2 years
	$PM_{2.5}$ (24-hour avg)	*Pooled estimate:* Moolgavkar (2003)—ICD 490–496 (COPD) Ito (2003)—ICD 490–496 (COPD)	>64 years
	$PM_{2.5}$ (24-hour avg)	Moolgavkar (2000)—ICD 490–496 (COPD)	20–64 years
	$PM_{2.5}$ (24-hour avg)	Ito (2003)—ICD 480–486 (pneumonia)	>64 years
	$PM_{2.5}$ (24-hour avg)	Sheppard (2003)—ICD 493 (asthma)	<65 years

Endpoint	Pollutant	Study	Study Population
Cardiovascular	$PM_{2.5}$ (24-hour avg)	*Pooled estimate:* Moolgavkar (2003)—ICD 390–429 (all cardiovascular) Ito (2003)—ICD 410–414, 427–428 (ischemic heart disease, dysrhythmia, heart failure)	>64 years
	$PM_{2.5}$ (24-hour avg)	Moolgavkar (2000)—ICD 390–429 (all cardiovascular)	20–64 years
Asthma-related ER visits	O_3 (8-hour max)	*Pooled estimate:* Peel et al. (2005) Wilson et al.(2005)	 All ages All ages
	$PM_{2.5}$ (24-hour avg)	Norris et al. (1999)	0–18 years
Other Health Endpoints			
Acute bronchitis	$PM_{2.5}$ (annual avg)	Dockery et al. (1996)	8–12 years
Upper respiratory symptoms	PM_{10} (24-hour avg)	Pope et al. (1991)	Asthmatics, 9–11 years
Lower respiratory symptoms	$PM_{2.5}$ (24-hour avg)	Schwartz and Neas (2000)	7–14 years
Asthma exacerbations	$PM_{2.5}$ (24-hour avg)	Pooled estimate: Ostro et al. (2001) (cough, wheeze and shortness of breath) Vedal et al. (1998) (cough)	6–18 years[a]
Work loss days	$PM_{2.5}$ (24-hour avg)	Ostro (1987)	18–65 years
School absence days	O_3 (8-hour max)	*Pooled estimate:* Gilliland et al. (2001) Chen et al. (2000)	5–17 years[b]
Minor Restricted Activity Days (MRADs)	O3 (8-hour max)	Ostro and Rothschild (1989)	18–65 years
	$PM_{2.5}$ (24-hour avg)	Ostro and Rothschild (1989)	18–65 years

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

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

5.4.2.1 $PM_{2.5}$ Premature Mortality Effect Coefficients

Both long- and short-term exposures to ambient levels of $PM_{2.5}$ air pollution have been associated with increased risk of premature mortality. The size of the mortality risk estimates from epidemiological studies, the serious nature of the effect itself, and the high monetary value ascribed to prolonging life make mortality risk reduction the most significant health endpoint quantified in this analysis.

Although a number of uncertainties remain to be addressed by continued research (NRC, 2002), a substantial body of published scientific literature documents the correlation between elevated $PM_{2.5}$ concentrations and increased mortality rates (U.S. EPA, 2009d). Time-series methods have been used to relate short-term (often day-to-day) changes in $PM_{2.5}$ concentrations and changes in daily mortality rates up to several days after a period of elevated $PM_{2.5}$ concentrations. Cohort methods have been used to examine the potential relationship between community-level PM exposures over multiple years (i.e., long-term exposures) and community-level annual mortality rates. Researchers have found statistically significant associations between $PM_{2.5}$ and premature mortality using both types of studies. In general, the risk estimates based on the cohort studies are larger than those derived from time-series studies. Cohort analyses are thought to better capture the full public health impact of exposure to air pollution over time, because they account for the effects of long-term exposures and possibly some component of short-term exposures (Kunzli et al., 2001; NRC, 2002). This section discusses some of the issues surrounding the estimation of $PM_{2.5}$-related premature mortality. To demonstrate the sensitivity of the benefits estimates to the specific sources of information regarding the impact of $PM_{2.5}$ exposures on the risk of premature death, we are providing estimates in our results tables based on studies derived from the epidemiological literature and from the EPA sponsored expert elicitation. The epidemiological studies from which these estimates are drawn are described below. The expert elicitation project and the derivation of effect estimates from the expert elicitation results are described in the 2006 $PM_{2.5}$ NAAQS RIA and Roman et al. (2008). In the interest of brevity we do not repeat those details here. However, Figure 5-18 summarizes the estimated $PM_{2.5}$-related premature mortalities avoided using risk estimates drawn from the expert elicitation.

Over a dozen epidemiological studies have found significant associations between various measures of long-term exposure to PM and elevated rates of annual mortality, beginning with Lave and Seskin (1977). Most of the published studies found positive (but not always statistically significant) associations with available PM indices such as total suspended particles (TSP). However, exploration of alternative model specifications sometimes raised questions about causal relationships (e.g., Lipfert et al., 1989). These early "ecological cross-sectional" studies (Lave and Seskin, 1977; Ozkaynak and Thurston, 1987) were criticized for a number of methodological limitations, particularly for inadequate control at the individual level for variables that are potentially important in causing mortality, such as wealth, smoking, and diet.

Over the last 17 years, several studies using "prospective cohort" designs have been published that appear to be consistent with the earlier body of literature. These new "prospective cohort" studies reflect a significant improvement over the earlier work because they include individual level information with respect to health status and residence. The most extensive analyses have been based on data from two prospective cohort groups, often referred to as the Harvard "Six-Cities Study" (Dockery et al., 1993; Laden et al., 2006) and the "American Cancer Society or ACS study" (Pope et al., 1995; Pope et al., 2002; Pope et al., 2004, Krewski et al. 2009); these studies have found consistent relationships between fine particle indicators and premature mortality across multiple locations in the United States. A third major data set comes from the California-based 7th Day Adventist Study (e.g., Abbey et al., 1999), which reported associations between long-term PM exposure and mortality in men. Results from this cohort, however, have been inconsistent, and the air quality results are not geographically representative of most of the United States, and the lifestyle of the population is not reflective of much of the U.S. population. Analysis is also available for a cohort of adult male veterans diagnosed with hypertension has been examined (Lipfert et al., 2000; Lipfert et al., 2003, 2006). The characteristics of this group differ from the cohorts in the Six-Cities, ACS, and 7th Day Adventist studies with respect to income, race, health status, and smoking status. Unlike previous long-term analyses, this study found some associations between mortality and ozone but found inconsistent results for PM indicators. Because of the selective nature of the population in the veteran's cohort, we have chosen not to include any effect estimates from the Lipfert et al. (2000) study in our benefits assessment.

Given their consistent results and broad geographic coverage, and importance in informing the NAAQS development process, the Six-Cities and ACS data have been particularly important in benefits analyses. The credibility of these two studies is further enhanced by the fact that the initial published studies (Pope et al., 1995 and Dockery et al., 1993) were subject to extensive reexamination and reanalysis by an independent team of scientific experts commissioned by the Health Effect Institute (HEI) (Krewski et al., 2000). The final results of the reanalysis were then independently peer reviewed by a Special Panel of the HEI Health Review Committee. The results of these reanalyses confirmed and expanded the conclusions of the original investigators. While the HEI reexamination lends credibility to the original studies, it also highlights sensitivities concerning the relative impact of various pollutants, such as SO_2, the potential role of education in mediating the association between pollution and mortality, and the influence of spatial correlation modeling. Further confirmation and extension of the findings of the 1993 Six City Study and the 1995 ACS study were recently completed using more recent air quality and a longer follow-up period for the ACS cohort was published over the past several years (Pope et al., 2002, 2004; Laden et al., 2006, Krewski et al. 2009). The follow up to the Harvard Six City Study both confirmed the effect size from the first analysis and provided additional confirmation that reductions in $PM_{2.5}$ are likely to result in reductions in the risk of premature death. This additional evidence stems from the observed reductions in $PM_{2.5}$ in each city during the extended follow-up period. Laden et al. (2006) found that mortality rates consistently went down at a rate proportionate to the observed reductions in $PM_{2.5}$.

A number of additional analyses have been conducted on the ACS cohort data (Jarrett et al., 2009; Pope et al., 2009). These studies have continued to find a strong significant relationship between $PM_{2.5}$ and mortality outcomes and life expectancy. Specifically, much of the recent research has suggested a stronger relationship between cardiovascular mortality and lung cancer mortality with $PM_{2.5}$, and a less significant relationship between respiratory-related mortality and $PM_{2.5}$. The extended analyses of the ACS cohort data (Krewski et al. 2009) provides additional refinements to the analysis of PM-related mortality by (a) extend the follow-up period by 2 years to the year 2000, for a total of 18 years; (b) incorporate ecological., or neighborhood-level co-variates so as to better estimate personal exposure; (c) perform an extensive spatial analysis using land use regression modeling. These additional refinements may make this analysis well-suited for the assessment of PM-related mortality for EPA benefits analyses.

In developing and improving the methods for estimating and valuing the potential reductions in mortality risk over the years, EPA consulted with the SAB-HES. That panel recommended using long-term prospective cohort studies in estimating mortality risk reduction (U.S. EPA-SAB, 1999b). This recommendation has been confirmed by a report from the National Research Council, which stated that "it is essential to use the cohort studies in benefits analysis to capture all important effects from air pollution exposure" (NRC, 2002, p. 108). More specifically, the SAB recommended emphasis on the ACS study because it includes a much larger sample size and longer exposure interval and covers more locations (e.g., 50 cities compared to the Six Cities Study) than other studies of its kind. Because of the refinements in the extended follow-up analysis, the SAB-HES recommended using the Pope et al. (2002) study as the basis for the primary mortality estimate for adults and suggests that alternate estimates of mortality generated using other cohort and time-series studies could be included as part of the sensitivity analysis (U.S. EPA-SAB, 2004b). The PM NAAQS Risk and Exposure Assessment (U.S EPA, 2010) utilized risk coefficients drawn from the Krewski et al. (2009) study. In a December of 2009 consultation with the SAB-HES, the Agency proposed utilizing the Krewski et al. (2009) extended analysis of the ACS cohort data. The panel was supportive of this approach.

As noted above, since 2004 SAB review, an extended follow-up of the Harvard Six cities study has been published (Laden et al., 2006) and in recent RIAs (see for example the SO_2 NAAQS, PM NAAQS, CAIR and Nonroad Diesel RIAs), we have included this estimate of mortality impacts based on application of the C-R function derived from this study. We use this specific estimate to represent the Six Cities study because it both reflects among the most up-to-date science and was cited by many of the experts in their elicitation responses. It is clear from the expert elicitation that the results published in Laden et al. (2006) are potentially influential, and in fact the expert elicitation results encompass within their range the estimates from both the Pope et al. (2002) and Laden et al. (2006) studies (see Figure 5-18 below). These are logical choices for anchor points in our presentation because, while both studies are well designed and peer reviewed, there are strengths and weaknesses inherent in each, which we believe argues for using both studies to generate benefits estimates.

5.4.2.2 Ozone Premature Mortality Effect Coefficients

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

With respect to the time-series studies, the conclusion regarding the relationship between short-term ozone exposure and premature mortality is based, in part, upon recent city-specific time-series studies such as the Schwartz (2004) analysis in Houston and the Huang et al. (2004) analysis in Los Angeles.[21] This conclusion is also based on recent meta-analyses by Bell et al. (2005), Ito et al. (2005), and Levy et al. (2005), and a new analysis of the National Morbidity, Mortality, and Air Pollution Study (NMMAPS) data set by Bell et al. (2004), which specifically sought to disentangle the roles of ozone, PM, weather-related variables, and seasonality. The 2006 Criteria Document states that "the results from these meta-analyses, as well as several single- and multiple-city studies, indicate that co-pollutants generally do not appear to substantially confound the association between ozone and mortality" (p. 7-103). However, CASAC raised questions about the implications of these time-series results in a policy context. Specifically, CASAC emphasized that "…while the time-series study design is a powerful tool to detect very small effects that could not be detected using other designs, it is also a blunt tool" (U.S. EPA-SAB, 2006). They point to findings (e.g., Stieb et al., 2002, 2003) that indicated associations between premature mortality and all of the criteria pollutants, indicating that "findings of time-series studies do not seem to allow us to confidently attribute observed effects to individual pollutants" (id.). They note that "not only is the interpretation of these associations complicated by the fact that the day-to-day variation in concentrations of these pollutants is, to a varying degree, determined by meteorology, the pollutants are often part of a large and highly correlated mix of pollutants, only a very few of which are measured" (id.). Even with these uncertainties, the CASAC Ozone Panel, in its review of EPA's Staff Paper, found "…premature total non-accidental and cardiorespiratory mortality for inclusion in the quantitative risk assessment to be appropriate."

In 2006 the EPA requested an NAS study to answer four key questions regarding ozone mortality: (1) how did the epidemiological literature to that point improve our understanding of the size of the ozone mortality effect? (2) How best can EPA quantify the level of ozone mortality impacts from short-term exposure? (3) How might EPA estimate the change in life expectancy? (4) What methods should EPA use to estimate the monetary value of changes in ozone-related mortality risk and life expectancy?

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

In 2008 the NAS (NRC, 2008) issued a series of recommendations to the EPA regarding the quantification and valuation of ozone-related short-term mortality. Chief among these was that "…short-term exposure to ambient ozone is likely to contribute to premature deaths" and the committee recommended that "ozone-related mortality be included in future estimates of the health benefits of reducing ozone exposures…" The NAS also recommended that "…the greatest emphasis be placed on the multicity and NMMAPS studies without exclusion of the meta-analyses" (NRC, 2008).

Recent evidence also suggests a relationship between long-term exposure to ozone and premature respiratory mortality in the ACS cohort (Jerrett et al. 2009). Jerrett and colleagues find that long-term exposure to ozone is linked to respiratory premature mortality in a two-pollutant model that controls for $PM_{2.5}$. This is the first long-term cohort study to have observed such a relationship. In a December of 2009 consultation with the SAB-HES, the Agency proposed utilizing the Jerrett et al. (2009) analysis of the ACS cohort data. In its advisory, the panel recommended quantifying ozone-related mortality using risk coefficients drawn from the short-term time-series studies.

In view of the findings of the Criteria document and the NAS panel, we include used estimates of short-term ozone mortality from the Bell et al. (2004) NMMAPS analysis, the Schwartz (2005) multi-city study, the Huang et al. (2005) multi-city study as well as effect estimates from the three meta-analyses (Bell et al. 2005, Levy et al. 2005 and Ito et al. 2005).

5.4.2.3 Chronic Bronchitis

CB is characterized by mucus in the lungs and a persistent wet cough for at least 3 months a year for several years in a row. CB affects an estimated 5 percent of the U.S. population (American Lung Association, 1999). A limited number of studies have estimated the impact of air pollution on new incidences of CB. Schwartz (1993) and Abbey et al. (1995) provide evidence that long-term PM exposure gives rise to the development of CB in the United States. Because the Transport Rule is expected to reduce primarily $PM_{2.5}$, this analysis uses only the Abbey et al. (1995) study, because it is the only study focusing on the relationship between $PM_{2.5}$ and new incidences of CB.

5.4.2.4 Nonfatal Myocardial Infarctions (Heart Attacks)

Nonfatal heart attacks have been linked with short-term exposures to $PM_{2.5}$ in the United States (Peters et al., 2001) and other countries (Poloniecki et al., 1997). We used a recent study by Peters et al. (2001) as the basis for the impact function estimating the relationship between $PM_{2.5}$ and nonfatal heart attacks. Peters et al. is the only available U.S. study to provide a specific estimate for heart attacks. Other studies, such as Samet et al. (2000) and Moolgavkar (2000), show a consistent relationship between all cardiovascular hospital admissions, including those for nonfatal heart attacks, and PM. Given the lasting impact of a heart attack on long-term health costs and earnings, we provide a separate estimate for nonfatal heart attacks. The estimate used in the Transport Rule analysis is based on the single available U.S. effect estimate. The finding of a specific impact on heart attacks is consistent with hospital admission and other studies showing relationships between fine particles and cardiovascular effects both within and outside the United States. Several epidemiologic studies (Liao et al., 1999; Gold et al., 2000; Magari et al., 2001) have shown that heart rate variability (an indicator of how much the heart is able to speed up or slow down in response to momentary stresses) is negatively related to PM levels. Heart rate variability is a risk factor for heart attacks and other coronary heart diseases (Carthenon et al., 2002; Dekker et al., 2000; Liao et al., 1997; Tsuji et al., 1996). As such, significant impacts of PM on heart rate variability are consistent with an increased risk of heart attacks.

5.4.2.5 Hospital and Emergency Room Admissions

Because of the availability of detailed hospital admission and discharge records, there is an extensive body of literature examining the relationship between hospital admissions and air pollution. Because of this, many of the hospital admission endpoints use pooled impact functions based on the results of a number of studies. In addition, some studies have examined the relationship between air pollution and emergency room visits. Since most emergency room visits do not result in an admission to the hospital (the majority of people going to the emergency room are treated and return home), we treat hospital admissions and emergency room visits separately, taking account of the fraction of emergency room visits that are admitted to the hospital.

The two main groups of hospital admissions estimated in this analysis are respiratory admissions and cardiovascular admissions. There is not much evidence linking ozone or PM with other types of hospital admissions. The only type of emergency room visits that have been consistently linked to ozone and PM in the United States are asthma-related visits.

To estimate avoided incidences of cardiovascular hospital admissions associated with $PM_{2.5}$, we used studies by Moolgavkar (2003) and Ito (2003). Additional published studies show a statistically significant relationship between PM_{10} and cardiovascular hospital admissions. However, given that the control options we are analyzing are expected to reduce primarily $PM_{2.5}$, we focus on the two studies that examine $PM_{2.5}$. Both of these studies provide an effect estimate for populations over 65, allowing us to pool the impact functions for this age group. Only Moolgavkar (2000) provided a separate effect estimate for populations 20 to 64.[22] Total cardiovascular hospital admissions are thus the sum of the pooled estimate for populations over 65 and the single study estimate for populations 20 to 64. Cardiovascular hospital admissions include admissions for myocardial infarctions. To avoid double-counting benefits from reductions in myocardial infarctions when applying the impact function for cardiovascular hospital admissions, we first adjusted the baseline cardiovascular hospital admissions to remove admissions for myocardial infarctions.

To estimate total avoided incidences of respiratory hospital admissions, we used impact functions for several respiratory causes, including chronic obstructive pulmonary disease (COPD), pneumonia, and asthma. As with cardiovascular admissions, additional published studies show a statistically significant relationship between PM_{10} and respiratory hospital admissions. We used only those focusing on $PM_{2.5}$. Both Moolgavkar (2000) and Ito (2003) provide effect estimates for COPD in populations over 65, allowing us to pool the impact functions for this group. Only Moolgavkar (2000) provides a separate effect estimate for populations 20 to 64. Total COPD hospital admissions are thus the sum of the pooled estimate for populations over 65 and the single study estimate for populations 20 to 64. Only Ito (2003) estimated pneumonia and only for the population 65 and older. In addition, Sheppard (2003) provided an effect estimate for asthma hospital admissions for populations under age 65. Total avoided incidences of PM-related respiratory-related hospital admissions are the sum of COPD, pneumonia, and asthma admissions.

To estimate the effects of PM air pollution reductions on asthma-related ER visits, we use the effect estimate from a study of children 18 and under by Norris et al. (1999). As noted earlier, there is another study by Schwartz examining a broader age group (less than 65), but the Schwartz study focused on PM_{10} rather than $PM_{2.5}$. We selected the Norris et al. (1999) effect

[22]Note that the Moolgavkar (2000) study has not been updated to reflect the more stringent GAM convergence criteria. However, given that no other estimates are available for this age group, we chose to use the existing study. Given the very small (<5 percent) difference in the effect estimates for people 65 and older with cardiovascular hospital admissions between the original and reanalyzed results, we do not expect this choice to introduce much bias.

estimate because it better matched the pollutant of interest. Because children tend to have higher rates of hospitalization for asthma relative to adults under 65, we will likely capture the majority of the impact of $PM_{2.5}$ on asthma emergency room visits in populations under 65, although there may still be significant impacts in the adult population under 65.

To estimate avoided incidences of respiratory hospital admissions associated with ozone, we used a number of studies examining hospital admissions for a range of respiratory illnesses, including pneumonia and COPD. Two age groups, adults over 65 and children under 2, were examined. For adults over 65, Schwartz (1995) provides effect estimates for two different cities relating ozone and hospital admissions for all respiratory causes (defined as ICD codes 460–519). Impact functions based on these studies were pooled first before being pooled with other studies. Two studies (Moolgavkar et al., 1997; Schwartz, 1994a) examine ozone and pneumonia hospital admissions in Minneapolis. One additional study (Schwartz, 1994b) examines ozone and pneumonia hospital admissions in Detroit. The impact functions for Minneapolis were pooled together first, and the resulting impact function was then pooled with the impact function for Detroit. This avoids assigning too much weight to the information coming from one city. For COPD hospital admissions, two studies are available: Moolgavkar et al. (1997), conducted in Minneapolis, and Schwartz (1994b), conducted in Detroit. These two studies were pooled together. To estimate total respiratory hospital admissions for adults over 65, COPD admissions were added to pneumonia admissions, and the result was pooled with the Schwartz (1995) estimate of total respiratory admissions. Burnett et al. (2001) is the only study providing an effect estimate for respiratory hospital admissions in children under 2.

We used two studies as the source of the concentration-response functions we used to estimate the effects of ozone exposure on asthma-related emergency room (ER) visits: Peel et al. (2005) and Wilson et al. (2005). We estimated the change in ER visits using the effect estimate(s) from each study and then pooled the results using the random effects pooling technique (see Abt, 2005). The Peel et al. study (2005) estimated asthma-related ER visits for all ages in Atlanta, using air quality data from 1993 to 2000. Using Poisson generalized estimating equations, the authors found a marginal association between the maximum daily 8-hour average ozone level and ER visits for asthma over a 3-day moving average (lags of 0, 1, and 2 days) in a single pollutant model. Wilson et al. (2005) examined the relationship between ER visits for respiratory illnesses and asthma and air pollution for all people residing in Portland, Maine from 1998–2000 and Manchester, New Hampshire from 1996–2000. For all models used in the analysis, the authors restricted the ozone data incorporated into the model to the months ozone levels are usually measured, the spring-summer months (April through September). Using the generalized additive model, Wilson et al. (2005) found a significant association between the maximum daily 8-hour average ozone level and ER visits for asthma in Portland, but found no significant association for Manchester. Similar to the approach used to generate effect estimates for hospital admissions, we used random effects pooling to combine the results across the individual study estimates for ER visits for asthma. The Peel et al. (2005) and Wilson et al. (2005) Manchester estimates were not significant at the 95 percent level, and thus, the confidence interval for the pooled incidence estimate based on these studies includes negative values. This is an artifact of the statistical power of the studies, and the negative values in the tails of the estimated effect distributions do not represent improvements in health as ozone concentrations are increased. Instead, these should be viewed as a measure of uncertainty due to limitations in the statistical power of the study. We included both hospital admissions and ER visits as separate endpoints associated with ozone exposure because our estimates of hospital admission costs do not include the costs of ER visits and most asthma ER visits do not result in a hospital admission.

5.4.2.6 Acute Health Events and School/Work Loss Days

In addition to mortality, chronic illness, and hospital admissions, a number of acute health effects not requiring hospitalization are associated with exposure to ambient levels of ozone and PM. The sources for the effect estimates used to quantify these effects are described below.

Around 4 percent of U.S. children between the ages of 5 and 17 experience episodes of acute bronchitis annually (American Lung Association, 2002c). Acute bronchitis is characterized by coughing, chest discomfort, slight fever, and extreme tiredness, lasting for a number of days. According to the MedlinePlus medical encyclopedia,[23] with the exception of cough, most acute bronchitis symptoms abate within 7 to 10 days. Incidence of episodes of acute bronchitis in children between the ages of 5 and 17 were estimated using an effect estimate developed from Dockery et al. (1996).

Incidences of lower respiratory symptoms (e.g., wheezing, deep cough) in children aged 7 to 14 were estimated using an effect estimate from Schwartz and Neas (2000).

Because asthmatics have greater sensitivity to stimuli (including air pollution), children with asthma can be more susceptible to a variety of upper respiratory symptoms (e.g., runny or stuffy nose; wet cough; and burning, aching, or red eyes). Research on the effects of air

[23]See http://www.nlm.nih.gov/medlineplus/ency/article/000124.htm, accessed January 2002.

pollution on upper respiratory symptoms has thus focused on effects in asthmatics. Incidences of upper respiratory symptoms in asthmatic children aged 9 to 11 are estimated using an effect estimate developed from Pope et al. (1991).

Health effects from air pollution can also result in missed days of work (either from personal symptoms or from caring for a sick family member). Days of work lost due to $PM_{2.5}$ were estimated using an effect estimate developed from Ostro (1987). Children may also be absent from school because of respiratory or other diseases caused by exposure to air pollution. Most studies examining school absence rates have found little or no association with $PM_{2.5}$, but several studies have found a significant association between ozone levels and school absence rates. We used two recent studies, Gilliland et al. (2001) and Chen et al. (2000), to estimate changes in absences (school loss days) due to changes in ozone levels. The Gilliland et al. study estimated the incidence of new periods of absence, while the Chen et al. study examined absence on a given day. We converted the Gilliland estimate to days of absence by multiplying the absence periods by the average duration of an absence. We estimated an average duration of school absence of 1.6 days by dividing the average daily school absence rate from Chen et al. (2000) and Ransom and Pope (1992) by the episodic absence rate from Gilliland et al. (2001). This provides estimates from Chen et al. (2000) and Gilliland et al. (2001), which can be pooled to provide an overall estimate.

MRAD result when individuals reduce most usual daily activities and replace them with less strenuous activities or rest, yet not to the point of missing work or school. For example, a mechanic who would usually be doing physical work most of the day will instead spend the day at a desk doing paper and phone work because of difficulty breathing or chest pain. The effect of $PM_{2.5}$ and ozone on MRAD was estimated using an effect estimate derived from Ostro and Rothschild (1989).

For the Transport Rule, we have followed the SAB-HES recommendations regarding asthma exacerbations in developing the primary estimate. To prevent double-counting, we focused the estimation on asthma exacerbations occurring in children and excluded adults from the calculation.[24] Asthma exacerbations occurring in adults are assumed to be captured in the

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[24]Estimating asthma exacerbations associated with air pollution exposures is difficult, due to concerns about double counting of benefits. Concerns over double counting stem from the fact that studies of the general population also include asthmatics, so estimates based solely on the asthmatic population cannot be directly added to the general population numbers without double counting. In one specific case (upper respiratory symptoms in children), the only study available is limited to asthmatic children, so this endpoint can be readily included in the calculation of total benefits. However, other endpoints, such as lower respiratory symptoms and MRADs, are estimated for the total population that includes asthmatics. Therefore, to simply add predictions of asthma-related symptoms

general population endpoints such as work loss days and MRADs. Consequently, if we had included an adult-specific asthma exacerbation estimate, we would likely double-count incidence for this endpoint. However, because the general population endpoints do not cover children (with regard to asthmatic effects), an analysis focused specifically on asthma exacerbations for children (6 to 18 years of age) could be conducted without concern for double-counting.

To characterize asthma exacerbations in children, we selected two studies (Ostro et al., 2001; Vedal et al., 1998) that followed panels of asthmatic children. Ostro et al. (2001) followed a group of 138 African-American children in Los Angeles for 13 weeks, recording daily occurrences of respiratory symptoms associated with asthma exacerbations (e.g., shortness of breath, wheeze, and cough). This study found a statistically significant association between $PM_{2.5}$, measured as a 12-hour average, and the daily prevalence of shortness of breath and wheeze endpoints. Although the association was not statistically significant for cough, the results were still positive and close to significance; consequently, we decided to include this endpoint, along with shortness of breath and wheeze, in generating incidence estimates (see below). Vedal et al. (1998) followed a group of elementary school children, including 74 asthmatics, located on the west coast of Vancouver Island for 18 months including measurements of daily peak expiratory flow (PEF) and the tracking of respiratory symptoms (e.g., cough, phlegm, wheeze, chest tightness) through the use of daily diaries. Association between PM_{10} and respiratory symptoms for the asthmatic population was only reported for two endpoints: cough and PEF. Because it is difficult to translate PEF measures into clearly defined health endpoints that can be monetized, we only included the cough-related effect estimate from this study in quantifying asthma exacerbations. We employed the following pooling approach in combining estimates generated using effect estimates from the two studies to produce a single asthma exacerbation incidence estimate. First, we pooled the separate incidence estimates for shortness of breath, wheeze, and cough generated using effect estimates from the Ostro et al. study, because each of these endpoints is aimed at capturing the same overall endpoint (asthma exacerbations) and there could be overlap in their predictions. The pooled estimate from the Ostro et al. study is then pooled with the cough-related estimate generated using the Vedal study.

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generated for the population of asthmatics to these total population-based estimates could result in double counting, especially if they evaluate similar endpoints. The SAB-HES, in commenting on the analytical blueprint for 812, acknowledged these challenges in evaluating asthmatic symptoms and appropriately adding them into the primary analysis (SAB-HES, 2004). However, despite these challenges, the SAB-HES recommends the addition of asthma-related symptoms (i.e., asthma exacerbations) to the primary analysis, provided that the studies use the panel study approach and that they have comparable design and baseline frequencies in both asthma prevalence and exacerbation rates. Note also, that the SAB-HES, while supporting the incorporation of asthma exacerbation estimates, does not believe that the association between ambient air pollution, including ozone and PM, and the new onset of asthma is sufficiently strong to support inclusion of this asthma-related endpoint in the primary estimate.

The rationale for this second pooling step is similar to the first; both studies are attempting to quantify the same overall endpoint (asthma exacerbations).

5.4.2.7 School Absences

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

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

5.4.2.8 Outdoor Worker Productivity

To monetize benefits associated with increased worker productivity resulting from improved ozone air quality, we used information reported in Crocker and Horst (1981). Crocker and Horst examined the impacts of ozone exposure on the productivity of outdoor citrus workers. The study measured productivity impacts. Worker productivity is measuring the value of the loss in productivity for a worker who is at work on a particular day, but due to ozone, cannot work as hard. It only applies to outdoor workers, like fruit and vegetable pickers, or construction workers. Here, productivity impacts are measured as the change in income associated with a change in ozone exposure, given as the elasticity of income with respect to ozone concentration. The reported elasticity translates a ten percent reduction in ozone to a 1.4 percent increase in income. Given the national median daily income for outdoor workers engaged in strenuous activity reported by the U.S. Census Bureau (2002), $81 per day (2006$), a ten percent reduction in ozone yields about $0.97 in increased daily wages. We adjust the national median daily income estimate to reflect regional variations in income using a factor based on the ratio of county median household income to national median household income. No information was available for quantifying the uncertainty associated with the central valuation estimate. Therefore, no uncertainty analysis was conducted for this endpoint.

5.4.3 Baseline Incidence Estimates

Epidemiological studies of the association between pollution levels and adverse health effects generally provide a direct estimate of the relationship of air quality changes to the *relative risk* of a health effect, rather than estimating the absolute number of avoided cases. For example, a typical result might be that a 10 ppb decrease in daily ozone levels might, in turn, decrease hospital admissions by 3 percent. The baseline incidence of the health effect is necessary to convert this relative change into a number of cases. A baseline incidence rate is the estimate of the number of cases of the health effect per year in the assessment location, as it corresponds to baseline pollutant levels in that location. To derive the total baseline incidence per year, this rate must be multiplied by the corresponding population number. For example, if the baseline incidence rate is the number of cases per year per million people, that number must be multiplied by the millions of people in the total population.

Table 5-6 summarizes the sources of baseline incidence rates and provides average incidence rates for the endpoints included in the analysis. For both baseline incidence and prevalence data, we used age-specific rates where available. We applied concentration-response functions to individual age groups and then summed over the relevant age range to provide an estimate of total population benefits. We highlight in blue those rates that have changed since the proposal RIA.

The baseline incidence rates for hospital and emergency department visits that we applied in this analysis are an improvement over the rates we used in the proposal analysis in two ways. First, these data are newer, and so are a more recent representation of the rates at which populations of different ages, and in different locations, visit the hospital and emergency department for illnesses that may be air pollution related. Second, these newer data are also more spatially refined. For many locations within the U.S., these data are resolved at the county- or state-level, providing a better characterization of the geographic distribution of hospital and emergency department visits. Newer and more spatially resolved incidence rates are likely to yield a more reliable estimate of air pollution-related hospitalizations and emergency department visits. Consistent with the proposal RIA, we continue to use county-level mortality rates. We have projected mortality rates such that future mortality rates are consistent with our projections of population growth (Abt Associates, 2008).

For the set of endpoints affecting the asthmatic population, in addition to baseline incidence rates, prevalence rates of asthma in the population are needed to define the applicable population. Table 5-7 lists the prevalence rates used to determine the applicable population for asthma symptom endpoints. Note that these reflect current asthma prevalence and assume no change in prevalence rates in future years. We again highlight in blue those rates that have been updated since the publication of the 2014 proposed Transport Rule RIA.

Table 5-6: Baseline Incidence Rates and Population Prevalence Rates for Use in Impact Functions, General Population

Endpoint	*Parameter*	*Rates* *Value*	*Rates* *Source*
Mortality	Daily or annual mortality rate projected to 2020	Age-, cause-, and county-specific rate	CDC Wonder (2006–2008) U.S. Census bureau
Hospitalizations	Daily hospitalization rate	Age-, region-, state-, county- and cause- specific rate	2007 HCUP data files[a]
Asthma ER Visits	Daily asthma ER visit rate	Age-, region-, state-, county- and cause- specific rate	2007 HCUP data files[a]
Chronic Bronchitis	Annual prevalence rate per person • Aged 18–44 • Aged 45–64 • Aged 65 and older	 0.0367 0.0505 0.0587	1999 NHIS (American Lung Association, 2002b, Table 4)
	Annual incidence rate per person	0.00378	Abbey et al. (1993, Table 3)
Nonfatal Myocardial Infarction (heart attacks)	Daily nonfatal myocardial infarction incidence rate per person, 18+	Age-, region-, state-, and county-specific rate	2007 HCUP data files[a]; adjusted by 0.93 for probability of surviving after 28 days (Rosamond et al., 1999)
Asthma Exacerbations	Incidence among asthmatic African-American children • daily wheeze • daily cough • daily dyspnea	0.076 0.067 0.037	Ostro et al. (2001)
Acute Bronchitis	Annual bronchitis incidence rate, children	0.043	American Lung Association (2002c, Table 11)
Lower Respiratory Symptoms	Daily lower respiratory symptom incidence among children[b]	0.0012	Schwartz et al. (1994, Table 2)
Upper Respiratory Symptoms	Daily upper respiratory symptom incidence among asthmatic children	0.3419	Pope et al. (1991, Table 2)
Work Loss Days	Daily WLD incidence rate per person (18–65) • Aged 18–24 • Aged 25–44 • Aged 45–64	 0.00540 0.00678 0.00492	1996 HIS (Adams, Hendershot, and Marano, 1999, Table 41); U.S. Bureau of the Census (2000)
School Loss Days	Rate per person per year, assuming 180 school days per year	9.9	National Center for Education Statistics (1996) and 1996 HIS (Adams et al., 1999, Table 47);
Minor Restricted-Activity Days	Daily MRAD incidence rate per person	0.02137	Ostro and Rothschild (1989, p. 243)

[a] Healthcare Cost and Utilization Program (HCUP) database contains individual level, state and regional-level hospital and emergency department discharges for a variety of ICD codes.

[b] Lower respiratory symptoms are defined as two or more of the following: cough, chest pain, phlegm, and wheeze.

Table 5-7. Asthma Prevalence Rates Used for this Analysis

	Asthma Prevalence Rates	
Population Group	*Value*	*Source*
All Ages	0.0780	American Lung Association (2010b, Table 7)
< 18	0.0941	
5–17	0.1070	
18–44	0.0719	
45–64	0.0745	
65+	0.0716	
African American, 5 to 17	0.1776	American Lung Association (2010b, Table 9)
African American, <18	0.1553	American Lung Association[b]

[A] See ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHIS/2000/.

[B] Calculated by ALA for U.S. EPA, based on NHIS data (CDC, 2008)

5.4.4 Economic Valuation Estimates

Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects for a large population. Therefore, the appropriate economic measure is WTP for changes in risk of a health effect rather than WTP for a health effect that would occur with certainty (Freeman, 1993). Epidemiological studies generally provide estimates of the relative risks of a particular health effect that is avoided because of a reduction in air pollution. We converted those to units of avoided statistical incidence for ease of presentation. We calculated the value of avoided statistical incidences by dividing individual WTP for a risk reduction by the related observed change in risk.

WTP estimates generally are not available for some health effects, such as hospital admissions. In these cases, we used the cost of treating or mitigating the effect as a primary estimate. These cost-of-illness (COI) estimates generally understate the true value of reducing the risk of a health effect, because they reflect the direct expenditures related to treatment, but not the value of avoided pain and suffering (Harrington and Portney, 1987; Berger, 1987). We provide unit values for health endpoints (along with information on the distribution of the unit value) in Table 5-8. All values are in constant year 2006 dollars, adjusted for growth in real income out to 2014 using projections provided by Standard and Poor's. Economic theory argues that WTP for most goods (such as environmental protection) will increase if real income increases. Many of the valuation studies used in this analysis were conducted in the late 1980s and early 1990s. Because real income has grown since the studies were conducted, people's willingness to pay for reductions in the risk of premature death and disease likely has grown as well. We did not adjust cost of illness-based values because they are based on current costs. Similarly, we did not adjust the value of school absences, because that value is based on current wage rates. For these two reasons, these cost of illness estimates may underestimate the economic value of avoided health impacts in 2014. The discussion below provides additional details on ozone and $PM_{2.5}$-related related endpoints.

5.4.4.1 Mortality Valuation

Following the advice of the EEAC of the SAB, EPA currently uses the VSL approach in calculating the primary estimate of mortality benefits, because we believe this calculation provides the most reasonable single estimate of an individual's willingness to trade off money for reductions in mortality risk (U.S. EPA-SAB, 2000). The VSL approach is a summary measure for the value of small changes in mortality risk experienced by a large number of people. For a period of time (2004-2008), the Office of Air and Radiation (OAR) valued mortality risk reductions using a value of statistical life (VSL) estimate derived from a limited analysis of some of the available studies. OAR arrived at a VSL using a range of $1 million to $10 million (2000$) consistent with two meta-analyses of the wage-risk literature. The $1 million value represented the lower end of the interquartile range from the Mrozek and Taylor (2002) meta-analysis of 33 studies. The $10 million value represented the upper end of the interquartile range from the Viscusi and Aldy (2003) meta-analysis of 43 studies. The mean estimate of $5.5 million (2000$) was also consistent with the mean VSL of $5.4 million estimated in the Kochi et al. (2006) meta-analysis. However, the Agency neither changed its official guidance on the use of VSL in rule-makings nor subjected the interim estimate to a scientific peer-review process through the Science Advisory Board (SAB) or other peer-review group.

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

Until updated guidance is available, the Agency determined that a single, peer-reviewed estimate applied consistently best reflects the SAB-EEAC advice it has received. Therefore, the Agency has decided to apply the VSL that was vetted and endorsed by the SAB in the Guidelines for Preparing Economic Analyses (U.S. EPA, 2000)[25] while the Agency continues its efforts to update its guidance on this issue. This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $6.3 million (2000$).[26] The Agency is committed to using scientifically sound, appropriately reviewed evidence in valuing mortality risk reductions and has made significant progress in responding to the SAB-EEAC's specific recommendations In the process, the Agency has identified a number of important issues to be considered in updating its mortality risk valuation estimates. These are detailed in a white paper on "Valuing Mortality Risk Reductions in Environmental Policy," submitted to the EPA's independent Science Advisory Board (SAB) for review. A meeting with the SAB on this paper was held on March 14, 2011 and formal recommendations are anticipated in Summer 2011. Draft guidance responding to SAB recommendations will be developed shortly thereafter.

As indicated in the previous section on quantification of premature mortality benefits, we assumed for this analysis that some of the incidences of premature mortality related to PM exposures occur in a distributed fashion over the 20 years following exposure. To take this into account in the valuation of reductions in premature mortality, we applied an annual 3% discount rate to the value of premature mortality occurring in future years.[27]

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

[26] In this analysis, we adjust the VSL to account for a different currency year (2006$) and to account for income growth to 2014. After applying these adjustments to the $6.3 million value, the VSL is $7.8M.

[27] The choice of a discount rate, and its associated conceptual basis, is a topic of ongoing discussion within the federal government. EPA adopted a 3% discount rate for its base estimate in this case to reflect reliance on a "social rate of time preference" discounting concept. We have also calculated benefits and costs using a 7% rate consistent with an "opportunity cost of capital" concept to reflect the time value of resources directed to meet regulatory requirements. In this case, the benefit and cost estimates were not significantly affected by the choice of discount rate. Further discussion of this topic appears in EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b).

The economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still developing. The adoption of a value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economics and public policy analysis community. EPA strives to use the best economic science in its analyses. Given the mixed theoretical finding and empirical evidence regarding adjustments to VSL for risk and population characteristics, we use a single VSL for all reductions in mortality risk.

Although there are several differences between the labor market studies EPA uses to derive a VSL estimate and the PM air pollution context addressed here, those differences in the affected populations and the nature of the risks imply both upward and downward adjustments. Table 5-11 lists some of these differences and the expected effect on the VSL estimate for air pollution-related mortality. In the absence of a comprehensive and balanced set of adjustment factors, EPA believes it is reasonable to continue to use the $6.3 million value (2000$) while acknowledging the significant limitations and uncertainties in the available literature.

Table 5-8: Expected Impact on Estimated Benefits of Premature Mortality Reductions of Differences Between Factors Used in Developing Applied VSL and Theoretically Appropriate VSL

Attribute	*Expected Direction of Bias*
Age	Uncertain, perhaps overestimate
Life Expectancy/Health Status	Uncertain, perhaps overestimate
Attitudes Toward Risk	Underestimate
Income	Uncertain
Voluntary vs. Involuntary	Uncertain, perhaps underestimate
Catastrophic vs. Protracted Death	Uncertain, perhaps underestimate

The SAB-EEAC has reviewed many potential VSL adjustments and the state of the economics literature. The SAB-EEAC advised EPA to "continue to use a wage-risk-based VSL as its primary estimate, including appropriate sensitivity analyses to reflect the uncertainty of these estimates," and that "the only risk characteristic for which adjustments to the VSL can be made is the timing of the risk" (U.S. EPA, 2000a). In developing our primary estimate of the benefits of premature mortality reductions, we have followed this advice and discounted over the lag period between exposure and premature mortality.

Uncertainties Specific to Premature Mortality Valuation**.** The economic benefits associated with reductions in the risk of premature mortality are the largest category of monetized benefits of the Transport Rule. In addition, in prior analyses, EPA has identified valuation of mortality-related benefits as the largest contributor to the range of uncertainty in monetized benefits (U.S. EPA, 1999b).[28] Because of the uncertainty in estimates of the value of reducing premature mortality risk, it is important to adequately characterize and understand the various types of economic approaches available for valuing reductions in mortality risk. Such an assessment also requires an understanding of how alternative valuation approaches reflect that some individuals may be more susceptible to air pollution-induced mortality or reflect differences in the nature of the risk presented by air pollution relative to the risks studied in the relevant economics literature.

The health science literature on air pollution indicates that several human characteristics affect the degree to which mortality risk affects an individual. For example, some age groups appear to be more susceptible to air pollution than others (e.g., the elderly and children). Health status prior to exposure also affects susceptibility. An ideal benefits estimate of mortality risk reduction would reflect these human characteristics, in addition to an individual's WTP to improve one's own chances of survival plus WTP to improve other individuals' survival rates. The ideal measure would also take into account the specific nature of the risk reduction commodity that is provided to individuals, as well as the context in which risk is reduced. To measure this value, it is important to assess how reductions in air pollution reduce the risk of dying from the time that reductions take effect onward and how individuals value these changes. Each individual's survival curve, or the probability of surviving beyond a given age, should shift as a result of an environmental quality improvement. For example, changing the current probability of survival for an individual also shifts future probabilities of that individual's survival. This probability shift will differ across individuals because survival curves depend on such characteristics as age, health state, and the current age to which the individual is likely to survive.

Although a survival curve approach provides a theoretically preferred method for valuing the benefits of reduced risk of premature mortality associated with reducing air pollution, the approach requires a great deal of data to implement. The economic valuation literature does not

[28] This conclusion was based on an assessment of uncertainty based on statistical error in epidemiological effect estimates and economic valuation estimates. Additional sources of model error such as those examined in the PM mortality expert elicitation may result in different conclusions about the relative contribution of sources of uncertainty.

yet include good estimates of the value of this risk reduction commodity. As a result, in this study we value reductions in premature mortality risk using the VSL approach.

Other uncertainties specific to premature mortality valuation include the following:

- *Across-study variation:* There is considerable uncertainty as to whether the available literature on VSL provides adequate estimates of the VSL for risk reductions from air pollution reduction. Although there is considerable variation in the analytical designs and data used in the existing literature, the majority of the studies involve the value of risks to a middle-aged working population. Most of the studies examine differences in wages of risky occupations, using a hedonic wage approach. Certain characteristics of both the population affected and the mortality risk facing that population are believed to affect the average WTP to reduce the risk. The appropriateness of a distribution of WTP based on the current VSL literature for valuing the mortality-related benefits of reductions in air pollution concentrations therefore depends not only on the quality of the studies (i.e., how well they measure what they are trying to measure), but also on the extent to which the risks being valued are similar and the extent to which the subjects in the studies are similar to the population affected by changes in pollution concentrations.

- *Level of risk reduction:* The transferability of estimates of the VSL from the wage-risk studies to the context of the PM NAAQS analysis rests on the assumption that, within a reasonable range, WTP for reductions in mortality risk is linear in risk reduction. For example, suppose a study provides a result that the average WTP for a reduction in mortality risk of 1/100,000 is $50, but that the actual mortality risk reduction resulting from a given pollutant reduction is 1/10,000. If WTP for reductions in mortality risk is linear in risk reduction, then a WTP of $50 for a reduction of 1/100,000 implies a WTP of $500 for a risk reduction of 1/10,000 (which is 10 times the risk reduction valued in the study). Under the assumption of linearity, the estimate of the VSL does not depend on the particular amount of risk reduction being valued. This assumption has been shown to be reasonable provided the change in the risk being valued is within the range of risks evaluated in the underlying studies (Rowlatt et al., 1998).

- *Voluntariness of risks evaluated:* Although job-related mortality risks may differ in several ways from air pollution-related mortality risks, the most important difference may be that job-related risks are incurred voluntarily, or generally assumed to be, whereas air pollution-related risks are incurred involuntarily. Some evidence suggests that people will pay more to reduce involuntarily incurred risks than risks incurred voluntarily. If this is the case, WTP estimates based on wage-risk studies may understate WTP to reduce involuntarily incurred air pollution-related mortality risks.

- *Sudden versus protracted death:* A final important difference related to the nature of the risk may be that some workplace mortality risks tend to involve sudden, catastrophic events, whereas air pollution-related risks tend to involve longer periods of disease and suffering prior to death. Some evidence suggests that WTP to avoid a risk of a protracted death involving prolonged suffering and loss of dignity and personal control is greater than the WTP to avoid a risk (of identical magnitude) of sudden death. To the extent that the mortality risks addressed in this assessment are associated with longer periods of illness or greater pain and suffering than are the risks addressed in the valuation literature, the WTP measurements employed in the present analysis would reflect a downward bias.

- *Self-selection and skill in avoiding risk:* Recent research (Shogren and Stamland, 2002) suggests that VSL estimates based on hedonic wage studies may overstate the average value of a risk reduction. This is based on the fact that the risk-wage trade-off revealed in hedonic studies reflects the preferences of the marginal worker (i.e., that worker who demands the highest compensation for his risk reduction). This worker must have either a higher workplace risk than the average worker, a lower risk tolerance than the average worker, or both. However, the risk estimate used in hedonic studies is generally based on average risk, so the VSL may be upwardly biased because the wage differential and risk measures do not match.

- *Baseline risk and age:* Recent research (Smith, Pattanayak, and Van Houtven, 2006) finds that because individuals reevaluate their baseline risk of death as they age, the marginal value of risk reductions does not decline with age as predicted by some lifetime consumption models. This research supports findings in recent stated preference studies that suggest only small reductions in the value of mortality risk reductions with increasing age.

5.4.4.2 Chronic Bronchitis Valuation

The best available estimate of WTP to avoid a case of CB comes from Viscusi, Magat, and Huber (1991). The Viscusi, Magat, and Huber study, however, describes a severe case of CB to the survey respondents. We therefore employ an estimate of WTP to avoid a pollution-related case of CB, based on adjusting the Viscusi, Magat, and Huber (1991) estimate of the WTP to avoid a severe case. This is done to account for the likelihood that an average case of pollution-related CB is not as severe. The adjustment is made by applying the elasticity of WTP with respect to severity reported in the Krupnick and Cropper (1992) study. Details of this adjustment procedure are provided in the Benefits Technical Support Document (TSD) for the Nonroad Diesel rulemaking (Abt Associates, 2003).

We use the mean of a distribution of WTP estimates as the central tendency estimate of WTP to avoid a pollution-related case of CB in this analysis. The distribution incorporates uncertainty from three sources: the WTP to avoid a case of severe CB, as described by Viscusi, Magat, and Huber; the severity level of an average pollution-related case of CB (relative to that of the case described by Viscusi, Magat, and Huber); and the elasticity of WTP with respect to severity of the illness. Based on assumptions about the distributions of each of these three uncertain components, we derive a distribution of WTP to avoid a pollution-related case of CB by statistical uncertainty analysis techniques. The expected value (i.e., mean) of this distribution, which is about $410,000 (2007$), is taken as the central tendency estimate of WTP to avoid a PM-related case of CB.

5.4.4.3 Nonfatal Myocardial Infarctions Valuation

The Agency has recently incorporated into its analyses the impact of air pollution on the expected number of nonfatal heart attacks, although it has examined the impact of reductions in other related cardiovascular endpoints. We were not able to identify a suitable WTP value for reductions in the risk of nonfatal heart attacks. Instead, we use a COI unit value with two components: the direct medical costs and the opportunity cost (lost earnings) associated with the illness event. Because the costs associated with a myocardial infarction extend beyond the initial event itself, we consider costs incurred over several years. Using age-specific annual lost earnings estimated by Cropper and Krupnick (1990) and a 3% discount rate, we estimated a present discounted value in lost earnings (in 2007$) over 5 years due to a myocardial infarction of $11,080 for someone between the ages of 25 and 44, $16,331 for someone between the ages of 45 and 54, and $94,396 for someone between the ages of 55 and 65. The corresponding age-specific estimates of lost earnings (in 2007$) using a 7% discount rate are $9,920, $14,621, and $84,513, respectively. Cropper and Krupnick (1990) do not provide lost earnings estimates for populations under 25 or over 65. As such, we do not include lost earnings in the cost estimates for these age groups.

We found three possible sources in the literature of estimates of the direct medical costs of myocardial infarction:

- Wittels et al. (1990) estimated expected total medical costs of myocardial infarction over 5 years to be $51,211 (in 1986$) for people who were admitted to the hospital and survived hospitalization. (There does not appear to be any discounting used.) Wittels et al. was used to value coronary heart disease in the 812 Retrospective Analysis of the Clean Air Act. Using the CPI-U for medical care, the Wittels estimate is $147,359 in year 2007$. This estimated cost is based on a medical cost model, which incorporated therapeutic options, projected outcomes, and prices (using "knowledgeable cardiologists" as consultants). The model used medical data and medical decision algorithms to estimate the probabilities of certain events and/or medical procedures being used. The authors note that the average length of hospitalization for acute myocardial infarction has decreased over time (from an average of 12.9 days in 1980 to an average of 11 days in 1983). Wittels et al. used 10 days as the average in their study. It is unclear how much further the length of stay for myocardial infarction may have decreased from 1983 to the present. The average length of stay for ICD code 410 (myocardial infarction) in the year-2000 Agency for Healthcare Research and Quality (AHRQ) HCUP database is 5.5 days. However, this may include patients who died in the hospital (not included among our nonfatal myocardial infarction cases), whose length of stay was therefore substantially shorter than it would be if they had not died.

- Eisenstein et al. (2001) estimated 10-year costs of $44,663 in 1997$, or $66,833 in 2007$ for myocardial infarction patients, using statistical prediction (regression) models to estimate inpatient costs. Only inpatient costs (physician fees and hospital costs) were included.

- Russell et al. (1998) estimated first-year direct medical costs of treating nonfatal myocardial infarction of $15,540 (in 1995$) and $1,051 annually thereafter. Converting to year 2007$, that would be $30,058 for a 5-year period (without discounting) or $39,256 for a 10-year period.

  In summary, the three different studies provided significantly different values (see Table 5-9).

Table 5-9: Alternative Direct Medical Cost of Illness Estimates for Nonfatal Heart Attacks

Study	*Direct Medical Costs (2007$)*	*Over an x-Year Period, for x =*
Wittels et al. (1990)	$147,359[a]	5
Russell et al. (1998)	$30,058[b]	5
Eisenstein et al. (2001)	$66,833[b]	10
Russell et al. (1998)	$39,256[b]	10

[a] Wittels et al. (1990) did not appear to discount costs incurred in future years.

[b] Using a 3% discount rate. Discounted values as reported in the study.

As noted above, the estimates from these three studies are substantially different, and we have not adequately resolved the sources of differences in the estimates. Because the wage-related opportunity cost estimates from Cropper and Krupnick (1990) cover a 5-year period, we used estimates for medical costs that similarly cover a 5-year period (i.e., estimates from Wittels et al. (1990) and Russell et al. (1998). We used a simple average of the two 5-year estimates, or $88,708, and added it to the 5-year opportunity cost estimate. The resulting estimates are given in Table 5-10.

Table 5-10: Estimated Costs Over a 5-Year Period (in 2007$) of a Nonfatal Myocardial Infarction

Age Group	*Opportunity Cost*	*Medical Cost*[a]	*Total Cost*
0–24	$0	$88,709	$88,709
25–44	$11,080[b]	$88,709	$99,789
45–54	$16,331[b]	$88,709	$105,040
55–65	$94,396[b]	$88,709	$183,105
> 65	$0	$88,709	$88,709

[a] An average of the 5-year costs estimated by Wittels et al. (1990) and Russell et al. (1998).

[b] From Cropper and Krupnick (1990), using a 3% discount rate.

5.4.4. Hospital Admissions Valuation

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

The International Classification of Diseases (ICD-9, 1979) code-specific COI estimates used in this analysis consist of estimated hospital charges and the estimated opportunity cost of time spent in the hospital (based on the average length of a hospital stay for the illness). We based all estimates of hospital charges and length of stays on statistics provided by the Agency for Healthcare Research and Quality (AHRQ 2000). We estimated the opportunity cost of a day spent in the hospital as the value of the lost daily wage, regardless of whether the hospitalized individual is in the workforce. To estimate the lost daily wage, we divided the 1990 median weekly wage by five and inflated the result to year 2007$ using the CPI-U "all items." The resulting estimate is $127.93. The total cost-of-illness estimate for an ICD code-specific hospital stay lasting *n* days, then, was the mean hospital charge plus $127.93 multiplied by *n*.

Table 5-11: Unit Values for Economic Valuation of Health Endpoints (2007$)

Health Endpoint	Central Estimate of Value Per Statistical Incidence		Derivation of Distributions of Estimates
	2000 Income Level	2014 Income Level	
Premature Mortality (Value of a Statistical Life)	$7,900,000	$8,700,000	EPA currently recommends a central VSL of $6.3m (2000$) based on a Weibull distribution fitted to 26 published VSL estimates (5 contingent valuation and 21 labor market studies). The underlying studies, the distribution parameters, and other useful information are available in Appendix B of EPA's current Guidelines for Preparing Economic Analyses (U.S. EPA, 2000).
Chronic Bronchitis (CB)	$430,000	$480,000	The WTP to avoid a case of pollution-related CB is calculated as where x is the severity of an average CB case, WTP_{13} is the WTP for a severe case of CB, and $ is the parameter relating WTP to severity, based on the regression results reported in Krupnick and Cropper (1992). The distribution of WTP for an average severity-level case of CB was generated by Monte Carlo methods, drawing from each of three distributions: (1) WTP to avoid a severe case of CB is assigned a 1/9 probability of being each of the first nine deciles of the distribution of WTP responses in Viscusi et al. (1991); (2) the severity of a pollution-related case of CB (relative to the case described in the Viscusi study) is assumed to have a triangular distribution, with the most likely value at severity level 6.5 and endpoints at 1.0 and 12.0; and (3) the constant in the elasticity of WTP with respect to severity is normally distributed with mean = 0.18 and standard deviation = 0.0669 (from Krupnick and Cropper [1992]). This process and the rationale for choosing it is described in detail in the Costs and Benefits of the Clean Air Act, 1990 to 2010 (U.S. EPA, 1999b).

Nonfatal Myocardial Infarction (heart attack)			No distributional information available. Age-specific cost-of-illness values reflect lost earnings and direct medical costs over a 5-year period following a nonfatal MI. Lost earnings estimates are based on Cropper and Krupnick (1990). Direct medical costs are based on simple average of estimates from Russell et al. (1998) and Wittels et al. (1990). Lost earnings: Cropper and Krupnick (1990). Present discounted value of 5 years of lost earnings: age of onset: at 3% at 7% 25–44 $8,774 $7,855 45–54 $12,932 11,578 55–65 $74,746 66,920 Direct medical expenses: An average of: 1. Wittels et al. (1990) ($102,658—no discounting) 2. Russell et al. (1998), 5-year period ($22,331 at 3% discount rate; $21,113 at 7% discount rate)
3% discount rate			
Age 0–24	$88,709	$88,709	
Age 25–44	$99,789	$99,789	
Age 45–54	$105,040	$105,040	
Age 55–65	$183,105	$183,105	
Age 66 and over	$88,709	$88,709	
7% discount rate			
Age 0–24	$87,889	$87,889	
Age 25–44	$98,970	$98,970	
Age 45–54	$104,220	$104,220	
Age 55–65	$182,285	$182,285	
Age 66 and over	$87,889	$87,889	
Hospital Admissions			
Chronic Obstructive Pulmonary Disease (COPD)	$17,106	$17,106	No distributional information available. The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
Asthma Admissions	$11,366	$11,366	No distributional information available. The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total asthma category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
All Cardiovascular	$28,760	$28,760	No distributional information available. The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total cardiovascular category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
All respiratory (ages 65+)	$24,157	$24,157	No distributions available. The COI point estimates (lost earnings plus direct medical costs) are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Agency for Healthcare Research and Quality, 2000 (www.ahrq.gov).

All respiratory (ages 0–2)	$10,402	$10,402	No distributions available. The COI point estimates (lost earnings plus direct medical costs) are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Agency for Healthcare Research and Quality, 2000 (www.ahrq.gov).
Emergency Room Visits for Asthma	$385	$385	No distributional information available. Simple average of two unit COI values: (1) $311.55, from Smith et al. (1997) and (2) $260.67, from Stanford et al. (1999).
Respiratory Ailments Not Requiring Hospitalization			
Upper Respiratory Symptoms (URS)	$30	$31	Combinations of the three symptoms for which WTP estimates are available that closely match those listed by Pope et al. result in seven different "symptom clusters," each describing a "type" of URS. A dollar value was derived for each type of URS, using mid-range estimates of WTP (IEc, 1994) to avoid each symptom in the cluster and assuming additivity of WTPs. In the absence of information surrounding the frequency with which each of the seven types of URS occurs within the URS symptom complex, we assumed a uniform distribution between $9.2 and $43.1.
Lower Respiratory Symptoms (LRS)	$19	$20	Combinations of the four symptoms for which WTP estimates are available that closely match those listed by Schwartz et al. result in 11 different "symptom clusters," each describing a "type" of LRS. A dollar value was derived for each type of LRS, using mid-range estimates of WTP (IEc, 1994) to avoid each symptom in the cluster and assuming additivity of WTPs. The dollar value for LRS is the average of the dollar values for the 11 different types of LRS. In the absence of information surrounding the frequency with which each of the 11 types of LRS occurs within the LRS symptom complex, we assumed a uniform distribution between $6.9 and $24.46.
Asthma Exacerbations	$52	$54	Asthma exacerbations are valued at $45 per incidence, based on the mean of average WTP estimates for the four severity definitions of a "bad asthma day," described in Rowe and Chestnut (1986). This study surveyed asthmatics to estimate WTP for avoidance of a "bad asthma day," as defined by the subjects. For purposes of valuation, an asthma exacerbation is assumed to be equivalent to a day in which asthma is moderate or worse as reported in the Rowe and Chestnut (1986) study. The value is assumed have a uniform distribution between $15.6 and $70.8.

Acute Bronchitis	$430	$450	Assumes a 6-day episode, with the distribution of the daily value specified as uniform with the low and high values based on those recommended for related respiratory symptoms in Neumann et al. (1994). The low daily estimate of $10 is the sum of the mid-range values recommended by IEc (1994) for two symptoms believed to be associated with acute bronchitis: coughing and chest tightness. The high daily estimate was taken to be twice the value of a minor respiratory restricted-activity day, or $110.
Work Loss Days (WLDs)	Variable (U.S. median = $130)	Variable (U.S. median = $130)	No distribution available. Point estimate is based on county-specific median annual wages divided by 50 (assuming 2 weeks of vacation) and then by 5—to get median daily wage. U.S. Year 2000 Census, compiled by Geolytics, Inc.
Minor Restricted Activity Days (MRADs)	$61	$64	Median WTP estimate to avoid one MRAD from Tolley et al. (1986). Distribution is assumed to be triangular with a minimum of $22 and a maximum of $83, with a most likely value of $52. Range is based on assumption that value should exceed WTP for a single mild symptom (the highest estimate for a single symptom—for eye irritation—is $16.00) and be less than that for a WLD. The triangular distribution acknowledges that the actual value is likely to be closer to the point estimate than either extreme.
School Absence Days	$90	$90	No distribution available

[A] Due to a clerical error, the VSL estimates summarized in the proposal RIA were incorrectly reported; this error was not present in the calculation of mortality impacts.

5.4.4.5 Asthma-Related Emergency Room Visits Valuation

To value asthma emergency room visits, we used a simple average of two estimates from the health economics literature. The first estimate comes from Smith et al. (1997), who reported approximately 1.2 million asthma-related emergency room visits in 1987, at a total cost of $186.5 million (1987$). The average cost per visit that year was $155; in 2007$, that cost was $419.37 (using the CPI-U for medical care to adjust to 2007$). The second estimate comes from Stanford et al. (1999), who reported the cost of an average asthma-related emergency room visit at $350.87, based on 1996–1997 data. A simple average of the two estimates yields a (rounded) unit value of $385.

5.4.4.6 Minor Restricted Activity Days Valuation

No studies are reported to have estimated WTP to avoid a minor restricted activity day. However, one of EPA's contractors, IEc (1994) has derived an estimate of willingness to pay to avoid a minor *respiratory* restricted activity day, using estimates from Tolley et al. (1986) of WTP for avoiding a combination of coughing, throat congestion and sinusitis. The IEc estimate of WTP to avoid a minor respiratory restricted activity day is $38.37 (1990$), or about $63.09 (2007$).

Although Ostro and Rothschild (1989) statistically linked ozone and minor restricted activity days, it is likely that most MRADs associated with ozone exposure are, in fact, minor *respiratory* restricted activity days. However, for the purpose of valuing this health endpoint, we used the estimate of mean WTP to avoid a minor respiratory restricted activity day.

5.4.4.7 School Absences Valuation

To value a school absence, we: (1) estimated the probability that if a school child stays home from school, a parent will have to stay home from work to care for the child; and (2) valued the lost productivity at the parent's wage. To do this, we estimated the number of families with school-age children in which both parents work, and we valued a school-loss day as the probability that such a day also would result in a work-loss day. We calculated this value by multiplying the proportion of households with school-age children by a measure of lost wages.

We used this method in the absence of a preferable WTP method. However, this approach suffers from several uncertainties. First, it omits willingness to pay to avoid the symptoms/illness that resulted in the school absence; second, it effectively gives zero value to school absences that do not result in work-loss days; and third, it uses conservative assumptions about the wages of the parent staying home with the child. Finally, this method assumes that parents are unable to work from home. If this is not a valid assumption, then there would be no lost wages.

For this valuation approach, we assumed that in a household with two working parents, the female parent will stay home with a sick child. From the Statistical Abstract of the United States (U.S. Census Bureau, 2001), we obtained: (1) the numbers of single, married and "other" (widowed, divorced or separated) working women with children; and (2) the rates of participation in the workforce of single, married and "other" women with children. From these two sets of statistics, we calculated a weighted average participation rate of 72.85 percent.

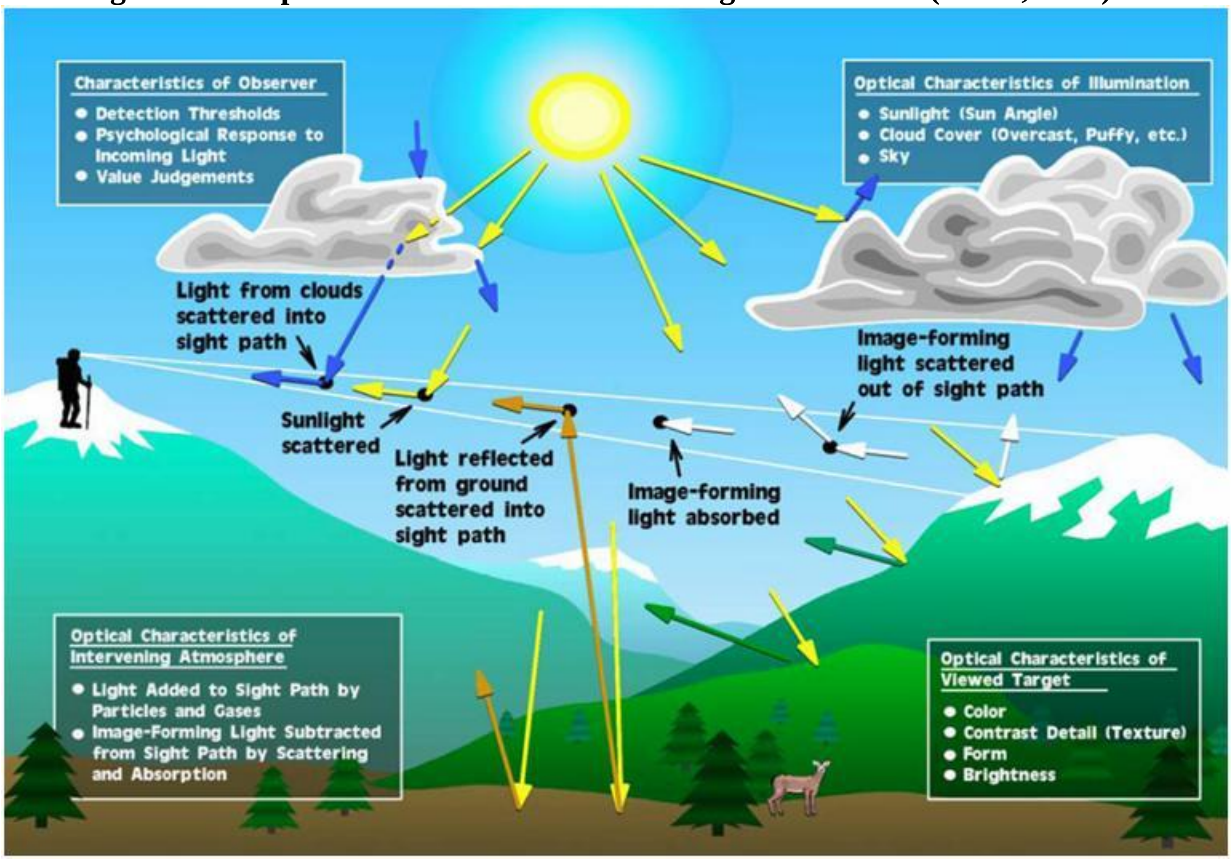
Our estimate of daily lost wage (wages lost if a mother must stay at home with a sick child) is based on the year 2007 median weekly wage among women ages 25 and older (U.S. Census Bureau, 2001). This median weekly wage is $675. Dividing by five gives an estimated median daily wage of $140. To estimate the expected lost wages on a day when a mother has to stay home with a school-age child, we first estimated the probability that the mother is in the workforce then multiplied that estimate by the daily wage she would lose by missing a workday: 72.85 percent times $140, for a total loss of $98.48. This valuation approach is similar to that used by Hall et al. (2003).

