Regulatory Impact Analysis of the Cross-State Air Pollution Rule (CSAPR) Update for the 2008 National Ambient Air Quality Standards for Ground-Level Ozone

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Regulatory Impact Analysis of the Cross-State Air Pollution Rule (CSAPR) Update for the 2008 National Ambient Air Quality Standards for Ground-Level Ozone

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EXECUTIVE SUMMARY

Overview

The EPA promulgated the original Cross-State Air Pollution Rule (original CSAPR) on August 8, 2011 (U.S. EPA, 2011), to address interstate transport of ozone pollution under the 1997 Ozone NAAQS.[1] The primary purpose of this Cross-State Air Pollution Rule Update (CSAPR Update) is to address interstate air quality impacts with respect to the 2008 Ozone National Ambient Air Quality Standards (NAAQS). Specifically, this CSAPR Update will reduce ozone season emissions of oxides of nitrogen (NO_X) in 22 eastern states that can be transported downwind as NO_X or, after transformation in the atmosphere, as ozone and contribute significantly to nonattainment or interfere with maintenance of the 2008 Ozone NAAQS in downwind states. For the 22 eastern states affected by this rule, the EPA is issuing Federal Implementation Plans (FIPs) that generally provide updated CSAPR NO_X ozone season emission budgets for electric generating units (EGUs) and is implementing these emission budgets via modifications to the CSAPR NO_X ozone season allowance trading program. The CSAPR Update is also intended to respond to the D.C. Circuit's July 28, 2015, remand of certain CSAPR NO_X ozone season emission budgets to the EPA for reconsideration. This Regulatory Impact Analysis (RIA) presents the health and welfare benefits and climate co-benefits of the CSAPR Update, and compares the benefits to the estimated costs of implementing the CSAPR Update for the 2017 analysis year. This RIA also reports certain other impacts of the CSAPR Update, such as its effect on employment and energy prices. This executive summary explains the analytic approach taken in the RIA and summarizes the RIA results.

ES.1 Identifying Needed Emission Reductions

As described in the preamble for the CSAPR Update, CSAPR provides a 4-step framework for addressing the requirements of CAA section 110(a)(2)(D)(i)(I) (sometimes called the "good neighbor" provision) for ozone or fine particulate matter ($PM_{2.5}$) standards: (1) identifying downwind receptors that are expected to have problems attaining or maintaining clean air standards (i.e., NAAQS); (2) determining which upwind states contribute to these

[1] CSAPR also addressed interstate transport of fine particulate matter ($PM_{2.5}$) under the 1997 and 2006 $PM_{2.5}$ NAAQS.

identified problems in amounts sufficient to "link" them to the downwind air quality problems; (3) for states linked to downwind air quality problems, identifying upwind emissions that significantly contribute to downwind nonattainment or interfere with downwind maintenance of a standard; and (4) reducing the identified upwind emissions via regional allowance trading programs, for states that are found to have emissions that significantly contribute to nonattainment or interfere with maintenance of the NAAQS downwind. The CSAPR Update applies this 4-step framework to update CSAPR to address interstate emissions transport for the 2008 ozone NAAQS in the eastern United States.

Application of the first two steps of the 4-step framework with respect to the 2008 ozone NAAQS provides the analytic basis for finding that ozone season emissions in 22 eastern states[2] affect the ability of downwind states to attain and maintain the 2008 ozone NAAQS. Figure ES-1 shows these states, which are affected by this rule. More details on the methods and results of applying this process can be found in the preamble for this CSAPR Update, and in Chapter 4 of this RIA.

[2] Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

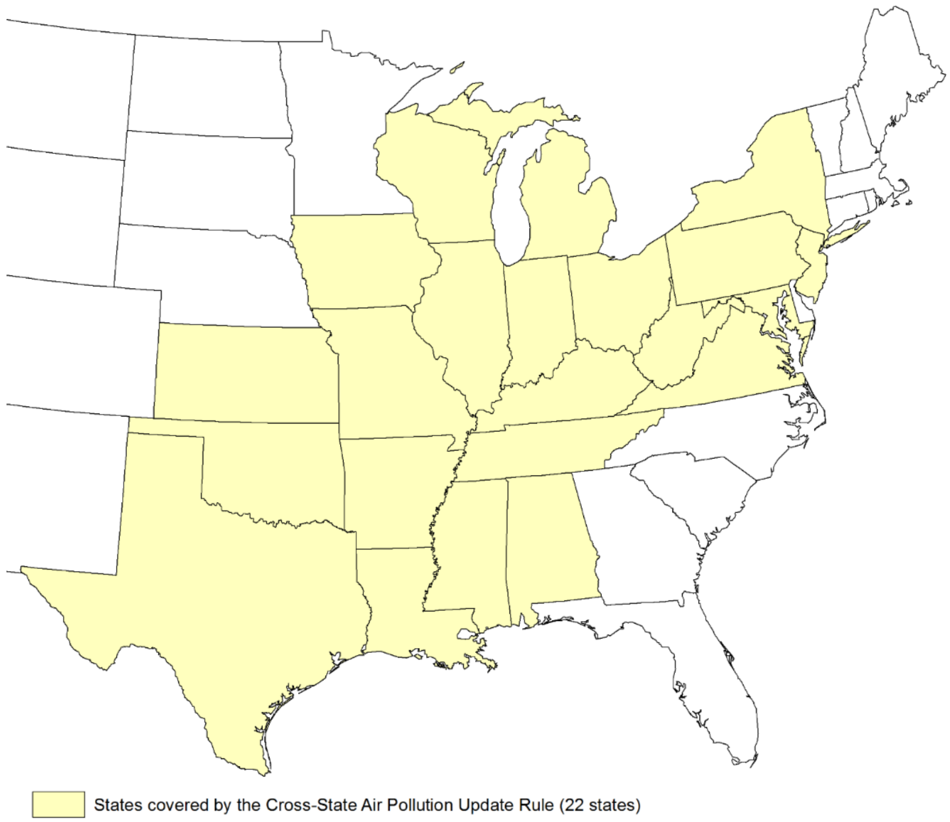

Figure ES-1. States Covered by the Cross-State Air Pollution Rule Update

Applying Step 3 of the 4-step framework, the CSAPR Update quantifies EGU NO_X emission budgets for these 22 eastern states. A state's CSAPR Update NO_X ozone season emission budget represents the quantity of remaining EGU NO_X emissions after reducing those emissions that significantly contribute to downwind nonattainment or interfere with maintenance of the 2008 Ozone NAAQS in an average year.[3] These updated CSAPR NO_X emissions budgets were developed considering EGU NO_X reductions that are achievable for the 2017 ozone season.[4] In calculating these budgets,the EPA applied the CSAPR multi-factor test to evaluate cost, available emission reductions, and downwind air quality impacts to determine the appropriate level of uniform NO_X control stringency that addresses the impacts of interstate transport on downwind nonattainment or maintenance receptors. The EPA is finalizing EGU

[3] For example, assuming no abnormal variation in electricity supply due to events such as abnormal meteorology.

[4] Non-EGU NO_X emission control measures and reductions are not included in this CSAPR Update.

NO_X ozone season emission budgets developed using uniform control stringency represented by $1,400 per ton control costs (2011$).[5] Applying Step 4 of the 4-step framework, the EPA is finalizing FIPs for each of the 22 states that require affected EGUs to participate in the CSAPR NO_X ozone season allowance trading program subject to the final emission budgets.

For this RIA, in order to implement the OMB Circular A-4 requirement to assess at least one less stringent and one more stringent alternative to a rulemaking, the EPA is also analyzing EGU NO_X ozone season emission budgets developed using uniform control stringency represented by $800 per ton (2011$) and emission budgets developed using uniform control stringency represented by $3,400 per ton (2011$).[6] The results of these analysis are summarized in section ES.3 below.

ES.2 Baseline and Analysis Years

The CSAPR Update sets forth the requirements for 22 eastern states to reduce their significant contribution to downwind nonattainment or interference with maintenance of the 2008 ozone NAAQS. To evaluate the benefits and costs of this regulation, it is important to first establish a baseline projection of both emissions and air quality in the analysis years of 2017 and 2020, taking into account currently on-the-books Federal regulations,[7] substantial Federal regulatory updates, enforcement actions, state regulations,[8] population, and where possible,

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[5] The basis for identifying this level of uniform control stringency is discussed in section VI.B of the preamble to the CSAPR Update rule and in the EGU NO_X Mitigation Strategies Final Rule TSD. Further, the basis for finalizing EGU NO_X emission budgets developed using this level of uniform NO_X control stringency is described in section VI.C of the preamble to the CSAPR Update Rule.

[6] The bases for identifying these levels of uniform control stringency are discussed in section VI.B of the preamble to the CSAPR Update rule.

[7] The proposed CSAPR Update used an IPM base case that included the EPA's Clean Power Plan (CPP). Many commenters requested that the agency not include the Clean Power Plan in the 2017 EGU projections. For the reasons discussed in Section V.B of the preamble, we have excluded the CPP from the base case modeling for this rule.

[8] After the emissions and air quality modeling for the final rule were underway, Pennsylvania published a new RACT rule that requires EGU and non-EGU NO_X reductions starting on January 1, 2017. The EPA was unable to explicitly include this final state rule in the baseline emission projections for the final CSAPR Update Rule. However, the EPA recognizes that the implementation of this final state rule will precede the first control period for the final CSAPR Update Rule. The agency quantifies costs and benefits of the CSAPR Update in this RIA that are incremental to Pennsylvania's RACT rule.

economic growth. Establishing this baseline for the analysis then allows us to estimate the incremental costs and benefits of the additional emission reductions that will be achieved by the CSAPR Update.[9]

The analysis in this RIA focuses on benefits, costs and certain impacts in 2017. Certain impacts in 2020, such as forecast emissions changes from the electricity sector, are also reported in this RIA. The results from the analysis in support of the CSAPR Update that are reported in this RIA are limited to these two analysis years. Other regulatory actions, including the 2015 ozone NAAQS, are expected to have a growing influence on the power sector in later years, as explained below. For this reason, the EPA expects that most of the CSAPR Update's influence on emissions reductions will occur between 2017 and 2020.

Below is a list of some of the national rules reflected in the baseline. Chapters 3 and 4 provide additional explanation about which rules are acccounted for in the baseline as well as other details about how the baseline was constructed for this RIA. For a more complete list of the rules reflected in the air quality modeling, please see the Technical Support Document: Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform (U.S. EPA, 2015). For a list of those regulations reflected in the compliance and cost modeling of the electricity sector, please see "EPA Base Case v.5.15 Using IPM Incremental Documentation" August, 2015.[10]

- Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units (U.S. EPA, 2015a)
- Tier 3 Motor Vehicle Emission and Fuel Standards (U.S. EPA, 2014)
- 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards (U.S. EPA, 2012)

[9] Note that this modeling platform does not include the Regional Haze Plan for Texas and Oklahoma, published January 5, 2016. The EPA does not believe this rule would substantially affect ozone season NO_X emissions in 2017, and therefore budgets determined for this rule.

[10] http://www.epa.gov/powersectormodeling/html

- Cross State Air Pollution Rule (CSAPR) (U.S. EPA, 2011)[11]
- Mercury and Air Toxics Standards (MATS) (U.S. EPA, 2011a)[12]
- Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles (U.S. EPA, 2011b)[13]
- C3 Oceangoing Vessels (U.S. EPA, 2010)
- Reciprocating Internal Combustion Engines (RICE) NESHAPs (U.S. EPA, 2010a)
- Regulation of Fuels and Fuel Additives: Modifications to Renewable Fuel Standard Program (RFS2) (U.S. EPA, 2010b)
- Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; for Model-Year 2012-2016 (U.S. EPA, 2010c)
- Hospital/Medical/Infectious Waste Incinerators: New Source Performance Standards and Emission Guidelines: Amendments (U.S. EPA, 2009)
- Emissions Standards for Locomotives and Marine Compression-Ignition Engines (U.S. EPA, 2008a)
- Control of Emissions for Nonroad Spark Ignition Engines and Equipment (U.S. EPA, 2008b)

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[11] On July 28, 2015, the D.C. Circuit issued its opinion regarding CSAPR on remand from the Supreme Court, *EME Homer City Generation, L.P., v. EPA*, No. 795 F.3d 118, 129-30, 138 (*EME Homer City II*). Unlike the modeling for the proposed rule, which was conducted prior to the D.C. Circuit's issuance of EME Homer City II, this projected base case accounts for compliance with the original CSAPR by including as constraints all original CSAPR emission budgets with the exception of remanded phase 2 NO_X ozone season emission budgets for 11 states and phase 2 NO_X ozone season emission budgets for four additional states that were finalized in the original CSAPR supplemental rule. Specifically, to reflect original CSAPR ozone season NO_X requirements, the modeling includes as constraints the original CSAPR NO_X ozone season emission budgets for 10 states -- Alabama, Arkansas, Georgia, Illinois, Indiana, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. For further discussion, see Chapter 4 of this RIA.

[12] In *Michigan v. EPA*, the Supreme Court reversed on narrow grounds a portion of the D.C. Circuit decision upholding the MATS rule, finding that the EPA erred by not considering cost when determining that regulation of EGUs was "appropriate" pursuant to CAA section 112(n)(1). 135 S.Ct. 192 (2015). On remand, the D.C. Circuit left the MATS rule in place pending the EPA's completion of its cost consideration in accordance with the Supreme Court's decision. *White Stallion Energy Ctr. v. EPA*, No. 12-1100 (Dec. 15, 2015) (order remanding MATS rule without vacatur). The EPA finalized its supplemental action responding to the Supreme Court's Michigan decision on April 14, 2016. 81 FR 24420 (April 25, 2016). The MATS rule is currently in place.

[13] This rule is Phase 1 of the Heavy Duty Greenhouse Gas Standards for New Vehicles and Engines (76 FR 57106, September 15, 2011). Phase 2 of the Heavy Duty Greenhouse Gas Standards for New Vehicles and Engines (80 FR 40138, July 13, 2015) is not included because the rulemaking was not finalized in time to include in this analysis.

- NO_x Emission Standard for New Commercial Aircraft Engines (U.S. EPA, 2005)
- Regional Haze Regulations and Guidelines for Best Available Retrofit Technology Determinations (U.S. EPA, 2005a)

With regard to the increment of impacts attributable to the CSAPR Update and the original CSAPR, the EPA does not believe that the costs and benefits for the original CSAPR and the CSAPR Update are entirely additive. The EPA recognizes that the majority of the benefits of the original CSAPR were derived from reductions in SO_2 and annual NOx emissions, and the benefits of the CSAPR Update are primarily based on ozone-season NOx emissions reductions. However, five years have passed between promulgation of the original CSAPR and the CSAPR Update, and the two rules have different baselines. In the intervening five years, changes in the power sector that are independent of these rules, such as changes in fuel costs and electricity markets as well as other federal and state level actions, which creates challenges when estimating the sum of the costs and benefits of these two rules. In addition, implementation of the original CSAPR was delayed such that its two phases were implemented as phase I – limits to be met by 2015, and phase II – limits to be met by 2017. The reductions estimated for the CSAPR Update in 2017, given that it replaces remanded original CSAPR budgets, may overlap with reductions that would have otherwise occurred for phase II. However, the benefits and costs of CSAPR are still notable given the enduring original CSAPR ozone season NOx budgets, annual NOx budgets, and SO_2 budgets. While the EPA did remove the remanded ozone season NOx budgets for three states, two of these states (North Carolina and South Carolina) remain subject to annual NOx requirements. These original CSAPR budgets are all present in EPA's modeling of the baseline and policy alternatives.

Also, EPA expects that most of the CSAPR Update's influence on emissions reductions will occur between 2017 and 2020. We have excluded the CPP from the base case modeling for this rule. The EPA does not anticipate significant interactions with the CPP and the near-term ozone season EGU NO_X emission reduction requirements under the CSAPR Update.

ES.3 Control Strategies and Emissions Reductions

The CSAPR Update requires EGUs in 22 eastern states to reduce interstate transport of NO_X emissions that significantly contribute to nonattainment or interfere with maintenance of the 2008 ozone NAAQS. The CSAPR Update sets EGU NO_X ozone season emission budgets (allowable emission levels) for 2017 and future years. The CSAPR Update also finalizes FIPs for each of the 22 states that require affected EGUs to participate in the CSAPR NO_X ozone season allowance trading program. The allowance trading program is the remedy in the FIP that achieves the ozone season NO_X emission reductions required by the CSAPR Update. The allowance trading program essentially converts the EGU NO_X emission budget for each of the 22 states subject to the FIP into a limited number of NO_X ozone season allowances that, on a tonnage basis, equal the state's ozone season emission budget.

The final CSAPR Update EGU NO_X ozone season emission budgets for each state were developed using uniform control stringency represented by $1,400 per ton of NO_X reductions for affected EGUs. Furthermore, this RIA analyzes regulatory control alternatives based on more and less stringent state emission budgets developed using uniform control stringency represented by $3,400 per ton and $800 per ton, respectively. As described in Chapter 4 the analysis in this RIA uses illustrative budgets that differ somewhat from the finalized budgets for the CSAPR Update, because the analysis for this RIA began before the budgets were finalized. Appendix 4A reports the emissions reductions and costs of EPA's analysis of the CSAPR Update with the finalized budgets.

The EPA analyzed ozone season NO_X emission reductions from implementing the CSAPR Update EGU NO_X ozone season emission budgets using the Integrated Planning Model (IPM). Table ES-1 shows the emission reductions expected from the CSAPR Update and the more and less stringent alternatives analyzed. Included in the table are annual and seasonal NO_X and carbon dioxide (CO_2) reductions over the contiguous U.S.

Table ES-1. Projected 2017* EGU Emissions Reductions of $NO_X$and CO_2 with the CSAPR Update NO_X Emission Budgets and More and Less Stringent Alternatives (Tons)**

	CSAPR Update	More Stringent Alternative	Less Stringent Alternative
NO_X (annual)	75,000	79,000	27,000
NO_X (ozone season)	61,000	66,000	27,000
CO_2 (annual)	1,600,000	2,000,000	1,300,000

* The forecast of annual reductions of CO_2 in 2017 is based on 2018 IPM direct model outputs.
** NO_x emissions are reported in English (short) tons; CO_2 is reported in metric tons. All estimates rounded to two significant figures.

ES.4 Costs

In addition to emission reductions, the EPA estimated compliance costs associated with the regulatory control alternatives. The compliance cost estimate represents the change in the cost of supplying electricy under each regulatory control alternative. This change reflects both the changes in electricity production costs resulting from application of NO_X control strategies, as well as differences in costs related to the small changes in the generation fuel mix projected to occur as a result of compliance with the emissions budgets. The Agency uses the compliance cost estimate from IPM as a proxy for social costs.

The estimate of the total cost of this CSAPR Update, therefore, is the combination of NO_X costs estimated by IPM and additional costs estimated outside of IPM. The cost estimates for the CSAPR Update and more and less stringent alternatives are presented in Table ES-2. All costs are in 2011 dollars.

Table ES-2. Cost Estimates (2011$) for CSAPR Update and More and Less Stringent Alternatives

Alterantive	Annualized*
CSAPR Update	$68,000,000
More Stringent Alternative	$82,000,000
Less Stringent Alternative	$8,000,000

*Costs are annualized over the period 2017 through 2020 using the 4.77 percent discount rate used in IPM's objective function for minimizing the net present value of the stream of total costs of electricity generation. An explanation of the annualization of these costs can be found in Chapter 4 of this RIA. All estimates are rounded to two significant figures.

ES.5 Benefits to Human Health and Welfare

Implementing this CSAPR Update is expected to reduce emissions of ozone season NO_X. In the presence of sunlight, NO_X and VOCs can undergo a chemical reaction in the atmosphere to form ozone. Reducing NO_X emissions also reduces human exposure to ozone and the incidence of ozone-related health effects, depending on local levels of volatile organic compounds (VOCs). In addition, implementing the CSAPR Update is expected to reduce emissions of NO_X throughout the year. Because NO_X is also a precursor to formation of ambient $PM_{2.5}$, reducing NO_X emissions would also reduce human exposure to ambient $PM_{2.5}$ throughout the year and would reduce the incidence of $PM_{2.5}$-related health effects. Finally, these emission reductions would lower ozone and $PM_{2.5}$ concentrations in regions beyond those subject to this

CSAPR Update, though this RIA does not account for benefits outside of the CSAPR Update 22-state region. Additionally, although we do not have sufficient data to quantify these impacts in this analysis, reducing emissions of NO_X would also reduce ambient exposure to nitrogen dioxide (NO_2) and its associated health effects.

In this section, we provide an overview of the monetized ozone benefits and $PM_{2.5}$-related co-benefits estimated from NO_X reductions for compliance with the CSAPR EGU NO_X ozone season emission budgets and for the more and less stringent alternatives. A full description of the underlying data, studies, and assumptions is provided in the PM NAAQS RIA (U.S. EPA, 2012a) and Ozone NAAQS RIA (U.S. EPA, 2015b). The EPA does not view the projected change in SO_2 from IPM as a meaningful impact of the policy. Accordingly, this RIA does not quantify SO_2-related $PM_{2.5}$ co-benefits.

ES.5.1 Human Health Benefits and Climate Co-benefits

This analysis utilizes a “damage-function” approach in calculating benefits, which estimates changes in individual health endpoints (specific effects that can be associated with changes in air quality) and assigns values to those changes assuming independence of the values for those individual endpoints. Because the EPA rarely has the time or resources to perform new research to measure directly either health outcomes or their values for regulatory analyses, our estimates are based on the best available methods of benefits transfer, which is the science and art of adapting primary research from similar contexts to estimate benefits for the environmental quality change under analysis. The benefit-per-ton approach we use in this RIA relies on estimates of human health responses to exposure to ozone and PM obtained from the peer-reviewed scientific literature. These estimates are used in conjunction with population data, baseline health information, air quality data and economic valuation information to conduct health impact and economic benefits assessments. These assessments form the key inputs to calculating benefit-per-ton estimates. Thus, to develop estimates of benefits for this RIA, we are transferring both the underlying health and economic information from previous studies and information on air quality responses to emission reductions from other air quality modeling.

To perform the benefits transfer in this RIA we follow a “benefit-per-ton” approach to estimating the ozone and $PM_{2.5}$ benefits. Benefit-per-ton approaches apply an average benefit-per-ton derived from modeling of benefits of specific air quality scenarios to estimates of emission reductions for scenarios where no air quality modeling is available. The benefit-per-ton values used in this RIA were estimating using air quality modeling conducted specifically for this RIA. The baseline air quality modeling used to estimate the benefit-per-ton values does not account for the Pennsylvania RACT, and the policy case is the CSAPR Update with the illustrative budgets described in Chapter 4. More information on these approaches is available in Chapter5 of the RIA.

The Health Impact Assessment (HIA) for ozone and $PM_{2.5}$, discussed further in Chapter 5 of this RIA, quantifies the changes in the incidence of adverse health impacts resulting from changes in human exposure to ozone and $PM_{2.5}$. We use the environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE) (version 1.1) to systematize health impact analyses by applying a database of key input parameters, including population projections, health impact functions, and valuation functions (US EPA, 2016). For this assessment, the HIA is limited to those health effects that are directly linked to ambient ozone and $PM_{2.5}$ concentrations. Table ES-3 provides national summaries of the reductions in estimated health incidences associated with the final CSAPR EGU NO_x ozone season emission budgets and for more and less stringent alternatives for 2017.

Table ES-3. Summary of Avoided Health Incidences from Ozone-Related and $PM_{2.5}$-Related Benefits for the CSAPR Update and More and Less Stringent Alternatives for 2017*

Ozone-related Health Effects	CSAPR Update	More Stringent Alternative	Less Stringent Alternative
Avoided Premature Mortality			
Smith *et al.* (2009) (all ages)	21	23	9
Zanobetti and Schwartz (2008) (all ages)	60	65	26
Avoided Morbidity			
Hospital admissions—respiratory causes (ages > 65)	59	64	26
Emergency room visits for asthma (all ages)	240	250	100
Asthma exacerbation (ages 6-18)	67,000	73,000	30,000
Minor restricted-activity days (ages 18-65)	170,000	180,000	75,000
School loss days (ages 5-17)	56,000	60,000	25,000
$PM_{2.5}$-related Health Effects			
Avoided Premature Mortality			
Krewski *et al.* (2009) (adult)	10	11	3.7
Lepeule *et al.* (2012) (adult)	23	25	8.4
Woodruff *et al.* (1997) (infant)	<1	<1	<1
Avoided Morbidity			
Emergency department visits for asthma (all ages)	6.1	6.5	2.2
Acute bronchitis (age 8–12)	15	15	5.2
Lower respiratory symptoms (age 7–14)	180	190	67
Upper respiratory symptoms (asthmatics age 9–11)	260	280	95
Minor restricted-activity days (age 18–65)	7,500	7,900	2,700
Lost work days (age 18–65)	1,300	1,300	450
Asthma exacerbation (age 6–18)	270	290	98
Hospital admissions—respiratory (all ages)	2.8	2.9	1.0
Hospital admissions—cardiovascular (age > 18)	3.8	4.0	1.4
Non-Fatal Heart Attacks (age >18)			
Peters *et al.* (2001)	12	13	4.3
Pooled estimate of 4 studies	1.3	1.4	0.46

* All estimates are rounded to whole numbers with two significant figures. Co-benefits for ozone are based on ozone season NOx emissions. In general, the 95th percentile confidence interval for the health impact function alone ranges from approximately ±30 percent for mortality incidence based on Krewski *et al.* (2009) and ±46 percent based on Lepeule *et al.* (2012). The confidence intervals around the ozone mortality estimates are on the order of ± 60 percent depending on the concentration-response function used.

There may be other indirect health impacts associated with reducing emissions, such as occupational health exposures. We refer the reader to Chapter 5 of this RIA, as well as to the Ozone NAAQS RIA (U.S. EPA, 2015b) and PM NAAQS RIA (U.S. EPA, 2012a) for more information regarding the epidemiology studies and risk coefficients applied in this analysis.

Co-benefits of the CSAPR Update come from reducing emissions of CO_2. Chapter 5 of this RIA provides a brief overview of the 2009 Endangerment Finding and climate science assessments released since then. Chapter 5 also provides information regarding the economic valuation of CO_2 using the social cost of carbon (SC-CO_2), a metric that estimates the monetary value of impacts associated with marginal changes in CO_2 emissions in a given year.

ES.5.2 Combined Health Benefits and Climate Co-Benefits Estimates

In this analysis we were able to monetize the estimated benefits associated with the reduced exposure to ozone and $PM_{2.5}$ and co-benefits of decreased emissions of $CO_{2.}$ Specifically, we estimated combinations of health benefits at discount rates of 3 percent and 7 percent (as recommended by the EPA's *Guidelines for Preparing Economic Analyses* [U.S. EPA, 2014] and OMB's *Circular A-4* [OMB, 2003]) and climate co-benefits using four SC-CO_2 estimates (the average SC-CO_2 at each of three discount rates—5 percent, 3 percent, 2.5 percent—and the 95^{th} percentile SC-CO_2 at 3 percent as recommended in the current SC-CO_2 technical support document (TSD) [U.S. EPA, 2015c]; see Chapter 5 of this RIA for more details). In this analysis we were unable to monetize the co-benefits associated with reducing exposure to NO_2, as well as ecosystem effects and visibility impairment associated with reductions in NO_X.

Table ES-3 reports the ozone and PM2.5-related benefits for the CSAPR Update and the more and less stringent alternatives for the 2017 analysis year. ES-4 provides the combined health and climate benefits for the CSAPR Update and for more and less stringent alternatives for the 2017 analysis year. In the table, ranges within the total benefits rows reflect multiple studies upon which the estimates of premature mortality were derived.

Table ES-3. Summary of Estimated Monetized Health Benefits for the CSAPR Update and More and Less Stringent Alternatives Regulatory Control Alternatives for 2017 (millions of 2011$) *

Pollutant		CSAPR Update	More Stringent Alternative	Less Stringent Alternative
NOx (as Ozone)		$370 to $610	$400 to $650	$160 to $270
NOx (as $PM_{2.5}$)	3% Discount Rate	$93 to $210	$98 to $220	$34 to $75
	7% Discount Rate	$83 to $190	$88 to $200	$30 to $67
Total	3% Discount Rate	$460 to $810	$500 to $870	$200 to $340
	7% Discount Rate	$450 to $790	$490 to $850	$190 to $330

* All estimates are rounded to two significant figures so numbers may not sum down columns. The health benefits range is based on adult mortality functions (e.g., from Krewski et al. (2009) with Smith et al. (2009) to Lepeule et al. (2012) with Zanobetti and Schwartz (2008)). The estimated monetized co-benefits do not include reduced health effects from direct exposure to NO_2, ecosystem effects or visibility impairment. All fine particles are assumed to have equivalent health effects. The CSAPR Update values, the more and less stringent alternatives were all calculated using a benefits per ton approach. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles and ozone. Benefits for ozone are based on ozone season NO_X emissions. Ozone benefits occur in analysis year, so they are the same for all discount rates. $PM_{2.5}$ benefits are based on annual NOx emissions and the nitrate-only fraction of $PM_{2.5}$. In general, the confidence intervals around the ozone mortality estimates are on the order of ± 60 percent depending on the concentration-response function used. The 95th percentile confidence interval for monetized $PM_{2.5}$ benefits ranges from approximately -90 percent to +180 percent of the central estimates based on Krewski *et al.* (2009) and Lepeule *et al.* (2012)..

Table ES-4. Combined Health Benefits and Climate Co-Benefits for the CSAPR Update and More and Less Stringent Alternatives for 2017 (millions of 2011$)*

$SC\text{-}CO_2$ Discount Rate**	Health and Climate Benefits (Discount Rate Applied to Health Co-Benefits) 3%	7%	Climate Co-Benefits Only
CSAPR Update			
5%	$480 to $830	$470 to $810	$19
3%	$530 to $880	$520 to $860	$66
2.5%	$560 to $910	$550 to $890	$100
3% (95th percentile)	$650 to $1,000	$640 to $980	$190
More Stringent Alternative			
5%	$490 to $840	$480 to $820	$25
3%	$550 to $900	$540 to $880	$87
2.5%	$590 to $940	$580 to $920	$130
3% (95th percentile)	$710 to $1,100	$700 to $1,000	$250
Less Stringent Alternative			
5%	$480 to $830	$470 to $810	$15
3%	$510 to $860	$500 to $840	$54
2.5%	$540 to $890	$530 to $870	$81
3% (95th percentile)	$610 to $960	$600 to $940	$150

*All estimates are rounded to two significant figures. Climate benefits are based on reductions in CO_2 emissions. Health benefits are based on benefit-per-ton estimates. Benefits for ozone are based on ozone season NOx emissions. Ozone benefits occur in analysis year, so they are the same for all discount rates. The health benefits reflect the sum of the ozone benefits and $PM_{2.5}$ co-benefits and reflect the range based on adult mortality functions (e.g., from Krewski *et al.* (2009) with Smith *et al.* (2009) to Lepeule *et al.* (2012) with Zanobetti and Schwartz (2008)). The monetized health benefits do not include reduced health effects from direct exposure to NO_2 as well as ecosystem effects and visibility impairment associated with reductions in NO_X. **As discussed in section 5.3, the $SC\text{-}CO_2$ estimates are calculated with four different values of a one metric ton reduction.

Table ES-5 summarizes the national monetized ozone-related and PM-related health benefits estimated to occur for the CSAPR Update and two regulatory control alternatives for the 2017 analysis year using discount rates of 3 percent (non-fatal heart attacks quantified using Peters et al. (2001)) and 7 percent (non-fatal heart attacks quantified using a pooled estimate that includes Pope et al. (2006)).

Table ES-5. Summary of Estimated Monetized Health Benefits for the CSAPR Update and More and Less Stringent Alternatives Regulatory Control Alternatives for 2017 (millions of 2011$) *

Pollutant		CSAPR Update	More Stringent Alternative	Less Stringent Alternative
NOx (as Ozone)		$370 to $610	$400 to $650	$160 to $270
NOx (as $PM_{2.5}$)	3% Discount Rate	$93 to $210	$98 to $220	$34 to $75
	7% Discount Rate	$83 to $190	$88 to $200	$30 to $67
Total	3% Discount Rate	$460 to $810	$500 to $870	$200 to $340
	7% Discount Rate	$450 to $790	$490 to $850	$190 to $330

* All estimates are rounded to two significant figures so numbers may not sum down columns. The health benefits range is based on adult mortality functions (e.g., from Krewski et al. (2009) with Smith et al. (2009) to Lepeule et al. (2012) with Zanobetti and Schwartz (2008)). The estimated monetized co-benefits do not include reduced health effects from direct exposure to NO_2, ecosystem effects, or visibility impairment. All fine particles are assumed to have equivalent health effects, but the benefit-per-ton estimates vary depending on the location and magnitude of their impact on $PM_{2.5}$ levels, which drive population exposure. The CSAPR Update values, the more and less stringent alternatives were all calculated using the benefits per ton approach based on the final modeling scenario. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles and ozone. Benefits for ozone are based on ozone season NO_X emissions. Ozone co-benefits occur in analysis year, so they are the same for all discount rates. and are based on annual NOx emissions and the nitrate-only fraction of $PM_{2.5}$. In general, the 95th percentile confidence interval for monetized $PM_{2.5}$ benefits ranges from approximately -90 percent to +180 percent of the central estimates based on Krewski *et al.* (2009) and Lepeule *et al.* (2012). The confidence intervals around the ozone mortality estimates are on the order of ± 60 percent depending on the concentration-response function used.