5.4.4.8 Visibility Valuation

Reductions in NO_2 and SO_2 emissions along with the secondary formation of $PM_{2.5}$ would improve the level of visibility throughout the United States because these suspended particles and gases degrade visibility by scattering and absorbing light (U.S. EPA, 2009d). Visibility is also referred to as visual air quality (VAQ), and it directly affects people's enjoyment of a variety of daily activities (U.S. EPA, 2009d). Good visibility increases quality of life where individuals live and work, and where they travel for recreational activities, including sites of unique public value, such as the Great Smoky Mountains National Park. This section discusses the measurement of the economic benefits of improved visibility. Visibility benefit estimates are generated for all Class I areas in the U.S., though the majority of the air quality improvements occur among eastern states.

Visual air quality (VAQ) is commonly measured as either light extinction, which is defined as the loss of light per unit of distance in terms of inverse megameters (Mm^{-1}) or the deciview (dv) metric (Pitchford and Malm, 1994), which is a logarithmic function of extinction. Extinction and deciviews are physical measures of the amount of visibility impairment (e.g., the amount of "haze"), with both extinction and deciview increasing as the amount of haze increases. Pitchford and Malm (1994) characterize a change of one deciview as "a small but perceptible scenic change under many circumstances." Light extinction is the optical characteristic of the atmosphere that occurs when light is either scattered or absorbed, which converts the light to heat. Particulate matter and gases can both scatter and absorb light. Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil (Sisler, 1996). The extent to which any amount of light extinction affects a person's ability to view a scene depends on both scene and light characteristics. For example, the appearance of a nearby object (i.e. a building) is generally less sensitive to a change in light extinction than the appearance of a similar object at a greater distance. See Figure 5-3 for an illustration of the important factors affecting visibility.

Figure 5-3: Important factors involved in seeing a scenic vista (Malm, 1999)



In conjunction with the U.S. National Park Service, the U.S. Forest Service, other Federal land managers, and State organizations in the U.S., the U.S. EPA has supported visibility monitoring in national parks and wilderness areas since 1988. The monitoring network known as IMPROVE (Interagency Monitoring of Protected Visual Environments) includes 156 sites that represent almost all of the Class I areas across the country (see Figure 5-4) (U.S. EPA, 2009d).

Figure 5-4: Mandatory Class I Areas in the U.S.

Annual average visibility conditions (reflecting light extinction due to both anthropogenic and non-anthropogenic sources) vary regionally across the U.S. (U.S. EPA, 2009d). Particulate sulfate is the dominant source of regional haze in the eastern U.S (>50% of the particulate light extinction) and an important contributor to haze elsewhere in the country (>20% of particulate light extinction) (U.S. EPA, 2009d). Higher visibility impairment levels in the East are due to generally higher concentrations of fine particles, particularly sulfates, and higher average relative humidity levels. (U.S. EPA, 2009d). Humidity increases visibility impairment because some particles such as ammonium sulfate and ammonium nitrate absorb water and form droplets that become larger when relative humidity increases, thus resulting in increased light scattering (U.S. EPA, 2009d).

While visibility trends have improved in most Class I areas, the recent data show that these areas continue to suffer from visibility impairment. In eastern parks, average visual range has decreased from 90 miles to 15-25 miles, and in the West, visual range has decreased from 140 miles to 35-90 miles (U.S. EPA, 2004; U.S. EPA, 1999b).

EPA distinguishes benefits from two categories of visibility changes: residential visibility and recreational visibility. In both cases economic benefits are believed to consist of use values and nonuse values. Use values include the aesthetic benefits of better visibility, improved road and air safety, and enhanced recreation in activities like hunting and birdwatching. Nonuse values are based on people's beliefs that the environment ought to exist free of human-induced haze. Nonuse values may be more important for recreational areas, particularly national parks and monuments.

Residential visibility benefits are those that occur from visibility changes in urban, suburban, and rural areas. In previous assessments, EPA used a study on residential visibility valuation conducted in 1990 (McClelland et al., 1993). Subsequently, EPA designated the McClelland et al. study as significantly less reliable for regulatory benefit-cost analysis consistent with SAB advice (U.S. EPA-SAB, 1999). Although a wide range of published, peer-review literature supports a non-zero value for residential visibility (Brookshire et al., 1982; Rae, 1983; Tolley et al., 1986; Chestnut and Rowe, 1990c; McClleand et al., 1993; Loehman et al., 1994), the residential visibility benefits have not been calculated in this analysis.

For recreational visibility, EPA has determined that only one existing study provides monetary estimates of the value of changes in recreational visibility; a contingent valuation (CV) survey conducted by Chestnut and Rowe in 1988 (Chestnut and Rowe, 1990a; 1990b). Although there are several other studies in the literature on recreational visibility valuation, they are older and use less robust methods. In EPA's judgment, the Chestnut and Rowe study contains many of the elements of a valid CV study and is sufficiently reliable to serve as the basis for monetary estimates of the benefits of visibility changes in recreational areas. There has been a great deal of controversy and significant development of both theoretical and empirical knowledge about how to conduct CV surveys in the past couple of decades. In EPA's judgment, the Chestnut and Rowe study contains many of the elements of a valid CV study and is sufficiently reliable to serve as the basis for monetary estimates of the benefits of visibility changes in recreational areas.[29] This study serves as an essential input to our estimates of the benefits of recreational visibility improvements in the primary benefits estimates.

For the purposes of this analysis, recreational visibility improvements are defined as those that occur specifically in federal Class I areas.[30] A key distinction between recreational and residential benefits is that only those people living in residential areas are assumed to receive benefits from residential visibility, while all households in the United States are assumed to derive some benefit from improvements in Class I areas. Values are assumed to be higher if the Class I area is located close to their home.[31] The Chestnut and Rowe study measured the demand for visibility in Class I areas managed by the National Park Service (NPS) in three broad regions of the country: California, the Southwest, and the Southeast. Respondents in five states were asked about their WTP to protect national parks or NPS-managed wilderness areas within a particular region. The survey used photographs reflecting different visibility levels in the specified recreational areas. The visibility levels in these photographs were later converted to deciviews for the current analysis. The survey data collected were used to estimate a WTP equation for improved visibility. In addition to the visibility change variable, the estimating equation also included household income as an explanatory variable.

The Chestnut and Rowe survey measured the demand for visibility in Class I areas managed by the NPS in three broad regions of the country that included 86 of the 156 Class I areas; California, the Colorado Plateau (Southwest), and the Southeast areas. We can infer the value of visibility changes in the other Class I areas by transferring values of visibility changes at Class I areas in the study regions. A complete description of the benefits transfer

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[29] An SAB advisory letter indicates that "many members of the Council believe that the Chestnut and Rowe study is the best available" (EPA-SAB-COUNCIL-ADV-00-002, 1999, p. 13). However, the committee did not formally approve use of these estimates because of concerns about the peer-reviewed status of the study. EPA believes the study has received adequate review and has been cited in numerous peer-reviewed publications (Chestnut and Dennis, 1997).

[30] EPA has designated 156 areas as mandatory Class I federal areas for visibility protection, including national parks that exceed 6,000 acres and wilderness areas that exceed 5,000 acres (40 CFR §81.400).

[31] For details of the visibility estimates discussed in this chapter, please refer to the Benefits TSD for the Nonroad Diesel rulemaking (Abt Associates, 2003).

method used to infer values for visibility changes in Class I areas outside the study regions is provided in the Appendix I of the PM NAAQS RIA (U.S. EPA, 2006).

The Chestnut and Rowe study (Chestnut and Rowe, 1990a; 1990b), although representing the best available estimates, has a number of limitations. These include the following:

- The vintage of the survey (late 1980s) invites questions whether the values would still be valid for current populations, or more importantly for this analysis, future populations in 2014.

The survey focused only on populations in five states, so the application of the estimated values to populations outside those states requires that preferences of populations in the five surveyed states be similar to those of non-surveyed states.

- There is an inherent difficulty in separating values expressed for visibility improvements from an overall value for improved air quality. The survey attempted to control for this by informing respondents that "other households are being asked about visibility, human health, and vegetation protections in urban areas and at national parks in other regions." However, most of the respondents did not feel that they were able to segregate visibility at national parks entirely from residential visibility and health effects.

- It is not clear exactly what visibility improvements the respondents to the Chestnut and Rowe survey were valuing. The WTP question asked about changes in average visibility, but the survey respondents were shown photographs of only summertime conditions, when visibility is generally at its worst. It is possible that the respondents believed those visibility conditions held year-round, in which case they would have been valuing much larger overall improvements in visibility than what otherwise would be the case. For the purpose of the benefits analysis for this rule, EPA assumed that respondents provided values for changes in annual average visibility. Because most policies will result in a shift in the distribution of visibility (usually affecting the worst days more than the best days), the annual average may not be the most relevant metric for policy analysis.

- The survey did not include reminders of possible substitutes (e.g., visibility at other parks) or budget constraints. These reminders are considered to be best practice for stated preference surveys.

- The Chestnut and Rowe survey focused on visibility improvements in and around national parks and wilderness areas in three regions of the United States: Southwest, Southeast and California. Given that national parks and wilderness areas exhibit unique characteristics, it is not clear whether the WTP estimate obtained from Chestnut and Rowe can be transferred to other national parks and wilderness areas, without introducing additional uncertainty.

In general, the survey design and implementation reflect the period in which the survey was conducted. Since that time, many improvements to the stated preference methodology have been developed. As future survey efforts are completed, EPA will incorporate values for visibility improvements reflecting the improved survey designs.

The estimated relationship from the Chestnut and Rowe study is only directly applicable to the populations represented by survey respondents. EPA used benefits transfer methodology to extrapolate these results to the population affected by the reductions in precursor emissions associated with this rule. A general WTP equation for improved visibility (measured in deciviews) was developed as a function of the baseline level of visibility, the magnitude of the visibility improvement, and household income. The behavioral parameters of this equation were taken from analysis of the Chestnut and Rowe data. These parameters were used to calibrate WTP for the visibility changes resulting from this rule. The method for developing calibrated WTP functions is based on the approach developed by Smith et al. (2002). Available evidence indicates that households are willing to pay more for a given visibility improvement as their income increases (Chestnut, 1997). The benefits estimates here incorporate Chestnut's estimate that a 1% increase in income is associated with a 0.9% increase in WTP for a given change in visibility. A more detailed explanation of the visibility benefits methodology is provided in Appendix I of the PM NAAQS RIA (U.S. EPA, 2006).

One major source of uncertainty for the visibility benefits estimate is the benefits transfer process used. Judgments used to choose the functional form and key parameters of the estimating equation for WTP for the affected population could have significant effects on the size of the estimates. Assumptions about how individuals respond to changes in visibility that are either very small or outside the range covered in the Chestnut and Rowe study could also affect the results.

In addition, our estimate of visibility benefits is incomplete. For example, we anticipate improvement in visibility in residential areas within the Transport Rule region for which we are currently unable to monetize benefits as well as improvements in recreational visibility in the Northeastern and Central regions of the U.S. The value of visibility benefits in areas where we were unable to monetize benefits could also be substantial.

5.4.4.9 Growth in WTP Reflecting National Income Growth Over Time

Our analysis accounts for expected growth in real income over time. Economic theory argues that WTP for most goods (such as environmental protection) will increase if real incomes increase. There is substantial empirical evidence that the income elasticity[32] of WTP for health risk reductions is positive, although there is uncertainty about its exact value. Thus, as real income increases, the WTP for environmental improvements also increases. Although many analyses assume that the income elasticity of WTP is unit elastic (i.e., a 10% higher real income level implies a 10% higher WTP to reduce risk changes), empirical evidence suggests that income elasticity is substantially less than one and thus relatively inelastic. As real income rises, the WTP value also rises but at a slower rate than real income.

The effects of real income changes on WTP estimates can influence benefits estimates in two different ways: through real income growth between the year a WTP study was conducted and the year for which benefits are estimated, and through differences in income between study populations and the affected populations at a particular time. Empirical evidence of the effect of real income on WTP gathered to date is based on studies examining the former. The Environmental Economics Advisory Committee (EEAC) of the

[32] Income elasticity is a common economic measure equal to the percentage change in WTP for a 1% change in income.

Science Advisory Board (SAB) advised EPA to adjust WTP for increases in real income over time but not to adjust WTP to account for cross-sectional income differences "because of the sensitivity of making such distinctions, and because of insufficient evidence available at present" (U.S. EPA-SAB, 2000a). A recent advisory by another committee associated with the SAB, the Advisory Council on Clean Air Compliance Analysis, has provided conflicting advice. While agreeing with "the general principle that the willingness to pay to reduce mortality risks is likely to increase with growth in real income (U.S. EPA-SAB, 2004a, p. 52)" and that "The same increase should be assumed for the WTP for serious nonfatal health effects (U.S. EPA-SAB, 2004a, p. 52)," they note that "given the limitations and uncertainties in the available empirical evidence, the Council does not support the use of the proposed adjustments for aggregate income growth as part of the primary analysis (U.S. EPA-SAB, 2004a, p. 53)." Until these conflicting advisories have been reconciled, EPA will continue to adjust valuation estimates to reflect income growth using the methods described below, while providing sensitivity analyses for alternative income growth adjustment factors.

Based on a review of the available income elasticity literature, we adjusted the valuation of human health benefits upward to account for projected growth in real U.S. income. Faced with a dearth of estimates of income elasticities derived from time-series studies, we applied estimates derived from cross-sectional studies in our analysis. Details of the procedure can be found in Kleckner and Neumann (1999). An abbreviated description of the procedure we used to account for WTP for real income growth between 1990 and 2014 is presented below.

Reported income elasticities suggest that the severity of a health effect is a primary determinant of the strength of the relationship between changes in real income and WTP. As such, we use different elasticity estimates to adjust the WTP for minor health effects, severe and chronic health effects, and premature mortality. Note that because of the variety of empirical sources used in deriving the income elasticities, there may appear to be inconsistencies in the magnitudes of the income elasticities relative to the severity of the effects (*a priori* one might expect that more severe outcomes would show less income elasticity of WTP). We have not imposed any additional restrictions on the empirical estimates of income elasticity. One explanation for the seeming inconsistency is the difference in timing of conditions. WTP for minor illnesses is often expressed as a short term payment to avoid a single episode. WTP for major illnesses and mortality risk reductions are based on longer term measures of payment (such as wages or annual income). Economic theory suggests that relationships become more elastic as the length of time grows, reflecting the ability to adjust spending over a longer time period. Based on this theory, it would be expected that WTP for reducing long term risks would be more elastic than WTP for reducing short term risks. We also expect that the WTP for improved visibility in Class I areas would increase with growth in real income. The relative magnitude of the income elasticity of WTP for visibility compared with those for health effects suggests that visibility is not as much of a necessity as health, thus, WTP is more elastic with respect to income. The elasticity values used to adjust estimates of benefits in 2014 are presented in Table 5-12.

Table 5-12: Elasticity Values Used to Account for Projected Real Income Growth[a]

Benefit Category	*Central Elasticity Estimate*
Minor Health Effect	0.14
Severe and Chronic Health Effects	0.45
Premature Mortality	0.40
Visibility	0.90

[a] Derivation of estimates can be found in Kleckner and Neumann (1999) and Chestnut (1997). COI estimates are assigned an adjustment factor of 1.0.

In addition to elasticity estimates, projections of real gross domestic product (GDP) and populations from 1990 to 2020 are needed to adjust benefits to reflect real per capita income growth. For consistency with the emissions and benefits modeling, we used national population estimates for the years 1990 to 1999 based on U.S. Census Bureau estimates (Hollman, Mulder, and Kallan, 2000). These population estimates are based on application of a cohort-component model applied to 1990 U.S. Census data projections (U.S. Bureau of Census, 2000). For the years between 2000 and 2014, we applied growth rates based on the U.S. Census Bureau projections to the U.S. Census estimate of national population in 2000. We used projections of real GDP provided in Kleckner and Neumann (1999) for the years

1990 to 2010.[33] We used projections of real GDP (in chained 1996 dollars) provided by Standard and Poor's (2000) for the years 2010 to 2014.[34]

Using the method outlined in Kleckner and Neumann (1999) and the population and income data described above, we calculated WTP adjustment factors for each of the elasticity estimates listed in Table 5-13. Benefits for each of the categories (minor health effects, severe and chronic health effects, premature mortality, and visibility) are adjusted by multiplying the unadjusted benefits by the appropriate adjustment factor. Note that, for premature mortality, we applied the income adjustment factor to the present discounted value of the stream of avoided mortalities occurring over the lag period. Also note that because of a lack of data on the dependence of COI and income, and a lack of data on projected growth in average wages, no adjustments are made to benefits based on the COI approach or to work loss days and worker productivity. This assumption leads us to underpredict benefits in future years because it is likely that increases in real U.S. income would also result in increased COI (due, for example, to increases in wages paid to medical workers) and increased cost of work loss days and lost worker productivity (reflecting that if worker incomes are higher, the losses resulting from reduced worker production would also be higher).

Table 5-13: Adjustment Factors Used to Account for Projected Real Income Growth[a]

Benefit Category	*2014*
Minor Health Effect	1.04
Severe and Chronic Health Effects	1.16
Premature Mortality	1.14
Visibility	1.35

[a] Based on elasticity values reported in Table 5-3, U.S. Census population projections, and projections of real GDP per capita.

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[33] U.S. Bureau of Economic Analysis, Table 2A (1992$) (available at http://www.bea.doc.gov/bea/dn/0897nip2/ tab2a.htm.) and U.S. Bureau of Economic Analysis, Economics and Budget Outlook. Note that projections for 2007 to 2010 are based on average GDP growth rates between 1999 and 2007.

[34] In previous analyses, we used the Standard and Poor's projections of GDP directly. This led to an apparent discontinuity in the adjustment factors between 2010 and 2011. We refined the method by applying the relative growth rates for GDP derived from the Standard and Poor's projections to the 2010 projected GDP based on the Bureau of Economic Analysis projections.

5.5 Unquantified Health and Welfare Benefits

This analysis is limited by the available data and resources. As such, we are not able to quantify several welfare benefit categories, as shown in Table 5-2. In this section, we provide a qualitative assessment of some of the major welfare benefit categories associated with reducing NO_2 and SO_2 emissions: health and ecosystem benefits of reducing nitrogen and sulfur emissions and deposition and vegetation benefits from reducing ozone.[35] In addition, there are mercury benefits associated with reducing mercury emissions and the role of sulfate deposition in mercury methylation. While we were unable to quantify how large these benefits might be as a result of the emission reductions achieved by this rule, previous EPA assessments show that these benefits could be substantial (U.S. EPA, 2008f; U.S. EPA, 2009c; U.S. EPA, 2007b; U.S. EPA, 1999b). The omission of these endpoints from the monetized results should not imply that the impacts are small or unimportant.

5.5.1 Ecosystem Services

Ecosystem services can be generally defined as the benefits that individuals and organizations obtain from ecosystems. EPA has defined ecological goods and services as the "outputs of ecological functions or processes that directly or indirectly contribute to social welfare or have the potential to do so in the future. Some outputs may be bought and sold, but most are not marketed" (U.S. EPA, 2006b). Figure 5-5 provides the Millennium Ecosystem Assessment's schematic demonstrating the connections between the categories of ecosystem services and human well-being. The interrelatedness of these categories means that any one ecosystem may provide multiple services. Changes in these services can affect human well-being by affecting security, health, social relationships, and access to basic material goods (MEA, 2005).

In the Millennium Ecosystem Assessment (MEA, 2005), ecosystem services are classified into four main categories:

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[35] Some quantitative estimates of the total value of certain recreational and environmental goods given current and historic emission levels are provided below. They do not reflect benefits that would accrue as a result of this result. However, these values would be expected to increase as emissions are decreased a result of this rule.

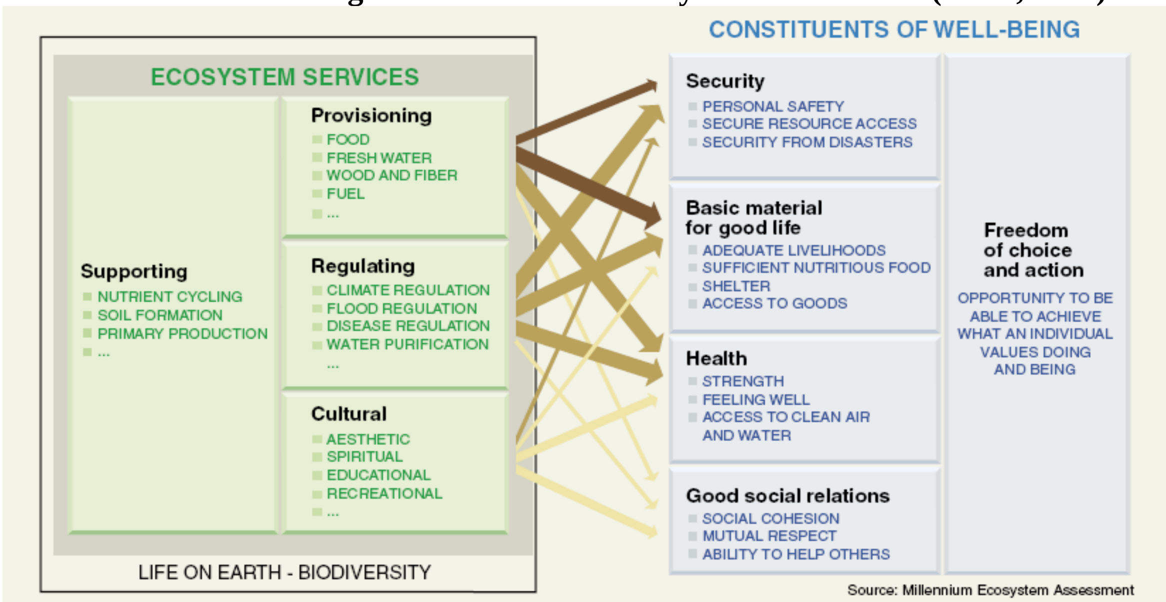
1. Provisioning: Products obtained from ecosystems, such as the production of food and water

2. Regulating: Benefits obtained from the regulation of ecosystem processes, such as the control of climate and disease

3. Cultural: Nonmaterial benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences

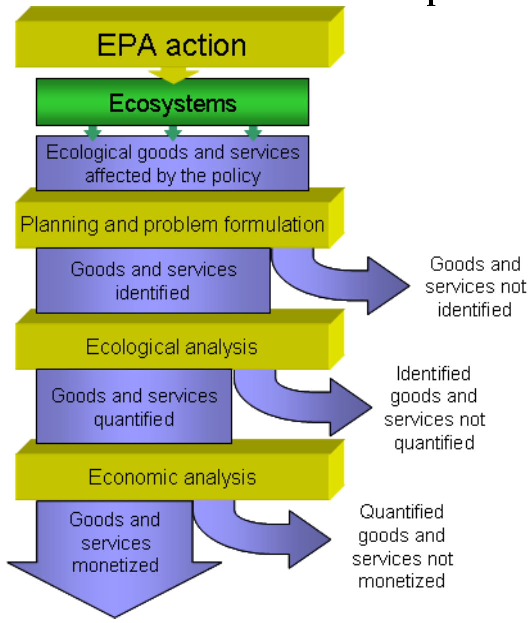
4. Supporting: Services necessary for the production of all other ecosystem services, such as nutrient cycles and crop pollination

Figure 5-5: Linkages between categories of ecosystem services and components of human well-being from Millennium Ecosystem Assessment (MEA, 2005)



The monetization of ecosystem services generally involves estimating the value of ecological goods and services based on what people are willing to pay (WTP) to increase ecological services or by what people are willing to accept (WTA) in compensation for reductions in them (U.S. EPA, 2006b). There are three primary approaches for estimating the monetary value of ecosystem services: market-based approaches, revealed preference methods, and stated preference methods (U.S. EPA, 2006b). Because economic valuation of ecosystem services can be difficult, nonmonetary valuation using biophysical measurements and concepts also can be used. An example of a nonmonetary valuation method is the use of relative-value indicators (e.g., a flow chart indicating uses of a water body, such as boatable, fishable, swimmable, etc.). It is necessary to recognize that in the analysis of the environmental responses associated with any particular policy or environmental management action, only a subset of the ecosystem services likely to be affected are readily identified. Of those ecosystem services that are identified, only a subset of the changes can be quantified. Within those services whose changes can be quantified, only a few will likely be monetized, and many will remain nonmonetized. The stepwise concept leading up to the valuation of ecosystems services is graphically depicted in Figure 5-6.

Figure 5-6: Schematic of the benefits assessment process (U.S. EPA, 2006b)



5.5.2 Ecosystem Benefits of Reduced Nitrogen and Sulfur Deposition

5.5.2.1 Science of Deposition

Nitrogen and sulfur emissions occur over large regions of North America. Once these pollutants are lofted to the middle and upper troposphere, they typically have a much longer lifetime and, with the generally stronger winds at these altitudes, can be transported long distances from their source regions. The length scale of this transport is highly variable owing to differing chemical and meteorological conditions encountered along the transport path (U.S. EPA, 2008f).. Sulfur is primarily emitted as SO_2, and nitrogen can be emitted as NO, NO_2, or NH_3. Secondary particles are formed from NO_x and SO_X gaseous emissions and associated chemical reactions in the atmosphere. Deposition can occur in either a wet (i.e., rain, snow, sleet, hail, clouds, or fog) or dry form (i.e., gases or particles). Together these emissions are deposited onto terrestrial and aquatic ecosystems across the U.S., contributing to the problems of acidification, nutrient enrichment, and methylmercury production as represented in Figures 5-7 and 5-8. Although there is some evidence that nitrogen deposition may have positive effects on agricultural and forest output through passive fertilization, it is likely that the overall value is very small relative to other health and welfare effects. In addition to deposition effects, SO_2 can affect vegetation at ambient levels near pollution sources.

Figure 5-7: Schematics of Ecological Effects of Nitrogen and Sulfur Deposition

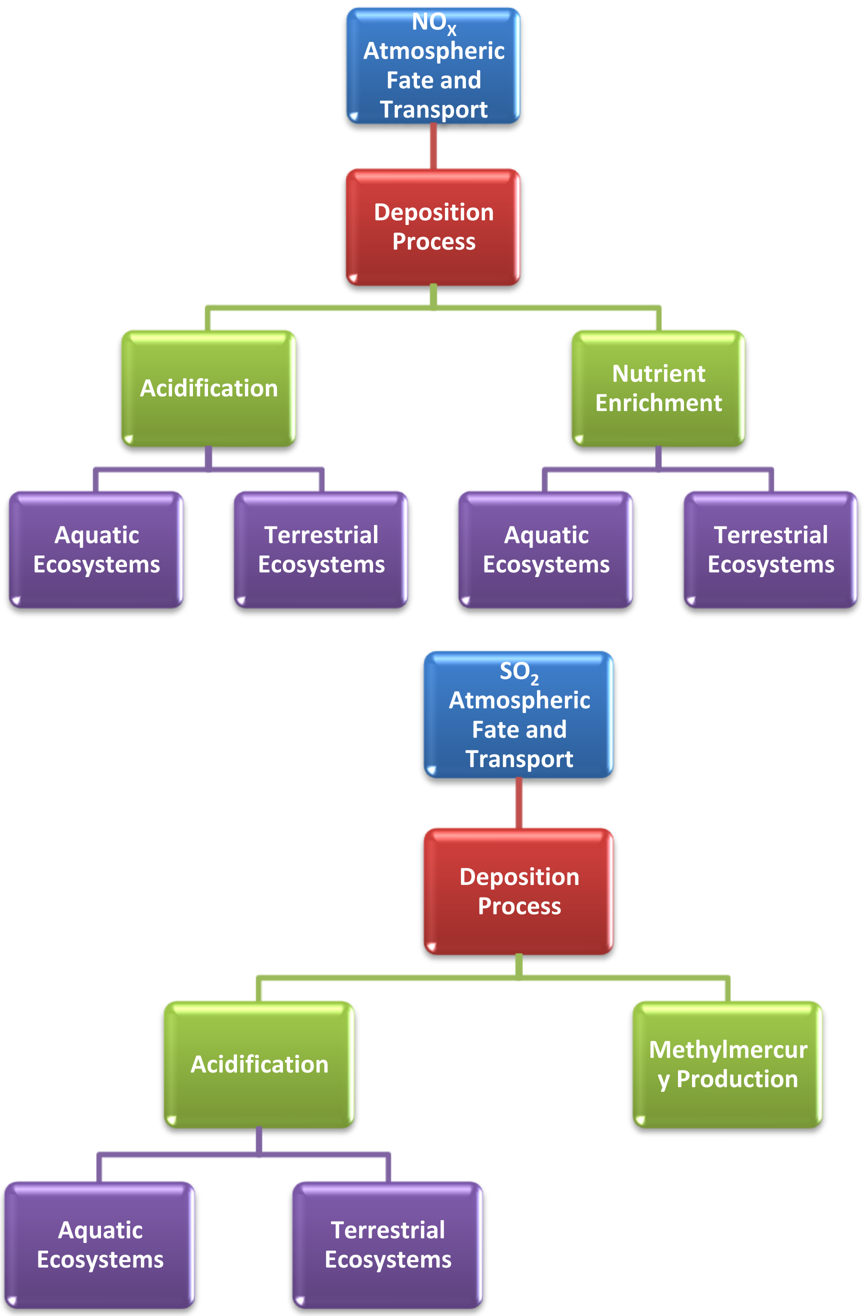
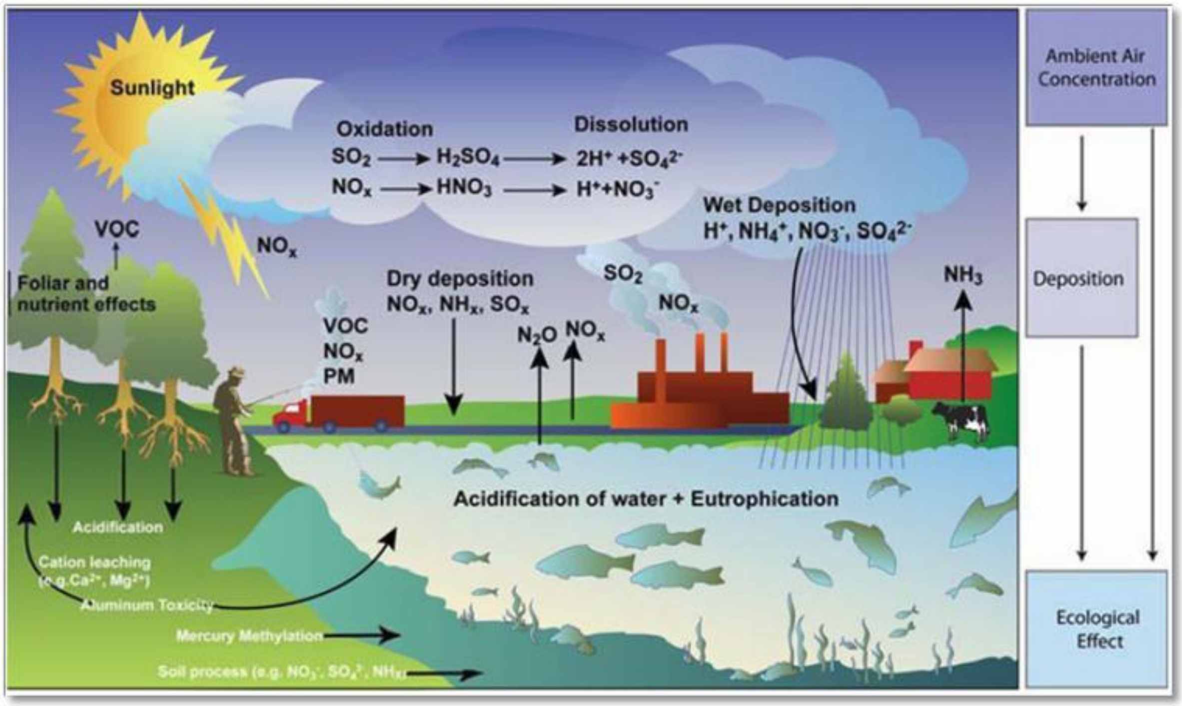


Figure 5-8. Nitrogen and sulfur cycling, and interactions in the environment (U.S. EPA, 2008f)



The atmospheric lifetimes of particles vary with particle size. Accumulation-mode particles such as sulfates are kept in suspension by normal air motions and have a lower deposition velocity than coarse-mode particles; they can be transported thousands of kilometers and remain in the atmosphere for a number of days. They are removed from the atmosphere primarily by cloud processes. Particulates affect acid deposition by serving as cloud condensation nuclei and contribute directly to the acidification of rain. In addition, the gas-phase species that lead to the dry deposition of acidity are also precursors of particles. Therefore, reductions in NO_2 and SO_2 emissions will decrease both acid deposition and PM concentrations, but not necessarily in a linear fashion. (U.S. EPA, 2008f). Sulfuric acid is also deposited on surfaces by dry deposition and can contribute to environmental effects (U.S. EPA, 2008f).

5.5.2.2 Ecological Effects of Acidification

Deposition of nitrogen and sulfur can cause acidification, which alters biogeochemistry and affects animal and plant life in terrestrial and aquatic ecosystems across the U.S. Soil acidification is a natural process, but is often accelerated by acidifying deposition, which can decrease concentrations of exchangeable base cations in soils (U.S. EPA, 2008f). Major terrestrial effects include a decline in sensitive tree species, such as red spruce (*Picea rubens*) and sugar maple (*Acer saccharum*) (U.S. EPA, 2008f). Biological effects of acidification in terrestrial ecosystems are generally linked to aluminum toxicity and decreased ability of plant roots to take up base cations (U.S. EPA, 2008f). Decreases in the acid neutralizing capacity and increases in inorganic aluminum concentration contribute to declines in zooplankton, macro invertebrates, and fish species richness in aquatic ecosystems (U.S. EPA, 2008f).

Geology (particularly surficial geology) is the principal factor governing the sensitivity of terrestrial and aquatic ecosystems to acidification from nitrogen and sulfur deposition (U.S. EPA, 2008f). Geologic formations having low base cation supply generally underlie the watersheds of acid-sensitive lakes and streams. Other factors contribute to the sensitivity of soils and surface waters to acidifying deposition, including topography, soil chemistry, land use, and hydrologic flow path (U.S. EPA, 2008f).

5.5.2.3 Aquatic Ecosystems

Aquatic effects of acidification have been well studied in the U.S. and elsewhere at various trophic levels. These studies indicate that aquatic biota have been affected by acidification at virtually all levels of the food web in acid sensitive aquatic ecosystems. . The ISA for NOx/SOx – Ecological Criteria concluded that the evidence is sufficient to infer a causal relationship between acidifying deposition and effects on biogeochemistry related to aquatic ecosystems and biota in aquatic ecosystems (U.S. EPA, 2008f).   Effects have been most clearly documented for fish, aquatic insects, other invertebrates, and algae. Biological effects are primarily attributable to a combination of low pH and high inorganic aluminum concentrations. Such conditions occur more frequently during rainfall and snowmelt that cause high flows of water and less commonly during low-flow conditions, except where chronic acidity conditions are severe. Biological effects of episodes include reduced fish condition factor[36], changes in species composition and declines in aquatic species richness

[36] Condition factor is an index that describes the relationship between fish weight and length, and is one measure of sublethal acidification stress that has been used to quantify effects of acidification on an individual fish (U.S.EPA, 2008f).

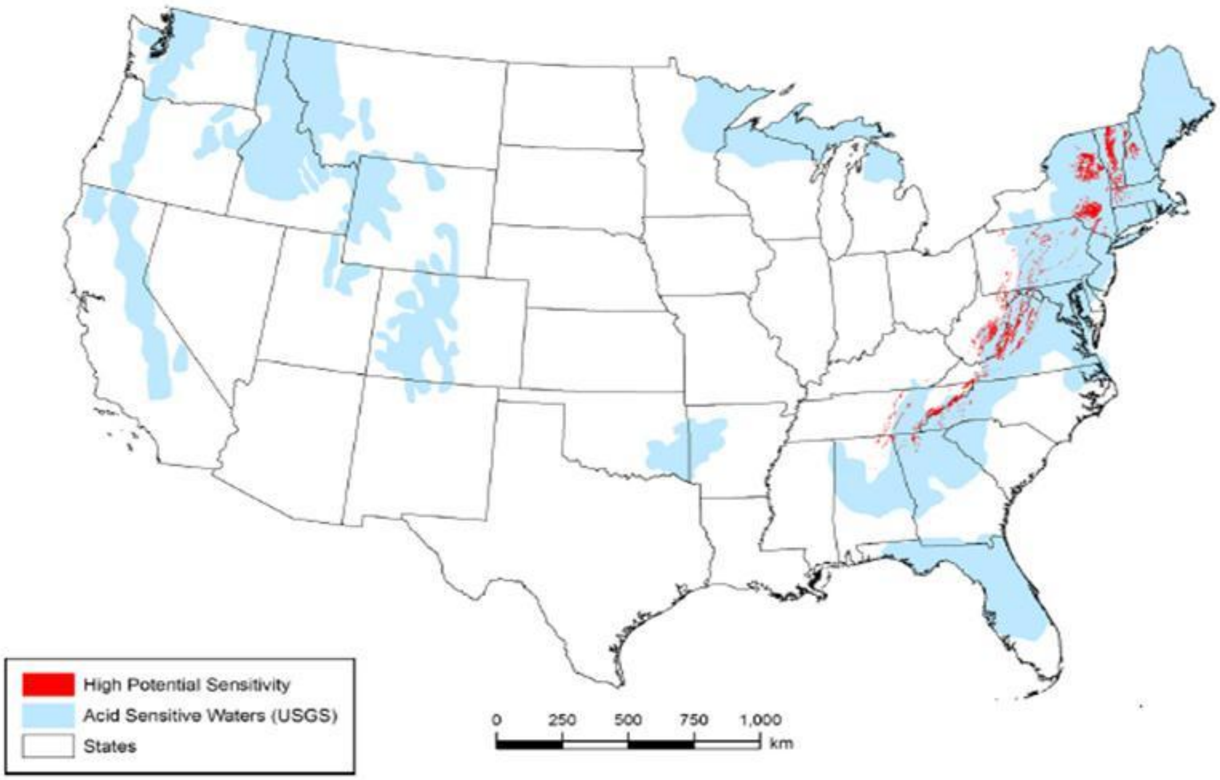
across multiple taxa, ecosystems and regions. These conditions may also result in direct fish mortality (Van Sickle et al., 1996). Biological effects in aquatic ecosystems can be divided into two major categories: effects on health, vigor, and reproductive success; and effects on biodiversity. Surface water with ANC values greater than 50 μeq/L generally provides moderate protection for most fish (i.e., brook trout, others) and other aquatic organisms (U.S. EPA, 2009c). Table 5-14 provides a summary of the biological effects experienced at various ANC levels.

Table 5-14: Aquatic Status Categories

Category Label	ANC Levels	Expected Ecological Effects
Acute Concern	<0 micro equivalent per Liter (μeq/L)	Near complete loss of fish populations is expected. Planktonic communities have extremely low diversity and are dominated by acidophilic forms. The number of individuals in plankton species that are present is greatly reduced.
Severe Concern	0–20 μeq/L	Highly sensitive to episodic acidification. During episodes of high acidifying deposition, brook trout populations may experience lethal effects. Diversity and distribution of zooplankton communities decline sharply.
Elevated Concern	20–50 μeq/L	Fish species richness is greatly reduced (i.e., more than half of expected species can be missing). On average, brook trout populations experience sublethal effects, including loss of health, reproduction capacity, and fitness. Diversity and distribution of zooplankton communities decline.
Moderate Concern	50–100 μeq/L	Fish species richness begins to decline (i.e., sensitive species are lost from lakes). Brook trout populations are sensitive and variable, with possible sublethal effects. Diversity and distribution of zooplankton communities also begin to decline as species that are sensitive to acidifying deposition are affected.
Low Concern	>100 μeq/L	Fish species richness may be unaffected. Reproducing brook trout populations are expected where habitat is suitable. Zooplankton communities are unaffected and exhibit expected diversity and distribution.

A number of national and regional assessments have been conducted to estimate the distribution and extent of surface water acidity in the U.S (U.S. EPA, 2008f). As a result, several regions of the U.S. have been identified as containing a large number of lakes and streams that are seriously impacted by acidification. Figure 5-9 illustrates those areas of the U.S. where aquatic ecosystems are at risk from acidification.

Figure 5-9: Areas Potentially Sensitive to Aquatic Acidification (U.S. EPA, 2008f)



Because acidification primarily affects the diversity and abundance of aquatic biota, it also affects the ecosystem services that are derived from the fish and other aquatic life found in these surface waters.

While acidification is unlikely to have serious negative effects on, for example, water supplies, it can limit the productivity of surface waters as a source of food (i.e., fish). In the northeastern United States, the surface waters affected by acidification are not a major source of commercially raised or caught fish; however, they are a source of food for some recreational and subsistence fishermen and for other consumers. For example, there is evidence that certain population subgroups in the northeastern United States, such as the Hmong and Chippewa ethnic groups, have particularly high rates of self-caught fish consumption (Hutchison and Kraft, 1994; Peterson et al., 1994). However, it is not known if and how their consumption patterns are affected by the reductions in available fish populations caused by surface water acidification.

Inland surface waters support several cultural services, including aesthetic and educational services and recreational fishing. Recreational fishing in lakes and streams is among the most popular outdoor recreational activities in the northeastern United States. Based on studies conducted in the northeastern United States, Kaval and Loomis (2003) estimated average consumer surplus values per day of $36 for recreational fishing (in 2007 dollars); therefore, the implied total annual value of freshwater fishing in the northeastern United States was $5.1 billion in 2006.[37] For recreation days, consumer surplus value is most commonly measured using recreation demand, travel cost models.

Another estimate of the overarching ecological benefits associated with reducing lake acidification levels in Adirondacks Park can be derived from the contingent valuation (CV) survey (Banzhaf et al., 2006), which elicited values for specific improvements in acidification-related water quality and ecological conditions in Adirondack lakes. The survey described a base version with minor improvements said to result from the program, and a scope version with large improvements due to the program and a gradually worsening status quo. After adapting and transferring the results of this study and converting the 10-year annual payments to permanent annual payments using discount rates of 3% and 5%, the WTP estimates ranged from $48 to $107 per year per household (in 2004 dollars) for the base version and $54 to $154 for the scope version. Using these estimates, the aggregate annual benefits of eliminating all anthropogenic sources of NO_x and SO_x emissions were estimated to range from $291 million to $829 million (U.S. EPA, 2009c).[38]

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[37] These estimates reflect the total value of the service, not the marginal change in the value of the service as a result of the emission reductions achieved by this rule.

[38] These estimates reflect the total value of the service, not the marginal change in the value of the service as a result of the emission reductions achieved by this rule.

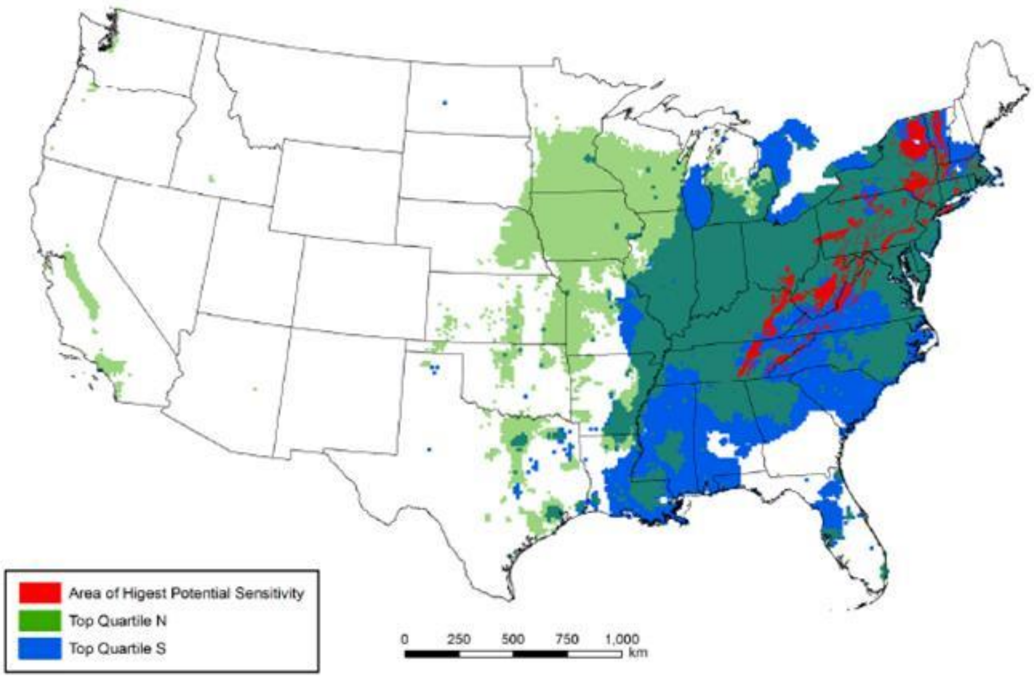
In addition, inland surface waters provide a number of regulating services associated with hydrological and climate regulation by providing environments that sustain aquatic food webs. These services are disrupted by the toxic effects of acidification on fish and other aquatic life. Although it is difficult to quantify these services and how they are affected by acidification, some of these services may be captured through measures of provisioning and cultural services.

5.5.2.4 Terrestrial Ecosystems

Acidifying deposition has altered major biogeochemical processes in the U.S. by increasing the nitrogen and sulfur content of soils, accelerating nitrate and sulfate leaching from soil to drainage waters, depleting base cations (especially calcium and magnesium) from soils, and increasing the mobility of aluminum. Inorganic aluminum is toxic to some tree roots. Plants affected by high levels of aluminum from the soil often have reduced root growth, which restricts the ability of the plant to take up water and nutrients, especially calcium (U. S. EPA, 2008f). These direct effects can, in turn, influence the response of these plants to climatic stresses such as droughts and cold temperatures. They can also influence the sensitivity of plants to other stresses, including insect pests and disease (Joslin et al., 1992) leading to increased mortality of canopy trees. In the U.S., terrestrial effects of acidification are best described for forested ecosystems (especially red spruce and sugar maple ecosystems) with additional information on other plant communities, including shrubs and lichen (U.S. EPA, 2008f). The ISA for NOx/SOx – Ecological Criteria concluded that the evidence is sufficient to infer a causal relationship between acidifying deposition and effects on biogeochemistry related to terrestrial ecosystems and biota in terrestrial ecosystems (U.S. EPA, 2008f).

Certain ecosystems in the continental U.S. are potentially sensitive to terrestrial acidification, which is the greatest concern regarding nitrogen and sulfur deposition U.S. EPA (2008f). Figure 5-10 depicts the areas across the U.S. that are potentially sensitive to terrestrial acidification.

Figure 5-10: Areas Potentially Sensitive to Terrestrial Acidification (U.S. EPA, 2008f)



Both coniferous and deciduous forests throughout the eastern U.S. are experiencing gradual losses of base cation nutrients from the soil due to accelerated leaching from acidifying deposition. This change in nutrient availability may reduce the quality of forest nutrition over the long term. Evidence suggests that red spruce and sugar maple in some areas in the eastern U.S. have experienced declining health because of this deposition. For red spruce, (*Picea rubens*) dieback or decline has been observed across high elevation landscapes of the northeastern U.S., and to a lesser extent, the southeastern U.S., and acidifying deposition has been implicated as a causal factor (DeHayes et al., 1999). Figure 5-11 shows the distribution of red spruce (brown) and sugar maple (green) in the eastern U.S.

Figure 5-11: Distribution of Red Spruce (pink) and Sugar Maple (green) in the Eastern U.S. (U.S. EPA, 2008f)

Terrestrial acidification affects several important ecological endpoints, including declines in habitat for threatened and endangered species (cultural), declines in forest aesthetics (cultural), declines in forest productivity (provisioning), and increases in forest soil erosion and reductions in water retention (cultural and regulating).

Forests in the northeastern United States provide several important and valuable provisioning services in the form of tree products. Sugar maples are a particularly important commercial hardwood tree species, providing timber and maple syrup. In the United States, sugar maple saw timber was nearly 900 million board feet in 2006 (USFS, 2006), and annual production of maple syrup was nearly 1.4 million gallons, accounting for approximately 19% of worldwide production. The total annual value of U.S. production in these years was approximately $160 million (NASS, 2008). Red spruce is also used in a variety of products including lumber, pulpwood, poles, plywood, and musical instruments. The total removal of red spruce saw timber from timberland in the United States was over 300 million board feet in 2006 (USFS, 2006).

Forests in the northeastern United States are also an important source of cultural ecosystem services—nonuse (i.e., existence value for threatened and endangered species), recreational, and aesthetic services. Red spruce forests are home to two federally listed species and one delisted species:

1. Spruce-fir moss spider (*Microhexura montivaga*)—endangered

2. Rock gnome lichen (*Gymnoderma lineare*)—endangered

3. Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*)—delisted, but important

Forestlands support a wide variety *of outdoor recreational* activities, including fishing, hiking, camping, off-road driving, hunting, and wildlife viewing. Regional statistics on recreational activities that are specifically forest based are not available; however, more general data on outdoor recreation provide some insights into the overall level of recreational services provided by forests. More than 30% of the U.S. adult population visited a wilderness or primitive area during the previous year and engaged in day hiking (Cordell et al., 2008). From 1999 to 2004, 16% of adults in the northeastern United States participated in off-road vehicle recreation, for an average of 27 days per year (Cordell et al., 2005). The average consumer surplus value per day of off-road driving in the United States was $25 (in 2007 dollars), and the implied total annual value of off-road driving recreation in the northeastern United States was more than $9 billion (Kaval and Loomis, 2003). More than 5% of adults in the northeastern United States participated in nearly 84 million hunting days (U.S. FWS and U.S. Census Bureau, 2007). Ten percent of adults in northeastern states participated in wildlife viewing away from home on 122 million days in 2006. For these recreational activities in the northeastern United States, Kaval and Loomis (2003) estimated average consumer surplus values per day of $52 for hunting and $34 for wildlife viewing (in 2007 dollars). The implied total annual value of hunting and wildlife viewing in the northeastern United States was, therefore, $4.4 billion and $4.2 billion, respectively, in 2006.

As previously mentioned, it is difficult to estimate the portion of these recreational services that are specifically attributable to forests and to the health of specific tree species. However, one recreational activity that is directly dependent on forest conditions is fall color viewing. Sugar maple trees, in particular, are known for their bright colors and are, therefore, an essential aesthetic component of most fall color landscapes. A survey of residents in the Great Lakes area found that roughly 30% of residents reported at least one trip in the previous year involving fall color viewing (Spencer and Holecek, 2007). In a separate study conducted in Vermont, Brown (2002) reported that more than 22% of households visiting Vermont in 2001 made the trip primarily for viewing fall colors.

Two studies estimated values for protecting high-elevation spruce forests in the southern Appalachian Mountains. Kramer et al. (2003) conducted a contingent valuation study estimating households' WTP for programs to protect remaining high-elevation spruce forests from damages associated with air pollution and insect infestation. Median household WTP was estimated to be roughly $29 (in 2007 dollars) for a smaller program, and $44 for the more extensive program. Jenkins et al. (2002) conducted a very similar study in seven Southern Appalachian states on a potential program to maintain forest conditions at status quo levels. The overall mean annual WTP for the forest protection programs was $208 (in 2007 dollars). Multiplying the average WTP estimate from these studies by the total number of households in the seven-state Appalachian region results in an aggregate annual range of $470 million to $3.4 billion for avoiding a significant decline in the health of high-elevation spruce forests in the Southern Appalachian region(U.S. EPA, 2009c).[39]

Forests in the northeastern United States also support and provide a wide variety of valuable regulating services, including soil stabilization and erosion control, water regulation, and climate regulation. The total value of these ecosystem services is very difficult to quantify in a meaningful way, as is the reduction in the value of these services associated with total nitrogen and sulfur deposition. As terrestrial acidification contributes to root damages, reduced biomass growth, and tree mortality, all of these services are likely to be affected; however, the magnitude of these impacts is currently very uncertain.

[39] These estimates reflect the marginal value of the service for the hypothetical program described in the survey, not the marginal change in the value of the service as a result of the emission reductions achieved by this rule.

5.5.3 Ecological Effects Associated with Gaseous Sulfur Dioxide

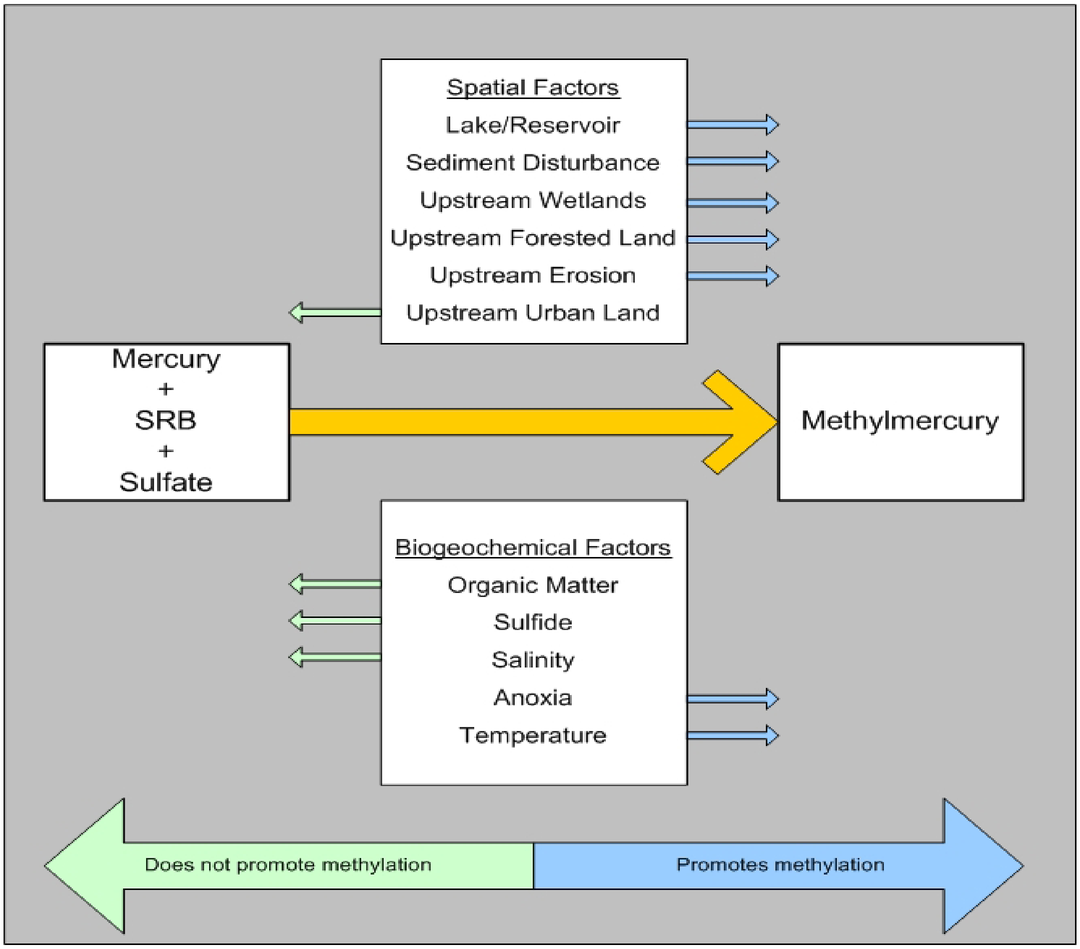
Uptake of gaseous sulfur dioxide in a plant canopy is a complex process involving adsorption to surfaces (leaves, stems, and soil) and absorption into leaves. SO_2 penetrates into leaves through to the stomata, although there is evidence for limited pathways via the cuticle. Pollutants must be transported from the bulk air to the leaf boundary layer in order to get to the stomata. When the stomata are closed, as occurs under dark or drought conditions, resistance to gas uptake is very high and the plant has a very low degree of susceptibility to injury. In contrast, mosses and lichens do not have a protective cuticle barrier to gaseous pollutants or stomates and are generally more sensitive to gaseous sulfur and nitrogen than vascular plants (U.S. EPA, 2008f). Acute foliar injury usually happens within hours of exposure, involves a rapid absorption of a toxic dose, and involves collapse or necrosis of plant tissues. Another type of visible injury is termed chronic injury and is usually a result of variable SO_2 exposures over the growing season. Besides foliar injury, chronic exposure to low SO_2 concentrations can result in reduced photosynthesis, growth, and yield of plants (U.S. EPA, 2008f). These effects are cumulative over the season and are often not associated with visible foliar injury. As with foliar injury, these effects vary among species and growing environment. SO_2 is also considered the primary factor causing the death of lichens in many urban and industrial areas (Hutchinson et al., 1996).

5.5.4 Ecological Effects Associated with the Role of Sulfate in Mercury Methylation and Reduced Mercury Emissions

Mercury is a persistent, bioaccumulative toxic metal that is emitted from power plants in three forms: gaseous elemental Hg (Hg^0), oxidized Hg compounds (Hg^{+2}), and particle-bound Hg (Hg_P). Elemental Hg does not quickly deposit or chemically react in the atmosphere, resulting in residence times that are long enough to contribute to global scale deposition. Oxidized Hg and HgP deposit quickly from the atmosphere impacting local and regional areas in proximity to sources. Methylmercury (MeHg) is formed by microbial action in the top layers of sediment and soils, after Hg has precipitated from the air and deposited into waterbodies or land. Once formed, MeHg is taken up by aquatic organisms and bioaccumulates up the aquatic food web. Larger predatory fish may have MeHg concentrations many times, typically on the order of one million times, that of the concentrations in the freshwater body in which they live.

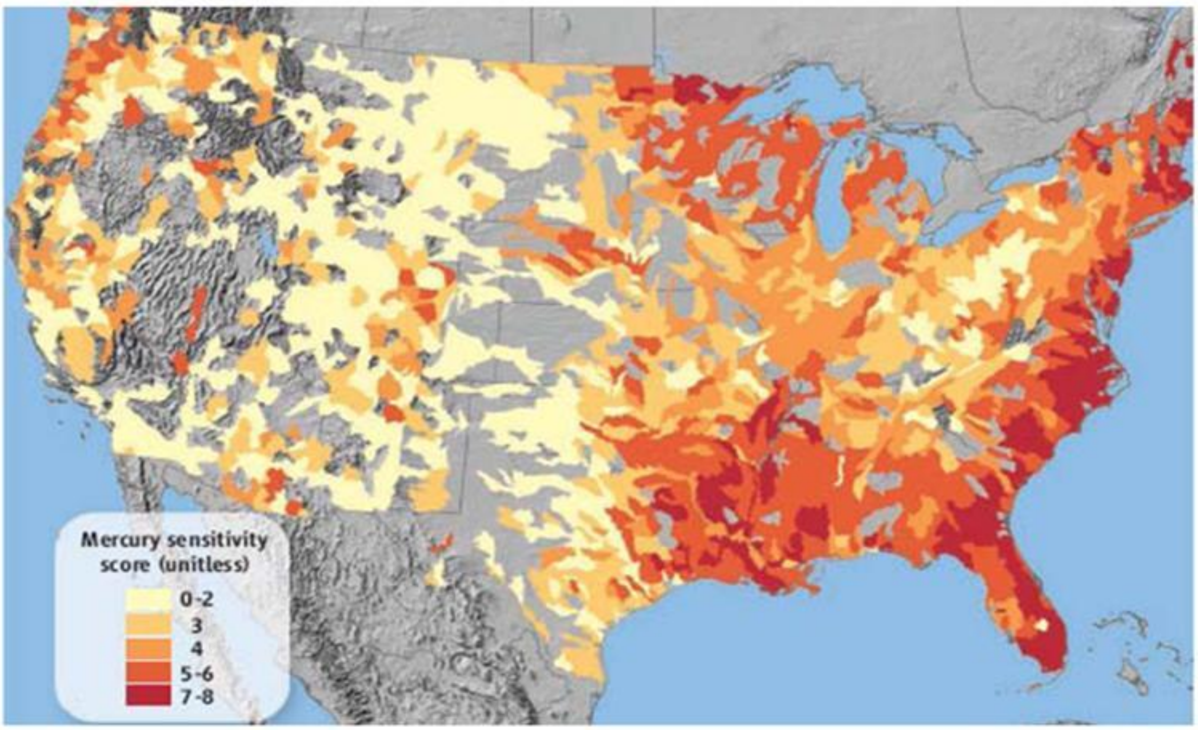
EPA's *2008 Integrated Science Assessment (ISA) for Oxides of Nitrogen and Sulfur–Ecological Criteria (Final Report)*concluded that evidence is sufficient to infer a casual relationship between sulfur deposition and increased mercury methylation in wetlands and aquatic environments (U.S. EPA, 2008f). Specifically, there appears to be a relationship between SO_4^{2-} deposition and mercury methylation; however, the rate of mercury methylation varies according to several spatial and biogeochemical factors whose influence has not been fully quantified (see Figure 5-11). Therefore, the correlation between SO_4^{2-} deposition and MeHg could not be quantified for the purpose of interpolating the association across waterbodies or regions. Nevertheless, because changes in MeHg in ecosystems represent changes in significant human and ecological health risks, the association between sulfur and mercury cannot be neglected (U.S. EPA, 2008f).

Figure 5-11. Spatial and Biogeochemical Factors Influencing MeHg Production



As research evolves and the computational capacity of models expands to meet the complexity of mercury methylation processes in ecosystems, the role of interacting factors may be better parsed out to identify ecosystems or regions that are more likely to generate higher concentrations of MeHg. Figure 5-12 illustrates the type of current and forward-looking research being developed by the U.S. Geological Survey (USGS) to synthesize the contributing factors of mercury and to develop a map of sensitive watersheds. The mercury score referenced in Figure 5-12 is based on SO_4^{2-} concentrations, acid neutralizing capacity (ANC), levels of dissolved organic carbon and pH, mercury species concentrations, and soil types to gauge the methylation sensitivity (Myers et al., 2007).

Figure 5.12: Preliminary USGS Map of Mercury Methylation–Sensitive Watersheds Derived from More than 55,000 Water Quality Sites and 2,500 Watersheds
(Myers et al., 2007)



Interdependent biogeochemical factors preclude the existence of simple sulfate-related mercury methylation models. It is clear that decreasing sulfate deposition is likely to result in decreased MeHg concentrations. Future research may allow for the characterization of a usable sulfate-MeHg response curve; however, no regional or classification calculation scale can be created at this time because of the number of confounding factors.

Decreases in SO_4^{2-} deposition have already shown promising reductions in MeHg.

Observed decreases in MeHg fish tissue concentrations have been linked to decreased acidification and declining SO_4^{2-} and mercury deposition in Little Rock Lake, WI (Hrabik and Watras, 2002); and to decreased SO_4^{2-} deposition in Isle Royale in Lake Superior, MI (Drevnick et al., 2007). Although the possibility exists that reductions in SO_4^{2-} emissions could generate a pulse in MeHg production because of decreased sulfide inhibition in sulfate-saturated waters, this effect would likely involve a limited number of U.S. waters (Harmon et al., 2007). Also, because of the diffusion and outward flow of both mercurysulfide complexes and SO_4^{2-}, increased mercury methylation downstream may still occur in sulfate-enriched ecosystems with increased organic matter and/or downstream transport capabilities.

Remediation of sediments heavily contaminated with mercury has yielded significant reductions of MeHg in biotic tissues. Establishing quantitative relations in biotic responses to MeHg levels as a result of changes in atmospheric mercury deposition, however, presents difficulties because direct associations can be confounded by all of the factors discussed in this section. Current research does suggest that the levels of MeHg and total mercury in ecosystems are positively correlated, so that reductions in mercury deposited into ecosystems would also eventually lead to reductions in MeHg in biotic tissues. Ultimately, an integrated approach that involves the reduction of both sulfur and mercury emissions may be most efficient because of the variability in ecosystem responses. Reducing SO_X emissions could have a beneficial effect on levels of MeHg in many waters of the United States.

In addition to the role of sulfate deposition on methylation, the technologies installed to reduce emissions of NO_x and SO_2 associated with this final rule would also reduce mercury emissions. Thus, the total mercury benefits would reflect both the reduction in methylation from decreased sulfate deposition as well as the reduction in mercury emissions. Due to time and resource limitations, we were unable in any event to model mercury dispersion, deposition, methylation, bioaccumulation in fish tissue, and human consumption of mercury-contaminated fish that would be needed in order to estimate the human health benefits from reducing these mercury emissions. Instead, we provide the following qualitative assessment of the human health and ecosystem effects associated with reducing exposure to methylmercury.

In the United States, humans are exposed to MeHg mainly by consuming fish that contain MeHg.. MeHg is the only form of mercury that biomagnifies in the food web.

Concentrations of MeHg in fish are generally on the order of a million times the MeHg concentration in water. In addition to mercury deposition, key factors affecting MeHg production and accumulation in fish include the amount and forms of sulfur and carbon species present in a given waterbody. Thus, two adjoining water bodies receiving the same deposition can have significantly different fish mercury concentrations.

Methylmercury builds up more in some types of fish and shellfish than in others. The levels of methylmercury in high and shellfish vary widely depending on what they eat, how long they live, and how high they are in the food chain. Most fish, including ocean species and local freshwater fish, contain some methylmercury. In general, higher mercury concentrations are expected in top predators, which are often large fish relative to other species in a waterbody.

Research shows that most people's fish consumption does not cause a mercury-related health concern (NRC, 2000). However, certain people may be at higher risk because of their routinely high consumption of fish (e.g., tribal and other subsistence fishers and their families who rely heavily on fish for a substantial part of their diet). The majority of fish consumed in the U.S. are ocean species. The methylmercury concentrations in ocean fish species are primarily influences by the global mercury pool. However, the methylmercury found in local fish can be due, at least partly, to mercury emissions from local sources.

The ecosystem service most directly affected by sulfate-mediated mercury methylation is the provision of fish for consumption as a food source. This service is of particular importance to groups engaged in subsistence fishing, pregnant women and young children. State-level fish consumption advisories for mercury are based on state criteria, many of which are based on EPA's fish tissue criterion for methylmercury (U.S. EPA, 2001) or on U.S. Food and Drug Administration's action levels (U.S. FDA, 2001). In 2008, there were 3,361 fish advisories issued at least in part for mercury contamination (80% of all fish advisories), covering 16.8 million lake acres (40% of total lake acreage) and 1.3 million river miles (35% of total river miles) over all 50 states, one U.S. territory, and 3 tribes (U.S. EPA, 2009f). Recently, the U.S. Geological Survey (USGS) examined mercury levels in top-predator fish, bed sediment, and water from 291 streams across the U.S. (Scudder et al., 2009). USGS detected mercury contamination in every fish sampled, and the concentration of mercury in fish exceeded EPA's criterion in 27% of the sites sampled.

In 2000, the National Research Council (NRC) of the NAS issued the NAS Study (NRC, 2000), which provides a thorough review of the effects of MeHg on human health. There are numerous studies that have been published more recently that report effects on neurologic and other endpoints. In its review of the literature, the NAS found neurodevelopmental effects to be the most sensitive and best documented endpoints and appropriate for establishing an RfD (NRC, 2000); in particular NAS supported the use of results from neurobehavioral or neuropsychological tests. The NAS report (NRC, 2000) noted that studies in animals reported sensory effects as well as effects on brain development and memory functions and support the conclusions based on epidemiology studies. The NAS noted that their recommended endpoints for an RfD are associated with the ability of children to learn and to succeed in school. They concluded the following: "The population at highest risk is the children of women who consumed large amounts of fish and seafood during pregnancy. The committee concludes that the risk to that population is likely to be sufficient to result in an increase in the number of children who have to struggle to keep up in school."

The NAS summarized data on cardiovascular effects available up to 2000. Based on these studies, the NRC (2000) concluded that "Although the data base is not as extensive for cardiovascular effects as it is for other end points (i.e. neurologic effects) the cardiovascular system appears to be a target for MeHg toxicity in humans and animals."[40] The NRC also stated that "additional studies are needed to better characterize the effect of methylmercury exposure on blood pressure and cardiovascular function at various stages of life." Additional cardiovascular studies have been published since 2000. EPA did not to develop a quantitative dose-response assessment for cardiovascular effects associated with MeHg exposures, as there is no consensus among scientists on the dose-response functions for these effects. In addition, there is inconsistency among available studies as to the association between MeHg exposure and various cardiovascular system effects. The pharmacokinetics of some of the exposure measures (such as toenail Hg levels) are not well understood. The studies have not yet received the review and scrutiny of the more well-established neurotoxicity data base.

[40] National Research Council (NRC). 2000. Toxicological Effects of Methylmercury. Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology. National Academies Press. Washington, DC. p. 229.

The Mercury Study noted that MeHg is not a potent mutagen but is capable of causing chromosomal damage in a number of experimental systems (U.S. EPA, 1997). The NAS concluded that evidence that human exposure to MeHg caused genetic damage is inconclusive; they note that some earlier studies showing chromosomal damage in lymphocytes may not have controlled sufficiently for potential confounders. One study of adults living in the Tapajós River region in Brazil (Amorim et al., 2000) reported a direct relationship between MeHg concentration in hair and DNA damage in lymphocytes; as well as effects on chromosomes. Long-term MeHg exposures in this population were believed to occur through consumption of fish, suggesting that genotoxic effects (largely chromosomal aberrations) may result from dietary, chronic MeHg exposures similar to and above those seen in the Faroes and Seychelles populations.

Although exposure to some forms of Hg can result in a decrease in immune activity or an autoimmune response (ATSDR, 1999), evidence for immunotoxic effects of MeHg is limited (NRC, 2000).

Based on limited human and animal data, MeHg is classified as a “possible” human carcinogen by the International Agency for Research on Cancer (IARC, 1994) and in IRIS (U.S. EPA, 2002). The existing evidence supporting the possibility of carcinogenic effects in humans from low-dose chronic exposures is tenuous. Multiple human epidemiological studies have found no significant association between Hg exposure and overall cancer incidence, although a few studies have shown an association between Hg exposure and specific types of cancer incidence (e.g., acute leukemia and liver cancer) (NAS, 2000).

There is also some evidence of reproductive and renal toxicity in humans from MeHg exposure. However, overall, human data regarding reproductive, renal, and hematological toxicity from MeHg are very limited and are based on either studies of the two high-dose poisoning episodes in Iraq and Japan or animal data, rather than epidemiological studies of chronic exposures at the levels of interest in this analysis.

Deposition of mercury to waterbodies can also have an impact on ecosystems and wildlife. Mercury contamination is present in all environmental media with aquatic systems experiencing the greatest exposures due to bioaccumulation. Bioaccumulation refers to the net uptake of a contaminant from all possible pathways and includes the accumulation that may occur by direct exposure to contaminated media as well as uptake from food. Wet and dry deposition of oxidized mercury is a dominant pathway for bringing mercury to terrestrial surfaces. In forest ecosystems, elemental mercury may also be absorbed by plants stomatally, incorporated by foliar tissues and released in litterfall (Ericksen et al., 2003). Mercury in throughfall, direct deposition in precipitation, and uptake of dissolved mercury by roots (Rea et al., 2002) are also important in mercury accumulation in terrestrial ecosystems. Soils have significant capacity to store large quantities of atmospherically deposited mercury where it can leach into groundwater and surface waters. Numerous studies have generated field data on the levels of mercury in a variety of wild species. The risk of mercury exposure extends to insectivorous terrestrial species such as songbirds, bats, spiders, and amphibians that receive mercury deposition or from aquatic systems near the forest areas they inhabit (Bergeron et al., 2010a, b; Cristol et al., 2008; Rimmer et al., 2005; Wada et al., 2009 & 2010). The body of work examining the effects of these exposures is growing but still incomplete given the complexities of the natural world.

The studies cited here provide a glimpse of the scope of mercury effects on wildlife particularly reproductive and survival effects at current exposure levels. These effects range across species from fish to mammals and spatially across a wide area of the United States. The literature is far from complete however. Much more research is required to establish a link between the ecological effects on wildlife and the effect on ecosystem services (services that the environment provides to people) for example recreational fishing, bird watching, and wildlife viewing. EPA is not, however, currently able to quantify or monetize the benefits of reducing mercury exposures affecting provision of ecosystem services.

5.5.5 Nitrogen Enrichment

5.5.5.1 Aquatic Enrichment

The ISA for NOx/SOx – Ecological Criteria concluded that the evidence is sufficient to infer a causal relationship between nitrogen deposition and the alteration of species richness, species composition, and biodiversity in wetland, freshwater aquatic and coastal marine ecosystems (U.S. EPA, 2008f).

One of the main adverse ecological effects resulting from N deposition, particularly in the Mid-Atlantic region of the United States, is the effect associated with nutrient enrichment in estuarine waters. A recent assessment of 141 estuaries nationwide by the National Oceanic and Atmospheric Administration (NOAA) concluded that 19 estuaries (13%) suffered from moderately high or high levels of eutrophication due to excessive inputs of both N and phosphorus, and a majority of these estuaries are located in the coastal area from North Carolina to Massachusetts (NOAA, 2007). For estuaries in the Mid-Atlantic region, the contribution of atmospheric distribution to total N loads is estimated to range between 10% and 58% (Valigura et al., 2001).

Eutrophication in estuaries is associated with a range of adverse ecological effects. The conceptual framework developed by NOAA emphasizes four main types of eutrophication effects—low dissolved oxygen (DO), harmful algal blooms (HABs), loss of submerged aquatic vegetation (SAV), and low water clarity. Low DO disrupts aquatic habitats, causing stress to fish and shellfish, which, in the short-term, can lead to episodic fish kills and, in the long-term, can damage overall growth in fish and shellfish populations. Low DO also degrades the aesthetic qualities of surface water. In addition to often being toxic to fish and shellfish, and leading to fish kills and aesthetic impairments of estuaries, HABs can, in some instances, also be harmful to human health. SAV provides critical habitat for many aquatic species in estuaries and, in some instances, can also protect shorelines by reducing wave strength; therefore, declines in SAV due to nutrient enrichment are an important source of concern. Low water clarity is in part the result of accumulations of both algae and sediments in estuarine waters. In addition to contributing to declines in SAV, high levels of turbidity also degrade the aesthetic qualities of the estuarine environment.

Estuaries in the eastern United States are an important source of food production, in particular fish and shellfish production. The estuaries are capable of supporting large stocks of resident commercial species, and they serve as the breeding grounds and interim habitat for several migratory species. To provide an indication of the magnitude of provisioning services associated with coastal fisheries, from 2005 to 2007, the average value of total catch was $1.5 billion per year. It is not known, however, what percentage of this value is directly attributable to or dependent upon the estuaries in these states.

In addition to affecting provisioning services through commercial fish harvests, eutrophication in estuaries may also affect the demand for seafood. For example, a well-publicized toxic pfiesteria bloom in the Maryland Eastern Shore in 1997, which involved thousands of dead and lesioned fish, led to an estimated $56 million (in 2007 dollars) in lost seafood sales for 360 seafood firms in Maryland in the months following the outbreak (Lipton, 1999).

Estuaries in the United States also provide an important and substantial variety of cultural ecosystem services, including water-based recreational and aesthetic services. The water quality in the estuary directly affects the quality of these experiences. For example, there were 26 million days of saltwater fishing coastal states from North Carolina to Massachusetts in 2006 (FWA and Census, 2007). Assuming an average consumer surplus value for a fishing day at $36 (in 2007 dollars) in the Northeast and $87 in the Southeast (Kaval and Loomis, 2003), the aggregate value was approximately $1.3 billion (in 2007 dollars). [41] In addition, almost 6 million adults participated in motorboating in coastal states from North Carolina to Massachusetts, for a total of nearly 63 million days annually during 1999–2000 (Leeworthy and Wiley, 2001). Using a national daily value estimate of $32 (in 2007 dollars) for motorboating (Kaval and Loomis (2003), the aggregate value of these coastal motorboating outings was $2 billion per year. [42] Almost 7 million participated in birdwatching for 175 million days per year, and more than 3 million participated in visits to non-beach coastal waterside areas.

Estuaries and marshes have the potential to support a wide range of regulating services, including climate, biological, and water regulation; pollution detoxification; erosion prevention; and protection against natural hazards from declines in SAV (MEA, 2005). SAV can help reduce wave energy levels and thus protect shorelines against excessive erosion, which increases the risks of episodic flooding and associated damages to near-shore properties or public infrastructure or even contribute to shoreline retreat.

5.5.5.2 Terrestrial Enrichment

Terrestrial enrichment occurs when terrestrial ecosystems receive N loadings in

[41] These estimates reflect the total value of the service, not the marginal change in the value of the service as a result of the emission reductions achieved by this rule.

[42] These estimates reflect the total value of the service, not the marginal change in the value of the service as a result of the emission reductions achieved by this rule.

excess of natural background levels, either through atmospheric deposition or direct application. Evidence presented in the Integrated Science Assessment (U.S. EPA, 2008f) supports a causal relationship between atmospheric N deposition and biogeochemical cycling and fluxes of N and carbon in terrestrial systems. Furthermore, evidence summarized in the report supports a causal link between atmospheric N deposition and changes in the types and number of species and biodiversity in terrestrial systems. Nitrogen enrichment occurs over a long time period; as a result, it may take as much as 50 years or more to see changes in ecosystem conditions and indicators. This long time scale also affects the timing of the ecosystem service changes. The ISA for NOx/SOx – Ecological Criteria concluded that the evidence is sufficient to infer a causal relationship between nitrogen deposition and the alteration of species richness, species composition, and biodiversity in terrestrial ecosystems (U.S. EPA, 2008f).

One of the main provisioning services potentially affected by N deposition is grazing opportunities offered by grasslands for livestock production in the Central U.S. Although N deposition on these grasslands can offer supplementary nutritive value and promote overall grass production, there are concerns that fertilization may favor invasive grasses and shift the species composition away from native grasses. This process may ultimately reduce the productivity of grasslands for livestock production. Losses due to invasive grasses can be significant; for example, based on a bioeconomic model of cattle grazing in the upper Great Plains, Leitch, Leistritz, and Bangsund (1996) and Leistritz, Bangsund, and Hodur (2004) estimated $130 million in losses due to a leafy spurge infestation in the Dakotas, Montana, and Wyoming. [43] However, the contribution of N deposition to these losses is still uncertain.

Terrestrial nutrient enrichment also affects cultural and regulating services. For example, in California, Coastal Sage Scrub (CSS) habitat concerns focus on a decline in CSS and an increase in nonnative grasses and other species, impacts on the viability of threatened and endangered species associated with CSS, and an increase in fire frequency. Changes in Mixed Conifer Forest (MCF) include changes in habitat suitability and increased tree mortality, increased fire intensity, and a change in the forest's nutrient cycling that may affect surface water quality through nitrate leaching (U.S. EPA, 2008f). CSS and MCF are an integral part of the California landscape, and together the ranges of these habitats include the densely populated and valuable coastline and the mountain areas. Numerous threatened and endangered species at both the state and federal levels reside in CSS and MCF. The value that California residents and the U.S. population as a whole place on CSS and MCF habitats is reflected in the various federal, state, and local government measures that have been put in place to protect these habitats, including the Endangered Species Act, conservation planning programs, and private and local land trusts. CSS and MCF habitat are showcased in many popular recreation areas in California, including several national parks and monuments. In addition, millions of individuals are involved in fishing, hunting, and wildlife viewing in California every year (DOI, 2007). The quality of these trips depends in part on the health of the ecosystems and their ability to support the diversity of plants and animals found in important habitats found in CSS or MCF ecosystems and the parks associated with those ecosystems. Based on analyses in the NOx SOx REA average values of the total benefits in 2006 from fishing, hunting, and wildlife viewing away from home in California were approximately $950 million, $170 million, and $3.6 billion, respectively (U.S.EPA, 2009c).[44] In addition, data from California State Parks (2003) indicate that in 2002, 69% of adult residents participated in trail hiking for an average of 24 days per year. The aggregate annual benefit for California residents from trail hiking in 2007 was $11 billion (U.S.EPA, 2009c).[45] It is not currently possible to quantify the loss in value of services due to nitrogen deposition as those losses are already reflected in the estimates of the contemporaneous total value of these recreational activities. Restoration of services through decreases in nitrogen deposition would likely increase the total value of recreational services.

Fire regulation is also an important regulating service that could be affected by nutrient enrichment of the CSS and MCF ecosystems by encouraging growth of more flammable grasses, increasing fuel loads, and altering the fire cycle. Over the 5-year period from 2004 to 2008, Southern California experienced, on average, over 4,000 fires per year burning, on average, over 400,000 acres per year (National Association of State Foresters [NASF], 2009). It is not possible at this time to quantify the contribution of nitrogen deposition, among many other factors, to increased fire risk.

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[44] These estimates reflect the total value of the service, not the marginal change in the value of the service as a result of the emission reductions achieved by this rule.

[45] These estimates reflect the total value of the service, not the marginal change in the value of the service as a result of the emission reductions achieved by this rule.

5.5.6 Benefits of Reducing Ozone Effects on Vegetation and Ecosystems

Ozone causes discernible injury to a wide array of vegetation (U.S. EPA, 2006a; Fox and Mickler, 1996). Sensitivity to ozone is highly variable across plant species, with over 65 plant species identified as “ozone-sensitive”, many of which occur in state and national parks and forests. In terms of forest productivity and ecosystem diversity, ozone may be the pollutant with the greatest potential for regional-scale forest impacts (U.S. EPA, 2006a). Studies have demonstrated repeatedly that ozone concentrations commonly observed in polluted areas can have substantial impacts on plant function (De Steiguer et al., 1990; Pye, 1988).

When ozone is present in the air, it can enter the leaves of plants, where it can cause significant cellular damage. Like carbon dioxide (CO_2) and other gaseous substances, ozone enters plant tissues primarily through the stomata in leaves in a process called “uptake” (Winner and Atkinson, 1986). Once sufficient levels of ozone (a highly reactive substance), or its reaction products, reaches the interior of plant cells, it can inhibit or damage essential cellular components and functions, including enzyme activities, lipids, and cellular membranes, disrupting the plant's osmotic (i.e., water) balance and energy utilization patterns (U.S. EPA, 2006a; Tingey and Taylor, 1982). With fewer resources available, the plant reallocates existing resources away from root growth and storage, above ground growth or yield, and reproductive processes, toward leaf repair and maintenance, leading to reduced growth and/or reproduction. Studies have shown that plants stressed in these ways may exhibit a general loss of vigor, which can lead to secondary impacts that modify plants' responses to other environmental factors. Specifically, plants may become more sensitive to other air pollutants, or more susceptible to disease, pest infestation, harsh weather (e.g., drought, frost) and other environmental stresses, which can all produce a loss in plant vigor in ozone-sensitive species that over time may lead to premature plant death. Furthermore, there is evidence that ozone can interfere with the formation of mycorrhiza, essential symbiotic fungi associated with the roots of most terrestrial plants, by reducing the amount of carbon available for transfer from the host to the symbiont (U.S. EPA, 2006a).

This ozone damage may or may not be accompanied by visible injury on leaves, and likewise, visible foliar injury may or may not be a symptom of the other types of plant damage described above. Foliar injury is usually the first visible sign of injury to plants from ozone exposure and indicates impaired physiological processes in the leaves (Grulke, 2003). When visible injury is present, it is commonly manifested as chlorotic or necrotic spots, and/or increased leaf senescence (accelerated leaf aging). Because ozone damage can consist of visible injury to leaves, it can also reduce the aesthetic value of ornamental vegetation and trees in urban landscapes, and negatively affects scenic vistas in protected natural areas.

Ozone can produce both acute and chronic injury in sensitive species depending on the concentration level and the duration of the exposure. Ozone effects also tend to accumulate over the growing season of the plant, so that even lower concentrations experienced for a longer duration have the potential to create chronic stress on sensitive vegetation. Not all plants, however, are equally sensitive to ozone. Much of the variation in sensitivity between individual plants or whole species is related to the plant's ability to regulate the extent of gas exchange via leaf stomata (e.g., avoidance of ozone uptake through closure of stomata) (U.S. EPA, 2006a; Winner, 1994). After injuries have occurred, plants may be capable of repairing the damage to a limited extent (U.S. EPA, 2006a). Because of the differing sensitivities among plants to ozone, ozone pollution can also exert a selective pressure that leads to changes in plant community composition. Given the range of plant sensitivities and the fact that numerous other environmental factors modify plant uptake and response to ozone, it is not possible to identify threshold values above which ozone is consistently toxic for all plants.

Because plants are at the base of the food web in many ecosystems, changes to the plant community can affect associated organisms and ecosystems (including the suitability of habitats that support threatened or endangered species and below ground organisms living in the root zone). Ozone impacts at the community and ecosystem level vary widely depending upon numerous factors, including concentration and temporal variation of tropospheric ozone, species composition, soil properties and climatic factors (U.S. EPA, 2006a). In most instances, responses to chronic or recurrent exposure in forested ecosystems are subtle and not observable for many years. These injuries can cause stand-level forest decline in sensitive ecosystems (U.S. EPA, 2006a, McBride et al., 1985; Miller et al., 1982). It is not yet possible to predict ecosystem responses to ozone with much certainty; however, considerable knowledge of potential ecosystem responses has been acquired through long-term observations in highly damaged forests in the United States (U.S EPA, 2006a).

5.5.6.1 Ozone Effects on Forests

Air pollution can affect the environment and affect ecological systems, leading to changes in the ecological community and influencing the diversity, health, and vigor of individual species (U.S. EPA, 2006a). Ozone has been shown in numerous studies to have a strong effect on the health of many plants, including a variety of commercial and ecologically important forest tree species throughout the United States (U.S. EPA, 2007b).

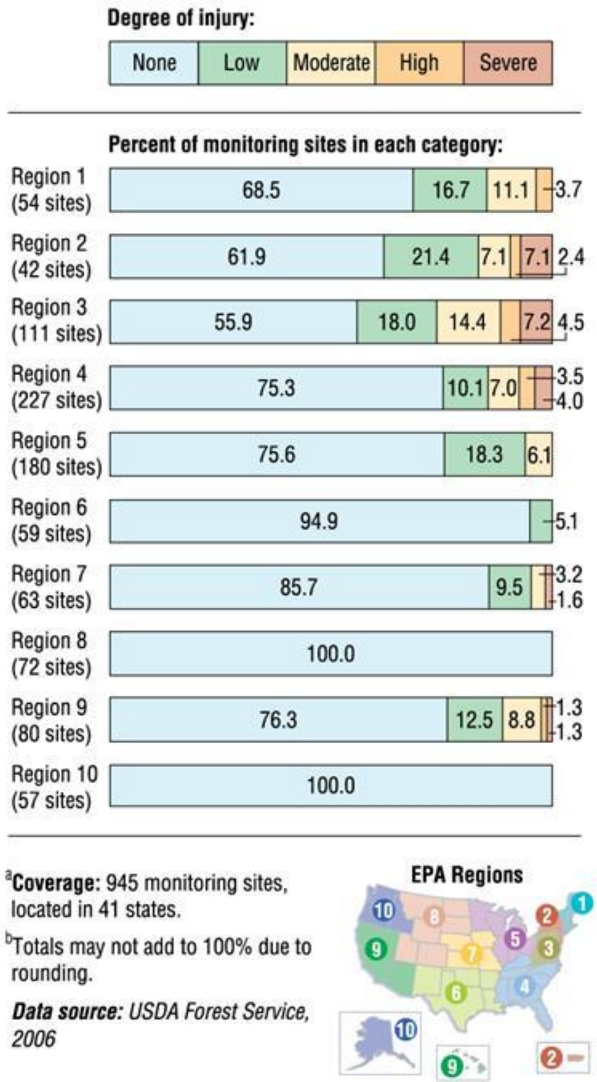
In the U.S., this data comes from the U.S. Department of Agriculture (USDA) Forest Service Forest Inventory and Analysis (FIA) program. As part of its Phase 3 program, formerly known as Forest Health Monitoring, FIA examines ozone injury to ozone-sensitive plant species at ground monitoring sites in forestland across the country (excluding woodlots and urban trees). FIA looks for damage on the foliage of ozone-sensitive forest plant species at each site that meets certain minimum criteria. Because ozone injury is cumulative over the course of the growing season, examinations are conducted in July and August, when ozone injury is typically highest.

Monitoring of ozone injury to plants by the USDA Forest Service has expanded over the last 15 years from monitoring sites in 10 states in 1994 to nearly 1,000 monitoring sites in 41 states in 2002. Since 2002, the monitoring program has further expanded to 1,130 monitoring sites in 45 states. Figure 5-13 shows the results of this monitoring program for the year 2002 broken down by U.S. EPA Regions.[46] Figure 5-14 identifies the counties that were included in Figure 5-13, and provides the county-level data regarding the presence or absence of ozone-related injury. As shown in Figure 5-14 large geographic areas of EPA Regions 6, 8, and 10 were not included in the assessment. Ozone damage to forest plants is classified using a subjective five-category biosite index based on expert opinion, but designed to be equivalent from site to site. Ranges of biosite values translate to no injury, low or moderate foliar injury (visible foliar injury to highly sensitive or moderately sensitive plants, respectively), and high or severe foliar injury, which would be expected to result in tree-level or ecosystem-level responses, respectively (U.S. EPA, 2006a; Coulston, 2004). The highest percentages of observed high and severe foliar injury, which are most likely to be associated with tree or ecosystem-level responses, are primarily found in the Mid-Atlantic

[46] The data are based on averages of all observations collected in 2002, which is the last year for which data are publicly available. For more information, please consult EPA's 2008 Report on the Environment (U.S. EPA, 2008b).

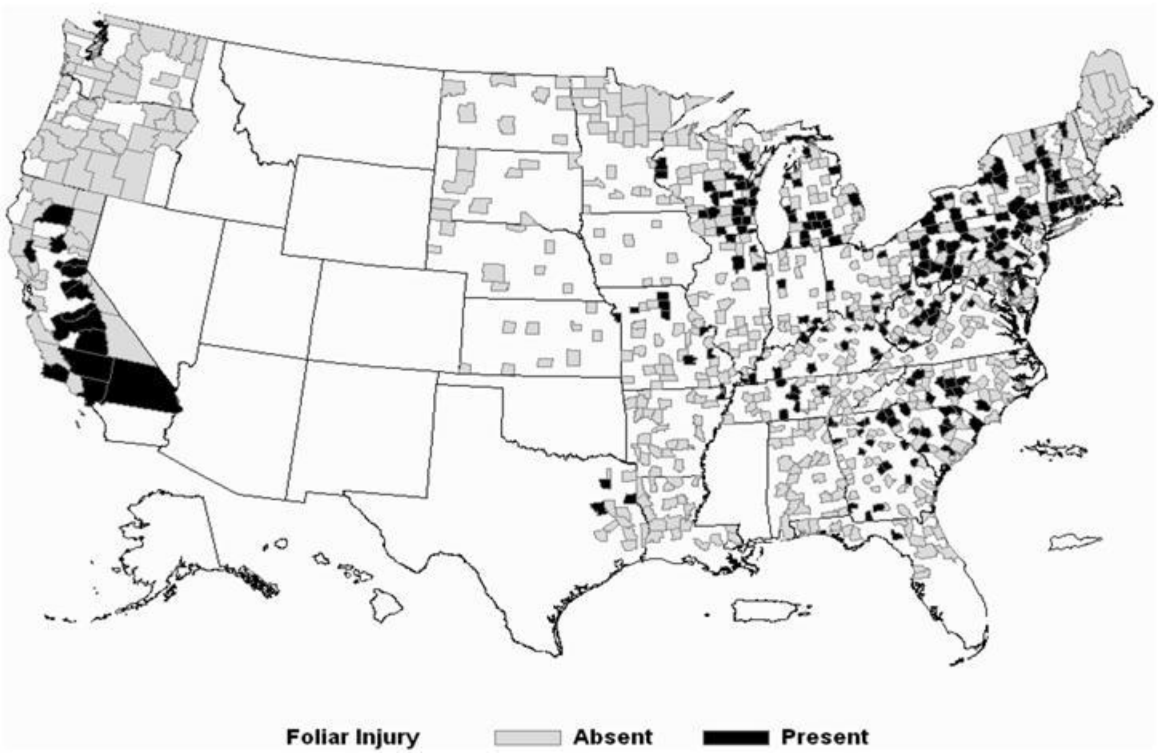
and Southeast regions. While the assessment showed considerable regional variation in ozone injury, this assessment targeted different ozone-sensitive species in different parts of the country with varying ozone sensitivity, which contributes to the apparent regional differences. It is important to note that ozone can have other, more significant impacts on forest plants (e.g. reduced biomass growth in trees) prior to showing signs of visible foliar injury (U.S. EPA, 2006a).

Figure 5-13: Visible Foliar Injury to Forest Plants from Ozone in U.S. by EPA Regions, [a, b, c]



[c] ***Degree of Injury:*** These categories reflect a subjective index based on expert opinion. Ozone can have other, more significant impacts on forest plants (e.g. reduced biomass growth in trees) prior to showing signs of visible foliar injury.

Figure 5-14. Presence and Absence of Visible Foliar Injury, as measured by U.S. Forest Service, 2002 (U.S. EPA, 2007)

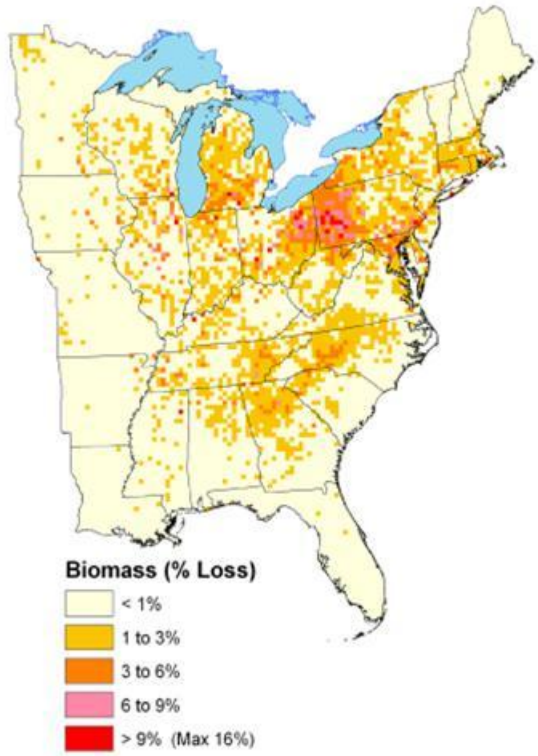


Assessing the impact of ground-level ozone on forests in the eastern United States involves understanding the risks to sensitive tree species from ambient ozone concentrations and accounting for the prevalence of those species within the forest. As a way to quantify the risks to particular plants from ground-level ozone, scientists have developed ozone-exposure/tree-response functions by exposing tree seedlings to different ozone levels and measuring reductions in growth as "biomass loss." Typically, seedlings are used because they are easy to manipulate and measure their growth loss from ozone pollution. The mechanisms of susceptibility to ozone within the leaves of seedlings and mature trees are identical, and the decreases predicted using the seedlings should be related to the decrease in overall plant fitness for mature trees, but the magnitude of the effect may be higher or lower depending on the tree species (Chappelka and Samuelson, 1998). In areas where certain ozone-sensitive species dominate the forest community, the biomass loss from ozone can be significant. Experts have identified 2% annual biomass loss as a level of concern, which would cause long term ecological harm as the short-term negative effects on seedlings compound to affect long-term forest health (Heck and Cowling, 1997).

Some of the common tree species in the United States that are sensitive to ozone are black cherry (*Prunus serotina*), tulip-poplar (*Liriodendron tulipifera)*, and eastern white pine (*Pinus strobus)*. Ozone-exposure/tree-response functions have been developed for each of these tree species, as well as for aspen (*Populus tremuliodes*), and ponderosa pine (*Pinus ponderosa*) (U.S. EPA, 2007b). Other common tree species, such as oak (*Quercus* spp.*)* and hickory (*Carya* spp.), are not as sensitive to ozone. Consequently, with knowledge of the distribution of sensitive species and the level of ozone at particular locations, it is possible to estimate a "biomass loss" for each species across their range. As shown in Figure 5-15, current ambient levels of ozone are associated with significant biomass loss across large geographic areas (U.S. EPA, 2009b). However, this information is unavailable for this final rule.

To estimate the biomass loss for forest ecosystems across the eastern United States, the biomass loss for each of the seven tree species was calculated using the three-month, 12-hour W126 exposure metric at each location, along with each tree's individual C-R functions. The W126 exposure metric was calculated using monitored ozone data from CASTNET and AQS sites, and a three-year average was used to mitigate the effect of variations in meteorological and soil moisture conditions. The biomass loss estimate for each species was then multiplied by its prevalence in the forest community using the U.S. Department of Agriculture (USDA) Forest Service IV index of tree abundance calculated from Forest Inventory and Analysis (FIA) measurements (Prasad, 2003). Sources of uncertainty include the ozone-exposure/plant-response functions, the tree abundance index, and other factors (e.g., soil moisture). Although these factors were not considered, they can affect ozone damage (Chappelka, 1998).

Figure 5-15: Estimated Black Cherry, Yellow Poplar, Sugar Maple, Eastern White Pine, Virginia Pine, Red Maple, and Quaking Aspen Biomass Loss due to Current Ozone Exposure, 2006-2008 (U.S. EPA, 2009b)



Ozone damage to the plants including the trees and understory in a forest can affect the ability of the forest to sustain suitable habitat for associated species particularly threatened and endangered species that have existence value – a nonuse ecosystem service - for the public. Similarly, damage to trees and the loss of biomass can affect the forest's provisioning services in the form of timber for various commercial uses. In addition, ozone can cause discoloration of leaves and more rapid senescence (early shedding of leaves), which could negatively affect fall-color tourism because the fall foliage would be less available or less attractive. Beyond the aesthetic damage to fall color vistas, forests provide the public with many other recreational and educational services that may be affected by reduced forest health including hiking, wildlife viewing (including bird watching), camping, picnicking, and hunting. Another potential effect of biomass loss in forests is the subsequent loss of climate regulation service in the form of reduced ability to sequester carbon (Felzer et al., 2005).

5.5.6.2 Ozone Effects on Crops and Urban Ornamentals

Laboratory and field experiments have also shown reductions in yields for agronomic crops exposed to ozone, including vegetables (e.g., lettuce) and field crops (e.g., cotton and wheat). Damage to crops from ozone exposures includes yield losses (i.e., in terms of weight, number, or size of the plant part that is harvested), as well as changes in crop quality (i.e., physical appearance, chemical composition, or the ability to withstand storage) (U.S. EPA, 2007b). The most extensive field experiments, conducted under the National Crop Loss Assessment Network (NCLAN) examined 15 species and numerous cultivars. The NCLAN results show that "several economically important crop species are sensitive to ozone levels typical of those found in the United States" (U.S. EPA, 2006a). In addition, economic studies have shown reduced economic benefits as a result of predicted reductions in crop yields, directly affecting the amount and quality of the provisioning service provided by these crops, associated with observed ozone levels (Kopp et al., 1985; Adams et al., 1986; Adams et al., 1989). In addition, visible foliar injury by itself can reduce the market value of certain leafy crops (such as spinach, lettuce). According to the Ozone Staff Paper, there has been no evidence that crops are becoming more tolerant of ozone (U.S. EPA, 2007b). Using the Agriculture Simulation Model (AGSIM) (Taylor, 1994) to calculate the agricultural benefits of reductions in ozone exposure, U.S. EPA estimated that attaining a W126 standard of 13 ppm-hr would produce monetized benefits of approximately $400 million to $620 million in 2006 (inflated to 2006 dollars) (U.S. EPA, 2007b). [47]

Urban ornamental plants are an additional vegetation category likely to experience some degree of negative effects associated with exposure to ambient ozone levels. Several ornamental species have been listed as sensitive to ozone (Abt Associates, 1995).Because ozone causes visible foliar injury, the aesthetic value of ornamentals (such as petunia, geranium, and poinsettia) in urban landscapes would be reduced (U.S. EPA, 2007b). Sensitive ornamental species would require more frequent replacement and/or increased maintenance (fertilizer or pesticide application) to maintain the desired appearance because of exposure to ambient ozone (U.S. EPA, 2007b). In addition, many businesses rely on healthy-looking vegetation for their livelihoods (e.g., horticulturalists, landscapers, Christmas

[47] These estimates illustrate the value of vegetation effects from a substantial reduction of ozone concentrations, not the marginal change in ozone concentrations anticipated a result of the emission reductions achieved by this rule.

tree growers, farmers of leafy crops, etc.) and a variety of ornamental species have been listed as sensitive to ozone (Abt Associates, 1995). The ornamental landscaping industry is multi-billion industry that affected both private property owners/tenants and by governmental units responsible for public areas (Abt Associates, 1995). Preliminary data from the 2007 Economic Census indicate that the landscaping services industry, which is primarily engaged in providing landscape care and maintenance services and installing trees, shrubs, plants, lawns, or gardens, was valued at $53 billion (U.S. Census Bureau, 2010). Therefore, urban ornamentals represent a potentially large unquantified benefit category. This aesthetic damage may affect the enjoyment of urban parks by the public and homeowners' enjoyment of their landscaping and gardening activities. In addition, homeowners may experience a reduction in home value or a home may linger on the market longer due to decreased aesthetic appeal. In the absence of adequate exposure-response functions and economic damage functions for the potential range of effects relevant to these types of vegetation, we cannot conduct a quantitative analysis to estimate these effects.

5.5.7 Unquantified SO_2 and NO_2-Related Human Health Benefits

Following an extensive evaluation of health evidence from epidemiologic and laboratory studies, the Integrated Science Assessment for Sulfur Dioxide concluded that there is a causal relationship between respiratory health effects and short-term exposure to SO_2 (U.S. EPA, 2008). The immediate effect of SO_2 on the respiratory system in humans is bronchoconstriction. Asthmatics are more sensitive to the effects of SO_2 likely resulting from preexisting inflammation associated with this disease. A clear concentration-response relationship has been demonstrated in laboratory studies following exposures to SO_2 at concentrations between 20 and 100 ppb, both in terms of increasing severity of effect and percentage of asthmatics adversely affected. Based on our review of this information, we identified four short-term morbidity endpoints that the SO_2 ISA identified as a "causal relationship": asthma exacerbation, respiratory-related emergency department visits, and respiratory-related hospitalizations. The differing evidence and associated strength of the evidence for these different effects is described in detail in the SO_2 ISA. The SO_2 ISA also concluded that the relationship between short-term SO_2 exposure and premature mortality was "suggestive of a causal relationship" because it is difficult to attribute the mortality risk effects to SO_2 alone. Although the SO_2 ISA stated that studies are generally consistent in reporting a relationship between SO_2 exposure and mortality, there was a lack of robustness of the observed associations to adjustment for pollutants. We did not quantify these benefits due to time constraints.

Epidemiological researchers have associated NO_2 exposure with adverse health effects in numerous toxicological, clinical and epidemiological studies, as described in the Integrated Science Assessment for Oxides of Nitrogen - Health Criteria (Final Report) (U.S. EPA, 2008c). The NO_2 ISA provides a comprehensive review of the current evidence of health and environmental effects of NO_2. The NO_2 ISA concluded that the evidence "is sufficient to infer a likely causal relationship between short-term NO_2 exposure and adverse effects on the respiratory system" (ISA, section 5.3.2.1). These epidemiologic and experimental studies encompass a number of endpoints including [Emergency Department (ED)] visits and hospitalizations, respiratory symptoms, airway hyperresponsiveness, airway inflammation, and lung function. Effect estimates from epidemiologic studies conducted in the United States and Canada generally indicate a 2-20% increase in risks for ED visits and hospital admissions and higher risks for respiratory symptoms (ISA, section 5.4). The NO_2 ISA concluded that the relationship between short-term NO_2 exposure and premature mortality was "suggestive but not sufficient to infer a causal relationship" because it is difficult to attribute the mortality risk effects to NO_2 alone. Although the NO_2 ISA stated that studies consistently reported a relationship between NO_2 exposure and mortality, the effect was generally smaller than that for other pollutants such as PM. We did not quantify these benefits due to time constraints.

5.6 Social Cost of Carbon and Greenhouse Gas Benefits

EPA has assigned a dollar value to reductions in carbon dioxide (CO_2) emissions using recent estimates of the "social cost of carbon" (SCC). The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change. The SCC estimates used in this analysis were developed through an interagency process that included EPA and other executive branch entities, and concluded in February 2010. EPA first used these SCC estimates in the benefits analysis for the final joint EPA/DOT Rulemaking to establish Light-Duty Vehicle Greenhouse Gas

Emission Standards and Corporate Average Fuel Economy Standards; see the rule's preamble for discussion about application of SCC (75 FR 25324; 5/7/10). The SCC Technical Support Document (SCC TSD) provides a complete discussion of the methods used to develop these SCC estimates.[48]

The interagency group selected four SCC values for use in regulatory analyses, which we have applied in this analysis: $5, $21, $35, and $65 per metric ton of CO_2 emissions[49] in 2010, in 2007 dollars. The first three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent, respectively. SCCs at several discount rates are included because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context. The fourth value is the 95th percentile of the SCC from all three models at a 3 percent discount rate. It is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. Low probability, high impact events are incorporated into all of the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high temperature outcomes, which in turn lead to higher projections of damages.

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that the interagency group estimated the growth rate of the SCC directly using the three integrated assessment models rather than assuming a constant annual growth rate. This helps to ensure that the estimates are internally consistent with other

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[48] Docket ID EPA-HQ-OAR-2009-0472-114577, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, Interagency Working Group on Social Cost of Carbon, with participation by Council of Economic Advisers, Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and Budget, Office of Science and Technology Policy, and Department of Treasury (February 2010). Also available at http://www.epa.gov/otaq/climate/regulations.htm

[49] The interagency group decided that these estimates apply only to CO_2 emissions. Given that warming profiles and impacts other than temperature change (e.g. ocean acidification) vary across GHGs, the group concluded "transforming gases into CO_2-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-CO_2 gases" (SCC TSD, pg 13).

modeling assumptions. The SCC estimates for the analysis years of 2014, in 2007 dollars are provided in Table 5-15.

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

The interagency group noted a number of limitations to the SCC analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes the interagency modeling exercise even more difficult. The interagency group hopes that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. Additional details on these limitations are discussed in the SCC TSD.

In light of these limitations, the interagency group has committed to updating the current estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, the interagency group has set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area.

Applying the global SCC estimates to the estimated reductions in CO_2 emissions for the range of policy scenarios, we estimate the dollar value of the climate related benefits captured by the models for each analysis year. For internal consistency, the annual benefits are discounted back to NPV terms using the same discount rate as each SCC estimate (i.e.

5%, 3%, and 2.5%) rather than 3% and 7%.[50] These estimates are provided in Table 5-16.

Table 5-15. Social Cost of Carbon (SCC) Estimates (per tonne of CO_2) for 2014 (in 2007$)[a]

Discount Rate and Statistic		*SCC estimate*
5%	Average	$5.5
3%	Average	$23.4
2.5%	Average	$37.7
3%	95%ile	$71.2

[a] The SCC values are dollar-year and emissions-year specific. SCC values represent only a partial accounting of climate impacts.

Table 5-16. Monetized SCC-Derived Benefits of CO_2 Emissions Reductions in 2014 (in millions of 2007$)[a]

Discount Rate and Statistic		*SCC-derived benefits*
Tons of CO_2 reduced (millions)		25
5%	Average	$140
3%	Average	$590
2.5%	Average	$950
3%	95%ile	$1,800

[a] The SCC values are dollar-year and emissions-year specific. SCC values represent only a partial accounting of climate impacts.

5.7 Benefits Results

Applying the impact and valuation functions described previously in this chapter to the estimated changes in ozone and PM yields estimates of the changes in physical damages (e.g., premature mortalities, cases, admissions, and change in light extinction) and the associated monetary values for those changes. Estimates of physical health impacts among those states in either the ozone or $PM_{2.5}$ trading region, or outside the trading region, are presented in Table 5-17. Monetized values for both health and welfare endpoints within the trading region are presented in Table 5-18, along with total aggregate monetized benefits. All of the monetary benefits are in constant-year 2007 dollars. The $PM_{2.5}$-related benefits of the more and less stringent scenarios were within about 15% of the selected remedy. The results

[50] It is possible that other benefits or costs of proposed regulations unrelated to CO_2 emissions will be discounted at rates that differ from those used to develop the SCC estimates.

of that analysis may be found in the cost-benefit comparison chapter (Chapter 10 of this RIA).

Table 5-17: Estimated Reduction in Incidence of Adverse Health Effects of the Selected remedy (95% confidence intervals)[A]

Health Effect	*Within transport region*	*Beyond transport region*	*Total*
PM-Related endpoints			
Premature Mortality			
Pope et al. (2002) (age >30)	13,000 (5,200—21,000)	33 (5—60)	13,000 (5,200—21,000)
Laden et al. (2006) (age >25)	34,000 (18,000—49,000)	84 (31—140)	34,000 (18,000—49,000)
Infant (< 1 year)	59 (-47—160)	0.15 (-0.2—0.5)	59 (-47—160)
Chronic Bronchitis	8,700 (1,600—16,000)	23 (-5—50)	8,700 (1,600—16,000)
Non-fatal heart attacks (age > 18)	15,000 (5,600—24,000)	40 (7—72)	15,000 (5,600—24,000)
Hospital admissions—respiratory (all ages)	2,700 (1,300—4,000)	5 (2—9)	2,700 (1,300—4,000)
Hospital admissions—cardiovascular (age > 18)	5,700 (4,200—6,600)	15 (10—19)	5,800 (4,200—6,600)
Emergency room visits for asthma (age < 18)	9,800 (5,800—14,000)	21 (7—36)	9,800 (5,800—14,000)
Acute bronchitis (age 8-12)	19,000 (-630—37,000)	50 (-29—130)	19,000 (-660—37,000)
Lower respiratory symptoms (age 7-14)	240,000 (120,000—360,000)	630 (130—1,100)	240,000 (120,000—360,000)
Upper respiratory symptoms (asthmatics age 9-18)	180,000 (57,000—310,000)	480 (-25—980)	180,000 (57,000—310,000)
Asthma exacerbation (asthmatics 6-18)	400,000 (45,000—1,100,000)	1,100 (-250—2,900)	400,000 (45,000—1,100,000)
Lost work days (ages 18-65)	1,700,000 (1,500,000—1,900,000)	4,300 (3,500—5,200)	1,700,000 (1,500,000—1,900,000)
Minor restricted-activity days (ages 18-65)	10,000,000 (8,400,000—11,000,000)	26,000 (20,000—32,000)	10,000,000 (8,400,000—12,000,000)

Ozone-related endpoints			
Premature mortality			
Bell et al. (2004) (all ages)	27 (11—42)	0.1 (0.01—0.3)	27 (11—42)

	Schwartz et al. (2005) (all ages)	41 (17—64)	0.2 (0.1—0.4)	41 (17—65)
	Huang et al. (2005) (all ages)	37 (17—57)	0.2 (0.1—0.4)	37 (17—57)
Meta-analyses	Ito et al. (2005) (all ages)	120 (78—160)	0.6 (0.3—0.9)	120 (79—160)
Meta-analyses	Bell et al. (2005) (all ages)	87 (48—130)	0.5 (0.2—0.8)	87 (48—130)
Meta-analyses	Levy et al. (2005) (all ages)	120 (89—150)	0.7 (0.4—0.9)	120 (90—160)
Hospital admissions—respiratory causes (ages > 65)		160 (21—280)	1.2 (0.1—2.3)	160 (21—290)
Hospital admissions—respiratory causes (ages <2)		83 (43—120)	0.5 (0.2—0.8)	84 (43—120)
Emergency room visits for asthma (all ages)		86 (-2—260)	0.4 (-0.2—1.4)	86 (-2—260)
Minor restricted-activity days (ages 18-65)		160,000 (80,000—240,000)	910 (240—1,600)	160,000 (80,000—240,000)
School absence days		51,000 (22,000—73,000)	290 (59—490)	51,000 (22,000—74,000)

[A] Estimates rounded to two significant figures; column values will not sum to total value.
[B] The negative estimates for certain endpoints are the result of the weak statistical power of the study used to calculate these health impacts and do not suggest that increases in air pollution exposure result in decreased health impacts.

Table 5-18: Estimated Economic Value of Health and Welfare Benefits (95% confidence intervals, billions of 2007$)[A]

Health Effect	*Pollutant*	*Within transport region*	*Beyond transport region[B]*	*Total*
Premature Mortality (Pope et al. 2002 PM mortality and Bell et al. 2004 ozone mortality estimates)				
3% discount rate	$PM_{2.5}$ & O_3	$100 ($8.3—$320)	$0.3 ($0.01—$0.9)	$100 ($8.3—$320)
7% discount rate	$PM_{2.5}$ & O_3	$94 ($7.5—$280)	$0.2 ($0.01—$0.8)	$94 ($7.5—$290)
Premature Mortality (Laden et al. 2006 PM mortality and Levy et al. 2005 ozone mortality estimates)				
3% discount rate	$PM_{2.5}$ & O_3	$270 ($23—$770)	$0.7 ($0.05—$2)	$270 ($23—$770)
7% discount rate	$PM_{2.5}$ & O_3	$240 ($21—$700)	$0.6 ($0.05—$1.8)	$240 ($21—$700)
Chronic Bronchitis	$PM_{2.5}$	$4.2 ($0.2—$19)	$0.01 ($-0.003--$0.06)	$4.2 ($0.2—$19)
Non-fatal heart attacks				
3% discount rate	$PM_{2.5}$	$1.7 ($0.3—$4.2)	$0.004 ($0.003—$0.01)	$1.7 ($0.3—$4.2)
7% discount rate	$PM_{2.5}$	$1.3 ($0.3—$3.1)	$0.004 ($0.002—$0.001)	$1.3 ($0.3—$3.1)
Hospital admissions—respiratory	$PM_{2.5}$ & O_3	$0.04 ($0.02—$0.06)	---	$0.04 ($0.02—$0.06)
Hospital admissions—cardiovascular	$PM_{2.5}$	$0.09 ($0.01—$0.2)	---	$0.09 ($0.01—$0.2)
Emergency room visits for asthma	$PM_{2.5}$ & O_3	$0.003 ($0.002—$0.006)	---	$0.003 ($0.002—$0.006)
Acute bronchitis	$PM_{2.5}$	$0.008 (<$-0.01—$0.02)[c]	---	$0.008 (<$-0.01—$0.02)[c]
Lower respiratory symptoms	$PM_{2.5}$	$0.004 ($0.002—$0.009)	---	$0.004 ($0.002—$0.009)
Upper respiratory symptoms	$PM_{2.5}$	$0.005 (<$0.01—$0.014)	---	$0.005 (<$0.01—$0.014)
Asthma exacerbation	$PM_{2.5}$	$0.02 ($0.002—$0.08)	---	$0.02 ($0.002—$0.08)
Lost work days	$PM_{2.5}$	$0.2 ($0.17—$0.24)	---	$0.2 ($0.17—$0.24)
School loss days	O_3	$0.01 ($0.004—$0.013)	---	$0.01 ($0.004—$0.013)
Minor restricted-activity days	$PM_{2.5}$ & O_3	$0.7 ($0.3—$1)	---	$0.7 ($0.3—$1)

Recreational visibility, Class I areas	$PM_{2.5}$			$4.1
Social cost of carbon (3% discount rate, 2014 value)	CO_2			$0.6
Monetized total Benefits (Pope et al. 2002 $PM_{2.5}$ mortality and Bell et al. 2004 ozone mortality estimates)				
3% discount rate	$PM_{2.5}$, O_3	**$110 ($8.8—$340)**	**$0.28 ($0.01—$0.9)**	**$120 ($14—$350)**
7% discount rate	$PM_{2.5}$, O_3	**$100 ($8—$310)**	**$0.25 ($0.01—$0.85)**	**$110 ($13—$320)**
Monetized total Benefits (Laden et al. 2006 $PM_{2.5}$ mortality and Levy et al. 2005 ozone mortality estimates)				
3% discount rate	$PM_{2.5}$, O_3	**$270 ($24—$800)**	**$0.7 ($0.05—$2.1)**	**$280 ($29—$810)**
7% discount rate	$PM_{2.5}$, O_3	**$250 ($22—$720)**	**$0.6 ($0.04—$1.9)**	**$250 ($26—$730)**

[A] Estimates rounded to two significant figures.
[B] Monetary value of endpoints marked with dashes are < $100,000. States included in transport region may be found in chapter 2.
[C] The negative estimates for certain endpoints are the result of the weak statistical power of the study used to calculate these health impacts and do not suggest that increases in air pollution exposure result in decreased health impacts.

Not all known PM- and ozone-related health and welfare effects could be quantified or monetized. The monetized value of these unquantified effects is represented by adding an unknown "B" to the aggregate total. The estimate of total monetized health benefits is thus equal to the subset of monetized PM- and ozone-related health and welfare benefits plus B, the sum of the nonmonetized health and welfare benefits; this B represents both uncertainty and a bias in this analysis, as it reflects those benefits categories that we are unable quantify in this analysis.

Total monetized benefits are dominated by benefits of mortality risk reductions. The primary analysis projects that the preferred remedy will result in between 13,000 and 34,000 $PM_{2.5}$ and ozone-related avoided premature deaths annually in 2014. Our estimate of total monetized benefits in 2014 for the selected remedy is between $120 billion and $280 billion using a 3 percent discount rate and between $110 billion and $250 using a 7 percent discount rate. Health benefits account for between 97 and 99 percent of total benefits depending on the $PM_{2.5}$ and ozone mortality estimates used, in part because we are unable to quantify most of the non-health benefits. The monetized benefit associated with reductions in the risk of premature mortality, which accounts for between $100 and $270 billion in 2014, depending again on the PM and ozone mortality risk estimates used, is between 93 and 97 percent of total monetized health benefits. The next largest benefit is for reductions in chronic illness (CB and nonfatal heart attacks), although this value is more than an order of magnitude lower than for premature mortality. Hospital admissions for respiratory and cardiovascular causes, visibility, MRADs, work loss days, school absence days, and worker productivity account for the majority of the remaining benefits. The remaining categories each account for a small percentage of total benefit; however, they represent a large number of avoided incidences affecting many individuals. A comparison of the incidence table to the monetary benefits table reveals that there is not always a close correspondence between the number of incidences avoided for a given endpoint and the monetary value associated with that endpoint. For example, there are almost 100 times more work loss days than premature mortalities, yet work loss days account for only a very small fraction of total monetized benefits. This reflects the fact that many of the less severe health effects, while more common, are valued at a lower level than the more severe health effects. Also, some effects, such as hospital admissions, are valued using a proxy measure of WTP. As such, the true value of these effects may be higher than that reported in Table 5-18.

Figures 5-15 and 5-16 illustrates the geographic distribution of avoided $PM_{2.5}$ and ozone-related mortalities estimated to result from the selected remedy. Figure 5-17 plots the cumulative distribution of the percentage of deaths due to PM2.5 and ozone in 2014, prior to and after the implementation of the Transport Rule remedy. As illustrated in this figure, once implemented the Transport Rule is estimated to reduce by a substantial fraction the percentage of total deaths due to $PM_{2.5}$ and ozone. While not quantified in this RIA, we expect the Transport Rule to produce important public health benefits for populations living in Canada. Approximately 90% of the Canadian population lives within 100 miles of the U.S. border, suggesting that some of the air quality improvements projected in areas near the U.S.-Canada border would be enjoyed by Canadian populations as well. A recent analysis (Chestnut and Mills, 2005) of the U.S. Acid Rain Program estimates annual benefits of the program in 2010 to both Canada and the United States at $122 billion and costs for that year at $3 billion (2000$)—a 40-to-1 benefit/cost ratio. These quantified benefits in the United States and Canada are the result of improved air quality prolonging lives, reducing heart attacks and other cardiovascular and respiratory problems, and improving visibility. The complete report is available in volume 77, issue 3, of the *Journal of Environmental*

Management.

These figures show that while there are very large health benefits throughout most of the East, there could be several areas where a very small disbenefit could result if further governmental actions do not occur to address them in the future. There are several upcoming planned federal actions that could lead to further large reductions throughout the US of ambient levels of fine particles and ozone. Additionally, state actions to address regional haze in the near future and the existing NAAQS for fine particles and ozone could address these situations. There are also other state actions, such as the recent Colorado Clean Air – Clean Jobs Act of April 2010 that is likely to convert much of the Front Range coal-fired generation in Colorado to natural gas in the near future.

Figure 5-15: Estimated reduction in excess $PM_{2.5}$-related premature mortalities estimated to occur in each county in 2014 as a result of the selected remedy.

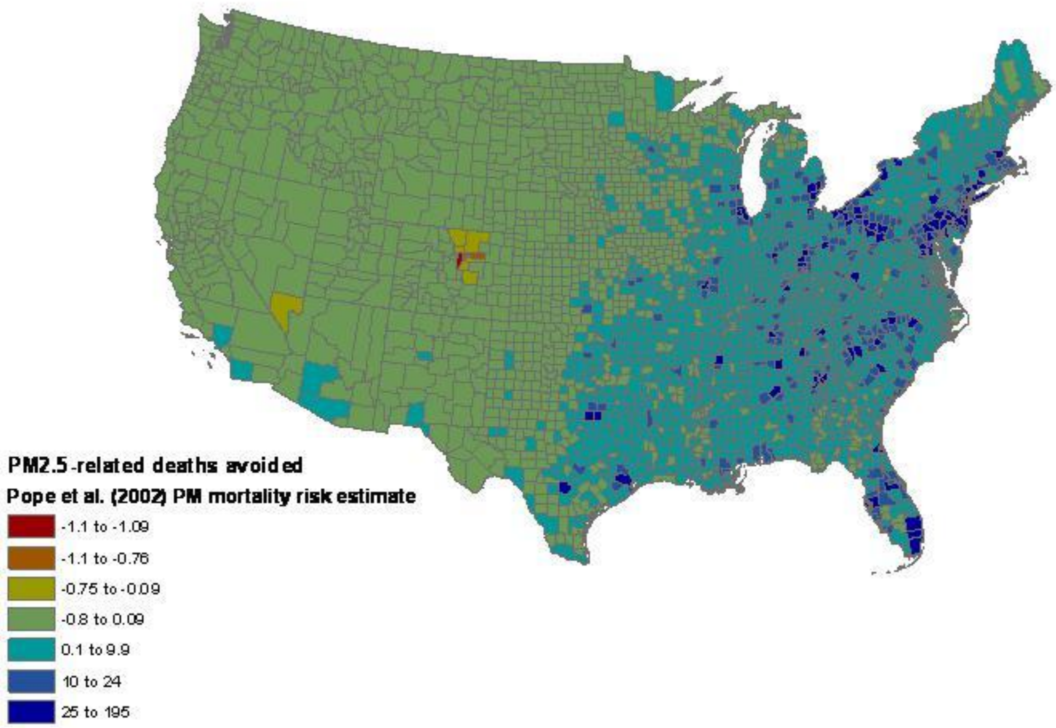


Figure 5-16: Estimated reduction in excess ozone-related premature mortalities estimated to occur in each county in 2014 as a result of the selected remedy

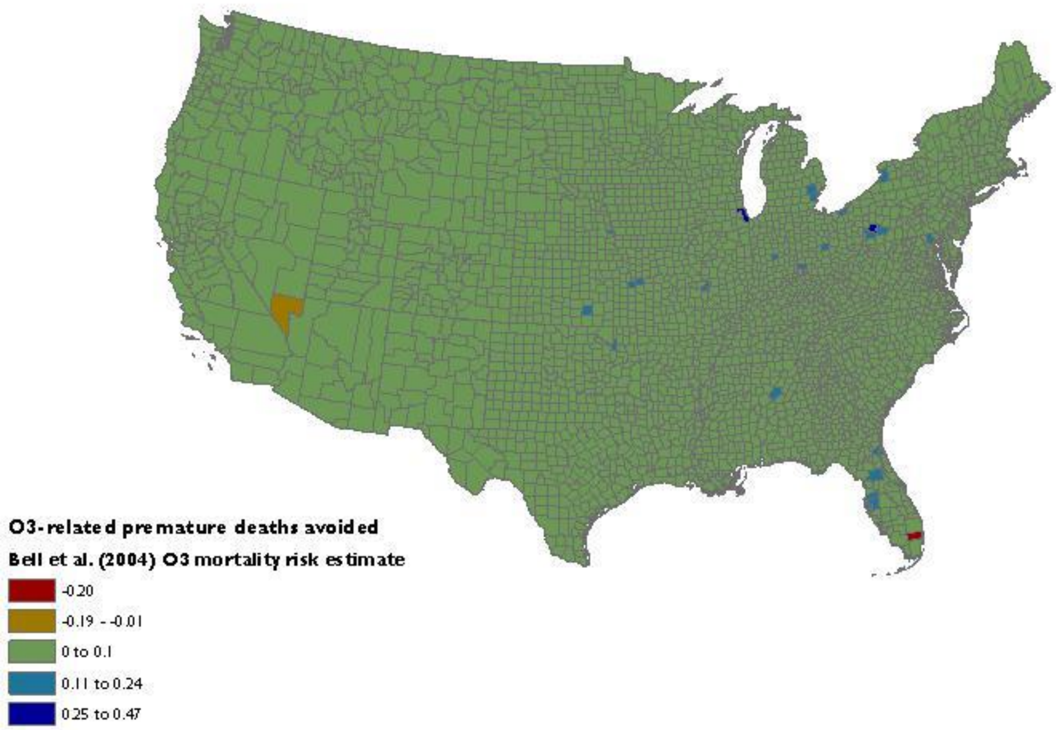
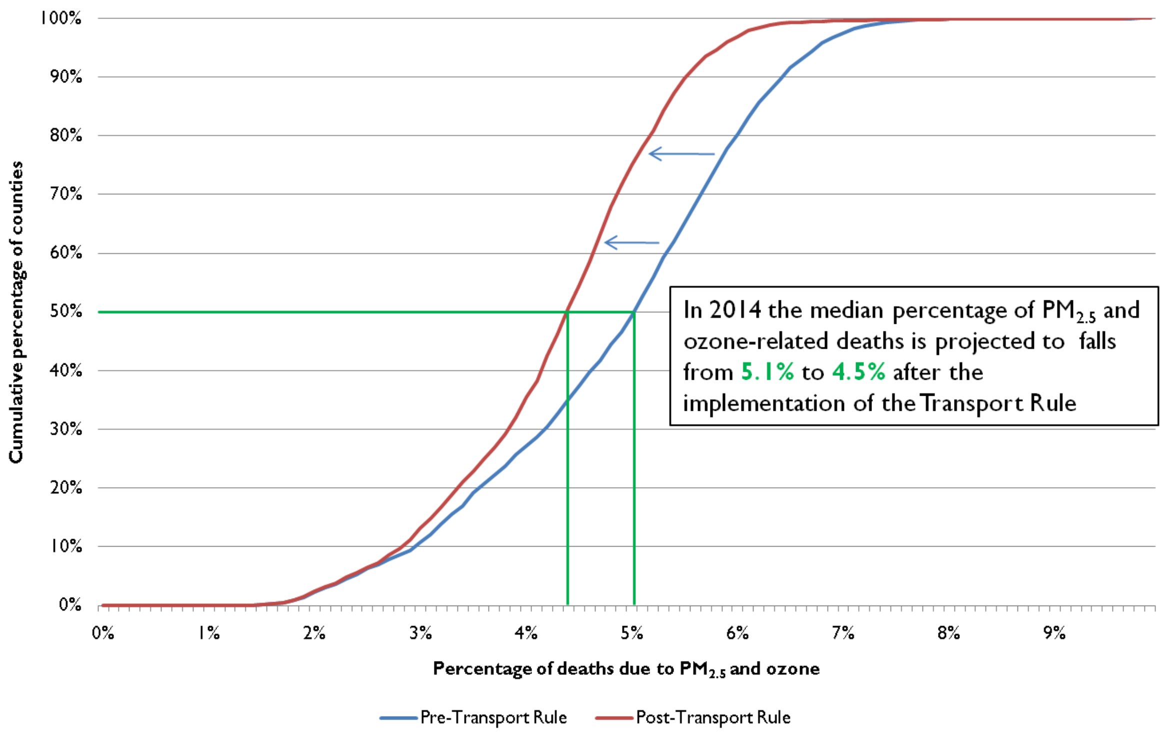


Figure 5-17: Cumulative percentage of the reduction in all-cause mortality attributable to reductions in $PM_{2.5}$ and Ozone resulting from the selected remedy by county in 2014[A]



[A]Bell et al. 2005 ozone mortality estimate and Pope et al. 2002 $PM_{2.5}$ mortality estimates.

Figure 5-18 summarizes an array of $PM_{2.5}$-related monetized benefits estimates based on alternative epidemiology and expert-derived PM-mortality estimate as well as the sum of ozone-related benefits using the Bell et al. (2004) mortality estimate.

Based on our review of the current body of scientific literature, EPA estimated PM-related mortality without applying an assumed concentration threshold. EPA's Integrated Science Assessment for Particulate Matter (U.S. EPA, 2009b), which was recently reviewed by EPA's Clean Air Scientific Advisory Committee (U.S. EPA-SAB, 2009a; U.S. EPA-SAB, 2009b), concluded that the scientific literature consistently finds that a no-threshold log-linear model most adequately portrays the PM-mortality concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response function. Consistent with this finding, we have conformed the threshold sensitivity analysis to the current state of the PM science improved upon our previous approach for estimating the sensitivity of the benefits estimates to the presence of an assumed threshold by incorporating a new "Lowest Measured Level" (LML) assessment.

This approach summarizes the distribution of avoided PM mortality impacts according to the baseline (i.e. pre-Transport Rule) $PM_{2.5}$ levels experienced by the population receiving the $PM_{2.5}$ mortality benefit (Figure 5-19). We identify on this figure the lowest air quality levels measured in each of the two primary epidemiological studies EPA uses to quantify PM-related mortality. This information allows readers to determine the portion of PM-related mortality benefits occurring above or below the LML of each study; in general, our confidence in the estimated PM mortality decreases as we consider air quality levels further below the LML in the two epidemiological studies. While the LML analysis provides some insight into the level of uncertainty in the estimated PM mortality benefits, EPA does not view the LML as a threshold and continues to quantify PM-related mortality impacts using a full range of modeled air quality concentrations.

The very large proportion of the avoided PM-related impacts we estimate in this analysis occur among populations exposed at or above the LML of each study (Figures 5-19) increasing our confidence in the PM mortality analysis. Approximately 69% of the avoided impacts occur at or above an annual mean $PM_{2.5}$ level of 10 $\mu g/m^3$ (the LML of the Laden et al. 2006 study); about 96% occur at or above an annual mean $PM_{2.5}$ level of 7.5 $\mu g/m^3$ (the

LML of the Pope et al. 2002 study). As we model mortality impacts among populations exposed to levels of $PM_{2.5}$ that are successively lower than the LML of each study our confidence in the results diminishes. However, the analysis above confirms that the great majority of the impacts occur at or above each study's LML.

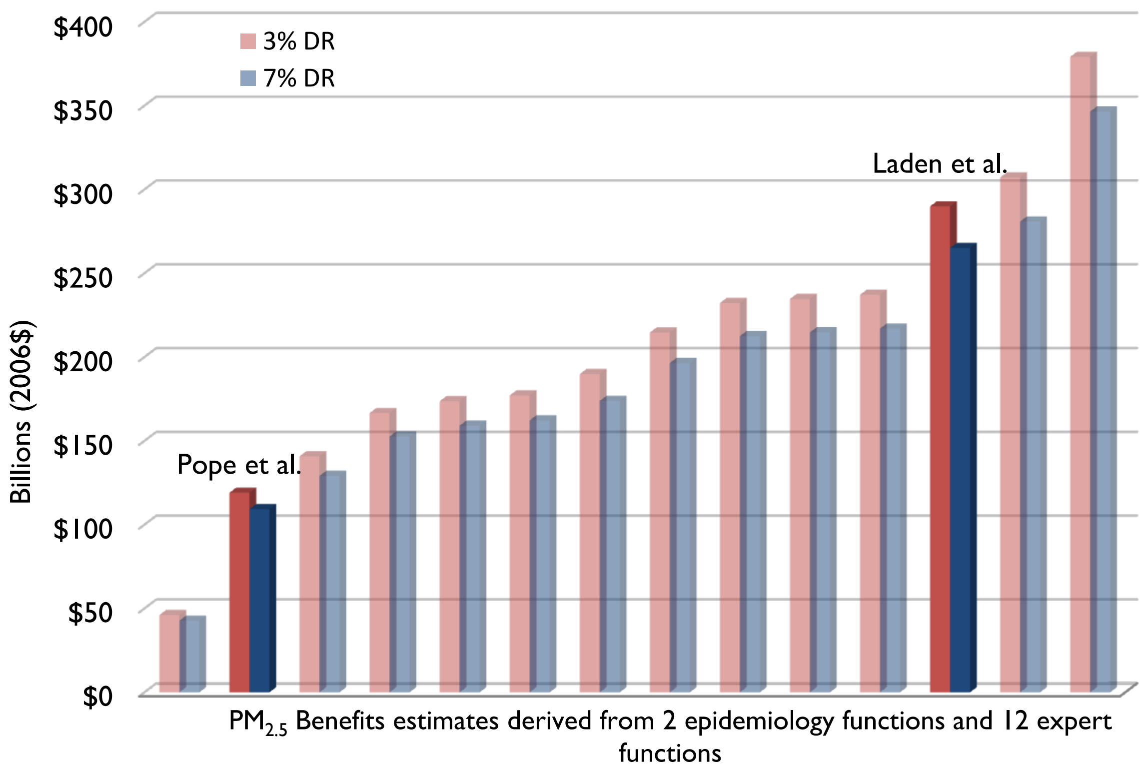
As an example, when considering mortality impacts among populations living in areas with an annual mean PM level of 8 µg/m3, we would place greater confidence in estimates drawn from the Pope et al. 2002 study, as this air quality level is above the LML of this study. Conversely, we would place equal confidence when estimating mortality impacts among populations living in locations where the annual mean PM levels are above 10 µg/m3 because this value is at or above the LML of each study.