ES.5.3 Unquantified Health and Welfare Co-Benefits

The monetized health co-benefits estimated in this RIA reflect a subset of co-benefits attributable to the health effect reductions associated with ambient fine particles. Data, time, and resource limitations prevented the EPA from quantifying the impacts to, or monetizing the co-benefits from several important benefit categories, including reduced exposure to NO_2, as well as ecosystem effects, and reduced visibility impairment from reduced NO_X emissions. These benefits were unable to be quantified due to the absence of air quality modeling data for these pollutants. This does not imply that there are no co-benefits associated with changes in exposures to NO_2 or changes in ecosystem effects and visibility impairments from NOx reduction; the identified co-benefits are listed in Table ES-6 below, and discussed more fully in Chapter 5 of this RIA.

Table ES-6. Unquantified Health and Welfare Co-benefits Categories

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Improved Human Health				
	Asthma hospital admissions (all ages)	—	—	NO_2 ISA[1]

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Reduced incidence of morbidity from exposure to NO_2	Chronic lung disease hospital admissions (age > 65)	—	—	NO_2 ISA[1]
	Respiratory emergency department visits (all ages)	—	—	NO_2 ISA[1]
	Asthma exacerbation (asthmatics age 4–18)	—	—	NO_2 ISA[1]
	Acute respiratory symptoms (age 7–14)	—	—	NO_2 ISA[1]
	Premature mortality	—	—	NO_2 ISA[1,2,3]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	—	—	NO_2 ISA[2,3]
Improved Environment				
Reduced visibility impairment	Visibility in Class 1 areas	—	—	PM ISA[1]
	Visibility in residential areas	—	—	PM ISA[1]
Reduced effects on materials	Household soiling	—	—	PM ISA[1,2]
	Materials damage (e.g., corrosion, increased wear)	—	—	PM ISA[2]
Reduced effects from PM deposition (metals and organics)	Effects on Individual organisms and ecosystems	—	—	PM ISA[2]
Reduced vegetation and ecosystem effects from exposure to ozone	Visible foliar injury on vegetation	—	—	Ozone ISA[1]
	Reduced vegetation growth and reproduction	—	—	Ozone ISA[1]
	Yield and quality of commercial forest products and crops	—	—	Ozone ISA[1]
	Damage to urban ornamental plants	—	—	Ozone ISA[2]
	Carbon sequestration in terrestrial ecosystems	—	—	Ozone ISA[1]
	Recreational demand associated with forest aesthetics	—	—	Ozone ISA[2]
	Other non-use effects			Ozone ISA[2]
	Ecosystem functions (e.g., water cycling, biogeochemical cycles, net primary productivity, leaf-gas exchange, community composition)	—	—	Ozone ISA[2]
Reduced effects from acid deposition	Recreational fishing	—	—	NO_x SO_x ISA[1]
	Tree mortality and decline	—	—	NO_x SO_x ISA[2]
	Commercial fishing and forestry effects	—	—	NO_x SO_x ISA[2]
	Recreational demand in terrestrial and aquatic ecosystems	—	—	NO_x SO_x ISA[2]
	Other non-use effects			NO_x SO_x ISA[2]
	Ecosystem functions (e.g., biogeochemical cycles)	—	—	NO_x SO_x ISA[2]
Reduced effects from nutrient enrichment	Species composition and biodiversity in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[2]
	Coastal eutrophication	—	—	NO_x SO_x ISA[2]
	Recreational demand in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[2]
	Other non-use effects			NO_x SO_x ISA[2]
	Ecosystem functions (e.g., biogeochemical cycles, fire regulation)	—	—	NO_x SO_x ISA[2]
Reduced vegetation effects from ambient exposure to NO_x				
	Injury to vegetation from NO_x exposure	—	—	NO_x SO_x ISA[2]

[1] We assess these co-benefits qualitatively due to data and resource limitations for this RIA. More information is contained in the integrated science assessments (ISAs) for the proposed or final NAAQS standards cited.

[2]We assess these co-benefits qualitatively because we do not have sufficient confidence in available data or methods.
[3] We assess these co-benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

ES.5 Results of Benefit-Cost Analysis

Below in Table ES-7, we present the primary costs and benefits estimates for 2017. Net benefits are also presented, reflecting the benefits of implementing the EGU NO_X emission budgets for the affected 22 states via the final FIPs, minus the costs of achieving those emissions reductions.

The guidelines of OMB Circular A-4 require providing comparisons of social costs and social benefits at discount rates of 3 and 7 percent. The four different uses of discounting in the RIA – (i) construction of annualized costs, (ii) adjusting the value of mortality risk for lags in mortality risk decreases, (iii) adjusting the cost of illness for non-fatal heart attacks to adjust for lags in follow up costs, and (iv) discounting climate co-benefits – are all appropriate. We explain our discounting of benefits in Chapter 5 of the RIA, specifically the application of discount rates of 3 and 7 percent to $PM_{2.5}$-related co-benefits and 2.5, 3, and 5 percent to climate co-benefits; we explain our discounting of costs, in which we use a single discount rate of 4.77 percent, in Chapter 4. Our estimates of net benefits represent the net value (in 2017) of benefits attributable to emission reductions needed to implement the NO_X emission budgets for each state.

Table ES-7. Total Costs, Total Monetized Benefits, and Net Benefits of the CSAPR Update and More and Less Stringent Alternatives in 2017 for U.S. (millions of 2011$)[a,b,c,d]

	CSAPR Update	More Stringent Alternative Alternative	Less Stringent Alternative
Climate Co-Benefits	$66	$87	$54
Air Quality Health Benefits	$460 to $810	$500 to $870	$200 to $340
Total Benefits	$530 to $880	$580 to $960	$250 to $400
Annualized Compliance Costs	$68	$82	$8
Net Benefits	$460 to $810	$500 to $880	$240 to $390
Non-Monetized Benefits[e]	Non-monetized climate benefits Reductions in exposure to ambient NO_2 and SO_2 Ecosystem benefits assoc. with reductions in emissions of NOx		

[a] Estimating multiple years of costs and benefits is limited for this RIA by data and resource limitations. As a result, we provide compliance costs and social benefits in 2017, using the best available information to approximate compliance costs and social benefits recognizing uncertainties and limitations in those estimates.
[b] Benefits ranges represent discounting of health benefits and climate co-benefits at a discount rate of 3 percent. See Chapter 5 for additional detail and explanation. The costs presented in this table reflect compliance costs annualized at a 4.77 percent discount rate and do not include monitoring, recordkeeping, and reporting costs, which are reported separately. See Chapter 4 for additional detail and explanation.
[c] All costs and benefits are rounded to two significant figures; columns may not appear to add correctly.
[d] Ozone and PM2.5 benefits from NO_X emission reductions are for the 22-state region only.
[Z] Non-monetized benefits descriptions are for all three alternatives and are qualitative.

ES.6 Analytical Changes Subsequent to the Proposal

Costs

The EPA's IPM modeling platform used to analyze this rule (v.5.15) is similar to the version used to analyze the CSAPR Update proposal, and incorporates minor updates made primarily in response to comments received on an August 4, 2015 Notice of Data Availability and the proposed rule.

Unlike the modeling for the proposed rule, which was conducted prior to the D.C. Circuit's issuance of *EME Homer City II*,[14] the base case for the final rule accounts for compliance with

[14] In *EME Homer City II*, the D.C. Circuit declared invalid the CSAPR phase 2 NO_X ozone season emission budgets of 11 states: Florida, Maryland, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Texas, Virginia, and West Virginia. *Id.* 795 F.3d at 129-30, 138. The court remanded those budgets to the EPA for reconsideration. *Id.* at 138. As a result, the EPA removed the original CSAPR phase 2 NO_X ozone season emission budgets as constraints for these 11 states in the 2017 IPM modeling.

the original CSAPR by including as constraints all original CSAPR emission budgets with the exception of remanded phase 2 NO_X ozone season emission budgets for 11 states and phase 2 NO_X ozone season emission budgets for four additional states that were finalized in the original CSAPR supplemental rule.[15] Additionally, the Clean Power Plan (CPP) is not included in this analysis. The base case results also reflect the recent Pennsylvania RACT, requires EGU NO_X reductions starting on January 1, 2017. For further discussion, see Chapter 4 of this RIA

Benefits

We modified our approach for estimating ozone and $PM_{2.5}$-related benefits between the proposed and final rule. First, we calculated new ozone and $PM_{2.5}$ benefit per ton estimates using the results of an updated air quality modeling scenario. These air quality modeling predictions more closely represent the selected policy option than the proposal modeling, but did not account for either the final emissions budgets or the Pennsylvania RACT rule. Thus, the air quality modeling scenario simulated a larger level of NOx emission reductions than the final policy option implemented. Consequently, we applied ozone and $PM_{2.5}$ benefit-per-ton values to quantify the benefits of the final policy option and more and less stringent alternative options.

Second, when estimating the $PM_{2.5}$-related benefits for the final CSAPR rule we use a benefit-per-ton value calculated using a nitrate-attributable $PM_{2.5}$ benefit-per-ton estimate; the proposal analysis used a total $PM_{2.5}$ benefit per-ton-value. The EPA determined that, considering the final CSAPR Update Rule illustrative emissions modeling results, using total $PM_{2.5}$ would incorrectly additionally account for the benefits of reduced sulfate and directly emitted $PM_{2.5}$ benefits, which the illustrative emissions modeling does not anticipate occurring.

Third, in this final rule the EPA estimated the benefits from the NOx emission reductions only for the CSAPR states, whereas the proposed rule estimate national benefits from reductions in NOx. The approach taken in the final rule likely underestimates total benefits to the extent that

[15] The EPA acknowledges that the CSAPR NO_X ozone season emission budgets for Iowa, Michigan, Oklahoma, and Wisconsin -- which were finalized in the original CSAPR Supplemental Rule (76 FR 80760, December 27, 2011) -- were linked to the same receptors that lead to the remand of other states' NO_X ozone season emission budgets in EME Homer City II.

downwind states in New England and certain Southeast states would likely improved air quality from this rule.

ES.7 References

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CHAPTER 1: INTRODUCTION AND BACKGROUND

Introduction

The EPA is finalizing this Cross-State Air Pollution Rule Update (CSAPR Update) to address interstate transport of emissions of nitrogen oxides (NO_X) that contribute significantly to nonattainment or interfere with maintenance of the 2008 Ozone National Ambient Air Quality Standard (NAAQS) in downwind states. The primary purpose of the CSAPR Update is to address interstate air quality problems with respect to the 2008 ozone NAAQS. However, the CSAPR Update is also intended to respond to the D.C. Circuit's July 28, 2015 remand of certain CSAPR NO_X ozone season emission budgets to the EPA for reconsideration. This Regulatory Impact Analysis (RIA) presents the health and welfare benefits of the CSAPR Update, and compares the benefits of the CSAPR Update to the estimated costs of implementing the rule in 2017. This RIA also reports certain other impacts of the CSAPR Update, such as its effect on employment and energy prices. This chapter contains background information regarding the CSAPR Update and an outline of the chapters of this RIA.

1.1 Background

The purpose of this rulemaking is to protect public health and welfare by reducing interstate emission transport that significantly contributes to nonattainment, or interferes with maintenance, of the 2008 ozone NAAQS in the eastern U.S. Ground-level ozone causes a variety of negative effects on human health, vegetation, and ecosystems. In humans, acute and chronic exposure to ozone is associated with premature mortality and a number of morbidity effects, such as asthma exacerbation. Ozone exposure can also negatively impact ecosystems, for example, by limiting tree growth. Studies have established that ozone occurs on a regional scale (i.e., hundreds of miles) over much of the eastern U.S., with elevated concentrations occurring in rural as well as metropolitan areas. The 2008 ozone NAAQS is an 8-hour standard that was set at 75 parts per billion (ppb). *See* 73 FR 16436 (March 27, 2008).

Clean Air Act (CAA or the Act) section 110(a)(2)(D)(i)(I), sometimes called the "good neighbor" provision, requires states to prohibit emissions that will contribute significantly to nonattainment in, or interfere with maintenance by, any other state with respect to any primary or secondary NAAQS.[16] The EPA promulgated the original Cross-State Air Pollution Rule (original CSAPR) on August 8, 2011[17] to address interstate transport for the 1997 Ozone NAAQS and the 1997 and 2006 Fine Particulate matter ($PM_{2.5}$) NAAQS.[18] (See section III.A.1.of the preamble to the CSAPR Update for a discussion of CSAPR litigation and implementation.)

As described in the preamble for the CSAPR Update, CSAPR provides a 4-step framework for addressing the requirements of the good neighbor provision for ozone or $PM_{2.5}$ standards: (1) identifying downwind receptors that are expected to have problems attaining or maintaining clean air standards (i.e., NAAQS); (2) determining which upwind states contribute to these problems in amounts sufficient to "link" them to the downwind air quality problems; (3) for states linked to downwind air quality problems, identifying upwind emissions that significantly contribute to nonattainment or interfere with maintenance; and (4) for states that are found to have emissions that significantly contribute to nonattainment or interfere with maintenance of the NAAQS downwind, reducing the identified upwind NO_X emissions via regional allowance trading programs. In the CSAPR Update, the EPA applies this 4-step framework to update CSAPR with respect to the 2008 ozone NAAQS. For 22 eastern states, this CSAPR Update finalizes electric generating unit (EGU) NO_X emission budgets representing the quantity of remaining EGU NO_X emissions after reducing those amounts that significantly contribute to downwind nonattainment or interfere with maintenance of the 2008 ozone NAAQS in an average year.[19] The CSAPR Update finalizes FIPs for each of the 22 states that require affected EGUs to participate in the CSAPR NO_X ozone season allowance trading program subject to these emission budgets. More details on the methods and results of applying this framework can be found in the preamble for this CSAPR Update and in Chapter 4 of this RIA.

[16] The EPA uses the term "states" to include the District of Columbia in this RIA.

[17] See 76 FR 48208 (August 8, 2011)

[18] CSAPR did not evaluate transport obligations for the 2008 ozone standard because the 2008 ozone NAAQS was under reconsideration during the analytic work for CSAPR.

[19] For example, assuming no abnormal variation in electricity supply due to events such as abnormal meteorology.

1.2.1 Role of Executive Orders in the Regulatory Impact Analysis

Several statutes and executive orders apply to any public document. Certain analyses required by these statutes and executive orders are presented in detail in Chapter 4, and all are discussed in the preamble to the CSAPR Update. Below, we briefly discuss the requirements of Executive Orders 12866 and 13563 and the guidelines of the Office of Management and Budget (OMB) Circular A-4 (U.S. OMB, 2003).

In accordance with Executive Orders 12866 and 13563 and the guidelines of OMB Circular A-4, the RIA analyzes the benefits and costs associated with emission reductions for compliance with the CSAPR Update. OMB Circular A-4 requires analysis of at least one potential alternative standard level more stringent than the CSAPR Update and one less stringent than the CSAPR Update. This RIA evaluates the benefits, costs, and certain impacts of a more and a less stringent alternative to the CSAPR Update.

1.2.2 Illustrative Nature of this Analysis

For the 22 CSAPR Update states, this rule finalizes EGU NO_X emission budgets and finalizes FIPs that require affected EGUs to participate in the CSAPR NO_X ozone season allowance trading program subject to these emission budgets. The EGU emission budgets assessed in this RIA are illustrative of those that the EPA is finalizing. Further, implementation via the CSAPR NO_X ozone season allowance trading program provides utilities with the flexibility to determine their own compliance path. This RIA develops and analyzes one possible scenario for compliance with the illustrative EGU NOx emission budgets and possible scenarios for EGU compliance with more and less stringent alternatives.

1.2.3 The Need for Air Quality or Emissions Standards

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

Environmental problems are classic examples of externalities – uncompensated benefits or costs imposed on another party as a result of one's actions. For example, the smoke from a factory may adversely affect the health of local residents and soil the property in nearby neighborhoods. Pollution emitted in one state may be transported across state lines and affect air quality in a neighboring state. If bargaining were costless and all property rights were well defined, people would eliminate externalities through bargaining without the need for government regulation.

From an economics perspective, setting an emissions standard (i.e., EGU NO_X ozone season emission budgets in this CSAPR Update) is a remedy to address an externality in which firms emit pollutants, resulting in health and environmental problems without compensation for those incurring the problems. Setting the emissions standard attempts to incentivize those who emit the pollutants to reduce their emissions, which lessens the impact on those who suffer the health and environmental problems from higher levels of pollution.

1.2 Overview and Design of the RIA

1.2.1 Methodology for Identifying Required Reductions

Application of the first two steps of the CSAPR framework (described above) with respect to the 2008 ozone NAAQS provides the analytic basis for finding that ozone season emissions in 22 eastern states[20] affect the ability of downwind states to attain and maintain the 2008 ozone NAAQS. Figure 1-1 shows the covered states.

[20] Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

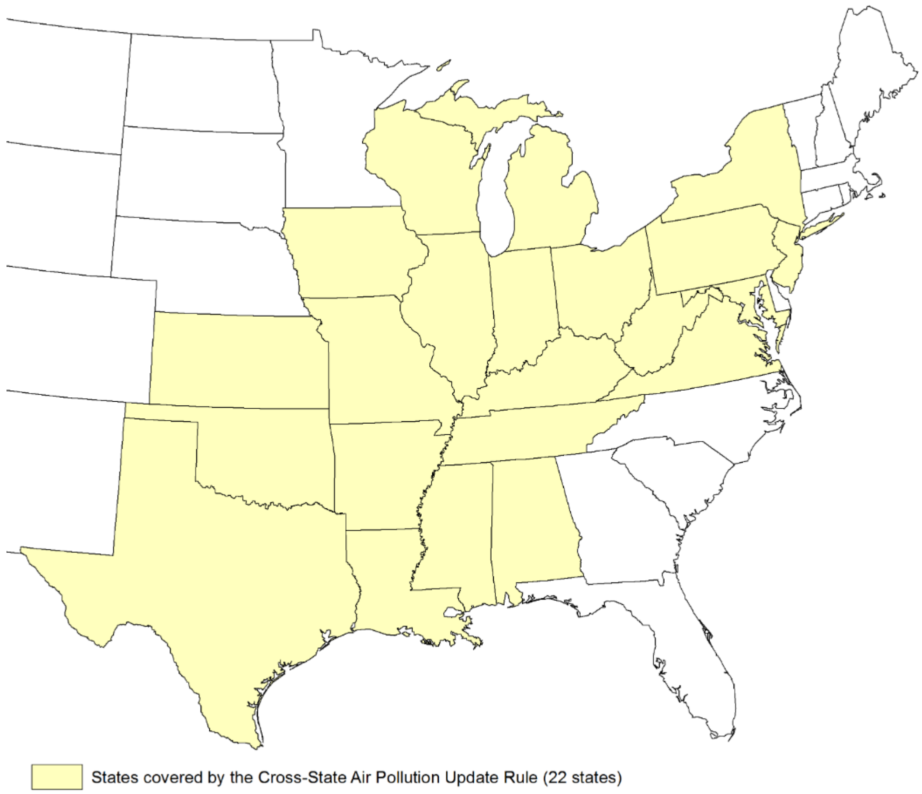

Figure 1-1. States Covered by the Cross-State Air Pollution Rule Update

Applying Step 3 of the 4-step framework, the CSAPR Update quantifies EGU NO_X emission budgets for these 22 eastern states. A state's CSAPR Update NO_X ozone season emission budget represents the quantity of remaining EGU NO_X emissions after reducing those emissions that significantly contribute to downwind nonattainment or interfere with maintenance of the 2008 Ozone NAAQS in an average year.[21] These updated CSAPR NO_X emissions budgets were developed considering EGU NO_X reductions that are achievable for the 2017 ozone season.[22] In calculating these budgets,the EPA applied the CSAPR multi-factor test to evaluate cost, available emission reductions, and downwind air quality impacts to determine the appropriate level of uniform NO_X control stringency that addresses the impacts of interstate transport on downwind nonattainment or maintenance receptors. The EPA is finalizing EGU

[21] For example, assuming no abnormal variation in electricity supply due to events such as abnormal meteorology.

[22] Non-EGU NO_X emission control measures and reductions are not included in this CSAPR Update.

NO_X ozone season emission budgets developed using uniform control stringency represented by $1,400 per ton control costs (2011$). Applying Step 4 of the 4-step framework, the EPA is finalizing FIPs for each of the 22 states that require affected EGUs to participate in the CSAPR NO_X ozone season allowance trading program subject to the final emission budgets.

For this RIA, in order to implement the OMB Circular A-4 requirement to assess at least one less stringent and one more stringent alternative to a rulemaking, the EPA is also analyzing EGU NO_X ozone season emission budgets developed using uniform control stringency represented by $800 per ton (2011$) and emission budgets developed using uniform control stringency represented by $3,400 per ton (2011$).

1.2.2 States Covered by the CSAPR Update

For the 22 states affected by one of the FIPs finalized in the CSAPR Update, the EPA is promulgating new FIPs with lower EGU NO_X ozone season emission budgets to reduce interstate transport for the 2008 ozone NAAQS. Of the 22 CSAPR Update states, 21 states[23] have original CSAPR NO_X ozone season FIP requirements with respect to the 1997 ozone NAAQS. One state, Kansas, has newly added CSAPR NO_X ozone season compliance requirements under this CSAPR Update. One state for which the EPA proposed a FIP in the proposed CSAPR Update rule, North Carolina, was found in the final air quality modeling not to be linked to any downwind nonattainment or maintenance receptors. Therefore, the EPA is not finalizing a FIP for North Carolina.

1.2.3 Regulated Entities

The CSAPR Update affects fossil fuel-fired EGUs in these 22 eastern states which are classified as code 221112 by the North American Industry Classification System (NAICS) and have a nameplate capacity of greater than 25 megawatts (MWe).

[23] Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

1.2.4 Baseline and Analysis Year

As described in the preamble, the EPA aligns implementation of the CSAPR Update with relevant attainment dates for the 2008 ozone NAAQS, consistent with the D.C. Circuit's decision *North Carolina v. EPA*.[24] The EPA's final 2008 Ozone NAAQS SIP Requirements Rule established the attainment deadline of July 20, 2018, for ozone nonattainment areas currently designated as Moderate.[25] Because the attainment date falls during the 2018 ozone season, the 2017 ozone season will be the last full season from which data can be used to determine attainment of the NAAQS by the July 20, 2018 attainment date. Therefore, the EPA has identified achievable upwind emission reductions and aligned implementation of these reductions, to the extent possible, for the 2017 ozone season.

The CSAPR Update sets forth the requirements for states to reduce their significant contribution to downwind nonattainment and interference with maintenance of the 2008 ozone NAAQS. To develop and evaluate control strategies for addressing these obligations, it is important to first establish a baseline projection of air quality in the analysis year of 2017, taking into account currently on-the-books Federal regulations, substantial Federal regulatory CSAPR updates, enforcement actions, state regulations, population, and where possible, economic growth. Establishing this baseline for the analysis then allows us to estimate the incremental costs and benefits of the additional emissions reductions that will be achieved by the CSAPR Update. Furthermore, the analysis in this RIA focuses on benefits, costs and certain impacts in 2017. Certain impacts in 2020, such as forecast emissions changes from the electricity sector, are also reported in this RIA. The results from the analysis in support of the CSAPR Update that are reported in this RIA are limited to these two analysis years. Other regulatory actions, including the 2015 ozone NAAQS and the Clean Power Plan (CPP), are expected to have a growing influence on the power sector in later years, as explained below. For this reason, the EPA expects that most of the CSAPR Update's influence on emissions reductions will occur between 2017 and 2020.

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[24] 531 F.3d 896, 911-12 (D.C. Cir. 2008) (holding that EPA should coordinate interstate transport compliance deadlines with downwind attainment deadlines).

[25] This deadline is in accordance with the D.C. Circuit's decision in *NRDC v. EPA*. 777 F.3d 456, 469 (D.C. Cir. 2014).

EPA limits its analysis to this timeframe considering that on October 1, 2015, the EPA strengthened the ground-level ozone NAAQS to 70 ppb. As discussed in the RIA for the final 2015 ozone NAAQS, it is assumed that potential nonattainment areas everywhere in the U.S., excluding California, will be designated such that they are required to attain the revised standard by 2025. Furthermore, the EPA is mindful of the need to address ozone transport for the 2015 ozone NAAQS. As discussed in the memo to EPA Regional Administrators, *Implementing the 2015 Ozone National Ambient Air Quality Standards*, implementation of the good neighbor provision for the 2015 ozone NAAQS may use the CSAPR framework. Given the statutory implementation timeline of good neighbor requirements with respect to the 2015 ozone NAAQS, the EPA anticipates that further actions to reduce interstate emission transport related to ozone pollution could take place in the near future.[26] Therefore, it is appropriate to evaluate the costs of the regulatory control alternatives over the 2017-2020 timeframe.

For the reasons discussed in section V.B of the preamble, we have excluded the CPP from the base case modeling for this rule. The EPA does not anticipate significant interactions with the CPP and the near-term ozone season EGU NO_X emission reduction requirements under the CSAPR Update. See sections V.B and VII.F of the preamble for further discussion.

1.2.5 Emissions Controls and Cost Analysis Approach

The EPA estimated the control strategies and compliance costs of the CSAPR Update using the Integrated Planning Model (IPM) as well as certain costs that are estimated outside the model, but use IPM inputs for their estimation. These cost estimates reflect costs incurred by the power sector, and include (but are not limited to) the costs of turning on existing NO_X control technology, fully operating existing NO_X control technology, purchasing, installing, and operating NO_X control technology, changes in fuel costs, and changes in the generation mix. A description of the methodologies used to estimate the costs and economic impacts to the power sector is contained in Chapter 4 of this RIA.

[26] See preamble section VII.

1.2.6 Benefits Analysis Approach

The EPA estimated human health benefits (i.e., mortality and morbidity effects) considering an array of health impacts attributable to changes in exposure to ozone and fine particulate matter ($PM_{2.5}$) from NOx reductions. We estimated these benefits using benefit-per-ton estimates derived from the BenMAP tool. The EPA also estimated the climate co-benefits of the CSAPR Update. A description of the methodologies used to estimate the human health and climate benefits is contained in Chapter 5 of this RIA. In addition, Chapter 5 contains a discussion of welfare co-benefits, such as ecosystem benefits from reduced nitrogen deposition.

1.3 Organization of the Regulatory Impact Analysis

This RIA is organized into the following remaining chapters:

- *Chapter 2: Electric Power Sector Profile.* This chapter describes the electric power sector in detail.
- *Chapter 3*: *Emissions and Air Quality Modeling Impacts*. The data, tools, and methodology used for the air quality modeling are described in this chapter, as well as the post-processing techniques used to produce a number of air quality metrics for input into the analysis of benefits and costs.
- *Chapter 4: Costs.* The chapter summarizes the data sources and methodology used to estimate the costs incurred by the power sector as well as changes in electricity and fuel prices.
- *Chapter 5: Benefits*. The chapter quantifies the health-related and climate benefits of the ozone-related air quality improvements associated with the three regulatory control alternatives analyzed.
- *Chapter 6: Economic Impacts.* The chapter summarizes the data sources and methodology used to estimate the economic impacts including employment impacts and impacts on small entities.
- *Chapter 7: Comparison of Benefits and Costs*. The chapter compares estimates of the total benefits with total costs and summarizes the net benefits of the three alternative regulatory control scenarios analyzed.

CHAPTER 2: ELECTRIC POWER SECTOR PROFILE

Overview

This chapter discusses important aspects of the power sector that relate to today's final action to update CSAPR with respect to the interstate transport of emissions of nitrogen oxides (NO_X) that contribute significantly to nonattainment or interfere with maintenance of the 2008 ozone NAAQS in downwind states. This chapter describes types of existing power-sector sources affected by the proposed regulation, and provides background on the power sector and electricity generating units (EGUs). In addition, this chapter provides some historical background on trends in the past decade in the power sector, as well as about existing EPA regulation of the power sector.

2.1 Background

In the past decade there have been significant structural changes in both the mix of generating capacity and in the share of electricity generation supplied by different types of generation. These changes are the result of multiple factors in the power sector, including normal replacements of older generating units with new units, changes in the electricity intensity of the U.S. economy, growth and regional changes in the U.S. population, technological improvements in electricity generation from both existing and new units, changes in the prices and availability of different fuels, and substantial growth in electricity generation by renewable and unconventional methods. Many of these trends will continue to contribute to the evolution of the power sector. The evolving economics of the power sector, in particular the increased natural gas supply and subsequent relatively low natural gas prices, have resulted in more gas being utilized as base load energy in addition to supplying electricity during peak load. This chapter presents data on the evolution of the power sector from 2000 through 2014. Projections of future power sector behavior and the impact of this rule are discussed in more detail in chapters 3 and 4 of this RIA.

2.2 Power Sector Overview

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

2.2.1 Generation

Electricity generation is the first process in the delivery of electricity to consumers. There are two important aspects of electricity generation; capacity and net generation. *Generating Capacity* refers to the maximum amount of production an EGU is capable of producing in a typical hour, typically measured in megawatts (MW) for individual units, or gigawatts (1 GW = 1,000 MW) for multiple EGUs. *Electricity Generation* refers to the amount of electricity actually produced by an EGU over some period of time, measured in kilowatt-hours (kWh) or gigawatt-hours (GWh = 1 million kWh). Net Generation is the amount of electricity that is available to the grid from the EGU (i.e., excluding the amount of electricity generated but used within the generating station for operations). Electricity generation is most often reported as the total annual generation (or some other period, such as seasonal). In addition to producing electricity for sale to the grid, EGUs perform other services important to reliable electricity supply, such as providing backup generating capacity in the event of unexpected changes in demand or unexpected changes in the availability of other generators. Other important services provided by generators include facilitating the regulation of the voltage of supplied generation.

Individual EGUs are not used to generate electricity 100 percent of the time. Individual EGUs are periodically not needed to meet the regular daily and seasonal fluctuations of electricity demand. Furthermore, EGUs relying on renewable resources such as wind, sunlight and surface water to generate electricity are routinely constrained by the availability of adequate wind, sunlight or water at different times of the day and season. Units are also unavailable during routine and unanticipated outages for maintenance. These factors result in the mix of generating capacity types available (e.g., the share of capacity of each type of EGU) being substantially different than the mix of the share of total electricity produced by each type of EGU in a given season or year.

Most of the existing capacity generates electricity by creating heat to create high pressure steam that is released to rotate turbines which, in turn, create electricity. Natural gas combined cycle (NGCC) units have two generating components operating from a single source of heat. The first cycle is a gas-fired turbine, which generates electricity directly from the heat of burning natural gas. The second cycle reuses the waste heat from the first cycle to generate steam, which is then used to generate electricity from a steam turbine. Other EGUs generate electricity by using water or wind to rotate turbines, and a variety of other methods including direct photovoltaic generation also make up a small, but growing, share of the overall electricity supply. The generating capacity includes fossil-fuel-fired units, nuclear units, and hydroelectric and other renewable sources (see Table 2-1). Table 2-1 also shows the comparison between the generating capacity in 2000 and 2014.

In 2014 the power sector consisted of over 19,000 generating units with a total capacity[27] of 1,038 GW, an increase of 255 GW (or 33 percent) from the capacity in 2000 (782 GW). The 255 GW increase consisted primarily of natural gas fired EGUs (211 GW) and wind generators (62 GW), with substantially smaller net increases and decreases in other types of generating units.

Table 2-1. Total Net Summer Electricity Generating Capacity by Energy Source, 2000 and 2014

	2000		2014		Change Between '00 and '14		
Energy Source	**Net Summer Capacity (MW)**	**% Total Capacity**	**Net Summer Capacity (MW)**	**% Total Capacity**	**% Increase**	**Capacity Change (MW)**	**% of Total Capacity Increase**
Coal	310,198	39%	295,906	29%	-5%	-14,293	-6%
Natural Gas	204,696	28%	415,592	40%	103%	210,896	83%
Nuclear	97,860	12%	98,569	10%	0.7%	709.3	0.3%
Hydro	97,769	11%	101,856	10%	4%	4,087	2%
Petroleum	60,710	8%	40,078	4%	-34%	-20,632	-8%
Wind	2,377	0.3%	64,156	6.2%	2599%	61,779	24%
Other Renewable	8,190	1.6%	19,768	1.9%	141%	11,578	5%
Misc	331	0.4%	1,631	0.2%	393%	1,300	0.5%
Total	782,131	100%	1,037,556	100%	33%	255,425	100%

Note: This table presents generation capacity. Actual net generation is presented in Table 2-2.
Source: U.S. EIA. Electric Power Annual 2014, Table 4.3

[27] This includes generating capacity at EGUs primarily operated to supply electricity to the grid and combined heat and power facilities classified as Independent Power Producers (IPP), and excludes generating capacity at commercial and industrial facilities that does not operate primarily as an EGU. Natural Gas information in this chapter (unless otherwise stated) reflects data for all generating units using natural gas as the primary fossil heat source. This includes Combined Cycle Combustion Turbine, Gas Turbine, steam, and miscellaneous (< 1 percent)

The 33 percent increase in generating capacity is the net impact of newly built generating units, retirements of generating units, and a variety of increases and decreases to the nameplate capacity of individual existing units due to changes in operating equipment, changes in emission controls, etc. During the period 2000 to 2014, a total of 368 GW of new generating capacity was built and brought online, and 80 GW existing units were retired. The overall net change in capacity was an increase of 288 GW, as shown in Figure 2-1.