Finally, Figure 5-20 illustrates the percentage of population exposed to different levels of annual mean PM2.5 levels in the baseline and after the implementation of the Transport Rule in 2014. The Transport Rule reduces overall PM2.5 levels substantially, particularly among highly exposed populations located within the states covered by the rule. Locations of the U.S. where annual mean PM levels are below the lowest measured level of the Pope study--western states in particular--are generally unaffected by the rule. However, for populations in the far western portion of the Transport Rule region, where annual mean $PM_{2.5}$ concentrations are below 7.5 µg /m3, there are benefits of the rule, although the relative magnitude of those benefits compared to benefits in the majority of the areas covered by the Transport Rule is small. In these areas there is lower confidence in the magnitude of the benefits associated with reductions in long-term $PM_{2.5}$. However, in these same areas, there may be additional benefits associated with short term elevated levels of PM, and there is relatively greater confidence in those benefits. In addition, we note that prior to the implementation of the Transport Rule, 85% of the population live in areas where $PM_{2.5}$ levels are projected to be above the lowest measured levels of the Pope study. Taken together, this information increases our confidence in the estimated mortality reductions for this rule.

While the LML of each study is important to consider when characterizing and interpreting the overall level PM-related benefits, as discussed earlier in this chapter, EPA believes that both cohort-based mortality estimates are suitable for use in air pollution health impact analyses. When estimating PM mortality impacts using risk coefficients drawn from the Laden et al. analysis of the Harvard Six Cities and the Pope et al. analysis of the

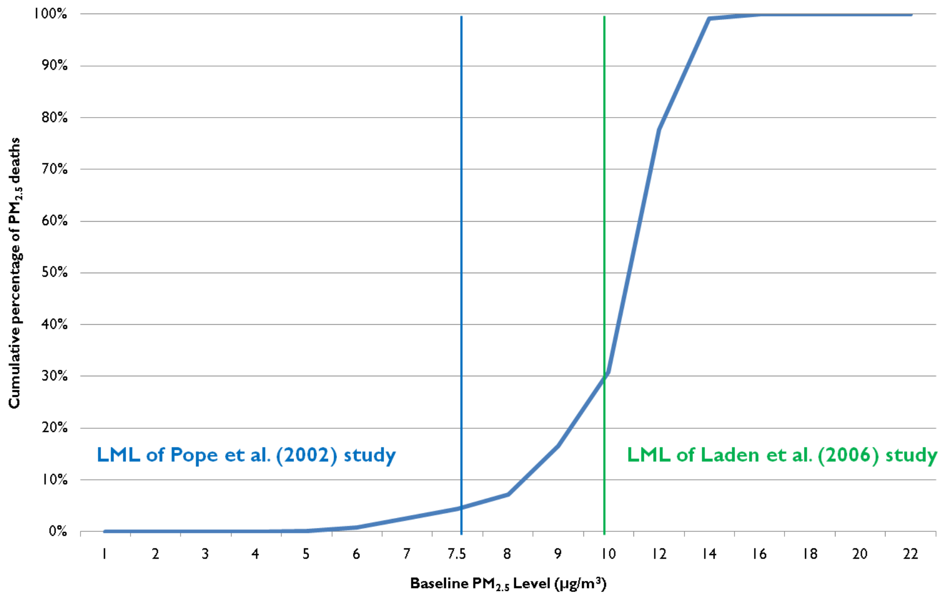
American Cancer Society cohorts there are innumerable other attributes that may affect the size of the reported risk estimates—including differences in population demographics, the size of the cohort, activity patterns and particle composition among others. The LML assessment presented here provides a limited representation of one key difference between the two studies.

Figure 5-18: Estimated $PM_{2.5}$- related premature mortalities avoided according to epidemiology or expert-derived PM mortality risk estimate[A]



[A] Column total equals sum of $PM_{2.5}$-related mortality and morbidity benefits and ozone-related morbidity and mortality benefits using the Bell et al. (2004) mortality estimate.

Figure 5-19: Distribution of $PM_{2.5}$-related mortality impacts by baseline $PM_{2.5}$ levels, $PM_{2.5}$ epidemiology study and lowest measured level (LML) of each study

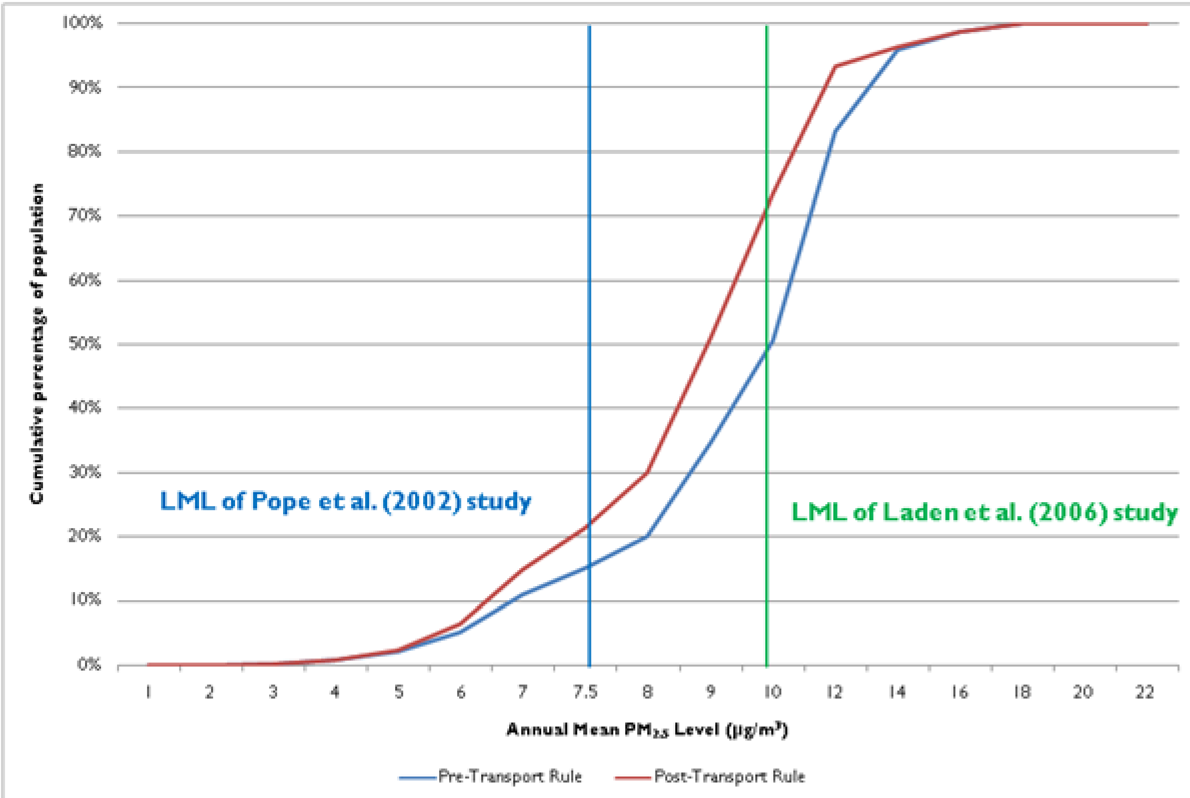


Of the deaths avoided:

96% occur among populations exposed to PM levels at or above the LML of the Pope et al. (2002) study

69% occur among populations exposed to PM levels at or above the LML of the Laden et al. (2006) study

Figure 5-20: Cumulative percentage of adult population at annual mean $PM_{2.5}$ levels (pre- and post-2014 Transport Rule)



5.8 Discussion

This analysis demonstrates the significant health and welfare benefits of the Transport Rule. We estimate that by 2014 the rule will have reduced the number of $PM_{2.5}$ and ozone-related premature mortalities by between 13,000 and 34,000, produce substantial non-mortality benefits and significantly improve visibility in Class 1 areas. This rule promises to yield significant welfare impacts as well, though the quantification of those endpoints in this RIA is incomplete. These significant health and welfare benefits suggest the important role that pollution from the EGU sector plays in the public health impacts of air pollution.

Inherent in any complex RIA such as this one are multiple sources of uncertainty. Some of these we characterized through our quantification of statistical error in the concentration response relationships and our use of the expert elicitation-derived PM mortality functions. Others, including the projection of atmospheric conditions and source-level emissions, the projection of baseline morbidity rates, incomes and technological development are unquantified. When evaluated within the context of these uncertainties, the health impact and monetized benefits estimates in this RIA can provide useful information regarding the public health impacts attributable to EGUs.

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CHAPTER 6

ELECTRIC POWER SECTOR PROFILE

This chapter discusses important aspects of the power sector that relate to the Transport Rule, including the types of power-sector sources affected by the Transport Rule, and provides background on the power sector and electric generating units (EGUs). In addition, this chapter provides some historical background on EPA regulation of and future projections for the power sector.

6.1 Power Sector Overview

The production and delivery of electricity to customers consists of three distinct segments: generation, transmission, and distribution.

6.1.1 Generation

Electricity generation is the first process in the delivery of electricity to consumers. Most of the existing capacity for generating electricity involves creating heat to rotate turbines which, in turn, create electricity. The power sector consists of over 17,000 generating units, comprising fossil-fuel-fired units, nuclear units, and hydroelectric and other renewable sources dispersed throughout the country (see Table 6-1).

Table 6-1. Existing Electricity Generating Capacity by Energy Source, 2009

Energy Source	Number of Generators	Generator Nameplate Capacity (MW)	Generator Net Summer Capacity (MW)
Coal	1,436	338,723	314,294
Petroleum	3,757	63,254	56,781
Natural Gas	5,470	459,803	401,272
Other Gases	98	2,218	1,932
Nuclear	104	106,618	101,004
Hydroelectric Conventional	4,005	77,910	78,518
Wind	620	34,683	34,296
Solar Thermal and Photovoltaic	110	640	619
Wood and Wood Derived Fuels	353	7,829	6,939
Geothermal	222	3,421	2,382
Other Biomass	1,502	5,007	4,317
Pumped Storage	151	20,538	22,160
Other	48	1,042	888
Total	17,876	1,121,686	1,025,400

Source: EIA Electric Power Annual 2009, Table 1.2

These electric generating sources provide electricity for commercial, industrial, and residential uses, each of which consumes roughly a quarter to a third of the total electricity produced (see Table 6-2). Some of these uses are highly variable, such as heating and air conditioning in residential and commercial buildings, while others are relatively constant, such as industrial processes that operate 24 hours a day.

Table 6-2. Total U.S. Electric Power Industry Retail Sales in 2009 (Billion kWh)

		Sales/Direct Use (Billion kWh)	Share of Total End Use
Retail Sales	Residential	1,364	37%
	Commercial	1,307	35%
	Industrial	917	25%
	Transportation	8	0.2%
Direct Use		127	3%
Total End Use		**3,724**	**100%**

Source: EIA Electric Power Annual 2009, Table 7.2

In 2009, electric generating sources produced 3,950 billion kWh to meet electricity demand. Roughly 70 percent of this electricity was produced through the combustion of fossil fuels, primarily coal and natural gas, with coal accounting for almost half of the total (see Table 6-3).

Table 6-3. Electricity Net Generation in 2009 (Billion kWh)

	Net Generation (Billion kWh)	**Fuel Source Share**
Coal	1,756	44.5%
Petroleum	39	1.0%
Natural Gas	921	23.3%
Other Gases	11	0.3%
Nuclear	799	20.2%
Hydroelectric	273	6.9%
Other	151	3.8%
Total	**3,950**	100%

Source: EIA Electric Power Annual 2009, Table 1.1
Note: Retail sales and net generation are not equal because net generation includes net exported electricity and loss of electricity that occurs through transmission and distribution.

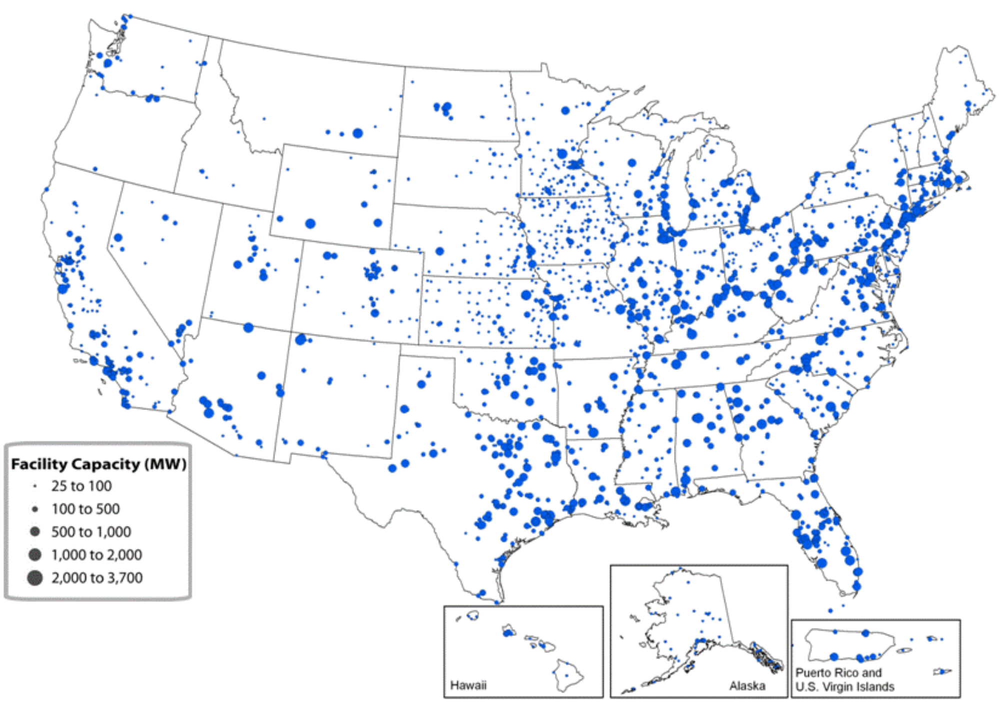
Coal-fired generating units typically supply "base-load" electricity, the portion of electricity loads which are continually present, and typically operate throughout the day. Along with nuclear generation, these coal units meet the part of demand that is relatively constant. Although much of the coal fleet operates as base load, there can be notable differences across various facilities (see Table 6-4). For example, coal-fired units less than 100 MW in size comprise 37 percent of the total number of coal-fired units, but only 6 percent of total coal-fired capacity. Gas-fired generation is better able to vary output and is the primary option used to meet the variable portion of the electricity load and typically supplies "peak" power, when there is increased demand for electricity (for example, when businesses operate throughout the day or when people return home from work and run appliances and heating/air-conditioning), versus late at night or very early in the morning, when demand for electricity is reduced.

Table 6-4. Coal Steam Electricity Generating Units, by Size, Age, Capacity, and Efficiency (Heat Rate)

Unit Size Grouping (MW)			No. Units	% of All Units	Avg. Age	Avg. Net Summer Capacity (MW)	Total Net Summer Capacity (MW)	% Total Capacity	Avg. Heat Rate (Btu/kWh)
0	*to*	25	193	15%	45	15	2,849	1%	11,154
>25	*to*	49	108	9%	42	38	4,081	1%	11,722
50	*to*	99	162	13%	47	75	12,132	4%	11,328
100	*to*	149	269	21%	49	141	38,051	12%	10,641
150	*to*	249	81	6%	43	224	18,184	6%	10,303
250	*and up*		453	36%	34	532	241,184	76%	10,193
Totals			1,266				316,480		

Source: National Electric Energy Data System (NEEDS) v.4.10
Notes: A lower heat rate indicates a higher level of efficiency. Table is limited to coal-steam units online in 2010 or earlier, and excludes those units with planned retirements.

Figure 6-1. Fossil Fuel-Fired Electricity Generating Facilities, by Size



Notes/Source: National Electric Energy Data System (NEEDS 4.10) (EPA, December 2010). This map displays facilities in the NEEDS 4.10 IPM frame. NEEDS reflects available capacity on-line by the end of 2011; this includes planned new builds and planned retirements. In areas with a dense concentration of facilities, some facilities may be obscured.

6.1.2 Transmission

Transmission is the term used to describe the movement of electricity over a network of high voltage lines, from electric generators to substations where power is stepped down for local distribution. In the US and Canada, there are three separate interconnected networks of high voltage transmission lines[51], each operating at a common frequency. Within each of these transmission networks, there are multiple areas where the operation of power plants is monitored and controlled to ensure that electricity generation and load are kept in balance. In some areas, the operation of the transmission system is under the control of a single regional operator; in others, individual utilities coordinate the operations of their generation, transmission, and distribution systems to balance their common generation and load needs.

6.1.3 Distribution

Distribution of electricity involves networks of lower voltage lines and substations that take the higher voltage power from the transmission system and step it down to lower voltage levels to match the needs of customers. The transmission and distribution system is the classic example of a natural monopoly, in part because it is not practical to have more than one set of lines running from the electricity generating sources to substations or from substations to residences and business.

Transmission has generally been developed by the larger vertically integrated utilities that typically operate generation and distribution networks. Distribution is handled by a large number of utilities that often purchase and sell electricity, but do not generate it. Transmission and distribution have been considered differently from generation in efforts to restructure the industry. As discussed below, electricity restructuring has focused primarily on efforts to reorganize the industry to encourage competition in the generation segment of the industry, including ensuring open access of generation to the transmission and distribution services needed to deliver power to consumers. In many state efforts, this has

[51] These three network interconnections are the western US and Canada, corresponding approximately to the area west of the Rocky Mountains; eastern US and Canada, not including most of Texas; and a third network operating in most of Texas. These are commonly referred to as the Western Interconnect Region, Eastern Interconnect Region, and ERCOT, respectively.

also included separating generation assets from transmission and distribution assets into distinct economic entities. Transmission and distribution remain price-regulated throughout the country based on the cost of service.

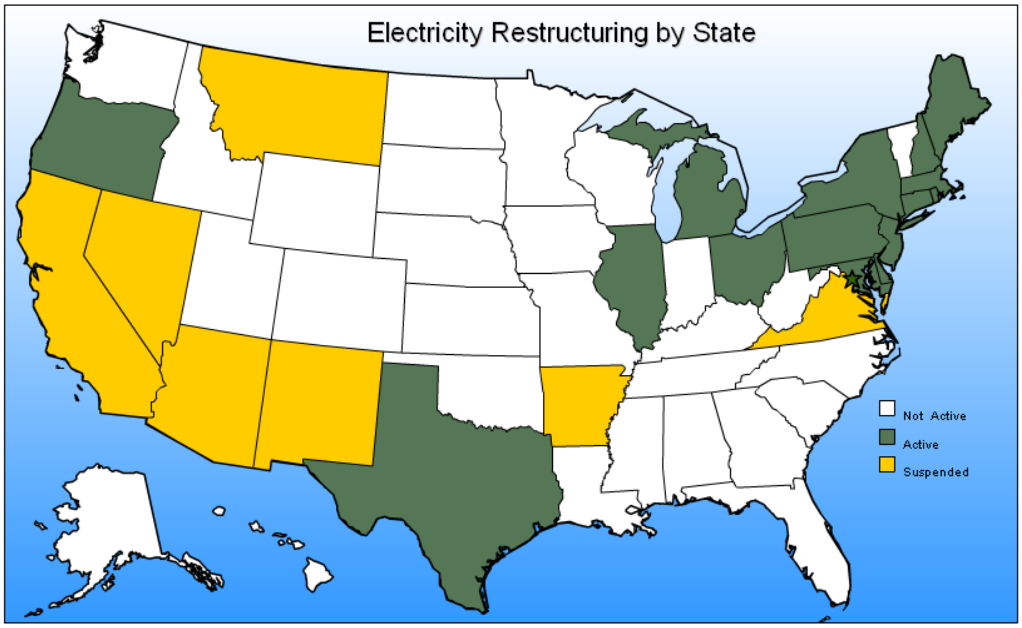
6.2 Deregulation and Restructuring

The process of restructuring and deregulation of wholesale and retail electric markets has changed the structure of the electric power industry. In addition to reorganizing asset management between companies, restructuring sought a functional unbundling of the generation, transmission, distribution, and ancillary services the power sector has historically provided, with the aim of enhancing competition in the generation segment of the industry.

Beginning in the 1970s, government policy shifted against traditional regulatory approaches and in favor of deregulation for many important industries, including transportation (notably commercial airlines), communications, and energy, which were all thought to be natural monopolies (prior to 1970) that warranted governmental control of pricing. However, deregulation efforts in the power sector were most active during the 1990s. Some of the primary drivers for deregulation of electric power included the desire for more efficient investment choices, the possibility of lower electric rates, reduced costs of combustion turbine technology that opened the door for more companies to sell power, and complexity of monitoring utilities' cost of service and establishing cost-based rates for various customer classes (see Figure 6-1).

The pace of restructuring in the electric power industry slowed significantly in response to market volatility and financial turmoil associated with bankruptcy filings of key energy companies in California. By the end of 2001, restructuring had either been delayed or suspended in eight states that previously enacted legislation or issued regulatory orders for its implementation (shown as "Suspended" in Figure 6-2 below). Another 18 other states that had seriously explored the possibility of deregulation in 2000 reported no legislative or regulatory activity in 2001 (DOE, EIA, 2003a) ("Not Active" in Figure 6-2 below). Currently, there are 15 states where price deregulation of generation (restructuring) has occurred ("Active" in Figure 6-2 below). Eight of these states are in the Transport Rule region. The effort is more or less at a standstill; there have been no recent proposals to the Federal Energy Regulatory Commission (FERC) for actions aimed at wider restructuring, and no additional states have begun retail deregulation activity

Figure 6-2. Status of State Electricity Industry Restructuring Activities

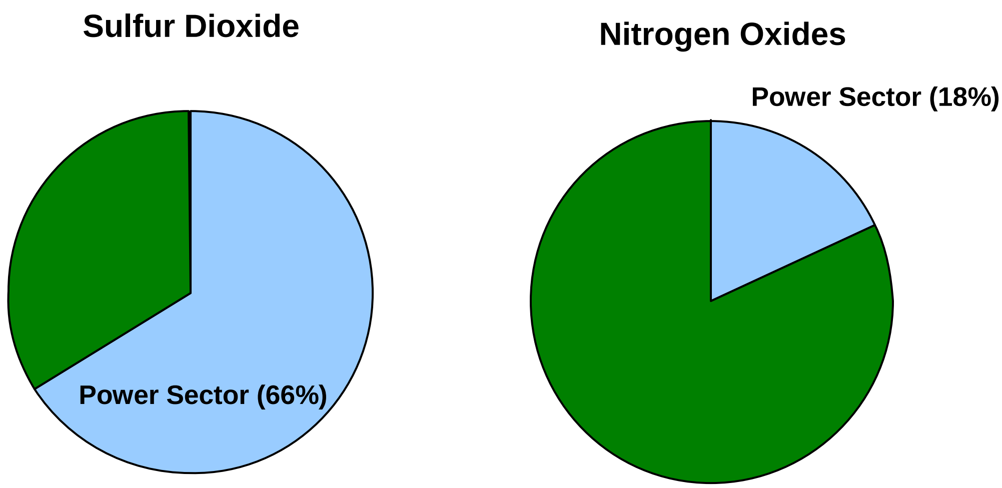


Source: EIA http://www.eia.doe.gov/cneaf/electricity/page/restructuring/restructure_elect.html (September, 2010).

6.3 Pollution and EPA Regulation of Emissions

The burning of fossil fuels, which generates about 70 percent of our electricity nationwide, results in air emissions of SO_2 and NO_X, important precursors in the formation of fine particles and ozone (NO_X only). The power sector is a major contributor of both these pollutants, and reductions of SO_2 and NO_X emissions are critical to EPA's efforts to bring about attainment with the fine particle and ozone NAAQS through programs like the Transport Rule. In 2008, the power sector accounted for 66 percent of total nationwide SO_2 emissions and 18 percent of total nationwide NO_X emissions (see Figure 6-3).

Figure 6-3. Emissions of SO_2 and NO_X from the Power Sector (2008)



Source: EPA http://www.epa.gov/ttn/chief/trends/

Different types of fossil fuel-fired units vary widely in their air emissions levels for SO_2 and NO_X, particularly when uncontrolled. For coal-fired units, NO_X emissions rates can vary from under 0.05 lbs/mmBtu (for a unit with selective catalytic reduction (SCR) for NO_X removal) to over 1 lb/mmBtu for an uncontrolled cyclone boiler. NO_X emissions from coal-fired power plants are formed during combustion and are a result of both nitrogen in coal and nitrogen in the air. SO_2 emissions rates can vary from under 0.1 lbs/mmBtu (for some units with flue gas desulfurization (FGD) for SO_2 removal) to over 5 lbs/mmBtu for units burning higher sulfur coal without any pollution controls. For an uncontrolled coal plant, SO_2 emissions are directly related to the amount of sulfur in the coal.

Oil- and gas-fired units also have a wide range of NO_X emissions depending on both the plant type and the controls installed. Gas-fired units with SCR can have emissions rates under 0.01 lbs/mmBtu, while completely uncontrolled units can have emissions rates in excess of 0.5 lbs/mmBtu. Gas-fired units have very little SO_2 emissions. NO_X emissions rates on oil-fired units can range from under 0.1 lbs/mmBtu (for units with new combustion controls) to over 0.6 lbs/mmBtu for units without combustion controls. SO_2 emissions for oil-fired units can range from under 0.1 lbs/mmBtu for units burning low sulfur distillate oil to over 2 lbs/mmBtu for units burning high sulfur residual oil.

6.4 Pollution Control Technologies

There are three options for reducing SO_2 emissions from coal-burning power plants. Units may switch from higher to lower sulfur coal, blend higher sulfur coal with lower sulfur coal, or use post-combustion controls, such as FGD (commonly referred to as scrubbers) or Dry Sorbent Injection (DSI). According to data submitted to EPA for compliance with the Title IV Acid Rain Program, the SO_2 emissions rates for coal-fired units without controls varied from under 0.4 lbs/mmBtu to over 5 lbs/mmBtu depending on the type of coal combusted. With controls, rates range from as low as 0.03 lbs/mmBtu to close to 1 lb/mmBtu.

It is generally easier to switch to a coal within the same rank (e.g., bituminous or sub-bituminous) because these coals will have similar heat contents and other characteristics. Switching completely to sub-bituminous coal (which typically has lower sulfur content) from bituminous coal is likely to require some modifications to the unit. Limited blending of sub-bituminous coal with bituminous coal can often be done with fewer modifications.

The two most commonly used scrubber types include wet scrubbers and spray dryers, also known as dry scrubbers. Wet scrubbers can use a variety of sorbents to capture SO_2, including limestone and magnesium-enhanced lime. The choice of sorbent can affect the performance, size, and capital and operating costs of the scrubber. New wet scrubbers typically achieve at least 96 percent SO_2 removal. Spray dryers use lime-based slurry and can achieve 92 percent removal.

An alternative to wet and dry scrubber technology is dry sorbent injection (DSI), which injects an alkaline powdered material (post combustion) to react with SO_2 and other acid gasses. The reacted product is removed by particulate matter (PM) control device. DSI technology is most efficient with a baghouse present downstream but can function with an electrostatic precipitator (ESP) downstream as well. Under these circumstances, the ESP requires more reagent per molecule of acid gas removed as compared to a similar operation with a baghouse. Finally, DSI may employ a multitude of sorbents (Trona,[52] sodium carbonate, calcium carbonate – and their bicarbonate counterparts) for a more tailored approach to reduce emissions based on the source, cost, and unit and fuel characteristics.

52 Trona refers to the chemical compound sodium sesquicarbonate.

One method of reducing NO_X emissions is through the use of combustion controls (such as low NO_X burners and over-fire air). Combustion controls adjust the coal combustion conditions to those where less formation of NO_X occurs. Post-combustion controls remove the NO_X after it has been formed. The most common post-combustion control is SCR. In SCR systems ammonia (NH_3) is injected, which combines with the NO_X in the flue gas, to form nitrogen and water and uses a catalyst to enhance the reaction. These systems can reduce NO_X by 90 percent and achieve emissions rates of around 0.06 lbs/mmBtu. Another post-combustion control is Selective Non-catalytic Reduction (SNCR). In this technology NO_X also is removed by injecting ammonia, but no catalyst is used. SNCR systems can reduce NO_X by up to 40 percent.

Some of the same control options available to coal-fired units are also applicable to units fueled by oil or gas. Combustion controls, SCR, and SNCR can also be applied to oil- and gas-fired boilers for NO_X control. Combustion controls and SCR are also routinely used for NO_X control on gas turbines.

For more detail on the cost and performance assumptions of pollution controls, see the documentation for the Integrated Planning Model (IPM), a dynamic linear programming model that EPA uses to examine air pollution control policies for SO_2 and NO_X throughout the contiguous United States for the entire power system. Documentation for IPM can be found at www.epa.gov/airmarkets/epa-ipm.

6.5 Air Regulation of the Power Sector

At the federal level, efforts to reduce emissions of SO_2 have been occurring since 1970. Policy makers have recognized the need to address these harmful emissions, and incremental steps have been taken to ensure that the country meets air quality standards. The Transport Rule is the next step towards realizing attainment of the national standards for $PM_{2.5}$ and ozone.

Even before widespread regulation of SO_2 and NO_X for the power sector, total suspended particulate matter (TSP) was a related target of state and federal action. Because larger particulates are visible as dark smoke from smokestacks, most states had regulations by 1970 limiting the opacity of emissions. Requirements for taller smokestacks also mitigated local impacts of TSP. Notably, such regulations effectively addressed large-diameter, filterable particulate matter rather than condensable particulate matter (such as $PM_{2.5}$) associated with SO_2 and NO_X emissions, which are not visible at the smokestack and have impacts far from their sources.

Federal regulation of SO_2 and NO_X emissions at power plants began with the 1970 Clean Air Act. The Act required the Agency to develop New Source Performance Standards (NSPS) for a number of source categories including coal-fired power plants. The first NSPS for power plants (subpart D) required new units to limit SO_2 emissions either by using scrubbers or by using low sulfur coal. NO_X was required to be limited through the use of low NO_X burners. A new NSPS (subpart Da), promulgated in 1978, tightened the standards for SO_2, requiring scrubbers on all new units.

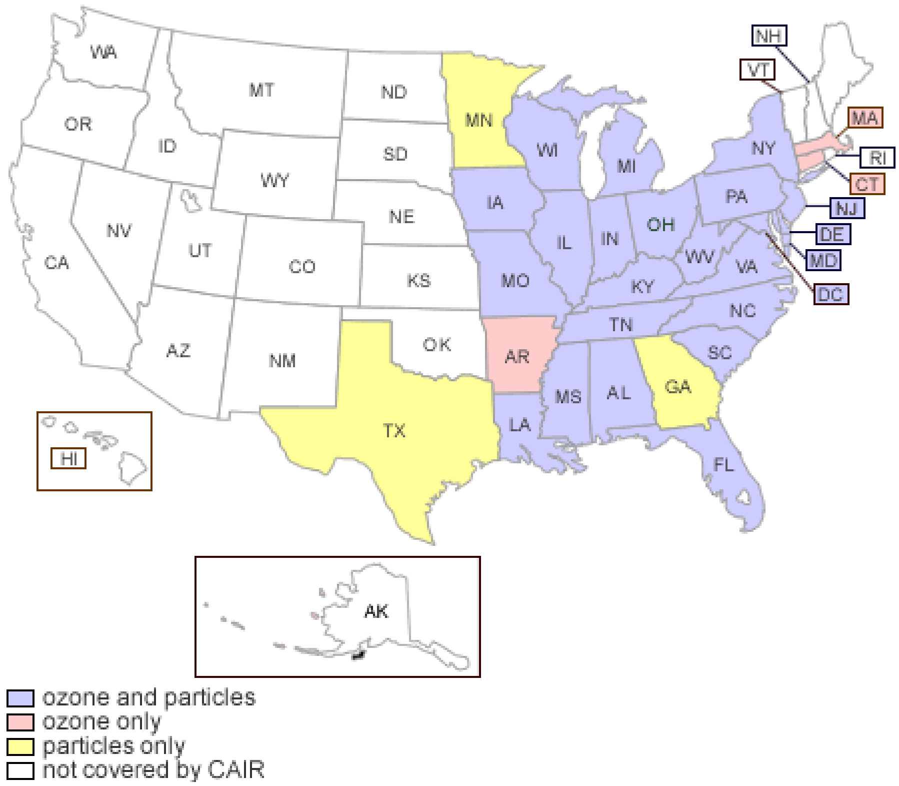
The 1990 Clean Air Act Amendments (CAAA) placed a number of new requirements on power plants. The Acid Rain Program, established under Title IV of the 1990 CAAA, requires major reductions of SO_2 and NO_X emissions. The SO_2 program sets a permanent cap on the total amount of SO_2 that can be emitted by electric power plants in the contiguous United States at about one-half of the amount of SO_2 these sources emitted in 1980. Using a market-based cap and trade mechanism allows flexibility for individual combustion units to select their own methods of compliance with the SO_2 reduction requirements. The program uses a more traditional approach to NO_X emissions limitations for certain coal-fired electric utility boilers, with the objective of achieving a 2 million ton reduction from projected NO_X emission levels that would have been emitted in 2000 without implementation of Title IV.

The Acid Rain Program comprises two phases for SO_2 and NO_X. Phase I applied primarily to the largest coal-fired electric generating sources from 1995 through 1999 for SO_2 and from 1996 through 1999 for NO_X. Phase II for both pollutants began in 2000. For SO_2, it applies to thousands of combustion units generating electricity nationwide; for NO_X it generally applies to affected units that burned coal during 1990 through 1995. The Acid Rain Program has led to the installation of a number of scrubbers on existing coal-fired units as well as significant fuel switching to lower sulfur coals. Under the NO_X provisions of Title IV, most existing coal-fired units installed low NO_X burners.

The CAAA also placed much greater emphasis on control of NO_X to reduce ozone nonattainment. This led to the formation of several regional NO_X trading programs as well as intrastate NO_X trading programs in states such as Texas. The northeastern states of the Ozone Transport Commission (OTC) required existing sources to meet Reasonably Available Control Technology (RACT) limits on NO_X in 1995 and in 1999 began an ozone-season cap and trade program to achieve deeper reductions. In 1998, EPA promulgated regulations (the NO_X SIP Call) that required 21 states in the eastern United States and the District of Columbia to reduce NO_X emissions that contributed to nonattainment in downwind states using the cap and trade approach. This program began in May of 2003 and has resulted in the installation of significant amounts of selective catalytic reduction.

The Clean Air Interstate Rule (CAIR) built on EPA's efforts in the NO_X SIP call to address specifically interstate pollution transport for ozone, and was EPA's first attempt to address interstate pollution transport for $PM_{2.5}$. It required significant reductions in emissions of SO_2 and NO_X in 28 states and the District of Columbia (see Figure 6-4 below). EGUs were found to be a major source of the SO_2 and NO_X emissions which contributed to fine particle concentrations and ozone problems downwind. Although the D.C. Circuit remanded the rule to EPA in 2008, it did so without vacatur, allowing the rule to remain in effect while EPA addresses the remand. Thus, CAIR is continuing to help states address ozone and $PM_{2.5}$ nonattainment and improve visibility by reducing transported precursors of SO_2 and NO_X through the implementation of three separate cap and trade compliance programs for annual NO_X, ozone season NO_X, and annual SO_2 emissions from power plants.

Figure 6-4. States Covered under the Clean Air Interstate Rule



Perhaps in anticipation of complying with CAIR, especially the more stringent second phase that was set to begin in 2015, several sources have recently been installing or planning to install advanced controls for SO_2 and NO_X to begin operating in the 2010 to 2015 timeframe. Many EPA New Source Review (NSR) settlements also require controls in those years, as do state rules in Georgia, Illinois, and Maryland. States like North Carolina, New York, Connecticut, Massachusetts, and Delaware have also moved to control these emissions to address nonattainment. Thus both federal and state efforts are continuing to bring about sizeable reductions in SO_2 and NO_X from the power sector. Section 6-1 below discusses how these recent activities are reflected in the Transport Rule base case. Details of the NSR settlements and state controls can be found in the IPM documentation referenced earlier.

6.6 Revenues, Expenses, and Prices

Due to lower retail electricity sales, total utility operating revenues declined in 2009 to $276 billion from a peak of almost $300 billion in 2008. However, operating expenses were appreciably lower and as a result, net income actually rose modestly compared to 2008 (see Table 6-5). Recent economic events have put downward pressure on electricity demand, thus dampening electricity prices (utility revenues), but have also reduced the price and cost of fossil fuels and other expenses. Electricity sales and revenues associated with the generation, transmission, and distribution of electricity are expected to rebound and increase modestly by 2015, where they are projected to be roughly $360 billion (see Table 6-6).

Table 6-5. Revenue and Expense Statistics for *Major U.S. Investor-Owned Electric Utilities* for 2009 ($millions)

	2008	2009
Utility Operating Revenues	**298,962**	**276,124**
Electric Utility	266,124	249,303
Other Utility	32,838	26,822
Utility Operating Expenses	**267,263**	**244,243**
Electric Utility	236,572	219,544
Operation	175,887	154,925
Production	140,974	118,816
Cost of Fuel	47,337	40,242
Purchased Power	84,724	67,630
Other	8,937	10,970
Transmission	6,950	6,742
Distribution	3,997	3,947
Customer Accounts	5,286	5,203
Customer Service	3,567	3,857
Sales	225	178
Administrative and General	14,718	15,991
Maintenance	14,192	14,092
Depreciation	19,049	20,095
Taxes and Other	26,202	29,081
Other Utility	30,692	24,698
Net Utility Operating Income	**31,699**	**31,881**

Source: EIA Electric Power Annual 2009, Table 8.1
Note: This data does not include information for public utilities.

Table 6-6. Projected Revenues by Service Category in 2015 for Public Power *and* Investor-Owned Utilities (billions)

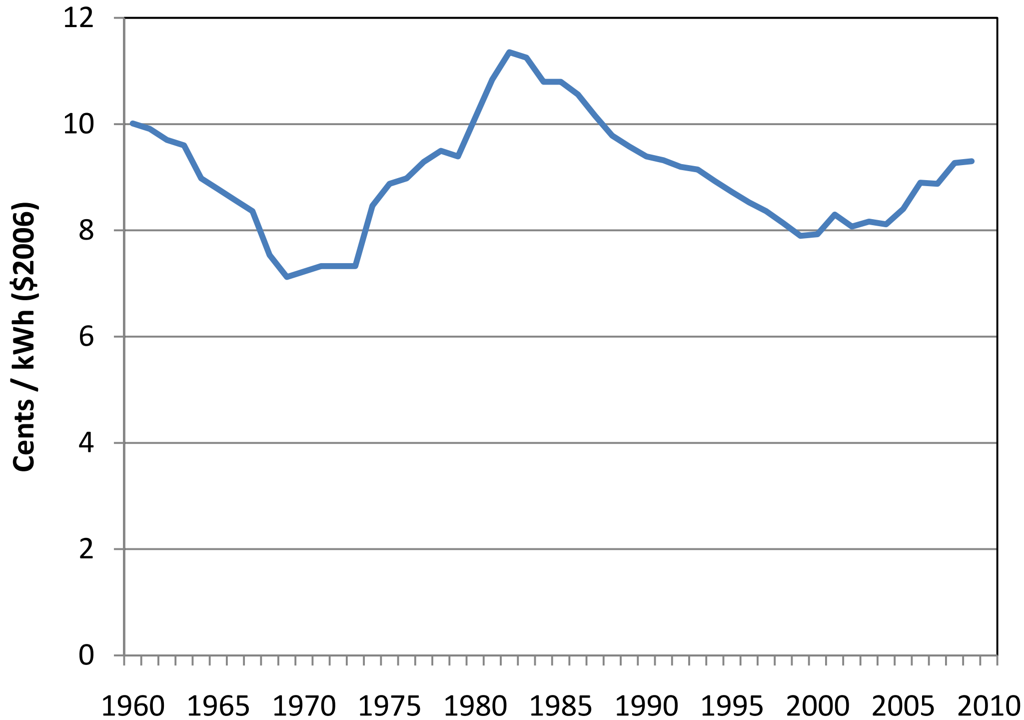
Generation	$195
Transmission	$36
Distribution	$129
	$360

Notes: Data is from EIA's AEO 2011, and is derived by taking either total electricity use (for generation) or sales (transmission and distribution) and multiplying by forecasted prices by service category from Table 8 (Electricity Supply, Disposition, Prices, and Emissions).

Based on EIA's Annual Energy Outlook 2011, Table 6-6 shows that in the base case, the power sector is expected to derive revenues of $360 billion in 2015. Table 6-5 shows that investor-owned utilities (IOUs) earned income of about 11.5% compared to total revenues in 2009. Assuming the same income ratio from IOUs (with no income kept by public power), and using the same proportion of power sales from public power as observed in 2009, EPA projects that the power sector will expend over $320 billion in 2015 alone to generate, transmit, and distribute electricity to end-use consumers.

Over the past 50 years, real retail electricity prices have ranged from around 7 cents per kWh in the early 1970s, to around 11 cents, reached in the early 1980s. Generally, retail electricity prices do not change rapidly and do not display the variability of other energy or commodity prices. Retail rate regulation has largely insulated consumers from the rising and falling wholesale electricity price signals whose variation on an hourly, daily, and seasonal basis is critical for driving lowest-cost matching of supply and demand. In fact, the real price of electricity today is lower than it was in the early 1960s and 1980s (see Figure 6-5).

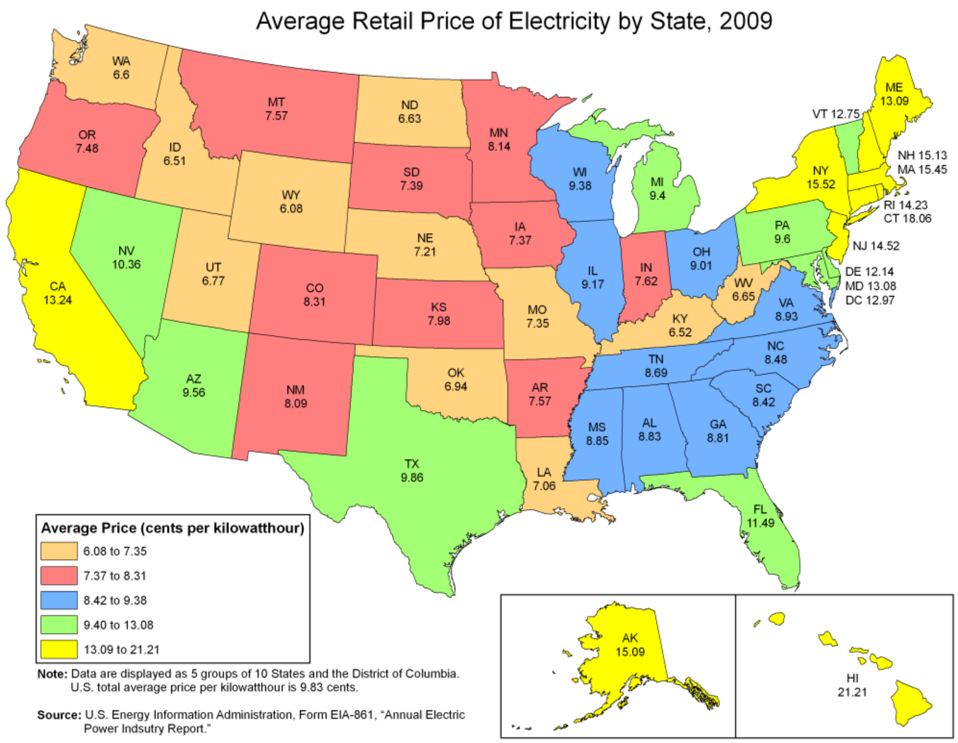
Figure 6-5. National Average Retail Electricity Price (1960 – 2009)



Source: EIA's Annual Energy Review 2009

On a state-by-state basis, retail electricity prices vary considerably. The Northeast and California have average retail prices that can be as much as double those of other states. (see Figure 6-6)

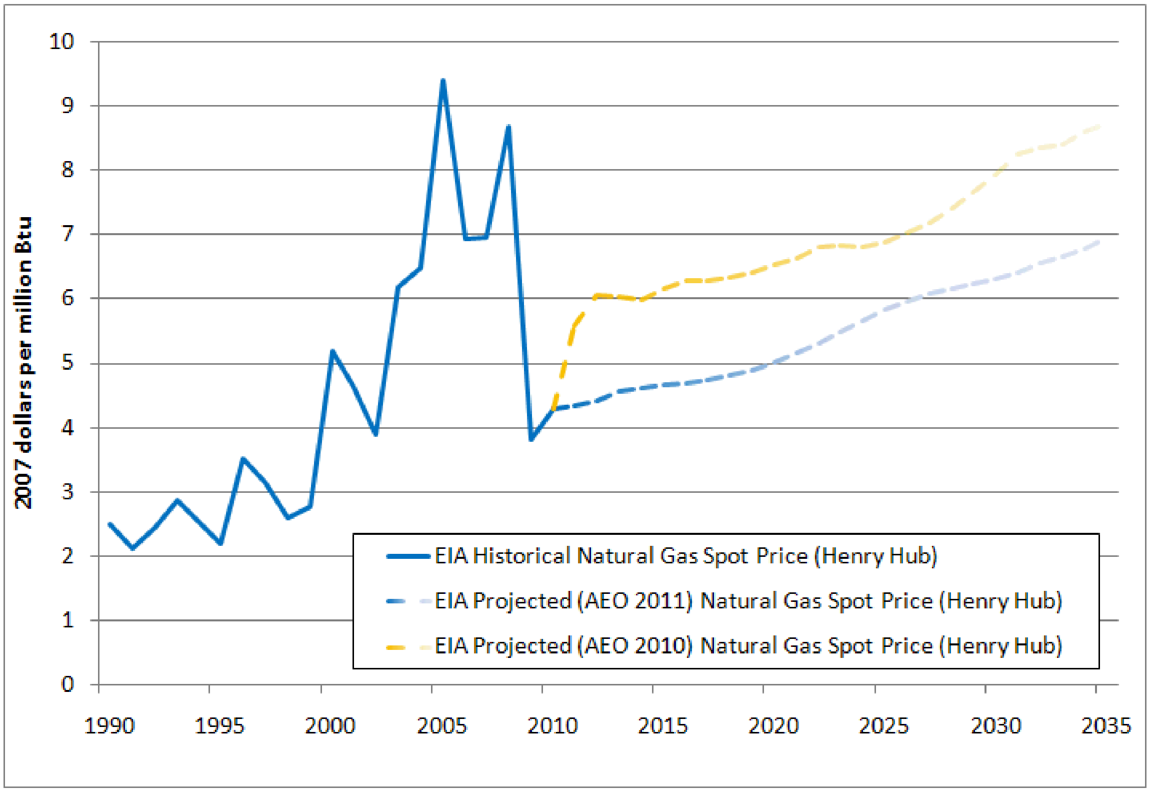
Figure 6-6 Average Retail Electricity Price by State (cents/kWh), 2009



6.6.1 Natural Gas Prices

The natural gas market in the United States has historically experienced significant price volatility from year to year, between seasons within a year, and can undergo major price swings during short-lived weather events (such as cold snaps leading to short-run spikes in heating demand). Over the last decade, gas prices (both Henry Hub prices and delivered prices to the power sector) have ranged from $3 per mmBtu to as high as $9 on an annual average basis (see Figure 6-7). During that time, the daily price of natural gas reached as high as $15/mmBtu. Recent forecasts of natural gas have also experienced considerable revision as new sources of gas have been discovered and come to market.

Figure 6-7. Natural Gas Spot Price, Annual Average (Henry Hub)

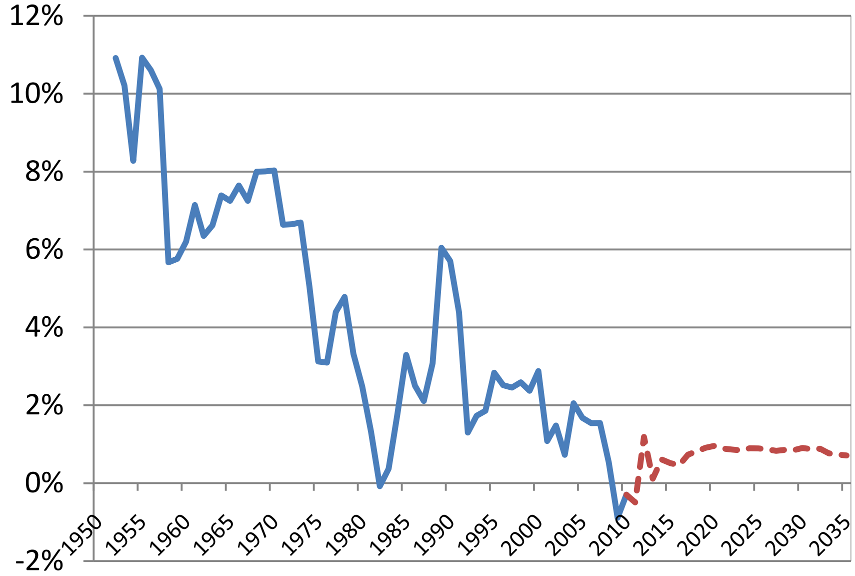


Source: EIA

6.7 Electricity Demand and Demand Response

Electricity performs a vital and high-value function in the economy. Historically, growth in electricity consumption has been closely aligned with economic growth. Overall, the U.S. economy has become more efficient over time, producing more output (GDP) per unit of energy input, with per capita energy use fairly constant over the past 30 years. The growth rate of electricity demand has also been in overall decline for the past sixty years (see Figure 6-8), with several key drivers that are worth noting. First, there has been a significant structural shift in the U.S. economy towards less energy-intensive sectors, like services. Second, companies have strong financial incentives to reduce energy expenditures. Third, companies are responding to the marketplace and continually develop and bring to market new technologies that reduce energy consumption. Fourth, complementary policies and energy efficiency standards at the state and Federal level have helped address market failures. These broader changes have altered the outlook for future electricity growth (see Figure 6-8).

Figure 6-8. Electricity Growth Rate (3 Year Rolling Average) and Projections from the Annual Energy Outlook 2011



Source: EIA Annual Energy Review 2009 and Annual Energy Outlook 2011

Energy efficiency initiatives have become more common, and investments in energy efficiency are projected to continue to increase for the next 5 to 10 years, driven in part by the growing number of states that have adopted energy efficiency resource standards. These investments, and other energy efficiency policies at both the state and federal level, create incentives to reduce energy consumption and peak load. According to EIA, demand-side management provided actual peak load reductions of 31.7 GW in 2009. For context, the current coal fleet is roughly 320 GW of capacity.

Demand for electricity, especially in the short run, is not very sensitive to changes in prices and is considered relatively price inelastic, although some demand reduction does occur in response to price. With that in mind, EPA modeling does not typically incorporate a "demand response" in its electric generation modeling (Chapter 8) to the increases in electricity prices typically projected for EPA rulemakings. Electricity demand is considered to be constant in EPA modeling applications and the reduction in production costs that would result from lower demand is not considered in the primary analytical scenario that is modeled. This leads to some overstatement in the private compliance costs that EPA estimates. Notably, the "compliance costs" are the changes in the electric power generation costs in the base case and pollution control options that are evaluated in Chapter 7. In simple terms, it is the resource costs of what the power industry will directly expend to comply with EPA's requirements.

6.8 Reference

EIA Electric Power Annual 2009. DOE/EIA-0348 (2009). Available at: http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.htm

CHAPTER 7

COST, ECONOMIC, AND ENERGY IMPACTS

This chapter reports the cost, economic, and energy impact analysis performed for the Transport Rule. EPA used the Integrated Planning Model (IPM), developed by ICF Consulting, to conduct its analysis. IPM is a dynamic linear programming model that can be used to examine air pollution control policies for SO_2 and NO_x (as well as other air pollutants) throughout the contiguous United States for the entire power system. Documentation for IPM can be found at http://www.epa.gov/airmarkets/progsregs/epa-ipm, and updates specific to Transport Rule modeling are available in the document titled: "Documentation Supplement for EPA Base Case v.4.10_FTransport – Updates for Final Transport Rule," available on the website and in the docket.

7.1 Background

Over the last decade, EPA has on several occasions used IPM to consider control options for reducing power-sector SO_2 and NO_x for regional transport. The best known example of one of these occasions is the Clean Air Interstate Rule (CAIR), the regulation that the current rule will replace. , The example of CAIR along with the analysis of the final Transport Rule below provide context and suggest alternative approaches to the Transport Rule (see Keohane 2009, 34–35 and Wagner 2009, 59).

Many EPA analyses with IPM have focused on legislative changes with national programs, such as EPA's IPM analyses of the Clean Air Planning Act (S.843 in 108th Congress), the Clean Power Act (S.150 in 109th Congress), the Clear Skies Act of 2005 (S.131 in 109th Congress), the Clear Skies Act of 2003 (S.485 in 108th Congress), and the Clear Skies Manager's Mark (of S.131). These analyses are available at EPA's website: (www.epa.gov/airmarkets/progsregs/cair/multi.html). EPA's IPM analysis for CAIR is another example of how the model has been used in regulatory analysis of SO_2 and NO_X control strategies, in this case dealing with a regulatory approach focusing on the eastern US: (www.epa.gov/airmarkets/progsregs/epa-ipm/cair/index.html). EPA also analyzed several multi-pollutant reduction scenarios in July 2009 at the request of Senator Tom Carper to illustrate the costs and benefits of multiple levels of SO_2 and NO_X control in the power sector.

In addition, EPA conducted extensive state-by-state analysis of control levels and the associated emissions projections related to upwind pollution that crosses state borders and impacts a downwind state's air quality monitors for the Transport Rule. More details on this analysis can be found in the Significant Contribution and State Emissions Budgets TSD.

As discussed in section 6.5, this rule comes during a period when many new SO_2 and NO_x controls are being installed. Many are needed for compliance with NSR settlements and state rules, while others may have been planned as a result of CAIR. Because CAIR remains in effect until it is replaced, emission reductions continue in the eastern US.

As discussed in section 2.4, the base case in this RIA assumes that CAIR is not in effect, but does take into account emissions reductions associated with the implementation of all federal rules, state rules and statutes, and other binding, enforceable commitments finalized by December 1, 2010, that are applicable the power industry and which govern the installation and operation of SO_2 and NO_x emissions controls in the timeframe covered in the analysis.

To address air quality problems, improve public health and the environment, and to respond to the Court decision in North Carolina v. EPA, the Agency is finalizing the Transport Rule. The Transport Rule requires annual SO_2 and NO_x reductions in 23 states, and also requires ozone season NO_x reductions in 20 States.[53] Many of the Transport Rule states are affected by both the annual SO_2 and NO_x reduction requirements and the ozone season NO_x requirements.

[53] EPA is issuing a supplemental proposal to request comment on requiring ozone-season NO_X reductions in six additional states under the Transport Rule (Iowa, Kansas, Michigan, Missouri, Oklahoma, and Wisconsin). Reductions that would be required by the supplemental proposal are included in the cost and impacts estimates described in this chapter, and therefore are accounted for in the benefits estimate.

The rule affects roughly 3,700 fossil-fuel-fired units with a nameplate capacity greater than 25 MW located at nearly 1,100 facilities. These sources accounted for roughly 82 percent of nationwide SO_2 emissions and 67 percent of nationwide NO_x emissions in 2010 (see Table 7-1).

Table 7-1. Annual Emissions of SO_2 and NO_x in 2010 and Percentage of Emissions in the Transport Rule Affected Region (tons)

	SO_2	NO_X
Transport Rule Annual NO_X and SO_2 States	4,251,996	1,424,228
Nationwide (Contiguous 48 States)	5,165,954	2,136,612
Emissions of Transport Rule States as Percentage of Nationwide Emissions	82%	67%

Source: EPA emissions data from all reporting units.
Note: Transport Rule annual NO_X and SO_2 states include Alabama, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

For SO_2 and annual NO_x, EPA modeled control requirements beginning in 2012 for the 23 eastern states shown in blue and green in Figure 7-1 below. In 16 of those states (shown in green), more stringent SO_2 requirements begin in 2014.[54] For ozone-season NO_x, separate ozone-season requirements were applied to the 26 states shown in green and yellow in Figure 7-1. Many of the Transport Rule states are affected by both the annual SO_2 and NO_x reduction requirements and the ozone-season (May–September) NO_x requirements. Table 7-2 show the emission budgets allotted to each state. For further discussion about the scope and requirements of the Transport Rule, see the Transport Rule preamble or Chapter 2 of this RIA.

[54] These 16 states include: Illinois, Indiana, Iowa, Kentucky, Maryland, Michigan, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin

As previously stated, the emissions, cost, air quality, and benefits analyses done for the Transport Rule are from a modeling scenario that requires annual SO_2 and NO_x reductions in 23 states and ozone season NO_x requirements in 26 states (See Figure 7-1). This modeling differs from the final Transport Rule because it includes ozone season NO_X requirements for six states (Iowa, Kansas, Michigan, Missouri, Oklahoma, and Wisconsin) that the final Transport Rule does not cover. (As discussed in the preamble to the final rule, EPA is issuing a supplemental proposal to request comment on the inclusion of these six states). Results presented in this chapter reflect inclusion of these six states in the Transport Rule.

Figure 7-1. Transport Rule Covered States

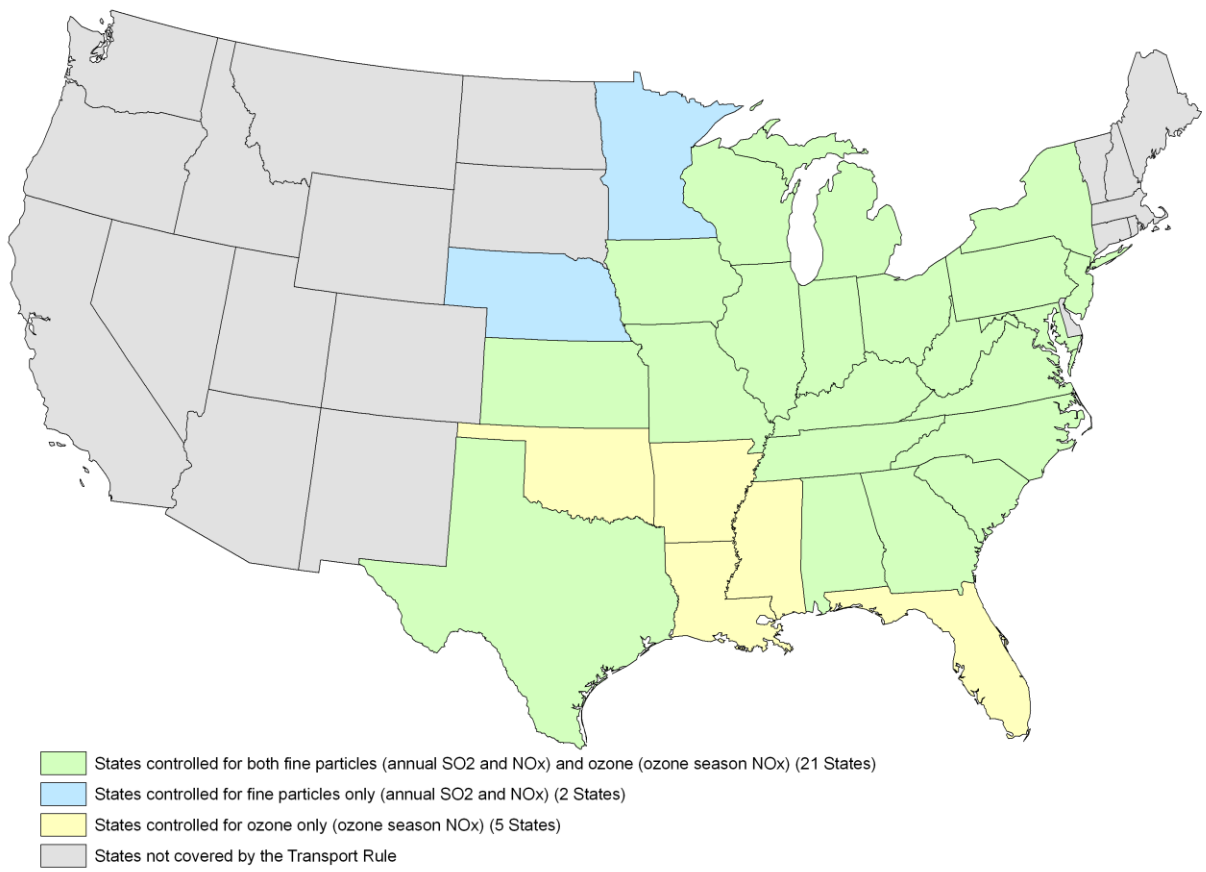


Table 7-2. Transport Rule Annual NO_x and SO_2 and NOx Ozone Season State Emission Budgets (tons)

	SO_2 Annual		NO_X Annual		NO_X Ozone Season	
	2012 and 2013	2014 and Later	2012 and 2013	2014 and Later	2012 and 2013	2014 and Later
Alabama	216,033	213,258	72,691	71,962	31,746	31,499
Arkansas	---	---	---	---	15,037	15,037
Florida	---	---	---	---	27,825	27,825
Georgia	158,527	95,231	62,010	40,540	27,944	18,279
Illinois	234,889	124,123	47,872	47,872	21,208	21,208
Indiana	285,424	161,111	109,726	108,424	46,876	46,175
Iowa	107,085	75,184	38,335	37,498	16,532*	16,207*
Kansas	41,528	41,528	30,714	25,560	13,536*	10,998*
Kentucky	232,662	106,284	85,086	77,238	36,167	32,674
Louisiana	---	---	---	---	13,432	13,432
Maryland	30,120	28,203	16,633	16,574	7,179	7,179
Michigan	229,303	143,995	60,193	57,812	25,752*	24,727*
Minnesota	41,981	41,981	29,572	29,572	---	---
Mississippi	---	---	---	---	10,160	10,160
Missouri	207,466	165,941	52,374	48,717	22,762*	21,073*
Nebraska	65,052	65,052	26,440	26,440	---	---
New Jersey	5,574	5,574	7,266	7,266	3,382	3,382

New York	27,325	18,585	17,543	17,543	8,331	8,331
North Carolina	136,881	57,620	50,587	41,553	22,168	18,455
Ohio	310,230	137,077	92,703	87,493	40,063	37,792
Oklahoma	---	---	---	---	21,835*	21,835*
Pennsylvania	278,651	112,021	119,986	119,194	52,201	51,912
South Carolina	88,620	88,620	32,498	32,498	13,909	13,909
Tennessee	148,150	58,833	35,703	19,337	14,908	8,016
Texas	243,954	243,954	133,595	133,595	63,043	63,043
Virginia	70,820	35,057	33,242	33,242	14,452	14,452
West Virginia	146,174	75,668	59,472	54,582	25,283	23,291
Wisconsin*	79,480	40,126	31,628	30,398	13,704	13,216
Total	3,301,008	2,128,264	609,435	574,107	1,245,869	1,164,910

*Note: as discussed in the preamble to the final rule, EPA is issuing a supplemental proposal to request comment on inclusion of these six states in the Ozone Season program.

Electricity demand is anticipated to grow by roughly 1 percent a year, and total electricity demand is projected to be 4,106 billion kWh by 2014. Table 7-3 shows current electricity generation alongside EPA's base case projections using EPA's IPM modeling. This rule relies on EIA's *Annual Energy Outlook for 2010*'s electric demand forecast for the US and employs a set of EPA assumptions regarding fuel supplies and the performance and cost of electric generation technologies as well as pollution controls. The base case assumption that CAIR is not in effect does have some modest influence on the fossil generation mix in this forecast, because CAIR had increased the costs of coal-fired generation relatively more than it had increased the costs to generation units that burned oil or natural gas.

Table 7-3. 2009 Electricity Net Generation and EPA Base Case Projections for 2012, 2014, 2020 and 2030 for the Contiguous 48 States (Billion kWh)

	Historical	Base Case			
	2009	2012	2014	2020	2030
Coal	1,754	1,958	2,017	2,037	2,071
Oil	29	0.09	0.10	0.14	0.19
Natural Gas	917	721	686	823	1,155
Nuclear	799	812	822	832	811
Hydroelectric	272	281	287	287	286
Non-hydro Renewables	143	233	250	288	328
Other	0	35	45	44	53
Total	**3,914**	**4,041**	**4,107**	**4,311**	**4,704**

Source: 2009 data from EIA Electric Power Annual 2009, Table 1.1 (adjusted to represent the Contiguous 48 States for consistency with projections, which are from the Integrated Planning Model run by EPA, 2011).

As noted above, IPM has been used for evaluating the economic and emission impacts of environmental policies for over a decade. The economic modeling presented in this chapter has been developed for specific analyses of the power sector. Thus, the model has been designed to reflect the industry as accurately as possible. As a result, EPA has used discount rates in IPM that are appropriate for the various types of investments and other costs that the power sector incurs (for example, the primary real discount rate is 5.5 % for pollution control retrofits). The discount rates used in IPM differ from discount rates used in other RIA analyses done for the Transport Rule, particularly the discount rates used in the benefits and macroeconomic analyses that are assumed to be social discount rates. (See Chapters 5 and 8 where social discount rates of 3% and 7% are used.) EPA uses the best available information from utilities, financial institutions, debt rating agencies, and government statistics as the basis for the discount rates used for power sector modeling in IPM. These discount rates have undergone review by the power sector and the Energy Information Administration.

More detail on IPM can be found in the model documentation, which provides additional information on the assumptions discussed here as well as all other assumptions and inputs to the model (http://www.epa.gov/airmarkets/progsregs/epa-ipm). Updates specific to Transport Rule modeling are also in the document titled: “Documentation

Supplement for EPA Base Case v.4.10_FTransport – Updates for Final Transport Rule."