The newly built generating capacity was primarily natural gas (265 GW), which was partially offset by gas retirements (35 GW). Wind capacity was the second largest type of new builds (62 GW), augmented by solar (10 GW). The overall mix of newly built and retired capacity, along with the net effect, is shown on Figure 2-1.

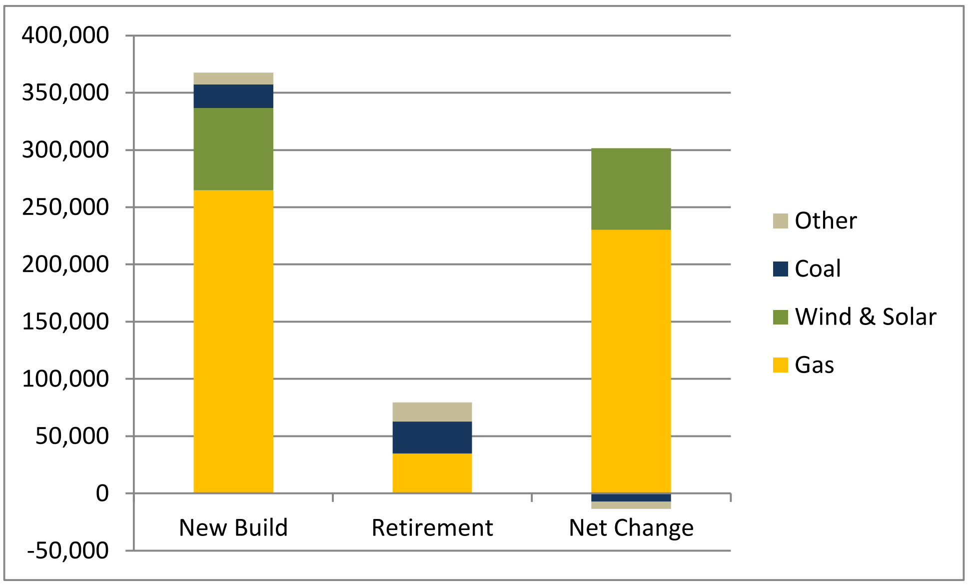

Figure 2-1. National New Build and Retired Capacity (MW) by Fuel Type, 2000-2014[28]

The information in Table 2-1 and Figure 2-1 present information about the generating capacity in the entire U.S. The CSAPR Update Rule, however, directly affects EGUs in 22 eastern states (i.e., the CSAPR 2008 Ozone Region), as discussed in Chapter 1. The share of generating capacity from each major type of generation differs between the CSAPR 2008 Ozone

[28] Source: EIA Form 860. Not visible: wind and solar retirements = 87 MW, net change in coal capacity = -4,186 MW

Region and the rest of the U.S. (non-region). Figure 2-2 shows the mix of generating capacity for each region. In 2014, the overall capacity in the CSAPR 2008 Ozone Region is 59% of the national total, reflecting the larger total population in the region. The mix of capacity is noticeably different in the two regions. In the CSAPR 2008 Ozone Region in 2014, coal makes up a significantly larger share of total capacity (34 percent) than it does in the rest of the country (20%). The shares of natural gas, however, are quite similar (40% in the CSAPR 2008 Ozone Region and 40% in the rest of the country). The difference in the share of coal's capacity is primarily balanced by relatively more hydro, wind, and solar capacity in the rest of country compared to the CSAPR 2008 Ozone Region.

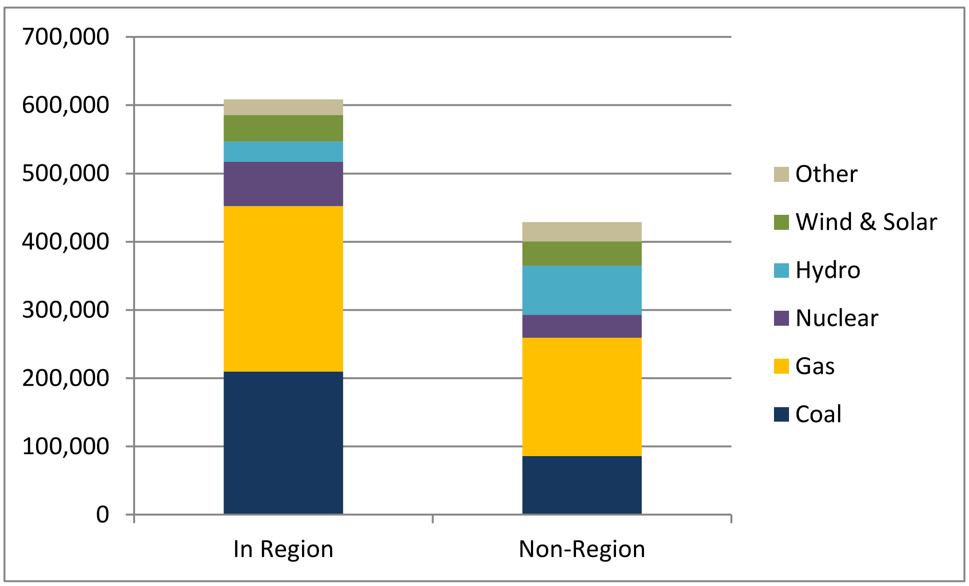

Figure 2-2. Regional Differences in Generating Capacity (MW), 2014.

Source: 2014 EIA Form 860 Note: "Other" includes petroleum, geothermal, other renewable, waste materials and misc."In-Region" refers to the 22 states within the CSAPR 2008 Ozone Region; "Non-Region" refers to all other states in the contiguous U.S.

In 2014, electric generating sources produced a net 3,937 TWh to meet national electricity demand, an 8 percent increase from 2000. As presented in Table 2-2, almost 70 percent of electricity in 2014 was produced through the combustion of fossil fuels, primarily coal and natural gas, with coal accounting for the largest single share. Although the share of the total generation from fossil fuels in 2014 (67 percent) was only modestly smaller than the total fossil share in 2000 (71 percent), the mix of fossil fuel generation changed substantially during that period. Coal generation declined by 19 percent and petroleum generation by 73 percent, while natural gas generation increased by 100 percent. This reflects both the increase in natural gas capacity during that period as well as an increase in the utilization of new and existing gas EGUs during that period. Wind generation also grew from a very small portion of the overall total in 2000 to almost 5 percent of the 2014 total.

Table 2-2. Net Generation in 2000 and 2014 (Trillion kWh = TWh)

	2000		2014		Change Between '00 and '14	
	Net Generation (TWh)	**Fuel Source Share**	**Net Generation (TWh)**	**Fuel Source Share**	**Net Generation Change (TWh)**	**% Change in Net Generation**
Coal	1,943	52%	1,569	40%	-374	-19%
Natural Gas	517	16%	1,033	26%	516	100%
Nuclear	753	20%	797	20%	44	6%
Hydro	265	7%	252	6%	-13	-5%
Petroleum	105	3%	28	1%	-77	-73%
Wind	5	0%	181	5%	176	3530%
Other Renewable	43	2%	66	2%	23	53%
Misc	2	0%	11	0%	9	434%
Total	**3,637**	**100%**	**3,937**	**100%**	**300**	**8%**

Source: U.S. EIA 2014 Electric Power Annual, Tables 3.2 and 3.3. Columns may not sum to totals due to rounding. Percent change based on rounded values

Coal-fired and nuclear generating units have historically supplied “base load” electricity, the portion of electricity loads which are continually present, and typically operate throughout all hours of the year. The 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 2-3). For example, coal-fired units less than 100 megawatts (MW) in size compose 31 percent of the total number of coal-fired units, but only 4 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 has historically supplied “peak” and “intermediate” 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 2-3 also shows comparable data for the capacity and age distribution of natural gas units. Compared with the fleet of coal EGUs, the natural gas fleet of EGUs is generally smaller and newer. While 57 percent of the coal EGU fleet capacity is over 500 MW per unit, only 8 percent of the gas fleet capacity is greater than 500 MW per unit. Many of the largest gas units are gas-fired steam-generating EGUs.

Table 2-3. Coal and Natural Gas Generating Units, by Size, Age, Capacity, and Average Heat Rate in 2014

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)
COAL							
0 – 24	130	12%	47	14	1,772	1%	12,269
25 – 49	80	8%	40	36	2,919	1%	11,718
50 – 99	117	11%	48	73	8,545	3%	11,725
100 - 149	106	10%	52	123	13,052	4%	10,926
150 - 249	166	16%	48	190	31,531	11%	10,524
250 - 499	197	19%	40	356	70,150	23%	10,450
500 - 749	183	17%	37	606	110,952	37%	10,222
750 - 999	57	5%	33	824	46,981	16%	9,952
1000 - 1500	11	1%	38	1259	13,850	5%	9,644
Total Coal	1047	100%	43	286	299,753	100%	10,900
NATURAL GAS							
0 – 24	1,990	36%	35	7	13,922	3%	13,212
25 – 49	837	15%	23	40	33,488	7%	11,712
50 – 99	1001	18%	23	71	71,185	16%	11,999
100 - 149	414	8%	21	125	51,753	11%	9,593
150 - 249	1024	19%	15	176	179,952	40%	8,368
250 - 499	192	3%	24	342	65,652	15%	8,935
500 - 749	41	1%	35	586	24,020	5%	10,808
750 - 1000	13	0.24%	38	851	11,062	2%	10,694
Total Gas	5512	100%	26	82	451,034	100%	11,419

Source: National Electric Energy Data System (NEEDS) v.5.15
Note: The average heat rate reported is the mean of the heat rate of the units in each size category (as opposed to a generation-weighted or capacity-weighted average heat rate.) A lower heat rate indicates a higher level of fuel efficiency. Table is limited to coal-steam units in operation in 2013 or earlier, and excludes those units in NEEDS with planned retirements in 2014 or 2015.

In terms of the age of the generating units, almost 50 percent of the total coal generating capacity has been in service for more than 40 years, while nearly 50 percent of the natural gas capacity has been in service less than 15 years. Figure 2-2 presents the cumulative age distributions of the coal and gas fleets, highlighting the pronounced differences in the ages of the fleets of these two types of fossil-fuel generating capacity. Figure 2-3 also includes the distribution of generation, which is similar to the distribution of capacity.

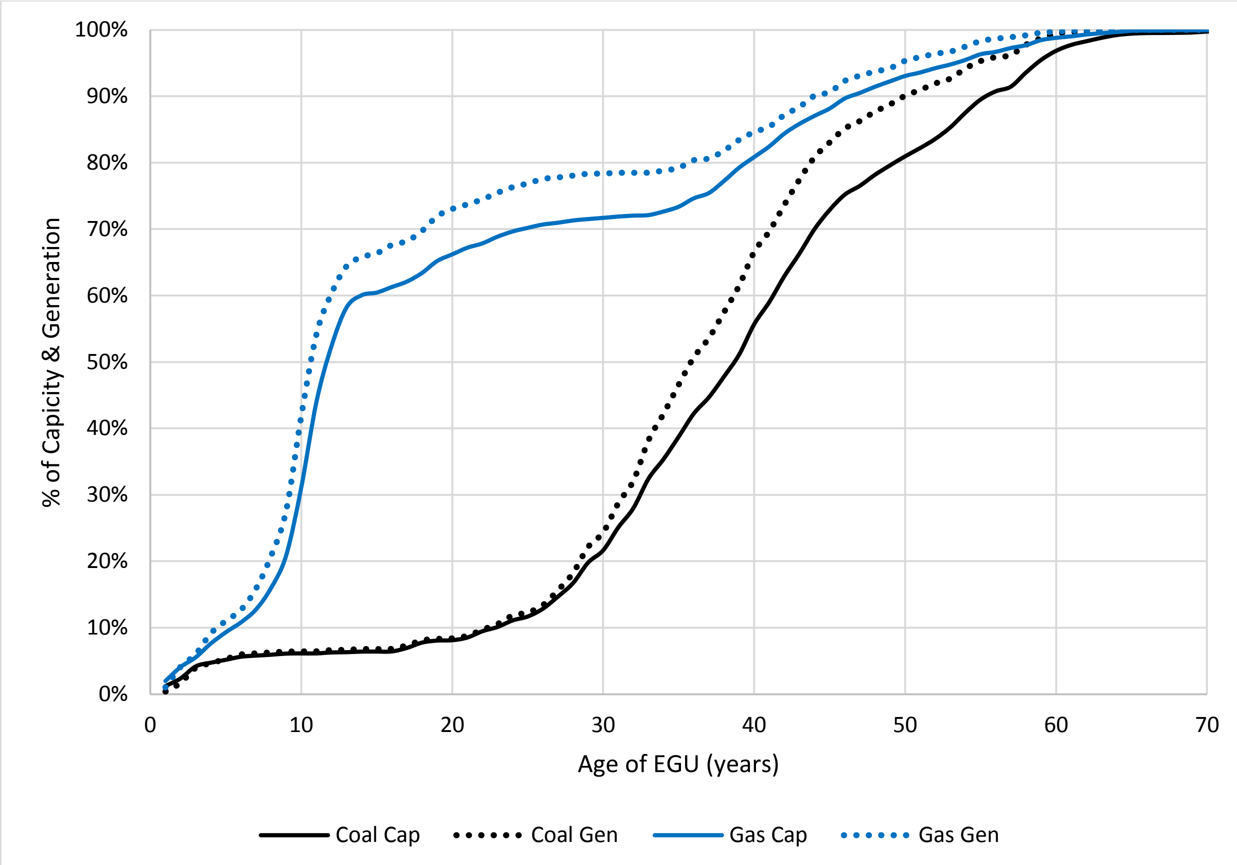

Figure 2-3. Cumulative Distribution in 2012 of Coal and Natural Gas Electricity Capacity and Generation, by Age

Source: eGRID 2012 (10-2015 release from EPA eGRID website). Figure presents data from generators that came online between 1943 and 2012 (inclusive); a 70 year period. Full eGrid data includes generators that came online as far back as 1915. Full data from 1915 onward is used in calculating cumulative distributions; figure truncation at 70 years is merely to improve visibility of diagram.
Not displayed: coal units (376 MW total, 1 percent of total) and gas units (62 MW, < .01 percent of total)) over 70 years old for clarity. Figure is limited to coal-steam units in NEEDS v5.13 in operation in 2013 or earlier (excludes ~2,100 MW of coal-fired IGCC and fossil waste capacity), and excludes those units in NEEDS with planned retirements in 2014 or 2015.

The locations of existing fossil units in EPA's National Electric Energy Data System (NEEDS) v.5.15 are shown in Figure 2-4. This map reflects generating capacity expected to be on-line at the end of 2018, and includes planned new builds already under construction and planned retirements. The size of each dot corresponds with the capacity of the facility it represents.

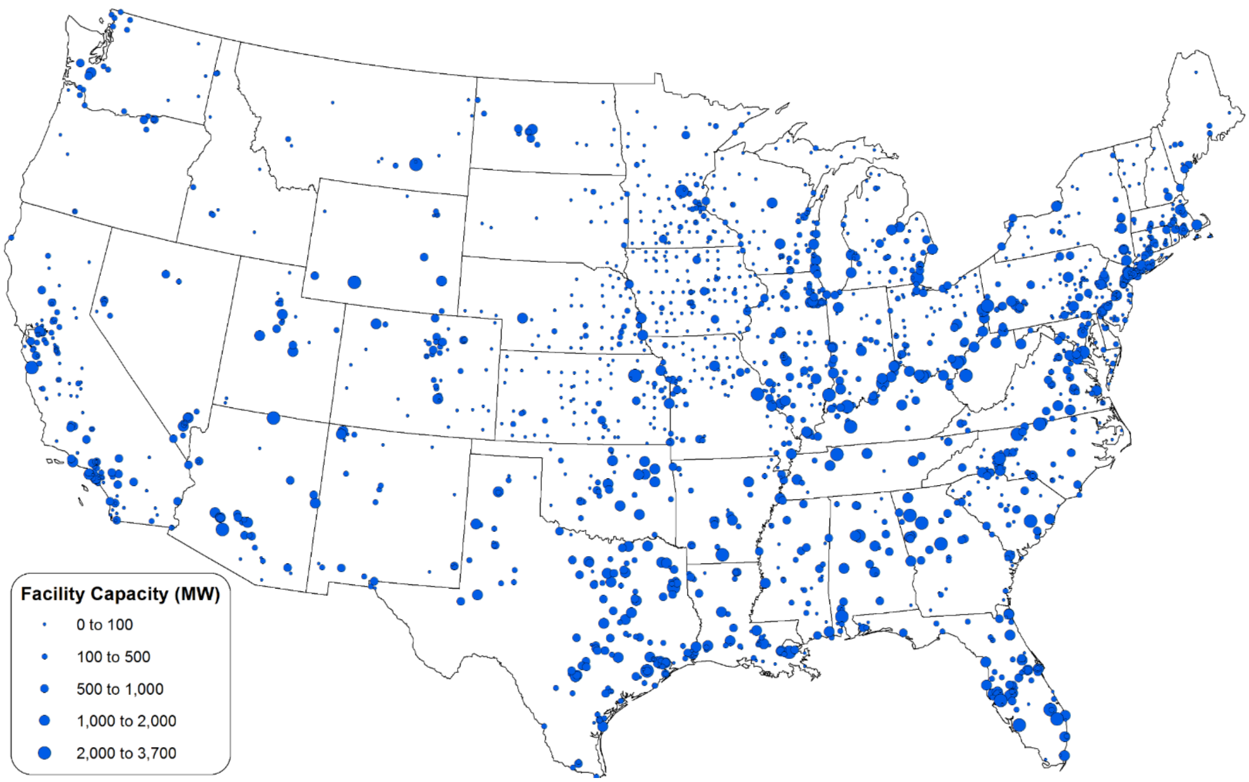

Figure 2-4. Fossil Fuel-Fired Electricity Generating Facilities, by Size

Source: National Electric Energy Data System (NEEDS) v.5.15
Note: This map displays fossil capacity at facilities in the NEEDS v.5.15 IPM frame. NEEDS v.5.15 reflects generating capacity expected to be on-line at the end of 2018. This includes planned new builds already under construction and planned retirements. In areas with a dense concentration of facilities, some facilities may be obscured.

2.2.2 Transmission

Transmission is the term used to describe the bulk transfer of electricity over a network of high voltage lines, from electric generators to substations where power is stepped down for local distribution. In the U.S. and Canada, there are three separate interconnected networks of high voltage transmission lines,[29] each operating synchronously. Within each of these transmission networks, there are multiple areas where the operation of power plants is monitored

[29] These three network interconnections are the Western Interconnection, comprising the western parts of both the US and Canada (approximately the area to the west of the Rocky Mountains), the Eastern Interconnection, comprising the eastern parts of both the US and Canada (except those part of eastern Canada that are in the Quebec Interconnection), and the Texas Interconnection (which encompasses the portion of the Texas electricity system commonly known as the Electric Reliability Council of Texas (ERCOT)). See map of all NERC interconnections at http://www.nerc.com/AboutNERC/keyplayers/Documents/NERC_Interconnections_Color_072512.jpg

and controlled by regional organizations 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;[30] in others, individual utilities[31] coordinate the operations of their generation, transmission, and distribution systems to balance the system across their respective service territories.

2.2.3 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 businesses.

Over the last few decades, several jurisdictions in the United States began restructuring the power industry to separate transmission and distribution from generation, ownership, and operation. Historically, vertically integrated utilities established much of the existing transmission infrastructure. However, as parts of the country have restructured the industry, transmission infrastructure has also been developed by transmission utilities, electric cooperatives, and merchant transmission companies, among others. Distribution, also historically developed by vertically integrated utilities, is now often managed by a number of utilities that purchase and sell electricity, but do not generate it. 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 states, such efforts have also included separating generation assets from transmission and distribution assets to form distinct economic entities. Transmission and distribution remain price-regulated throughout the country based on the cost of service.

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[30] E.g., PMJ Interconnection, LLC, Western Area Power Administration (which comprises 4 sub-regions).

[31] E.g., Los Angeles Department of Power and Water, Florida Power and Light.

2.3 Sales, Expenses, and Prices

These electric generating sources provide electricity for ultimate commercial, industrial and residential customers. Each of the three major ultimate categories consume roughly a quarter to a third of the total electricity produced[32] (see Table 2-4). 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. The distribution between the end use categories changed very little between 2000 and 2014.

Table 2-4. Total U.S. Electric Power Industry Retail Sales, 2000 and 2014 (billion kWh)

		2000		2014	
		Sales/Direct Use (Billion kWh)	**Share of Total End Use**	**Sales/Direct Use (Billion kWh)**	**Share of Total End Use**
Sales	Residential	1,192	33%	1,407	36%
	Commercial	1,055	29%	1,352	35%
	Industrial	1,064	30%	998	26%
	Transportation	NA		8	0.2%
	Other	109	3%	NA	
Total		3,421	95%	3,765	96%
Direct Use		171	5%	139	4%
Total End Use		**3,592**	**100%**	**3,903**	**100%**

Source: Table 2.2, EIA Electric Power Annual, 2014 and 2010

Notes: Retail sales are not equal to net generation (Table 2-2) because net generation includes net exported electricity and loss of electricity that occurs through transmission and distribution.
Direct Use represents commercial and industrial facility use of onsite net electricity generation; and electricity sales or transfers to adjacent or co-located facilities for which revenue information is not available.

2.3.1 Electricity Prices

Electricity prices vary substantially across the United States, differing both between the ultimate customer categories and also by state and region of the country. Electricity prices are typically highest for residential and commercial customers because of the relatively high costs of distributing electricity to individual homes and commercial establishments. The higher prices for residential and commercial customers are the result both of the necessary extensive distribution

[32] Transportation (primarily urban and regional electrical trains) is a fourth ultimate customer category which accounts less than one percent of electricity consumption.

network reaching to virtually every part of the country and every building, and also the fact that generating stations are increasingly located relatively far from population centers (which increases transmission costs). Industrial customers generally pay the lowest average prices, reflecting both their proximity to generating stations and the fact that industrial customers receive electricity at higher voltages (which makes transmission more efficient and less expensive). Industrial customers frequently pay variable prices for electricity, varying by the season and time of day, while residential and commercial prices historically have been less variable. Overall industrial customer prices are usually considerably closer to the wholesale marginal cost of generating electricity than residential and commercial prices.

On a state-by-state basis, all retail electricity prices vary considerably. In 2014, the national average retail electricity price (all sectors) was 10.44 cents/KWh, with a range from 7.13 cents (Washington) to 33.43 (Hawaii).[33]

Average national retail electricity prices increased between 2000 and 2014 by 15.5 percent in real terms (2011$). The amount of increase differed for the three major end use categories (residential, commercial and industrial). National average industrial prices increased the most (15.3 percent), and commercial prices increased the least (8.9 percent). The real year prices for 2000 through 2014 are shown in Figure 2-5.

[33] EIA State Electricity Profiles with Data for 2014 (http://www.eia.gov/electricity/state/)

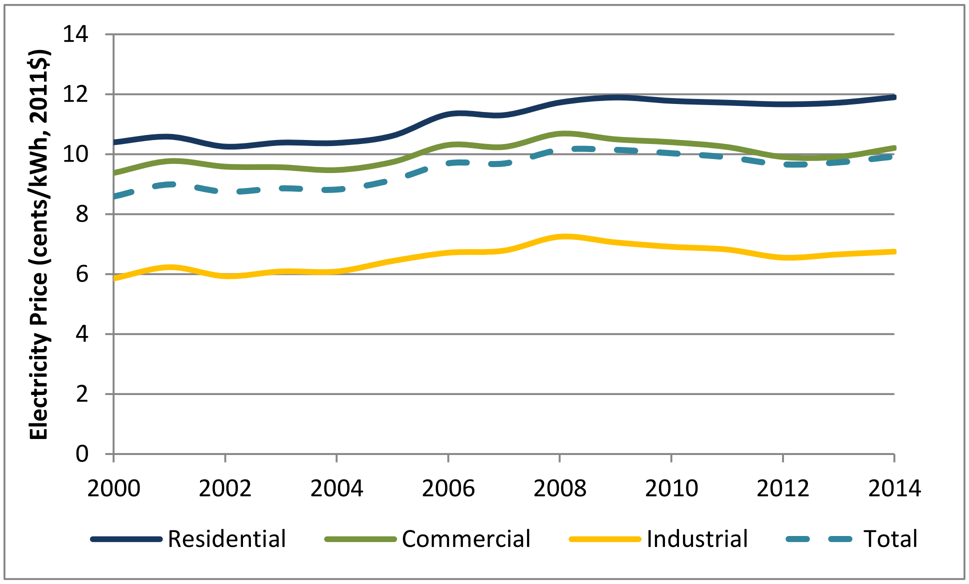


Figure 2-5. Real National Average Electricity Prices for Three Major End-Use Categories

Source: EIA Monthly Energy Review, Table 9.8

Most of these electricity price increases occurred between 2002 and 2008; since 2008 nominal electricity prices have been relatively stable while overall inflation continued to increase. The increase in nominal electricity prices for the major end use categories, as well as increases in the GDP price and CPI-U indices for comparison, are shown in Figure 2-6.

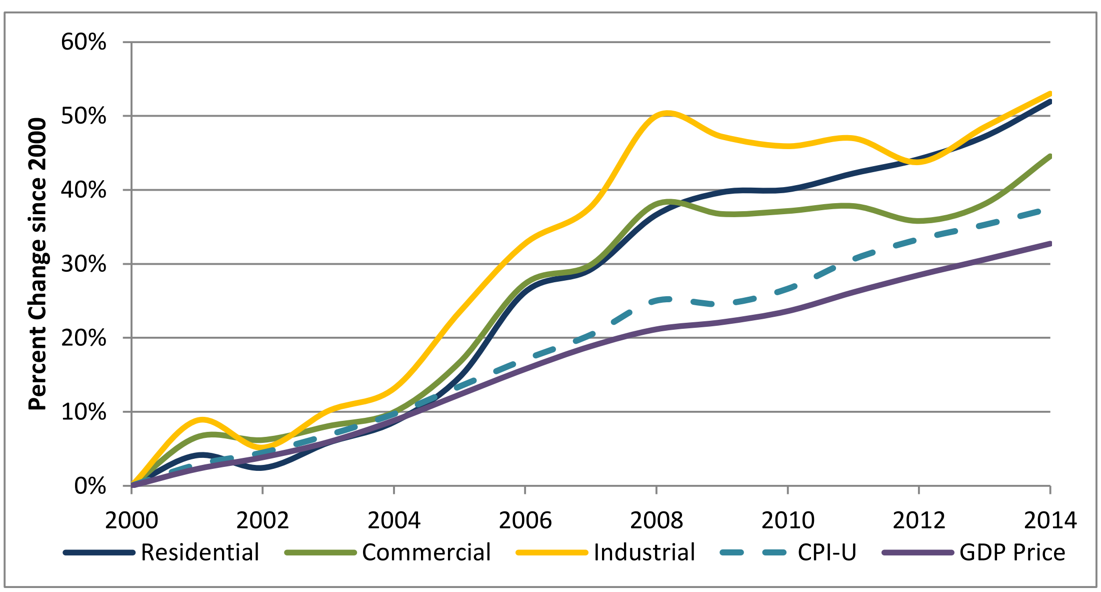


Figure 2-6. Relative Increases in Nominal National Average Electricity Prices for Major End-Use Categories, With Inflation Indices

For a longer term perspective, Figure 2-7 shows real[34] (2011$) electricity prices for the three major customer categories since 1960, and Figure 2-8 shows the relative change in real electricity prices relative to the prices since 1960. As can be seen in the figures, the price for industrial customers has always been lower than for either residential or commercial customers, but the industrial price has been more volatile. While the industrial real price of electricity in 2014 was relatively unchanged from 1960, residential and commercial real prices are 22 percent and 28 percent lower respectively than in 1960.

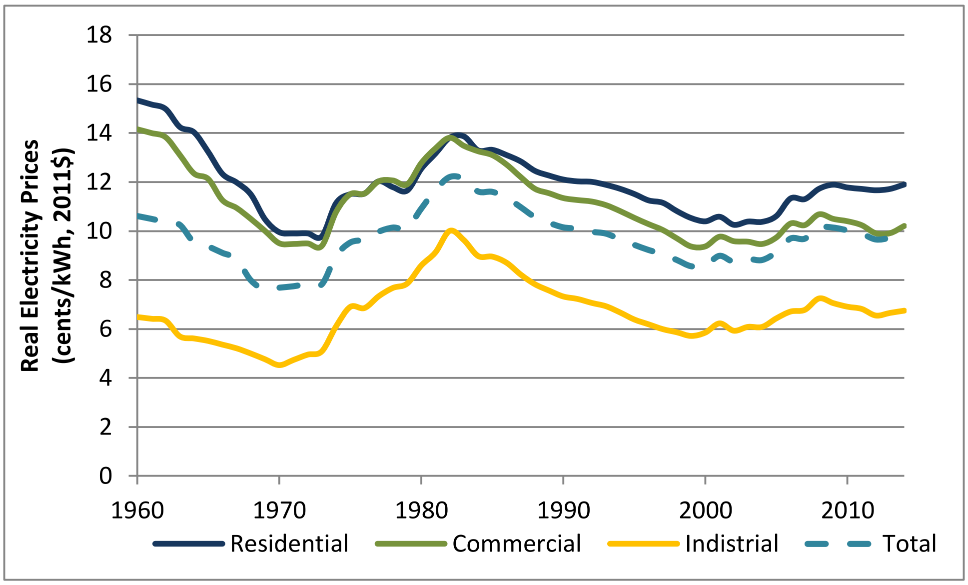


Figure 2-7. Real National Average Electricity Prices for Three Major End-Use Categories (including taxes), 1960-2014 (2011$)

Source: EIA Monthly Energy Review , May 2016, Table 9.8

[34] All prices in this section are estimated as real 2011 prices adjusted using the GDP implicit price deflator unless otherwise indicated.

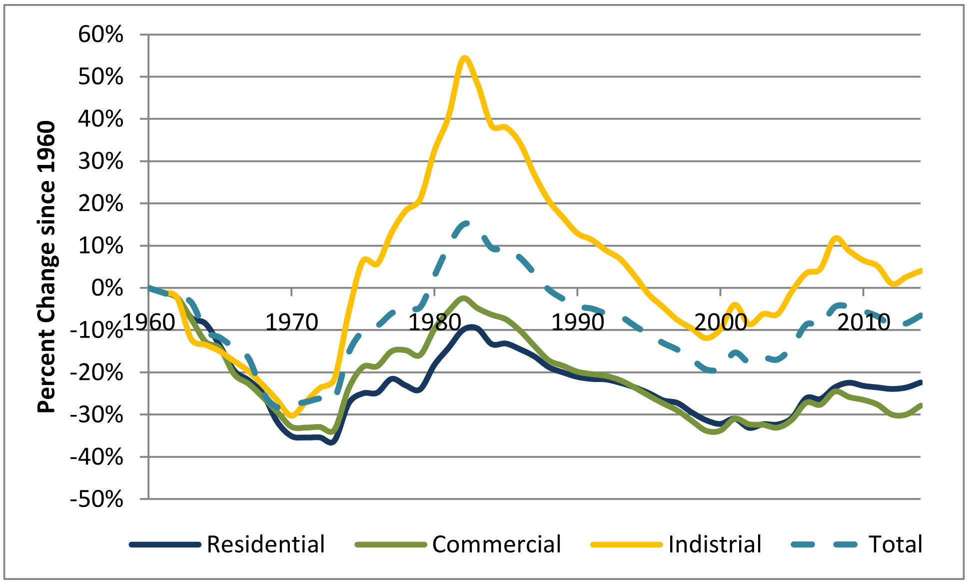


Figure 2-8. Relative Change in Real National Average Electricity Prices (2011$) for Three Major End-Use Categories

Source: EIA Monthly Energy Review, May 2016, Table 9.8

2.3.2 Prices of Fossil Fuels Used for Generating Electricity

Another important factor in the changes in electricity prices are the changes in delivered fuel prices[35] for the three major fossil fuels used in electricity generation; coal, natural gas and oil. Relative to real prices in 2000, the national average real price (in 2011$) of coal delivered to EGUs in 2014 had increased by 49 percent, while the real price of natural gas decreased by 12 percent. The real price of delivered oil increased by 109 percent, but with oil declining as an EGU fuel (in 2014 oil generated only 1 percent of electricity) the doubling of delivered oil prices had little overall impact in the electricity market. The combined real delivered price of all fossil fuels in 2014 increased by 44 percent over 2000 prices. Figure 2-9 shows the relative changes in real price of all 3 fossil fuels between 2000 and 2014.