7.2 Projected SO_2 and NO_x Emissions and Reductions

The Transport Rule achieves substantial emission reductions. EPA projects annual SO_2 emission reductions of 62 percent and annual NO_x emission reductions of 11 percent in the covered region by 2014 relative to the base case. Additionally, EPA projects ozone-season NO_x reductions of 11 percent in the Transport Rule region (see Table 7-4). There is also a small decrease in CO_2 emissions as a result of the Transport Rule.

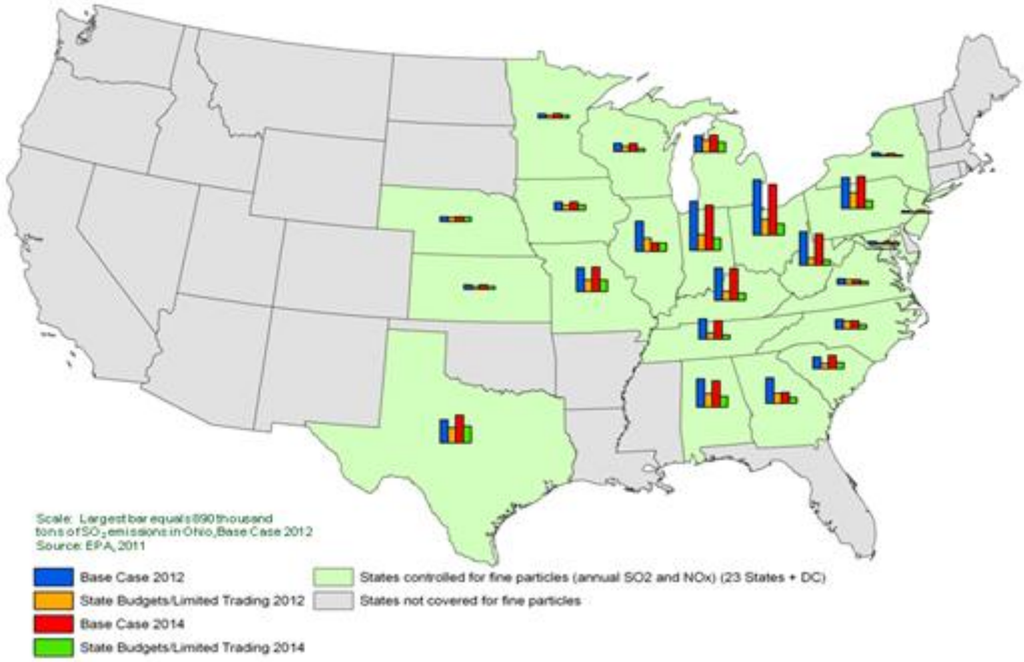
In Figure 7-2 below, the results of EPA modeling of the Transport Rule show that substantial SO_2 emission reductions occur in the Midwest and Mid-Atlantic regions of the country. Because banking of allowances is allowed to encourage early reductions, 2012 SO_2 reductions are greater overall than state budgets alone would require in that year. For many coal-fired electric generation units throughout the region it is economically advantageous to make extra emissions reductions in 2012 through fuel switching to have allowances to later use or sell in 2014 and beyond, when the Transport Rule becomes more stringent and when electric generators will also need to meet higher electric demand. Because of the banking provisions, the relative economics of making pollution reductions below the state assurance levels in 2012 versus making emissions reductions later favor doing more in 2012. Annual NO_x emissions reductions occur across the Transport Rule region (see Figure 7-3), and with the Transport Rule, ozone-season NO_x emission reductions are lower than they would have been with the NO_x SIP Call (base case) (see Figure 7-4).

Table 7-4. Projected Emissions of SO_2, NO_X, and CO_2 with the Base Case (No Further Controls) and with Transport Rule (Million Tons)

		2012				2014			
		Base	TR	Change	% Change	Base	TR	Change	% Change
SO_2 (Annual)	Contiguous 48 States	7.9	3.9	-3.9	-50%	7.2	3.4	-3.8	-53%
	TR States	7.0	3.0	-4.0	-57%	6.2	2.4	-3.9	-62%
NO_X (Annual)	Contiguous 48 States	2.1	2.0	-0.2	-7%	2.1	1.9	-0.2	-9%
	TR States	1.4	1.3	-0.1	-9%	1.4	1.2	-0.2	-11%
NO_X (Summer)	Contiguous 48 States	0.9	0.9	-0.1	-7%	0.9	0.8	-0.1	-9%
	TR States	0.7	0.6	-0.1	-9%	0.7	0.6	-0.1	-11%
CO_2 (Annual)	Contiguous 48 States	2,444	2,431	-12	-1%	2,482	2,454	-28	-1%
	TR States	1,769	1,749	-19	-1%	1,799	1,765	-24	-2%

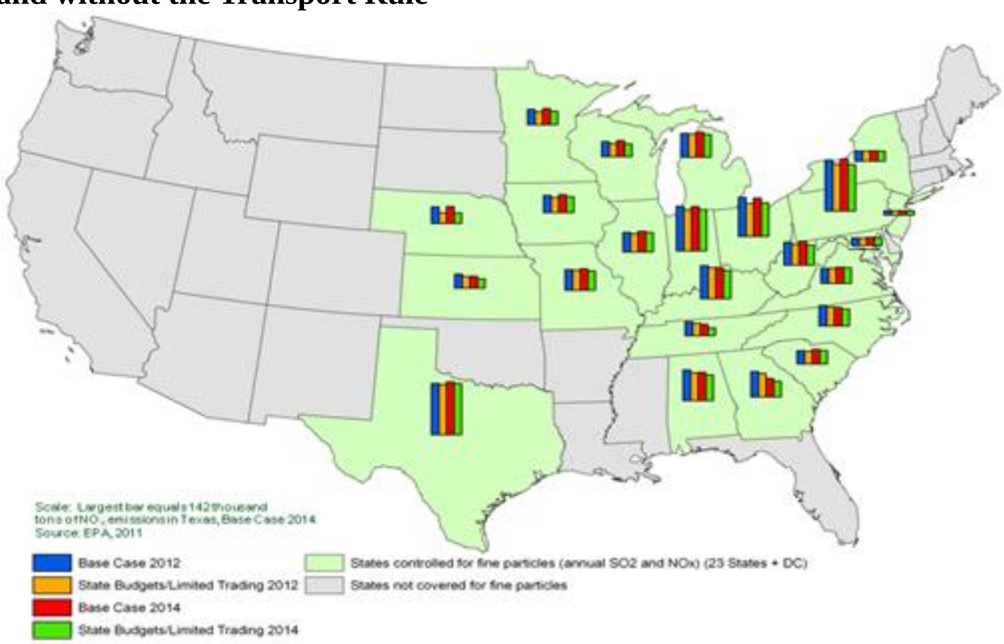
Note: Numbers may not add due to rounding. The emissions data presented here are EPA modeling results and the Transport Rule region includes states modeled for the annual SO_2 and NO_x requirements. "Summer" is from May 1–September 30, which is the ozone season. Base case includes Title IV Acid Rain Program, NO_x SIP Call, and state rules through December 1, 2010.
Source: Integrated Planning Model run by EPA, 2011.

Figure 7-2. SO_2 Emissions from the Power Sector in 2012 and 2014 with and without the Transport Rule



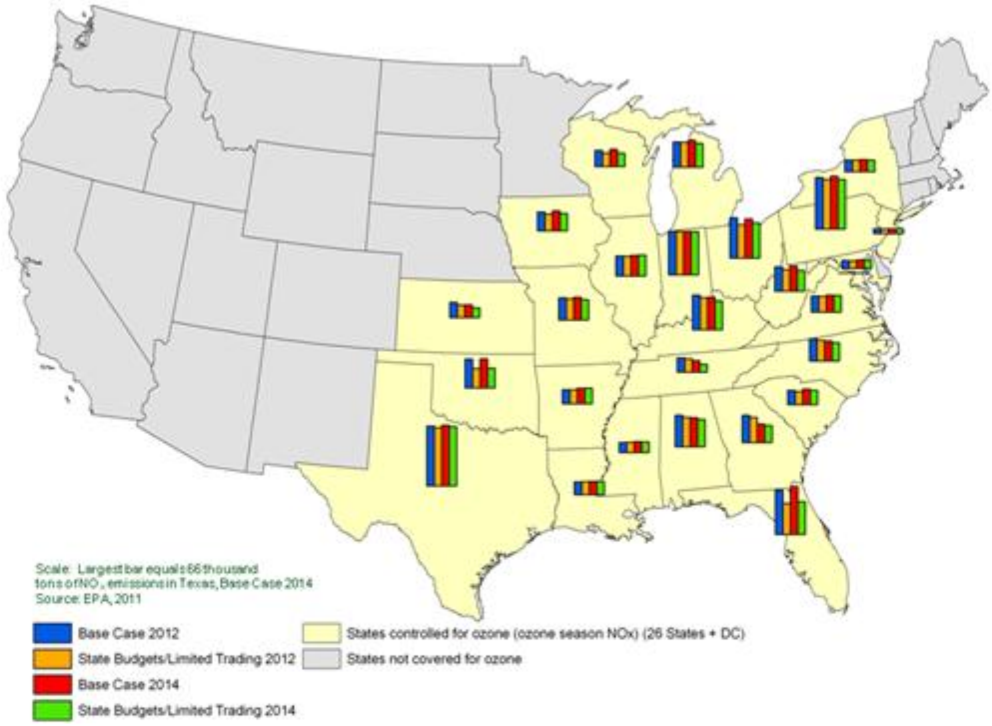
Source: EPA, IPM, 2011.

Figure 7-3. Annual NO_x Emissions from the Power Sector in 2012 and 2014 with and without the Transport Rule



Source: EPA, IPM, 2011.

Figure 7-4. Ozone-season NO_x Emissions from the Power Sector in 2012 and 2014 with and without Transport Rule



Source: EPA, IPM, 2011.

7.3 Overview of Costs and Other Impacts

As shown above in Figure 7-1, the Transport Rule directly affects 23 states in controlling pollution related to fine particles. For ozone, it also affects a distinct but overlapping group of 20[55] states. The states in one or both of these regions constitute most of the fossil-fuel-fired generation and capacity in the contiguous US, especially coal-fired (see Tables 7-5 and 7-6 below).

55 EPA is issuing a supplemental proposal to request comment on requiring ozone-season NO_X reductions in six additional states under the Transport Rule (Iowa, Kansas, Michigan, Missouri, Oklahoma, and Wisconsin).

Table 7-5. 2010 Fossil-fuel Generation Nationwide and in the Transport Region (Thousand Megawatthours)

	Contiguous US	Transport Rule Fine Particle Area	Transport Rule Ozone Area
Coal-fired	1,829,176	1,405,021	1,510,557
Oil-fired	13,680	5,955	12,080
Natural Gas-fired	894,598	409,534	633,636
Total	**3,954,846**	**2,598,207**	**2,989,910**

Source: EIA Electric Power Monthly with data for December 2010, Tables 1.6B, 1.7.B, 1.8.B, 1.10.B.

Table 7-6. Total Fossil-fuel Capacity Nationwide and in the Transport Region

	Contiguous US	Transport Rule Fine Particle Area	Transport Rule Ozone Area
Pulverized Coal	316	247	266
Combined Cycle	199	97	142
Other Oil/Gas	247	155	196
Total	**998**	**630**	**743**

Source: EPA's NEEDS v4.10.

While most impacts of the Transport Rule affect the covered states themselves, national impacts are important. Because the electric grid is connected irrespective of state boundaries, effects on electrical generation in one state have spillover effects in other states. Likewise, because the Transport Rule states have the vast majority of coal-fired generation, changes in their coal consumption and demand affect coal prices nationwide. In some cases, such as retail electricity prices and the operation of pollution controls, nationwide information would not be as relevant as regional totals. But for most of the following sections, nationwide projections provide a more complete picture of the Transport Rule's impacts.

7.4 Projected Compliance Costs

The power industry's "compliance costs" are the changes in electric power generation costs in the base case and alternative pollution control approaches that are examined in this chapter. In simple terms, these costs are the resource costs of what the power industry will directly expend to comply with EPA's requirements. This is not the "social cost" of the control approaches, which is separately explained and estimated in Chapter 8.

EPA projects that the annual incremental compliance costs of the Transport Rule are $1.4 billion in 2012 and $0.8 billion in 2014 (see Table 7-7 below). Another measure of this impact is the change in electricity prices (discussed in section 7.10). Costs generally are higher in 2012 than in 2014 because of reduced compliance flexibility in 2012, which is too soon for sources to retrofit new FGD and SCR that were not already planned.

Table 7-7. Annualized Compliance Cost of the Transport Rule

	2012	2014	2020
Annualized Compliance Cost (billions of 2007$)	$1.4	$0.8	$0.6

Note: Numbers rounded to the nearest hundred million for annualized cost.
Source: Integrated Planning Model run by EPA, 2011.

For context, the projected annualized compliance costs are a small fraction of the $320 billion in expenditures EPA projects that the power sector will make in 2015 alone to generate, transmit, and distribute electricity to end-use consumers. For more information, see Chapter 6.

7.5 Projected Approaches to Emissions Reductions

Fossil-fuel-fired electric generating units in the Transport Region are projected to achieve NO_x and SO_2 emissions reductions through a combination of compliance options. These actions include sustained operation of existing controls originally built for CAIR, additional pollution control installations at coal-fired generators, coal switching (including blending of coals), and increased dispatch of more efficient units and lower-emitting generation technologies (e.g., some reduction of coal-fired generation with an increase of generation from natural gas). In addition, there will be some affected sources that find it more economic to retire rather than invest in new pollution control equipment. These facilities are generally amongst the oldest, least efficient power plants and typically run infrequently.

In 2012, a small shift from coal- and oil-fired generation to greater use of natural gas lowers emissions a small amount (see Table 7-11). NO_x emissions reductions largely stem from year-round operation of selective catalytic reduction (SCR) controls that would otherwise operate only during the ozone season (see Table 7-10). Additionally, a modest amount of NO_x reduction stems from new low- NO_x burners installations on older coal-fired units in states that were not in the original CAIR program but are covered in the ozone program of this rule. The Transport Rule's 2012 SO_2 emissions reductions largely result from sustained operation of all existing FGDs (scrubbers) in states controlled for PM, including those scrubbers built originally for CAIR and which may not have reason to operatein the absence of the Transport Rule. Other 2012 SO_2 reductions are achieved by units choosing to burn lower-sulfur coals as the least-cost compliance approach. In 2014, the Transport Rule drives the sector to install 5.9 GW of new FGD and 3 GW of new dry sorbent injection (DSI), which allow for significant additional SO_2 reductions in the Group 1 states.

Table 7-8 below provides a profile of sulfur contents in alternative coal supplies that offer substantial SO_2 reduction opportunities by increased blending or fuel-switching to cleaner grades. The table shows the degree to which uncontrolled coal-fired generation switches from relatively dirtier coals to relatively cleaner coals in response to imposition of the Transport Rule.

Table 7-8. Percent of Generation without SO_2 Controls by Coal Sulfur Content, 2014

	Very Low (<0.8 lb/mmBtu)	Low (0.81-1.2 lbs/mmBtu)	Low-Medium (1.21-1.66 lbs/mmBtu)	High-Medium (1.67-3.34 lb/mmBtu)	High (>3.35 lb/mmBtu)
Base Case	27%	37%	8%	15%	13%
Transport Rule	59%	28%	7%	3%	2%

Source: Integrated Planning Model run by EPA, 2011.

Table 7-9 shows total coal use among both controlled (i.e., operating either FGD or DSI) and uncontrolled EGUs in the states subject to the SO_2 program. The Transport Rule is associated with only a slight reduction (3% in 2014) in total coal use compared to the base case. More importantly, the table reinforces that the rule drives increased overall use of cleaner bituminous and subbituminous coals, especially very low sulfur subbituminous. This trend appears even when, as in this table, coal use at controlled units and very small units are included.

Table 7-9. Coal Use by Sulfur Category in the $PM_{2.5}$ Transport Region for the Base Case and Transport Rule* (million short tons)

		Lignite	Subbituminous			Bituminous				Total
			High sulfur	Low sulfur	Very low sulfur	High sulfur	High-medium sulfur	Low-medium sulfur	Low sulfur	
2012	Base	30	13	145	156	91	211	83	3	732
	TR	25	2	77	255	83	195	74	12	723
2014	Base	37	13	145	154	102	216	71	9	747
	TR	32	2	108	202	88	202	73	18	724

*These coal usage results are for the 23 states covered by the rule in the trading program to reduce SO_2 emissions.
Source: Integrated Planning Model run by EPA, 2011.

EPA does not project additional SO_2 control retrofits in 2012. For SO_2, EPA believes that to meet the 2012/2013 state assurance levels, compliance strategies would at most involve: operation of existing controls year-round, operation of controls that are scheduled to become operational by 2012, switching to a lower sulfur coal, and/or a general optimization of dispatch. EPA projects incremental FGD installations of about 5.9 GW by 2014 (see Table 7-10). These FGD retrofits are primarily wet scrubbers. Additionally, approximately 3 GW of DSI is projected to be installed by 2014. EPA believes that the January 1, 2014 starting date is as expeditious as practicable for sources to install such controls, and that retrofits of this limited extent can be realized in the 30 month interim between signature and the start of 2014. For further discussion, see discussion in section VII.C.2 of the preamble.

Table 7-10. Newly-Constructed Advanced SO_2 Control Retrofits on Coal-fired Generation by Technology Built with the Base Case and with the Transport Rule (GW) in 2014

	Base Case	Transport Rule	Incremental Retrofits
Wet FGD	4.6	10.3	5.7
Dry FGD	3.6	3.8	0.2
DSI	6.8	9.8	3.0

Note: FGD (Flue Gas Desulphurization) and DSI (Dry Sorbent Injection) are advanced SO_2 controls. Source: Integrated Planning Model run by EPA, 2011.

In 2014, the Transport Rule is also projected to result in the operation of an additional 25 GW of flue gas desulfurization (scrubbers) for SO_2 control and the year-round operation of an additional 5 GW of selective catalytic reduction technology (SCR) for NO_x control on existing coal-fired generation capacity (see “Existing Controls Induced to Operate” in Table 7-11). These controls were largely built for compliance with CAIR and are thus assumed not to operate in the base case.

Table 7-11. Coal-fired Capacity Operating Advanced Pollution Controls with the Transport Rule, 2014 (GW)

	Existing Controls Induced to Operate	Newly-Built Controls	Total Operational Controls
FGD	25	6	209
DSI	0	3	10
SCR	5	0	146

Note: FGD (Flue Gas Desulphurization) and DSI (Dry Sorbent Injection) are advanced SO_2 controls. SCR (Selective Catalytic Reduction) is an advanced NO_X control. Source: Integrated Planning Model run by EPA, 2011.

Projected operation of advanced pollution controls accounts for the vast majority of the NO_x reductions, while for SO_2 the reductions from the FGD and DSI controls are also supplemented by the continued and expanded use of relatively cleaner coals at uncontrolled units.

7.6 Projected Allowance Prices

Table 7-12 shows the projected allowance prices for the four trading programs under the Transport Rule in 2012 and 2014. These are the marginal emission reduction costs (i.e., the cost of reducing the last ton of a pollutant subject to the Transport Rule budgets) that EPA projected using the Integrated Planning Model (IPM) to analyze the final rule's remedy, in those states where the variability limits do not bind (in states where the variability limits bind, the marginal cost of emission reductions is higher than the allowance price). Under the trading programs, the marginal emission reduction costs inform the market-clearing price to emit that balances the supply of and demand for allowances under the Transport Rule programs.

The projected allowance prices differ from the cost-effective thresholds that were the original basis of the state budgets because they reflect the ability of the electricity sector to use the trading program flexibilities to achieve the aggregate required cost-effective emission reductions at minimized marginal costs. Most notably, banking allows entities to make emission reductions beyond what is needed in early years (accelerating environmental improvements) and smooth the trajectory of emission reductions in later years to minimize cost.

EPA believes that these projected marginal costs under the Transport Rule programs can inform allowance price discovery as program participants seek cost-effective reductions at individual units and in the compliance marketplace.

Table 7-12. Projected allowance prices for the four Transport Rule programs in 2012 and 2014 (2007$)

	Emission Allowance Prices ($/Ton)	
	2012	**2014**
Annual SO2 Group 1 Trading Program	1,000	1,100
Annual SO2 Group 2 Trading Program	600	700
Annual NOx Trading Program	500	600
Ozone Season NOx Trading Program	1,300	1,500

Note: EPA has provided projections rounded to the nearest hundred dollars because the model's point estimates do not reflect the price-discovery process of real-world markets that do not feature the same perfect information as in IPM.

7.7 Projected Generation Mix

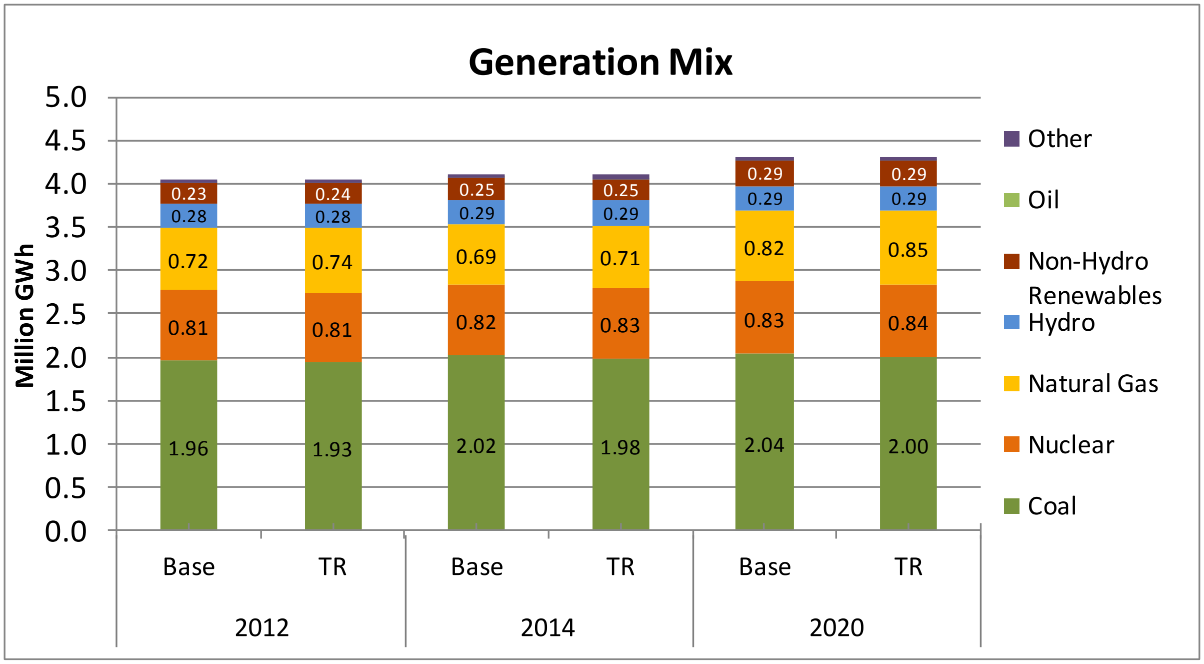
Table 7-13 and Figure 7-5 show the generation mix with the Transport Rule. Coal-fired generation and natural-gas-fired generation are projected to remain relatively unchanged because of the phased-in nature of the Transport Rule, which allows industry the appropriate amount of time to install the necessary pollution controls. Additionally, the operating costs of complying coal-fired units are not so affected as to result in major changes in the electricity generation mix. Both the base case and the Transport Rule case show shifts away from oil and natural gas generation and toward increased coal generation between 2012 and 2014.

Table 7-13. Generation Mix with the Base Case (No Further Controls) and with Transport Rule, Contiguous US (Thousand GWh)

	2009	2012				2014			
	Historical	Base	TR	Change from Base	Percent Change	Base	TR	Change from Base	Percent Change
Coal	1,754	1,958	1,935	-23	-1.2%	2,017	1,978	-39	-1.9%
Oil	29	0.09	0.09	0.00	-2.2%	0.10	0.11	0.01	5.8%
Natural Gas	917	721	739	18	2.5%	686	714	28	4.1%
Nuclear	799	812	812	0	0.0%	822	829	7	0.8%
Hydroelectric	272	281	282	1	0.2%	287	286	-1	-0.4%
Non-hydro Renewables	143	233	239	6	2.7%	250	250	1	0.2%
Other	0	35	35	0.0	0.0%	45	45	0.6	1.3%
Total	**3,914**	**4,041**	**4,043**	**2**	**0.0%**	**4,107**	**4,102**	**-4**	**-0.1%**

Note: Numbers may not add due to rounding.
Source: 2009 data from EIA Electric Power Annual 2009, Table 2.1 and Net Generation by State by Type of Producer by Energy Source (EIA-906); 2012 and 2014 projections are from the Integrated Planning Model run by EPA, 2011.

Figure 7-5. Generation Mix with the Base Case (No Further Controls) and with Transport Rule



Source: Integrated Planning Model run by EPA, 2011.

Relative to the base case, about 4.8 GW of coal-fired capacity is projected to be uneconomic to maintain (less than 2 percent of all coal-fired capacity in the Transport Rule states, or about 1% of all capacity nationally) by 2014. Notably, about 3 GW of capacity would have closed by 2014 in the base case without the Transport Rule (for a total of 7.8 GW of retirement in 2014 due to economic conditions and the Transport Rule) . Uneconomic units, for the most part, are small and infrequently used generating units that are dispersed throughout the states covered in the Transport Rule. In practice, units projected to be uneconomic to maintain may be "mothballed," retired, or kept in service to ensure transmission reliability in certain parts of the grid. EPA modeling is unable to distinguish between these potential outcomes. IPM can only predict that specific generating units are uneconomic to maintain, based on their fuel, operating and fixed costs, and whether they are needed to meet both demand and reliability reserve requirements.

7.8 Projected Capacity Additions

In addition, EPA projects that most future growth in electric demand will be met with new natural gas-fired capacity (see Table 7-14) in both the base and Transport Rule scenarios.

Table 7-14. Total Generation Capacity by 2014 (GW)

	2010	Base	TR	Change
Pulverized Coal	317	312	307	-5
Natural Gas Combined Cycle	201	205	205	0
Other Oil/Gas	253	232	233	0
Non-Hydro Renewables	31	70	70	0
Hydro	99	99	99	0
Nuclear	102	103	104	1
Other	5	81	85	4
Total	1,009	1,103	1,103	0

Source: 2010 data from EPA's NEEDS v4.10. Projections from Integrated Planning Model run by EPA.
Note: "Renewables" include biomass, geothermal, solar, and wind electric generation capacity.

7.9 Projected Coal Production for the Electric Power Sector

Coal production for electricity generation is expected to increase relative to current levels, with or without the Transport Rule (see Table 7-15). Under the Transport Rule, EPA projects coal production for use by the power sector will increase above 2009 levels by 21 million tons in 2012 and by a further 14 million tons in 2014, as opposed to 30 million tons in 2012 and a further 26 million tons in 2014 without the Transport Rule in place.

The Transport Rule will encourage the installation of new controls and operation of existing pollution controls for SO_2 and NO_x removal. Many of these pollution controls can achieve SO_2 removal rates of 95 percent or greater, which allows industry to rely more heavily on local bituminous coal in the eastern and central parts of the country that has a higher sulfur content and is less expensive to transport than western subbituminous coal. Note, for example, the projected increase in Appalachian coal production under the Transport

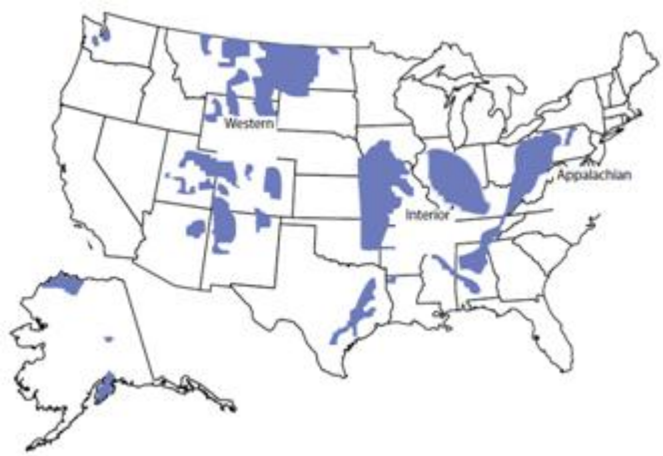
Rule in 2014, which contrasts with the projected 11 million ton decrease over that time in the absence of the rule. Production of low-sulfur western coal also increases as a result of the Transport Rule in both 2012 and 2014, as some units pursue fuel-switching to lower-sulfur coals to achieve emission reductions. Notwithstanding the Transport Rule, coal production in the interior region is still projected to increase more than 60% above 2009 levels by 2014.

Table 7-15. Coal Production for the Electric Power Sector with the Base Case (No Further Controls) and with the Transport Rule (Million Tons)

Supply Area	2009 Historical	2012 Base	2012 TR	2012 Change from Base	2014 Base	2014 TR	2014 Change from Base
Appalachia	246	193	184	-9	182	186	4
Interior	129	209	189	-20	238	210	-27
West	553	544	565	21	554	556	3
Waste Coal	14	14	14	0	14	14	0
Imports	19	31	31	0	30	30	0
Total	961	991	983	-8	1,017	996	-21

Source: Production: U.S. Energy Information Administration (EIA data), Coal Distribution -- Annual (Final), web site http://www.eia.doe.gov/cneaf/coal/page/coaldistrib/a_distributions.html (posted February 18, 2011); Waste Coal: U.S. EIA, Monthly Energy Review, January 2011 Edition, Table 6.1 Coal Overview, web site http://www.eia.doe.gov/emeu/mer/coal.html (posted January 31, 2011). Imports: U.S. Energy Information Administration (EIA) and U.S. Census. All projections from Integrated Planning Model run by EPA, 2011.

Figure 7-6. Total Coal Production by Coal-Producing Region, 2007 (Million Short Tons)



Note: Regional totals do not include refuse recovery
Source: EIA Annual Coal Report, 2007

7.10 Projected Retail Electricity Prices

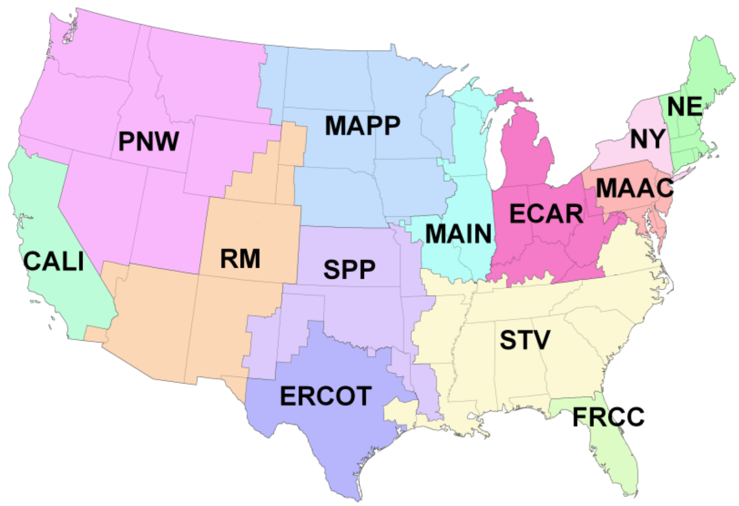
Retail electricity prices for the Transport Rule region are projected to increase a small amount with the Transport Rule (see Table 7-16). Regional retail electricity prices in the eastern half of the country are projected to range from 0.1 to 3 percent higher with the Transport Rule in 2014. By 2014, retail electricity prices in the regions directly affected by the Transport Rule, on average, are projected to be roughly 0.8 percent higher with the Transport Rule.

Table 7-16. Projected Regional Retail Electricity Prices with the Base Case (No Further Controls) and with Transport Rule (2007 cents/kWh)

	Base			Transport Rule			Percent Change		
	2012	2014	2020	2012	2014	2020	2012	2014	2020
ECAR	7.4	7.9	8.1	7.7	8.2	8.3	3.0%	3.1%	2.9%
ERCOT	7.8	8.8	8.7	8.1	8.9	8.8	3.4%	0.3%	1.9%
MAAC	8.4	9.4	10.3	8.7	9.5	10.4	4.0%	1.4%	1.2%
MAIN	7.3	7.9	8.4	7.5	8.1	8.4	2.0%	1.7%	0.9%
MAPP	7.8	8.0	7.9	7.8	8.1	7.9	0.4%	0.8%	0.3%
NY	12.5	13.7	13.3	12.8	13.7	13.4	2.5%	0.4%	0.4%
NE	11.4	12.3	11.8	11.7	12.3	11.9	1.8%	-0.1%	0.6%
FRCC	9.5	10.2	9.7	9.6	10.2	9.8	1.1%	-0.2%	0.4%
STV	7.7	7.9	7.8	7.8	7.9	7.8	0.9%	0.5%	0.4%
SPP	7.4	7.6	7.4	7.4	7.6	7.4	0.8%	0.1%	-0.1%
PNW	6.9	7.1	6.9	6.9	7.1	6.9	0.5%	0.0%	0.0%
RM	8.6	9.1	9.4	8.7	9.2	9.4	0.7%	0.2%	0.3%
CALI	12.7	13.0	12.5	12.9	13.0	12.5	0.8%	0.0%	0.2%
TR Region Average	8.5	9.2	9.2	8.7	9.3	9.3	2.2%	0.8%	1.0%
Contiguous U.S. Average	8.5	9.0	8.9	8.6	9.0	9.0	1.7%	0.8%	0.9%

Source: EPA's Retail Electricity Price Model.

Figure 7-7. Retail Price Model Regions



7.11 Projected Fuel Price Impacts

The impacts of the Transport Rule on coal prices and natural gas prices are shown below in Tables 7-17 and 7-18. Overall, the projected average coal price decrease is related to the small decrease in projected coal demand. Projected gas price changes are directly related to the projected increase in natural gas consumption under the Transport Rule.

IPM modeling of natural gas prices uses both short- and long-term price signals to balance supply of and demand in competitive markets for the fuel across the modeled time horizon. As such, it should be understood that the pattern of IPM natural gas price projections over time is not a forecast of natural gas prices incurred by *end-use consumers* at any particular point in time. The natural gas market in the United States has historically experienced significant price volatility from year to year, between seasons within a year, and even sees major price swings during short-lived weather events (such as cold snaps leading to short-run spikes in heating demand). These short-term price signals are fundamental for allowing the market to successfully align immediate supply and demand needs; however, end-use consumers are typically shielded from experiencing these rapid fluctuations in natural gas prices by retail rate regulation and by hedging through longer-term fuel supply contracts. IPM assumes these longer-term price arrangements take place "outside of the model" and on top of the "real-time" shorter-term price variation necessary to align supply and demand. Therefore, the model's natural gas price projections should not be mistaken for traditionally experienced consumer price impacts related to natural gas, but a reflection of expected average price changes over the time period 2012 to 2030.

For this analysis, in order to represent a natural gas price evolution that end-use consumers can anticipate under retail rate regulation and/or typical hedging behavior, EPA is displaying the weighted average of IPM's natural gas price projections for the 2012-2030 time horizon (see Table 7-18). In that framework, consumer natural gas price impacts are anticipated to range from 0.2% to 0.3% based on consumer class in response to the Transport Rule.

Table 7-17. Average Minemouth and Delivered Coal Prices with the Base Case and with the Transport Rule (2007$/MMBtu)

		2012			2014		
	2007	Base	TR	Percent Change from Base	Base	TR	Percent Change from Base
Minemouth	1.27	1.35	1.29	-4.3%	1.37	1.35	-1.7%
Delivered	1.76	2.08	2.05	-1.4%	2.12	2.10	-0.9%

Source: Historical data from EIA AEO 2010 Reference Case Table 15 (Coal Supply, Distribution, and Prices); projections from the Integrated Planning Model run by EPA, 2011.

Table 7-18. 2012-2030 Weighted Average Henry Hub and Delivered Natural Gas Prices with the Base Case and with the Transport Rule (2007$/MMBtu)

	Base	TR	Percent Change from Base
Henry Hub	5.32	5.34	0.4%
Delivered - Electric Power	5.60	5.62	0.3%
Delivered - Residential	10.97	10.99	0.2%

Source: Projections from the Integrated Planning Model run by EPA (2011) adjusted to Henry Hub prices using historical data from EIA AEO 2011 reference case to derive residential prices.

7.12 Key Differences in EPA Model Runs for Transport Rule Modeling Geography

As previously stated, the emissions, cost, air quality, and benefits analyses done for the Transport Rule are from a modeling scenario that requires annual SO_2 and NO_x reductions in 23 states and ozone season NO_x requirements in 26 states (See Figure 7-1). This modeling differs from the final Transport Rule because it includes ozone season NO_X requirements for six states (Iowa, Kansas, Michigan, Missouri, Oklahoma, and Wisconsin) that the final Transport Rule does not cover. (As discussed in the preamble to the final rule, EPA is issuing a supplemental proposal to request comment on inclusion of these six states).

7.13 Projected Primary PM Emissions from Power Plants

IPM does not endogenously model primary PM emissions from power plants. These emissions are calculated as a function of IPM outputs, emission factors and control configuration. IPM-projected fuel use (heat input) is multiplied by PM emission factors (based in part on the presence of PM-relevant pollution control devices) to determine PM emissions. Primary PM emissions are calculated by adding the filterable PM and condensable PM emissions.

Filterable PM emissions for each unit are based on historical information regarding existing emissions controls and types of fuel burned and ash content of the fuel burned, as well as the projected emission controls (e.g., scrubbers and fabric filters).

Condensable PM emissions are based on plant type, sulfur content of the fuel, and SO_2 and PM control configurations. Although EPA's analysis is based on the best available emission factors, these emission factors do not account for the potential changes in condensable PM emissions due to the installation and operation of SCRs. The formation of additional condensable PM (in the form of SO_3 and H_2SO_4) in units with SCRs depends on a number of factors, including coal sulfur content, combustion conditions and characteristics of the catalyst used in the SCR, and is likely to vary widely from unit to unit. SCRs are generally designed and operated to minimize increases in condensable PM. This limitation means that IPM post-processing is potentially underestimating condensable PM emissions for units with SCRs. In contrast, it is possible that IPM post-processing overestimates condensable PM emissions in a case where the unit is combusting a low-sulfur coal in the presence of a scrubber.

EPA plans to continue improving and updating the PM emission factors and calculation methodologies. For a more complete description of the methodologies used to post-process PM emissions from IPM, see "IPM ORL File Generation Methodology" (March, 2011).

7.14 Analysis Approach and Limitations

EPA's modeling is based on its best judgment for various input assumptions that are uncertain. Assumptions for future fuel prices and electricity demand growth deserve particular attention because of the importance of these two key model inputs to the power sector. As a general matter, the Agency selects the best available information from available engineering studies of air pollution controls and has set up what it believes is the most reasonable modeling framework for analyzing the cost, emission changes, and other impacts of regulatory controls.

The annualized cost estimates of the private compliance costs that are provided in this analysis are meant to show the increase in production (engineering) costs to the power sector of the Transport Rule selected remedy and any alternatives. In simple terms, the private compliance costs that are presented are the annual increase in revenues required for the industry to be as well off after the Transport Rule is implemented as before. To estimate these annualized costs, EPA uses a conventional and widely-accepted approach that is commonplace in economic analysis of power sector costs for estimating engineering costs in annual terms. For estimating annualized costs, EPA has applied a capital recovery factor (CRF) multiplier to capital investments and added that to the annual incremental operating expenses. The CRF is derived from estimates of the cost of capital (private discount rate), the amount of insurance coverage required, local property taxes, and the life of capital. The private compliance costs presented earlier are EPA's best estimate of the direct private compliance costs of the Transport Rule.

The annualized cost of the Transport Rule, as quantified here, is EPA's best assessment of the cost of implementing the Transport Rule. These costs are generated from rigorous economic modeling of changes in the power sector due to the Transport Rule. This type of analysis using IPM has undergone peer review and federal courts have upheld regulations covering the power sector that have relied on IPM's cost analysis.

The direct private compliance cost includes, but is not limited to, capital investments in pollution controls, operating expenses of the pollution controls, investments in new generating sources, and additional fuel expenditures. EPA believes that the cost assumptions used for the Transport Rule reflect, as closely as possible, the best information available to the Agency today. The relatively small cost associated with monitoring emissions, reporting, and record keeping for affected sources is not included in these annualized cost estimates, but EPA has done a separate analysis and estimated the cost to be approximately $26.2 million (see Section 9.3., Paperwork Reduction Act, of this RIA for more information).

Cost estimates for the Transport Rule are based on results from ICF's Integrated

Planning Model. The model minimizes the costs of producing electricity (including abatement costs) while meeting load demand and other constraints (full documentation for IPM can be found at http://www.epa.gov/airmarkets/progsregs/epa-ipm and in the document titled: "Documentation Supplement for EPA Base Case v.4.10_FTransport – Updates for Final Transport Rule"). The structure of the model assumes that the electric utility industry will be able to meet environmental emission caps at least cost. Montgomery (1972) has shown that this least cost solution corresponds to the equilibrium of an emission permit system. See also Atkinson and Tietenburg (1982), Krupnick et al. (1980), and McGartland and Oates (1985). However, to the extent that transaction and/or search costs, combined with institutional barriers, restrict the ability of utilities to exhaust all the gains from emission trading, costs are underestimated by the model. Utilities in the IPM model also have "perfect foresight." To the extent that utilities misjudge future conditions affecting the economics of pollution control, costs may be understated as well.

The "perfect foresight" of the model is also relevant in the context of the assurance provisions required in the Transport Rule. Because of the sizeable penalties associated with violating assurance provisions, EPA believes it will be economical for units to comply with the provisions. EPA modeled these provisions, which restrict emissions from a state to the budget plus variability limits on a 1-year basis, as state-specific emissions caps set at the budget plus average variability, or state assurance level. The Power Sector Variability Technical Support Document contains further details on these assurance provisions.

Modeling the assurance provisions as caps means that the model must meet the same limit each year, but it also allows the model to optimize with perfect foresight the present and future limits.   The model minimizes production costs while meeting required generation and reserve margin, but sources in reality may choose to make greater emission reductions than required in exchange for more certainty about emissions variability. IPM captures the cost associated with making required reductions in each state, but because of its "perfect foresight," the model likely cannot capture the true benefit to sources of having a range of allowed variability.

From another vantage point, this modeling analysis does not take into account the potential for advancements in the capabilities of pollution control technologies for SO_2 and NO_x removal as well as reductions in their costs over time after 2014. Market-based cap and trade regulation serves to promote innovation and the development of new and cheaper technologies. As an example, cost estimates of the Acid Rain SO_2 trading program by Resources for the Future (RFF) and MIT's Center for Energy and Environmental Policy Research (CEEPR) have been as much as 83 percent lower than originally projected by the EPA (see Carlson et al., 2000; Ellerman, 2003). It is important to note that the original analysis for the Acid Rain Program done by EPA also relied on an optimization model like IPM. Ex ante, EPA cost estimates of roughly $2.7 to $6.2 billion[56] in 1989 were an overestimate of the costs of the program in part because of the limitation of economic modeling to predict technological improvement of pollution controls and other compliance options such as fuel switching. Ex post estimates of the annual cost of the Acid Rain SO_2 trading program range from $1.0 to $1.4 billion. Harrington et al. have examined cost analyses of EPA programs and found a tendency for predicted costs to overstate actual implementation costs in market-based programs (Harrington, Morgenstern, and Nelson, 2000). In recognition of this, EPA's mobile source program uses adjusted engineering cost estimates of pollution control equipment and installation costs to account for this fact, which EPA has not done in this case.[57] The Agency is considering approaches to make this adjustment in the future, or at least to be able to provide a sense of the rough amount by which costs could be overstated in the analysis that has occurred.

EPA's latest update of IPM incorporates state rules or regulations and various NSR settlements adopted through December, 2010. Documentation for IPM can be found at http://www.epa.gov/airmarkets/progsregs/epa-ipm and in the document titled: " Documentation Supplement for EPA Base Case v.4.10_FTransport – Updates for Final Transport Rule." Any state or settlement action since that time has not been accounted for in our analysis in this chapter.

As configured in this application, IPM does not take into account demand response (i.e., consumer reaction to electricity prices). The increased retail electricity prices shown in Table 7-16 would prompt end users to curtail (to some extent) their use of electricity and encourage them to use substitutes.[58] The response would lessen the demand for electricity,

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56 2010 Phase II cost estimate in $1995.

57 See regulatory impact analysis for the Tier 2 Regulations for passenger vehicles (1999) and Heavy-Duty Diesel Vehicle Rules (2000).

58 The degree of substitution/curtailment depends on the costs and performance of the goods that substitute for

resulting in electricity price increases slightly lower than IPM predicts, which would also reduce generation and emissions. Because of demand response, certain unquantified negative costs (i.e., savings) result from the reduced resource costs of producing less electricity because of the lower quantity demanded. To some degree, these saved resource costs will offset the additional costs of pollution controls and fuel switching that we would anticipate with the Transport Rule. Although the reduction in electricity use is likely to be small, the cost savings from such a large industry[59] is not insignificant. EIA analysis examining multi-pollutant legislation under consideration in 2003 indicates that the annualized costs of the Transport Rule may be overstated substantially by not considering demand response, depending on the magnitude and coverage of the price increases.[60]

On balance, after consideration of various unquantified costs (and savings that are possible), EPA believes that the annual private compliance costs that we have estimated are more likely to overstate the future annual compliance costs that industry will incur, rather than understate those costs.

Finally, EPA's projected impacts of this final rule do not reflect minor technical corrections to SO2 budgets in three states (KY, MI, and NY). These projections also assumed preliminary variability limits that were smaller than the variability limits finalized in this rule. EPA conducted sensitivity analysis confirming that these differences do not meaningfully alter any of the Agency's findings or conclusions based on the projected cost, benefit, and air quality impacts presented for the final Transport Rule. The results of this sensitivity analysis are presented in Appendix F in the final Transport Rule RIA.

7.15 Significant Energy Impact

The Transport Rule has a significant impact according to *E.O. 13211: Actions that*

more energy consuming goods, which is reflected in the demand elasticity.

[59] Investor-owned utilities alone accounted for nearly $300 billion in revenue in 2008 (EIA).

[60] See "Analysis of S. 485, the Clear Skies Act of 2003, and S. 843, the Clean Air Planning Act of 2003." Energy Information Administration. September, 2003. EIA modeling indicated that the Clear Skies Act of 2003 (a nationwide cap and trade program for SO_2, NO_X, and mercury), demand response could lower present value costs by as much as 47% below what it would have been without an emission constraint similar to the Transport Rule.

Significantly Affect Energy Supply, Distribution, or Use. Under the provisions of this final rule, EPA projects that approximately 4.8 GW of additional coal-fired generation may be removed from operation by 2014. In practice, however, the units projected to be uneconomic to maintain may be "mothballed," retired, or kept in service to ensure transmission reliability in certain parts of the grid. These units are predominantly small and infrequently-used generating units dispersed throughout the area affected by the rule. If current forecasts of either natural gas prices or electricity demand were revised in the future to be higher, that would create a greater incentive to keep these units operational.

EPA estimates that average retail electricity price could increase in the contiguous U.S. by about 1.7 percent in 2012 and 0.8 percent in 2014. This is generally less of an increase than often occurs with fluctuating fuel prices and other market factors. Related to this, EPA projects limited impacts on coal and gas prices. The average delivered coal price decreases by about 1.4 percent in 2012 and 0.9 percent in 2014 relative to the base case as a result of decreased coal demand and shifts in the type of coal demanded. As discussed above in section 7.11, EPA also projects that electric power sector-delivered natural gas price will increase by about 0.3% over the 2012-2030 timeframe and that natural gas use for electricity generation will increase by approximately 200 billion cubic feet (BCF) by 2014. These impacts are well within the range of price variability that is regularly experienced in natural gas markets. Finally, under the Transport Rule, EPA projects that coal production for use by the power sector will increase above 2009 levels by 21 million tons in 2012 and a further 14 million tons in 2014, as opposed to 30 million tons in 2012 and a further 26 million tons in 2014 without the Transport Rule in place. The Transport Rule is not projected to impact production of coal for uses outside the power sector (e.g., export, industrial sources), which represent approximately 6% of total coal production in 2009. EPA does not believe that this rule will have any other impacts (e.g., on oil markets) that exceed the significance criteria.

EPA believes that a number of features of the rulemaking serve to reduce its impact on energy supply. First, the trading component of the Transport Rule provides considerable flexibility to the power sector and enables industry to comply with the emission reduction requirements in the most cost-effective manner, thus minimizing overall costs and the ultimate impact on energy supply. Second, the emission budgets for SO_2 are set in two phases, providing adequate time for EGUs to install pollution controls ahead of the second phase. In addition, both the operational flexibility of trading and the ability to bank allowances for future years help industry plan for and ensure reliability in the electrical system.

7.16 References

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CHAPTER 8
MACROECONOMIC AND EMPLOYMENT IMPACTS

8.1 Partial Equilibrium Analysis (Multiple Markets)

In this chapter, we provide estimates of the economic impacts to industry sectors outside the electric power industry and social costs associated with the selected remedy. Economic impacts presented in this chapter are changes in price and outputs for affected products from a large number of industry sectors (100). Social costs are estimates of the costs to society associated with the control and administrative costs presented in Chapter 7. Such costs are estimated from changes in consumer and producer surplus, as discussed in more detail below.

Our partial equilibrium analysis uses a market model that simulates how stakeholders (consumers and industries) might respond to the additional regulatory program costs. In this section, we provide an overview of the economic model and the results for a short-run economic impact analysis (in this case, for 2014). While the Multimarket Model has not been peer-reviewed, EPA plans to peer-review the model in the near future. More details on the economic model, the results, and data used by the model can be found in Appendix B.

8.1.1 Overview

Although several tools are available to estimate social costs, current EPA guidelines suggest that multimarket models "…are best used when potential impacts on related markets might be considerable" and modeling using a computable general equilibrium model is not available or practical (EPA, 2010, p. 9-21). Other guides for environmental economists offer similar advice (Berck and Hoffmann, 2002; Just, Hueth, and Schmitz, 2004). Multimarket models focus on "short-run" time horizons and measure a policy's near-term or transition costs as stated in the EPA Economic Resource Document (EPA, 1999). These models have greater levels of aggregation than detailed partial equilibrium models of compliance for individual sectors, like IPM, but represent more sectors of the economy.

A linked partial equilibrium model is useful for evaluating relative economic impacts across related markets and providing a measure of consumer and producer surplus losses. It may not be sufficient for fully estimating social costs, just as a single market model may not be appropriate for fully estimating social costs. Generally speaking, the smaller the effect of a regulation on partial-equilibrium measures of social welfare such as consumer and producer surplus, the more accurately those estimates reflect the true social cost.[61] However, a transition or short-term evaluation using a partial equilibrium model does not explicitly account for resources to be reallocated across sectors according to relative price changes (although the multi-market model does account for certain resource constraints and the employment of intermediate inputs). Furthermore, these models (if static) may not capture how resource use and consumption shifts over time in response to the regulation, which may be accounted for with a dynamic computable general equilibrium model. Therefore, we use care in referring to the estimate of total change in surplus coming out of the Multimarket model as a social cost. For regulations with a relatively modest impact on the economy, however, such as this final rule, the change in surplus estimated by this model may provide a reasonable approximation of the social cost.

Our multimarket model contains the following features:

Industry sectors and benchmark data set[62]

-100 industry sectors
-multiple benchmark years

Economic behavior

-industries respond to regulatory costs by changing production rates

-market prices rise and fall to reflect higher energy and other non-energy material -costs and changes in demand

-customers respond to price increases and consumption falls

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[61] A general equilibrium framework (e.g., such as that employed in the EMPAX model used by US EPA) is necessary for determining social costs in a theoretically complete way, but general equilibrium models have their own drawbacks and their application may not be practical or sufficiently informative to warrant their use.

[62] A benchmark data set is included in the model to define the prepolicy equilibrium in the year of analysis (i.e., 2015 in this rule) for the 100 sectors included. Thus, the dataset provides a benchmark for estimating economic impacts and social costs in the year of analysis.

Model scope

-100 sectors are linked with each other based on their use of energy and other non-energy materials. For example, the construction industry is linked with the petroleum, cement, and steel industries and is influenced by price changes that occur in each sector. The links allow EPA to account for indirect effects the regulation has on related markets.

-production adjustments influence employment levels

-international trade (imports/exports) responds to domestic price changes

Model time horizon ("short run") for a single period (2015)[63]

-fixed production resources (e.g., capital) lead to an upward-sloping industry supply function

-firms cannot alter certain input mixes; there is no substitution among intermediate production inputs

-there is no explicit labor market (a real wage and labor supply is not determined within the model)

-investment and government expenditures are fixed.

Although the model is intended to examine transition or short-term effects of this rulemaking, the results may be muted due to the use of annualized capital cost as an input to the model rather than the total capital cost.

Labor and Capital Markets and Pre-existing Distortions in Other Markets

Unlike CGE models, our multimarket model does not include a national labor or capital market. As a result, we do not estimate real wage changes, changes in labor /leisure choices, or savings and investment decisions within the model.

[63] For this analysis, we use 2015 as our analysis year and as a proxy for 2014. This allows us to maintain consistency with the results of the analysis using IPM (found in Chapter 7) that serve as inputs to this economic impact analysis.

Therefore we do not consider whether policies interact with existing distortions, particularly tax distortions in a ways that increase or decrease estimates of the social cost. Since savings and investment decisions are not modeled, social costs associated with capital stock changes are also not considered.

Although the model is intended to examine transition or short-term effects of this rulemaking, the estimate of the short-term effects may be understated due to the way the model accounts for changes in capital demand. The cost of new capital associated with the rule is accounted for by imposing an increase in the annualized capital cost rather than the total capital cost in the year of analysis. Additionally, using an economic impact model that constrains the physical capital stock to be fixed will not fully depict the social costs of an adjustment to a post-policy equilibrium as discussed in the EPA Economics Guidelines.

The own-price elasticities used by the Multimarket Model are drawn from secondary sources, as fully described in Appendix B. While the Multimarket Model is a short-run model that examines transitional costs that arise as a result of a new regulation, the estimation methods used by the secondary sources generally assume that people and firms have more flexibility to adjust consumption and production decisions than they would have in a short-run model. Consequently, use of these elasticities within the Multimarket Model may in some cases lead to estimates of larger market output changes than would actually occur in the short-run, all other things being equal.

On the other hand, while the scale of environmental regulation often is not sufficient to influence government spending and investment demand, the Leontief structure for intermediate goods and its assumption of fixed investment and government spending may make the Multimarket Model less responsive to regulatory shocks. Given the competing sources of bias, the ultimate direction of the bias with regards to economic impacts and social costs is difficult to ascertain *a priori*.

8.1.2 Economic Impact Analysis Results

Market-Level Results

Market-level impacts include price and quantity adjustments including the changes in international trade (Table 8-1).For the final Transport Rule, , the Agency's economic model suggests the average national price increase for energy is 0.16%. Higher energy costs result in subsequent manufacturing sector price increases nationwide of 0.01% or less. Imports also slightly rise because of higher U.S. prices. The one exception is transportation services; since sectors using transportation services are producing less, the demand for transportation services declines. The size of the transportation services demand shift outweighs any supply side cost increases that place upward pressure on service prices (e.g. higher electricity and refined petroleum prices). As a result, the average transportation services price falls.

Social Cost Estimates of Transport Rule

In the short run, the Agency's partial equilibrium multi-market model suggests that industries are able to pass on $0.7 billion (2007$) of the Transport Rule's costs to U.S. households in the form of higher prices (Table 8-2). Existing U.S. industries' surplus falls by $0.2 billion and the net U.S. loss in aggregate, is $0.9 billion (2007$). This is slightly higher than the annualized nationwide compliance cost estimate of the final rule as shown in Chapter 7 of the RIA because it excludes gains to other countries discussed below.

Table 8-1. Short-Term Market-Level Changes (in percent) within the U.S. Economy in 2014

Industry Sector	U.S. Prices	U.S. Production	Imports	U.S. Consumption	Exports
Energy	-0.163%	-0.031%	0.009%	-0.016%	-0.031%
Coal	-0.017	-0.047	-0.048	-0.052	0.003
Crude Oil Extraction	0.004	-0.053	0.027	−0.003	0.000
Electric generation	0.770	-0.059	0.000	-0.059	-0.137
Natural Gas	0.004	-0.033	0.057	-0.018	-0.002
Refined Petroleum	0.002	-0.002	0.003	-0.001	-0.0002
Nonmanufacturing	0.0004	-0.002	0.001	-0.0016	-0.001
Manufacturing					
Food, beverages, and textiles	0.004	-0.005	0.006	-0.003	-0.003

Lumber, paper, and printing	0.008	-0.005	0.009	-0.003	-0.006
Chemicals	0.002	-0.006	0.003	-0.003	-0.002
Plastics and Rubber	0.005	-0.006	0.008	−0.003	-0.005
Nonmetallic Minerals	0.009	−0.006	0.011	-0.003	-0.009
Primary Metals	0.007	−0.007	0.007	-0.004	−0.007
Fabricated Metals	0.006	-0.002	0.007	−0.002	-0.003
Machinery and Equipment	0.0007	-0.002	0.0005	-0.002	-0.0008
Electronic Equipment	0.0007	-0.002	0.0007	-0.002	-0.001
Transportation Equipment	0.0008	-0.003	0.001	-0.002	-0.001
Other	0.002	-0.007	0.004	-0.003	-0.003
Wholesale and Retail Trade	0.001	−0.002	0.001	-0.002	-0.002
Transportation Services	-0.003	−0.003	−0.003	-0.003	0.003
Other Services	0.001	−0.002	0.0007	-0.002	-0.001

Note: Approximated using the IPM cost analysis. For example, with the $0.8 billion increase in costs for the electric power sector, IPM projects a 0.77 percent increase in the retail price of electricity in 2015. All other energy market-level changes are determined within the multimarket model. Appendix B provides additional details.

As U.S. prices rise, other countries are affected through international trade relationships. The price of goods produced in the United States increase, domestic exports decline, and domestic production is replaced to a certain degree by imports; the model estimates a net gain of about $0.04 billion for other countries. The net change in total surplus is *lower* than the annualized nationwide compliance cost estimate of the final rule as shown in Chapter 7 of the RIA. Our estimate of social costs for the rule incorporates the net change in total surplus, and this estimate is $0.81 billion (2007 dollars) as shown in Table 8-2, or nearly identical to the compliance costs.[64] Compliance costs based on the pre-policy output levels would be overstated if we do not consider the new lower levels of consumption as a result of higher market prices.[65]

[64] The same is true for many recent rulemakings, including the Boiler MACT.

[65] There are small additional losses associated with the foregone benefits associated with reduced consumption (e.g. deadweight loss). However, in a perfectly competitive market without pre-existing distortions, the costs represent only a small fraction of total social costs. A more detailed discussion of the economic costs of regulation is found in Chapter 8 of EPA (2010).

Table 8-2. Distribution of Social Costs (billions, 2007$): 2015

Change in U.S. consumer surplus	−$0.68
Change in U.S. producer surplus	−$0.17
Net Change in U.S. Surplus	**−$0.85**
Net change in rest of world surplus	$0.04
Net change in Total Surplus	**−0.81$**

The surplus losses are concentrated in the electric generation sector (percent) and other services (percent). Other services include information, finance and insurance, real estate, professional services, management, administrative services, education, health care, arts, accommodations, and public services. Although electricity costs represent a small share of total service industry production costs, the service sectors represent a significant economic sector within the U.S. economy and use a large amount of electricity. The transition or short-term evaluation using a partial equilibrium model does not allow for resources to be allocated according to price changes. So the results of the model do not capture any distortions in the economy that may results as the price of electricity changes. If the distortions are significant, the “true” social cost would be higher than the compliance cost and the results of this partial equilibrium model.

8.1.3 Alternative Approach to Estimating Social Cost

In the Transport Rule proposed last summer, EPA used a different model to estimate the social cost of the regulatory approach than applied in this RIA. That model, EPA’s Economic Model for Policy Analysis (EMPAX), is a computable general equilibrium model (CGE) which dynamically cascades the cost of a regulation through the entire economy. However, since that rule was proposed, an updated version of EMPAX was used to estimate the social cost of the Clean Air Act in a new EPA report entitled “The Benefits and Costs of the Clean Air Act from 1990 to 2020. This report is available at http://www.epa.gov/air/sect812/feb11/fullreport.pdf.

This updated version of EMPAX added in the benefit-side effects (incorporating labor-force and health care expenditures) which significantly changed the social cost estimate from the previous edition. In December 2010, EPA’s Science Advisory Board (SAB) found that “The inclusion of benefit-side effects (reductions in mortality, morbidity, and healthcare expenditures) in a computable general equilibrium (CGE) model represents a significant step forward in benefit-cost analysis." http://yosemite.epa.gov/sab/sabproduct.nsf/1E6218DE3BFF682E852577FB005D46F1/$File/EPA-COUNCIL-11-001-unsigned.pdf. A description of the changes to the model and implications are covered in detail in chapter 8 of the section 812 report. EPA has determined that it needs to update the EMPAX model version used for RIAs to add this benefit-side effect prior to use in any additional regulatory analysis. In addition, the total nationwide annual compliance costs of the Transport Rule are now much lower than estimated for the proposal, and now are low enough so that EMPAX may not be as appropriate a model to use to for social costs and other economic impact estimation for this final rule. With the benefit-side effects updates now in the process of being incorporated into the model in response to SAB's guidance, and the relatively low nationwide annual compliance cost incurred by the electric power sector for this final rule as mentioned earlier in this RIA, EPA will not use EMPAX for this final RIA.

8.2 Employment Impacts for the Transport Rule

In addition to addressing the costs and benefits of the Transport Rule, EPA has estimated the impacts of this rulemaking on labor demand, and the results are presented in this section.[66] While a standalone analysis of employment impacts is not included in a standard cost-benefit analysis, such an analysis is of particular concern in the current economic climate. Executive Order 13563, states, "Our regulatory system must protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation" (emphasis added). Therefore, we have provided this partial employment analysis to inform the discussion of labor demand and job impacts. We provide an estimate of the employment impacts on the regulated industry over time. We also provide the short-term employment impacts (increase in labor demand) associated with the construction of needed pollution control equipment.

We have not quantified the rule's effects on all labor in other sectors not regulated by this rule, or the effects induced by changes in workers' incomes. What follows is an

[66] See TSD as part of the Transport Rule Docket: "Employment Estimates of Direct Labor in Response to the Transport Rule in 2014."

overview of the various ways that environmental regulation can affect employment, followed by a discussion of the estimated impacts of this rule. EPA continues to explore the relevant theoretical and empirical literature and seeks public comment in order to ensure that such estimates are as accurate, useful and informative as possible.

From an economic perspective, labor is an input into producing goods and services; if regulation requires that more labor be used to produce a given amount of output, that additional labor is reflected in an increase in the cost of production. Moreover, when the economy is at full employment, we would not expect an environmental regulation to have an impact on overall employment since labor is being shifted from one sector to another. On the other hand, in periods of high unemployment, an increase in labor demand due to regulation may have the potential to result in a net increase in overall employment. With significant numbers of workers unemployed, the opportunity costs associated with displacing jobs in other sectors are likely to be smaller.

To provide a partial picture of the employment consequences of this rule, EPA takes two approaches. First, the analysis uses the results of Morgenstern, Pizer, and Shih (2002) to estimate the effects of the regulation on the regulated industry, the electric power industry in this case. This approach has been used by EPA in recent Regulatory Impact Analyses. (See, for example, the Regulatory Impact Analysis for the recently finalized Industrial Boilers and Commercial and Institutional Solid Waste (CISWI) rulemakings, promulgated on February 21, 2011). Second, EPA uses projections from IPM to estimate the short-term employment effects resulting from construction and resource requirements as a result of the additional demand for pollution control equipment. Historically, EPA has only reported employment impacts on a few regulations. Section 8.3 discusses the estimates of the employment consequences in the electricity sector, using the Morgenstern, et al. approach. Section 8.4 estimates the employment effects in the environmental protection sector, using the second approach.

8.3 Employment Impacts primarily on the regulated industry: Morgenstern, Pizer, and Shih (2002)

EPA examined possible employment effects within the electric utility sector using a peer-reviewed, published study that explores historical relationships between industrial employment and environmental regulations (Morgenstern, Pizer, and Shih, 2002). The fundamental insight of Morgenstern, et al. is that environmental regulations can be understood as requiring regulated firms to add a new output (environmental quality) to their product mixes. Although legally compelled to satisfy this new demand, regulated firms have to finance this additional production with the proceeds of sales of their other (market) products. Satisfying this new demand requires additional inputs, including labor, and may alter the relative proportions of labor and capital used by regulated firms in their production processes.

Thus, Morgenstern et al. decompose the overall effect of a regulation on employment into the following three subcomponents:

The "Demand Effect": higher production costs raise market prices, reducing consumption (and production), thereby reducing demand for labor within the regulated industry [67];

The "Cost Effect": As production costs increase, plants use more of all inputs, including labor, to maintain a given level of output. For example, in order to reduce pollutant emissions while holding output levels constant, regulated firms may require additional labor;

The "Factor-Shift Effect": Regulated firms' production technologies may be more or less labor intensive after complying with a regulation (i.e., more/less labor is required per dollar of output).

Decomposing the overall employment impact of environmental regulation into three subcomponents clarifies the conceptual relationship between environmental regulation and employment in regulated sectors, and permitted Morgenstern, et al. to provide an empirical estimate of the net impact. For present purposes, the net effect is of particular interest, and is the focus of our analysis.

Using plant-level Census information between the years 1979 and 1991, Morgenstern et al. estimate the size of each effect for four polluting and regulated industries (petroleum,

[67] The Morgenstern et al. results rely on industry demand and supply elasticities to determine cost pass-through and reductions in output.

plastic material, pulp and paper, and steel). On average across the four industries, each additional $1 million ($1987) spending on pollution abatement results in a (statistically insignificant) net increase of 1.55 (+/- 2.24) jobs. As a result, the authors conclude that increases in pollution abatement expenditures do not necessarily cause economically significant employment changes. The conclusion is similar to Berman and Bui (2001) who found that increased air quality regulation in Los Angeles did not cause in large employment changes[68].

Since the Morgenstern, et al. parameter estimates are expressed in jobs per million ($1987)[69] of environmental compliance expenditures, their study offers a transparent and simple way to transfer estimates for other employment analysis. For each of the three job effects outlined above, EPA used the Morgenstern et al. four industry average parameters and standard errors along with the estimated private compliance costs to provide a range of electricity sector employment effects associated with the Transport Rule.

By applying these estimates to pollution abatement costs for the final rule for the electric power sector, we estimated each effect. The results are

Demand effect: −to + jobs in the directly affected sector with a central estimate of −;

Cost effect: + to + jobs in the directly affected sector with a central estimate of +; and

Factor-shift effect: + to + jobs in the directly affected sector with a central estimate of +.

EPA estimates the net employment effect to range from - to + jobs in the directly affected sector with a central estimate of +. [70, 71]

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[68] For alternative views, see Henderson (1996) and Greenstone (2002).