[35] Fuel prices in this section are all presented in terms of price per MMBtu to make the prices comparable.

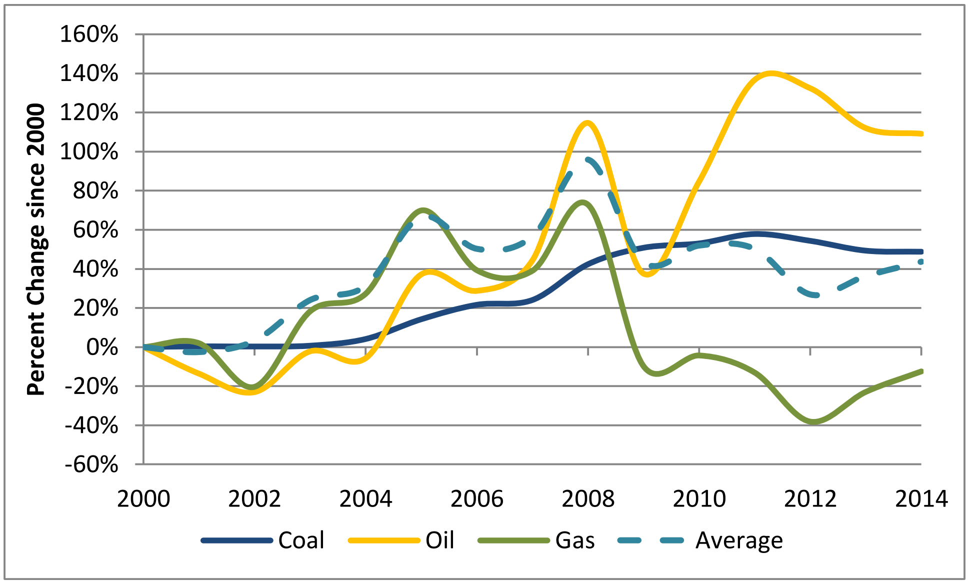


Figure 2-9. Relative Real Prices of Fossil Fuels for Electricity Generation; Change in National Average Real Price per MMBtu Delivered to EGU

Source: Monthly Energy Review, May 2016, Table 9.9

2.3.3 Changes in Electricity Intensity of the U.S. Economy from 2000 to 2014

An important aspect of the changes in electricity generation (i.e., electricity demand) between 2000 and 2014 is that while total net generation increased by 8 percent over that period, the demand growth for generation was lower than both the population growth (13 percent) and real GDP growth (27 percent). Figure 2-10 shows the growth of electricity generation, population and real GDP during this period.

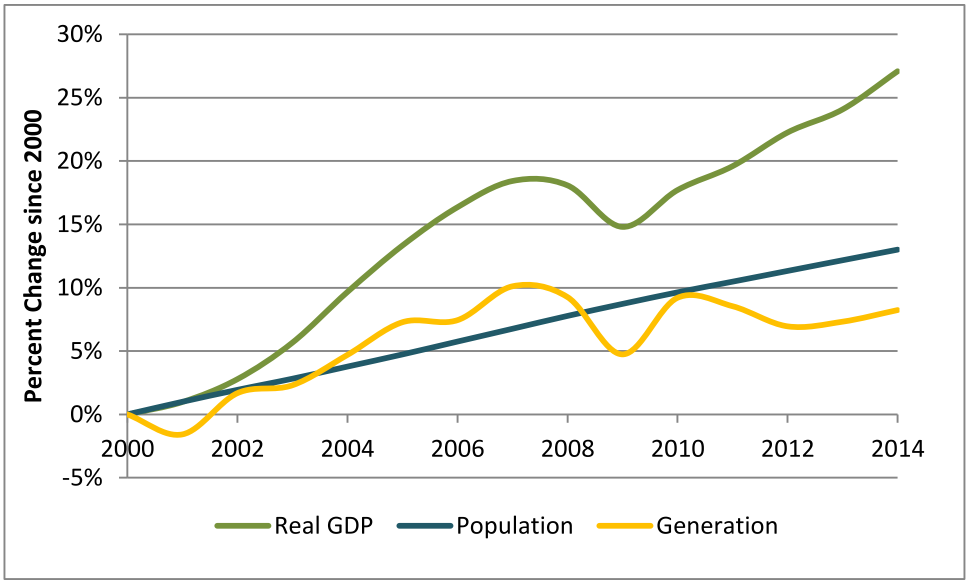


Figure 2-10. Relative Growth of Electricity Generation, Population and Real GDP Since 2000

Sources: Generation: U.S. EIA Monthly Energy Review, May 2016. Table 7.2a Electricity Net Generation: Total (All Sectors). Population: U.S. Census. Real GDP: 2016 Economic Report of the President, Table B-3.

Because demand for electricity generation grew more slowly than both the population and GDP, the relative electric intensity of the U.S. economy improved (i.e., less electricity used per person and per real dollar of output) during 2000 to 2014. On a per capita basis, real GDP per capita grew by 12 percent between 2000 and 2014. At the same time electricity generation per capita decreased by 4 percent. The combined effect of these two changes improved the overall electricity efficiency of the U.S. market economy. Electricity generation per dollar of real GDP decreased 15 percent. These relative changes are shown in Figure 2-11. Figures 2-10 and 2-11 clearly show the effects of the 2007 – 2009 recession on both GDP and electricity generation, as well as the effects of the subsequent economic recovery.

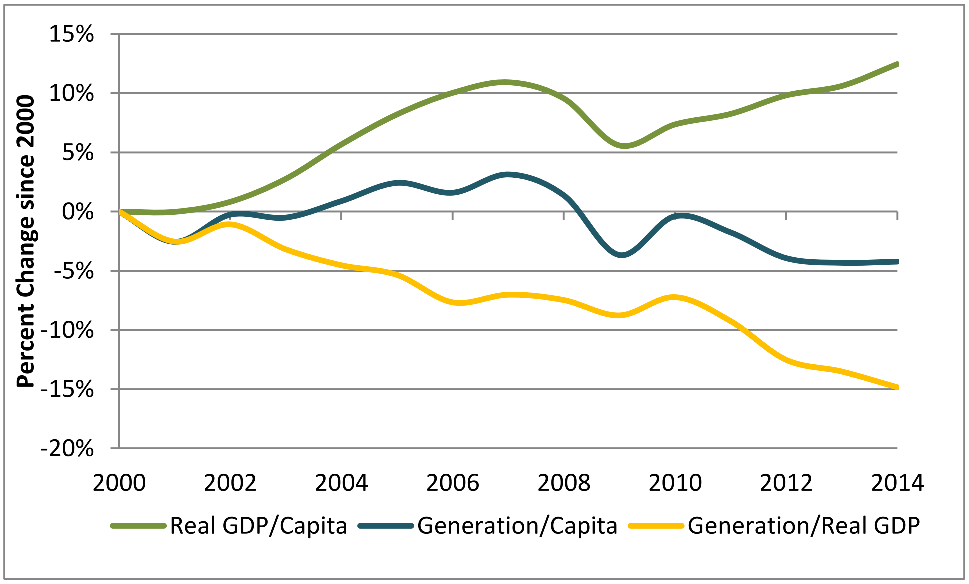


Figure 2-11. Relative Change of Real GDP, Population and Electricity Generation Intensity Since 2000

Sources: Generation: U.S. EIA Monthly Energy Review, May 2016. Table 7.2a Electricity Net Generation: Total (All Sectors). Population: U.S. Census. Real GDP: 2016 Economic Report of the President, Table B-3.

2.4 Deregulation and Restructuring

The process of restructuring and deregulation of wholesale and retail electricity 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 economic incentive to provide least-cost electric rates through market competition, reduced costs of combustion turbine technology that opened the door for more companies to sell power with smaller investments, and complexity of monitoring utilities’ cost of service and establishing cost-based rates for various customer classes. Deregulation and market restructuring in the power sector involved the divestiture of generation from utilities, the formation of organized wholesale spot energy markets with economic mechanisms for the rationing of scarce transmission resources during periods of peak demand, the introduction of retail choice programs, and the establishment of new forms of market oversight and coordination.

The pace of restructuring in the electric power industry slowed significantly in response to market volatility in California and financial turmoil associated with bankruptcy filings of key energy companies. 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 2-12). Eighteen other states that had seriously explored the possibility of deregulation in 2000 reported no legislative or regulatory activity in 2001 (EIA, 2003) ("Not Active" in Figure 2-13). Currently, there are 15 states plus the District of Columbia where price deregulation of generation (restructuring) has occurred ("Active" in Figure 2-13). Power sector restructuring is more or less at a standstill; by 2010 there were no active proposals under review by the Federal Energy Regulatory Commission (FERC) for actions aimed at wider restructuring, and no additional states have begun retail deregulation activity since that time.

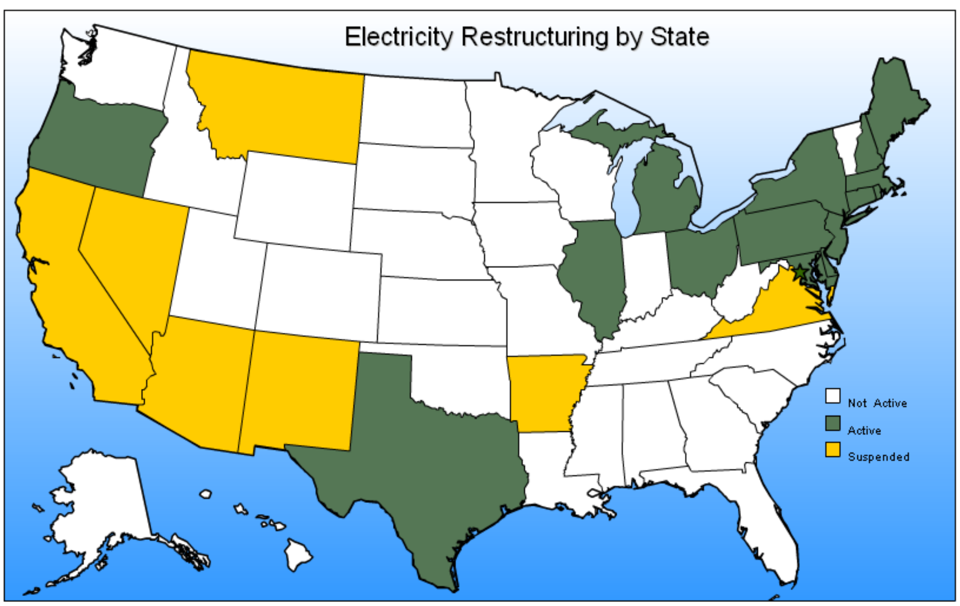


Figure 2-12. Status of State Electricity Industry Restructuring Activities

Source: EIA 2010. "Status of Electricity Restructuring by State." Available online at: <http://www.eia.gov/cneaf/electricity/page/restructuring/restructure_elect.html>.

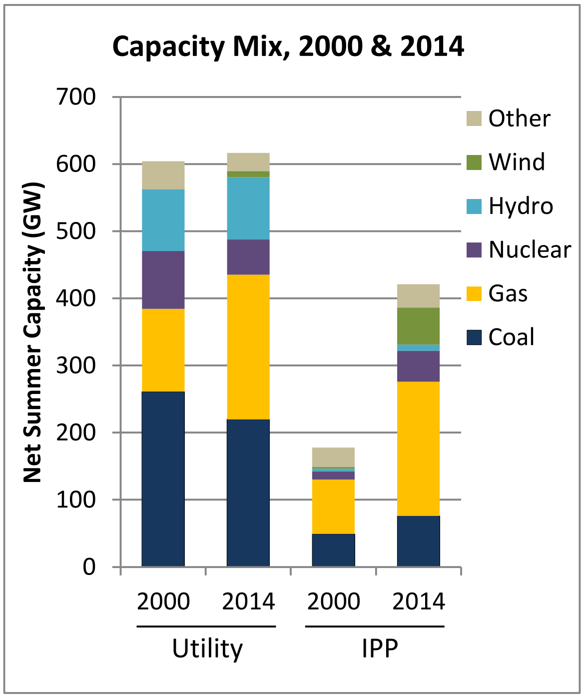
One major effect of the restructuring and deregulation of the power sector was a significant change in type of ownership of electricity generating units in the states that deregulated prices. Throughout most of the 20th century electricity was supplied by vertically integrated regulated utilities. The traditional integrated utilities provided generation, transmission and distribution in their designated areas, and prices were set by cost of service regulations set by state government agencies (e.g., Public Utility Commissions). Deregulation and restructuring resulted in unbundling of the vertical integration structure. Transmission and distribution continued to operate as monopolies with cost of service regulation, while generation shifted to a mix of ownership affiliates of traditional utility ownership and some generation owned and operated by competitive companies known as Independent Power Producers (IPPs). The resulting generating sector differed by state or region, as the power sector adapted to the restructuring and deregulation requirements in each state.

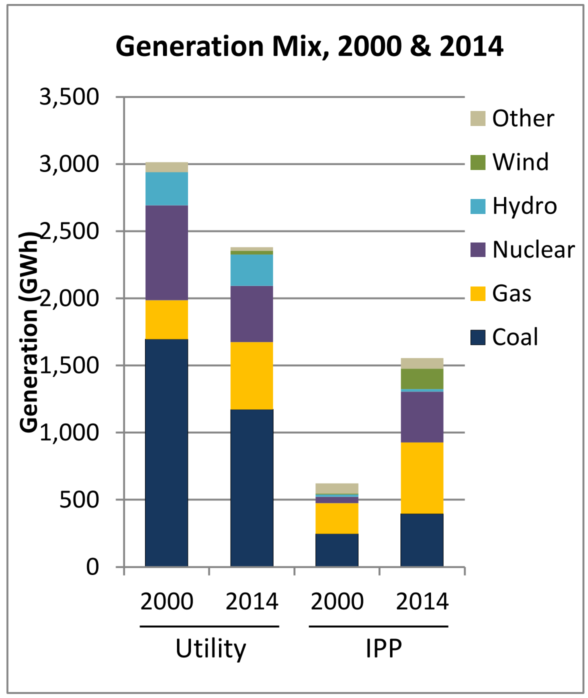
By the year 2000, the major impacts of adapting to changes brought about by deregulation and restructuring during the 1990s were nearing completion. In 2000, traditional utilities owned 77 percent of U.S. generating capacity (MW) while IPPs[36] owned 23 of U.S. generating capacity, respectively. The mix of electricity generated (MWh) was more heavily weighted towards the utilities, with a distribution in 2000 of 83 percent, and 17 percent for IPPs.

Since 2000, IPPs have expanded faster than traditional utilities, substantially increasing their share by 2014 of both capacity (59 percent utility, 41 percent IPPs) and generation (60 percent utility, 40 percent IPP).

The mix of capacity and generation for each of the ownership types is shown in Figures 2-13 (capacity) and 2-14 (generation). The capacity and generation data for commercial and industrial owners are not shown on these figures due to the small magnitude of those ownership types. A portion of the shift of capacity and generation is due to sales and transfers of generation assets from traditional utilities to IPPs, rather than strictly the result of newly built units.

[36] IPP data presented in this section include both combined and non-combined heat and power plants.





Figures 2-13 & 2-14. Capacity and Generation Mix by Ownership Type, 2000 & 2014

CHAPTER 3: EMISSIONS AND AIR QUALITY MODELING IMPACTS

Overview

This Chapter describes the methods for estimating emissions and air quality for the 2017 baseline and 2017 illustrative final CSAPR Update emissions budgets described in Chapter 4. In Section 3.1, we describe the air quality modeling platform, in Section 3.2 we describe the development of emissions inventories used in the air quality modeling, and in Section 3.3 we describe the methods for processing the air quality modeling outputs to create inputs for estimating benefits. The 2017 baseline and illustrative control case air quality model predictions were used to calculate "benefit per ton" factors of reduced nitrogen oxides (NO_X) on both ozone and fine particulate matter ($PM_{2.5}$) concentrations.[37,38] These factors were then used to estimate the benefits of the regulatory control alternatives, as described in Chapter 5. Details on the air quality modeling are provided in the Air Quality Modeling Technical Support Document, which can be found in the docket for this rule.

3.1 Air Quality Modeling Platform

We use the emissions inputs described in Section 3.2 for national scale applications of the Comprehensive Air Quality Model with Extensions (CAMx) modeling system to estimate ozone and $PM_{2.5}$ air quality in the contiguous U.S. CAMx is a three-dimensional grid-based Eulerian photochemical model designed to estimate ozone and $PM_{2.5}$ concentrations over seasonal and annual time periods. 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 ozone and $PM_{2.5}$ concentrations.

For this analysis we used CAMx to simulate air quality for every hour of every day of the year. These model applications require 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 2011 base year and 2017 emissions for the baseline and the final CSAPR Update emissions budgets, (2) meteorological data inputs for the year 2011,

[37] The 2017 baseline air quality model predictions were also used to inform the EPA's ozone transport policy analysis by identifying which states significantly contribute to nonattainment or interfere with maintenance of downwind receptors. See *Ozone Transport Policy Analysis Proposed Rule* Technical Support Document, which can be found in the docket for this proposed rule.

[38] Note that the baseline underlying the air quality modeling does not reflect the updated IPM emissions baseline used to develop costs and benefits in Chapters 4 and 5. See the discussion in section 3.2.2 of this chapter.

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. The model predictions for the 2011 base year, the baseline in 2017, and the final CSAPR Update emissions budgets were combined with ambient air quality observations to calculate seasonal mean ozone air quality metrics and annual mean $PM_{2.5}$ for the baseline in 2017 and the final CSAPR Update emissions budgets, which were then used as input for the benefits analysis.

3.1.1 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., 2011 base year, 2017 baseline and 2017 final CSAPR Update emissions budgets).

3.1.2 Air Quality Modeling Domain

Figure 3-1 shows the geographic extent of the modeling domain that was used for air quality modeling in this analysis. The domain covers the 48 contiguous states, along with the southern portions of Canada and the northern portions of Mexico. This modeling domain contains 25 vertical layers with a top at about 17,550 meters, or 50 millibars (mb), and horizontal grid resolution of 12 km x 12 km. The model simulations produce hourly air quality concentrations for each 12 km^2 grid cell across the modeling domain.

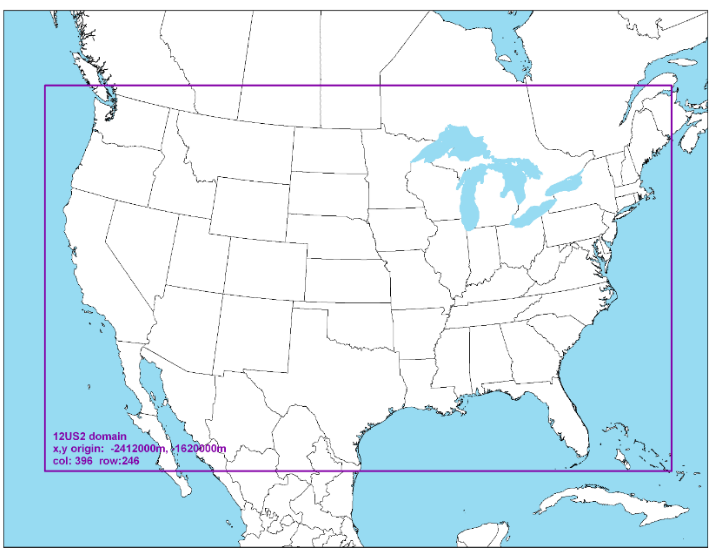


Figure 3-1. National air quality modeling domain.

3.1.3 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 2011 base year, the 2017 baseline, and final CSAPR Update emissions budgets. All other inputs were specified for the 2011 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, as described in Section 3.2. The meteorological data model inputs for the 2011 base year were derived from running Version 3.4 of the Weather Research Forecasting Model (WRF). The meteorological outputs from WRF include hourly-varying horizontal wind components (i.e., speed and direction), temperature, moisture, vertical diffusion rates, and rainfall rates for each grid cell in each vertical layer. The CAMx 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).

3.2 Development of Emissions Inventories

3.2.1 2011 Base Year Emissions

The 2011 emissions inventories are primarily based on the 2011 National Emissions Inventory, version 2 (2011NEIv2) for point sources, nonpoint sources, commercial marine vessels (CMV), nonroad mobile sources and fires, although the inventories used for modeling often have temporal resolution additional to what is available in the NEI. The onroad mobile source emissions are similar to those in the 2011NEIv2, but were generated using the official release 2014a version of the Motor Vehicle Emissions Simulator (MOVES2014a) (http://www3.epa.gov/otaq/models/moves/), while the 2011NEIv2 emissions were generated using MOVES2014. Biogenic emissions and emissions inventories for Canada and Mexico are also included in the air quality modeling. The meteorological data used to develop and temporally allocate emissions were consistent with the 2011 data used for the air quality modeling.

The emissions inventories and modeling thereof incorporate comments received on the Notice of Data Availability (NODA) published in the Federal Register on August 4, 2015 (80 FR

46271), and from comments on the earlier notices for the 2011 and 2018 emissions modeling platforms: the Notice of Availability of the Environmental Protection Agency's 2011 Emissions Modeling Platform issued November 27, 2013 (78 FR 70935) and the Notice of Availability of the Environmental Protection Agency's 2018 Emissions Modeling Platform issued January 14, 2014 (79 FR 2437), respectively. The Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (Houyoux et al., 2000) version 37 was used to prepare the emissions inventories for CAMx. Details regarding the development of the emission inventories and emissions modeling for the 2011 base year and the 2017 baseline are documented in the Technical Support Document Preparation of Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform (EPA, 2016) and can be found in the docket for the CSAPR Update.

3.2.2 2017 Baseline Emissions

The emission inventories for the 2017 future baseline have been developed using projection methods that are specific to emission source type. Future emissions are projected from the 2011 base year either by running models to estimate future year emissions from specific types of emission sources (e.g., EGUs, and onroad and nonroad mobile sources), or for other types of sources by adjusting the base year emissions according to the best estimate of changes expected to occur in the intervening years (e.g., non-EGU point and nonpoint sources). The same emissions are used in the base and future years for biogenic, fire, and offshore oil platform sources.[39] For the remaining sectors, rules and specific legal obligations that go into effect in the intervening years, along with changes in activity for the sector, are considered when possible. The modeled 2017 baseline emission inventories represent predicted emissions that account for Federal and State measures promulgated or under reconsideration by February, 2016. With the exception of speciation profiles for mobile sources and temporal profiles for EGUs, the same ancillary data files are used to prepare the future year emissions inventories for air quality modeling as were used to prepare the 2011 base year inventories. Details on the included measures are provided the emissions modeling TSD (EPA, 2016) and in Chapter 4 .

[39] The biogenic and fire emissions are normally held constant between base and future years. The offshore emissions were held constant due to the lack of detailed information available to adequately project those emissions to future years.

The 2017 baseline inventory for EGUs represents demand growth, fuel resource availability, generating technology cost and performance, and other economic factors affecting power sector behavior. The EGU emissions for the air quality modeling were developed using the IPM version 5.15 base case.[40] The IPM base case reflects the expected emissions accounting for the effects of environmental rules and regulations, consent decrees and settlements, plant closures, units built, control devices installed, and forecast unit construction through the calendar year 2017. Significant federal and state measures that area accounted for in the baseline EGU emissions in 2017 are discussed in Chapter 4.

The 2018 emissions output from IPM were adjusted to reflect 2017 emissions levels as described in "Calculating 2017 NOx Emissions" (see http://www2.epa.gov/airmarkets/calculating-2017-nox-emissions). Temporal allocation was used to process the seasonal emissions outputs from IPM to hourly emissions. To the extent possible, this temporal allocation process preserved the emissions patterns from the base year (2011), while keeping the maximum emissions below those that occurred in the period 2011-2014.

Projections for most stationary emissions sources other than EGUs (i.e., non-EGUs) were developed by using the EPA Control Strategy Tool (CoST) to create post-controls future year inventories. CoST is described at http://www3.epa.gov/ttnecas1/cost.htm. The 2017 baseline non-EGU stationary source emissions inventory includes all enforceable national rules and programs, including the Reciprocating Internal Combustion Engines (RICE) and cement manufacturing National Emissions Standards for Hazardous Air Pollutants (NESHAPs) and Boiler Maximum Achievable Control Technology (MACT) reconsideration reductions. Projection factors and percent reductions for non-EGU point sources reflect comments received by EPA in response to 80 FR 46271, along with emissions reductions due to national and local rules, control programs, plant closures, consent decrees and settlements. Ancillary reductions to criteria air pollutant (CAP) emissions from stationary engines as a result of the Reciprocating Internal Combustion Engines (RICE) National Emission Standard for Hazardous Air Pollutants

[40] IPM is a multiregional, dynamic, deterministic linear programming model of the U.S. electric power sector. This model is described in more detail in Chapter 4 of this RIA. The documentation for version 5.15 can be found on EPA's power sector modeling website: https://www.epa.gov/airmarkets/power-sector-modeling

(NESHAP) are included. Reductions due to the New Source Performance Standards (NSPS) volatile organic compound (VOC) controls for oil and gas sources, and the NSPS controls for process heaters, internal combustion engines, and natural gas turbines are also included.

Regional projection factors for point and nonpoint oil and gas emissions were developed using Annual Energy Outlook (AEO) 2014 (U.S. EIA, 2014) projections from year 2011 to year 2018. Projected emissions for corn ethanol, cellulosic ethanol and biodiesel plants, refineries and upstream impacts represent the Energy Independence and Security Act (EISA) renewable fuel standards mandate in the Renewable Fuel Standards Program (RFS2). Airport-specific terminal area forecast (TAF) data were used for aircraft to account for projected changes in landing/takeoff activity.

Projection factors for livestock are based on expected changes in animal population from 2005 Department of Agriculture data, updated according to EPA experts in July 2012; fertilizer application ammonia (NH_3) emissions projections include upstream impacts representing EISA. Area fugitive dust projection factors for categories related to livestock estimates are based on expected changes in animal population and upstream impacts from EISA. Fugitive dust for paved and unpaved roads take growth in VMT and population into account. Residential Wood Combustion (RWC) projection factors reflect assumed growth of wood burning appliances based on sales data, equipment replacement rates and change outs. These changes include growth in lower-emitting stoves and a reduction in higher emitting stoves. Impacts from the NSPS for wood burning devices are also included.

Projection factors for the remaining nonpoint sources such as stationary source fuel combustion, industrial processes, solvent utilization, and waste disposal, reflect comments received on the projection of these sources as a result of rulemakings and outreach to states on emission inventories, and they also include emission reductions due to control programs. Future year portable fuel container (PFC) inventories reflect the impact of the final Mobile Source Air Toxics (MSAT2) rule along with state comments received in response to 80 FR 46271.

The MOVES2014a-based 2017 onroad emissions account for changes in activity data and the impact of on-the-books national rules including: the Tier 3 Vehicle Emission and Fuel Standards Program, the Light-Duty Vehicle Tier 2 Rule, the Heavy Duty Diesel Rule, the Mobile

Source Air Toxics Rule, the Renewable Fuel Standard (RFS2), the Light Duty Green House Gas/Corporate Average Fuel Efficiency (CAFE) standards for 2012-2016, the Heavy-Duty Vehicle Greenhouse Gas Rule, the 2017 and the Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule (LD GHG). The 2017 onroad emissions also include state rules related to the adoption of low emission vehicle (LEV) standards, inspection and maintenance programs, Stage II refueling controls, and local fuel restrictions. For California, the baseline emissions were provided by the California Air Resources Board and include most this state's on-the-books regulations, such as those for idling of heavy-duty vehicles, chip reflash, public fleets, track trucks, drayage trucks, and heavy duty trucks and buses (CARB, 2016).

The nonroad mobile source emissions for 2017, including those for railroads and commercial marine vessel emissions, also include all national control programs. These control programs include the Clean Air Nonroad Diesel Rule – Tier 4, the Nonroad Spark Ignition rules, and the Locomotive-Marine Engine rule. For ocean-going vessels (Class 3 marine), the emissions data reflect the 2005 voluntary Vessel Speed Reduction (VSR) within 20 nautical miles, the 2007 and 2008 auxiliary engine rules, the 40 nautical mile VSR program, the 2009 Low Sulfur Fuel regulation, the 2009-2018 cold ironing regulation, the use of 1% sulfur fuel in the Emissions Control Area (ECA) zone, the 2012-2015 Tier 2 NO_x controls, the 2016 0.1% sulfur fuel regulation in ECA zone, and the 2016 International Marine Organization (IMO) Tier 3 NO_x controls. Non-U.S. and U.S. category 3 commercial marine emissions were projected to 2017 using consistent methods that incorporated controls based on ECA and IMO global NO_x and sulfur dioxide (SO_2) controls. For California, the 2017 emissions for these categories reflect the state's Off-Road Construction Rule for "In-Use Diesel", cargo handling equipment rules in place as of 2011 (see http://www.arb.ca.gov/ports/cargo/cargo.htm), and state rules through 2011 related to Transportation Refrigeration Units, the Spark-Ignition Marine Engine and Boat Regulations adopted on July 24, 2008 for pleasure craft, and the 2007 and 2010 regulations to reduce emissions from commercial harbor craft.

The modeled 2011 emission case uses 2010 Canada emissions data, which is the latest year for which Environment Canada had provided data at the time the modeling was performed. Although no accompanying future-year projected baseline inventories were provided in a form suitable for this analysis, for the 2017 emissions, known shutdowns to Canadian coal EGU units in Ontario were incorporated. In addition, onroad and nonroad mobile source emissions were scaled to represent average changes in U.S. emissions due to the similarities between U.S. and Canadian mobile source regulations. For Mexico, emissions compiled from the Inventario Nacional de Emisiones de Mexico, 2008 were used for 2011, as that was the latest complete inventory available. For the 2017 baseline, projected emissions for the year 2018 based on the 2008 inventory were used (ERG, 2014). Table 3-1 shows the modeled national 2011 and 2017 NO_X and VOC emissions by sector. Additional details on the base year and projected inventories and on the emissions by state are given in the emissions modeling TSD (US EPA, 2016).

Table 3-1. 2011 Base Year and 2017 Baseline NOx and VOC Emissions by Sector (thousand tons)

Sector	2011 NO_x	2017 NO_x	2011 VOC	2017 VOC
EGU-point	2,100	1,300	38	36
NonEGU-point	1,200	1,200	800	800
Point oil and gas	510	440	160	170
Fires	380	380	4,800	4,800
Nonpoint oil and gas	660	730	2,500	2,900
Residential wood combustion	34	36	440	440
Other nonpoint	720	730	3,700	3,500
Nonroad	1,600	1,100	2,000	1,400
Onroad	5,600	3,000	2,700	1,500
Commercial marine vessels (CMV)	410	360	13	13
Locomotive	790	680	41	28
Biogenics	910	910	42,800	42,800
TOTAL	**15,000**	**10,900**	**59,900**	**58,400**

3.2.3 2017 Illustrative Emissions Case for the Final CSAPR Update Emissions Budgets

The EPA's approach to developing IPM v5.15-based emissions for the final CSAPR Update emissions budgets is methodologically consistent with the EPA's approach to establishing the final EGU NO_X ozone-season emissions budgets to reduce interstate ozone transport for the 2008 ozone NAAQS. These illustrative EGU NO_X ozone-season emissions budgets and their associated assurance levels, along with corresponding emission changes for other pollutants as predicted by IPM, were modeled in IPM v5.15 to create the illustrative final emissions case. As noted in Chapter 4, section 4.3.1, although IPM v5.15 was used for modeling EGU emission for the baseline and the illustrative final emissions case, there were additional updates to EGU emissions that were included in the IPM run for the CSAPR Update illustrative final emissions case that were not included in the baseline. See Chapter 4, Table 4-4 for the illustrative final emissions.

The emissions for the illustrative final emissions case were processed for air quality modeling in the same way as the 2017 baseline. The only difference in the emissions inventories were the EGU emissions. The hourly temporal allocation for the illustrative final emissions case inventories preserved the patterns from the 2017 baseline to the extent possible by maintaining consistent unit-specific and regional, where appropriate, profiles in both cases. Thus, the same hourly temporal patterns in the baseline are reflected in this final emissions case, including any adjustments made to constrain the hourly 2017 emissions below the maximum levels during the 2011-2014 period.

3.2.4 Effect of Emissions Reductions on Downwind Receptors

As described in Sections V and VI of the preamble, and in the Ozone Transport Policy Analysis Final Rule TSD, and summarized here, EPA evaluated the effect of the CSAPR Update on nonattainment and maintenance receptors with respect to interstate transport for the 2008 ozone NAAQS. The 2008 ozone standard is 75 parts per billion (ppb), annual fourth-highest daily maximum 8 hour concentration, averaged over 3 years. As described in Section V of the preamble, the nonattainment and maintenance receptors with respect to interstate transport for the 2008 ozone NAAQS in 2017 were identified using air quality modeling for 2011 and 2017 combined with measured design values[41] for a base period encompassing 2009-2013. There are 19 receptors in 9 states identified as non-attainment and/or maintenance monitors for this CSAPR Update.[42] Six of these monitors are non-attainment monitors and 13 are maintenance monitors. The average of the average design values of all 19 receptors is 75.9 ppb in 2017. The average of the maximum design values of all 19 receptors is 78.1 ppb in 2017.