[69] The Morgenstern et al. analysis uses "production worker" as defined in the US Census Bureau's Annual Survey of Manufactures (ASM) in order to define a job. This definition can be found on the Internet at http://www.census.gov/manufacturing/asm/definitions/index.html.

[70] Since Morgenstern's analysis reports environmental expenditures in $1987, we make an inflation adjustment the IPM costs using the ratio of the consumer price index, U.S. city, all items reported by the U.S. Bureau of Labor Statistics: CPI_{1987}/CPI_{2007} = (113.6/207.3) = 0.55

These estimates are shown in Table 8-3.

Table 8-3. Employment Impacts Using Peer-Reviewed Study

	Estimates using Morgenstern et al. (2002)			
	Demand Effect	**Cost Effect**	**Factor Shift Effect**	**Net Effect**
Change in Full-Time Jobs per Million Dollars of Environmental Expenditure[a]	−3.56	2.42	2.68	1.55
Standard Error	2.03	0.83	1.35	2.24
EPA estimate for Transport Rule[b]	+200 to -3,000	+400 to 2,000	0 to +2,000	-1,000 to 3,000

[a] Expressed in 1987 dollars. See footnote 8 for inflation adjustment factor used in the analysis.

[b] According to the 2007 Economic Census, the electric power generation, transmission and distribution sector (NAICS 2211) had approximately 510,000 paid employees. Both the midpoint and range for each effect are reported in the last row of the table.

All ranges for these job changes are based on the 95th percentile of results. EPA recognizes there will be other employment effects which are not considered in the Morgenstern et al. study. For example, employment in environmental protection industries may increase as firms purchase more pollution control equipment and services to meet the rule's requirements. EPA does provide such an estimate of employment change later in this section in a separate analysis. On the other hand, industries that use electricity will face higher electricity prices as the result of the transport rule, reduce output, and demand less labor. In the earlier part of Chapter 8 we use a Multimarket Model to estimate that there will be a .002% reduction in output in nonmanufacturing industries and .002 to .007 percent reductions in output in various manufacturing industries. It is difficult, however, to extend these results to an estimate of employment effects across these many different industries;

[71] Net employment effect = 1.55× $832 million × 0.55. This estimated net result is not statistically different from zero.

therefore, we feel we do not currently have sufficient information to quantify these impacts as potential employment losses.

8.3.1 Limitations

Although the Morgenstern et al. paper provides information about the potential job effects of environmental protection programs, there are several caveats associated with using those estimates to analyze the final rule. First, the Morgenstern et al. estimates presented in Table 8-3 and used in EPA's analysis represent the weighted average parameter estimates for a set of manufacturing industries (pulp and paper, plastics, petroleum, and steel). Morgenstern, et al. present those industries' estimates separately, and they range from -1.13 jobs per $1 million (in 1987 dollars) of environmental expenditures for pulp and paper, to +6.90 jobs for plastics. Only two of the total jobs estimates are statistically significantly different from zero, and the overall weighted average used here, 1.55 jobs per $1 million, is not statistically significant. Moreover, here we are applying the estimate to the electricity generating industry.

Second, relying on Morgenstern et al. implicitly assumes that estimates derived from 1979–1991 data are still applicable. Third, the methodology used in Morgenstern et al. assumes that regulations affect plants in proportion to their total costs. In other words, each additional dollar of regulatory burden affects a plant by an amount equal to that plant's total costs relative to the aggregate industry costs. By transferring the estimates, EPA assumes a similar distribution of regulatory costs by plant size and that the regulatory burden does not disproportionately fall on smaller or larger plants.

8.4 Employment Impacts of the Transport Rule - Environmental Protection Sector Approach, by 2014 [72]

The Transport Rule will require additional pollution control equipment and services in order to reduce emissions from the power sector and address nonattainment and the transport of air emissions cross state borders. Historically, new categories of employment have been created in the process of implementing regulations that reduce air emissions and other forms of pollution.. When a regulation is promulgated, the first response of industry is to order pollution control equipment and services in order to comply with the regulation

[72] EPA expects that the installation of retrofit control equipment in response to the requirements of this rule will primarily take place within 2014.

when it becomes effective. Revenue and employment in the environmental technology industry have grown steadily between 2000 and 2008, reaching an industry total of approximately $300 billion in revenues and 1.7 million employees in 2008.[73] While these revenues and employment figures represent gains for the environmental technologies industry, they are costs to the regulated industries required to install the equipment. Moreover, it is not clear the 1.7 million employees in 2008 represent anything other than workers diverted from other productive employment as opposed to new additional employment.

Regulated firms hire workers to design and construct pollution control equipment. Once the equipment is installed, regulated firms hire workers to operate and maintain the pollution control equipment – much like they hire workers to produce more output. Morgenstern, Pizer, and Shih (2002) examined how regulated industries respond to regulation. They found that on average, employment goes up in regulated firms. Of course, these firms may also reassign existing employees to do these activities.

Environmental regulations support employment in many basic industries. In addition to the increase in employment in the environmental protection industry (increased orders for pollution control equipment), environmental regulations also support employment in industries that provide intermediate goods to the environmental protection industry. For example, $1 billion in capital expenditures to reduce air pollution involves the purchase of abatement equipment. The equipment manufacturers, in turn, order steel, tanks, vessels, blowers, pumps, and chemicals to manufacture and install the equipment.

A study (2008) by Bezdek, Wendling, and DiPernab found that "investments in environmental protection industries create jobs and displace jobs, but the net effect on employment is positive."

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[73] In 2008, the industry totaled approximately $315 billion in revenues and 1.9 million employees including indirect employment effects, pollution abatement equipment production employed approximately 4.2 million workers in 2008. These indirect employment effects are based on a multiplier for indirect employment = 2.24 (1982 value from Nestor and Pasurka - approximate middle of range of multipliers 1977-1991). Environmental Business International (EBI), Inc., San Diego, CA. Environmental Business Journal, monthly (copyright). http://www.ebiusa.com/ EBI data taken from the Department of Commerce International Trade Administration Environmental Industries Fact Sheet from April 2010: http://web.ita.doc.gov/ete/eteinfo.nsf/068f3801d047f26e85256883006ffa54/4878b7e2fc08ac6d85256883006c452c?OpenDocument

The focus of this part of the employment analysis is on short-term jobs related to the compliance actions of the affected entities and includes estimates of the employment impacts due to the increased demand for pollution control equipment.[74] Results indicate that the Transport Rule has the potential to result in a net increase of labor in these industries, driven by the increased demand for new pollution controls. Overall, the preliminary results of the environmental protection sector approach indicate that the Transport Rule could support an increase of about 2,230 job-years[75] by 2014.

8.4.1 Overall Approach and Methodology for Environmental Protection Sector Approach

EPA commissioned ICF International to provide estimates for the Environmental Protection Sector, and the analysis utilizes a bottom-up engineering based methodology combined with macroeconomic data on industrial output and productivity, to estimate employment impacts in the environmental control sector of the economy. It relies on projections from the IPM model and projections for new pollution control equipment and related costs, along with data from the Bureau of Labor Statistics and other sources. The approach also relies upon prior EPA studies on similar issues, and in particular uses data and information from an extensive resource study conducted in 2002, which was updated in the Spring of 2011 and reflects more recent information.[76] The approach involves using IPM projected results from the Transport Rule analysis for the set of pollution control technologies expected to be installed to comply with the rule, along with data from secondary sources, to estimate the job impacts using this approach.[77] This includes the labor needed to design, manufacture and install the needed pollution control equipment over the years leading up to compliance in 2014.

For construction labor, the labor needs are derived from the 2002 EPA resource analysis for installing various retrofits (FGD – Flue Gas Desulfurization scrubbers, SCR-

[74] For more detail on methodology, approach, and assumptions, see Appendix D in this RIA: “Employment Estimates of Direct Labor in Response to the Transport Rule in 2014.”

[75] Numbers of job years are not the same as numbers of individual jobs, but represents the amount of work that can be performed by the equivalent of one full-time individual for a year (or FTE). For example, 25 job years may be equivalent to five full-time workers for five years, twenty-five full-time workers for one year, or one full-time worker for twenty-five years.

[76] Engineering and Economic Factors Affecting the Installation of Control Technologies for Multipollutant Strategies EPA-600/R-02/073 (2002).

[77] Detailed results from IPM for the Transport Rule can be found in Chapter 7 of the RIA.

selective catalytic reduction, and DSI - dry sorbent injection) and are further classified into different labor categories, such as boilermakers, engineers and a catch-all "other installation labor." For the inputs needed (e.g., steel), the 2002 resource study was used to determine the steel demand for each MW of additional pollution control and combined with labor productivity data from the Economic Census and BLS for relevant industries.

More detail on methodology, assumptions, and data sources can be found in Appendix D of this RIA - "Employment Estimates of Direct Labor in Response to the Transport Rule in 2014."

Projections from IPM were used to estimate the incremental retrofit capacities projected in response to the final rule. These additional pollution controls are shown in Table 8-4 below, and reflect the added pollution controls needed to meet the requirements of the rule. Additional information on the power sector impacts can be found in Chapter 7 of the RIA.

Table 8-4. Increased Pollution Control Demand due to the Transport Rule, by 2014 (GW)

Retrofit Type	Existing Controls Induced to Operate	Newly Built Controls
FGD	25	6
SCR	5	0
DSI	0	3

8.4.2 Summary of Employment Estimates from Environmental Protection Sector Approach

Table 8-5 presents additional detail on the estimated employment impacts using the environmental protection sector approach resulting from the Transport Rule. Results for the Environmental Protection Sector Approach indicate the Transport Rule could support or create roughly 2,230 one-time job-years of increased demand for direct labor, driven by the need to design and build the pollution control equipment.

Table 8-5. Employment Effects Using the Environmental Protection Sector Approach for the Transport Rule by 2014 (in Job-Years)

Employment	Incremental Employment
One-Time Employment Changes for Construction	
1. Boilermakers	890
2. Engineers	440
3. General Construction	880
4. Steel Manufacturing	20

8.4.3 Other Employment Impacts of the Transport Rule

We expect ongoing employment impacts on regulated and non-regulated entities for a variety of reasons. These include labor changes in the regulated entities resulting from shifts in demand for fuels, increased demand for materials and the labor required to provide them to operate pollution control equipment, reductions in employment resulting from coal retirements, and reductions in other industries due to slight projected increases in the price of electricity and natural gas. The most notable of the ones we are unable to estimate are the impacts on employment as a result of the increase in electricity and other energy prices in the economy. Because of this inability to estimate all the important employment impacts, EPA neither sums the impacts that the Agency is able to estimate for the ongoing non-regulated group or make any inferences of whether there is a net gain or loss of employment for the non-regulated group. These other ongoing employment impacts are found in Table 8-6, and these employment impacts are not included in the Agency estimate of employment impacts for this Transport Rule for the reasons mentioned in this paragraph. The data in Table 8-6 come from an analysis of short-term employment impacts presented in Appendix D. That analysis focuses on the first-order employment impacts related to the compliance actions of the affected entities within the power sector, but not the ripple effects of these impacts on the broader economy (i.e., the "multiplier" effect) or economy-wide effects of changes to the energy markets.

Table 8-6. Employment Impacts for Entities Not Regulated by the Transport Rule

Employment Changes for Ongoing Annual Operation

Employment Changes from Changes to Demand in Materials[78]	
1. Limestone (FGD)	2,440
2. Ammonia (SCR)	30
3. Catalyst (SCR)	20
4. Sodium Bicarbonate (DSI)	160
Sub-Total:	**2,650**
Employment Changes for Ongoing Annual Retrofit Operation	**2,320**
Employment Annual Changes due to Coal Capacity Retirements	**(2,710)**
Annual Employment Changes due to Changes in Fuel Use	
1. Coal	(2,030)
2. Natural Gas	810
3. New Natural Gas Pipeline	230
Sub-Total:	**(990)**

8.5 Summary

The two approaches use different analytical techniques and are applied to different industries during different time periods, and they use different units of analysis. These estimates should not be summed because of the different metrics, length and methods of analysis as mentioned in Section 8.4. The Morgenstern estimates are used for the ongoing employment impacts for the regulated entities (the electric power sector). The short term estimates for employment needed to design, construct, and install the pollution control equipment in the period leading up to the compliance date are also provided. Finally some of the other types of employment impacts that will be ongoing are not included in the employment impacts estimated for the final Transport Rule.

Table 8-7 shows the employment impacts of the final Transport Rule as estimated by the environmental protection sector approach and by the Morgenstern approach.

Table 8-7. Estimated Employment Impact Table

	Annual (reoccurring)	**One time (construction during compliance period)**
Environmental Protection Sector approach*	Not Applicable	**2,230**
Net Effect on Electric Utility Sector Employment from Morgenstern et al. approach***	****+700** **- 1,000 to +3,000******	Not Applicable

*These one-time impacts on employment are estimated in terms of job-years.

**This estimate is not statistically different from zero.

***These annual or recurring employment impacts are estimated in terms of production workers as defined by the US Census Bureau's Annual Survey of Manufacturers (ASM).

**** Based on the 95% confidence interval of the Morgenstern study.

8.6 References

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CHAPTER 9
STATUTORY AND EXECUTIVE ORDER ANALYSES

This chapter presents discussion and analyses relating to relevant Executive Orders and statutory requirements relevant for the Transport Rule. We discuss potential impacts to affected small entities as required by the Regulatory Flexibility Act (RFA), as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA). We also describe the analysis conducted to meet the requirements of the Unfunded Mandates Reform Act of 1995 (UMRA) that assess the impact of the Transport Rule for state, local and Tribal governments and the private sector. Analyses conducted to comply with the Paperwork Reduction Act (PRA) are also discussed. In addition, we address the requirements of Executive Order (EO) 13045: Protection of Children from Environmental Health and Safety Risks; EO 13175: Consultation and Coordination with Indian Tribal Governments; and EO 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. The Discussion of Executive Order 13211: Actions that Significantly Affect Energy Supply, Distribution or Use is provided in Chapter 7 of this RIA.

9.1 Small Entity Impacts

The Regulatory Flexibility Act (5 U.S.C. 601 et seq.), as amended by the Small Business Regulatory Enforcement Fairness Act (Public Law No. 104-121), provides that whenever an agency is required to publish a general notice of proposed rulemaking, it must prepare and make available an initial regulatory flexibility analysis, unless it certifies that the proposed rule, if promulgated, will not have a significant economic impact on a substantial number of small entities (5 U.S.C. 605[b]). Small entities include small businesses, small organizations, and small governmental jurisdictions.

For the purposes of assessing the impacts of the Transport Rule on small entities, a small entity is defined as:

(1) A small business according to the Small Business Administration size standards by the North American Industry Classification System (NAICS) category of the owning entity. The range of small business size standards for electric utilities is 4 billion kilowatt-hours of production or less;

(2) a small government jurisdiction that is a government of a city, county, town, district, or special district with a population of less than 50,000; and

(3) a small organization that is any not-for-profit enterprise that is independently owned and operated and is not dominant in its field.

Table 9-1 lists entities potentially affected by this final rule with the applicable NAICS code.

Table 9-1. Potentially Regulated Categories and Entities[a]

Category	NAICS Code[b]	Examples of Potentially Regulated Entities
Industry	221112	Fossil fuel-fired electric utility steam generating units.
Federal Government	221112[c]	Fossil fuel-fired electric utility steam generating units owned by the federal government.
State/Local/ Tribal Government	221112[c]	Fossil fuel-fired electric utility steam generating units owned by municipalities.
	921150	Fossil fuel-fired electric utility steam generating units in Indian Country.

[a]Include NAICS categories for source categories that own and operate electric generating units only.
[b]North American Industry Classification System.
[c]Federal, state, or local government-owned and operated establishments are classified according to the activity

in which they are engaged.

EPA examined the potential economic impacts to small entities associated with this rulemaking based on assumptions of how the affected entities will implement control measures to meet their NO_x and SO_2 budgets. This analysis does not examine potential indirect economic impacts associated with the Transport Rule, such as employment effects in industries providing fuel and pollution control equipment, or the potential effects of electricity price increases on industries and households.

9.1.1 Identification of Small Entities

EPA used Velocity Suite's Ventyx data as a basis for identifying plant ownership and compiling the list of potentially affected small entities, in conjunction with IPM outputs.[79] The Ventyx data set contains detailed ownership and corporate affiliation information. For plants burning fossil fuel as the primary fuel, plant-level boiler and generator capacity, heat input, generation, and emissions data were aggregated by owner and then parent company. Entities with more than 4 billion kWh of annual electricity generation were removed from the list, as were municipal-owned entities serving a population greater than 50,000. For cooperatives, investor-owned utilities, and subdivisions that generate less than 4 billion kWh of electricity annually but may be part of a large entity, additional research on power sales, operating revenues, and other business activities was performed to make a final determination regarding size. Because the rule does not affect units with a generating capacity of less than 25 MW, small entities that do not own at least one generating unit with a capacity greater than or equal to 25 MW were dropped from the data set. According to EPA's analysis, about 390 small entities were exempted by this provision. Finally, small entities for which IPM does not project generation in 2014 in the base case were omitted from the analysis because they are not projected to be operating and thus will not face the costs of compliance with the Transport Rule. After omitting entities for the reasons above,

[79] For details, see http://www.ventyx.com/

EPA identified a total of 108 potentially affected small entities, out of a possible 610.[80] The number of potentially affected small entities by ownership type is listed in Table 9-2.

9.1.2 Overview of Analysis and Results

This section presents the methodology and results for estimating the impact on the Transport Rule to small entities in 2014 based on the following endpoints:

- annual economic impacts of the Transport Rule on small entities and
- ratio of small entity impacts to revenues from electricity generation.

9.1.2.1 Methodology for Estimating Impacts of the Transport Rule on Small Entities

An entity can comply with the Transport Rule through some combination of the following: installing retrofit technologies, purchasing allowances, switching to a cleaner fuel, or reducing emissions through a reduction in generation or improved efficiency. Additionally, units with more allowances than needed can sell these allowances in the market. The chosen compliance strategy will be primarily a function of the unit's marginal control costs and its position relative to the marginal control costs of other units.

To attempt to account for each potential control strategy, EPA estimates compliance costs as follows:

$$C_{Compliance} = \Delta\ C_{Operating+Retrofit} + \Delta\ C_{Fuel} + \Delta\ C_{Allowances} + \Delta\ C_{Transaction} + \Delta\ R$$

where C represents a component of cost as labeled, and Δ R represents the value of foregone electricity generation, calculated as the difference in revenues between the base case and the Transport Rule.

In reality, compliance choices and market conditions can combine such that an entity may actually experience a savings in any of the individual components of cost. Under the Transport Rule, some units will forgo some level of electricity generation (and thus revenues) to comply and this impact will be lessened on these entities by the projected increase in electricity prices under the Transport Rule. On the other hand, those maintaining or

[80] There are 95 entities that are not technically electricity generating utilities so we applied other criteria that would apply to financial or industrial companies and found that they did not meet the definitions of small entities in this context.

increasing generation levels will see an increase in electricity revenues and as a result, lower net compliance costs. If entities are able to increase revenue more than an increase in fuel cost and other operating costs, ultimately they will have negative net compliance costs (or savings). Elsewhere, units burning high or medium sulfur coal might decide to pay relatively more for low-sulfur coal under the Transport Rule and sell allowances on the market, in the hopes of negating some or all of their compliance costs. Overall, small entities are not projected to install relatively costly emissions control retrofits, but may choose to do so in some instances. Because this analysis evaluates the total costs along each of the compliance strategies laid out above for each entity, it inevitably captures savings or gains such as those described. As a result, what we describe as cost is really more of a measure of the net economic impact of the rule on small entities.

For this analysis, EPA used IPM-parsed outputs to estimate costs based on the parameters above, at the unit level. These impacts were then summed for each small entity, adjusting for ownership share. Net impact estimates were based on the following: operating and retrofit costs, sale or purchase of allowances, and the change in fuel costs or electricity generation revenues under the Transport Rule relative to the base case. These individual components of compliance cost were estimated as follows:

(1) Operating and retrofit costs: Using the IPM-parsed output for the base case and the Transport Rule, EPA identified units that install control technology under the Transport Rule and the technology installed. The equations for calculating retrofit costs were adopted from EPA's version of IPM. The model calculates the capital cost (in $/MW); the fixed operation and maintenance (O&M) cost (in $/MW-year); the variable O&M cost (in $/MWh); and the total annualized retrofit cost for units projected to install FGD, DSI, SCR, or SNCR.

(**2) Sale or purchase of allowances:** EPA estimated the value of initial SO2 and NOx annual and NOx ozone season allowance holdings. For both SO2 and NOx, the state emission budgets were assumed to be apportioned to units based on their share of the state's historic heat input (but not exceeding the unit's maximum historic emissions). Using 2006-2010 data, the three highest, non- zero annual heat input values within the 5 year period are selected and averaged for each unit. EPA calculated each unit's SO2 and NOx annual and NOx ozone season allowance allocations as the ratio of that unit's historic heat input to the sum of all units' historic heat input in the applicable state, times the final state budget for existing units. Thus each unit's allocation is the unit's proportional share of the state budget, based on historic heat input. See Allowance Allocations in the Existing and New Units under the Transport Rule Federal Implementation Plans TSD.

To estimate the value of allowances holdings, allocated allowances were subtracted from projected emissions, and the difference was then multiplied by the allowance prices projected by IPM for 2014. Units were assumed to purchase or sell allowances to exactly cover their projected emissions under the Transport Rule.

(3) Fuel costs: Fuel costs were estimated by multiplying fuel input (MMBtu) by region and fuel-type-adjusted fuel prices ($/MMBtu) from IPM. The change in fuel expenditures under the Transport Rule was then estimated by taking the difference in fuel costs between the Transport Rule and the base case.

(4) Value of electricity generated: EPA estimated electricity generation by first estimating unit capacity factor and maximum fuel capacity. Unit capacity factor is estimated by dividing fuel input (MMBtu) by maximum fuel capacity (MMBtu). The maximum fuel capacity was estimated by multiplying capacity (MW) * 8,760 operating hours * heat rate (MMBtu/MWh). The value of electricity generated is then estimated by multiplying capacity (MW) * capacity factor * 8,760 * regional-adjusted retail electricity price ($/MWh), for all entities except those categorized as "Private" in Ventyx. For private entities, EPA used wholesale electricity price instead retail electricity price because most of the private entities are independent power producers (IPP). IPPs sell their electricity to wholesale purchasers and do not own transmission facilities and thus their revenue was estimated with wholesale electricity prices.

As discussed later in this analysis, 70 percent of small entities projected to incur positive costs under the Transport Rule do not have to operate in a competitive market environment and thus should be able to pass compliance costs on to consumers. We defined cost of service regions as regions with a deregulation percentage of less than 20 percent. The deregulation percentage is defined for this analysis as a percentage estimating the degree of competition in electricity market, as provided by EIA. The lower this percentage means that there are more areas with cost of service market characteristics. We have used the estimates published in AEO 2010.

To somewhat account for this cost pass-through, we incorporated the projected regional-adjusted retail electricity price calculated under the Transport Rule in our estimation of generation revenue under the Transport Rule.

(5) Administrative costs: Because most affected units are already monitored as a result of other regulatory requirements, EPA considered the primary administrative cost to be transaction costs related to purchasing or selling allowances. EPA assumed that transaction costs were equal to 1.5 percent of the total absolute value of a unit's allowances. This assumption is based on market research by ICF International.

9.1.2.2 Results

The potential impacts of the Transport Rule on small entities are summarized in Table 9-2. All costs are presented in $2007. EPA estimated the annualized net compliance cost to small entities to be approximately $38 million in 2014. As the table below indicates, net compliance costs for some ownership groups are actually negative, implying the group as a whole is estimated to have cost savings under the Transport Rule. The fact that these groups have net savings does not mean that each small entity in that group would benefit from the Transport Rule. In most cases, the net savings are driven by a few entities that are able to increase their electricity revenues by increasing generation and taking advantage of higher electricity prices.

Table 9-2. Projected Impact of the Transport Rule on Small Entities in 2014

EGU Ownership Type	Number of Potentially Affected Entities	Total Net Compliance Cost ($2007 millions)	Number of Small Entities with Compliance Costs >1% of Generation Revenues	Number of Small Entities with Compliance Costs >3% of Generation Revenues
Cooperative	25	$52.9	7	5
Investor-Owned Utility	9	-$9.9	0	0
Municipal	51	$3.0	15	5
Subdivision	5	-$2.1	0	0
Private	18	-$5.7	2	1
Total	108	$38.1	24	11

Note: The total number of potentially affected entities in this table excludes around 390 entities that have been dropped because they will not be affected by the Transport Rule, because they only own units less than 25 MW.. Also, the total number of entities with costs greater than 1 percent or 3 percent of revenues includes only entities experiencing positive costs. A negative cost value implies that the group of entities experiences a net savings under the Transport Rule. Definitions of types of entities are the following: Cooperative = User-owned utility company; Investor-Owned Utility = Utility owned by stockholders; Municipal = Publicly owned utility; Subdivision = County, municipality, hospital district or school district that receives electric service from an entity; Private = Privately owned electric companies not openly traded on stock markets

Source: IPM analysis

EPA assessed the economic and financial impacts of the rule using the ratio of compliance costs to the value of revenues from electricity generation, focusing in particular on entities for which this measure is greater than 1 percent. Although this metric is commonly used in EPA impact analyses, it makes the most sense when as a general matter an analysis is looking at small businesses that operate in competitive environments. However, small businesses in the electric power industry often operate in a price-regulated environment where they are able to recover expenses through rate increases. Given this, EPA considers the 1 percent measure in this case a crude measure of the price increases these small entities will be asking of rate commissions or making at publicly owned companies.

EPA assessed the potential impact of this action on small entities and found that there are about 660 potentially affected small units (i.e., greater than 25 MW and generating less than 4MM MWh) out of 3,625 existing units greater than 25 MW in the TR region. The majority of these EGUs are owned by entities that do not meet the small entity definition. The remaining 271 of 660 EGUs are owned by 108 potentially affected small entities and are likely to be affected by today's rule. Of the 108 small entities considered in this analysis, 24 entities may experience compliance costs greater than 1 percent of generation revenues in 2014. Entities that experience negative net costs under the Transport Rule are excluded from these totals. These results do not fully account for the reality that about 70 percent of these entities operate in cost of service markets and thus should be able to recover all of their costs of complying with the Transport Rule. In EPA's modeling, most of the cost impacts for these small entities and their associated units are driven by lower electricity generation relative to the base case. Specifically, two units reduce their generation by significant amounts, driving the bulk of the costs for all small entities. Excluding these two units, another driver of small entity impacts for sub-divisions and private small entities is higher fuel costs, which the affected units would be expected to use irrespective of whether they had to comply with this rule. Increased fuel costs are often passed through to rate-payers as common practice in many areas of the U.S. due to fuel adder arrangements instituted by state public utility commissions. Finally, EPA's decision to exclude units smaller than 25 MW has already significantly reduced the burden on potentially small entities by nearly 390. Hence, EPA has concluded that there is no significant economic impact on a substantial number of small entities (No SISNOSE) for this rule. The number of entities with compliance costs exceeding 3 percent of generation revenues is also included in Table 9-2.

The distribution across entities of economic impacts as a share of base case revenue is summarized in Table 9-3. Although the distributions of economic impacts on each ownership type are in general fairly tight, there are a few outliers for which the percentage of economic impacts as a share of revenue is either very low or very high relative to the capacity-weighted average. In the cases where entities are projected to experience negative net impacts that are a high percentage of revenues, these entities have units that are able to increase generation with the Transport Rule or sell excess allowances, thus increasing revenues. In the cases where entities are projected to experience positive net impacts that are a high percentage of revenues, these entities do not find it economic to retrofit and are unable to switch to a lower sulfur coal. Thus, another reason for entities incurring impacts is that they are expected to reduce their generation under the Transport Rule which reduces revenues collected from electricity sales and inflates net costs.

Table 9-3. Summary of Distribution of Economic Impacts of the Transport Rule on Small Entities in 2014

EGU Ownership Type	Capacity-Weighted Average Economic Impacts as a % of Generation Revenues	Min	Max
Cooperative	-0.1%	-13.1%	47.8%
Investor-owned utility	-2%	-13.6%	-0.4%
Municipal	-0.7%	-78.1%	26.0%
Subdivision	-0.4%	-13.2%	6.7%
Private	-3%	-2.0%	0.2%
All	**-1.0%**	**-78.1%**	**47.8%**

Source: IPM analysis

The separate components of annualized costs to small entities under the Transport Rule are summarized in Table 9-4. The most significant components of incremental cost to these entities under the Transport Rule are due to lower electricity revenues as some EGUs reduce their generation under the policy case in IPM. This effect is most prominent for Cooperatives in particular, as two coal units reduce a significant portion of their generation. As discussed above, excluding these two units from the sample, leads to an overall cost savings for the rest of the Co-ops. Allowances purchases also account for a portion of the total costs to small entities. All ownership types, with the exception of municipals, are net purchasers of allowances. Additionally, fuel costs and operating costs appear to decrease for cooperatives, but this is mostly due to one large unit significantly cutting its generation, thus translating to lower variable costs for the whole group. Across all other ownership types, with the exception of municipals, electricity revenues actually increase. This is due largely to the projected increase in electricity prices under the Transport Rule.

Table 9-4. Incremental Annualized Costs under the Transport Rule Summarized by Ownership Group and Cost Category in 2014 ($2007 millions)

EGU Ownership Type	Retrofit + Operating Cost	Net Purchase of Allowances	Fuel Cost	Lost Electricity Revenue	Administrative Cost
Cooperative	-$11.3	$4.9	-$50.7	-$109.8	$0.2
Investor-Owned Utility	$0.2	$1.0	-$0.6	$10.6	$0.0
Municipal	$4.1	-$3.4	-$0.8	-$3.0	$0.1
Subdivision	$0.2	$0.6	$3.1	$6.0	$0.0
Private	$0.3	$3.2	$7.2	$16.5	$0.1
TOTAL	-$6.5	$6.3	-$41.8	-$79.6	$0.5

Source: IPM analysis.

Furthermore, 601 MW of total small entity capacity, or about 1 percent of total small entity capacity in the Transport Rule region, is projected to be uneconomic to maintain under the Transport Rule relative to the base case. To put these numbers in context, of all affected capacity under the Transport Rule, about 4.8 GW (1.6 percent) of coal-fired capacity is projected to be uneconomic to maintain relative to the base case. This comparison suggests that small entities should not be disproportionately affected by the Transport Rule. In practice, units projected to be uneconomic to maintain may be mothballed, retired, or kept in service to ensure transmission reliability in certain parts of the grid. Our IPM modeling is unable to distinguish between these potential outcomes.

9.1.3 Summary of Small Entity Impacts

EPA examined the potential economic impacts to small entities associated with this rulemaking based on assumptions of how the affected states will implement control measures to meet their emissions. To summarize, of the 108 small entities potentially affected, and the 610 small entities in the Transport Rule region that are included in EPA's modeling, 25 may experience compliance costs in excess of 1 percent of revenues in 2014, based on assumptions of how the affected states implement control measures to meet their emissions budgets as set forth in this rulemaking. Potentially affected small entities experiencing compliance costs in excess of 1 percent of revenues have some potential for significant impact resulting from implementation of the Transport Rule. However, as noted above, it is EPA's position that because very few of the affected entities currently operate in a competitive market environment, they should generally be able to pass the costs of complying with the Transport Rule on to rate-payers. Furthermore, the decision to include only units greater than 25 MW in size exempts around 390 potentially small entities that would otherwise be affected by the Transport Rule.

9.2 Unfunded Mandates Reform Act (UMRA) Analysis

Title II of the UMRA of 1995 (Public Law 104-4)(UMRA) establishes requirements for federal agencies to assess the effects of their regulatory actions on state, local, and Tribal governments and the private sector. Under Section 202 of the UMRA, 2 U.S.C. 1532, EPA generally must prepare a written statement, including a cost-benefit analysis, for any proposed or final rule that includes any Federal mandate that may result in the expenditure by State, local, and Tribal governments, in the aggregate, or by the private sector, of $100,000,000 or more ... in any one year. A Federal mandate is defined under Section 421(6), 2 U.S.C. 658(6), to include a Federal intergovernmental mandate and a Federal private sector mandate. A Federal intergovernmental mandate, in turn, is defined to include a regulation that would impose an enforceable duty upon State, Local, or Tribal governments, Section 421(5)(A)(i), 2 U.S.C. 658(5)(A)(i), except for, among other things, a duty that is a condition of Federal assistance, Section 421(5)(A)(i)(I). A Federal private sector mandate includes a regulation that would impose an enforceable duty upon the private sector, with certain exceptions, Section 421(7)(A), 2 U.S.C. 658(7)(A).

Before promulgating an EPA rule for which a written statement is needed under Section 202 of the UMRA, Section 205, 2 U.S.C. 1535, of the UMRA generally requires EPA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective, or least burdensome alternative that achieves the objectives of the rule. EPA included descriptions of three remedy options that it considered when developing its proposed rule: (1) the proposed remedy of State Budgets/Limited Trading, (2) State Budgets/Intrastate Trading, and (3) Direct Controls. Moreover, section 205 allows EPA to adopt an alternative other than the least costly, most cost-effective or least burdensome alternative if the Administrator publishes with the final rule an explanation why that alternative was not adopted.

Furthermore, as EPA stated in the proposal and final rule, EPA is not directly establishing any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments. Thus, under the Transport Rule, EPA is not obligated to develop under Section 203 of the UMRA a small government agency plan.

EPA analyzed the economic impacts of the Transport Rule on government entities and this section presents the results of that analysis. The analysis does not examine potential indirect economic impacts associated with the Transport Rule, such as employment effects in industries providing fuel and pollution control equipment, or the potential effects of electricity price increases on industries and households. Analyses of employment effects and the potential effects of electricity price increases on industries can be found in Chapter 8 of this RIA.

9.2.1 Identification of Government-Owned Entities

Using Ventyx data, EPA identified state- and municipality-owned utilities and subdivisions in the Transport Rule region. EPA then used IPM-parsed output to associate these plants with individual generating units. Entities that did not own at least one unit with a generating capacity of greater than 25 MW were omitted from the analysis because of their exemption from the rule. This exempts 354 entities owned by state or local governments. Additionally, government-owned entities for which IPM does not project generation in 2014 under the base case or the Transport Rule were exempted from this analysis, because they are not projected to be operating and thus will not face the costs of compliance with the Transport Rule. Eleven additional entities were dropped from the analysis for this reason. EPA identified 98 state or municipality-owned utilities that are potentially affected by the Transport Rule, out of a possible 463. These results are summarized in Table 9-5.

9.2.2 Overview of Analysis and Results

After identifying potentially affected government entities, EPA estimated the impact of the Transport Rule in 2014 based on the following:

- total impacts of compliance on government entities and
- ratio of government entity impacts to revenues from electricity generation.

The financial burden to owners of EGUs under the Transport Rule is composed of compliance and administrative costs. This section outlines the compliance and administrative costs for the 98 potentially affected government-owned units in the Transport Rule region.

9.2.2.1 Methodology for Estimating Impacts of the Transport Rule on Government Entities

The primary burden on state and municipal governments that operate utilities under the Transport Rule is the cost of installing control technology on units to meet SO_2 and NO_x emission limits or the cost of purchasing allowances. However, an entity can comply with the Transport Rule through any combination of the following: installing retrofit technologies, purchasing allowances, switching to a cleaner fuel, or reducing emissions through a reduction in generation. Additionally, units with more allowances than needed can sell these allowances on the market. The chosen compliance strategy will be primarily a function of the unit's marginal control costs and its position relative to the marginal control costs of other units.

To attempt to account for each potential control strategy, EPA estimates compliance costs as follows:

$$C_{Compliance} = \Delta\ C_{Operating+Retrofit} + \Delta\ C_{Fuel} + \Delta\ C_{Allowances} + \Delta\ C_{Transaction} + \Delta\ R$$

where C represents a component of cost as labeled, and $\Delta\ R$ represents the retail value of foregone electricity generation.

In reality, compliance choices and market conditions can combine such that an entity may actually experience a savings in any of the individual components of cost. Under the Transport Rule, for example, some units will forgo some level of electricity generation (and thus revenues) to comply. The impact of forgone generation revenues will be lessened by the projected increase in electricity prices under the Transport Rule; while those not reducing generation levels will see an increase in electricity revenues. Because this analysis evaluates the total costs along each of the four compliance strategies laid out above for each entity, it inevitably captures savings or gains such as those described. As a result, what we describe as cost is really more of a measure of the net economic impact of the rule on small entities.

In this analysis, EPA used unit-level IPM-parsed outputs for the base case and the Transport Rule to estimate compliance costs based on the parameters above. These costs were then aggregated for each small government entity, adjusting for ownership share. Compliance cost estimates were based on the following: operating and retrofit costs, sale or purchase of allowances, and the change in fuel costs or electricity generation revenues under the Transport Rule relative to the base case. These components of compliance cost were estimated as follows:

(1) Retrofit and operating costs: Using the IPM-parsed output for the base case and the Transport Rule, EPA identified units that install control technology under the Transport Rule and the technology installed. The equations for calculating retrofit costs for SCR, SNCR, and FGD were adopted from EPA's version of IPM (version 4.10). The model calculates the capital cost (in $/MW), the fixed O&M cost (in $/MW-year), the variable O&M cost (in $/MWh).

(2) Sale or purchase of allowances: EPA estimated the value of initial SO2 and NOx annual and NOx ozone season allowance holdings. For both SO2 and NOx, the state emission budgets were assumed to be apportioned to units based on their share of the state's historic heat input (but not exceeding the unit's maximum historic emissions). Using 2006-2010 data, the three highest, non- zero annual heat input values within the 5 year period are selected and averaged for each unit. EPA calculated each unit's SO2 and NOx annual and NOx ozone season allowance allocations as the ratio of that unit's historic heat input to the sum of all units' historic heat input in the applicable state, times the final state budget for existing units. Thus each unit's allocation is the unit's proportional share of the state budget, based on historic heat input. See Allowance Allocations in the Transport Rule Federal Implementation Plans TSD.

To estimate the value of allowances holdings, allocated allowances were subtracted from projected emissions, and the difference was then multiplied by the allowance price projected by IPM. Units were assumed to purchase or sell allowances to exactly cover their projected emissions under the Transport Rule.

(3) Fuel costs: Fuel costs were estimated by multiplying fuel input (MMBtu) by region and fuel type-adjusted fuel prices ($/MMBtu) from IPM. The change in fuel expenditures under the Transport Rule was then estimated by taking the difference in fuel costs between the Transport Rule and the base case.

(4) Value of electricity generated: EPA estimated electricity generation by first estimating the unit capacity factor and maximum fuel capacity. The unit capacity factor is estimated by dividing fuel input (MMBtu) by maximum fuel capacity (MMBtu). The maximum fuel capacity was estimated by multiplying capacity (MW) * 8,760 operating hours * heat rate (MMBtu/MWh). The value of electricity generated was then estimated by multiplying capacity (MW) * capacity factor * 8,760 * regional-adjusted retail electricity price ($/MWh).

(5) Administrative costs: Because most affected units are already monitored as a result of other regulatory requirements, EPA considered the primary administrative cost to be transaction costs related to purchasing or selling allowances. EPA assumed that transaction costs were equal to 1.5 percent of the total absolute value of a unit’s allowances. This assumption is based on market research by ICF International.

9.2.2.2 Results

A summary of economic impacts on government-owned entities is presented in Table 9-5. According to EPA's analysis, the total net economic impact on each category of government-owned entity (state- and municipality-owned utilities and subdivisions) is expected to be about $26 million in 2014.[81]

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[81] All costs are reported in 2007 dollars.

Table 9-5. Summary of Potential Impacts on Government Entities under the Transport Rule in 2014

EGU Ownership Type	Potentially Affected Entities	Projected Annualized Costs ($2007 millions)	Number of Government Entities with Compliance Costs >1% of Generation Revenues	Number of Government Entities with Compliance Costs >3% of Generation Revenues
Municipal	86	$15.5	25	12
State	6	$0.9	0	0
Subdivision	6	$9.5	1	0
Total	**98**	**$25.9**	**26**	**12**

Note: The total number of potentially affected entities in this table excludes the 365 entities that have been dropped because they will not be affected by the Transport Rule, either because they only own units less than 25 MW (354 entities) or because they would not operate in either the base or the policy cases (the remaining 11 entities). Also, the total number of entities with costs greater than 1 percent or 3 percent of revenues includes only entities experiencing positive costs.

Source: IPM analysis

As was done for the small entities analysis, EPA further assessed the economic and financial impacts of the rule using the ratio of compliance costs to the value of revenues from electricity generation in the base case, also focusing specifically on entities for which this measure is greater than 1 percent. EPA projects that 26 government entities will have compliance costs greater than 1 percent of revenues from electricity generation in 2014. As was true with the small entity analysis, one main driver of cost increases for these government entities appear to be revenue losses due to lower electricity generation relative to the base case. As will be discussed below in more detail, while government entities do face higher costs under the Transport Rule than under the base case, these cost increases are actually lower than what EPA estimated under the proposed rule. Revenues from electricity generation for these entities, however, go down more than what EPA estimated under the proposed Transport Rule, leading to a net cost increase for these entities. Entities that are projected to experience negative compliance costs under the Transport Rule are not included in those totals. This approach is more indicative of a significant impact when an analysis is looking at entities operating in a competitive market environment. Government-owned entities do not operate in a competitive market environment and therefore will be able to recover expenses under the Transport Rule through rate increases. Given this, EPA considers the 1 percent measure in this case a crude measure of the extent to which rate increases will be made at publicly owned companies.

The distribution across entities of economic impacts as a share of base case revenue is summarized in Table 9-6. Although the distributions of economic impacts on each ownership type are in general fairly tight, there are a few outliers for which the percentage of economic impacts as a share of revenue is either very low or very high relative to the capacity-weighted average. This is especially true for municipality-owned entities where the maximum economic impact as a share of base case revenues is approximately 35 percent. Thus, a few municipality-owned entities experience economic impacts that are significantly higher than the capacity-weighted average for this group. Another reason for entities incurring impacts is that they are expected to reduce their generation under the Transport Rule which reduces revenues collected from electricity sales and inflates net costs. In the cases where entities are projected to experience negative net impacts that are a high percentage of revenues, these entities have units that are able to increase generation with the Transport Rule or sell excess allowances, thus increasing revenues.

Table 9-6. Distribution of Economic Impacts on Government Entities under the Transport Rule in 2014

EGU Ownership Type	Capacity-Weighted Average Economic Impacts as a % of Generation Revenues	Min	Max
Municipal	-0.00%	-78.1%	34.5%
State	0.02%	-2.6%	0.6%
Sub-division	0.65%	-2.0%	1.3%
All	**-0.04%**	**-78.1%**	**34.5%**

Source: IPM analysis

The separate components of annualized incremental cost under the Transport Rule to each group of government entities are summarized in Table 9-7. While all groups experience higher costs in general, there is a wide variation in these increases across groups. Municipal entities have the highest retrofit and operating costs as they dominate the universe of affected government entities. Municipal and state entities are net sellers of allowances, which lessens the net impact of the rule for these entities. Sub-divisions are net purchasers of allowances, though the higher electricity revenues for them negate those cost increases as a group. Both sub-divisions and state-owned entities benefit from higher electricity revenues, but they also incur higher fuel costs as they increase their electricity generation. In aggregate, cost increases across the three groups are about $29 million relative to the base case (compared to about $135 million projected in the proposal). As a group, these entities also gain about $3 million in higher electricity revenues (compared to $150 million increased revenues projected in the proposal), resulting in a net increase of about $26 million in impacts under the final rule.

Table 9-7. Incremental Annualized Costs under the Transport Rule Summarized by Ownership Group and Cost Category ($2007 millions) in 2014

EGU Ownership Type	Retrofit + Operating Cost	Net Purchase of Allowances	Fuel Cost	Increased Electricity Revenue	Administrative Cost
Municipal	$28. 8	-$6.9	-$21.6	-$14.4	$0.8
State	$3.6	-$2.8	$7.6	$7.7	$0.1
Subdivision	$0.2	$4.6	$14.5	$9.9	$0.1

Source: ICF International analysis based on IPM analysis

IPM modeling of the Transport Rule projects that approximately 76 MW (4 units) of municipality-owned capacity would be uneconomic to maintain under the Transport Rule, beyond what is projected in the base case. This represents about 0.4 percent of all subdivision, state, and municipality capacity in the Transport Rule region. For comparison, overall affected capacity under the Transport Rule, about 4.2 GW, or 1.6 percent of all coal-fired capacity is projected to be uneconomic to maintain relative to the base case. This comparison suggests that government entities should not face a disproportionate burden under the Transport Rule. In practice, units projected to be uneconomic to maintain may be "mothballed," retired, or kept in service to ensure transmission reliability in certain parts of the grid. Our IPM modeling is unable to distinguish between these potential outcomes.

9.2.3 Summary of Government Entity Impacts

EPA examined the potential economic impacts on state and municipality-owned entities associated with this rulemaking based on assumptions of how the affected states will implement control measures to meet their emissions. According to EPA's analysis, the total net economic impact on government-owned entities is expected to be about $26 million in 2014. Of the 98 government entities considered in this analysis and the 463 government entities in the Transport Rule region that are included in EPA's modeling, 26 may experience compliance costs in excess of 1 percent of revenues in 2014, based on our assumptions of how the affected states implement control measures to meet their emissions budgets as set forth in this rulemaking.

Government entities projected to experience compliance costs in excess of 1 percent of revenues have some potential for significant impact resulting from implementation of the Transport Rule. However, as noted above, it is EPA's position that because these government entities can pass on their costs of compliance to rate-payers, they will not be significantly affected. Furthermore, the decision to include only units greater than 25 MW in size exempts 354 government entities that would otherwise be potentially affected by the Transport Rule.

9.3 Paperwork Reduction Act

In compliance with the Paperwork Reduction Act (44 U.S.C. 3501 et seq.), EPA has submitted a proposed Information Collection Request (ICR) (EPA ICR number 2391.02) to the Office of Management and Budget (OMB) for review and approval. The ICR describes the nature of the information collection and its estimated burden and cost associated with the final rule, including estimates of the anticipated monitoring, reporting, and record-keeping burden and associated costs for states, local governments, and sources. In cases where information is already collected by a related program, the ICR takes into account only the additional burden. This situation arises in states that are also subject to requirements of the Consolidated Emissions Reporting Rule (EPA ICR number 0916.10; OMB control number 2060-0088) or for sources that are subject to the Acid Rain Program (EPA ICR number 1633.13; OMB control number 2060-0258), NO_x SIP Call (EPA ICR number 1857.03; OMB control number 2060-0445), or CAIR (EPA ICR number 2152.04; OMB control number 2060-0570) requirements.

The record-keeping and reporting burden to sources resulting from states choosing to participate in a regional cap-and-trade program is approximately $26 million annually. The total number of burden hours associated with the record-keeping and reporting burden to Transport Rule-affected sources, states, and EPA for states choosing to participate in a regional cap-and-trade program is approximately 185,000 hours annually. These estimates include the annualized cost of installing and operating appropriate SO_2 and NO_x emissions monitoring equipment to measure and report the total emissions of these pollutants from affected EGUs (serving generators greater than 25 megawatts capacity). The burden to state and local air agencies includes any necessary SIP revisions, performance of monitoring certification, and fulfilling of audit responsibilities.

EPA received no adverse comment on the ICR submitted for the proposed Transport Rule (EPA ICR number 2391.01). More information on the ICR analysis is included in the Transport Rule docket.

9.4 Protection of Children from Environmental Health and Safety Risks

Executive Order 13045 (62 FR 19885, April 23, 1997) applies to any rule that: (1) is determined to be "economically significant" as defined under EO 12866, and (2) concerns an environmental health or safety risk that EPA has reason to believe may have a disproportionate effect on children. If the regulatory action meets both criteria, the Agency must evaluate the environmental health or safety effects of this planned rule on children, and explain why this planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the Agency.

This rule is not subject to EO 13045 because it does not involve decisions on environmental health or safety risks that may disproportionately affect children. The EPA believes that the emission reductions from the strategies in this final rule will further improve air quality and will further improve children's health.

9.5 Executive Order 13132, Federalism

Under EO 13132, EPA may not issue an action that has federalism implications, that imposes substantial direct compliance costs, and that is not required by statute, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by State and local governments, or EPA consults with State and local officials early in the process of developing the proposed action.

EPA has concluded that this action does not have federalism implications. It will not impose substantial direct effects on State or local governments, or on the relationship between the Federal government and the States, or on the distribution of power and responsibilities among the various levels of government, as specified in EO 13132. Thus, Executive Order 13132 does not apply to the final rule.

In the spirit of EO 13132, and consistent with EPA policy to promote communications between EPA and State and local governments, EPA did provide information to State and local officials. EPA sent a letter to the ten Representative National Organizations to draw their attention to the Transport Rule Notice of Data Availability (NODA) on allowance allocations and other related matters and to invite their comments. Following that letter in early 2011, EPA participated in informational calls with the Environmental Councils of the States (ECOS) and the National Governors Association to provide information about the NODA directly to State and local officials. There were no new concerns raised during these informational calls.

9.6 Executive Order 13175, Consultation and Coordination with Indian Tribal Governments

Subject to EO 13175 (65 FR 67249, November 9, 2000) EPA may not issue a regulation that has Tribal implications, that imposes substantial direct compliance costs, and that is not required by statute, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by Tribal governments, or EPA consults with Tribal officials early in the process of developing the proposed regulation and develops a Tribal summary impact statement. EO 13175 requires EPA to develop an accountable process to ensure "meaningful and timely input by tribal officials in the development of regulatory policies that have tribal implications."

EPA has concluded that this action may have Tribal implications. However, it will neither impose substantial direct compliance costs on Tribal governments, nor preempt Tribal law. EPA consulted with tribal officials during the process of finalizing this regulation to permit them to have meaningful and timely input into its development.

EPA received comments on the proposed rule that the Agency did not properly conduct consultation during the proposal phase of the rulemaking. In response to these comments, EPA sent a letter to all federally-recognized tribes in the country offering consultation. In addition, several comments also noted that the Agency did not adequately consider opportunities for tribes to enter into any of the trading programs and, in particular, did not consider sovereignty issues when addressing how to distribute allowances to potential new units in Indian country. On January 7, 2011, EPA issued a NODA requesting comment on allocations for new units in Indian country, among other topics. The Agency held a formal consultation call with three tribes on January 21, 2011. A follow up call was held on Feb. 4, 2011 with 11 tribes. EPA considered the additional input from these consultation and information calls, in conjunction with the public comments, in the development of the final rule. Accordingly, EPA created an Indian country new unit set-aside to specifically address tribes's concerns regarding the protection of tribal sovereignty in the distribution of allowances for new units in Indian country.

As required by section 7(a) of the Executive Order, EPA's Tribal Consulation official has certified that the requirements of the Executive Order have been met in a meaningful and timely manner. A copy of the certification is included in the docket for this action.

9.7 Environmental Justice

Executive Order (EO) 12898 (59 FR 7629 (Feb. 16, 1994)) establishes federal executive policy on environmental justice. Its main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States.

9.7.1. Consideration of Environmental Justice Issues in the Rule Development Process

During development of this final Transport Rule, EPA considered its impacts on low-income, minority, and tribal communities in several ways. EPA's assessment included a) the structure of the rule and responses to comments received on the proposed rule on issues specific to these communities; b) expected SO2 and NOX emission reductions; c) expected PM2.5 and ozone air quality improvements; d) expected health benefits, including asthma and other health effects of particular concern for environmental justice communities; and e) a quantitative assessment of the expected socioeconomic distribution of a key health benefit (reduction in premature mortality). This last analysis, the distributional analysis, estimated the $PM_{2.5}$ mortality risks according to race, income, and educational attainment before and after implementation of the Transport Rule. A description of these analyses and the conclusions reached can be found in section XII. J of the preamble for this final Transport Rule.

Briefly, all of these analyses indicate large health and environmental benefits for susceptible and vulnerable populations as a result of implementing this Transport Rule. The final rule will provide significant health and environmental benefits to numerous low-income, minority, and tribal individuals in both rural areas and inner cities in the region affected by this rule. This includes, among others, people with asthma, people with heart disease, and people living in ozone or fine particle ($PM_{2.5}$) nonattainment areas.

The distributional analysis indicates that the populations with the largest improvement (i.e. largest decline) in PM2.5 mortality risk as a result of the Transport Rule in 2014 (compared to the base case in 2014) are people living in the highest-risk counties. Among these counties, the largest improvements are for people with less than high school or high school education. These reductions in risk within the highest-risk counties, as well as the reductions in risk within the other 95 percent of counties, are distributed among populations of different races fairly evenly. Therefore, there is no indication that people of particular race receive a greater benefit (or smaller benefit) than others. None of the analyses, including the distributional analysis, showed evidence of adverse effects for any socioeconomic group.

These analyses are based on the same data and modeling tools used for the other analyses of this Transport Rule. A detailed description of the underlying data and analytical techniques used can be found in Chapter 3 of this RIA (emissions), Chapter 4 (air quality), and Chapter 5 (benefits). The analysis of the human health benefits of the rule, including the socioeconomic distribution of mortality benefits among different populations, is described in Appendix A of this RIA.

9.7.2. Meaningful Public Participation

During the comment period for the proposed rule, EPA reached out specifically to environmental justice communities and organizations to notify them of the opportunity to provide comments on this rule and to solicit their comments on both the proposed rule and upcoming actions. EPA held public hearings on this rule and received an extensive number of comments in writing. EPA has responded to these comments as part of this final rulemaking.

CHAPTER 10

COMPARISON OF BENEFITS AND COSTS

10.1 Comparison of Benefits and Costs

As shown in Chapter 8, the estimated social costs to implement the final Transport Rule, as described in this document, are approximately $0.81 billion in 2014 (2007 dollars). As shown in Chapter 5, the estimated benefits from implementation of the final Transport Rule are approximately $120 to 280 billion + $110 to 250 billion + B in 2014 (2007 dollars, based on a discount rate of 3 percent and 7 percent, respectively and rounded to three significant figures) EPA can thus calculate the net benefits of the final rule by subtracting the estimated social costs from the estimated benefits in 2014. The annual net benefits of the final Transport rule are approximately $120 to 280 + B billion using a 3 percent discount rate or $110 to 250 + B billion using a 7 percent discount rate. (B represents the sum of all unquantified benefits and disbenefits of the regulation.) Therefore, EPA expects that implementation of this rule, based solely on economic efficiency criteria, will provide society with a significant net gain in social welfare, notwithstanding the expansive set of health and environmental effects we were unable to quantify. Further quantification of directly emitted $PM_{2.5}$-, mercury-, acidification-, and eutrophication-related impacts would increase the estimated net benefits of the rule. Table 10-1 presents a summary of the benefits, costs, and net benefits of the final rule.

As explained in Chapter 5, EPA presents two types of probabilistic approaches to characterize uncertainty in the benefit estimates for the Transport Rule. The first approach generates a distribution of benefits based on the classical statistical error expressed in the underlying health and economic valuation studies used in the benefits modeling framework. The second approach uses the results from a pilot expert elicitation project designed to characterize key aspects of uncertainty in the ambient $PM_{2.5}$/mortality relationship, and augments the uncertainties in the mortality estimate with the statistical error reported for other endpoints in the benefit analysis.

EPA also analyzed the costs and benefits of two alternative scenarios that impose relatively more stringent and relatively less stringent SO_2 budgets in Group 1 states, compared to the final Transport Rule, beginning in 2014, in accordance with Circular A-4 Guidance (OMB, 2003). These scenarios are illustrative of the cost and benefit impacts of varying program stringency. They are designed to show the effects of more stringent and less stringent SO_2 reduction requirements in a regulatory structure that is otherwise the same as the remedy.

Both of the alternative scenarios represent an interstate trading program to achieve emission reductions, as in the final Transport rule remedy. Both alternative scenarios impose the same NOx and SO_2 emission reduction requirements in 2012 as imposed by the final Transport Rule. The options vary in stringency for the SO_2 budgets in Group 1 states that exist in the final rule's remedy, which are modeled on emission reductions in 2014 available for those states up to a marginal cost of $2,300 per ton.[82] Beginning in 2014, the less stringent alternative scenario imposes higher SO_2 budgets in Group 1 states based on modeled emissions from the $1,600 per ton cost threshold analysis described in preamble section VI.B. The more stringent alternative scenario reflects 2014 reduction requirements based on modeled emissions at the $10,000 per ton cost threshold.

Air quality modeling was not conducted for these two alternatives. EPA applied a benefit- per-ton approach appropriate for deriving PM-related benefits for these alternative scenarios from the full benefit estimation methodology conducted for the final Transport Rule's remedy, as described in Chapter 5. The alternative scenarios' social costs are estimated using the Multimarket Model while using the private compliance costs are projected using IPM. Table 10-2 presents the emissions forecast for SO_2 and NOx in 2014 under the Transport Rule and the more or less stringent scenarios. Table 10-3 presents the estimated social costs and health benefits, including net social benefit, of the two alternative scenarios alongside corresponding estimates for the final Transport Rule remedy.

[82] The Group 1 states are Illinois, Indiana, Iowa, Kentucky, Maryland, Michigan, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin.

Table 10-1. Summary of Annual Benefits, Costs, and Net Benefits of the Final Transport Rule in 2014[a] (billions of 2007 dollars)

Description	Preferred Remedy
Social costs[b]	
3 percent discount rate	$0.81
7 percent discount rate	$0.81
Social benefits[c,d,e]	
3 percent discount rate	$120 to $280 + B
7 percent discount rate	$110 to $250 + B
Health-related benefits:	
3 percent discount rate	$110 to $270 + B
7 percent discount rate	$100 to $250 + B
Visibility benefits	$4.1
Net benefits (benefits-costs)[e,f]	
3 percent discount rate	$120 to $280
7 percent discount rate	$110 to $250

[a] Estimated rounded to two significant figures.

[b] Note that costs are the annualized total social costs of reducing pollutants including NO_x and SO_2 for the EGU source category in the final Transport Rule region in 2014. Social costs are estimated using the MultiMarket model, the model employed by EPA in this RIA to estimate economic impacts to industries outside the electric power sector. This model does not estimate indirect impacts associated with a regulation such as this one. More information on the social costs can be found in Chapter 8 and Appendix B of this RIA.

[c] Total benefits are comprised primarily of monetized PM-related health benefits. The reduction in premature fatalities each year accounts for over 90 percent of total monetized benefits. Benefits in this table are nationwide (with the exception of ozone and visibility) and are associated with NO_x and SO_2 reductions. Ozone benefits represent benefits nationwide. Visibility benefits represent benefits in Class I areas in the southeast, southwest and California. The estimate of social benefits also includes CO_2-related benefits calculated using the social cost of carbon, discussed further in Chapter 5.

[d] Not all possible benefits or disbenefits are quantified and monetized in this analysis. B is the sum of all unquantified benefits and disbenefits. Potential benefit categories that have not been quantified and monetized are listed in Table 1-4.

[e] Valuation assumes discounting over the SAB-recommended 20-year segmented lag structure. Results reflect the use of 3 percent and 7 percent discount rates consistent with EPA and OMB guidelines for preparing economic analyses (EPA, 2010; OMB, 2003).

[f] Net benefits are rounded to three significant figures. Columnar totals may not sum due to rounding.

Table 10-2. Projected 2014 National Emissions of SO_2 and NO_X with the Base Case (No Further Controls) and with Transport Rule (Million Tons) and for More and Less Stringent Scenarios.

Pollutant	*Base Case*	*Selected Remedy*	*Less Stringent Scenario*	*More Stringent Scenario*
SO_2 (Annual)	**7.2**	**3.4**	**3.5**	**2.4**
NO_X (Annual)	**2.1**	**1.9**	**1.8**	**1.8**
NO_X (Ozone Season)	**0.9**	**0.8**	**0.8**	**0.8**

Table 10-3. Summary of PM Annual Health Benefits, Costs, and Net Benefits of Versions of the Selected Remedy Option in 2014[a] (billions of 2007 dollars)

Description	*Selected Remedy*	*Less Stringent Scenario*	*More Stringent Scenario*
Social costs[b]			
3 percent discount rate	\$0.81	\$0.43	\$3.6
7 percent discount rate	\$0.81	\$0.43	\$3.6
Health PM benefits[c,d]			
3 percent discount rate	\$110 to \$270 + B	\$98 to \$240 + B	\$130 to \$320 + B
7 percent discount rate	\$100 to \$250 + B	\$89 to \$220 + B	\$120 to \$290 + B
Net benefits (benefits-costs)[e,f]			
3 percent discount rate	\$110 to \$270 + B	\$98 to \$240 + B	\$130 to \$320 + B
7 percent discount rate	\$100 to \$250 + B	\$88 to \$220 + B	\$120 to \$290 + B

[a] Estimates rounded to two significant figures.

[b] Note that costs are the annualized total social costs of reducing pollutants including NO_x and SO_2 for the EGU source category in the final Transport Rule region in 2014. Social costs are estimated using the MultiMarket model, the model employed by EPA in this RIA to estimate economic impacts to industries outside the electric power sector. This model does not estimate indirect impacts associated with a regulation such as this one. More information on the social costs can be found in Chapter 8 and Appendix B of this RIA.

[c] Due to methodological limitations, the health benefits of these remedy options include $PM_{2.5}$ –related benefits but omit visibility, ozone, and CO_2-related benefits. We present the $PM_{2.5}$ –related benefits of the preferred

remedy, omitting these other important benefits, so that readers may compare directly the benefits of the preferred and alternate remedies. Total benefits are comprised primarily of the value of PM-related avoided premature mortalities. The reduction in these premature mortalities in each year account for over 90 percent of total $PM_{2.5}$-related monetized benefits. Benefits in this table are nationwide and are associated with NO_x and SO_2 reductions. To ensure that the benefits of the selected remedy and the more and less stringent scenarios are directly comparable, we exclude the visibility-related benefits of the selected remedy from this table; these visibility-related benefits are approximately $ 4.1 billion (2007$).

[d] Not all possible benefits or disbenefits are quantified and monetized in this analysis. B is the sum of all unquantified benefits and disbenefits. Potential benefit categories that have not been quantified and monetized are listed in Table 1-5.

[e] Valuation assumes discounting over the SAB-recommended 20-year segmented lag structure. Results reflect the use of 3 percent and 7 percent discount rates consistent with EPA and OMB guidelines for preparing economic analyses (EPA, 2010; OMB, 2003).

[f] Net benefits are rounded to three significant figures. Columnar totals may not sum due to rounding.

* The 2014 compliance costs (incremental to the base case) for the selected remedy, less stringent scenario, and more stringent scenario are approximately $0.8, $0.4 and $3.6 billion in 2007 dollars.

10.2 References

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Appendix A

Distribution of the $PM_{2.5}$-Related Benefits Among Vulnerable and Susceptible Populations

Characterizing the distribution of health impacts across the population

This analysis aims to answer two principal questions regarding the distribution of $PM_{2.5}$-related benefits resulting from the implementation of the final Transport Rule:

1. What is the baseline distribution of $PM_{2.5}$-related mortality risk according to the race, income and education of the population?
2. How does the Transport Rule change the distribution of risk among populations of different races—particularly among those populations at greatest risk in the baseline?83

In this analysis we find that the level of $PM_{2.5}$ mortality risk is not distributed equally throughout the U.S., or among populations of different levels of educational attainment—though the level of mortality risk appears to be shared fairly equally among populations of different races. We find that the Transport Rule provides air quality improvements, and lowers $PM_{2.5}$-related mortality risk, fairly equally among minority populations and greatly reduces $PM_{2.5}$ mortality risk among those populations at greatest risk in the baseline.

Methodology

As a first step, we estimate the level of $PM_{2.5}$-related mortality risk in each county in the continental U.S. based on 2005 air quality levels, which provides a baseline against which projected changes in $PM_{2.5}$ risk attributable to the Transport rule may be compared. This portion of the analysis follows an approach described elsewhere (Fann et al. 2011a, Fann et al. 2011b), wherein modeled 2005 $PM_{2.5}$ levels are used to calculate the proportion of all-cause mortality risk attributable to total $PM_{2.5}$ levels in each county in the Continental U.S. Within each county we estimate the level of all-cause $PM_{2.5}$ mortality risks for adult populations as well as the level of $PM_{2.5}$ mortality risk according to the race, income and educational attainment of the population.

83 In this analysis we assess the change in risk among populations of different race, income and educational attainment. As we discuss further in the methodology, we consider this last variable because of the availability of education-modified $PM_{2.5}$ mortality risk estimates.

Our approach to calculating $PM_{2.5}$ mortality risk is generally consistent with the primary analysis with the two exceptions: the PM mortality risk coefficients used to quantify impacts and the baseline mortality rates used to calculate mortality impacts (a detailed discussion of how both the mortality risk coefficients and baseline incidence rates are used to estimate the incidence of $PM_{2.5}$-related deaths may be found in the benefits chapter). We substitute risk estimates drawn from the Krewski et al. (2009) extended analysis of the ACS cohort. In particular, we applied the all-cause mortality risk estimate random effects Cox model that controls for 44 individual and 7 ecological covariates, using average exposure levels for 1999-2000 over 116 U.S. cities (Krewski et al. 2009) (RR=1.06, 95% confidence intervals 1.04—1.08 per 10µg/m^3 increase in $PM_{2.5.}$ This mean relative risk estimate is identical to the Pope et al. (2002) risk estimate applied for the primary analysis (thought the standard error around the mean RR estimate is slightly different).

Within both this and other analyses of the ACS cohort (see: Krewski et al. 2000), educational attainment has been found to be inversely related to the risk of all-cause mortality. That is, populations with lower levels of education (in particular, < grade 12) are more vulnerable to $PM_{2.5}$-related mortality. Krewski and colleagues note that "…the level of education attainment may likely indicate the effects of complex and multifactorial socioeconomic processes on mortality…", factors that we would like to account for in this EJ assessment. When estimating PM mortality impacts among populations according to level of education, we applied $PM_{2.5}$ mortality risk coefficients modified by educational attainment: less than grade 12 (RR = 1.082, 95% confidence intervals 1.024—1.144 per 10 µg/m^3 change), grade 12 (RR = 1.072, 95% confidence intervals 1.020—1.127 per 10 µg/m^3 change), and greater than grade 12 (RR = 1.055, 95% confidence intervals 1.018—1.094 per 10 µg/m^3 change). The Pope et al. (2002) study does not provide education-stratified RR estimates. The principal reason we applied risk estimates from the Krewski study was to ensure that the risk coefficients used to estimate all-cause mortality risk and education-modified mortality risk were drawn from a consistent modeling framework.

The other key difference between this distributional analysis and the primary analysis relates to the baseline mortality rates. As described in the benefits chapter, we calculate PM-related mortality risk relative to baseline mortality rates in each county. Traditionally we have applied county-level age- and sex-stratified rates when calculating these impacts (Abt, 2008). For the calculation of PM impacts by race, we incorporated race-specific (stratified by White/Black/Asian/Native American) baseline mortality rates. This approach improves our ability to characterize the relationship between race and susceptibility to $PM_{2.5}$-related mortality.

The result of this analysis is a distribution of $PM_{2.5}$ mortality risk estimates by county, stratified by each of the three population variables (race, income and educational attainment). We next identified the counties at or above the median and upper 95th percentile of the $PM_{2.5}$ mortality risk distribution. We selected this percentile cut-off to capture the very highest levels of $PM_{2.5}$ mortality risk. The second step of the analysis was to repeat the sequence above by estimating $PM_{2.5}$ mortality risk in 2014 prior to, and after, the implementation of the Transport Rule. We also report the per-person $PM_{2.5}$ exposure for each of the three scenarios (2005, 2014, 2014 post-Transport Rule) by populations of different race.

Results

The level of $PM_{2.5}$ exposure and mortality risk among all populations declines significantly between 2005, 2014 prior to, and then after, the implementation of the Transport Rule (Table 1, Figures 1—3). In each figure we outline in yellow those counties at or above the 2005 median risk level. The number of counties at or above this level falls significantly between 2005 and the implementation of the 2014 Transport Rule, suggesting that the combination of this rule as well as others being implemented between 2005 and 2014 greatly reduce the level of PM mortality risk among adult populations.

We next stratify the PM mortality risk according to race, income and educational attainment. For these analyses we estimated the change in PM mortality risk between 2005 and 2014 among populations living in those counties at the upper 95th percentile of the mortality risk in the 2005 baseline; we then compared the change in risk among these populations living in high-risk counties with populations living in all other counties. Figures 4—6 summarize these results. Tables 2-4 enumerate the data used to construct these figures.

In Figure 4, we plot the level of PM mortality risk among populations of different races according to whether those populations live in counties identified as “greater risk” counties or “all other counties.” As described above, we define “greater risk” counties as those at or above the 95th percentile of $PM_{2.5}$ mortality risk in 2005, and “all other counties” as those with $PM_{2.5}$ mortality risk below this level. The results of this analysis suggest that the $PM_{2.5}$ mortality risk among these populations at “greater risk” falls significantly between 2005, 2014 and the implementation of the 2014 Transport Rule. Upon implementing the 2014 Transport Rule, the estimated $PM_{2.5}$ mortality risk among these populations is roughly equal to the level of $PM_{2.5}$

mortality risk experienced by those populations in “all other counties” in 2005. These results also suggest that all populations, irrespective of race, are receiving a reduction in $PM_{2.5}$ mortality risk; limits to data resolution prevent us from delineating the PM mortality risk according to population race with confidence.

In Figure 5, we illustrate the change in the level of $PM_{2.5}$ mortality risk among populations living in those counties that meet two criteria: (1) the county is at the upper 95^{th} percentile of mortality risk in 2005; (2) the county is at the upper 95^{th} percentile in terms of the number of individuals living below the poverty line. We also estimate the change in $PM_{2.5}$ risk among all other counties. The analysis indicates that people living in the highest risk and poorest counties will experience a larger improvement in PM2.5 mortality risk than those living in lower risk counties containing a smaller number of individuals living below the poverty line..

In Figure 6, we summarize the change in $PM_{2.5}$ mortality risk among populations who have attained three alternate levels of education—less than highschool, highschool and greater than highschool. As described above, we apply education-stratified $PM_{2.5}$ mortality risk coefficients for this analysis. These results indicate that populations with less than a highschool education are at higher risk of $PM_{2.5}$ mortality in 2005, irrespective of whether these populations live in “greater risk” counties, according to the definition described above. Between 2005 and the 2014 Transport Rule, all populations see their mortality risk fall, regardless of educational attainment.

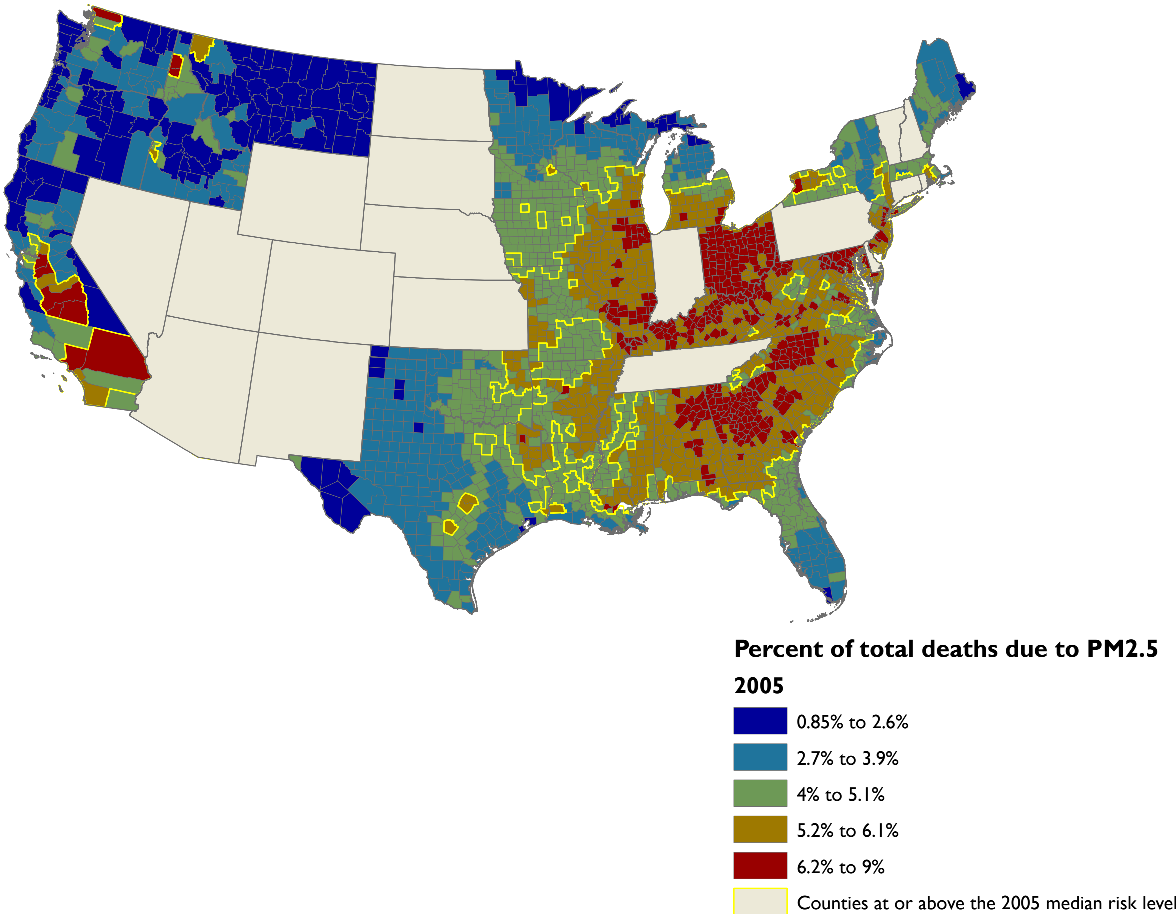


Figure 1: Distribution of $PM_{2.5}$ mortality risk in 2005

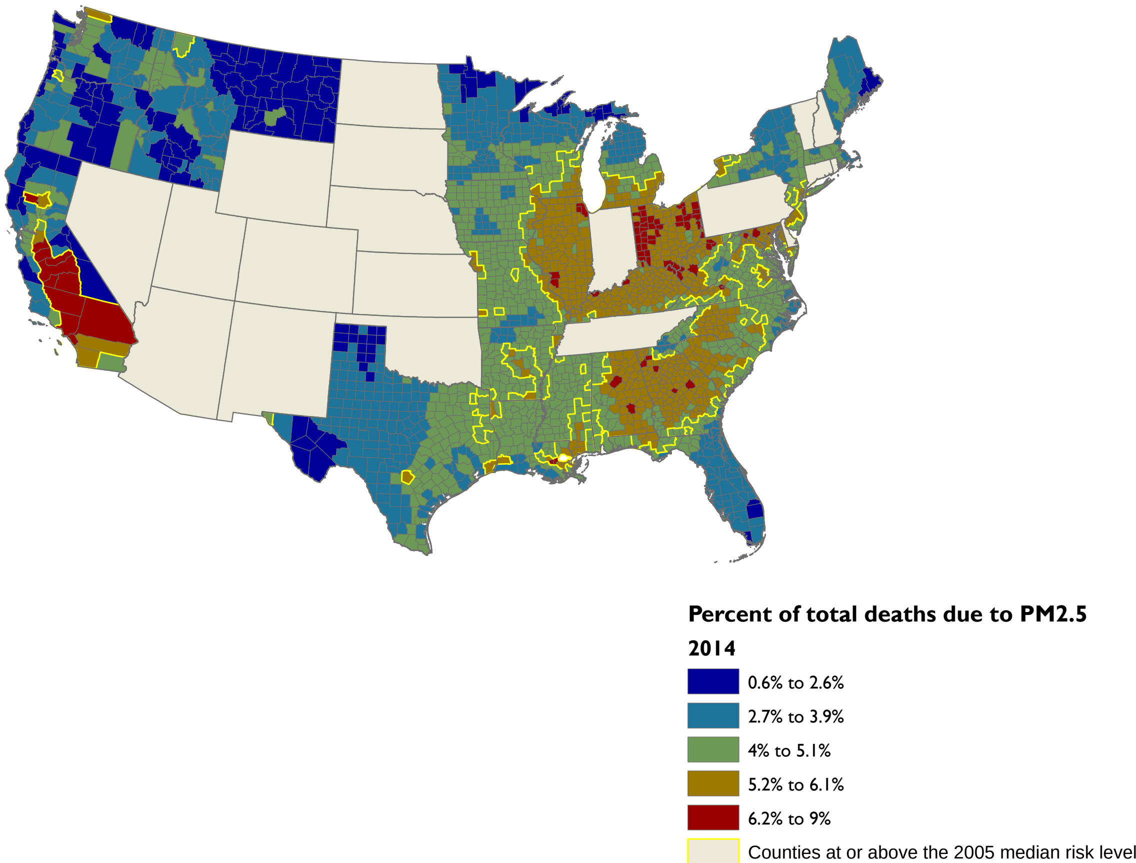


Figure 2: Distribution of $PM_{2.5}$ mortality risk in 2014 (prior to the implementation of the Transport Rule)

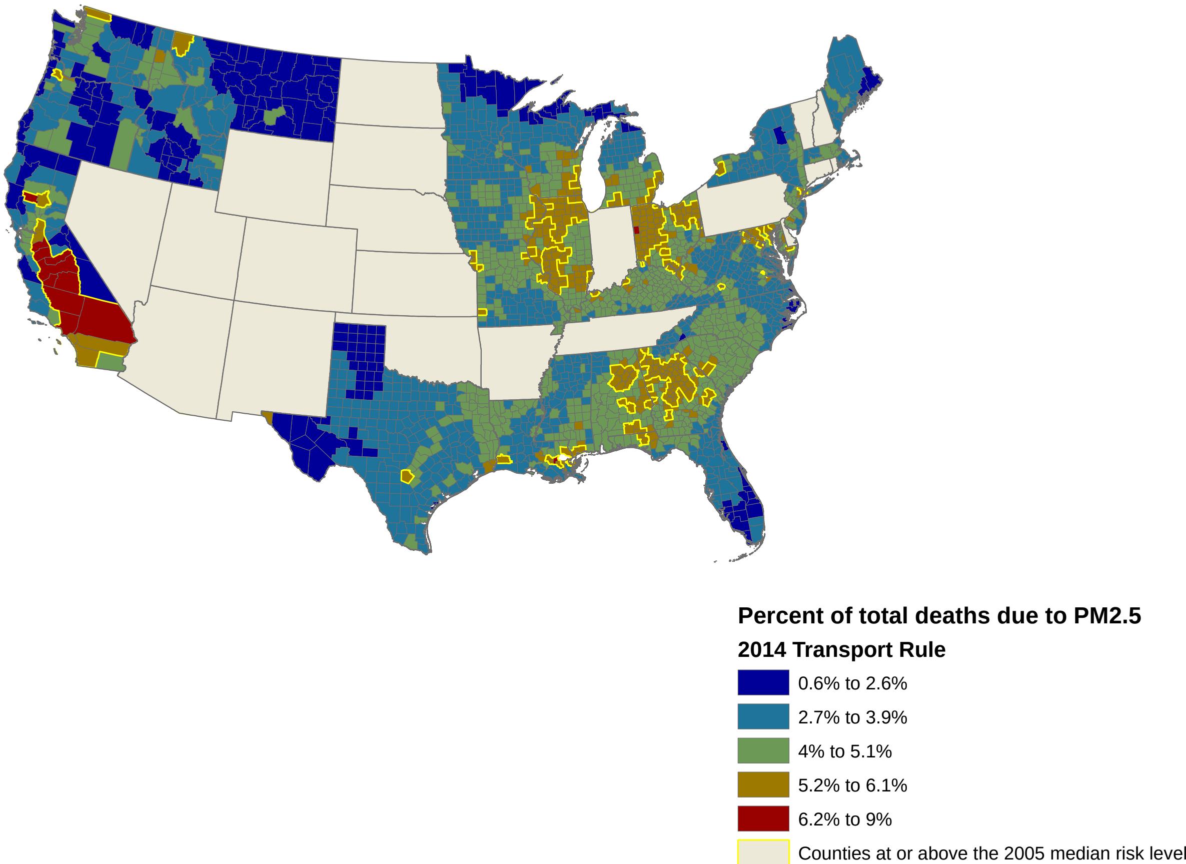
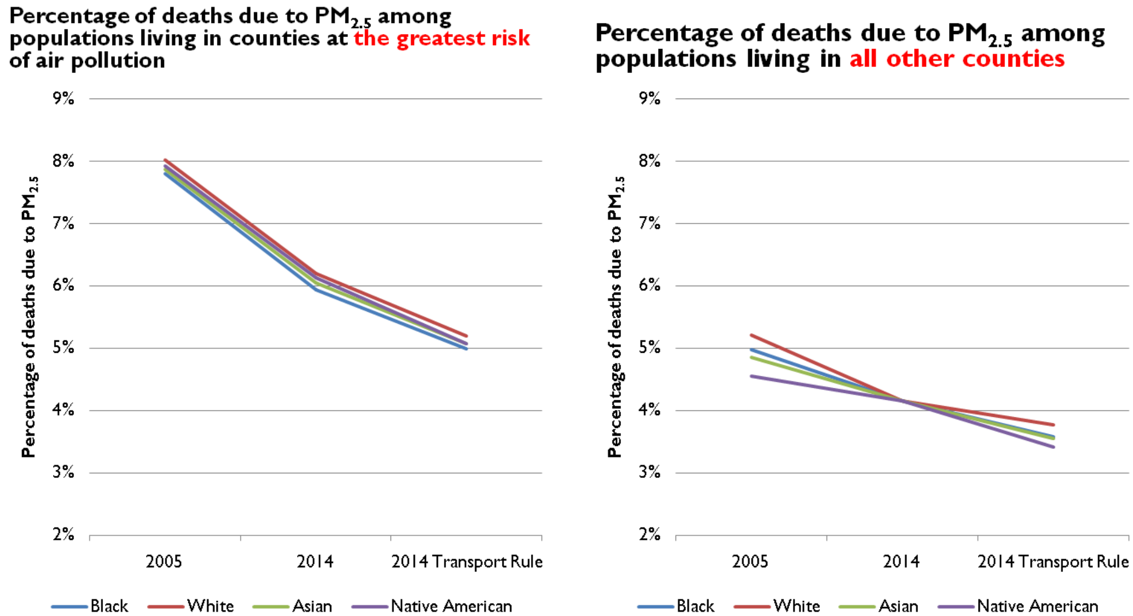


Figure 3: Distribution of $PM_{2.5}$ mortality risk in 2014 (after the implementation of the Transport Rule)

Table 1: Per-person level of annual mean $PM_{2.5}$ exposure (μg/m^3/person) between 2005 and the 2014 Transport Rule

Year	**Race**			
	Asian	*Black*	*Native American*	*White*
2005	11.5	12.1	9	10.7
2014 (pre-Transport Rule)	9.4	9.6	7.7	8.7
2014 (post-Transport Rule	8.9	8.5	7.1	7.8

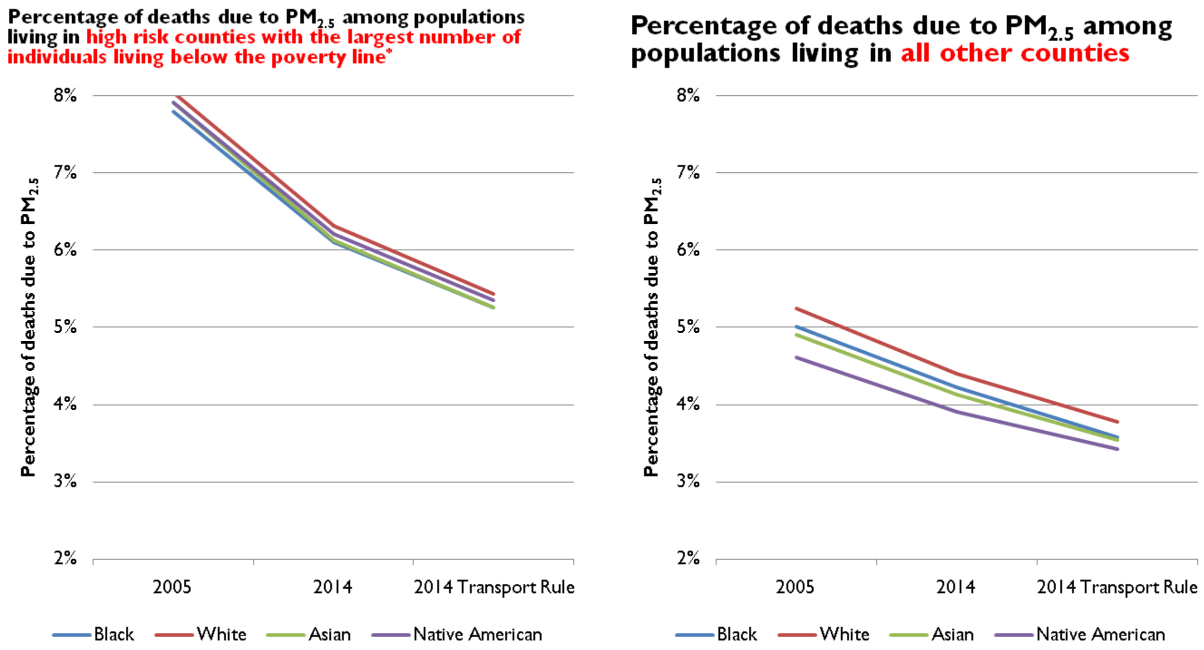


*Data are not sensitive enough to delineate the relative level of $PM_{2.5}$ mortality risk among races with confidence. However, we are more confident that populations, irrespective of race, receive a substantial health benefit.

Figure 4: Change in the percentage of $PM_{2.5}$-attributable deaths by race between 2005 and the implementation of the 2014 Transport Rule

Table 2: Numerical values used for Figure 4 above

Year	**Race**			
	Asian	*Black*	*Native American*	*White*
Among populations at greater risk				
2005	7.9%	7.8%	7.9%	8.0%
2014 (pre-Transport Rule)	6.2%	5.9%	6.1%	6.2%
2014 (post-Transport Rule	5.1%	5%	5.1%	5.2%
Among all other populations				
2005	4.9%	5.0%	4.5%	5.2%
2014 (pre-Transport Rule)	4.2%	4.2%	4.2%	4.2%
2014 (post-Transport Rule	3.5%	3.6%	3.4%	3.8%

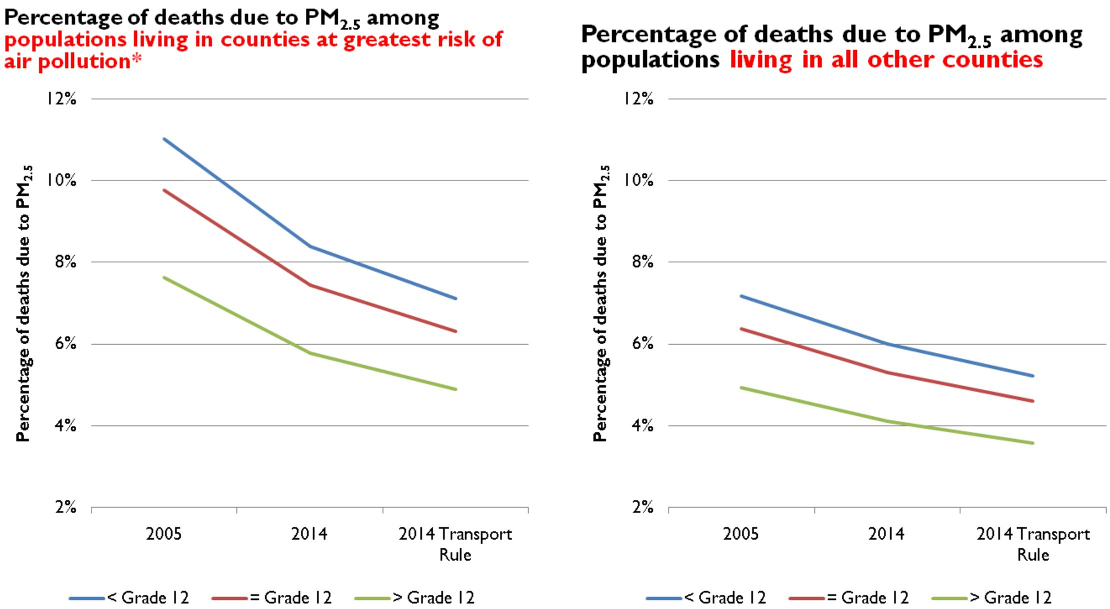


*The upper 95th percentile of counties with the highest $PM_{2.5}$ mortality risk and the largest number of individuals living below the census-defined poverty line.

Figure 5: Change in the percentage of $PM_{2.5}$-attributable deaths among populations by poverty level between 2005 and the implementation of the 2014 Transport Rule

Table 3: Numerical values used for Figure 5 above

Year	**Race**			
	Asian	*Black*	*Native American*	*White*
Among populations living in counties with the largest number of individuals living below the poverty line				
2005	7.9%	7.8%	7.9%	8%
2014 (pre-Transport Rule)	6.1%	6.1%	6.2%	6.3%
2014 (post-Transport Rule	5.3%	5.3%	5.4%	5.4%
Among all other populations				
2005	4.9%	5%	4.6%	5.3%
2014 (pre-Transport Rule)	4.1%	4.2%	3.9%	4.4%
2014 (post-Transport Rule	3.5%	3.6%	3.4%	3.8%



*Analysis uses PM risk estimates that account for the increased level of baseline risk experienced by those populations with lower levels of educational attainment.

Figure 6: Change in the percentage of $PM_{2.5}$-attributable deaths among populations by educational attainment between 2005 and the implementation of the 2014 Transport Rule

Table 4: Numerical values used for Figure 6 above

Year	**Race**		
	< Grade 12	*= Grade 12*	*> Grade 12*
Among populations at greater risk			
2005	11.0%	9.1%	7.5%
2014 (pre-Transport Rule)	8.4%	7.4%	5.8%
2014 (post-Transport Rule	7.1%	6.3%	4.9%
Among all other populations			
2005	7.2%	6.4%	4.9%
2014 (pre-Transport Rule)	6%	5.3%	4.1%
2014 (post-Transport Rule	5.2%	4.6%	3.6%

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APPENDIX B
OAQPS MULTIMARKET MODEL TO ASSESS THE ECONOMIC IMPACTS OF ENVIRONMENTAL REGULATION

B.1 Introduction

An economic impact analysis (EIA) provides information about a policy's effects (i.e., social costs); emphasis is also placed on how the costs are distributed among stakeholders (EPA, 2010). In addition, large-scale policies that may affect a large number of industries or a substantial part of the whole economy require additional analysis to better understand how costs are passed across the economy. Although several tools are available to estimate social costs, current EPA guidelines suggest that multimarket models "…are best used when potential economic impacts and equity effects on related markets might be considerable" and modeling using a computable general equilibrium model is not available or practical (EPA, 2010, p. 9-21). Other guides for environmental economists offer similar advice (Berck and Hoffmann, 2002; Just, Hueth, and Schmitz, 2004).

Multimarket models focus on "short-run" time horizons and measure a policy's near term or transition costs (EPA, 1999). Recent studies suggest short-run analyses can complement full dynamic general equilibrium analysis.

The multimarket model described in this appendix is a relatively new addition to the Office of Air Quality Planning and Standards' (OAQPS's) economic model tool kit; it is designed to be used as a transparent tool that can respond quickly to requests about how stakeholders in 100 U.S. industries might respond to new environmental policy. It was used to analyze the economic impacts of the industrial boiler NESHAP and CISWI final rules recently signed by EPA. Next, we provide an overview of the model, data, and parameters.

B.2 Multimarket Model

The multimarket model contains the following features:

Industry sectors and benchmark data set

100 industry sectors
a single benchmark year (2015)[84]

[84] As mentioned in Chapter 8, we use 2015 as a proxy for 2014 in order to maintain consistency between the analysis from this model and the IPM outputs (generated for 2015, as mentioned in Chapter 7) that serve as inputs to this analysis.

Economic behavior

- industries respond to regulatory costs by changing production rates
- market prices rise to reflect higher energy and other nonenergy material costs
- customers respond to these price increases and consumption falls

Model scope

- 100 sectors are linked with each other based on their use of energy and other nonenergy materials. For example, the construction industry is linked with the petroleum, cement, and steel industries and is influenced by price changes that occur in each sector. The links allow EPA to account for indirect effects the regulation has on related markets.

- Links come from input-output information from IMPLAN as used in OAQPS's computable general equilibrium (CGE) model, the Economic Model for Policy Analysis (EMPAX)

- production adjustments influence employment levels

- international trade (imports/exports) behavior considered

Model time horizon ("short-run")

- fixed production resources (e.g., capital) leads to an upward-sloping industry supply function

  firms cannot alter input mixes; there is no substitution among intermediate production inputs

- investment and government expenditures are fixed.

Labor and Capital Markets and Pre-existing Distortions in Other Markets

- Unlike CGE models, our multimarket model does not include a national labor or capital market. As a result, we do not estimate real wage changes, changes in labor /leisure choices, or savings and investment decisions within the model. Therefore we do not consider whether policies interact with existing distortions, particularly tax distortions in a ways that increase or decrease estimates of the social cost. Since savings and investment decisions are not modeled, social costs associated with capital stock changes are also not considered.

B.2.1 Industry Sectors and Benchmark Data Set

The multimarket model includes 100 industries. For the benchmark year, the model uses information from OAQPS's computable general equilibrium model's balanced social accounting matrix (SAM) and the following accounting identity holds:

$$\text{Output} + \text{Imports} = \text{Consumption} + \text{Investment} + \text{Government} + \text{Exports} \qquad \text{(E.1)}$$

If we abstract and treat each industry as a national market, the identity represents the prepolicy (baseline) market-clearing condition, or benchmark "equilibrium"; supply equals demand in each market. In Table B-1, we identify the 100 industries for the multimarket model; Table B-2 provides the 2015 benchmark data set. Since the benchmark data are reported in value terms, we also use the common "Harberger convention" and choose units where are all prices are one in the benchmark equilibrium (Shoven and Whalley, 1995).

Table B-1. Industry Sectors Included in Multimarket Model

Industry Label	*Description*	*Representative NAICS*[a]
Energy Industries		
COL	Coal	2121
CRU	Crude Oil Extraction	211111 (exc. nat gas)
ELE	Electric Generation	2211
GAS	Natural Gas	211112 2212 4862
OIL	Refined Petroleum	324
Nonmanufacturing		
AGR	Agricultural	11
MIN	Mining	21 less others
CNS	Construction	23
Manufactured Goods		
Food, beverages, and textiles		
ANM	Animal Foods	3111
GRN	Grain Milling	3112
SGR	Sugar	3113
FRU	Fruits and Vegetables	3114
MIL	Dairy Products	3115
MEA	Meat Products	3116
SEA	Seafood	3117
BAK	Baked Goods	3118
OFD	Other Food Products	3119
BEV	Beverages and Tobacco	312
TEX	Textile Mills	313
TPM	Textile Product Mills	314
WAP	Wearing Apparel	315
LEA	Leather	316
Lumber, paper, and printing		
SAW	Sawmills	3211
PLY	Plywood and Veneer	3212
LUM	Other Lumber	3219
PAP	Pulp and Paper Mills	3221
CPP	Converted Paper Products	3222
PRN	Printing	323
Chemicals		
CHM	Chemicals and Gases	3251
RSN	Resins	3252
FRT	Fertilizer	3253
MED	Drugs and Medicine	3254
PAI	Paints and Adhesives	3255
SOP	Soap	3256
OCM	Other Chemicals	3259

(continued)

Table B-1. Industry Sectors Included in Multimarket Model (continued)

Industry Label	*Description*	*Representative NAICS*[a]
Plastics and Rubber		
PLS	Plastic	3261
RUB	Rubber	3262
Nonmetallic Minerals		
CLY	Clay	3271
GLS	Glass	3272
CEM	Cement	3273
LIM	Lime and Gypsum	3274
ONM	Other Non-Metallic Minerals	3279
Primary Metals		
I_S	Iron and Steel	3311 3312 33151
ALU	Aluminum	3313 331521 331524
OPM	Other Primary Metals	3314 331522 331525 331528
Fabricated Metals		
FRG	Forging and Stamping	3321
CUT	Cutlery	3322
FMP	Fabricated Metals	3323
BOI	Boilers and Tanks	3324
HRD	Hardware	3325
WIR	Springs and Wires	3326
MSP	Machine Shops	3327
EGV	Engraving	3328
OFM	Other Fabricated Metals	3329
Machinery and Equipment		
CEQ	Construction and Agricultural Equipment	3331
IEQ	Industrial Equipment	3332
SEQ	Service Industry Equipment	3333
HVC	HVAC Equipment	3334
MEQ	Metalworking Equipment	3335
EEQ	Engines	3336
GEQ	General Equipment	3339
Electronic Equipment		
CPU	Computers	3341
CMQ	Communication Equipment	3342
TVQ	TV Equipment	3343
SMI	Semiconductor Equipment	3344
INS	Instruments	3345
MGT	Magnetic Recording Equipment	3346
LGT	Lighting	3351
APP	Appliances	3352

(continued)

Table B-1. Industry Sectors Included in Multimarket Model (continued)

Industry Label	*Description*	*Representative NAICS*[a]
Electronic Equipment (continued)		
ELQ	Electric Equipment	3353
OEQ	Other Electric Equipment	3359
Transportation Equipment		
M_V	Motor Vehicles	3361
TKB	Truck Bodies	3362
MVP	Motor Vehicle Parts	3363
ARC	Aircraft	3364
R_R	Rail Cars	3365
SHP	Ships	3366
OTQ	Other Transport Equipment	3369
Other		
FUR	Furniture	337
MSC	Miscellaneous Manufacturing	339
Services		
Wholesale and Retail Trade		
WHL	Wholesale Trade	42
RTL	Retail Trade	44–45
Transportation Services		
ATP	Air Transportation	481
RTP	Railroad Transportation	482
WTP	Water Transportation	483
TTP	Freight Truck Transportation	484
PIP	Pipeline Transport	486
OTP	Other Transportation Services	485 487 488
Other Services		
INF	Information	51
FIN	Finance and Insurance	52
REL	Real Estate	53
PFS	Professional Services	54
MNG	Management	55
ADM	Administrative Services	56
EDU	Education	61
HLT	Health Care	62
ART	Arts	71
ACM	Accommodations	72
OSV	Other Services	81
PUB	Public Services	92

[a] NAICS = North American Industry Classification System. Industry assignments are based on data used in the EMPAX-modeling system, which relies on the commodity code system used in IMPLAN.

Table B-2. 2015 Benchmark Data Set (billion 2007$)

Industry Label	*Industry Description*	*Output*	*Imports*	*Consumption*	*Investment and Government*	*Exports*
ACM	Accommodations	$940	$7	$919	$20	$8
ADM	Administrative Services	$923	$39	$885	$72	$5
AGR	Agricultural	$349	$71	$390	$6	$25
ALU	Aluminum	$81	$21	$88	$4	$10
ANM	Animal Foods	$50		$41	Less than $1	$10
APP	Appliances	$34	$26	$48	$8	$4
ARC	Aircraft	$257	$57	$68	$116	$129
ART	Arts	$286		$276	$3	$7
ATP	Air Transportation	$174	$34	$98	$30	$80
BAK	Baked Goods	$68	$4	$69	$3	Less than $1
BEV	Beverages and Tobacco	$157	$62	$217	$1	$1
BOI	Boilers and Tanks	$35	$3	$22	$10	$5
CEM	Cement	$74		$68	$4	$3
CEQ	Construction and Agricultural Equipment	$95	$31	$61	$42	$23
CHM	Chemicals and Gases	$355	$124	$409	$12	$58
CLY	Clay	$12	$6	$14	$1	$3
CMQ	Communication Equipment	$96	$43	$60	$57	$23
CNS	Construction	$1,393	$107	$816	$684	Less than $1
COL	Coal	$48	$2	$46		$4
CPP	Converted Paper Products	$60	$2	$48	$7	$7
CPU	Computers	$193	$85	$171	$52	$54
CRU	Crude Oil Extraction	$75	$213	$289		
CUT	Cutlery	$13	$6	$11	$6	$3
EDU	Education	$1,122		$296	$810	$15
EEQ	Engines	$46	$18	$37	$8	$20
EGV	Engraving	$26		$11	$6	$9
ELE	Electric Generation	$339	Less than $1	$304	$35	Less than $1
ELQ	Electric Equipment	$46	$21	$31	$22	$14
FIN	Finance and Insurance	$2,345	$157	$2,308	$51	$144
FMP	Fabricated Metals	$85	$4	$77	$9	$3
FRG	Forging and Stamping	$25	Less than $1	$22	$1	$2
FRT	Fertilizer	$53	$6	$40	$5	$14
FRU	Fruits and Vegetables	$82	$14	$85	$5	$6
FUR	Furniture	$78	$42	$104	$14	$2

(continued)

Table B-2. 2015 Benchmark Data Set (billion 2007$) (continued)

Industry Label	*Industry Description*	*Output*	*Imports*	*Consumption*	*Investment and Government*	*Exports*
GAS	Natural Gas	$150	$34	$170	$7	$7
GEQ	General Equipment	$72	$41	$62	$31	$20
GLS	Glass	$37	Less than $1	$21	$3	$12
GRN	Grain Milling	$86	$10	$83	$2	$11
HLT	Health Care	$2,154		$2,108	$22	$24
HRD	Hardware	$10	$5	$6	$4	$4
HVC	HVAC Equipment	$46	$12	$36	$13	$8
I_S	Iron and Steel	$156	$53	$181	$12	$16
IEQ	Industrial Equipment	$35	$18	$21	$18	$15
IFN	Information	$1,502	$84	$1,409	$162	$13
INS	Instruments	$145	$47	$89	$64	$38
LEA	Leather	$4	$25	$28	Less than $1	$1
LGT	Lighting	$16	$15	$23	$7	$2
LIM	Lime and Gypsum	$9		$2	$1	$7
LUM	Other Lumber	$57	$3	$45	$12	$3
M_V	Motor Vehicles	$304	$180	$346	$86	$52
MEA	Meat Products	$193	$11	$189	$5	$10
MED	Drugs and Medicine	$318	$131	$379	$22	$49
MEQ	Metalworking Equipment	$30	$13	$20	$17	$6
MGT	Magnetic Recording Equipment	$19	$2	$15	$3	$4
MIL	Dairy Products	$96	$4	$94	$5	$2
MIN	Mining	$65	$3	$39	$15	$13
MNG	Management	$560	$10	$453	Less than $1	$116
MSC	Miscellaneous Manufacturing	$213	$134	$221	$60	$65
MSP	Machine Shops	$48	$2	$40	$7	$4
MVP	Motor Vehicle Parts	$246	$92	$254	$19	$64
OCM	Other Chemicals	$56	$2	$28	$11	$19
OEQ	Other Electric Equipment	$43	$22	$38	$10	$16
OFD	Other Food Products	$102	$9	$102	$2	$7
OFM	Other Fabricated Metals	$71	$35	$64	$27	$15
OIL	Refined Petroleum	$650	$171	$728	$19	$74
ONM	Other Non-Metallic Minerals	$18	$7	$22	$1	$3
OPM	Other Primary Metals	$51	$34	$66	$3	$16
OSV	Other Services	$2,628		$1,676	$602	$351

(continued)

Table B-2. 2015 Benchmark Data Set (billion 2007$) (continued)

Industry Label	*Industry Description*	*Output*	*Imports*	*Consumption*	*Investment and Government*	*Exports*
OTP	Other Transportation Services	$350		$300	$27	$23
OTQ	Other Transport Equip	$26	$9	$17	$11	$7
PAI	Paints and Adhesives	$44	$2	$36	$3	$7
PAP	Pulp and Paper Mills	$151	$25	$154	$6	$16
PFS	Professional Services	$2,439	$87	$2,002	$490	$34
PIP	Pipeline Transport	$44	$101	$50	Less than $1	$95
PLS	Plastic	$173	$19	$169	$5	$17
PLY	Plywood and Veneer	$26	$11	$35	$1	$2
PRN	Printing	$57	$1	$39	$11	$7
PUB	Public Services	$1,248	$54	$406	$896	Less than $1
R_R	Rail Cars	$13	$2	$7	$3	$5
REL	Real Estate	$3,165	$2	$2,975	$111	$81
RSN	Resins	$133	$29	$117	$7	$38
RTL	Retail Trade	$1,688	$58	$1,652	$82	$12
RTP	Railroad Transportation	$79	Less than $1	$49	$7	$23
RUB	Rubber	$45	$24	$43	$17	$10
SAW	Sawmills	$40	$12	$49	$1	$3
SEA	Seafood	$14	$4	$16	$1	$1
SEQ	Service Industry Equipment	$38	$31	$30	$31	$9
SGR	Sugar	$38	$7	$40	$2	$3
SHP	Ships	$43	$6	$15	$25	$8
SMI	Semiconductor Equipment	$188	$85	$197	$14	$61
SOP	Soap	$100	$6	$89	$4	$14
TEX	Textile Mills	$28	$11	$32	$1	$6
TKB	Truck Bodies	$67	$12	$39	$25	$15
TPM	Textile Product Mills	$26	$18	$37	$3	$4
TTP	Freight Truck Transportation	$337	$49	$295	$37	$54
TVQ	TV Equipment	$24	$46	$63	$4	$3
WAP	Wearing Apparel	$23	$90	$112	$1	Less than $1
WHL	Wholesale Trade	$1,535	$37	$1,219	$174	$178
WIR	Springs and Wires	$7		$2	$1	$3
WTP	Water Transportation	$50		$15	$13	$22

B.2.2 Economic Behavior

B.2.2.1 U.S. Supply

In a postpolicy scenario (e.g. the preferred trading remedy in the Transport Rule), industry responds to changes in the new market-clearing “net” price for the good or service sold:

$$\%\Delta\text{"net" price} = \%\Delta\text{ market price} - \%\Delta\text{ direct costs} - \%\Delta\text{ indirect costs} \qquad (E.2)$$

The %Δ direct costs are approximated using the IPM cost analysis and baseline value of output. For example, with the $0.8 billion increase in compliance costs for the electricity sector in 2014, IPM projects a 0.77 percent increase in the retail price of electricity as mentioned in Chapter 7 of this RIA. For the electric power sector (EPS), percentage change in direct costs would be represented in the model as follows:

$$\%\Delta\text{ direct costs} = 0.77\% \qquad (E.3)$$

To ensure the market-clearing electricity price matches IPM results, we adjust the supply elasticity to reflect a horizontal supply function (i.e. supply is infinitely elastic near market equilibrium).

The multimarket model simultaneously considers how the policy influences other industry supply functions (via changes in energy and other intermediate material prices). As a result, the multimarket model can provide additional information about how policy costs (higher electricity prices) are transmitted through the economy in the short run. As shown in Figure B-1, the higher electricity prices provide other industries with incentives to alter production rates at current market prices; market prices must rise to maintain the original prepolicy production levels (Q). As shown in Figure B-2, the other indirect cost change provides the industry with additional incentives to alter production rates at current market prices.

The %Δ indirect effects associated with each input are approximated using an input “use” ratio and the price change that occurs in the input market.

$$\%\Delta\text{ indirect costs} = \text{input use ratio x }\%\Delta\text{ input price} \qquad (B.4)$$

The social accounting matrix provides an internally consistent estimate of the use ratio and describes the dollar amount of an input that is required to produce a dollar of output. Higher ratios suggest strong links between industries, while lower ratios suggest weaker links. Given the short time horizon such as that for this analysis with a compliance year of 2014 or earlier, we assume the input use ratio is fixed and cannot adjust their input mix; this is a standard assumption in public and commercial input-output (IO) and SAM multiplier models (Berck and Hoffmann, 2002). Morgenstern and colleagues (2004) and Ho and colleagues (2008) also use this assumption when examining near-term effects of environmental policy.

Figure B-1. Higher Electricity Prices Reduce Other Sector Production Rates at Benchmark Prices

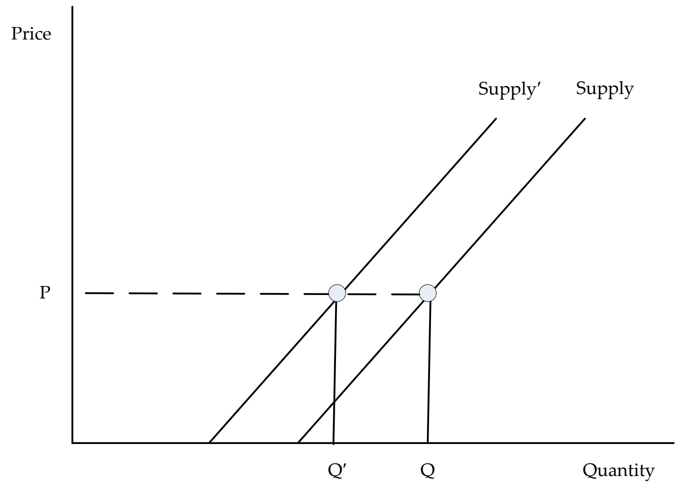
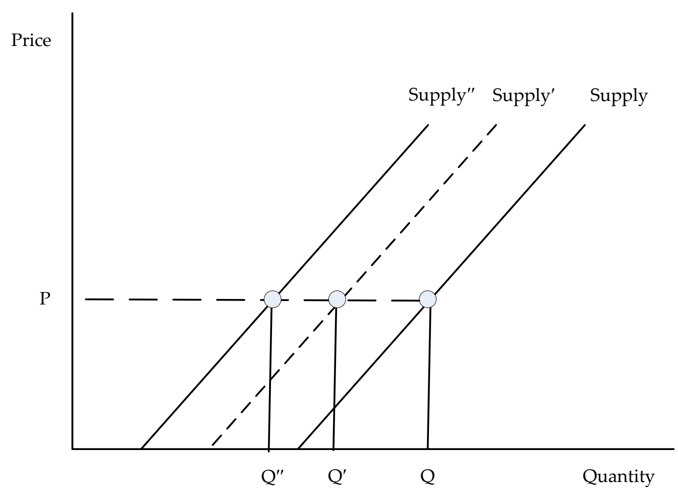


Figure B-2. Indirect Costs Further Reduce Production Rates at Benchmark Prices



Following guidance in the OAQPS economic resource manual (EPA, 1999), we use a general form for the U.S. industry supply function:

$$Q'_g = b\left(P'_g - t - \sum_{i=1}^{n} \alpha_{gi}(P'_i - P_i)\right)^{\varepsilon_g} \tag{E.5}$$

where

Q'_g = with-policy supply quantity (g)

b = calibrated scale parameter for the supply price relationship

P'_g = with-policy price for output (g)

t = direct compliance costs per unit of supply

α_{gi} = input use ratio (g using input i)

P'_i = with-policy input (i) price

P_i = benchmark input (i) price

ε_g = price elasticity of supply for output (g)

The key supply parameter that controls the industry production adjustments is the price elasticity of supply (ε_g). To our knowledge, there is no existing empirical work that estimates short-run supply elasticities for all industry groups used in the multimarket model. As a result, we assume the U.S. supply elasticities are a function of econometrically estimated rest-of-world (ROW) export supply elasticities (see discussion in the next section). We report the values currently available in the model in Table B-5.

B.2.2.2 International Competition

International competition is captured by a single ROW supply function:

$$Q'_g = c\left(P'_g\right)^{\varepsilon_g^{ROW}} \tag{B.6}$$

where

Q'_g = with-policy supply quantity (g)

c = calibrated scale parameter for the supply and price relationship

P'_g = with-policy U.S. price for output (g)

ε_g^{ROW} = price elasticity of supply of goods from the ROW to the United States (imports) (g)

The key supply parameter that controls the ROW supply adjustments is the price elasticity of supply (ε_g^{ROW}). We obtained these estimates for a variety of industry groups from a recently published article by Broda and colleagues (2008b).

B.2.2.3 Price Elasticity of Supply: Rest of World (ROW)

Broda and colleagues (2008a and 2008b) provide an empirical basis for the multimarket model supply elasticities. Broda et al. provide over 1,000 long-run trade elasticities that RTI organized to be comparable with the 100-sector model. The first step was to match the Harmonized Trade System (HS) elasticities estimated in the article to the appropriate NAICS codes. Many of the HS codes correspond with a detailed NAICS codes (5- and 6-digit level), while the multimarket sector industries typically correspond with more aggregated sectors (NAICS 2-, 3-, or 4-digit levels). To adapt these labels to our model, we combined the 5- and 6-digit NAICS under their 3- and 4-digit codes and calculated an average elasticity value for codes that fell within the multimarket model's aggregate industrial sectors.85 This gives a crude way to account for the variety of products detailed in the original data set. We also restricted the long-run elasticity sample to those that Broda et al. classify as "medium" and "low" long-run categories; these categories tend to have lower elasticity values that are more likely to be consistent with the multimarket model's modeling horizon (i.e., in the short run, importers are likely to have less flexibility to respond to price changes implying the elasticities are low rather than high).[86]

Our ideal preference was to use an exact 3- or 4-digit match from the medium category if one was available. If the multimarket model had a 4-digit code for which there was no direct match, we aggregated up a level and applied the relevant 3-digit elasticity. If a multimarket code was not covered in the medium set of elasticities, we used the low elasticity category. This method was sufficient for mapping the majority of the sectors in the model. After applying our inverse elasticity values to the multimarket sectors, we calculated the inverse of the value to arrive at the actual supply elasticity. Since Broda et al.'s article focused on industrial production goods, some of the multimarket sectors were not covered in the elasticity data. These sectors included mainly service industries, transportation, and energy sources.

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[85] Given Broda et al.'s research design, the parameter estimates reported are inverse export supply elasticities. For example, a reported parameter estimate for inverse export supply elasticity of 1.6 would imply a ROW supply elasticity of 1/1.6, or 0.6. A one percent increase in the domestic price lead to an 0.6 increase in the volume of goods supplied (i.e., exported) to the U.S. by other countries (p. 2043).

[86] Broda et al.'s intent was to use these categories to describe or proxy for domestic market power.

Table B-5. Supply Elasticities

Industry Label	*Industry Description*	*Rest of World (ROW)*	*U.S.*
ACM	Accommodations	0.7	0.7
ADM	Administrative Services	0.7	0.7
AGR	Agricultural	1.0	1.0
ALU	Aluminum	0.8	0.5
ANM	Animal Foods	1.1	0.8
APP	Appliances	0.9	0.8
ARC	Aircraft	0.9	0.6
ART	Arts	0.7	0.7
ATP	Air Transportation	0.7	0.7
BAK	Baked Goods	0.8	0.7
BEV	Beverages and Tobacco	2.9	2.9
BOI	Boilers and Tanks	1.1	0.8
CEM	Cement	0.9	0.7
CEQ	Construction and Agricultural Equipment	0.8	0.6
CHM	Chemicals and Gases	1.1	0.8
CLY	Clay	0.8	0.6
CMQ	Communication Equipment	2.5	1.0
CNS	Construction	0.7	0.7
COL	Coal	2.2	2.2
CPP	Converted Paper Products	0.9	0.7
CPU	Computers	1.0	0.7
CRU	Crude Oil Extraction	3.7	3.7
CUT	Cutlery	1.4	1.1
EDU	Education	0.7	0.7
EEQ	Engines	1.2	1.0
EGV	Engraving	1.1	0.8
ELE	Electric Generation	[a]	[a]
ELQ	Electric Equipment	0.8	0.6
FIN	Finance and Insurance	0.7	0.7
FMP	Fabricated Metals	1.2	1.1
FRG	Forging and Stamping	1.6	1.5

(continued)

Table B-5. Supply Elasticities (continued)

Industry Label	*Industry Description*	*Rest of World (ROW)*	*U.S.*
FRT	Fertilizer	1.0	0.7
FRU	Fruits and Vegetables	1.0	0.7
FUR	Furniture	1.9	1.9
GAS	Natural Gas	12.2	12.2
GEQ	General Equipment	1.0	0.7
GLS	Glass	0.8	0.6
GRN	Grain Milling	1.7	1.5
HLT	Health Care	0.7	0.7
HRD	Hardware	1.1	0.8
HVC	HVAC Equipment	0.9	0.6
I_S	Iron and Steel	1.0	0.6
IEQ	Industrial Equipment	0.9	0.6
INF	Information	0.7	0.7
INS	Instruments	0.9	0.6
LEA	Leather	0.9	0.7
LGT	Lighting	1.1	0.7
LIM	Lime and Gypsum	0.9	0.7
LUM	Other Lumber	0.9	0.7
M_V	Motor Vehicles	1.3	0.7
MEA	Meat Products	1.2	3.9
MED	Drugs and Medicine	1.3	1.0
MEQ	Metalworking Equipment	0.7	0.5
MGT	Magnetic Recording Equipment	1.0	0.7
MIL	Dairy Products	1.1	0.9
MIN	Mining	2.2	2.2
MNG	Management	0.7	0.7
MSC	Miscellaneous Manufacturing	1.0	0.8
MSP	Machine Shops	1.1	0.8
MVP	Motor Vehicle Parts	0.9	0.6
OCM	Other Chemicals	1.1	0.6
OEQ	Other Electric Equipment	1.0	0.7
OFD	Other Food Products	1.1	0.7

(continued)

Table B-5. Supply Elasticities (continued)

Industry Label	*Industry Description*	*Rest of World (ROW)*	*U.S.*
OFM	Other Fabricated Metals	0.9	0.6
OIL	Refined Petroleum	1.0	0.7
ONM	Other Non-metallic Minerals	1.5	0.7
OPM	Other Primary Metals	0.7	0.5
OSV	Other Services	0.7	0.7
OTP	Other Transportation Services	0.7	0.7
OTQ	Other Transport Equipment	1.0	0.7
PAI	Paints and Adhesives	1.0	0.7
PAP	Pulp and Paper Mills	1.1	0.7
PFS	Professional Services	0.7	0.7
PIP	Pipeline Transport	2.0	2.0
PLS	Plastic	1.0	0.7
PLY	Plywood and Veneer	1.3	1.3
PRN	Printing	1.0	0.7
PUB	Public Services	0.7	0.7
R_R	Rail Cars	1.8	0.7
REL	Real Estate	0.7	0.7
RSN	Resins	1.0	0.7
RTL	Retail Trade	0.7	0.7
RTP	Railroad Transportation	0.7	0.7
RUB	Rubber	1.3	1.1
SAW	Sawmills	0.8	0.6
SEA	Seafood	1.1	0.8
SEQ	Service Industry Equipment	0.8	0.6
SGR	Sugar	1.1	0.8
SHP	Ships	1.0	0.7
SMI	Semiconductor Equipment	1.2	1.0
SOP	Soap	0.8	0.6
TEX	Textile Mills	1.0	0.7
TKB	Truck Bodies	3.2	3.1
TPM	Textile Product Mills	0.8	0.6
TTP	Freight Truck Transportation	0.7	0.7
TVQ	TV Equipment	5.8	5.4

(continued)

Table B-5. Supply Elasticities (continued)

Industry Label	*Industry Description*	*Rest of World (ROW)*	*U.S.*
WAP	Wearing Apparel	1.2	0.8
WHL	Wholesale Trade	0.7	0.7
WIR	Springs and Wires	1.9	0.8
WTP	Water Transportation	0.7	0.7

[a] For this analysis, EPA adjusted the domestic supply elasticity parameter to approximate a horizontal market supply function. This allows the multi-market model to replicate the predicted retail price changes estimated by IPM.

Note: RTI mapped Broda et al. data for their industry aggregation to the multimarket model's 100 industries. Domestic supply elasticities are typically assumed to be within one standard deviation of the sample of supply elasticities used for the ROW. In selected cases where this information is not available, the U.S. supply elasticity is set equal to the ROW.

Source: Broda, C., N. Limao, and D. Weinstein. 2008a. "Export Supply Elasticities." http://faculty.chicagobooth.edu/christian.broda/website/research/unrestricted/TradeElasticities/TradeElasticities.html. Accessed September 2009.

In order to fill these gaps, we turned to the source substitution elasticities from Purdue University's Global Trade Analysis Project (GTAP).[87] Although the elasticities in the GTAP model are a different type of international trade elasticity and cannot be directly applied in the multimarket model (e.g., they are based on the Armington structure[88]), the parameters provide us with some additional information about the relative trade elasticity differences between industry sectors. To use the GTAP information to develop assumptions about the multimarket model sectors with missing elasticities, we chose a base industrial sector (iron and steel) for which we had parameter value from Broda et al. Next, we developed industry-specific ratios for missing industries using the corresponding GTAP sector trade elasticities and the GTAP iron and steel sector. We multiplied the resulting ratio by the Broda et al. iron and steel parameter (1.0). For example, the GTAP trade elasticity for coal (6.10) is approximately 2.2 times the trade elasticity for iron and steel (2.95). As a result, the multimarket import supply elasticity for coal is computed as 2.2 (2.2 x 1.0).

[87] See Chapter 14 of the GTAP 7 Database Documentation for the full description of the parameters at https://www.gtap.agecon.purdue.edu/resources/download/4184.pdf; see Table 14.2 for elasticities.

[88] Detailed documentation of the entire GTAP 7 Database is available at https://www.gtap.agecon.purdue.edu/databases/v7/v7_doco.asp. The GTAP also uses a unique system of categorizing commodities that does not match the NAICS or HS system exactly.

B.2.2.4 Price Elasticity of Supply: United States

We also used Broda et al.'s elasticities to derive a set of domestic supply elasticities for the model. We have assumed that a product's domestic supply would be equal to or less elastic than other countries' supply of imports. When we aggregated and averaged the original elasticities to the 3- and 4-digit NAICS level for our foreign supply elasticities, we also calculated the standard deviation of each 3- and 4-digit NAICS sample. By adding the standard deviation to the corresponding foreign supply and then taking the inverse, we were able to calculate a domestic supply elasticity for each sector that was lower than its foreign counterpart while maintaining the structure of the original elasticities. For sectors in which no standard deviation was available,[89] we used professional judgment to apply the closest available substitute from a similar industry. Without a comparable way of scaling our foreign elasticities for the sectors in which we used the GTAP elasticities, we elected to keep the domestic and foreign supply elasticities the same.

B.2.2.5 Demand

Uses for industry output are divided into three groups: investment/government use, domestic intermediate uses, and other final use (domestic and exports). Given the short time horizon, investment/government does not change. Intermediate use is determined by the input use ratios and the industry output decisions.

$$Q'_i = \alpha_{gi} Q'_g \qquad \text{(B.7)}$$

Q'_i = with-policy input demand quantity (i)

α_{gi} = input use ratio (g using input i)

Q'_g = with-policy output quantity (g)

Other final use does respond to market price changes. Following guidance in the OAQPS economic resource manual (EPA, 1999), we use a general form for the U.S. industry demand function:

$$Q'_g = a\left(P'_g\right)^{\eta_g} \qquad \text{(B.8)}$$

where

Q'_g = with-policy demand quantity (g)

[89] No standard deviations were calculated for the 3- and 4-digit codes that had only one observation (i.e., Broda et al.'s model used the exact 3- or 4-digit code).

a = calibrated scale parameter for the demand and price relationship
P'_g = with-policy price for output (g)
η_g = price elasticity of demand (g)

The key parameter that controls consumption adjustments is the price elasticity of demand (η_g). To approximate the response, we use demand elasticities reported in Ho, Morgenstern, and Shih (2008). To estimate the demand elasticities, Ho, Morgenstern, and Shih used a CGE model[90] and simulate the effects of placing a small tax on output and recording the quantity change. The general equilibrium quantity change associated with the tax considers all price and income changes that led to the quantity change. Table B-6 reports the values taken from Ho, Morgenstern, and Shih (2008) that are currently used for demand responses of other final uses (domestic and exports).

The current version of the multimarket model does not currently consider the consequences of exogenous demand shocks to the scale parameter (a) that the policy may bring about. For example, IPM explicitly models changes in fuel use (a switch from coal to natural gas) that utilities may use to meet the Transport Rule. Increases in natural gas demand subsequently lead to price increases for natural gas.[91] As a result of higher natural gas prices, industries with more intensive natural gas use may shrink while those with less intensive natural gas use may expand. A similar story with opposite effects occurs in the coal market; reduced demand lowers coal prices and may result in surplus loss for the coal industry. The Transport Rule may also increase the demand for materials for retrofits and increases in the prices of those goods as well as the demand for retrofit equipment; the demand increase will lead to relative expansion and contraction of industries. EPA acknowledges that the current multimarket model does not account for these types of changes in the market demand curves.

B.2.2.6 Model Scope and Distribution of Impacts

The multimarket model includes 100 sectors covering energy, manufacturing, and service applications. Each sector's production technology requires the purchase of energy and other intermediate goods made by other sectors included in the model. Linking the sectors in this manner allows the model to trace direct and indirect policy effects across different sectors. Therefore, it is best used when potential economic impacts and equity effects on related markets might be important to stakeholders not directly affected by an environmental policy. However,

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[90] The authors use the Adkins–Garbaccio CGE Model (Adkins, 2006).

[91] However, IPM treats the natural gas price increase as a cost to the electricity sector, but does not simultaneously consider that higher prices may result in a surplus gain to owners of natural gas reserves.

the model can also be run in single-market partial equilibrium mode to support and provide insights for other types of environmental policies.

With respect to distributional impacts, the relative market price elasticities also influence the distribution of social costs across stakeholders. In markets where the demand side is more responsive to price changes than suppliers, industry would bear more of the surplus losses. In the context of the Multimarket Model, this is more likely to occur in markets where the household has elastic demand and the household is the primary source of market demand (versus demand from intermediate, investment, and government sectors). However, in markets where the supply side is more responsive to own price changes, consumers would bear more of the losses. Given the Multimarket Model's demand structure, this is more likely to occur in markets where the primary source of demand is intermediate, investment, and government sectors. With electricity having a low elasticity of demand, electric power producers' responsiveness to own price changes is greater than that for the demand side for electricity. Thus, it is not surprising that consumers incur more of the surplus losses associated with this final rule than producers.

B.2.2.7 Model Time Horizon

The model is designed to address short-run and transitional effects associated with environmental policy. Production technologies are fixed; the model does not assess substitution among production inputs (labor, energy intermediates, and other intermediates) and assumes each investment cannot be changed during the time frame of the analysis. These issues are better addressed using other frameworks such as CGE modeling. Similarly, government purchases from each sector do not adjust in response to changes in goods/service prices. Although, employment levels (number of jobs) adjust as production levels change, wages are assumed to be fixed.

Table B-6. U.S. Demand Elasticities

Industry Label	*Industry Description*	*Demand Elasticity* η_g
ACM	Accommodations	−0.7
ADM	Administrative Services	−0.7
AGR	Agricultural	−0.8
ALU	Aluminum	−1.0
ANM	Animal Foods	−0.6
APP	Appliances	−2.6
ARC	Aircraft	−2.5
ART	Arts	−0.7
ATP	Air Transportation	−0.8
BAK	Baked Goods	−0.6
BEV	Beverages and Tobacco	−0.6
BOI	Boilers and Tanks	−0.5
CEM	Cement	−0.8
CEQ	Construction and Agricultural Equipment	−1.7
CHM	Chemicals and Gases	−1.0
CLY	Clay	−0.8
CMQ	Communication Equipment	−2.6
CNS	Construction	−0.8
COL	Coal	−0.1
CPP	Converted Paper Products	−0.7
CPU	Computers	−2.6
CRU	Crude Oil Extraction	−0.3
CUT	Cutlery	−0.5
EDU	Education	−0.7
EEQ	Engines	−1.7
EGV	Engraving	−0.5
ELE	Electric Generation	−0.2
ELQ	Electric Equipment	−2.6
FIN	Finance and Insurance	−0.7
FMP	Fabricated Metals	−0.5
FRG	Forging and Stamping	−0.5
FRT	Fertilizer	−1.0
FRU	Fruits and Vegetables	−0.6
FUR	Furniture	−0.7

(continued)

Table B-6. U.S. Demand Elasticities (continued)

Industry Label	*Industry Description*	*Demand Elasticity* η_g
GAS	Natural Gas	−0.3
GEQ	General Equipment	−1.7
GLS	Glass	−0.8
GRN	Grain Milling	−0.6
HLT	Health Care	−0.7
HRD	Hardware	−0.5
HVC	HVAC Equipment	−1.7
I_S	Iron and Steel	−1.0
IEQ	Industrial Equipment	−1.7
INF	Information	−0.7
INS	Instruments	−2.6
LEA	Leather	−1.1
LGT	Lighting	−2.6
LIM	Lime and Gypsum	−0.8
LUM	Other Lumber	−0.7
M_V	Motor Vehicles	−2.5
MEA	Meat Products	−0.6
MED	Drugs and Medicine	−1.0
MEQ	Metalworking Equipment	−1.7
MGT	Magnetic Recording Equipment	−2.6
MIL	Dairy Products	−0.6
MIN	Mining	−0.6
MNG	Management	−0.7
MSC	Miscellaneous Manufacturing	−1.7
MSP	Machine Shops	−0.5
MVP	Motor Vehicle Parts	−2.5
OCM	Other Chemicals	−1.0
OEQ	Other Electric Equipment	−2.6
OFD	Other Food Products	−0.6
OFM	Other Fabricated Metals	−0.5
OIL	Refined Petroleum	−0.1
ONM	Other Non-metallic Minerals	−0.8
OPM	Other Primary Metals	−1.0
OSV	Other Services	−0.7
OTP	Other Transportation Services	−0.8

(continued)

Table B-6. U.S. Demand Elasticities (continued)

Industry Label	*Industry Description*	*Demand Elasticity* η_g
OTQ	Other Transport Equip	−2.5
PAI	Paints and Adhesives	−1.0
PAP	Pulp and Paper Mills	−0.7
PFS	Professional Services	−0.7
PIP	Pipeline Transport	−0.8
PLS	Plastic	−1.0
PLY	Plywood and Veneer	−0.7
PRN	Printing	−0.7
PUB	Public Services	−0.7
R_R	Rail Cars	−2.5
REL	Real Estate	−0.7
RSN	Resins	−1.0
RTL	Retail Trade	−0.7
RTP	Railroad Transportation	−0.8
RUB	Rubber	−1.0
SAW	Sawmills	−0.7
SEA	Seafood	−0.6
SEQ	Service Industry Equipment	−1.7
SGR	Sugar	−0.6
SHP	Ships	−2.5
SMI	Semiconductor Equipment	−2.6
SOP	Soap	−1.0
TEX	Textile Mills	−1.1
TKB	Truck Bodies	−2.5
TPM	Textile Product Mills	−1.1
TTP	Freight Truck Transportation	−0.8
TVQ	TV Equipment	−2.6
WAP	Wearing Apparel	−2.4
WHL	Wholesale Trade	−0.7
WIR	Springs and Wires	−0.5
WTP	Water Transportation	−0.8

Note: RTI assigned an elasticity using the most similar industry from Ho and colleagues' industry aggregation.

Source: Ho, M. S, R. Morgenstern, and J. S. Shih. 2008. "Impact of Carbon Price Policies on US Industry." RFF Discussion Paper 08-37. Http://Www.Rff.Org/Publications/Pages/Publicationdetails.Aspx?. Publicationid=20680. Accessed August 2009. Table B.6.