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[41] Ozone design value for a given monitoring site is the 3-year average (consecutive years) of the 4th highest 8-hour daily maximum ozone concentrations at that site.

[42] Section V.C of the preamble describes the approach for projecting future ozone design values.

As described in the Ozone Transport Policy Analysis Final Rule TSD, these design values were identified using an updated version of the EGU base case, the same one that was used to establish emission budgets for the final CSAPR Update.[43] Like the base case used to estimate the costs and benefits of the CSAPR Update, this base case accounts for the Pennsylvania NOx RACT final rule promulgated in April 2016. However, the 2017 EGU emission levels in this base case also account for recent historical information about emissions, which grounds the 2017 emission projections in historic data for the purpose of setting emission budgets. To evaluate the effect of the CSAPR Update on the 19 nonattainment and/or maintenance receptors, we assume that the affected source emissions under the CSAPR Update equals the EGU NO_X ozone season emission budgets.[44] That is, that the difference in the affected source emission levels from the updated base case and the final EGU NO_X ozone season emission budgets was used to estimate the change in average and maximum design values at the 19 receptors reported in this section of the RIA.

The ozone Air Quality Assessment Tool (AQAT) was used to estimate the impact of the upwind states' EGU NO_X reductions on downwind ozone pollution concentrations. Specifically, AQAT was used to forecast both the average and maximum design values at the 19 receptors. The AQAT was developed specifically for use in the CSAPR Update rule. This tool uses air quality modeling outputs to calibrate the predicted change in ozone concentrations to reflect changes in NO_X emissions. See the Ozone Transport Policy Analysis Final Rule TSD for the air quality estimates and for details on the construction of the AQAT. The effect of the CSAPR Update on the 19 nonattainment and/or maintenance receptors is an average reduction in the average and maximum ozone design values of 0.28 ppb and 0.29 ppb in 2017, respectively. The emission reductions are expected to reduce the average and maximum design values below the level of the NAAQS at three of the 19 receptors, therefore resolving their nonattainment and maintenance issues, while bringing the other 16 receptors closer to attainment and maintenance. Results for each of the 19 receptors are described in the Ozone Transport Policy Analysis Final Rule TSD.

[43] In the Ozone Transport Policy Analysis Final Rule TSD, this updated base case is referred to as the "$0/ton emissions budget level with PA RACT."

[44] In the Ozone Transport Policy Analysis Final Rule TSD, these budgets are referred to as the "Final $1400/ton Emission Budgets."

3.3 Post-Processing of Air Quality Modeling for Benefits Calculations

3.3.1 Converting CAMx Ozone Outputs to Benefits Inputs

The CAMx model generates predictions of hourly ozone concentrations for every grid cell. Future-year estimates of ozone for each of three health benefits metrics for ozone were calculated using model predictions. The modeled change in ozone between the 2011 base year and the 2017 future baseline and illustrative control case were used to create relative reduction factors (RRFs) which were then applied to 2011 ambient ozone concentrations, as described below. The health benefits metrics for ozone are May through September seasonal average 8-hour daily maximum ozone concentrations. The procedures for determining the ozone RRFs for these metrics are similar to those described in EPA guidance for modeling attainment of the ozone standard (EPA, 2014). This guidance recommends that model predictions be used in a relative sense to estimate changes expected to occur in ozone concentrations for a future year emissions case. The RRFs and future year ozone concentrations were calculated using EPA's software Modeled Attainment Test Software (MATS) (Abt, 2014). EPA used MATS to estimate the ozone impacts of the emissions reductions in the 2017 illustrative control case.

For the purposes of projecting future ozone concentrations for input to the benefits calculations, we applied MATS using the base year 2011 modeling results and the results from the 2017 baseline and 2017 illustrative control case scenarios. In our application of MATS for ozone we used the ozone monitoring data centered about 2011 (2010-2012 ozone data) from the Aerometric Information Retrieval System (AIRS) as the set of base-year measured concentrations. The ambient ozone data and modeled ozone outputs were combined using the MATS "eVNA" spatial fusion technique to generate gridded sets of spatial fields (interpolated ozone metrics for each modeled 12km grid cell in the modeling domain) for each of the three ozone metrics for the 2011 base year period. The ratio of the seasonal average model-predicted future case ozone concentrations to the corresponding seasonal average model-predicted 2011 concentrations in each grid cell (RRF's) was calculated and then multiplied by the gridded interpolated ozone concentrations for each metric to produce gridded ozone concentrations for the 2017 baseline and 2017 illustrative control case. The resulting gridded files for the 2017 baseline and illustrative control cases were then input to the Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE) (version 1.1) (Abt, 2012) to calculate benefit per ton factors for each metric. Information on the calculation of the benefit per ton factors is provided in Chapter 5.

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

The CAMx model (ENVIRON, 2014) generates predictions of hourly $PM_{2.5}$ species concentrations for every grid cell. The species include a primary fraction and several secondary $PM_{2.5}$ species (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 RRFs applied to 2010-2012 ambient $PM_{2.5}$ and $PM_{2.5}$ species concentrations, as described below.

The procedures for determining the RRFs are similar to those in EPA guidance for modeling the $PM_{2.5}$ NAAQS (EPA, 2014). 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 modeled attainment test procedure for calculating future year $PM_{2.5}$ values is described in the modeling guidance and is codified in EPA's MATS. EPA used this procedure to estimate the ambient impacts of the emissions reductions in the 2017 illustrative control case. For the purposes of projecting future $PM_{2.5}$ concentrations for input to the benefits calculations, we applied the modeled attainment test procedure using the base year 2011 modeling results and the results from the 2017 baseline and 2017 illustrative control case. In our application of MATS for $PM_{2.5}$ we used the $PM_{2.5}$ monitoring data and speciated monitoring data centered about 2011 (2010-2012) from the state $PM_{2.5}$ Federal Reference Method (FRM) network, the Chemical Speciation Network (CSN) and Interagency Monitoring of Protected Visual Environments (IMPROVE) network as the set of base-year measured concentrations. The ambient $PM_{2.5}$ and species data and modeled $PM_{2.5}$ and species outputs were combined using the MATS "eVNA" spatial fusion technique to generate gridded sets of spatial fields (interpolated annual average $PM_{2.5}$ and species concentrations for each modeled 12km grid cell in the modeling domain) for the 2011 base year period. The ratio of the quarterly average model-predicted future case $PM_{2.5}$ species concentrations to the corresponding quarterly average model-predicted 2011 species concentrations in each grid cell (RRF's) were calculated and then multiplied by the gridded interpolated $PM_{2.5}$ species concentrations to produce gridded $PM_{2.5}$ species concentrations for the 2017 baseline and 2017 illustrative control case. Output files from this process include both quarterly and annual mean $PM_{2.5}$ mass concentrations and $PM_{2.5}$ species concentrations which are then processed to produce BenMAP input files containing annual mean $PM_{2.5}$ mass concentrations for the 2017 baseline and for the 2017 illustrative control case. These data files were then input to BenMAP to calculate $PM_{2.5}$ benefit per ton factors. Information on the calculation of the benefit per ton factors is provided in Chapter 5.

3.4 Limitations

The air quality modeling for this analysis relied upon state-of-the-science tools, methods, and data. Still, there are uncertainties associated with the projected baseline and illustrative control case ozone concentrations that stem from limitations and uncertainties in the individual components of the modeling process. These include (1) limitations in the emissions inventories for specific source categories in terms of representing base year emissions and the methodologies and economic assumptions associated with projecting emissions to a future year, (2) uncertainties in the construct of the photochemical model that may affect the characterization of physical properties and chemical reactions, (3) uncertainties in other model inputs such as meteorology and international transport, and (4) uncertainties in the measured ozone concentrations that are used as the basis for projecting future concentrations at individual locations and the spatial fields used for benefits calculations. It is not clear that the net effect of the limitations and uncertainties in the modeling process bias the analysis in either direction. Rather, they should be viewed as considerations in interpreting the results.

3.5 References

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CHAPTER 4: COST, EMISSIONS, AND ENERGY IMPACTS

Overview

This chapter reports the compliance costs, emissions, and energy analyses performed for the final CSAPR Update. The EPA used the Integrated Planning Model (IPM), developed by ICF International, to conduct most of the analysis discussed in this chapter.

As explained in detail below, this chapter presents analysis of three regulatory control alternatives. These regulatory control alternatives include assumptions about the possible actions that electric generating units (EGUs) may pursue to reduce their nitrogen oxides (NO_X) emissions in order to comply with the EGU NO_X ozone season emission budgets in the 22-state region.

The chapter is organized as follows: following a summary of the regulatory control alternatives analyzed and a summary of the EPA's methodology, we present estimates of compliance costs, as well as estimated impacts on emissions, generation, capacity, fuel use, fuel price, and retail electricity price. Additional impacts are presented in subsequent chapters.

4.1 Regulatory Control Alternatives

The primary purpose of the CSAPR Update is to address interstate air quality impacts with respect to the 2008 ozone National Ambient Air Quality Standards (NAAQS). The EPA originally published CSAPR on August 8, 2011,[45] to address interstate transport of ozone pollution under the 1997 ozone NAAQS.[46] The CSAPR Update will reduce ozone season (May 1 through September 30) NO_X emissions in 22 eastern states that can be transported downwind as NO_X or, after transformation in the atmosphere, as ozone, and can negatively affect air quality and public health in downwind areas. For these 22 eastern states, the EPA is issuing Federal Implementation Plans (FIPs) that generally provide updated CSAPR NO_X ozone season emission budgets for EGUs. These emission budgets represent the remaining EGU emissions after reducing those amounts of each state's emissions that significantly contribute to downwind nonattainment or interfere with maintenance of the 2008 ozone NAAQS in downwind states, as required under Clean Air Act (CAA) section 110(a)(2)(D)(i)(I). The CSAPR Update FIPs also require affected EGUs to participate in the CSAPR NO_X ozone season allowance trading program subject to these emission budgets starting with the 2017 ozone season. The allowance trading program is the remedy in the FIPs that achieves the ozone season NO_X emission reductions required by the rule. The allowance trading program essentially converts the EGU NO_X emission budget for each of the 22 states into a limited number of NO_X allowances that, on a tonnage basis, equal the state's ozone season NO_X emission budget. EGUs covered by the FIPs are able to trade NO_X ozone season allowances among EGUs within their state and across state boundaries, with emissions and the use of allowances subject to certain limits.

This RIA evaluates the benefits, costs and certain impacts of compliance with three regulatory control alternatives. The CSAPR Update EGU NO_X ozone season emission budgets that the EPA is finalizing were developed using uniform control stringency represented by $1,400 per ton (2011$), whereas the more and less stringent alternatives were developed using uniform control stringency represented by $3,400 per ton and $800 per ton (2011$), respectively. The EPA assesses compliance with these sets of emission budgets through implementation of the CSAPR NO_X ozone season allowance trading program. Aside from the difference in emission budgets, other key regulatory features of the allowance trading program, such as the ability to bank allowances for future use, are the same across all the three different sets of NO_X emission budgets analyzed. This chapter describes the EPA's analysis of the CSAPR Update and more and less stringent alternatives. As described below, the emission budgets evaluated for the CSAPR Update regulatory control alternatives in this RIA are illustrative because they differ somewhat from the budgets finalized in this rule.

4.1.2 Regulatory Control Alternatives Analyzed

In accordance with Executive Orders 12866 and 13563, the guidelines of OMB Circular A-4, and EPA's *Guidelines for Preparing Economic Analyses,* this RIA analyzes the benefits and costs associated with complying with the CSAPR Update. The final CSAPR Update emission budgets in this RIA represents illustrative EGU NO_X ozone season emission budgets for each state that were developed using uniform control stringency represented by $1,400 per ton (2011$).[47]

Additionally, OMB Circular A-4 requires analysis of at least one potential alternative standard level that is more stringent than the finalized standard and one that is less stringent than the finalized standard. In response to this requirement, this RIA analyzes the final CSAPR Update emission budgets as well as a more and a less stringent alternative to the CSAPR Update. The more and less stringent alternatives differ from the CSAPR Update in that they set different EGU NO_X ozone season emission budgets for the affected EGUs. The less-stringent scenario uses emission budgets that were developed using uniform control stringency represented by $800 per ton (2011$). The more-stringent scenario uses emission budgets that were developed using uniform control stringency represented by $3,400 per ton (2011$). These sets of emissions budgets are analogous to those that the EPA explicitly took comment on in the CSAPR Update proposal. We continue to analyze these scenarios alongside the finalized approach to evaluate how economic and environmental information that has been updated since proposal affected these non-finalized options. See section VI of the preamble for further details of these emission budgets.

All three scenarios are illustrative in nature, and the budgets included in the "CSAPR Update" scenario differ slightly from the budgets finalized in this rule. That is because subsequent to completion of the analysis of these three scenarios, the EPA made minor updates to budgets as well as to the modeling platform[48]. The EPA finds that the three illustrative regulatory control alternatives presented in this RIA variously provide a reasonable approximation of the impacts of the final rule, as well as an evaluation of the relative impacts of two regulatory alternatives. This finding is supported by an analysis of the costs and impacts (but not the benefits) of the final CSAPR Update emission budgets, as estimated using the updated modeling platform. This analysis is provided in Appendix 4A.

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[47] The budget setting process is described in the preamble and in detail in the Ozone Transport Policy Analysis Technical Support Document (TSD)

[48] See EPA v.5.15 CSAPR Update Rule Base Cases Using IPM Incremental Documentation , available in the docket.

Table 4-1 reports the illustrative EGU NO_X ozone season emission budgets that are evaluated in this RIA. As described above, starting in 2017, emissions from affected EGUs across this entire region cannot exceed the sum of emission budgets but for the ability to use banked allowances from previous years for compliance. Furthermore, emissions from affected EGUs in a particular state are subject to the CSAPR assurance provisions, which require additional allowance surrender penalties (a total of 3 allowances per-ton of emissions) on emissions that exceed a state's CSAPR NO_X ozone season assurance level, or 121 percent of the emission budget. The CSAPR NO_X ozone season allowance trading program is described in further detail in Section VII of the preamble.

Table 4-1 Illustrative NO_X Ozone Season Emission Budgets (Tons) Evaluated in this RIA

	CSAPR Update (Not Finalized Budgets)	More Stringent Alternative	Less Stringent Alternative
Alabama	12,599	11,406	13,548
Arkansas[49]	9,211	9,041	12,060
Delaware[50]	497	494	497
Illinois	14,588	14,464	14,632
Indiana	21,527	19,804	26,419
Iowa	11,272	11,065	11,477
Kansas	7,782	7,730	7,785
Kentucky	19,675	19,475	23,030
Louisiana	18,636	18,470	19,087
Maryland	3,457	2,838	3,795
Michigan	16,483	15,222	18,630
Mississippi	6,315	6,191	6,350
Missouri	15,085	14,604	16,628
New Jersey	2,057	2,061	2,063
New York	5,050	4,928	5,129
Ohio	18,763	18,599	22,372
Oklahoma	11,742	9,254	13,871
Pennsylvania	19,554	19,479	29,875
Tennessee	9,115	9,115	9,115
Texas	51,931	50,022	54,544

[49] The EPA is finalizing CSAPR EGU NO_X ozone season emission budgets for Arkansas of 12,048 tons for 2017 and 9,210 tons for 2018 and subsequent control periods. This RIA assessment assumes compliance with Arkansas' illustrative emission budget for 2018 in 2017 and subsequent control periods.

[50] Delaware is excluded from the final CSAPR Update policy, but was included in the illustrative policy modeling.

	CSAPR Update (Not Finalized Budgets)	More Stringent Alternative	Less Stringent Alternative
Virginia	9,224	8,758	9,263
West Virginia	18,152	17,706	25,730
Wisconsin	7,862	7,791	7,922
TOTAL	310,577	298,515	353,821

Note that EGUs have flexibility in determining how they will comply with the allowance trading program. As discussed below, the way that they comply may differ from the methods forecast in the modeling for this RIA.

See section 4.3 for further discussion of the modeling approach used in the analysis presented below.

4.2 Power Sector Modeling Framework

IPM is a state-of-the-art, peer-reviewed, dynamic linear programming model that can be used to project power sector behavior under future business-as-usual conditions, and to examine prospective air pollution control policies throughout the contiguous United States for the entire electric power system. EPA used IPM to project likely future electricity market conditions with and without the CSAPR Update.

IPM is a multi-regional, dynamic, deterministic linear programming model of the contiguous U.S. electric power sector. It provides estimates of least cost capacity expansion, electricity dispatch, and emissions control strategies while meeting energy demand and environmental, transmission, dispatch, and reliability constraints. The EPA has used IPM for over two decades to better understand power sector behavior under future business-as-usual conditions and to evaluate the economic and emission impacts of prospective environmental policies. The model is designed to reflect electricity markets as accurately as possible. The EPA uses the best available information from utilities, industry experts, gas and coal market experts, financial institutions, and government statistics as the basis for the detailed power sector modeling in IPM. The model documentation provides additional information on the assumptions discussed here as well as all other model assumptions and inputs.[51]

The model incorporates a detailed representation of the fossil-fuel supply system that is used to estimate equilibrium fuel prices. The model includes an endogenous representation of the North American natural gas supply system through a natural gas module that reflects a partial supply and demand equilibrium of the North American gas market, accounting for varying levels of potential power sector and non-power sector gas demand and corresponding gas production and price levels.[52] This module consists of 118 supply, demand, and storage nodes and 15 liquefied natural gas re-gasification facility locations that are tied together by a series of linkages (i.e., pipelines) that represent the North American natural gas transmission and distribution network.

IPM also endogenously models the partial equilibrium of coal supply and EGU coal demand levels throughout the contiguous U.S., taking into account assumed non-power sector demand and imports/exports. IPM reflects 36 coal supply regions, 14 coal grades, and the coal transport network, which consists of over four thousand linkages representing rail, barge, and truck and conveyer linkages. The coal supply curves in IPM were developed during a thorough bottom-up, mine-by-mine approach that depicts the coal choices and associated supply costs that power plants would face if selecting that coal over the modeling time horizon. The IPM documentation outlines the methods and data used to quantify the economically recoverable coal reserves, characterize their cost, and build the 36 coal regions' supply curves.[53]

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[51] The documentation of EPA's Base Case using IPM (v5.15) contains detailed information, including all the underlying assumptions, data sources, and architecture parameters. The documentation for EPA's Base Case v.5.15 using IPM consists of a comprehensive document for IPM v. 5.13, and an incremental update document for both v.5.14 and v.5.15. All are available at available at: http://www.epa.gov/airmarkets/powersectormodeling.html

[52] See Chapter 10 of EPA's Base Case using IPM (v5.15) documentation, available at: http://www.epa.gov/airmarkets/powersectormodeling.html

[53] See Chapter 9 of EPA's Base Case using IPM (v.5.15) documentation, available at: http://www.epa.gov/airmarkets/powersectormodeling.html

To estimate the annualized costs of additional capital investments[54] in the power sector, the EPA uses a conventional and widely accepted approach that applies a capital recovery factor (CRF) multiplier to capital investments and adds that to the annual incremental operating expenses. The CRF is derived from estimates of the power sector's cost of capital (i.e., private discount rate), the amount of insurance coverage required, local property taxes, and the life of capital.[55] It is important to note that there is no single CRF factor applied in the model; rather, the CRF varies across technologies, book life of the capital investments, and regions in the model in order to better simulate power sector decision-making.

The EPA has used IPM extensively over the past two decades to analyze options for reducing power sector emissions. Previously, the model has been used to estimate the costs, emission changes, and power sector impacts for the Clean Air Interstate Rule (U.S. EPA, 2005), the original Cross-State Air Pollution Rule (U.S. EPA, 2011), the Mercury and Air Toxics Standards (MATS) (U.S. EPA, 2011a), the Clean Power Plan (CPP) for Existing Power Plants (U.S. EPA, 2015), and the Carbon Pollution Standards for New Power Plants (U.S. EPA, 2015a). The EPA has also used IPM to estimate the air pollution reductions and power sector impacts of water and waste regulations affecting EGUs, including Cooling Water Intakes (316(b)) Rule (U.S. EPA, 2014), Disposal of Coal Combustion Residuals from Electric Utilities (CCR) (U.S. EPA, 2015b) and Steam Electric Effluent Limitation Guidelines (ELG) (U.S. EPA, 2015c).

The model and the EPA's input assumptions undergo periodic formal peer review. The rulemaking process also provides opportunity for expert review and comment by a variety of stakeholders, including owners and operators of capacity in the electricity sector that is represented by the model, public interest groups, and other developers of U.S. electricity sector models. The feedback that the Agency receives provides a highly-detailed review of key input assumptions, model representation, and modeling results. IPM has received extensive review by

[54] Due to the near-term compliance timing for the CSAPR Update, the EPA does not allow IPM to build certain new capital investments such as new, unplanned natural gas or renewable capacity or new SCR or SNCR in the near-term. The EPA's illustrative compliance modeling does allow for new combustion controls, which represent the most likely potential capital expenditure in the 2017 analysis year.

[55] See Chapter 8 of EPA's Base Case using IPM (v5.15) documentation, available at: http://www.epa.gov/airmarkets/powersectormodeling.html

energy and environmental modeling experts in a variety of contexts. For example, in the late 1990s, the Science Advisory Board reviewed IPM as part of the CAA Amendments Section 812 prospective studies[56] that are periodically conducted. The model has also undergone considerable interagency scrutiny when it was used to conduct over a dozen legislative analyses (performed at Congressional request) over the past decade. The Agency has also used the model in a number of comparative modeling exercises sponsored by Stanford University's Energy Modeling Forum over the past 15 years. IPM has also been employed by states (e.g., for RGGI, the Western Regional Air Partnership, Ozone Transport Assessment Group), other Federal and state agencies, environmental groups, and industry.

4.3 EPA's Power Sector Modeling of the Base Case and Three Regulatory Control Alternatives

The IPM "base case" for any regulatory impact analysis is a business-as-usual scenario that represents expected behavior in the electricity sector under market and regulatory conditions in the absence of the rule. As such, an IPM base case represents an element of the 2017 and 2020 baseline for this RIA.[57] The EPA frequently updates the IPM base case to reflect the latest available electricity demand forecasts from the U.S. Energy Information Agency (EIA) as well as expected costs and availability of new and existing generating resources, fuels, emission control technologies, and regulatory requirements.

4.3.1 EPA's IPM v.5.15 Base Cases for the CSAPR Update

EPA's IPM modeling platform used to analyze this rule (v.5.15) is similar to the version used to analyze the CSAPR Update proposal, and incorporates minor updates made primarily in response to comments received on an August 4, 2015 Notice of Data Availability and the proposed rule.

[56] http://www2.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act

[57] As described in Chapter 5 of EPA's *Guidelines for Preparing Economic Analyses*, the baseline "should incorporate assumptions about exogenous changes in the economy that may affect relevant benefits and costs (e.g., changes in demographics, economic activity, consumer preferences, and technology), industry compliance rates, other regulations promulgated by EPA or other government entities, and behavioral responses to the proposed rule by firms and the public." (USEPA, 2010).

As with the CSAPR Update proposal, the IPM v.5.15 modeling platform incorporates federal and most state laws and regulations whose provisions were either in effect or enacted and clearly delineated by February 1, 2016.[58] The base case includes the Final Mercury and Air Toxics Standards (MATS),[59] and two non-air federal rules affecting EGUs: Cooling Water Intakes (316(b)) Rule (U.S. EPA, 2014), and Combustion Residuals from Electric Utilities (CCR) (U.S. EPA, 2015b). Additionally, all new capacity projected by the model is compliant with Clean Air Act 111(b) standards, including the final standards of performance for GHG emissions from new sources. As described in section IV.B of the preamble, the Clean Power Plan (CPP) is not included in this analysis.

Unlike the base case used in the analysis of the proposed rule, which was conducted prior to the D.C. Circuit's issuance of EME Homer City II,[60] the base case for the final rule accounts for compliance with the original CSAPR by including as constraints all original CSAPR emission budgets with the exception of remanded Phase 2 NO_X ozone season emission budgets for 11 states and Phase 2 NO_X ozone season emission budgets for four additional states that were finalized in the original CSAPR supplemental rule.[61] For more information, see section V of the preamble.

[58] Note that this modeling platform does not include the Regional Haze Plan for Texas and Oklahoma, published January 5, 2016. EPA does not believe this rule would substantially affect ozone season NO_X emissions in 2017, and therefore budgets determined for this rule.

[59] In Michigan v. EPA, the Supreme Court reversed on narrow grounds a portion of the D.C. Circuit decision upholding MATS, finding that EPA erred by not considering cost when determining that regulation of EGUs was "appropriate" pursuant to CAA section 112(n)(1). 135 S.Ct. 192 (2015). The case was remanded to the D.C. Circuit for further proceedings, and because MATS was remanded but not vacated, MATS currently remain in place.

[60] In *EME Homer City II*, the D.C. Circuit declared invalid the CSAPR phase 2 NO_X ozone season emission budgets of 11 states: Florida, Maryland, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Texas, Virginia, and West Virginia. *Id.* 795 F.3d at 129-30, 138. The court remanded those budgets to the EPA for reconsideration. *Id.* at 138. As a result, the EPA removed the original CSAPR phase 2 NO_X ozone season emission budgets as constraints for these 11 states in the 2017 IPM modeling.

[61] The EPA acknowledges that the CSAPR NO_X ozone season emission budgets for Iowa, Michigan, Oklahoma, and Wisconsin -- which were finalized in the original CSAPR Supplemental Rule (76 FR 80760, December 27, 2011) -- were linked to the same receptors that lead to the remand of other states' NO_X ozone season emission budgets in EME Homer City II.

Additionally, after the IPM modeling for the final rule was underway, Pennsylvania published a new RACT rule[62] that would require EGU NO_X reductions starting on January 1, 2017. The EPA was unable to explicitly include this final state rule in the IPM base case for the final CSAPR Update. However, the EPA recognizes that the implementation of this final state rule will precede the first control period for the final CSAPR Update. The agency believes that it is reasonable to remove the impacts of the Pennsylvania RACT rule from the estimated impacts of the CSAPR Update to appropriately reflect the emission reductions, costs, and benefits attributable to the CSAPR Update. Therefore, the EPA evaluated the EGU emission reductions expected to result from Pennsylvania's RACT rule exogenously and isolated these impacts from the EPA's assessment of emission reductions, benefits, and costs estimated for the CSAPR Update and the more and less stringent alternatives. For more information, see the Pennsylvania Additional RACT Requirements for Major Sources of NO_X and VOCs Memo to the Docket.

Other updates to the v.5.15 base cases used in this final rule include largely unit-level specifications (e.g., pollution control configurations and emissions rates), and planned power plant construction and closures that the EPA was aware of by February 1, 2016. In Maryland, emission rates of units were updated to reflect compliance with the state's RACT rule. Additionally, given the lead times for new combined cycle plants, EPA did not allow the model to build additional capacity of that type in 2018 beyond announced new builds.[63] Similarly, EPA did not allow new renewable generation to be built before 2018, nor did EPA allow the model to retire any units beyond announced retirements before 2020. Finally, NO_X-specific pollution control retrofits were limited to retrofits that occurred in the base case. For a detailed account of all updates made to the v.5.15 modeling platform, see the EPA v.5.15 CSAPR Update Rule Base Cases Using IPM Incremental Documentation , available in the docket..

EPA also updated the National Electric Energy Data System (NEEDS)[64], based largely on public comment received in response to an August 4, 2015 Notice of Data Availability and

[62] Published April 23, 2017 (http://www.pabulletin.com/secure/data/vol46/46-17/694.html)

[63] Additionally, note that no new coal-fired capacity was projected in 2016 or 2018 in any of the model runs compelted for this analysis.

[64] http://www2.epa.gov/airmarkets/power-sector-modeling-platform-v515

the proposed rule. This database contains the unit-level data that is used to construct the "model" plants that represent existing and planned-committed units in EPA modeling applications of IPM.[65] NEEDS includes detailed information on each individual EGU, including geographic, operating, air emissions, and other data on every generating unit in the contiguous U.S.

While the EPA used the IPM v.5.15 platform throughout the development and analysis of the final CSAPR Update, minor updates were made to this modeling platform over the course of the final rule development. Subsequent to the initial base case projections that provided power sector emissions data used for air quality modeling,[66] the EPA made minor updates to the modeling platform, which focus primarily on electricity generating unit-level input assumptions regarding NO_X rates. The EPA believes that these updates, while relatively minor in the context of national emission projections, improve the model's ability to reflect the electric power system in relation to the CSAPR Update, and enable the EPA to provide the best projections possible to evaluate this rule. For more information, see the EPA v.5.15 CSAPR Update Rule Base Cases Using IPM Incremental Documentation. .

The analysis of cost and impacts presented in this chapter is based on a single IPM base case, the Illustrative Base Case, and represents incremental impacts projected solely as a result of compliance with the illustrative emission budgets presented in Table 4-1 above. Note that further analysis, which includes additional updates, is presented in Appendix 4A.

4.3.2. Methodology for Evaluating the Regulatory Control Alternatives

To estimate the costs, benefits, and economic and energy market impacts of the CSAPR Update, the EPA conducted quantitative analysis of the three regulatory control alternatives: the illustrative final CSAPR Update emission budgets and more and less stringent alternatives. Details about these regulatory control alternatives, including state-specific EGU NO_X ozone-season emissions budgets for each alternative as analyzed in this RIA, are provided above in section 4.1.

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[65] For more information, see Chapter 4 of the IPM Documentation.

[66] The air quality modeling, used to quantify upwind state contributions, is described in Chapter 2 of this RIA and Section V of the preamble.

Before undertaking power sector analysis to evaluate compliance with the regulatory control alternatives, the EPA first considered available EGU NO_X mitigation strategies that could be implemented for the first compliance period (i.e., the 2017 ozone season). The EPA considered all widely-used EGU NO_X control strategies: optimizing NO_X removal by existing, operational selective catalytic reduction (SCRs) and turning on and optimizing existing idled SCRs; turning on existing idled SNCRs; installation of (or upgrading to) state-of-the-art NO_X combustion controls; shifting generation to units with lower NO_X emission rates; and installing new SCRs and SNCRs. Similarly, as proposed, EPA determined that the power sector could implement all of these NO_X mitigation strategies, except installation of new SCRs or SNCRs, for the 2017 ozone-season. For more details on these assessments, including the assessment of EGU NO_X mitigation costs and feasibility, please refer to the Final EGU NO_X Mitigation Strategies TSD, in the docket for this rule.

These mitigation strategies are primarily captured within the model. However, due to limitations on model size, IPM v.5.15 does not have the ability to determine, within the model, whether or not to operate existing EGU post-combustion NO_X controls (i.e., SCR or SNCR) in response to a regulatory emission requirement.[67] Whether or not an existing post-combustion NOx control at a particular EGU is operating in a model scenario is determined by the model user. In order to evaluate compliance with the regulatory control alternatives, the EPA determined, outside the model, whether or not operation of existing controls that are idle in the base case would be reasonably expected for compliance with each of the evaluated regulatory control alternatives. After imposing the requirement to operate these controls, IPM estimated the associated NO_X reductions and impacts associated with each regulatory alternative.

The EGU NO_X mitigation strategies that are assumed to operate or are available to reduce NO_X in order to comply with each of the regulatory control alternatives are shown in Table 4-2; more information about the estimated costs of these controls can be found in the EGU NO_X Mitigation Strategies TSD.

[67] EGUs with idled SCR or SNCR in the base case represent a small percentage (less than 10 percent) of the EGU fleet that is equipped with NO_X post-combustion controls.

Table 4-2. NO_X Mitigation Strategies Implemented for Compliance with the Regulatory Control Alternatives

Regulatory Control Alternative	NO_X Controls Implemented
Less Stringent Alternative	(1) Fully operating existing SCRs to achieve 0.081 lb/MMBtu NO_X emission rate (costs estimated outside IPM)[68] (2) Shift generation to minimize costs (costs estimated within IPM)
CSAPR Update	(All controls above) (3) Turn on idled SCRs (costs estimated within IPM) (4) Install or upgrade combustion controls (costs estimated outside IPM)
More Stringent Alternative	(All controls above) (5) Turn on idled SNCRs (costs estimated within IPM)

In addition to the limitation on ozone season NO_X emissions required by the EGU emissions budgets for the 22 states, there are four important features of the allowance trading program represented in the model that may influence the level and location of NO_X emissions from affected EGUs. They are: the ability of affected EGUs to buy and sell NO_X ozone season allowances from one another for compliance purposes; the ability of affected EGUs to bank NO_X ozone season allowances for future use; the effect of limits on the total ozone season NO_X emissions from affected EGUs in each state required by the assurance provisions; and the treatment of banked 2015 and 2016 vintage NO_X ozone season allowances issued under the original CSAPR to address interstate ozone transport for the 1997 ozone NAAQS. Each of these features of the ozone season allowance trading program is described below.

Affected EGUs are expected to choose the least-cost method of complying with the requirements of the allowance trading program, and the distribution of ozone season NO_X emissions across affected EGUs is generally governed by this cost-minimizing behavior in the analysis. The total ozone season NO_X emissions from affected EGUs in this analysis are limited to the amount allowed by the sum of the NO_X budgets across the 22 states. Furthermore, allowances may be banked for future use. The number of banked allowances is influenced by the determination, outside the model, whether or not existing controls that are idle in the base case are turned on and by if it is less costly to abate ozone season NO_X emissions in a current ozone

[68] For consistency with the budgets analyzed in this chapter, the illustrative policy cases assumes that fully operated SCRs can achieve NO_X emissions rates of up to 0.081 lbs/MMBtu. Note that the final budgets are based on an assumed NO_X rate of 0.10 lbs/MMBtu, which is the modeling assumption used in the analysis of the final budgets presented in Appendix 4A.

season than to abate emissions in a later ozone season. Affected EGUs are expected to bank NO_X ozone season allowances in the 2017 ozone season for use in the later ozone season. Based on observation, the EPA believes that this is a reasonable illustrative compliance path for EGUs, which may wish to bank allowances for future use under economic reasons or non-economic reasons such as being prepared for future variability in power sector operations.

While there are no explicit limits on the exchange of allowances between affected EGUs and on the banking of 2017 and future vintage NO_X ozone season allowances, the assurance provisions limit the amount of seasonal NO_X emissions by affected EGUs in each of the 22 states. The assurance level limits affected EGU emissions over an ozone season to the state's NO_X ozone season emission budget plus an increment equal to 21 percent of each state's emissions budget. This increment is called the variability limit. See section VII.E.4 of the preamble for a discussion of the purpose of the assurance provision and further detail about how the variability limits and assurance levels are determined. If a state exceeds its assurance level in a given year, sources within that state are assessed a total of 3-to-1 allowance surrender on the excess tons. Section VII.E.4 of the preamble also explains how the EPA then determines which EGUs are subject to this surrender requirement. In the modeling, the assurance provisions are represented by a limit on the total ozone season NO_X emissions that may be emitted by affected EGUs in each state, and thus the modeling does not permit affected EGUs to emit beyond the assurance levels and thus incur penalties.

As described in section VII.C.2 of the preamble, the rule allows 2015 and 2016 vintage NO_X ozone season allowances (that had been issued under CSAPR to address interstate ozone transport for the 1997 ozone NAAQS) to be used for compliance with this rule, following a one-time conversion that reduces the overall quantity of banked allowances from that time period. Based on EPA's expectation that its conversion of allowances will limit the use of banked allowances to one year of states' aggregated variability limits, , the treatment of these banked allowances is represented in the modeling as an additional 65,221 tons of NO_X allowances, the equivalent of one year of the variability limit associated with the illustrative emission budgets, that may be used by affected EGUs during the 2017 ozone season or in later ozone seasons.

4.3.3 Methodology for Estimating Compliance Costs

This section describes EPA's approach to quantify estimated compliance costs associated with the three regulatory control alternatives. These compliance costs include estimates projected directly by the model as well as calculations performed outside of the model that use IPM model inputs and methods. The model projections capture the costs associated with three of the NO_X mitigation strategies: turning on idled SCRs, turning on idled SNCRs, and shifting generation to lower-NO_X emitting EGUs. The costs of increasing the use and optimizing the performance of existing and operating SCRs,[69] and for installing or upgrading NO_X combustion controls, were estimated outside of the model. The costs for these two NO_X mitigation strategies are calculated based on IPM emissions projections and utilize the same NO_X control cost equations used in IPM. Therefore, this estimate is consistent with modeled projections and provides the best available quantification of the costs of these NO_X mitigation strategies.

The following steps summarize the EPA's methodology for estimating the component of compliance costs that are calculated outside of the model for the CSAPR Update scenario:

(1) In the model projections, identify all model plants in the 22-state region that can adopt the following NO_X mitigation strategies:

- Fully operating existing SCRs
- Installing or upgrading NO_X combustion controls

(2) Estimate the total NO_X reductions that are attributable to each of these strategies:[70]

- Fully operating existing SCRs (SCRs operating in base case): 24,100 tons
- Fully operating existing SCRs (SCRs not operating in base case): 4,500 tons
- Installing or upgrading NO_X combustion controls: 9,700 tons

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[69] This includes optimizing the performance of SCRs that were not operating.

[70] For more information on how NO_X reductions were attributed to strategies, see the excel files in the docket for this rule entitled "Illustrative Cases Reduction Analysis 2018 and 2020 for RIA" and "Final Policy Case Reduction Analysis 2018 and 2020 for RIA".

(3) Estimate the average cost associated with each of these strategies:[71]

- Fully operating existing SCRs (SCRs operating in base case): $670/ton
- Fully operating existing SCRs (SCRs not operating in base case): $1,000/ton
- Installing or upgrading NO_X combustion controls: $1,200/ton

(4) Multiply (2) by (3) to estimate the total cost associate with each of these strategies.

Table 4-3 summarizes the results of this methodology for the illustrative CSAPR Update scenario in 2017.

Table 4-3. Summary of Methodology for Calculating Compliance Costs Estimated Outside of IPM for CSAPR Update, 2017 (2011$)

NO_X Mitigation Strategy	NO_X Ozone Season Emissions (Tons)	Average Cost ($/ton)	Total Cost ($MM)
Maximizing the use of existing SCRs (operating in Base Case)	24,100	670	16
Maximizing the use of existing SCRs (not operating in Base Case)	4,500	1,000	4.5
Installing/upgrading NO_X combustion controls[72]	9,700	1,200	12

The total costs of compliance with the regulatory control alternatives are estimated as the sum of the costs that are modeled within IPM and the costs that are calculated outside the model.

4.4 Estimated Impacts of the Regulatory Control Alternatives

4.4.1 Emission Reduction Assessment

As discussed in Chapter 3, the EPA determined that NO_X emissions in 22 eastern states affect the ability of downwind states to attain and maintain the 2008 ozone NAAQS. For these 22 eastern states, the EPA is issuing Federal Implementation Plans (FIPs) that generally update

[71] See NO_X Mitigation Strategy TSD for derivation of cost-per-ton estimates for fully operating SCRs and upgrading to state-of-the-art combustion controls.

[72] This includes 3,030 tons of reductions from combustion control retrofits in Arkansas that are not expected until 2018.

the existing CSAPR NO_X ozone-season emission budgets for EGUs and implement these budgets via the CSAPR NO_X ozone-season allowance trading program.

The NO_X emissions reductions are presented in this RIA for two time periods: 2017 (the principal year of interest for the CSAPR update) and 2020. As with proposal RIA, the 2017 emissions estimates are based on IPM projections for 2018, and reflect exogenous adjustments to account for known differences between 2017 and 2018 (e.g., planned closures, coal-to-gas conversions, and planned SCR retrofits). For more information on these and other adjustments, see Policy Analysis TSD.

Table 4-4 presents the estimated reduction in power sector NO_X emissions resulting from compliance with the evaluated regulatory control alternatives (i.e., emissions budgets) in the 22-state region, as well as the impact on states not in the region. The emission reductions follow an expected pattern: the less stringent alternative produces substantially smaller emission reductions than EPA's final emissions budgets, and the more stringent alternative results in slightly more NO_X reductions.

Table 4-4. EGU Ozone Season NO_X Emissions and Emission Changes (thousand tons) for the Base Case and the Regulatory Control Alternatives

Ozone Season NO_X (thousand tons)		Base Case	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative
2017	Region	369.5	308.3	342.7	303.2	-61.2	-26.8	-66.3
	Non-Region	205.4	205.3	205.4	205.5	-0.1	0.0	0.2
	Total	574.8	513.5	548.1	508.8	-61.3	-26.8	-66.1
2020	Region	374.6	302.8	347.7	297.8	-71.8	-26.9	-76.8
	Non-Region	181.6	181.5	181.6	181.8	-0.1	0.0	0.2
	Total	556.2	484.3	529.3	479.6	-71.9	-26.9	-76.6

The results of EPA's IPM analysis show that, with respect to compliance with the illustrative EGU NO_X emission budgets, maximizing the use of existing operating SCRs provides the largest amount of ozone season NO_X emission reductions 42 percent), and turning on idled SCRs produces an additional 32 percent of the total ozone season NO_X reductions. Combustion controls (16 percent) and generation shifting (10 percent) make up the remainder of the ozone season NO_X reductions. In the more stringent alternative, compliance by turning on idle existing SNCRs makes up 1 percent of the total reductions and generation shifting increases to 16 percent, while the shares attributed to the other four mitigation measures are similar to, if slightly smaller than, the shares for compliance with the finalized EGU NO_X emissions budgets. In the less stringent alternative, compliance by maximizing the use of existing operating SCRs provides 85% of the total reductions, with the remainder attributable to generation shifting.

In addition to the ozone season NO_X reductions, there will also be reductions of other air emissions emitted by EGUs burning fossil fuels (i.e., co-pollutants). These other emissions include the annual total changes in emissions of NOx, SO_2 and CO_2. The small SO_2 emissions increase is attributable primarily to a few model plants, for which the model projected a slightly different 2016 MATS control strategy in the base case than with the CSAPR Update, resulting in a small change in SO_2 emissions. Since the MATS rule is currently effective, the EPA believes that the MATS control strategies at these plants are currently in place, and not likely to change as a result of the CSAPR Update. Therefore, the EPA does not view the projected SO_2 increase as a meaningful impact of the policy. The co-pollutant emission reductions are presented in Table 4-5.

Table 4-5. EGU Annual Emissions and Emissions Changes for NO_X, SO_2 and CO_2 for the Regulatory Control Alternatives

Annual NO_X (thousand tons)		Base Case	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative
2017	Region	806.6	732.2	779.7	727.3	-74.5	-26.9	-79.3
	Non-Region	439.1	439.0	439.1	439.2	0.0	0.0	0.1
	Total	1,245.7	1,171.2	1,218.8	1,166.5	-74.5	-26.9	-79.2
2020	Region	820.2	735.5	793.2	730.6	-84.7	-27.0	-89.5
	Non-Region	415.3	415.3	415.3	415.4	0.0	0.0	0.1
	Total	1,235.5	1,150.7	1,208.5	1,146.0	-84.8	-27.0	-89.4

Annual SO_2 (thousand tons)		Base Case	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative
2017	Region	914.8	918.9	915.9	922.1	4.1	1.1	7.3
	Non-Region	324.1	322.1	323.7	321.7	-2.0	-0.4	-2.4
	Total	1,238.9	1,241.0	1,239.6	1,243.8	2.2	0.7	5.0

2020	Region	914.8	918.9	915.9	922.1	4.1	1.1	7.3
	Non-Region	324.1	322.1	323.7	321.7	-2.0	-0.4	-2.4
	Total	1,238.9	1,241.0	1,239.6	1,243.8	2.2	0.7	5.0

Annual CO_2 (MM metric tonnes)		**Base Case**	**CSAPR Update**	**Less-Stringent Alternative**	**More-Stringent Alternative**	**CSAPR Update**	**Less-Stringent Alternative**	**More-Stringent Alternative**
2017	Region	1,237.2	1,235.5	1,235.8	1,234.9	-1.7	-1.4	-2.3
	Non-Region	653.5	653.6	653.6	653.7	0.1	0.1	0.3
	Total	1,890.7	1,889.1	1,889.4	1,888.6	-1.6	-1.3	-2.0
2020	Region	1,237.2	1,235.5	1,235.8	1,234.9	-1.7	-1.4	-2.3
	Non-Region	653.5	653.6	653.6	653.7	0.1	0.1	0.3
	Total	1,890.7	1,889.1	1,889.4	1,888.6	-1.6	-1.3	-2.0

4.4.2 Compliance Cost Assessment

The estimates of the changes in the cost of supplying electricity for the regulatory control alternatives are presented in Table 4-6. The costs associated with compliance with monitoring, recordkeeping, and reports requirements are not included within the estimates in this table and can be found in preamble section X.B.

Table 4-6. Compliance Cost Estimates (millions of 2011$) for the Regulatory Control Alternatives

	CSAPR Update	**Less-Stringent Alternative**	**More-Stringent Alternative**
2017-2020 (Annualized)	68.4	8.0	82.0
2017 (Annual)	0.01	-55.7	-0.4
2020 (Annual)	136.9	77.1	164.6

"2017-2020 (Annualized)" reflects total estimated annual compliance costs levelized over the period 2017 through 2020, discounted using a 4.77 discount rate. "2017 (Annual)" and "2020 (Annual)" reflect point estimates in each of those years.

There are several notable aspects of the results presented in Table 4-6. The most notable result in Table 4-6 is that the estimated annual compliance costs for the less and more stringent alternatives are negative (i.e., a cost reduction) in 2017, although these regulatory control alternatives reduce annual NO_X emissions by approximately 27,000 and 79,000 tons respectively as shown in Table 4-5. While seemingly counterintuitive, estimating negative compliance costs in a single year is possible given the assumption of perfect foresight. IPM's objective function is to minimize the discounted net present value (NPV) of a stream of annual total cost of generation over a multi-decadal time period.[73] For example, with the assumption of perfect foresight it is possible that on a national basis within the model the least-cost compliance strategy may be to delay a new investment which was projected to occur sooner in the base case. Such a delay could result in a lowering of annual cost in an early time period and increase it in later time periods.

In addition to evaluating annual compliance cost impacts, the EPA believes that a full understanding of these three regulatory control alternatives benefits from an evaluation of annualized costs over the 2017-2020 time frame. EPA limits its analysis to this timeframe considering that on October 1, 2015, the EPA strengthened the ground-level ozone NAAQS to 70 ppb. The EPA is mindful of the need to address ozone transport for the 2015 ozone NAAQS. Given the statutory implementation timeline of good neighbor requirements with respect to the 2015 ozone NAAQS, the EPA anticipates that further actions to reduce interstate emission transport related to ozone pollution could take place in the near future.[74] Therefore, it is appropriate to evaluate the costs of the regulatory control alternatives over the 2017-2020 timeframe. Starting with the estimated annual cost time series, it is possible to estimate the net present value of that stream, and then estimate a levelized annual cost associated with compliance with each regulatory control alternative.[75] For this analysis we first calculated the NPV of the stream of costs from 2017 through 2020[76] using a 4.77 percent discount rate. EPA typically uses a 3 and a 7 percent discount rate to discount future year social benefits and social costs in regulatory impact analyses (USEPA, 2010). In this cost annualization we use a 4.77

[73] For more information, see Chapter 2 of the IPM Documentation.

[74] See preamble section VII.

[75] The XNPV() function in Microsoft Excel 2013 was used to calculate the NPV of the variable stream of costs, and the PMT() function in Microsoft Excel 2013 is used to calculate the level annualized cost from the estimated NPV.

[76] Consistent with the relationship between IPM run years and calendar years, the EPA assigned 2020 compliance cost estimates to both 2019 and 2020 in the calculation of NPV. For more information, see Chapter 7 of the IPM Documentation.

percent discount rate, which is consistent with the rate used in IPM's objective function for minimizing the NPV of the stream of total costs of electricity generation.[77]

After calculating the NPV of the cost streams, the same 4.77 percent discount rate and 2017-2020 time period is used to calculate the levelized annual (i.e., annualized) cost estimates shown in Table 4-6.[78]

Additionally, note that the 2017-2020 equivalent annualized compliance cost estimates have the expected relationship to each other; the annualized costs are lowest for the less stringent alternatives, and highest for the more stringent alternative.

4.4.3 Impacts on Fuel Use, Prices and Generation Mix

While the CSAPR Update is expected to result in significant NO_X emissions reductions, it is estimated to result in relatively modest impacts to the power sector. While these impacts are relatively small in percentage terms, consideration of these potential impacts is an important component of assessing the relative impact of the regulatory control alternatives. In this section we discuss the estimated changes in fuel use, fuel prices, generation by fuel type, capacity by fuel type, and retail electricity prices.

Tables 4-7 and 4-8 present the percentage changes in national coal and natural gas usage by EGUs in 2017 These fuel use estimates reflect a modest shift to natural gas from coal. The projected impacts in 2020 are similarly very small.

Table 4-7. 2017 Projected Power Sector Coal Use for the Base Case and the Regulatory Control Alternatives

	Million Tons				Percent Change from Base Case		
	Base Case	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative
Appalachia	118	117	118	117	-0.2%	-0.1%	-0.4%

[77] The IPM Base Case documentation (Section 8.2.1 Introduction to Discount Rate Calculations) states "The real discount rate for expenditures (e.g., capital, fuel, variable operations and maintenance, and fixed operations and maintenance costs) in the EPA Base Case v.5.13 is 4.77%. This serves as the default discount rate for all expenditures."

[78] The PMT() function in Microsoft Excel 2013 is used to calculate the level annualized cost from the estimated NPV.

Imports	0	0	0	0	N/A	N/A	N/A
Interior	227	227	227	227	0.0%	0.0%	0.0%
Waste Coal	6	6	6	6	0.0%	0.0%	0.0%
West	352	351	351	350	-0.4%	-0.4%	-0.5%
Total	703	701	701	700	-0.2%	-0.2%	-0.3%

Table 4-8. 2017 Projected Power Sector Natural Gas Use for the Base Case and the Regulatory Control Alternatives

Trillion Cubic Feet				Percent Change from Base Case		
Base Case	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative
8.8	8.8	8.8	8.8	0.2%	0.1%	0.3%

Tables 4-9 and 4-10 present the projected coal and natural gas prices in 2017, as well as the percent change from the base case projected as a result of the regulatory control alternatives. These minor impacts in 2017 are consistent with the small changes in fuel use summarized above. The projected impacts in 2020 are similarly very small.

Table 4-9. 2017 Projected Minemouth and Power Sector Delivered Coal Price for the Base Case and the Regulatory Control Alternatives

	$/MMBtu				Percent Change from Base Case		
	Base Case	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative
Minemouth	1.51	1.51	1.51	1.51	-0.1%	-0.2%	-0.3%
Delivered	2.31	2.31	2.31	2.31	-0.1%	-0.2%	-0.2%

Table 4-10. 2017 Projected Henry Hub and Power Sector Delivered Natural Gas Price for the Base Case and the Regulatory Control Alternatives

	$/MMBtu				Percent Change from Base Case		
	Base Case	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative
Henry Hub	4.33	4.33	4.33	4.33	0.0%	0.0%	0.1%
Delivered	4.52	4.52	4.52	4.53	0.0%	0.0%	0.0%

Table 4-11 presents the projected percentage changes in the amount of electricity generation in 2017 by fuel type. Consistent with the fuel use projections and emissions trends above, the EPA projects very small overall shift from coal to gas. The projected impact in 2020 is similarly very small.

Table 4-11. 2017 Projected Generation by Fuel Type for the Base Case and the Regulatory Control Alternatives

	Generation (MWh)				Percent Change from Base Case		
	Base Case	**CSAPR Update**	**Less-Stringent Alternative**	**More-Stringent Alternative**	**CSAPR Update**	**Less-Stringent Alternative**	**More-Stringent Alternative**
Coal	1,388	1,386	1,387	1,385	-0.2%	-0.1%	-0.2%
Natural Gas	1,195	1,198	1,197	1,199	0.2%	0.1%	0.3%
Nuclear	787	787	787	787	0.0%	0.0%	0.0%
Hydro	281	281	281	281	0.0%	0.0%	0.0%
Non-Hydro RE	421	421	421	421	0.0%	0.0%	0.0%
Oil\Gas Steam	50	50	50	50	0.0%	0.0%	0.0%
Other	8	8	8	8	0.9%	-1.2%	0.4%
Total	4,131	4,131	4,131	4,131	0.0%	0.0%	0.0%

Note: In this table, "Non-Hydro RE" includes biomass, geothermal, landfill gas, solar, and wind

Table 4-12 presents the projected percentage changes in the amount of generating capacity in 2020 by primary fuel type. As explained above, none of the regulatory control alternatives are expected to have a net impact on overall capacity by primary fuel type in 2017, and the model was specified accordingly.

Table 4-12. 2020 Projected Capacity by Fuel Type for the Base Case and the Regulatory Control Alternatives

	Capacity (GW)				Percent Change from Base Case		
	Base Case	**CSAPR Update**	**Less-Stringent Alternative**	**More-Stringent Alternative**	**CSAPR Update**	**Less-Stringent Alternative**	**More-Stringent Alternative**
Coal	209	209	209	209	-0.3%	-0.2%	-0.3%
Natural Gas	391	391	391	391	0.0%	0.0%	0.0%
Nuclear	101	101	101	102	0.3%	0.1%	0.3%
Hydro	107	107	107	107	0.0%	0.0%	0.0%
Non-Hydro RE	138	138	138	138	0.0%	0.0%	0.0%
Oil\Gas Steam	83	83	83	83	0.0%	0.0%	0.0%
Other	5	5	5	5	0.0%	0.0%	0.0%
Total	1,035	1,035	1,035	1,035	0.0%	0.0%	0.0%

Note: In this table, "Non-Hydro RE" includes biomass, geothermal, landfill gas, solar, and wind

The EPA estimated the change in the retail price of electricity (2011$) using the Retail Price Model (RPM).[79] The RPM was developed by ICF International for the EPA, and uses the IPM estimates of changes in the cost of generating electricity to estimate the changes in average retail electricity prices. The prices are average prices over consumer classes (i.e., consumer, commercial and industrial) and regions, weighted by the amount of electricity used by each class and in each region. The RPM combines the IPM annual cost estimates in each of the 64 IPM regions with EIA electricity market data for each of the 22 electricity supply regions in the electricity market module of the National Energy Modeling System (NEMS).[80]

Tables 4-13 and 4-14 present the projected percentage changes in the retail price of electricity for the three regulatory control alternatives in 2017 and 2020, respectively. Consistent with other projected impacts presented above, average retail electricity prices at both the national and regional level are projected to be small. By 2020, the EPA estimates that this rule will result in a 0.1% increase in national average retail electricity price, or by about 0.1 mills/kWh (about 0.01 cents/kWh).

Table 4-13. Average Retail Electricity Price by Region for the Base Case and the Regulatory Control Alternatives, 2017

	2017 Average Retail Electricity Price (2011 mills/kWh)				Percent Change from Base Case		
Region	**Base Case**	**CSAPR Update**	**Less-Stringent Alternative**	**More-Stringent Alternative**	**CSAPR Update**	**Less-Stringent Alternative**	**More-Stringent Alternative**
ERCT	79.5	79.5	79.5	79.6	0.0%	0.0%	0.1%
FRCC	102.3	102.2	102.2	102.2	-0.1%	-0.1%	-0.1%
MROE	100.4	100.4	100.4	100.4	0.0%	0.0%	0.0%
MROW	87.6	87.5	87.6	87.5	-0.1%	-0.1%	-0.1%
NEWE	126.8	126.8	126.8	126.8	0.0%	0.0%	0.0%
NYCW	166.2	166.2	166.2	166.2	0.0%	0.0%	0.0%
NYLI	136.3	136.3	136.3	136.4	0.0%	0.0%	0.0%
NYUP	119.2	119.3	119.2	119.3	0.1%	0.0%	0.1%

79 See documentation available at: https://www.epa.gov/airmarkets/power-sector-modeling

80 See documentation available at: http://www.eia.gov/forecasts/aeo/nems/documentation/electricity/pdf/m068(2014).pdf

RFCE	103.1	103.0	103.5	103.1	-0.1%	0.4%	0.0%
RFCM	103.0	103.0	102.9	103.0	0.0%	-0.1%	0.0%
RFCW	88.6	88.7	88.6	88.7	0.1%	0.0%	0.1%
SRDA	82.5	82.5	82.4	82.5	0.0%	-0.1%	0.0%
SRGW	83.8	83.8	83.8	83.8	0.0%	0.0%	0.0%
SRSE	101.6	101.6	101.5	101.6	0.0%	-0.1%	0.0%
SRCE	79.7	79.7	79.6	79.6	0.0%	-0.1%	-0.1%
SRVC	98.3	98.3	98.3	98.3	0.0%	0.0%	0.0%
SPNO	102.2	102.2	102.2	102.1	0.0%	0.0%	-0.1%
SPSO	79.0	79.1	79.0	79.2	0.1%	0.1%	0.2%
AZNM	109.6	109.6	109.6	109.6	0.0%	0.0%	0.0%
CAMX	145.5	145.5	145.5	145.5	0.0%	0.0%	0.0%
NWPP	72.6	72.6	72.6	72.6	0.0%	0.0%	0.0%
RMPA	87.1	87.1	87.1	87.1	0.0%	0.0%	0.0%
NATIONAL	97.3	97.3	97.3	97.3	0.0%	0.0%	0.0%

Table 4-14. Average Retail Electricity Price by Region for the Base Case and the Regulatory Control Alternatives, 2020

	2020 Average Retail Electricity Price (2011 mills/kWh)				Percent Change from Base Case		
Region	Base Case	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative	CSAPR Update	Less-Stringent Alternative	More-Stringent Alternative
ERCT	88.6	88.7	88.7	88.8	0.1%	0.1%	0.2%
FRCC	104.3	104.4	104.4	104.4	0.1%	0.1%	0.1%
MROE	99.1	99.1	99.1	99.1	0.0%	0.0%	0.0%
MROW	87.7	87.8	87.8	87.8	0.1%	0.1%	0.1%
NEWE	130.6	130.7	130.7	130.7	0.1%	0.0%	0.1%
NYCW	171.9	172.1	172.0	172.1	0.1%	0.1%	0.1%
NYLI	141.6	141.7	141.6	141.7	0.1%	0.0%	0.1%
NYUP	123.1	123.3	123.2	123.3	0.2%	0.1%	0.2%
RFCE	108.1	108.3	108.2	108.3	0.2%	0.1%	0.2%
RFCM	103.7	103.8	103.8	103.8	0.1%	0.0%	0.1%
RFCW	91.4	91.6	91.7	91.7	0.2%	0.3%	0.3%
SRDA	85.5	85.6	85.6	85.6	0.1%	0.1%	0.1%
SRGW	85.9	86.0	86.0	86.1	0.1%	0.2%	0.3%
SRSE	100.4	100.4	100.4	100.4	0.0%	0.0%	0.0%
SRCE	80.2	80.2	80.2	80.2	0.0%	0.0%	0.0%
SRVC	97.7	97.8	97.7	97.7	0.1%	0.0%	0.1%
SPNO	101.1	101.1	101.1	101.0	0.0%	0.0%	-0.1%
SPSO	81.7	81.9	81.8	82.0	0.2%	0.1%	0.3%

AZNM	110.6	110.6	110.6	110.6	0.0%	0.0%	0.0%
CAMX	144.4	144.4	144.4	144.4	0.0%	0.0%	0.0%
NWPP	69.4	69.4	69.4	69.4	0.0%	0.0%	0.0%
RMPA	87.4	87.4	87.4	87.4	0.0%	0.1%	0.0%
NATIONAL	99.0	99.1	99.1	99.1	0.1%	0.1%	0.1%

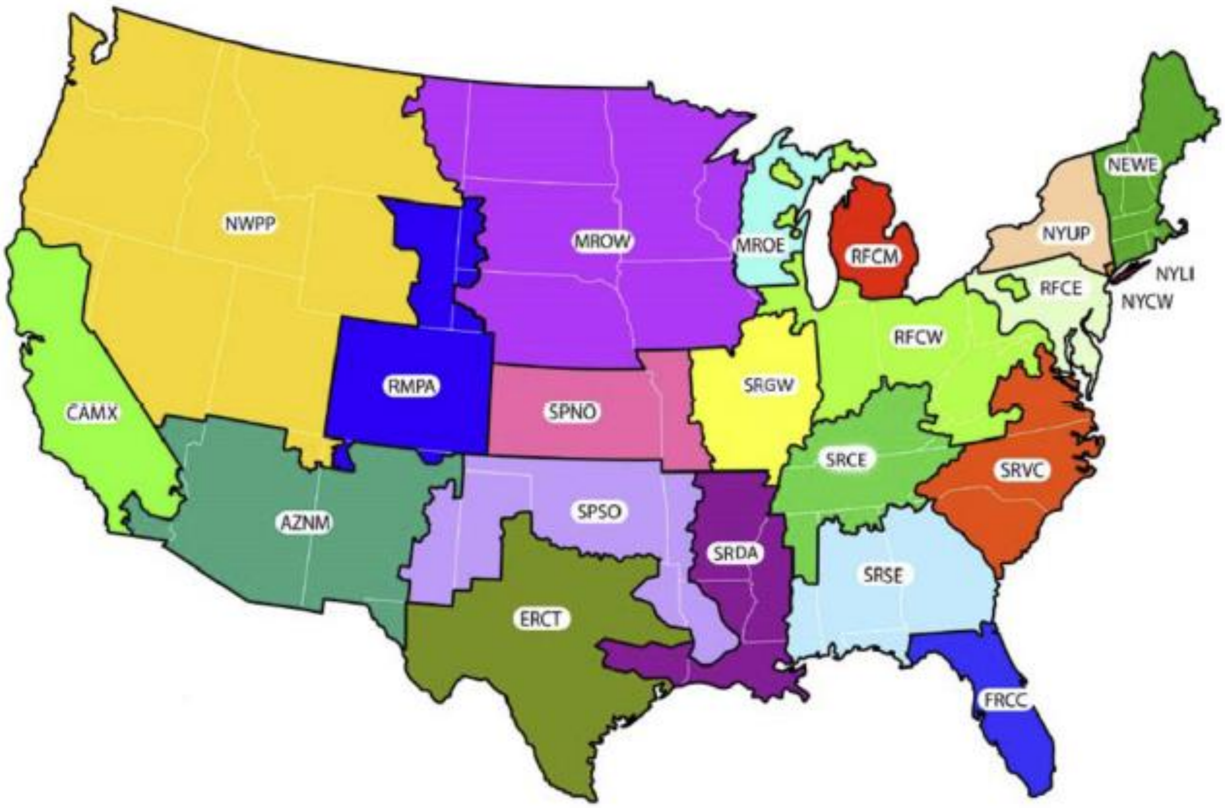

Figure 4-1. Electricity Market Module Regions

Source: EIA (http://www.eia.gov/forecasts/aeo/pdf/nerc_map.pdf)

4.5 Social Costs

As discussed in the EPA Guidelines for Preparing Economic Analyses, social costs are the total economic burden of a regulatory action (USEPA, 2010). This burden is the sum of all opportunity costs incurred due to the regulatory action, where an opportunity cost is the value lost to society of any goods and services that will not be produced and consumed as a result of reallocating some resources towards pollution mitigation. Estimates of social costs may be compared to the social benefits expected as a result of a regulation to assess its net impact on society. The social costs of a regulatory action will not necessarily be equal to the expenditures by the electricity sector to comply with the rule. Nonetheless, here we use compliance costs as a proxy for social costs.

The compliance cost estimates for the final and more or less stringent alternatives presented in this chapter are the change in expenditures by the electricity generating sector required by the power sector for compliance under each alternative. The change in the expenditures required by the power sector to maintain compliance reflect the changes in electricity production costs resulting from application of NO_X control strategies, including changes in expenditures resulting from changes in the mix of fuels used for generation, necessary to comply with the emissions budgets. Ultimately, part of the compliance costs may be borne by electricity consumers through higher electricity prices. As discussed above, the electricity and fossil fuel price impacts from this final rule are expected to be small.

4.6 Limitations

EPA's modeling is based on expert judgment of various input assumptions for variables whose outcomes are in fact uncertain. As a general matter, the Agency reviews the best available information from engineering studies of air pollution controls and new capacity construction costs to support a reasonable modeling framework for analyzing the cost, emission changes, and other impacts of regulatory actions.

The IPM-projected annualized cost estimates of private compliance costs provided in this analysis are meant to show the increase in production (generating) costs to the power sector in response to the final rule. To estimate these annualized costs, EPA uses a conventional and widely-accepted approach that applies a capital recovery factor (CRF) multiplier to capital investments and adds 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 final rule. These cost estimates are based on rigorous power sector modeling using ICF's Integrated Planning Model. IPM assumes "perfect foresight" of market conditions over the time horizon modeled; to the extent that utilities and/or energy regulators misjudge future conditions affecting the economics of pollution control, costs may be understated.

As discussed in section 4.3.2, IPM v.5.15 does not have the capacity to endogenously determine whether or not to maximize the use of existing EGU post-combustion NO_X controls (i.e., SCR), or install/upgrade combustion controls in response to a regulatory control requirement. These decisions were imposed exogenously on the model, as documented in section 4.3.2 and Policy Analysis TSD. While the emission projections reflect operation of these controls, the projected compliance costs were supplemented with exogenously estimated costs of maximizing SCR operation and installing/upgrading combustion controls (see section 4.3.3). As a result of this modeling approach, the dispatch decisions made within the model do not take into consideration the additional operating costs associated with these two types compliance strategies (the operating costs of the units on which these strategies are imposed do not reflect the additional costs of these strategies). These additional costs are relatively minor, and do not have a significant impact on the overall finding that the economic impacts of this rule are minimal.