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APPENDIX C
SUMMARY OF STATE-LEVEL MORTALITY IMPACTS

Table C-1: Avoided PM2.5-related premature deaths in 2014 for the selected remedy by state

State	Pope et al. (2002) mortality estimate	Laden et al. (2006) mortality estimate
Alabama	380 (150--610)	980 (530--1400)
Arizona	8.9 (3.5--14)	23 (12--33)
Arkansas	200 (79--320)	510 (280--740)
California	7.9 (3.1--13)	20 (11--30)
Colorado	-4.4 (-8.2---0.52)	-11 (-19---3.8)
Connecticut	130 (50--200)	320 (180--470)
Delaware	55 (22--89)	140 (77--200)
District of Columbia	29 (11--46)	74 (40--110)
Florida	600 (230--960)	1,500 (830--2200)
Georgia	580 (230--930)	1500 (810--2200)
Idaho	0.038 (0.012--0.064)	0.098 (0.048--0.15)
Illinois	590 (230--950)	1,500 (820--2200)
Indiana	530 (210--850)	1,300 (740--2000)
Iowa	93 (36--150)	240 (130--340)
Kansas	82 (32--130)	210 (110--300)
Kentucky	530 (210--850)	1,400 (740--2000)
Louisiana	200 (79--320)	520 (280--750)
Maine	23 (9.2--38)	60 (33--88)

Maryland	400 (160--650)	1,000 (560--1500)
Massachusetts	150 (60--250)	390 (210--570)
Michigan	540 (210--870)	1,400 (760--2000)
Minnesota	75 (29--120)	190 (110--280)
Mississippi	220 (87--360)	570 (310--820)
Missouri	330 (130--530)	840 (460--1200)
Montana	-0.12 (-0.23---0.0086)	-0.3 (-0.51---0.093)
Nebraska	31 (12--49)	78 (43--110)
Nevada	-0.59 (-1.1---0.087)	-1.5 (-2.5---0.55)
New Hampshire	31 (12--49)	78 (43--110)
New Jersey	450 (180--730)	1,200 (630--1700)
New Mexico	9 (3.5--15)	23 (13--34)
New York	780 (300--1200)	2,000 (1100--2900)
North Carolina	750 (300--1200)	1,900 (1000--2800)
North Dakota	3.1 (1.2--5)	7.9 (4.3--12)
Ohio	1,300 (500--2000)	3,200 (1800--4600)
Oklahoma	160 (61--250)	400 (220--580)
Oregon	0.06 (0.0055--0.11)	0.15 (0.049--0.26)
Pennsylvania	1,200 (450--1800)	2,900 (1600--4200)
Rhode Island	31 (12--50)	80 (44--120)
South Carolina	380 (150--600)	960 (530--1400)
South Dakota	8.4 (3.3--13)	22 (12--31)
Tennessee	650 (260--1000)	1,700 (910--2400)

Texas	670 (260--1100)	1,700 (940--2500)
Utah	0.28 (0.11--0.46)	0.73 (0.4--1.1)
Vermont	17 (6.7--28)	44 (24--64)
Virginia	610 (240--980)	1,600 (850--2300)
Washington	0.07 (0.025--0.11)	0.18 (0.092--0.26)
West Virginia	280 (110--450)	700 (390--1000)
Wisconsin	170 (66--270)	430 (230--630)
Wyoming	-0.14 (-0.23---0.045)	-0.36 (-0.54---0.18)

Table C-2: Avoided ozone-related premature deaths in 2014 for the selected remedy by state

State	Bell et al. (2004) mortality estimate	Levy et al. (2006) mortality estimate
Alabama	0.76 (0.33--1.2)	3.5 (2.6--4.4)
Arizona	0.013 (0.0056--0.02)	0.06 (0.044--0.076)
Arkansas	0.31 (0.14--0.48)	1.4 (1.1--1.8)
California	0.015 (0.0067--0.024)	0.071 (0.052--0.089)
Colorado	0.002 (-0.0066--0.011)	0.009 (-0.01--0.028)
Connecticut	0.1 (0.046--0.16)	0.48 (0.35--0.6)
Delaware	0.063 (0.028--0.098)	0.29 (0.21--0.36)
District of Columbia	0.041 (0.018--0.063)	0.19 (0.14--0.24)
Florida	2.1 (0.67--3.5)	9.7 (6.6--13)
Georgia	1 (0.45--1.6)	4.8 (3.5--6.1)
Idaho	0.0005 (0.0002--0.0007)	0.0021 (0.0016--0.0027)
Illinois	1.4 (0.62--2.2)	6.4 (4.7--8.1)

Indiana	0.88 (0.39--1.4)	4.1 (3--5.1)
Iowa	0.65 (0.29--1)	3 (2.2--3.7)
Kansas	0.76 (0.33--1.2)	3.5 (2.6--4.4)
Kentucky	0.83 (0.37--1.3)	3.9 (2.8--4.9)
Louisiana	0.3 (0.13--0.46)	1.4 (1--1.8)
Maine	0.023 (0.01--0.036)	0.11 (0.077--0.13)
Maryland	0.62 (0.28--0.97)	2.9 (2.1--3.6)
Massachusetts	0.15 (0.065--0.23)	0.66 (0.49--0.84)
Michigan	1.2 (0.51--1.8)	5.3 (3.9--6.7)
Minnesota	0.58 (0.25--0.91)	2.7 (1.9--3.4)
Mississippi	0.3 (0.13--0.47)	1.4 (1--1.8)
Missouri	1.3(0.5 7--2)	6 (4.4--7.5)
Montana	0.0026 (0.0011--0.0041)	0.012 (0.0089--0.015)
Nebraska	0.35 (0.15--0.54)	1.6 (1.2--2)
Nevada	-0.022 (-0.037---0.0065)	-0.1 (-0.14---0.069)
New Hampshire	0.04 (0.018--0.063)	0.18 (0.13--0.23)
New Jersey	0.55 (0.24--0.86)	2.5 (1.8--3.1)
New Mexico	0.024 (0.011--0.038)	0.12 (0.085--0.15)
New York	1 (0.44--1.6)	4.5 (3.3--5.7)
North Carolina	1.1 (0.49--1.8)	5.2 (3.8--6.6)
North Dakota	0.025 (0.011--0.039)	0.12 (0.085--0.15)
Ohio	2 (0.88--3.1)	9.1 (6.7--11)
Oklahoma	1.1 (0.48--1.7)	5.1 (3.8--6.5)

Oregon	0.0003 (0.0001--0.0004)	0.0012 (0.0009--0.0015)
Pennsylvania	2.4 (1.1--3.8)	11 (8.2--14)
Rhode Island	0.025 (0.011--0.039)	0.11 (0.084--0.14)
South Carolina	0.72 (0.32--1.1)	3.3 (2.4--4.2)
South Dakota	0.076 (0.034--0.12)	0.35 (0.26--0.45)
Tennessee	1 (0.46--1.6)	4.9 (3.6--6.2)
Texas	0.86 (0.33--1.4)	4 (2.8--5.2)
Utah	0.0019 (0.0008--0.003)	0.009 (0.0067--0.011)
Vermont	0.029 (0.013--0.044)	0.13 (0.097--0.17)
Virginia	0.6 (0.26--0.94)	2.8 (2--3.5)
Washington	0.0011 (0.0005--0.0017)	0.0052 (0.0038--0.0065)
West Virginia	0.5 (0.22--0.78)	2.3 (1.7--2.9)
Wisconsin	0.83 (0.37--1.3)	3.8 (2.8--4.8)
Wyoming	0.001 (-0.0001--0.0022)	0.0048 (0.0022--0.0074)

APPENDIX D
EMPLOYMENT ESTIMATES OF DIRECT LABOR IN RESPONSE TO THE FINAL TRANSPORT RULE IN 2014

This appendix presents the short-term employment estimates for the Transport Rule. The focus of the employment analysis in this study is only on the first order employment impacts related to the compliance actions of the affected entities within the power sector. It does not include the ripple effects of these impacts on the broader economy (i.e., the "multiplier" effect), nor does it include the wider economy-wide effects of the changes to the energy markets (such as higher electricity prices).[92] Moreover, this study provides only a static snapshot of the impacts for 2014 and does not account for the dynamic adjustments of the affected entities as they adapt to the Transport Rule such as those arising from technological innovation and learning-by-doing.

The estimates of the employment impacts are divided into several categories: job gains due to the increased demand for pollution control equipment; job losses due to retirements of coal capacity; and job shifts due to changes in demand for fuels. Results indicate that the Transport Rule has the potential to provide some short-term employment opportunities, primarily driven by the demand for new pollution control equipment. The employment gains related to the new pollution controls are likely to be tempered by losses due to certain coal retirements, although, as discussed below, some of these workers who lose their jobs due to plant retirements could find replacement employment operating the new pollution controls at nearby units. Finally, job losses due to reduced coal demand may be partially offset by job gains due to increased natural gas demand, resulting in small negative (about a thousand) net change in employment due to fuel demand changes. Overall, the preliminary results indicate that the Transport Rule could support a net of about 3,500 job-years in 2014. These results are summarized in Table 1 below.

Table 1: Net Employment Changes (Job-years in 2014)

New Pollution Control Equipment	7,200
Retirements of Generating Units	(2,710)
Changes in Fuel Use	(990)
Net Effect	**3,500**

The job-years estimated here is a snapshot of the first order employment effect of the

92 For more detail on the costs and energy impacts of the proposed rule, see Chapter 7 of the Regulatory Impact Analysis accompanying the Transport Rule.

Transport Rule in 2014. While there is no temporal dimension to this study, most of these jobs are likely to last over an extended time period, some more than the others. Most of the construction-related labor demand, for example, is expected to provide a short-term, temporary boost to employment that could last a few years, along with any multiplier effects that are not included in these job-year estimates. Most of the operational labor n0eeds are likely to be longer term. Thus, in terms of the impacts of the Transport Rule on economy-wide employment over time, this study shows there is likely to be a temporary boost to employment levels starting around 2014, which would likely recede thereafter as the construction phases for the needed pollution controls wind down. Over time, the operational jobs, which constitute a large portion of the pollution control related job impacts, will continue to provide a boost to employment over "business as usual" baseline employment levels. Note that this synopsis does not account for other employment impacts of the Transport Rule, such as those resulting from higher energy prices.

Overall Approach

The estimates for the near-term employment effects of the proposed rule utilize basic methodologies to estimate these job impacts relying on approaches used in prior EPA studies on similar issues. The basic approach involved using power sector projections and various energy market implications under the Transport Rule from modeling conducted with the EPA Base Case version 4.10, using the Integrated Planning Model (IPM®), along with data from secondary sources, to estimate the first order employment impacts for 2014. Throughout this analysis, incremental employment is measured in job-years, since there is no temporal dimension to this analysis.[93] Also, this TSD does not include estimates of total employment impacts *over time*, though there is a distinction between short-term construction-related labor needs and more long-term operational labor needs for new pollution controls (though these operational labor requirements are also measured in 2014 job-years only).

93 A job-year is defined as the amount of work that can be performed by the equivalent of one full-time individual for one year (or FTE).

Employment Changes due to New Pollution Control Equipment

EPA's Base Case v.4.10 and the Transport Rule policy case IPM projections were used to estimate the incremental pollution control demand.[94] These are shown in Table 2 below:[95]

Table 2: Increased Pollution Control Demand due to the Transport Rule, 2014 (GW)

Pollution Control Type	Existing Controls Induced to Operate	Newly-Built Controls
Scrubbers (FGD)	25	6
Selective Catalytic Reduction (SCR)	5	0
Dry Sorbent Injection (DSI)	0	3

The employment impacts due to increased pollution control demand are divided into four categories, two of which are associated with the construction and installation related labor requirements, while the remaining two are associated with the resources required for the ongoing operation of these equipment. The two categories of labor needed for constructing and installing these controls are for construction-related sectors, such as boilermakers, engineers, and other installation labor; and for the labor needed to manufacture the steel used in the control equipment. The two categories of labor needs for resource requirements include employment in sectors that supply resources needed to run these pollution controls (such as reagents and catalysts); and utility sector jobs to operate these control equipment. The following sections discuss the approach for each:

- For the installation related construction labor, per-unit labor needs were taken from an extensive 2002 EPA resource analysis for multi-pollutant strategies that analyzed the

94 Results for this analysis were developed using various outputs from EPA's Base Case v.4.10 using ICF's Integrated Planning Model (IPM®). This case includes all of the underlying modeling that was developed by EPA with technical support from ICF Consulting, Inc. IPM is a multi-regional, dynamic, deterministic linear programming model of the U.S. electric power sector. It provides forecasts of least cost capacity expansion, electricity dispatch, and emission control strategies while meeting energy demand and environmental, transmission, dispatch, and reliability constraints. See http://www.epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html for more info.

95 According to the EPA Policy Case results, there is some overlap between the different types of pollution control equipment demand at individual facilities. To the extent that there could be some efficiency gains at plants installing multiple controls due to economies of scale, the job estimates presented here could overstate the impacts.

resource requirements for installing various pollution control equipment (including FGD and SCR).[96] For controls not included in the 2002 EPA study, such as DSI, additional information was supplied by Andover Technology Partners (ATP), which was also one of the contributors of the 2002 EPA study. Using the same resource requirement approach as done in the 2002 EPA study, ATP provided estimates of unit labor needs based on scaling the labor requirements for ACIs (to derive estimates for DSI) [97] Thus, all of the unit labor needed for different pollution control installations can be traced back to the 2002 EPA study, with appropriate engineering adjustments. The installation labor was sub-divided into different labor categories, such as boilermakers, engineers and a catch-all "other installation labor", using information from the 2002 EPA study, adjusted for the new pollution controls, such as DSIs.

- In addition to construction labor, it was assumed that installing the pollution controls requires labor for steel as the primary raw material, leading to employment in the steel manufacturing industry. Again this approach is consistent with the 2002 EPA study. The increased steel demand is estimated using the per-MW steel demand from the EPA study along with the estimated increases in pollution controls. For DSI, the same proportionality assumption is taken from ATP for installation labor to estimate the steel needed for installation.

- For the longer term, and more significant labor associated with operating the pollution controls, per-unit estimates of the main resources needed for these equipment (see Table 3 below for a list of the resources) are taken from the 2002 EPA study, augmented by DSI resource use estimates from ATP. These were then multiplied by the incremental GW for each pollution control to obtain the total (physical) quantity of resources needed.[98] Total tonnage (or volume for SCR catalyst) for each resource was then converted to dollars of increased economic output for these resources using price estimates obtained from publicly available sources (see Table 3). Finally, the labor productivity for each particular sector was used to estimate the number of job-years these would likely create in 2014. Labor productivities for each sector were adjusted to account for increased worker productivity in 2014. Data for baseline worker productivity and corresponding growth rates to account for future productivities came from the Economic Census and the Bureau of Labor Statistics

96 "*Engineering and Economic Factors Affecting the Installation of Control Technologies for Multi-pollutant Strategies*". EPA/ORD, 2002.

97 DSI and Fabric Filter System Installation Labor Estimate. Memorandum by Andover Technology Partners to ICF International. January 26, 2011.

98 Except for Ammonia, where the usage was calculated based on the total predicted NOx reduced, consistent with the 2002 EPA study approach.

(BLS) estimates.[99]

- The final employment vector estimated was for the utility sector labor needed to operate these pollution control equipment. This estimate was based on the incremental Fixed Operation and Maintenance (FOM) costs from the EPA runs using IPM, excluding costs due to retirements. The assumption in this TSD was that the FOM costs -- defined as the maintenance costs incurred by the utility irrespective of whether the equipment is operated (such as those for payroll) – are a good proxy for estimating the incremental labor demand to operate these pollution controls. The FOM costs were then translated into employment based on estimates of payroll per worker for the power sector taken from the 2007 Economic Census and BLS estimates.[100]

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99 Total value of shipments in 2007 and total employees were taken from 2007 Economic Census, Statistics by Industry for Mining and Manufacturing sectors. The average annual growth rate of labor productivity was taken from the Bureau of Labor Statistics. Average growth rate calculated for years 1992-2007, applied to 2007 productivity to determine 2014 estimates of productivity. For steel, limestone, ammonia, and SCR catalyst, the value of shipments and employment estimates were taken from the 2000 Survey of Manufacturers. See the Appendix for more details about the data used for these calculations.

100 Same sources as other productivity estimates (2007 Economic Census and BLS), however, uses employees and total payroll rather than revenue or value of shipments.

Table 3: Estimated Pollution Control Resource Needs (Quantity and Prices Used)

	Amount of Resource Used	Price Used ($/unit)
Steel (tons)	19,906	$ 550
Limestone, FGD (tons) [101]	8,112,715	$ 75
Ammonia, SCR (tons)	77,387	$ 150
Catalyst, SCR (m3)	723	$ 8,475
Sodium Bicarbonate, DSI (tons)	675,725	$ 120

Price Sources: Steel: Platts, Steel Markets Daily, Vol 3 Issue 209, October 29, 2009.

Limestone: FGD Tech Evaluation, March 2007.

Ammonia: Development of Supply Curves for Abatement of GHG from Coal-fired Utility Boilers, Air Pollution Prevention and Control Division, US-EPA, RTP and NC State University, 2009.

Catalyst: EPA Air Pollution Control Cost Manual, Sixth Edition, January 2002. ;

Sodium Bicarbonate: Communication with Andover Technology Partners, Feb 7, 2011.

Results

Table 4 presents the estimated employment impacts in 2014 resulting from the additional pollution controls needed to meet the Transport Rule requirements. The Transport Rule is estimated to lead to a total capital investment of about $4 to $5 billion in order for the regulated entities to meet the limits under the proposed rule (this capital cost will be amortized over many years). According to this analysis, these investments could provide the opportunity to support over 7,000 job-years to design, construct, and operate the needed pollution control equipment in 2014. Note, some of these jobs are expected to start before, and continue beyond 2014 (such as

101 EPA's modeling for the Transport Rule indicates most of the incremental scrubber capacity is likely to be wet scrubbers. EPA assumes a lower price for the limestone used in wet scrubbers relative to the reagent used in dry scrubbers. The $75/ton price for limestone was used to be consistent with a similar analysis conducted for the proposed Mercury and Air Toxics Standards (March 2011) where EPA projected mostly dry scrubbers that use a more expensive lime reagent. This simplification is likely to overestimate the job impacts. However, this study does not include the positive employment impacts arising from the waste disposal costs assumed in EPA's modeling, again to be consistent with the Toxics Rule TSD, which is likely to lead to underestimation of the total job impacts.

the resource related job-years), but this analysis only provides a snapshot for 2014.

Table 4: Jobs Due to Pollution Control Equipment under the Transport Rule (Job-years in 2014)

Jobs for Construction	Incremental Employment
Boilermakers	890
Engineers	440
General Construction	880
Steel Manufacturing	20
Sub-Total:	**2,230**
Jobs for Operation	
Jobs from Increased Operating Resource Use	
Limestone (FGD)	2,440
Ammonia (SCR)	30
Catalyst (SCR)	20
Sodium Bicarbonate (DSI)	160
Sub-Total:	**2,650**
Jobs for Pollution Control Operation	**2,320**
Total Labor:	**7,200**

Note: Totals may not add due to rounding

The number of job-years estimated for pollution control installation is driven primarily by incremental FGD capacity. As shown in Table 2, up to 31 GW of additional FGD capacity is projected to be used in 2014 to comply with the Transport Rule. Out of this, only about 6 GW is estimated to be new scrubber capacity requiring construction and installation of the pollution control equipment. While the remaining 25 GW is projected to be existing scrubbers that were not operated under the EPA base case assumptions, and hence are not likely to lead to jobs due to construction, these scrubbers do provide significant operational employment opportunities. The results above show a higher proportion of operational jobs than, for example, was estimated for the utility Toxics Rule. This implies while the jobs due to the Transport Rule are only a fraction of the total estimated for the Toxics Rule, these jobs are more likely to last longer over time since there is less need for installing new pollution control equipment but a higher demand for operating equipment that may not be operated in absence of the Transport Rule (i.e. under the "business-as-usual" base case).

Moreover, of the roughly 7,200 job-years estimated in Table 4, over 2,300 job-years, or over 30 percent, are estimated to occur within the utility sector for labor needed to operate the pollution controls (referred to as "Jobs for Pollution Control Operation" in Table 4). The rest of the labor demand will benefit the pollution control industry and other economic sectors. The increased demand for resources and chemicals needed to operate the pollution controls will provide a boost to employment in sectors such as mining, chemicals, other manufacturing sectors, and to a smaller extent, in construction-related sectors.

Employment Changes due to Coal Retirements

Employment changes due to plant retirements were estimated by first identifying the retiring units from EPA's modeling using IPM,all of which are coal-fired units. EPA projects that there will be roughly 4.8 GW of additional coal retirements by 2014 with the Transport Rule in place.[102]

In order to convert the retired coal capacity into potential employment losses, it was assumed that changes in the operating costs for the retired coal units can be used as a proxy for the lost economic output due to fossil retirements. Thus, the changes in the O&M costs (both FOM and VOM) for these particular retiring units were derived from the EPA Base Case and Transport Rule policy case runs using IPM, and converted to lost jobs using data from the Economic Census and BLS output/worker estimates for the utility sector.[103]

Note that the lost economic output due to fossil retirements is likely to affect not just the utility sector, but others as well. Employment losses due to plant retirements will not only affect those that are directly working at the plant (i.e., plant operators), but would also affect administrative and other "back-office" workers for those utilities and their support organizations. This TSD assumes that the FOM costs related to retiring plants are a good proxy for these types of job losses. Moreover, because the VOM costs represent the variable costs of operating the plant, including costs of materials needed to run any installed pollution control equipment (such as cost of reagents, etc.), this TSD assumes that the VOM costs can be used as an indicator of the employment effects on the resource suppliers to these plants and units. Thus, the retirement

102 Retirement estimates are based on system-level results for the EPA runs using IPM. Where applicable, parsed data from the IPM for the relevant EPA runs were adjusted to account for partial retirements.

103 The same specific sources as cited before, however, used workers and total payroll.

related employment losses shown below are assumed to include losses directly affecting the utility sector as well as other "upstream" sectors that provide material inputs needed to operate these plants. Table 5 shows those results.

Table 5: Job Losses due to Coal Capacity Retirements

O&M Decrease from Retirements ($MM)	303
Workers Per Million$ in payroll	8.9
Workers lost due to retirements (job-year):	**2,710**

Results indicate there could potentially be about 2,700 job losses (measured in job-years for 2014, but any *net* job losses under this category are likely to be permanent), due to coal retirements. However, two mitigating factors could reduce the negative employment impacts due to retirements. First, many of the retiring units are at plants that are likely to have other units operating under the policy scenario. In such cases, some of the excess labor pool at the retiring units could well be absorbed at other units within the same firm.[104]

Second, as Table 4 indicates, utilities are expected to have the need to fill over two thousand additional job slots to operate the pollution controls needed to meet the requirements of the Transport Rule. If workers with experience at existing coal facilities become available through plant retirements, it would seem logical for many of these workers to be absorbed in operating these new pollution controls. While it is not possible to determine how many of these workers from particular coal retirements could be employed to operate the new pollution controls, it is likely that a significant portion of them could find gainful employment at nearby units.

Employment Changes due to Changes in Fuel Use

Two types of employment impacts due to projected fuel use changes are estimated in this TSD. First, employment losses due to reductions in coal demand were estimated using an approach similar to EPA's coal employment analyses under Title IV of the Clean Air Act

104 According to EPA modeling results, approximately 70 percent of the coal retirements (in terms of capacity) occur at plants with other operating units under the Transport Rule policy case.

Amendments.[105] Using this approach, changes in coal demand (in short tons) for various coal supplying regions were taken from EPA's Base and Policy Case runs. These changes were converted to job-years using EIA data on regional coal mining productivity (in short tons per employee hour), using 2008 labor productivity estimates.[106] [107] Results of the coal employment impacts of the Transport Rule are presented in Table 6 below.

Table 6: Employment Due To Changes in Coal Use

Coal by Region	**Change in Coal Demand (MM Tons)**	**Labor Productivity**	**Job-year Change**
Appalachia	3.8	2.91	630
Interior	(27.2)	4.81	(2,720)
West	2.9	19.91	70
Waste Coal	(0.03)	5.96	(0)
Net Total	**(20.5)**	**--**	**(2,030)**

Notes: Used US national coal productivity for waste coal
Totals may not add due to rounding

For natural gas demand, labor productivity per unit of natural gas was unavailable, unlike coal labor productivities used above. Most secondary data sources (such as Census and EIA) provide estimates for the combined oil and gas extraction sector. This TSD thus uses an adjusted labor productivity estimate for the combined oil and gas sector that accounts for the relative contributions of oil and natural gas in the total sector output (in terms of the value of energy output in MMBtu). This estimate of labor productivity is then used with the incremental natural gas demand for the Transport Rule to estimate the job-years for 2014. In addition, the pipeline construction costs were estimated using proportionality assumptions from those used for the

105 Impacts of the Acid Rain Program on Coal Industry Employment. EPA 430-R-01-002 March 2001.

106 From US Energy Information Administration (EIA) Annual Energy Review, Coal Mining Productivity Data. Used 2008.

107 Unlike the labor productivity estimates for various equipment resources which were forecasted to 2014 using BLS average growth rates, this study uses the most recent historical productivity estimates for fuel sectors. In general, labor productivity for the fuel sectors (both coal and natural gas) showed a significantly higher degree of variability in recent years than the manufacturing sectors, which would have introduced a high degree of uncertainty in forecasting productivity growth rates for future years.

Toxics Rule TSD.[108] These results are summarized in Table 7 below.

Table 7: Total Employment Impact due to Changes in Fuel Use (2014)

Fuel Type	Employment
Coal Job Years Lost	**(2,030)**
Natural Gas	
Incremental Natural Gas Use (MMBtu)	212,279,900
Labor Productivity (MMBtu/job-year)	261,840
Job-years gained	**810**
Gas Pipeline	
Capital Cost for New Pipeline Capacity (US total: MM $/year)	44.2
Workers/million $ in Pipeline Construction	5.1
Job-years gained	**230**
Net Employment Effects of Fuel use changes	**(990)**

Note: Totals may not add due to rounding

Thus, about 2,000 job losses in the coal mining sector are likely to be partially offset by about 1,000 job gains in the production and transportation-related jobs in the natural gas related sectors, for a net effect of less than a thousand job losses due to changes in fuel use.

Conclusion

Overall, the impact of the Transport Rule on short-term employment resulting from investments in pollution control equipment is expected to be small. The Transport Rule is estimated to lead to a total pollution control-related capital investment of about $4 to $5 billion. Of the jobs associated with pollution controls, over two-thirds are likely to be associated with operating these controls while the remaining one-third is estimated to be driven by the need to install new controls. Employment losses due to coal retirements that will likely have a negative effect on some utilities and the coal mining sector could offset some of the positive gains from

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108 See "Employment Estimates of Direct Labor in Response to the Proposed Toxics Rule in 2015". Technical Support Document, March 2011.

pollution control and in the natural gas sector. As previously discussed, this assessment does not account for the long-run economy-wide effects of the Transport Rule. The employment impacts estimated in this study are mostly based on approaches in prior EPA studies on similar topics. The main source for resource estimates used here is the 2002 EPA multi-pollutant resource analysis, which was also the basis for subsequent EPA labor analyses, such as the 2005 Clean Air Interstate Rule (CAIR) TSD on boilermaker labor, as well as the more recent utility Toxics Rule employment TSD.[109] Thus, results presented here are consistent with prior EPA studies on similar topics.

109 CAIR Technical Support Document. Boilermaker Labor Analysis and Installation Timing. March 2005.

Supplemental Information

This section provides further details on the inputs and methodology used in the labor calculations presented above. The Appendix begins with the pollution control labor section, presenting the inputs for the four primary sections of equipment labor and describing the process by which the labor estimates were obtained from the available data, followed by similar discussions for coal retirements and fuel use change employment analysis.

Pollution Control Equipment Labor

- **Installation Labor**

Table 8: Installation Labor Requirement

Pollution Control Type	Incremental GW Installed	Man-hours/MW	Boilermakers (%)	Engineers (%)	Others (%)
FGD	6	760	40	20	40
SCR	0	700	45	7	48
DSI	3	44	50	17	33

Source: EPA Multi-pollutant Strategies 2002 report; DSI and FF adjustments based on Andover Technology Partners.

Installation labor is estimated using the incremental GW installed for each pollution control type from EPA's modeling using IPM. This was then converted into total man-hours needed for installation using estimates of man-hours/MW from the 2002 EPA study, supplemented by information from ATP. Total man-hours for each pollution control type were then converted into man-years assuming 2,080 working hours per year.

Total man-years for each pollution control type were then broken down into various sectors using the percentages, shown in Table 8. These percentages were estimated from the 2002 study and supplemented by ATP information for DSI.

- **Installation Resource Labor**

Table 9: Installation Resource Needs

Pollution Control Type	Steel (Tons/MW)
FGD	2.25
SCR	2.5
DSI	2.2

Sources: Steel and Catalyst Usage: EPA Multi-pollutant Strategies 2002 report; Steel Price: Platts, Steel Markets Daily, Vol 3 Issue 209, October 29 2009; Productivity: 2000 Annual Survey of Manufacturers: Iron and Steel Pipes and Tube Manufacturing, BLS for Productivity Growth Rate.

For installation resource labor, steel is the primary resource input used for new pollution control installations, consistent with the 2002 EPA multi-pollutant study. The first step used the incremental installed pollution control capacity and estimates of steel usage (tons/MW), as shown in Table 9 above, to calculate the total steel needed in tons, by pollution control type. Steel usage estimates were used from the 2002 EPA study, supplemented by ATP information for DSI. The total amount of steel was then converted into a dollar value for steel expenditure using an average steel price ($550/ton), using data from Platts Steel Markets Daily (see notes to Table 9 above). Resulting total steel expenditure was then converted to labor using the productivity estimates calculated from the Economic Census data using workers per $ Million in total output for the iron and steel manufacturing industry (= 2.2 workers/$Million).[110]

- **Operating Resource Labor**

Table 10: Resources Needed for Operation

Pollution Control Type	Incremental Total GW (Includes Existing Units)	Resource (Units in parenthesis)	Usage Estimates	Price ($/unit)	Industry Assumed for Productivity Calculations	Productivity*
FGD	30.3	Limestone (Tons/MWh)	0.036	75	Lime Manufacturing	4.0

110 In general, the productivity estimates for various sectors were derived using data from the 2000 Annual Survey of Manufacturers or 2007 Economic Census. These were then forecasted to 2014 using corresponding average growth rates estimated using data from the Bureau of Labor Statistic (BLS) information on productivity growth rates.

<table>
<tr><td rowspan="3">SCR</td><td rowspan="3">5
(NOx reduction: 396,870,600 lbs)</td><td>Ammonia (lbs/lb NOx Reduced)</td><td>0.39</td><td>150</td><td>All Other Basic Inorganic Chemical Manufacturing</td><td>2.1</td></tr>
<tr><td>Initial Catalyst (m3/MW)</td><td>1.2</td><td rowspan="2">8,475</td><td rowspan="2">Combined: Other Nonferrous Metal Primary and Secondary Smelting and Refining</td><td rowspan="2">3.2</td></tr>
<tr><td>Operational Catalyst (m3/MWh)</td><td>0.00002</td></tr>
<tr><td>DSI</td><td>3</td><td>Sodium Bicarbonate (Tons/MWh)</td><td>0.03</td><td>120</td><td>Potash Soda and Borate Mineral Mining</td><td>2.0</td></tr>
</table>

**Workers/$Million in Output, Forecasted to 2014*
Sources: Usage: EPA Multi-pollutant Strategies 2002 report, DSI from Andover Technology Partners;
Prices: Limestone: FGD Tech Evaluation, March 2007
Ammonia: Development of Supply Curves for Abatement of GHG from Coal-fired Utility Boilers, Air Pollution Prevention and Control Division, US-EPA, RTP and NC State University, 2009
Catalyst: EPA Air Pollution Control Cost Manual, Sixth Edition, January 2002.
Sodium Bicarbonate: Communication with Andover Technology Partners, Feb 7 2011;
Productivity: 2000 and 2007 Economic Census, Productivity Growth rates from BLS.

Labor related to resources used in operating pollution control equipment was estimated using the total incremental GW of pollution control capacity which was first converted to total MWh of incremental capacity assuming 85 percent capacity factor. For each pollution control type, the next step involved choosing the primary operating resource, except for SCRs for which two resources – ammonia and catalyst – were chosen. [111] This approach is consistent with the 2002 EPA study. The next step involved estimating the resource needs by each control type, generally in tons of material (cubic meters (m3) for catalyst), using the resource usage estimates as shown in Table 10.[112] Using the total usage for each pollution control input (in tons or m3) and associated average prices, total expenditure by each resource type was then calculated. This total expenditure was then converted to labor using workers per $Million in total output for the industry associated with producing each respective input material.

111 SCRs have an operational input of catalyst as well as an initial input needed when the unit is first installed. While the initial value is calculated using only the installed new control capacity, that number and the associated labor needs are included to estimate the total volume of catalyst required.

112 Ammonia has a usage rate based on lbs of NOx reduced, so we estimated our ammonia usage using the total NOx reduced between the base and policy cases.

- **Operating Labor**

Table 11: Operating Labor Assumptions

Incremental FOM ($ Million)	259
Productivity*	8.9

**Workers per $Million in Payroll for Electricity Generating Sector, Forecast to 2014*
Sources: Productivity from 2007 Economic Census and Growth Rate from BLS.

Labor requirement to operate the controls is estimated for all equipment types combined, using the incremental FOM costs based on EPA modeling assumptions for the Transport Rule. Resulting FOM cost estimate was then converted to labor needs using the workers/$ Million in total payroll for the Electric Generating Sector.

Retirement Labor

Table 12: Inputs to Labor from Retirements

Capacity of Incremental Retirements (MW)	4,772
O&M Decrease scaled to SSR Retirements ($MM) (To account for Partial Retirements)	302.8
Workers Per $Million in payroll, forecast to 2014	8.9

Sources: Productivity from 2007 Economic Census and Growth Rate from BLS.

Retirement labor was estimated by first identifying the retiring units from the parsed outputs (using incremental retirements in EPA's Transport Rule policy case run). The next step involved estimating the capacity of incremental retirements as well as the change in the O&M costs due to these retirements. Because of the discrepancies between partial retirements in parsed outputs and System Summary Reports (SSR), O&M costs were scaled proportionately to reflect the lower SSR-based estimates, as shown in Table 12 above. O&M cost decreases were then converted to job-years lost due to retirements using workers per $Million in payroll.

Fuel Use Labor

Table 13: Inputs to Labor for Fuel Use

Coal by Region	**Incremental Fuel Use (Tons)**	**2008 Short Tons/Employee hour**
Appalachia	3,780,000	2.9
Interior	(27,190,000)	4.8
West	2,870,000	19.9
Waste Coal	(30,000)	6.0

Natural Gas		
EIA Total Natural Gas Production 2007 (TCF)		24.664
EIA Total Crude Oil Production 2007 (Barrels)		1,848,450,000
EIA Natural Gas Heat Content 2007 (Btu/cf)		1,027
EIA Petroleum Heat Content (MMBtu/Barrel)		6.151
Total Crude Oil and Natural Gas Production (MMBtu)		36,699,744,000
Economic Census 2007 Oil and Gas Extraction Employees		140,160
MMBtu per Man-year for Oil and Gas Extraction		261,842
Incremental Natural Gas from EPA (IPM) Results (TCF)		0.207
Incremental Natural Gas from EPA (IPM) Results (Converted to MMBtu)		212,279,903
Pipeline	Capital Cost of New Pipeline ($MM)	Productivity
	44.2	5.1

Note: Heat Contents from EIA are assumed to be for fuels used in Electric Power Sector Sources: Short Tons per hour from US EIA, Coal Industry Annual. Total Production from 2009 EIA Annual Energy Review. Heat Contents from EIA, Heat Content of Natural Gas Consumed and 2009 Annual Energy Review. Employment Data from 2007 Economic Census.

Fuel use related employment impacts were estimated using EPA's Base Case and the Transport Rule runs using IPM for incremental changes in coal and natural gas use. For coal, estimates of coal use in tons by region from the relevant EPA runs were used in conjunction with labor productivity estimates from EIA for each region (in short tons/ employee hour), to calculate the change in job-hours needed. These were then converted to job-years, assuming 2,080 working hours per year. As discussed in the main report above, because of the high variability in coal mining labor productivity in recent years, no attempt was made to forecast coal (and natural gas, for consistency) productivities, instead the most recent historical estimates were used in this TSD (which was the 2008 labor productivity for coal).

For natural gas, the first step was estimating labor productivity since such information was not available directly from any reliable source. EIA production data from the Annual Energy Review for natural gas and crude oil (in TCF and barrels, respectively), along with EIA heat content estimates were used to find total crude oil and natural gas production in MMBtu for 2007. Labor productivity in MMBtu per job-year for the Oil and Gas Extraction sector was then estimated using data from the Census on oil and gas extraction employment. Then, incremental natural gas demand (in Tcf) from the relevant EPA runs was converted to MMBtu of natural gas demand using EIA data on natural gas heat content. This was then used with the labor productivity estimated above to calculate the total job-years needed for increased natural gas demand for the Transport Rule.

Jobs related to pipeline construction were estimated in proportion to the increased natural gas demand under this rule relative to those estimated for the utility Toxics Rule. More details on the approach used to convert pipeline information into jobs for the Toxics Rule are provided in the Toxics Rule employment TSD.

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APPENDIX E
ALTERNATE PRESENTATION OF THE BENEFITS OF THE FINAL FEDERAL TRANSPORT RULE

In this appendix, we provide an alternate presentation of the benefits of the final Federal Transport Rule. This alternate presentation is an attempt to incorporate the recommendations from EPA's recently published *Guidelines for Preparing Economic Analyses* (U.S. EPA, 2010). The *Guidelines* provide four basic principles for constructing thorough and transparent results tables:

- All meaningful benefits and costs are included,
- The types of benefits and costs are briefly described in plain terms,
- The benefits are expressed first in natural or physical units, and
- Explanatory notes accompany each benefit and cost entry.

By adopting these general principles, the tables provided in this appendix do not exactly match the tables provided in the benefits chapter of this RIA and previous RIAs, but they are consistent with the types of information previously provided. In Part A, we identify the quantified and unquantified benefits of this rule, indicate whether each specific effect has been quantified and monetized in this assessment, and explain the lack of quantification for certain effects. In Part B, we provide the benefits in natural units for each specific effect that was quantified in this assessment, including the 95^{th} percentile confidence intervals. In Part C, we provide the dollar value of the benefits monetized in this assessment at discount rates of 3% and 7%, including the 95^{th} percentile confidence intervals. To avoid repetition, we have limited Parts B and C to the quantified effects for the selected regulatory option. In each table, we identify the section of the RIA where each effect and the underlying assumptions are discussed in detail.

It is important to emphasize that the list of unquantified effects is not exhaustive, nor is quantification of each effect complete. In order to identify the most meaningful human health and environmental benefits, we excluded effects not identified as having at least a causal, likely causal, or suggestive relationship with the affected pollutants in the most recent comprehensive scientific assessment, such as an Integrated Science Assessment. This does not imply that additional relationships between these and other human health and environmental benefits and the affected pollutants do not exist. Due to this decision criterion, some effects that were identified in previous lists of unquantified benefits have been dropped (e.g., UVb exposure). In addition, some quantified effects represent only a partial accounting of likely impacts due to limitations in the currently available data (e.g., climate effects from CO_2, etc).

As the use of these tables evolves, further refinements will be made to improve the information provided and to assure consistency with previous EPA analysis and EPA and OMB guidelines

Part A: Overview of Benefits for Transport Rule

Benefits Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Improved Human Health				
Reduced incidence of premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimates and expert elicitation estimates (age >25 or age >30)	✓	✓	Section 5.4
	Infant mortality (age <1)	✓	✓	Section 5.4
Reduced incidence of morbidity from exposure to $PM_{2.5}$	Chronic Bronchitis (age >26)	✓	✓	Section 5.4
	Non-fatal heart attacks (age > 18)	✓	✓	Section 5.4
	Hospital admissions—respiratory	✓	✓	Section 5.4
	Hospital admissions—cardiovascular (age > 18)	✓	✓	Section 5.4
	Emergency room visits for asthma (age < 18)	✓	✓	Section 5.4
	Acute bronchitis (age 8-12)	✓	✓	Section 5.4
	Lower respiratory symptoms (age 7-14)	✓	✓	Section 5.4
	Upper respiratory symptoms (asthmatics age 9-18)	✓	✓	Section 5.4
	Asthma exacerbation (asthmatics age 6-18)	✓	✓	Section 5.4
	Lost work days (age 18-65)	✓	✓	Section 5.4
	Minor restricted-activity days (age 18-65)	✓	✓	Section 5.4
	Other cardiovascular effects (e.g., stroke, other ages)	--	--	PM ISA[2]
	Other respiratory effects (e.g., non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	--	--	PM ISA[2]
	Reproductive and developmental effects	--	--	PM ISA[2,3]
	Cancer, mutagenicity, and genotoxicity effects	--	--	PM ISA[2,3]
Reduced incidence of mortality from exposure to ozone	Premature mortality based on short-term study estimates (all ages)	✓	✓	Section 5.4
	Premature mortality based on long-term study estimates (age 30-99)	--	--	Ozone CD, Draft Ozone ISA[3]
Reduced incidence of morbidity from exposure to ozone	Hospital admissions—respiratory causes (age > 65)	✓	✓	Section 5.4
	Hospital admissions—respiratory causes (age <2)	✓	✓	Section 5.4
	Emergency room visits for asthma (all ages)	✓	✓	Section 5.4
	Minor restricted-activity days (age 18-65)	✓	✓	Section 5.4
	School absence days (age 5-17)	✓	✓	Section 5.4
	Decreased outdoor worker productivity (age 18-65)	--	✓	Section 5.4
	Other respiratory effects (e.g., premature aging of lungs)	--	--	Ozone CD, Draft Ozone ISA[2]
	Cardiovascular and nervous system effects	--	--	Ozone CD, Draft Ozone ISA[3]
	Reproductive and developmental effects	--	--	Ozone CD, Draft Ozone ISA[3]
Reduced incidence of morbidity from exposure to NO_2	Asthma hospital admissions (all ages)	--	--	Section 5.5, NO_2 ISA[1]
	Chronic lung disease hospital admissions (age > 65)	--	--	Section 5.5, NO_2 ISA[1]
	Respiratory emergency department visits (all ages)	--	--	Section 5.5, NO_2 ISA[1]
	Asthma exacerbation (asthmatics age 4-18)	--	--	Section 5.5, NO_2 ISA[1]
	Acute respiratory symptoms (age 7-14)	--	--	Section 5.5, NO_2 ISA[1]
	Premature mortality	--	--	NO_2 ISA[2,3]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	--	--	NO_2 ISA[2,3]
Reduced incidence of morbidity from exposure to SO_2	Respiratory hospital admissions (age > 65)	--	--	Section 5.5, SO_2 ISA[1]
	Asthma emergency room visits (all ages)	--	--	Section 5.5, SO_2 ISA[1]
	Asthma exacerbation (asthmatics age 4-12)	--	--	Section 5.5, SO_2 ISA[1]
	Acute respiratory symptoms (age 7-14)	--	--	Section 5.5, SO_2 ISA[1]
	Premature mortality	--	--	SO_2 ISA[2,3]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	--	--	SO_2 ISA[2,3]
Reduced incidence of morbidity from exposure to methylmercury	Neurologic effects - IQ loss	--	--	IRIS, NRC, 2000[1]
	Other neurologic effects (e.g., developmental delays, memory, behavior)	--	--	IRIS, NRC, 2000[2]
	Cardiovascular effects	--	--	IRIS,NRC, 2000[2,3]
	Genotoxic, immunologic, and other toxic effects	--	--	IRIS, NRC, 2000[2,3]

[1] We assess these benefits qualitative due to time and resource limitations for this analysis.

[2] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.

[3] We assess these benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

Benefits Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Improved Environment				
Reduced visibility impairment	Visibility in Class I areas in SE, SW, and CA regions	--	✓	Section 5.4
	Visibility in Class I areas in other regions	--	--	Section 5.4[2]
	Visibility in residential areas	--	--	Section 5.4[1,2]
Reduced climate effects	Global climate impacts from CO_2	--	✓	Section 5.4
	Climate impacts from ozone and PM	--	--	Ozone CD, Draft Ozone ISA, PM ISA[1,2]
	Other climate impacts (e.g., other GHGs, other impacts)	--	--	IPCC[2]
Reduced effects on materials	Household soiling	--	--	PM ISA[1,2]
	Materials damage (e.g., corrosion, increased wear)	--	--	PM ISA[1,2]
Reduced effects from PM deposition (metals and organics)	Effects on Individual organisms and ecosystems	--	--	PM ISA[1,2]
Reduced vegetation and ecosystem effects from exposure to ozone	Visible foliar injury on vegetation	--	--	Ozone CD, Draft Ozone ISA[2]
	Reduced vegetation growth and reproduction	--	--	Ozone CD, Draft Ozone ISA[1,2]
	Yield and quality of commercial forest products and crops	--	--	Ozone CD, Draft Ozone ISA[1,3]
	Damage to urban ornamental plants	--	--	Ozone CD, Draft Ozone ISA[2]
	Carbon sequestration in terrestrial ecosystems	--	--	Ozone CD, Draft Ozone ISA[2]
	Recreational demand associated with forest aesthetics	--	--	Ozone CD, Draft Ozone ISA[2]
	Ecosystem functions (e.g., water cycing, biogeochemical cycles, net primary productivity, leaf-gas exchange, community composition)	--	--	Ozone CD, Draft Ozone ISA[2]
Reduced effects from acid deposition	Recreational fishing	--	--	NOx SOx ISA[1]
	Tree mortality and decline	--	--	NOx SOx ISA[2]
	Commercial fishing and forestry effects	--	--	NOx SOx ISA[2]
	Recreational demand in terrestrial and aquatic ecosystems	--	--	NOx SOx ISA[2]
	Ecosystem functions (e.g., biogeochemical cycles)	--	--	NOx SOx ISA[2]
Reduced effects from nutrient enrichment	Species composition and biodiversity in terrestrial and estuarine ecosystems	--	--	NOx SOx ISA[2]
	Coastal eutrophication	--	--	NOx SOx ISA[2]
	Recreational demand in terrestrial and estuarine ecosystems	--	--	NOx SOx ISA[2]
	Ecosystem functions (e.g., biogeochemical cycles, fire regulation)	--	--	NOx SOx ISA[2]
Reduced vegetation effects from ambient exposure to SO2 and NOx	Injury to vegetation from SO2 exposure	--	--	NOx SOx ISA[2]
	Injury to vegetation from NOx exposure	--	--	NOx SOx ISA[2]
Reduced effects from mercury methylation and deposition	Increased mercury methylation from sulfur deposition	--	--	NOx SOx ISA[2]
	Effects on fish, birds, and mammals (e.g., reproductive effects)	--	--	Mercury Study RTC[2,3]
	Commercial, subsistence and recreational fishing	--	--	Mercury Study RTC[2]

[1] We assess these benefits qualitative due to time and resource limitations for this analysis.

[2] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.

[3] We assess these benefits qualitatively because current evidence is only suggestive of causality.

Part B: Quantified Benefits for Transport Rule

Benefits Category	Specific Effect	Quantified Benefits (Point Estimates)	Quantified Benefits (95th percentile confidence intervals)	Units of effect	More Information on effect
Improved Human Health					
Reduced incidence of premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimatesand expert elicitation estimates[1]			avoided premature deaths from exposure in 2014	Section 5.4.2.1
	Pope et al. (2002) (age >30)	*13,000*	*(5,200—21,000)*		
	Laden et al. (2006) (age >25)	*34,000*	*(18,000—49,000)*		
	Infant mortality	59	(-47—160)		
Reduced incidence of morbidity from exposure to $PM_{2.5}$	Chronic Bronchitis (age >26)	8,700	(1,600—16,000)	avoided incidence in 2014	Sections 5.4.2.3 to 5.4.2.8
	Non-fatal heart attacks (age > 18)	15,000	(5,600—24,000)		
	Hospital admissions—respiratory	2,700	(1,300—4,000)		
	Hospital admissions—cardiovascular (age > 18)	5,800	(4,200—6,600)		
	Emergency room visits for asthma (age < 18)	9,800	(5,800—14,000)		
	Acute bronchitis (age 8-12)	19,000	(-660—37,000)		
	Lower respiratory symptoms (age 7-14)	240,000	(120,000—360,000)		
	Upper respiratory symptoms (asthmatics age 9-18)	180,000	(57,000—310,000)		
	Asthma exacerbation (asthmatics age 6-18)	400,000	(45,000—1,100,000)		
	Lost work days (age 18-65)	1,700,000	(1,500,000—1,900,000)		
	Minor restricted-activity days (age 18-65)	10,000,000	(8,400,000—12,000,000)		
Reduced incidence of mortality from exposure to ozone	Premature mortality based on short-term study estimates[1]			avoided premature deaths from exposure in 2014	Section 5.4.2.2
	Bell et al. (2004) (all ages)	*27*	*(11—42)*		
	Schwartz et al. (2005) (all ages)	*41*	*(17—65)*		
	Huang et al. (2005) (all ages)	*37*	*(17—57)*		
	Ito et al. (2005) (all ages)	*120*	*(79—160)*		
	Bell et al. (2005) (all ages)	*87*	*(48—130)*		
	Levy et al. (2005) (all ages)	*120*	*(90—160)*		
Reduced incidence of morbidity from exposure to ozone	Hospital admissions—respiratory causes (age > 65)	160	(21—290)	avoided incidence in 2014	Section 5.4.2.2
	Hospital admissions—respiratory causes (age <2)	84	(43—120)		
	Emergency room visits for asthma (all ages)	86	(-2—260)		
	Minor restricted-activity days (age 18-65)	160,000	(80,000—240,000)		
	School absence days	51,000	(22,000—74,000)		
	Decreased outdoor worker productivity	*	*	*	
Improved Environment					
Reduced visibility impairment	Visibility in Class I areas in SE, SW, and CA regions	*	*	*	*
Reduced climate effects	Global climate impacts from CO_2	*	*	*	*
Unquantified Benefits					
Improved Human Health and Improved Environment	See Part A Table	N/A	N/A	N/A	*

* Effect monetized but not quantified

[1] These represent alternate mortality estimates that should not be summed together

Part B: Dollar-valued Benefits for Transport Rule

Benefits Category	Specific Effect	Dollar Benefits (billions of 2007$ in 2014, 3% discount rate, point estimate)	Dollar Benefits (billions of 2007$ in 2014, 3% discount rate, 95^{th} percentile confidence interval)	Dollar Benefits (billions of 2007$ in 2014, 7% discount rate, point estimate)	Dollar Benefits (billions of 2007$ in 2014, 7% discount rate, 95^{th} percentile confidence interval)	Basis of Valuation	More Information on valuation
Improved Human Health							
Reduced incidence of premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimates and expert elicitation estimates[1]					Value of a Statistical Life	Section 5.4.4.1, Table 5-11
	Pope et al. (2002) (age >30)	*$100*	*($8.3—$320)*	*$94*	*($7.5—$280)*		
	Laden et al. (2006) (age >25)	*$270*	*($23—$770)*	*$240*	*($21—$690)*		
	Infant mortality	$0.52	($0.0—$2.4)	$0.52	(<$0.01—$2.4)		
Reduced incidence of morbidity from exposure to $PM_{2.5}$	Chronic Bronchitis (age >26) Non-fatal heart attacks (age > 18) Hospital admissions—respiratory Hospital admissions—cardiovascular (age > 18) Emergency room visits for asthma (age < 18) Acute bronchitis (age 8-12) Lower respiratory symptoms (age 7-14) Upper respiratory symptoms (asthmatics age 9-18) Asthma exacerbation (asthmatics age 6-18) Lost work days (age 18-65) Minor restricted-activity days (age 18-65)	$6.9	($1.1—$25)	$6.5	($1.1—$24)	Willingness to Pay and Cost of Illness Studies	Sections 5.4.4.2 to 5.4.4.7, Table 5-11
Reduced incidence of mortality from exposure to ozone	Premature mortality based on short-term study estimates[1]					Value of a Statistical Life	Section 5.4.4.1, Table 5-11
	Bell et al. (2004) (all ages)	*$0.23*	*($0.02—$0.69)*	*$0.23*	*($0.02—$0.69)*		
	Schwartz et al. (2005) (all ages)	*$0.36*	*($0.03—$1.10)*	*$0.36*	*($0.03—$1.10)*		
	Huang et al. (2005) (all ages)	*$0.33*	*($0.03—$0.97)*	*$0.33*	*($0.03—$0.97)*		
	Ito et al. (2005) (all ages)	*$1.00*	*($0.1—$2.9)*	*$1.00*	*($0.1—$2.9)*		
	Bell et al. (2005) (all ages)	*$0.76*	*($0.07—$2.2)*	*$0.76*	*($0.07—$2.2)*		
	Levy et al. (2005) (all ages)	*$1.10*	*($0.1—$2.9)*	*$1.10*	*($0.1—$2.9)*		
Reduced incidence of morbidity from exposure to ozone	Hospital admissions—respiratory causes (age > 65) Hospital admissions—respiratory causes (age <2) Emergency room visits for asthma (all ages) Minor restricted-activity days (age 18-65) School absence days	$0.02	($0.009—$0.04)	$0.02	($0.009—$0.04)	Willingness to Pay and Cost of Illness Studies	Sections 5.4.4.2 to 5.4.4.7, Table 5-11
	Decreased outdoor worker productivity					Labor Productivity Study	Section 5.4.2.8
Improved Environment							
Reduced visibility impairment	Visibility in Class I areas in SE, SW, and CA regions	$3.9	N/A	$3.9	N/A	Willingness to Pay Study	Section 5.4.4.8
Reduced climate effects	Global climate impacts from CO_2	$0.60	N/A	N/A	N/A	Social Cost of Carbon	Section 5.6
TOTAL BENEFITS that Have Been Monetized (billions of 2007$ in 2014)		**$120**	**($13—$350)**	**$110**	**($13—$320)**	Pope et al. 2002 $PM_{2.5}$ mortality and Bell et al. 2004 ozone mortality estimates	Section 5.7
		$280	**($29—$800)**	**$250**	**($26—$730)**	Laden et al. 2006 $PM_{2.5}$ mortality and Levy et al. 2005 ozone mortality estimates	
Unquantified Benefits							
Improved Human Health and Improved Environment	See Part A Table	N/A	N/A	N/A	N/A	N/A	Section 5.5

[1] These represent alternate mortality estimates that should not be summed together.

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APPENDIX F
ALTERNATE TABLES BASED ON REMEDY SENSITIVTY WITH REVISED VARIABILITY LIMITS

The projected impacts of the final Transport Rule reported throughout the preamble and RIA do not reflect minor technical corrections to SO2 budgets in three states (KY, MI, and NY). The modeling results reported in the preamble and RIA also assumed preliminary variability limits that were smaller than the variability limits finalized in this rule. EPA conducted sensitivity analysis confirming that these differences do not meaningfully alter any of the Agency's findings or conclusions based on the projected cost, benefit, and air quality impacts presented for the final Transport Rule. The results of this sensitivity analysis are presented in the tables below.

Table F-1. Annual Emissions of SO_2 and NO_x in 2010 and Percentage of Emissions in the Transport Rule Affected Region (tons)

	SO_2	NO_X
Transport Rule Annual NO_X and SO_2 States	4,251,996	1,424,228
Nationwide (Contiguous 48 States)	5,165,954	2,136,612
Emissions of Transport Rule States as Percentage of Nationwide Emissions	82%	67%

Source: EPA emissions data from all reporting units.
Note: Transport Rule annual NO_X and SO_2 states include Alabama, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

Table F-2. Transport Rule Annual NO_x and SO_2 and NOx Ozone Season State Emission Budgets (tons)

	SO_2 Annual		NO_X Annual		NO_X Ozone Season	
	2012 and 2013	2014 and Later	2012 and 2013	2014 and Later	2012 and 2013	2014 and Later
Alabama	216,033	213,258	72,691	71,962	31,746	31,499
Arkansas	---	---	---	---	15,037	15,037
Florida	---	---	---	---	27,825	27,825
Georgia	158,527	95,231	62,010	40,540	27,944	18,279
Illinois	234,889	124,123	47,872	47,872	21,208	21,208
Indiana	285,424	161,111	109,726	108,424	46,876	46,175
Iowa	107,085	75,184	38,335	37,498	16,532*	16,207*
Kansas	41,528	41,528	30,714	25,560	13,536*	10,998*
Kentucky	232,662	106,284	85,086	77,238	36,167	32,674
Louisiana	---	---	---	---	13,432	13,432
Maryland	30,120	28,203	16,633	16,574	7,179	7,179
Michigan	229,303	143,995	60,193	57,812	25,752*	24,727*
Minnesota	41,981	41,981	29,572	29,572	---	---
Mississippi	---	---	---	---	10,160	10,160
Missouri	207,466	165,941	52,374	48,717	22,762*	21,073*
Nebraska	65,052	65,052	26,440	26,440	---	---
New Jersey	5,574	5,574	7,266	7,266	3,382	3,382
New York	27,325	18,585	17,543	17,543	8,331	8,331

North Carolina	136,881	57,620	50,587	41,553	22,168	18,455
Ohio	310,230	137,077	92,703	87,493	40,063	37,792
Oklahoma	---	---	---	---	21,835*	21,835*
Pennsylvania	278,651	112,021	119,986	119,194	52,201	51,912
South Carolina	88,620	88,620	32,498	32,498	13,909	13,909
Tennessee	148,150	58,833	35,703	19,337	14,908	8,016
Texas	243,954	243,954	133,595	133,595	63,043	63,043
Virginia	70,820	35,057	33,242	33,242	14,452	14,452
West Virginia	146,174	75,668	59,472	54,582	25,283	23,291
Wisconsin*	79,480	40,126	31,628	30,398	13,704	13,216
Total	3,301,008	2,128,264	609,435	574,107	1,245,869	1,164,910

*Note: as discussed in the preamble to the final rule, EPA is issuing a supplemental proposal to request comment on inclusion of these six states in the Ozone Season program.

Table F-3. 2009 Electricity Net Generation and EPA Base Case Projections for 2012, 2014, 2020 and 2030 for the Contiguous 48 States (Billion kWh)

	Historical	Base Case			
	2009	2012	2014	2020	2030
Coal	1,754	1,958	2,017	2,037	2,071
Oil	29	0.09	0.10	0.14	0.19
Natural Gas	917	721	686	823	1,155
Nuclear	799	812	822	832	811
Hydroelectric	272	281	287	287	286
Non-hydro Renewables	143	233	250	288	328
Other	0	35	45	44	53
Total	**3,914**	**4,041**	**4,107**	**4,311**	**4,704**

Source: 2009 data from EIA Electric Power Annual 2009, Table 1.1 (adjusted to represent the Contiguous 48 States for consistency with projections, which are from the Integrated Planning Model run by EPA, 2011).

Table F-4. Projected Emissions of SO_2, NO_X, and CO_2 with the Base Case (No Further Controls) and with Transport Rule (Million Tons)

		2012				2014			
		Base	TR	Change	% Change	Base	TR	Change	% Change
SO_2 (Annual)	Contiguous 48 States	7.9	3.9	-3.9	-50%	7.2	3.4	-3.8	-52%
	TR States	7.0	3.0	-4.0	-57%	6.2	2.4	-3.8	-61%
NO_X (Annual)	Contiguous 48 States	2.1	2.0	-0.2	-7%	2.1	1.9	-0.2	-9%
	TR States	1.4	1.3	-0.1	-9%	1.4	1.2	-0.2	-11%
NO_X (Summer)	Contiguous 48 States	0.9	0.9	-0.1	-8%	0.9	0.8	-0.1	-9%
	TR States	0.7	0.6	-0.1	-9%	0.7	0.6	-0.1	-11%
CO_2 (Annual)	Contiguous 48 States	2444	2430	-13	-1%	2482	2454	-28	-1%
	TR States	1769	1747	-22	-1%	1799	1765	-44	-2%

Note: Numbers may not add due to rounding. The emissions data presented here are EPA modeling results and the Transport Rule region includes states modeled for the annual SO_2 and NO_x requirements. "Summer" is from May 1–September 30, which is the ozone season. Base case includes Title IV Acid Rain Program, NO_x SIP Call, and state rules through December 1, 2010.
Source: Integrated Planning Model run by EPA, 2011.

Table F-5. 2010 Fossil-fuel Generation Nationwide and in the Transport Region (Thousand Megawatthours)

	Contiguous US	Transport Rule Fine Particle Area	Transport Rule Ozone Area
Coal-fired	1,829,176	1,405,021	1,510,557
Oil-fired	13,680	5,955	12,080
Natural Gas-fired	894,598	409,534	633,636
Total	**3,954,846**	**2,598,207**	**2,989,910**

Source: EIA Electric Power Monthly with data for December 2010, Tables 1.6B, 1.7.B, 1.8.B, 1.10.B.

Table F-6. Total Fossil-fuel Capacity Nationwide and in the Transport Region

	Contiguous US	Transport Rule Fine Particle Area	Transport Rule Ozone Area
Pulverized Coal	316	247	266
Combined Cycle	199	97	142
Other Oil/Gas	247	155	196
Total	**998**	**630**	**743**

Source: EPA's NEEDS v4.10.

Table F-7. Annualized Compliance Cost of the Transport Rule

	2012	2014	2020
Annualized Compliance Cost (billions of 2007$)	$1.7	$0.7	$0.4

Note: Numbers rounded to the nearest hundred million for annualized cost.
Source: Integrated Planning Model run by EPA, 2011.

Table F-8. Percent of Generation without SO_2 Controls by Coal Sulfur Content, 2014

	Very Low (<0.8 lb/mmBtu)	Low (0.81-1.2 lbs/mmBtu)	Low-Medium (1.21-1.66 lbs/mmBtu)	High-Medium (1.67-3.34 lb/mmBtu)	High (>3.35 lb/mmBtu)
Base Case	27%	37%	8%	15%	13%
Transport Rule	58%	29%	8%	3%	2%

Source: Integrated Planning Model run by EPA, 2011.

Table F-9. Coal Use by Sulfur Category in the $PM_{2.5}$ Transport Region for the Base Case and Transport Rule* (million short tons)

		Lignite	Subbituminous			Bituminous				Total
			High sulfur	Low sulfur	Very low sulfur	High sulfur	High-medium sulfur	Low-medium sulfur	Low sulfur	
2012	Base	30	13	145	156	91	211	83	3	732
	TR	25	2	79	256	77	192	78	13	723
2014	Base	37	13	145	154	102	216	71	9	747
	TR	32	2	106	200	92	202	72	17	724

*These coal usage results are for the 23 states covered by the rule in the trading program to reduce SO_2 emissions. Source: Integrated Planning Model run by EPA, 2011.

Table F-10. Newly-Constructed Advanced SO_2 Control Retrofits on Coal-fired Generation by Technology Built with the Base Case and with the Transport Rule (GW) in 2014

	Base Case	Transport Rule	Incremental Retrofits
Wet FGD	4.6	10.7	6.0
Dry FGD	3.6	4.1	0.5
DSI	6.8	8.9	2.1

Note: FGD (Flue Gas Desulphurization) and DSI (Dry Sorbent Injection) are advanced SO_2 controls. Source: Integrated Planning Model run by EPA, 2011.

Table F-11. Coal-fired Capacity Operating Advanced Pollution Controls with the Transport Rule, 2014 (GW)

	Existing Controls Induced to Operate	Newly-Built Controls	Total Operational Controls
FGD	24	7	209
DSI	0	2	9
SCR	5	0	146

Note: FGD (Flue Gas Desulphurization) and DSI (Dry Sorbent Injection) are advanced SO_2 controls. SCR (Selective Catalytic Reduction) is an advanced NO_X control. Source: Integrated Planning Model run by EPA, 2011.

Table F-12. Projected allowance prices for the four Transport Rule programs in 2012 and 2014 (2007$)

	Emission Allowance Prices ($/Ton)	
	2012	**2014**
Annual SO2 Group 1 Trading Program	1,100	1,300
Annual SO2 Group 2 Trading Program	600	700
Annual NOx Trading Program	500	600
Ozone Season NOx Trading Program	1,600	1,800

Table F-13. Generation Mix with the Base Case (No Further Controls) and with Transport Rule, Contiguous US (Thousand GWh)

	2009	2012				2014			
	Historical	Base	TR	Change from Base	Percent Change	Base	TR	Change from Base	Percent Change
Coal	1,754	1,958	1,933	-24	-1.2%	2,017	1,977	-40	-1.9%
Oil	29	0.09	0.09	0.00	-0.0%	0.10	0.11	0.01	5.8%
Natural Gas	917	721	741	18	2.7%	686	715	29	4.1%
Nuclear	799	812	812	0	0.0%	822	828	6	0.8%
Hydroelectric	272	281	282	1	0.3%	287	286	-1	-0.3%
Non-hydro Renewables	143	233	239	6	2.7%	250	250	1	0.3%
Other	0	35	35	0.0	0.0%	45	45	0.6	1.3%
Total	**3,914**	**4,041**	**4,043**	**2**	**0.1%**	**4,107**	**4,102**	**-4**	**-0.1%**

Note: Numbers may not add due to rounding.
Source: 2009 data from EIA Electric Power Annual 2009, Table 2.1 and Net Generation by State by Type of Producer by Energy Source (EIA-906); 2012 and 2014 projections are from the Integrated Planning Model run by EPA, 2011.

Table F-14. Total Generation Capacity by 2014 (GW)

	2010	Base	TR	Change
Pulverized Coal	317	312	307	-6
Natural Gas Combined Cycle	201	205	205	0
Other Oil/Gas	253	232	233	0
Non-Hydro Renewables	31	70	70	0
Hydro	99	99	99	0
Nuclear	102	103	104	1
Other	5	81	85	4
Total	1,009	1,029	1,025	0

Source: 2010 data from EPA's NEEDS v4.10. Projections from Integrated Planning Model run by EPA.
Note: "Renewables" include biomass, geothermal, solar, and wind electric generation capacity.

Table F-15. Coal Production for the Electric Power Sector with the Base Case (No Further Controls) and with the Transport Rule (Million Tons)

	2009	2012			2014		
Supply Area	Historical	Base	TR	Change from Base	Base	TR	Change from Base
Appalachia	246	193	185	-9	182	183	1
Interior	129	209	184	-26	238	216	-22
West	553	544	570	26	554	552	-1
Waste Coal	14	14	14	0	14	14	0
Imports	19	31	31	0	30	30	0
Total	961	991	983	-8	1,017	995	-22

Source: Production: U.S. Energy Information Administration (EIA data), Coal Distribution -- Annual (Final), web site http://www.eia.doe.gov/cneaf/coal/page/coaldistrib/a_distributions.html (posted February 18, 2011); Waste Coal: U.S. EIA, Monthly Energy Review, January 2011 Edition, Table 6.1 Coal Overview, web site http://www.eia.doe.gov/emeu/mer/coal.html (posted January 31, 2011). Imports: U.S. Energy Information Administration (EIA) and U.S. Census. All projections from Integrated Planning Model run by EPA, 2011.

Table F-16. Projected Regional Retail Electricity Prices with the Base Case (No Further Controls) and with Transport Rule (2007 cents/kWh)

	Base			Transport Rule			Percent Change		
	2012	2014	2020	2012	2014	2020	2012	2014	2020
ECAR	7.4	7.9	8.1	7.7	8.1	8.3	3.5%	2.9%	2.2%
ERCOT	7.8	8.8	8.7	8.1	8.8	8.8	4.0%	0.2%	1.8%
MAAC	8.4	9.4	10.3	8.8	9.5	10.4	4.6%	1.4%	1.1%
MAIN	7.3	7.9	8.4	7.5	8.1	8.4	2.4%	1.7%	0.9%
MAPP	7.8	8.0	7.9	7.8	8.1	7.9	0.4%	0.7%	0.2%
NY	12.5	13.7	13.3	12.9	13.7	13.4	2.9%	0.4%	0.4%
NE	11.4	12.3	11.8	11.7	12.3	11.8	2.1%	-0.2%	0.4%
FRCC	9.5	10.2	9.7	9.6	10.2	9.8	1.3%	-0.3%	0.3%
STV	7.7	7.9	7.8	7.8	7.9	7.8	1.0%	0.5%	0.4%
SPP	7.4	7.6	7.4	7.4	7.6	7.4	0.9%	0.0%	-0.2%
PNW	6.9	7.1	6.9	7.0	7.1	6.9	0.6%	0.0%	0.0%
RM	8.6	9.1	9.4	8.7	9.2	9.4	0.9%	0.2%	0.2%
CALI	12.7	13.0	12.5	12.9	13.0	12.5	1.0%	-0.1%	0.2%
TR Region Average	8.5	9.2	9.2	8.7	9.3	9.3	2.6%	0.8%	0.8%
Contiguous U.S. Average	8.5	9.0	8.9	8.6	9.0	9.0	2.0%	0.7%	0.7%

Source: EPA's Retail Electricity Price Model.

Table F-17. Average Minemouth and Delivered Coal Prices with the Base Case and with the Transport Rule (2007$/MMBtu)

		2012			2014		
	2007	Base	TR	Percent Change from Base	Base	TR	Percent Change from Base
Minemouth	1.27	1.35	1.29	-4.6%	1.37	1.35	-1.7%
Delivered	1.76	2.08	2.05	-1.4%	2.12	2.10	-0.9%

Source: Historical data from EIA AEO 2010 Reference Case Table 15 (Coal Supply, Distribution, and Prices); projections from the Integrated Planning Model run by EPA, 2011.

Table F-18. 2012-2030 Weighted Average Henry Hub and Delivered Natural Gas Prices with the Base Case and with the Transport Rule (2007$/MMBtu)

	Base	TR	Percent Change from Base
Henry Hub	5.32	5.34	0.5%
Delivered - Electric Power	5.60	5.62	0.4%
Delivered - Residential	10.97	10.99	0.2%

Source: Projections from the Integrated Planning Model run by EPA (2011) adjusted to Henry Hub prices using historical data from EIA AEO 2011 reference case to derive residential prices.