Additionally, the modeling includes two emission reduction strategies that are exogenously imposed where applicable: turning on idled SCRs (CSAPR Update and more-stringent alternative) and turning on idled SNCRs (mores stringent alternative only). While these strategies are exogenously imposed, the costs and emissions reductions are accounted for endogenously. Since the costs of these strategies are accounted for within the model, they are able to influence the projected behavior of the EGUs within the model.

The annualized cost of the final rule, as quantified here, is EPA's best assessment of the cost of implementing the rule. These costs are generated from rigorous economic modeling of changes in the power sector due to implementation of the CSAPR Update.

4.7 References

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APPENDIX 4A: COST, EMISSIONS, AND ENERGY IMPACTS OF FINAL CSAPR UPDATE BUDGETS

This appendix reports the compliance costs, emissions, and energy analyses performed for the final CSAPR Update NO_X ozone season emission budgets. The tables below summarize the analysis of the final emissions budgets, which differ slightly from the illustrative budgets analyzed outside of this appendix. The differences between the results below and the results of the illustrative budgets presented in this chapter are minor, consistent with the small differences in NO_X ozone season budgets and small updates to the modeling assumptions.[81]

Table 4A-1 CSAPR Update NO_X Ozone Season Emission Budgets (Tons)

State	CSAPR Update Final Budgets
Alabama	13,211
Arkansas	9,210
Iowa	11,272
Illinois	14,601
Indiana	23,303
Kansas	8,027
Kentucky	21,115
Louisiana	18,639
Maryland	3,828
Michigan	16,545
Missouri	15,780
Mississippi	6,315
New Jersey	2,062
New York	5,135
Ohio	19,522
Oklahoma	11,641
Pennsylvania	17,952
Tennessee	7,736
Texas	52,301
Virginia	9,223
Wisconsin	7,915
West Virginia	17,815

[81] Consistent with the assumptions underlying the budgets, the final modeling assumes a NO_X rate of 0.10 lbs/MMBtu for fully-operated SCRs (see Ozone Transport Policy Analysis Final Rule TSD). Additionally, as discussed in the EPA v.5.15 CSAPR Update Rule Base Cases Using IPM Incremental Documentation, the NO_X rates of some units were updated to reflect recently observed performance.

TOTAL	313,148

Note: The budget displayed for Arkansas is its 2018 budget. In 2017, for all cases, Arkansas has a budget of 12,048.

Table 4A-2. EGU Ozone Season NO_X Emissions and Emission Changes (thousand tons) for the Base Case and the CSAPR Update

Ozone Season NO_X (thousand tons)		Base Case	CSAPR Update	Change
2017	Region	371.7	319.8	-51.9
	Non-Region	206.4	206.4	0.0
	Total	578.1	526.2	-51.9
2020	Region	380.6	314.0	-66.6
	Non-Region	182.6	182.6	0.0
	Total	563.2	496.6	-66.6

Table 4A-3. EGU Annual Emissions and Emissions Changes for NO_X, SO_2 and CO_2 for the CSAPR Update

Annual NO_X		Base Case	CSAPR Update	Change
2017	Region	812.4	750.3	-62.1
	Non-Region	441.1	441.1	0.0
	Total	1,253.5	1,191.5	-62.1
2020	Region	829.6	753.8	-75.8
	Non-Region	417.3	417.4	0.0
	Total	1,246.9	1,171.2	-75.7

Annual SO_2 (thousand tons)		Base Case	CSAPR Update	Change
2017	Region	909.4	919.4	10.0
	Non-Region	324.7	321.8	-2.9
	Total	1,234.1	1,241.2	7.0
2020	Region	909.4	919.4	10.0
	Non-Region	324.7	321.8	-2.9
	Total	1,234.1	1,241.2	7.0

Annual CO_2 (MM Metric Tonnes)		Base Case	CSAPR Update	Change
2017	Region	1,235.9	1,235.4	-0.4
	Non-Region	653.4	653.6	0.1
	Total	1,889.3	1,889.0	-0.3
2020	Region	1,235.9	1,235.4	-0.4

Non-Region	653.4	653.6	0.1
Total	1,889.3	1,889.0	-0.3

Table 4A-4. Compliance Cost Estimates (millions of 2011$) for the CSAPR Update

	CSAPR Update
2017-2020 (Annualized)	89.0
2017 (Annual)	-18.3
2020 (Annual)	198.2

"2017-2020 (Annualized)" reflects total estimated annual compliance costs levelized over the period 2017 through 2020, discounted using a 4.77 discount rate. "2017 (Annual)" and "2020 (Annual)" reflect point estimates in each of those years. These costs do not include monitoring, reporting, and recordkeeping costs, which are estimated to be a reduction of $1,347,291 per year.

Table 4A-5. 2017 Projected Power Sector Coal Use for the Base Case and the CSAPR Update

	Base Case	CSAPR Update	Percent Change from Base Case
Appalachia	116	117	1.1%
Imports	0	0	N/A
Interior	227	227	0.0%
Waste Coal	6	6	0.0%
West	353	351	-0.6%
Total	702	701	-0.1%

Table 4A-6. 2017 Projected Power Sector Natural Gas Use for the Base Case and the CSAPR Update

	Base Case	CSAPR Update	Percent Change from Base Case
Natural Gas Use	8.8	8.8	-0.01%

Table 4A-7. 2017 Projected Minemouth and Power Sector Delivered Coal Price for the Base Case and the CSAPR Update

	Base Case	CSAPR Update	Percent Change from Base Case
Minemouth	1.51	1.51	0.2%
Delivered	2.31	2.31	0.0%

Table 4A-8. 2017 Projected Henry Hub and Power Sector Delivered Natural Gas Price for the Base Case and the CSAPR Update

	Base Case	CSAPR Update	Percent Change from Base Case
Henry Hub	4.34	4.33	-0.1%
Delivered	4.53	4.52	-0.1%

Table 4A-9. 2017 Projected Generation by Fuel Type for the Base Case and the CSAPR Update

	Base Case	CSAPR Update	Percent Change from Base Case
Coal	1,386	1,386	0.0%
Natural Gas	1,198	1,198	0.0%
Nuclear	787	787	0.0%
Hydro	281	281	0.2%
Non-Hydro RE	421	421	0.0%
Oil\Gas Steam	50	50	0.0%
Other	8	8	0.3%
Total	4,130	4,131	0.0%

Note: In this table, “Non-Hydro RE” includes biomass, geothermal, landfill gas, solar, and wind

Table 4A-10. 2020 Projected Capacity by Fuel Type for the Base Case and the CSAPR Update

	Base Case	CSAPR Update	Percent Change from Base Case
Coal	209	209	-0.3%
Natural Gas	391	391	0.0%
Nuclear	101	101	0.3%
Hydro	107	107	0.0%
non-Hydro RE	138	138	0.0%
Oil\Gas Steam	83	83	0.0%
Other	5	5	0.0%
Total	1,035	1,035	0.0%

Note: In this table, “Non-Hydro RE” includes biomass, geothermal, landfill gas, solar, and wind

Table 4A-11. Average Retail Electricity Price by Region for the Base Case and the CSAPR Update, 2017

Region	Base Case	CSAPR Update	Percent Change from Base Case

ERCT	79.6	79.5	0.0%
FRCC	102.3	102.2	-0.1%
MROE	100.4	100.4	0.0%
MROW	87.5	87.5	0.0%
NEWE	126.8	126.8	0.0%
NYCW	166.3	166.2	-0.1%
NYLI	136.4	136.4	0.0%
NYUP	119.3	119.3	0.0%
RFCE	103.2	103.1	-0.1%
RFCM	103.0	103.0	0.0%
RFCW	88.6	88.7	0.1%
SRDA	82.5	82.5	0.0%
SRGW	83.8	83.8	0.1%
SRSE	101.6	101.6	0.0%
SRCE	79.7	79.7	0.0%
SRVC	98.3	98.3	0.0%
SPNO	102.1	102.1	0.0%
SPSO	79.0	79.1	0.1%
AZNM	109.6	109.6	0.0%
CAMX	145.5	145.5	0.0%
NWPP	72.6	72.6	0.0%
RMPA	87.1	87.1	0.0%
NATIONAL	97.3	97.3	0.0%

Table 4A-12. Average Retail Electricity Price by Region for the Base Case and the CSAPR Update, 2020

Region	Base Case	CSAPR Update	Percent Change from Base Case
ERCT	88.6	88.7	0.1%
FRCC	104.3	104.4	0.1%
MROE	99.1	99.1	0.0%
MROW	87.7	87.8	0.1%
NEWE	130.6	130.7	0.1%
NYCW	171.9	172.1	0.1%
NYLI	141.5	141.7	0.1%
NYUP	123.2	123.3	0.1%
RFCE	108.2	108.3	0.1%
RFCM	103.7	103.8	0.1%
RFCW	91.4	91.6	0.2%
SRDA	85.5	85.6	0.1%
SRGW	85.9	85.9	0.1%

SRSE	100.4	100.4	0.1%
SRCE	80.1	80.2	0.1%
SRVC	97.7	97.8	0.0%
SPNO	101.1	101.1	0.0%
SPSO	81.7	81.9	0.2%
AZNM	110.6	110.6	0.0%
CAMX	144.3	144.4	0.0%
NWPP	69.4	69.4	0.0%
RMPA	87.4	87.4	0.0%
NATIONAL	99.0	99.1	0.1%

CHAPTER 5: ESTIMATED HUMAN HEALTH BENEFITS AND CLIMATE CO-BENFITS

5.1 Introduction

As discussed above, this final rule is an update of the Cross-State Air Pollution Rule (CSAPR) to further reduce interstate transport of Electricity Generating Unit (EGU) ozone season nitrogen oxides (NO_X) emissions that contribute significantly to nonattainment or that interfere with maintenance of the 2008 ozone National Ambient Air Quality Standard (NAAQS). The EPA is implementing emission budgets for EGU NOx emissions through the CSAPR NO_X ozone season allowance trading program. Updating the CSAPR in this way will reduce emissions of NO_X during the summer ozone season and provide ancillary annual NO_X and carbon dioxide (CO_2) benefits (i.e., co-benefits). This chapter describes the methods used to estimate the monetized ozone-related air quality health benefits, the fine particulate matter ($PM_{2.5}$)-related air quality health co-benefits from reductions in NO_X emissions, and climate co-benefits from reductions of CO_2 emissions. These health benefits are associated with reducing exposure to ambient ozone and $PM_{2.5}$ by reducing emissions of precursor pollutants (i.e., NO_X). Data, resource, and methodological limitations prevent the EPA from monetizing several important co-benefits from reducing emissions of pollutants including SO_2 and VOC as well as reduced ecosystem effects and visibility impairment associated with reductions in NOx. We discuss these and other unquantified benefits further in this chapter.

This chapter reports estimates of the monetized air quality health benefits and climate co-benefits associated with emission reductions for the CSAPR Update and two regulatory control alternatives across several discount rates. The estimated benefits associated with these emission reductions are beyond those achieved by previous EPA air quality rules, including the original CSAPR that affected cross-state transport of NO_X and SO_2.[82]

[82] For reasons described in section IV.B of the preamble for the final CSAPR Update, the Clean Power Plan is not included in the baseline for this analysis. Section 4.3.1 of this RIA discusses the treatment of remanded CSAPR budgets.

5.2 Estimated Human Health Benefits

The CSAPR update is expected to reduce emissions of ozone season NO_X. In the presence of sunlight, NO_X and VOCs can undergo a chemical reaction in the atmosphere to form ozone. Reducing NO_X emissions also reduces human exposure to ozone and the incidence of ozone-related health effects, though this depends partly on local levels of volatile organic compounds (VOCs). The CSAPR update will also reduce emissions of NO_X throughout the year. Because NO_X is also a precursor to formation of ambient $PM_{2.5}$, reducing these emissions would also reduce human exposure to ambient $PM_{2.5}$ throughout the year and would reduce the incidence of $PM_{2.5}$-related health effects.[83] This RIA does not quantify $PM_{2.5}$-related benefits associated with SO_2 emission changes. (For further explanation of the modeled SO_2 emissions changes, see Chapter 4, section 4.4.1).

The benefits estimates reported in this chapter are limited to those that would occur in the 22-state final CSAPR Update region. Reducing NOx may also reduce ozone and $PM_{2.5}$ concentrations in areas outside the 22 states that are the subject of the CSAPR Update, though the impact of reducing these pollutants in those areas are not assessed in this Chapter. Reducing emissions of NO_X would reduce ambient exposure to NO_2 (which is a product of combustion) and its associated health effects, though we do not quantify these effects because we lacked sufficient data to quantify these effects. A full description of the epidemiological studies we use, the methods we apply and the tools we employ to quantify the incidence of these effects may be found in the PM NAAQS RIA (U.S. EPA, 2012a) and Ozone NAAQS RIA (U.S. EPA, 2015).

Implementing these updated CSAPR EGU NO_X emissions budgets for the ozone season in 22 eastern states may reduce ambient ozone and $PM_{2.5}$ concentrations below the National Ambient Air Quality Standards (NAAQS) in some areas and assist other areas with attaining the ozone and $PM_{2.5}$ NAAQS. The NAAQS RIAs (U.S. EPA, 2008, 2012a, 2015) also calculated the benefits of attaining alternate ozone and PM NAAQS, and so differences in the design and analytical objectives of each RIA are worth noting here. The NAAQS RIAs illustrate the potential costs and benefits of attaining a revised air quality standard nationwide based on an array of emission reduction strategies for different sources reflecting the application of identified

[83] Additionally, this RIA does not estimate changes in emissions of directly emitted particles.

and unidentified controls, incremental to implementation of existing regulations and controls needed to attain the NAAQS that currently is in effect. In short, NAAQS RIAs hypothesize, but do not predict, the strategies that States may choose to enact when implementing a revised NAAQS. Setting a NAAQS does not directly result in costs or benefits, and as such, the EPA's NAAQS RIAs are illustrative. The estimated costs and benefits from NAAQS RIAs are not intended to be added to the costs and benefits of other regulations that result in specific costs of control and prescribe specific emission reductions. Indeed, some of the emissions reductions estimated to result from implementing the CSAPR update may achieve some of the air quality improvements that resulted from the hypothesized attainment strategies presented in the NAAQS RIAs. The CSAPR Update is intended to achieve the air quality improvements identified in the RIA for the 2008 NAAQS, with appropriate adjustments to baseline conditions between the analysis in that RIA and the analysis presented in this RIA. Implementing this CSAPR Update will assist downwind areas in attaining and maintaining the 2008 ozone NAAQS. The ambient ozone reduced by this rule would also achieve some of the air quality improvements assumed in the baseline for the 2015 ozone NAAQS RIA.[84]

As discussed in Chapter 4, the IPM modeling showing compliance with the CSAPR update and two regulatory control alternatives for which emission reductions are estimated in this RIA is one possible path for compliance with the CSAPR Update emissions budgets. However, the EPA believes the magnitude and location of the air quality changes are well characterized because the rule limits emissions from a specific sector. Emissions reduced by this rule will ultimately be reflected in the baseline of future NAAQS analyses and would lower the additional emissions reductions needed to attain revised future NAAQS. For more information on the relationship between illustrative analyses, such as for the NAAQS and its associated implementation rules, please see the Ozone NAAQS RIA (U.S. EPA, 2015).

5.2.1 Health Impact Assessment for Ozone and $PM_{2.5}$

The *Integrated Science Assessment for Ozone and Related Photochemical Oxidants* (Ozone ISA) (U.S. EPA, 2013b) identified the human health effects associated with chronic and

[84] In other words, the 2015 ozone NAAQS RIA evaluated the costs and benefits of attaining the 2015 NAAQS, starting from a baseline that included attainment of the 2008 NAAQS.

acute ambient ozone exposure, which include premature death and a variety of morbidity effects. Similarly, the *Integrated Science Assessment for Particulate Matter* (PM ISA) (U.S. EPA, 2009b) identified the human health effects associated with ambient $PM_{2.5}$ exposure, which include premature death and a variety of morbidity effects associated with acute and chronic exposures. Table 5-1 identifies the quantified and monetized benefit and co-benefit categories captured in the EPA's health benefits estimates for reduced exposure to ambient ozone and $PM_{2.5}$. Although the table below does not list unquantified health effects or welfare effects, such as acidification and nutrient enrichment, these effects are described in detail in Chapters 5 and 6 of the PM NAAQS RIA (U.S. EPA, 2012a) and summarized later in this chapter. The list of unquantified benefits categories is not exhaustive and effects may not have been quantified completely.

Table 5-1. Human Health Effects of Ambient Ozone and $PM_{2.5}$

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Improved Human Health				
Reduced incidence of mortality from exposure to ozone	Premature mortality based on short-term study estimates (all ages)	✓	✓	Ozone ISA
	Premature mortality based on long-term study estimates (age 30–99)	—	—	Ozone ISA[1]
Reduced incidence of morbidity from exposure to ozone	Hospital admissions—respiratory causes (age > 65)	✓	✓	Ozone ISA
	Hospital admissions—respiratory causes (age <2)	✓	✓	Ozone ISA
	Emergency department visits for asthma (all ages)	✓	✓	Ozone ISA
	Minor restricted-activity days (age 18–65)	✓	✓	Ozone ISA
	School absence days (age 5–17)	✓	✓	Ozone ISA
	Decreased outdoor worker productivity (age 18–65)	—	—	Ozone ISA[1]
	Other respiratory effects (e.g., premature aging of lungs)	—	—	Ozone ISA[2]
	Cardiovascular and nervous system effects	—	—	Ozone ISA[2]
	Reproductive and developmental effects	—	—	Ozone ISA[2,3]
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)	✓	✓	PM ISA
	Infant mortality (age <1)	✓	✓	PM ISA
Reduced incidence of morbidity from exposure to $PM_{2.5}$	Non-fatal heart attacks (age > 18)	✓	✓	PM ISA
	Hospital admissions—respiratory (all ages)	✓	✓	PM ISA
	Hospital admissions—cardiovascular (age >20)	✓	✓	PM ISA
	Emergency room visits for asthma (all ages)	✓	✓	PM ISA
	Acute bronchitis (age 8-12)	✓	✓	PM ISA
	Lower respiratory symptoms (age 7-14)	✓	✓	PM ISA
	Upper respiratory symptoms (asthmatics age 9-11)	✓	✓	PM ISA
	Asthma exacerbation (asthmatics age 6-18)	✓	✓	PM ISA
	Lost work days (age 18-65)	✓	✓	PM ISA
	Minor restricted-activity days (age 18-65)	✓	✓	PM ISA
	Chronic Bronchitis (age >26)	—	—	PM ISA[1]
	Emergency room visits for cardiovascular effects (all ages)	—	—	PM ISA[1]
	Strokes and cerebrovascular disease (age 50-79)	—	—	PM ISA[1]
	Other cardiovascular effects (e.g., other ages)	—	—	PM ISA[2]
	Other respiratory effects (e.g., pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA[2]
	Reproductive and developmental effects (e.g., low birth weight, pre-term births, etc.)	—	—	PM ISA[2,3]
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA[2,3]

[1] We assess these co-benefits qualitatively due to data and resource limitations for this analysis, but we have quantified them in sensitivity analyses for other analyses.
[2] We assess these co-benefits qualitatively because we do not have sufficient confidence in available data or methods.
[3] We assess these co-benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

We follow a "damage-function" approach in calculating benefits, which estimates changes in individual health endpoints and assigns a dollar value to those changes. Because the EPA rarely has the time or resources to perform new research to measure directly either health outcomes or their values for regulatory analyses, our estimates are based on the best available methods of benefits transfer, which is the science and art of adapting primary research from similar contexts to estimate benefits for the environmental quality change under analysis. We use two benefits transfer techniques to quantify the ozone and $PM_{2.5}$-attributable benefits. We first perform a health impact assessment (HIA) to estimate the avoided deaths and illnesses resulting from implementing the CSAPR Update. We next use a "benefit-per-ton" approach to estimate the ozone and $PM_{2.5}$ benefits of the CSAPR Update and the more and less stringent alternatives.

An HIA quantifies the changes in the incidence of adverse health impacts resulting from changes in human exposure to ozone and $PM_{2.5}$. We use the environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE) (version 1.1) to calculate a health impact function that combines information from the modeled air quality predictions for this rule with a database of key input parameters, including population projections, health impact functions, and valuation functions (EPA, 2014). For this assessment, the HIA is limited to those health effects that are directly linked to ambient ozone and $PM_{2.5}$ concentrations. There may be other indirect health impacts associated with reducing emissions, such as occupational health exposures. Epidemiological studies generally provide estimates of the relative risks of a particular health effect for a given increment of air pollution (often per 10 ppb for ozone or per 10 $\mu g/m^3$ for $PM_{2.5}$). These relative risks can be used to develop risk coefficients that relate a unit reduction in pollution (e.g., ozone) to changes in the incidence of a health effect. We refer the reader to the Ozone NAAQS RIA (U.S. EPA, 2015) and PM NAAQS RIA (U.S. EPA, 2012a) for more information regarding the epidemiology studies and risk coefficients applied in this analysis.

The final air quality modeling simulation predicted changes in ozone and $PM_{2.5}$ from a baseline scenario that did not fully account for certain emission changes that are reflected in the policy scenario. Chapter 4 describes in greater detail how the emissions baseline was subsequently modified to account for the Pennsylvania RACT as well as other smaller-scale changes to the estimated EGU-level emissions. Because we could not use these air quality predictions directly, we instead employed a benefit-per-ton approach. Using the BenMAP-CE tool noted above, we first quantified the change in the number of ozone and $PM_{2.5}$-attributable avoided deaths and illnesses, and the dollar value of these outcomes, estimated to result from the modeled air quality scenario relative to the baseline. We divide these values by the change in emissions to calculate an average benefit per ton. Thus, to develop estimates of benefits for this RIA, we are transferring both the underlying health and economic information from a final air quality modeling scenario to the illustrative policy emissions reductions, including more and less stringent policy alternatives. Below, we describe in greater detail the data we used to calculate these benefit per ton values.

Before describing our technique for calculating the benefit per ton estimates, we briefly elaborate on the procedure for estimating the incidence of adult premature deaths in this RIA below. The size of the mortality effect estimates from epidemiological studies, the serious nature of the effect itself, and the high monetary value ascribed to reducing risks of premature death make mortality risk reduction the most significant health endpoint quantified in this analysis.

5.2.1.1 Mortality Effect Coefficients for Short-term Ozone Exposure

The overall body of evidence indicates that there is likely to be a causal relationship between short-term ozone exposure and premature death. The 2013 ozone Integrated Science Assessment (ISA) concludes that the evidence suggests that ozone effects are independent of the relationship between PM and mortality. (U.S. EPA, 2013a). However, the ISA notes that the interpretation of the potential confounding effects of PM on ozone-mortality risk estimates requires caution due to the PM sampling schedule (in most cities) which limits the overall sample size available for evaluating potential confounding of the ozone effect by PM (U.S. EPA 2013a).

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

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 multi-city and National Morbidity and Mortality Air Pollution Studies (NMMAPS) studies without exclusion of the meta-analyses" (NRC, 2008). In addition, NAS recommended that EPA "should give little or no weight to the assumption that there is no causal association between estimated reductions in premature mortality and reduced ozone exposure" (NRC, 2008). In 2010, the Health Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis, while reviewing EPA's *The Benefits and Costs of the Clean Air Act 1990 to 2020* (U.S. EPA, 2011a), also confirmed the NAS recommendation to include ozone mortality benefits (U.S. EPA-SAB, 2010a).

In view of the findings of the ozone ISA, the NAS panel, the Science Advisory Board—Health Effects Subcommittee (SAB-HES) panel, and the Clean Air Scientific Advisory Committee (CASAC) panel, we estimate ozone-related premature mortality for short-term exposure in the core health effects analysis using effect coefficients from the Smith et al. (2009) NMMAPS analysis and the Zanobetti and Schwartz (2008) multi-city study with several additional studies as sensitivity analyses. This emphasis on newer multi-city studies is consistent with recommendations provided by the NAS in their ozone mortality report (NRC, 2008). CASAC supported using the Smith et al. (2009) and Zanobetti and Schwartz (2008) studies for the ozone Health Risk and Exposure Assessment (U.S. EPA-SAB, 2012, 2014), and these are multi-city studies published more recently (as compared with other multi-city studies or meta-analyses included in the sensitivity analyses – see discussion below).

Smith et al. (2009) reanalyzed the NMMAPS dataset, evaluating the relationship between short-term ozone exposure and mortality. While this study reproduces the core national-scale estimates presented in Bell et al. (2004), it also explored the sensitivity of the mortality effect to different model specifications including (a) regional versus national Bayes-based adjustment,[85] (b) co-pollutant models considering PM_{10}, (c) all-year versus ozone-season based estimates, and (d) consideration of a range of ozone metrics, including the daily 8-hour max. In addition, the Smith et al. (2009) study did not use the trimmed mean approach employed in the Bell et al. (2004) study in preparing ozone monitor data.[86] In selecting effect estimates from Smith et al. (2009), we use an ozone-only estimate for non-accidental mortality using the 8-hour max metric for the warmer ozone season. For the sensitivity analysis, we included a co-pollutant model (ozone and PM_{10}) from Smith et al. (2009) for all-cause mortality, using the 8-hour max ozone metric for the ozone season. Using a single pollutant model for the core analysis and the co-pollutant model in the sensitivity analysis reflects our concern that the reduced sampling frequency for days with co-pollutant measurements (1/3 and 1/6) could affect the ability of the study to characterize the ozone effect. This choice is consistent with the ozone ISA, which concludes that ozone effects are likely to be independent of the relationship between PM and mortality (U.S. EPA, 2013a).

The Zanobetti and Smith (2008) study evaluated the relationship between ozone exposure (using an 8-hour mean metric for the warm season June-August) and all-cause mortality in 48 U.S. cities using data collected between 1989 and 2000. The study presented single pollutant C-R functions based on shorter (0-3 day) and longer (0-20 day) lag structures, with the comparison of effects based on these different lag structures being a central focus of the study. We used the shorter day lag based C-R function since this had the strongest effect and tighter confidence interval. We converted the effect estimate from an 8-hour mean metric to an equivalent effect estimate based on an 8-hour max to account for the period of the day in which most individuals

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[85] In Bayesian modeling, effect estimates are "updated" from an assumed prior value using observational data. In the Smith et al. (2009) approach, the prior values are either a regional or national mean of the individual effect estimates obtained for each individual city. The Bayesian adjusted city-specific effect estimates are then calculated by updating the selected prior value based on the relative precision of each city-specific estimate and the variation observed across all city-specific individual effect estimates. City-specific estimates are pulled towards the prior value if they have low precision and/or if there is low overall variation across estimates. City-specific estimates are given less adjustment if they are precisely estimated and/or there is greater overall variation across estimates.

[86] There are a number of concerns regarding the trimmed mean approach including (1) the potential loss of temporal variation in the data when the approach is used (this could impact the size of the effect estimate), and (2) a lack of complete documentation for the approach, which prevents a full reviewing or replication of the technique.

are exposed to ozone. To do this, we used the ozone metric approach wherein the original effect estimate (and standard error) is multiplied by the appropriate ozone metric adjustment ratio.

5.2.1.2 $PM_{2.5}$ Mortality Effect Coefficients for Adults and Infants

A substantial body of published scientific literature documents the association between elevated $PM_{2.5}$ concentrations and increased premature mortality (U.S. EPA, 2009b). This body of literature reflects thousands of epidemiology, toxicology, and clinical studies. The PM ISA completed as part of the most recent review of the PM NAAQS, which was twice reviewed by the SAB-CASAC (U.S. EPA-SAB, 2009a, 2009b), concluded that there is a causal relationship between mortality and both long-term and short-term exposure to $PM_{2.5}$ based on the entire body of scientific evidence (U.S. EPA, 2009b). The size of the mortality effect 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.

Researchers have found statistically significant associations between $PM_{2.5}$ and premature mortality using different types of study designs. 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 exposure to elevated $PM_{2.5}$ concentrations. Cohort methods have been used to examine the potential relationship between community-level $PM_{2.5}$ exposures over multiple years (i.e., long-term exposures) and community-level annual mortality rates that have been adjusted for individual level risk factors. When choosing between using short-term studies or cohort studies for estimating mortality benefits, cohort analyses are thought to capture more of the public health impact of exposure to air pollution over time because they account for the effects of long-term exposures, as well as some fraction of short-term exposures (Kunzli et al., 2001; NRC, 2002). The NRC 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). The NRC further noted that "the overall effect estimates may be a combination of effects from long-term exposure plus some fraction from short-term exposure. The amount of overlap is unknown" (NRC, 2002, p. 108-9). To avoid double counting, we focus on applying the risk coefficients from the long-term cohort studies in estimating the mortality impacts of reductions in $PM_{2.5}$.

Over the last three decades, several studies using “prospective cohort” designs have been published that are consistent with the earlier body of literature. Two prospective cohort studies, often referred to as the Harvard “Six Cities Study” (Dockery et al., 1993; Laden et al., 2006; Lepeule et al., 2012) and the “American Cancer Society” or “ACS study” (Pope et al., 1995; Pope et al., 2002; Pope et al., 2004; Krewski et al., 2009), provide the most extensive analyses of ambient $PM_{2.5}$ concentrations and mortality. These studies have found consistent relationships between fine particle indicators and premature mortality across multiple locations in the United States. The credibility of these two studies is further enhanced by the fact that the initial published studies (Pope et al., 1995; Dockery et al., 1993) were subject to extensive reexamination and reanalysis by an independent team of scientific experts commissioned by the Health Effects Institute (HEI) and by a Special Panel of the HEI Health Review Committee (Krewski et al., 2000). Publication of studies confirming and extending the findings of the 1993 Six Cities Study and the 1995 ACS study using more recent air quality data and a longer follow-up period for the ACS cohort provides additional validation of the findings of these original studies (Pope et al., 2002, 2004; Laden et al., 2006; Krewski et al., 2009; Lepeule et al., 2012). The SAB-HES also supported using these two cohorts for analyses of the benefits of PM reductions, and concluded, “the selection of these cohort studies as the underlying basis for PM mortality benefit estimates [is] a good choice. These are widely cited, well studied and extensively reviewed data sets” (U.S. EPA-SAB, 2010a). As both the ACS and Six Cities studies have inherent strengths and weaknesses, we present benefits estimates using relative risk estimates from the most recent extended reanalysis of these cohorts (Krewski et al., 2009; Lepeule et al., 2012). Presenting results using both ACS and Six Cities is consistent with other recent RIAs (e.g., U.S. EPA, 2010c, 2011a, 2011c, 2015). The PM ISA concludes that the ACS and Six Cities cohorts provide the strongest evidence of the association between long-term $PM_{2.5}$ exposure and premature mortality with support from a number of additional cohort studies (described below).

The extended analyses of the ACS cohort data (Krewski et al., 2009) refined the earlier ACS studies by (a) extending the follow-up period by 2 years to the year 2000, for a total of 18 years; (b) incorporating almost double the number of urban areas; (c) addressing confounding by spatial autocorrelation by incorporating ecological, or community-level, co-variates; and (d) performing an extensive spatial analysis using land use regression modeling in two large urban areas. These enhancements make this analysis well-suited for the assessment of mortality risk from long-term $PM_{2.5}$ exposures for the EPA's benefits analyses.

In 2009, the SAB-HES again reviewed the choice of mortality risk coefficients for benefits analysis, concluding that "[t]he Krewski et al. (2009) findings, while informative, have not yet undergone the same degree of peer review as have the aforementioned studies. Thus, the SAB-HES recommends that EPA not use the Krewski et al. (2009) findings for generating the Primary Estimate" (U.S. EPA-SAB, 2010a). Since this time, the Krewski et al. (2009) has undergone additional peer review, which we believe strengthens the support for including this study in this RIA. For example, the PM ISA (U.S. EPA, 2009b) included this study among the key mortality studies. In addition, the risk assessment supporting the PM NAAQS (U.S. EPA, 2010b) used risk coefficients drawn from the Krewski et al. (2009) study, the most recent reanalysis of the ACS cohort data. The PM risk assessment cited a number of advantages that informed the selection of the Krewski et al. (2009) study as the source of the core effect estimates, including the extended period of observation, the rigorous examination of model forms and effect estimates, the coverage for ecological variables, and the large dataset with over 1.2 million individuals and 156 MSAs (U.S. EPA, 2010b). The CASAC also provided extensive peer review of the PM risk assessment and supported the use of effect estimates from this study (U.S. EPA-SAB, 2009a, b, 2010b).

Consistent with the PM risk assessment (U.S. EPA, 2010b), which was reviewed by the CASAC (U.S. EPA-SAB, 2009a, b), we use the all-cause premature mortality risk estimate based on the random-effects Cox proportional hazard model that incorporates 44 individual and 7 ecological covariates (RR=1.06, 95% confidence intervals 1.04–1.08 per 10 µg/m^3 increase in $PM_{2.5}$). The relative risk estimate (1.06 per 10 µg/m^3 increase in $PM_{2.5}$) is identical to the risk estimate drawn from the earlier Pope et al. (2002) study, though the confidence interval around the Krewski et al. (2009) risk estimate is narrower.

In the most recent Six Cities study, which was published after the last SAB-HES review, Lepeule et al. (2012) evaluated the sensitivity of previous Six Cities results to model specifications, lower exposures, and averaging time using eleven additional years of cohort follow-up that incorporated recent lower exposures. The authors found significant associations between $PM_{2.5}$ exposure and increased risk of premature all-cause, cardiovascular and lung cancer mortality. The authors also concluded that the C-R relationship was linear down to $PM_{2.5}$ concentrations of 8 μg/m^3 and that premature mortality rate ratios for $PM_{2.5}$ fluctuated over time, but without clear trends, despite a substantial drop in the sulfate fraction. We use the all-cause mortality risk estimate based on a Cox proportional hazard model that incorporates 3 individual covariates. (RR=1.14, 95% confidence intervals 1.07–1.22 per 10 μg/m^3 increase in $PM_{2.5}$). The relative risk estimate is slightly smaller than the risk estimate drawn from Laden et al. (2006), with relatively smaller confidence intervals.

Given that monetized benefits associated with $PM_{2.5}$ are driven largely by reductions in premature mortality, it is important to characterize the uncertainty in this endpoint. In order to do so, we utilize the results of an expert elicitation sponsored by the EPA and completed in 2006 (Roman et al., 2008; IEc, 2006). The results of that expert elicitation can be used as a characterization of uncertainty in the C-R functions.

In addition to the adult premature mortality studies described above, several studies show an association between PM exposure and premature mortality in children under 5 years of age.[87] The PM ISA states that less evidence is available regarding the potential impact of $PM_{2.5}$ exposure on infant mortality than on adult mortality. Furthermore, the results of studies in children under 5 from several countries include a range of findings with some finding significant associations. Specifically, the PM ISA concluded that evidence exists for a stronger effect at the post-neonatal period and for respiratory-related mortality, although this trend is not consistent across all studies. In addition, compared to avoided premature deaths estimated for adult mortality, avoided premature deaths for infants are significantly smaller because the number of infants in the population is much smaller than the number of adults and the epidemiology studies on infant mortality provide smaller risk coefficients associated with exposure to $PM_{2.5}$.

In 2004, the SAB-HES noted the release of the WHO Global Burden of Disease Study focusing on ambient air, which cites several recently published time-series studies relating daily PM exposure to mortality in children (U.S. EPA-SAB, 2004). With regard to the cohort study conducted by Woodruff et al. (1997), the SAB-HES noted several strengths of the study,

[87] For the purposes of this analysis, we only calculate benefits for infants age 0–1, not all children under 5 years old.

including the use of a larger cohort drawn from a large number of metropolitan areas and efforts to control for a variety of individual risk factors in infants (e.g., maternal educational level, maternal ethnicity, parental marital status, and maternal smoking status). Based on these findings, the SAB-HES recommended that the EPA incorporate infant mortality into the primary benefits estimate and that infant mortality be evaluated using an impact function developed from the Woodruff et al. (1997) study (U.S. EPA-SAB, 2004).

In 2010, the SAB-HES again noted the increasing body of literature relating infant mortality and PM exposure and supported the inclusion of infant mortality in the monetized benefits (U.S. EPA-SAB, 2010a). The SAB-HES generally supported the approach of estimating infant mortality based on Woodruff et al. (1997) but also noted that a more recent study by Woodruff et al. (2006) continued to find associations between $PM_{2.5}$ and infant mortality in California. The SAB-HES also noted, "when PM_{10} results are scaled to estimate $PM_{2.5}$ impacts, the results yield similar risk estimates." Consistent with *The Benefits and Costs of the Clean Air Act 1990 to 2020* (U.S. EPA, 2011a), we continue to rely on the earlier 1997 study in part due to the national–scale of the earlier study.

5.2.2 Economic Valuation for Health Benefits

After quantifying the change in adverse health impacts, we estimate the economic value of these avoided impacts. Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects by a small amount for a large population. Therefore, the appropriate economic measure is willingness to pay (WTP) for changes in risk of a health effect. For some health effects, such as hospital admissions, WTP estimates are generally not available, so we use the cost of treating or mitigating the effect. These cost-of-illness (COI) estimates generally (although not necessarily 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. The unit values applied in this analysis are provided in Table 5-9 of the PM NAAQS RIA for each health endpoint (U.S. EPA, 2012a).

For this final rule avoided premature deaths account for over 90 percent of monetized ozone-related benefits and 98 percent of monetized PM-related co-benefits. The economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still evolving. 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 communities. Following the advice of the SAB's Environmental Economics Advisory Committee (SAB-EEAC), the EPA uses the value of statistical life (VSL) approach in calculating estimates of mortality benefits, because we believe this calculation provides the most reasonable estimate of an individual's willingness to trade off wealth for reductions in mortality risk (U.S. EPA-SAB, 2000). The VSL is a summary measure for the value of small changes in mortality risk experienced by a large number of people.[88]

The EPA continues work to update its guidance on valuing mortality risk reductions, and, in the process, has engaged the SAB-EEAC on different facets of this issue. Until updated mortality risk valuation guidance is available, however, the Agency determined that applying a single, peer-reviewed estimate in a consistent fashion best reflects the SAB-EEAC advice it has received. Therefore, pending future revisions to its mortality risk valuation guidance, the EPA continues to apply the VSL that was vetted and endorsed by the SAB in the *Guidelines for Preparing Economic Analyses* (U.S. EPA, 2014).[89] 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 $6.3 million (2000$).[90] We then adjust this VSL to account for the currency year and to account for income growth from 1990 to the analysis year. Specifically, the VSL applied in this analysis in 2011$ after adjusting for income growth is $9.9 million for 2017.

The Agency is committed to using scientifically sound, appropriately reviewed evidence in valuing mortality risk reductions and has made significant progress in responding to recent SAB-EEAC recommendations. In March 2016, the EPA presented to the SAB-EEAC a proposed

[88] The SAB endorsed an EPA proposal to change the moniker and the units of the mortality risk valuation measure applied in benefits analyses (US EPA 2011; Report # EPA-SAB-11-011) but encouraged EPA to explore alternatives more formally before deciding on which to use. EPA plans to explore alternatives through focus groups and other risk communication exercises.

[89] In the updated *Guidelines for Preparing Economic Analyses* (U.S. EPA, 2010e), the EPA retained the VSL endorsed by the SAB with the understanding that further updates to the mortality risk valuation guidance would be forthcoming.

[90] In 1990$, this base VSL is $4.8 million.

methodology for updating Agency mortality risk valuation estimates based on a previous SAB Advisory (US EPA 2016). The proposed methodology is currently under review, with formal SAB recommendations anticipated later this year.In valuing $PM_{2.5}$-related premature mortality, we discount the value of premature mortality occurring in future years using rates of 3 percent and 7 percent (OMB, 2003). We assume that there is a "cessation" lag between changes in PM exposures and the total realization of changes in health effects. Although the structure of the lag is uncertain, the EPA follows the advice of the SAB-HES to assume a segmented lag structure characterized by 30 percent of mortality reductions in the first year, 50 percent over years 2 to 5, and 20 percent over the years 6 to 20 after the reduction in $PM_{2.5}$ (U.S. EPA-SAB, 2004c). Changes in the cessation lag assumptions do not change the total number of estimated deaths but rather the timing of those deaths. Because short-term ozone-related premature mortality occurs within the analysis year, the estimated ozone-related benefits are identical for all discount rates.

5.2.3 Health Benefit Estimates for Ozone

We performed an HIA in BenMAP-CE and then calculated benefit per ton values to estimate the ozone benefits for the final CSAPR Update alternative and for the more and less stringent alternatives in this RIA. The EPA has applied this approach in several previous RIAs (e.g., U.S. EPA, 2011b, 2011c, 2012b, 2014a, 2015) to quantify the avoided number of deaths and illnesses and the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of summer season NO_X (an ozone precursor). We generated benefit-per-ton estimates for ozone based on air quality modeling for the illustrative CSAPR Update alternative described in Chapter 4 of this RIA. As described in Chapter 4 of this RIA and further below, the air quality model runs for the baseline and CSAPR Update alternative reflect different EGU NO_X emission levels for reasons other than the abatement necessary to comply with the CSAPR Update. For this reason, it was necessary to estimate a benefit-per-ton value from these two air quality model runs which allows us to then value the benefits solely attributable to NOx reductions associated with the CSAPR Update. We then applied that benefit-per-ton value to the NOx emission reductions attributable to the CSAPR Update for the CSAPR Update alternative, as well as for the more and less stringent alternatives. The BPT estimates correspond to NO_X emissions from U.S. EGUs during the ozone-season (May to September). These estimates assume that EGU-attributable ozone formation at the regional-level is due to

NO_X alone. Because EGUs emit little VOC relative to NO_X emissions, it is unlikely that VOCs emitted by EGUs would contribute substantially to regional ozone formation.

When we characterize analytical uncertainty below we describe how the benefit-per-ton estimates have certain limitations. Specifically, the benefit-per-ton estimates reflect the geographic distribution of the modeled illustrative CSAPR Update. For this rule, the change in EGU NOx emissions between the baseline and CSAPR Update alternative matches well the NOx reductions solely attributable to the CSAPR Update, but not perfectly. For this reason, the resulting ozone benefit per ton estimate may not reflect fully the size or geographic distribution of emission reductions anticipated from the selected policy. In order to address this potential limitation, we limited the benefits estimate for NO_X reductions associated with ozone (and $PM_{2.5}$), to only those benefits that would occur in the 22-state region of the final CSAPR Update. The benefit per ton estimates may also not reflect well the local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors for any specific location. Notwithstanding these limitations, we believe that this approach is reasonably able to characterize the ozone-related benefits from the rule.

5.2.4 Health Benefit Estimates for $PM_{2.5}$

We used a combination of an HIA and a “benefit-per-ton” approach to estimate the $PM_{2.5}$ co-benefits for the final CSAPR Update alternative and for more and less stringent alternatives in this RIA. These values represent the total monetized human health co-benefits (the sum of valued avoided premature mortality and avoided premature morbidity), of reducing one ton of nitrate-apportioned $PM_{2.5}$ from EGU-attributable NO_X. We generated benefit-per-ton estimates for nitrate $PM_{2.5}$ based on the same air quality modeling simulations used to generate the benefit-per-ton estimate for ozone. To calculate nitrate-apportioned $PM_{2.5}$ benefits we then multiplied the benefit-per-ton estimates by the change in annual NO_X emissions reductions attributable to the CSAPR Update as well as the more and less stringent CSAPR Update alternatives. These estimates correspond to the annual NO_X emission reductions from U.S. EGUs. This nitrate $PM_{2.5}$ benefit-per-ton estimate shares the limitations of the ozone NO_X benefit-per-ton estimate noted above.

5.2.5 Updated Methodology in the Final RIA

We modified our analytical approach between the proposal and this final RIA. For the final RIA, an updated air quality modeling scenario was completed, which better reflected the selected policy option than did the proposal air quality modeling, and therefore it is appropriate to use updated benefit-per-ton values for the final rule. However, the final air quality model results preceded final adjustments to the policy options. Furthermore, the Pennsylvania RACT was not included in the base case IPM model scenario, and therefore is not reflected in the air quality baseline. This omission accounts for the larger NOx emission reductions between the air quality model runs than is seen between the IPM base case and the CSAPR Update alternative. Consequently, the benefit-per-ton value for ozone and nitrate-attributed $PM_{2.5}$ had to be applied to the CSAPR Update alternative NOx emission reductions in addition to the more and less stringent alternatives NOx emission reductions.

Unlike the CSAPR Update proposal RIA which provided national estimates of the benefits of the proposed rule, for the final CSAPR Update we calculated benefits only for the 22 CSAPR Update states. We applied the NOx emission reductions only from the CSAPR Update states in order to provide a benefit-per-ton value for ozone and nitrate-attributed $PM_{2.5}$ that captures the benefits to the CSAPR states. We believed this approach was made necessary by the fact that the air quality modeling simulation accounted for NOx emission reductions occurring outside of the 22 CSAPR state region that were not reflected in the final policy scenario. This approach to calculating the benefit per ton values likely underestimates total benefits because it excludes certain downwind states such as those in New England and in the southeast that would likely see benefits from this rule.

When estimating $PM_{2.5}$-attributable benefits we use benefit per ton values calculated using a nitrate-attributable $PM_{2.5}$ benefit per ton estimate; the proposal analysis used a total $PM_{2.5}$ benefit per ton value. We determined that the controls in this rule would have a meaningful influence on both NOx and $PM_{2.5}$ formation from nitrate. The EPA determined that, considering the final CSAPR Update Rule illustrative emissions modeling results, using total $PM_{2.5}$ benefit per ton would incorrectly additionally account for the benefits of reduced sulfate and directly emitted $PM_{2.5}$ benefits, which the illustrative emissions modeling does not anticipate.[91]

5.2.6 Estimated Health Benefits Results

Table 5-2 provides the benefit-per-ton estimates for the analysis year 2017. Table 5-3 provides the emission reductions estimated to occur in the analysis year. Table 5-4 summarizes the national monetized ozone-related and PM-related health benefits estimated to occur for the CSAPR Update and two regulatory control alternatives for the 2017 analysis year using discount rates of 3 percent (non-fatal heart attacks quantified using Peters *et al.* (2001)) and 7 percent (non-fatal heart attacks quantified using a pooled estimate that includes Pope *et al.* (2006)). Table 5-5 provides national summaries of the reduced counts of premature deaths and illnesses associated with the CSAPR update and two more and less stringent alternatives for the 2017 analysis year.[92] Figure 5-1 provides a visual representation of the range of estimated ozone and $PM_{2.5}$-related benefits using benefit-per-ton estimates based on concentration-response functions from different studies and expert opinion for the CSAPR update evaluated for 2017.

Table 5-2. Summary of Ozone and PM2.5 Benefit-per-Ton Estimates Based on Air Quality Modeling in 2017 (2011$)*

Pollutant	Discount Rate	National
NO_X (as Ozone)	N/A	$6,000 to $9,900
NO_X (as $PM_{2.5}$)	3%	$1,200 to $2,800
	7%	$1,100 to $2,500

[91] This approach potentially excludes any impacts of NOx on changes in sulfate particles.

[92] Incidence estimates were generated using the same "per ton" approach as used to generate the dollar benefit per ton values.

* The range of estimates reflects the range of epidemiology studies for avoided premature mortality for ozone and $PM_{2.5}$. All estimates are rounded to two significant figures. Benefit-per-ton estimates for ozone are based on the modeled ozone season NO_X emissions in the 22-state region (78,000 short tons) used in the air quality runs that were used to estimate the benefit-per-ton value. Ozone co-benefits occur in the analysis year. The monetized co-benefits do not include reduced health effects from direct exposure to NO_2, or ecosystem effects or visibility impairment from reduced NO_X. All fine particles are assumed to have equivalent health effects, but the benefit-per-ton estimates vary depending on the location and magnitude of their impact on $PM_{2.5}$ concentrations, which drive population exposure. The $PM_{2.5}$ attributed to this rule only includes the nitrate fraction of $PM_{2.5}$. Benefit-per-ton estimates for PM are based on the annual modeled $PM_{2.5}$ in the 22-state region (89,000 short tons) used in the air quality runs that were used to estimate the benefit-per-ton value. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles and ozone., so they are the same for all discount rates. In general, the 95th percentile confidence interval for monetized $PM_{2.5}$ benefits ranges from approximately -90 percent to +180 percent of the central estimates based on Krewski *et al.* (2009) and Lepeule *et al.* (2012). The confidence intervals around the ozone mortality estimates are on the order of ± 60 percent depending on the concentration-response function used.

Table 5-3. Emission Reductions of Criteria Pollutants in CSAPR Update States for the CSAPR Update and More and Less Stringent Alternatives in 2017 (thousands of short tons)*

	CSAPR Update	More Stringent Alternative	Less Stringent Alternative
Ozone Season NO_X	61,000	66,000	27,000
All Year NO_X	75,000	79,000	27,000

*All emissions shown in the table are rounded.

Table 5-4. Summary of Estimated Monetized Health Benefits for the CSAPR Update and More and Less Stringent Alternatives Regulatory Control Alternatives for 2017 (millions of 2011$) *

Pollutant		CSAPR Update	More Stringent Alternative	Less Stringent Alternative
NOx (as Ozone)		$370 to $610	$400 to $650	$160 to $270
NOx (as $PM_{2.5}$)	3% Discount Rate	$93 to $210	$98 to $220	$34 to $75
	7% Discount Rate	$83 to $190	$88 to $200	$30 to $67
Total	3% Discount Rate	$460 to $810	$500 to $870	$200 to $340
	7% Discount Rate	$450 to $790	$490 to $850	$190 to $330

* All estimates are rounded to two significant figures so numbers may not sum down columns. The health benefits range is based on adult mortality functions (e.g., from Krewski et al. (2009) with Smith et al. (2009) to Lepeule et al. (2012) with Zanobetti and Schwartz (2008)). The estimated monetized co-benefits do not include reduced health effects from direct exposure to NO_2, ecosystem effects, or visibility impairment. All fine particles are assumed to have equivalent health effects, but the benefit-per-ton estimates vary depending on the location and magnitude of their impact on $PM_{2.5}$ levels, which drive population exposure. The CSAPR Update values, the more and less stringent alternatives were all calculated using the benefits per ton approach based on the final modeling scenario. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles and ozone. Benefits for ozone are based on ozone season NO_X emissions. Ozone co-benefits occur in analysis year, so they are the same for all discount rates. and are based on annual NOx emissions and the nitrate-only fraction of $PM_{2.5}$. In general, the 95th percentile confidence interval for monetized $PM_{2.5}$ benefits ranges from approximately -90 percent to +180 percent of the central estimates based on Krewski *et al.* (2009) and Lepeule *et al.* (2012). The confidence

intervals around the ozone mortality estimates are on the order of ± 60 percent depending on the concentration-response function used.

Table 5-5. Summary of Avoided Health Incidences from Ozone-Related and $PM_{2.5}$-Related Benefits for the CSAPR Update and More and Less Stringent Alternatives for 2017*

Ozone-related Health Effects	CSAPR Update	More Stringent Alternative	Less Stringent Alternative
Avoided Premature Mortality			
Smith *et al.* (2009) (all ages)	21	23	9
Zanobetti and Schwartz (2008) (all ages)	60	65	26
Avoided Morbidity			
Hospital admissions—respiratory causes (ages > 65)	59	64	26
Emergency room visits for asthma (all ages)	240	250	100
Asthma exacerbation (ages 6-18)	67,000	73,000	30,000
Minor restricted-activity days (ages 18-65)	170,000	180,000	75,000
School loss days (ages 5-17)	56,000	60,000	25,000
$PM_{2.5}$-related Health Effects			
Avoided Premature Mortality			
Krewski *et al.* (2009) (adult)	10	11	3.7
Lepeule *et al.* (2012) (adult)	23	25	8.4
Woodruff *et al.* (1997) (infant)	<1	<1	<1
Avoided Morbidity			
Emergency department visits for asthma (all ages)	6.1	6.5	2.2
Acute bronchitis (age 8–12)	15	15	5.2
Lower respiratory symptoms (age 7–14)	180	190	67
Upper respiratory symptoms (asthmatics age 9–11)	260	280	95
Minor restricted-activity days (age 18–65)	7,500	7,900	2,700
Lost work days (age 18–65)	1,300	1,300	450
Asthma exacerbation (age 6–18)	270	290	98
Hospital admissions—respiratory (all ages)	2.8	2.9	1.0
Hospital admissions—cardiovascular (age > 18)	3.8	4.0	1.4
Non-Fatal Heart Attacks (age >18)			
Peters *et al.* (2001)	12	13	4.3
Pooled estimate of 4 studies	1.3	1.4	0.46

* All estimates are rounded to whole numbers with two significant figures. Co-benefits for ozone are based on ozone season NOx emissions. In general, the 95th percentile confidence interval for the health impact function alone ranges from approximately ±30 percent for mortality incidence based on Krewski *et al.* (2009) and ±46 percent based on Lepeule *et al.* (2012). The confidence intervals around the ozone mortality estimates are on the order of ± 60 percent depending on the concentration-response function used.

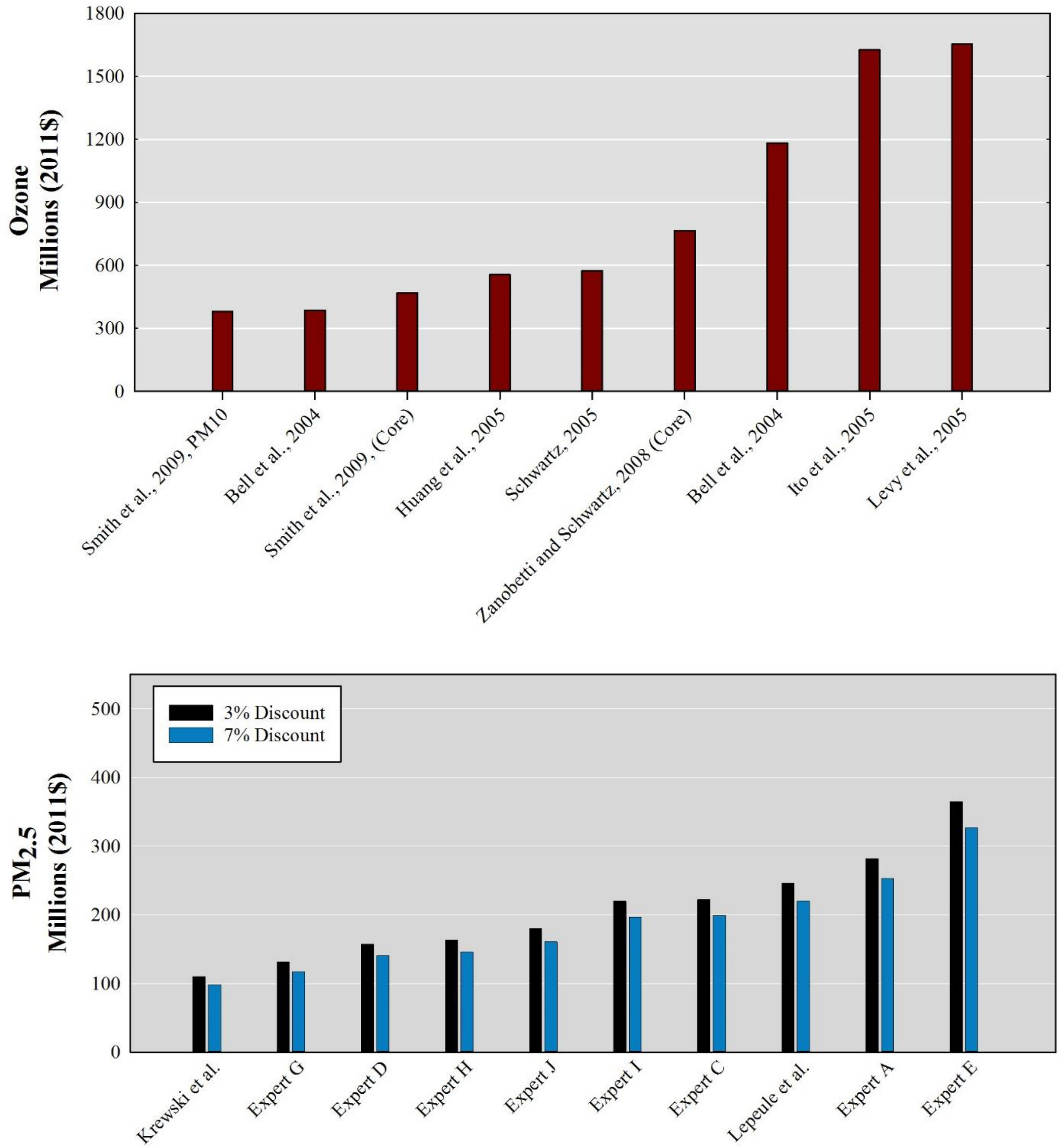


Figure 5-1. Monetized Health Benefits of CSAPR update for 2017 *

*The $PM_{2.5}$ graph shows the estimated $PM_{2.5}$ co-benefits at discount rates of 3% and 7% using effect coefficients derived from the Krewski *et al.* (2009) study and the Lepeule *et al.* (2012) study, as well as 8 of the 12 effect coefficients derived from EPA's expert elicitation on PM mortality (Roman *et al.*, 2008); four of the coefficients reported no mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response functions provided in those studies. Ozone benefits occur in the analysis year, so they are the same for all discount rates. These estimates do not include benefits from reductions in CO_2. The monetized co-benefits do not include reduced health effects from direct exposure to NO_2 as well as ecosystem effects or visibility impairment from reductions in NO_X.

5.2.7 Characterization of Uncertainty in the Estimated Health Benefits

In any complex analysis using estimated parameters and inputs from numerous models, there are likely to be many sources of uncertainty. This analysis is no exception. This analysis includes many data sources as inputs, including emission inventories, air quality data from models (with their associated parameters and inputs), population data, population estimates, health effect estimates from epidemiology studies, economic data for monetizing benefits, and assumptions regarding the future state of the world (i.e., regulations, technology, and human behavior). Each of these inputs may be uncertain and would affect the estimated benefits. When the uncertainties from each stage of the analysis are compounded, even small uncertainties can have large effects on the total quantified benefits. The use of the benefit-per-ton approach adds additional uncertainties beyond those for analyses based directly on air quality modeling. Therefore, the estimates of benefits should be viewed as illustrating the general magnitude of benefits of the CSAPR update and regulatory control alternatives for the 2017 analysis year, rather than the actual benefits anticipated from implementing the rule.

This RIA shares the same detailed uncertainty assessment found in the Ozone NAAQS RIA (U.S. EPA, 2015) or the PM NAAQS RIA (U.S. EPA, 2012a) because of the air quality modeling input data used to run the benefits model. The results of the quantitative and qualitative uncertainty analyses presented in the Ozone NAAQS RIA and PM NAAQS RIA provide some information regarding the uncertainty inherent in the estimated benefits results presented in this analysis. For example, sensitivity analyses conducted for the PM NAAQS RIA indicate that alternate cessation lag assumptions could change the estimated $PM_{2.5}$-related mortality co-benefits discounted at 3 percent by between 10 percent and –27 percent and that alternative income growth adjustments could change the $PM_{2.5}$-related mortality benefits by between 33 percent and −14 percent. Although we generally do not calculate confidence intervals for benefit-per-ton estimates as they can provide an incomplete picture about the overall uncertainty in the benefits estimates, the PM NAAQS RIA provides an indication of the random sampling error in the health impact and economic valuation functions using Monte Carlo methods. In general, the 95^{th} percentile confidence interval for monetized $PM_{2.5}$ benefits ranges from approximately -90 percent to +180 percent of the central estimates based on Krewski *et al.* (2009) and Lepeule *et al.* (2012). The 95^{th} percentile confidence interval for the health impact function alone ranges from approximately ±30 percent for mortality incidence based on Krewski *et al.* (2009) and ±46 percent based on Lepeule *et al.* (2012).

After determining the health impact assessment using the air quality modeling data, we calculated and applied benefit-per-ton estimates, which reflect specific geographic patterns of emissions reductions and specific air quality and benefits modeling assumptions. For example, these estimates may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual co-benefits of controlling PM and ozone precursors. As such, it is not feasible to estimate the proportion of co-benefits occurring in different locations. Use of these benefit-per-ton values to estimate benefits may lead to higher or lower benefit estimates than if benefits were calculated based on direct air quality modeling. Great care should be taken in applying these estimates to emission reductions occurring in any specific location, as these are all based on a broad emission reduction scenario and therefore represent average benefits-per-ton over the entire region. The benefit-per-ton for emission reductions in specific locations may be very different than the estimates presented here. To the extent that the geographic distribution of the emissions reductions achieved by implementing the final rule relative to the baseline used to estimate costs and emission reductions is different than the emissions reductions in the air quality modeling of the illustrative budgets and the baseline described in Chapter 3, the benefits may be underestimated or overestimated.

The benefits reported here reflect the reduction in NOx emissions among the 22 CSAPR states alone. Excluding states outside of the 22-state region may under-estimates benefits because it does not reflect the improved air quality that could occur among states downwind of the 22-state region. However, for reasons noted above, the air quality modeling simulation for this analysis did not account for the size and distribution of reduced NOx emissions in this rule. The modeling used to estimate the BPT values simulated emission changes in certain states—including North Carolina and Georgia—that were not attributable to the CSAPR Update. These emissions changes are not reflected in the base case modeling run that was used to estimate the BPT values. However, these emissions changes are reflected in the illustrative CSAPR Update alternative modeling run that was ultimately used to estimate both the BPT values and the costs and benefits of the CSAPR Update.[93] To avoid incorrectly accounting for ozone-related benefits from reduced NOx emissions from such locations, we elected to calculate benefits only within the 22-state region. Finally, by estimating ozone health impacts from May to September only, we may have underestimated ozone related benefits in areas experiencing a longer ozone season.

Our estimate of the total monetized benefits is based on the EPA's interpretation of the best available scientific literature and methods and supported by the SAB-HES and the National Academies of Science (NRC, $2002_{2.5}$-related premature mortality, which accounts for 98 percent of the monetized $PM_{2.5}$ health co-benefits.

1. We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ varies considerably in composition across sources, but the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. The PM ISA concluded that "many constituents of $PM_{2.5}$ can be linked with multiple health effects, and the evidence is not yet sufficient to allow differentiation of those constituents or sources that are more closely related to specific outcomes" (U.S. EPA, 2009b).

2. We assume that the health impact function for fine particles is log-linear without a threshold. Thus, the estimates include health co-benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5}$, including both areas that do not meet the fine particle standard and those areas that are in attainment, down to the lowest modeled concentrations.

3. We assume that there is a "cessation" lag between the change in PM exposures and the total realization of changes in mortality effects. Specifically, we assume that some of the incidences of premature mortality related to $PM_{2.5}$ exposures occur in a distributed fashion over the 20 years following exposure based on the advice of the SAB-HES (U.S. EPA-SAB, 2004c), which affects the valuation of mortality co-benefits at different discount rates.

In general, we are more confident in the magnitude of the risks we estimate from simulated $PM_{2.5}$ concentrations that coincide with the bulk of the observed PM concentrations in the epidemiological studies that are used to estimate the benefits. Likewise, we are less confident in the risk we estimate from simulated $PM_{2.5}$ concentrations that fall below the bulk of the observed

[93] These emissions updates were made to better represent subsequent baseline emissions from those EGUs. They are also included in the base case used to estimate the cost and emissions changes from the CSAPR Update.

data in these studies. Concentration benchmark analyses (e.g., lowest measured level [LML], one standard deviation below the mean of the air quality data in the study, etc.) allow readers to determine the portion of population exposed to annual mean $PM_{2.5}$ levels at or above different concentrations, which provides some insight into the level of uncertainty in the estimated $PM_{2.5}$ mortality benefits. In this analysis, we apply two concentration benchmark approaches (LML and one standard deviation below the mean) that have been incorporated into recent RIAs and the EPA's *Policy Assessment for Particulate Matter* (U.S. EPA, 2011d). There are uncertainties inherent in identifying any particular point at which our confidence in reported associations becomes appreciably less, and the scientific evidence provides no clear dividing line. However, the EPA does not view these concentration benchmarks as a concentration threshold below which we would not quantify health benefits of air quality improvements.[94] Rather, the co-benefits estimates reported in this RIA are the best estimates because they reflect the full range of air quality concentrations associated with the regulatory control alternatives. The PM ISA concluded that the scientific evidence collectively is sufficient to conclude that the relationship between long-term $PM_{2.5}$ exposures and mortality is causal and that, overall, the studies support the use of a no-threshold log-linear model to estimate PM-related long-term mortality (U.S. EPA, 2009b).

There is also a series of key assumptions associated with our analysis of ozone-related effects which introduce uncertainty into our estimates:

- **Key assumption and uncertainties related to modeling of ozone-related premature mortality**: Ozone-related short-term mortality represents a substantial proportion of total monetized benefits (over 94% of the ozone-related-benefits), and these estimates have the following key assumptions and uncertainties. We utilize a log-linear impact function without a threshold in modeling short-term ozone-related mortality. However, we acknowledge reduced confidence in specifying the nature of the C-R function in the range of ≤20ppb and below (ozone ISA, section 2.5.4.4). Thus, ozone-related premature deaths

[94] For a summary of the scientific review statements regarding the lack of a threshold in the $PM_{2.5}$-mortality relationship, see the TSD entitled *Summary of Expert Opinions on the Existence of a Threshold in the Concentration-Response Function for* $PM_{2.5}$*-related Mortality* (U.S. EPA, 2010b).

estimated at or below this level are subject to greater uncertainty, but we cannot judge whether (and in what direction) these impacts might be biased.

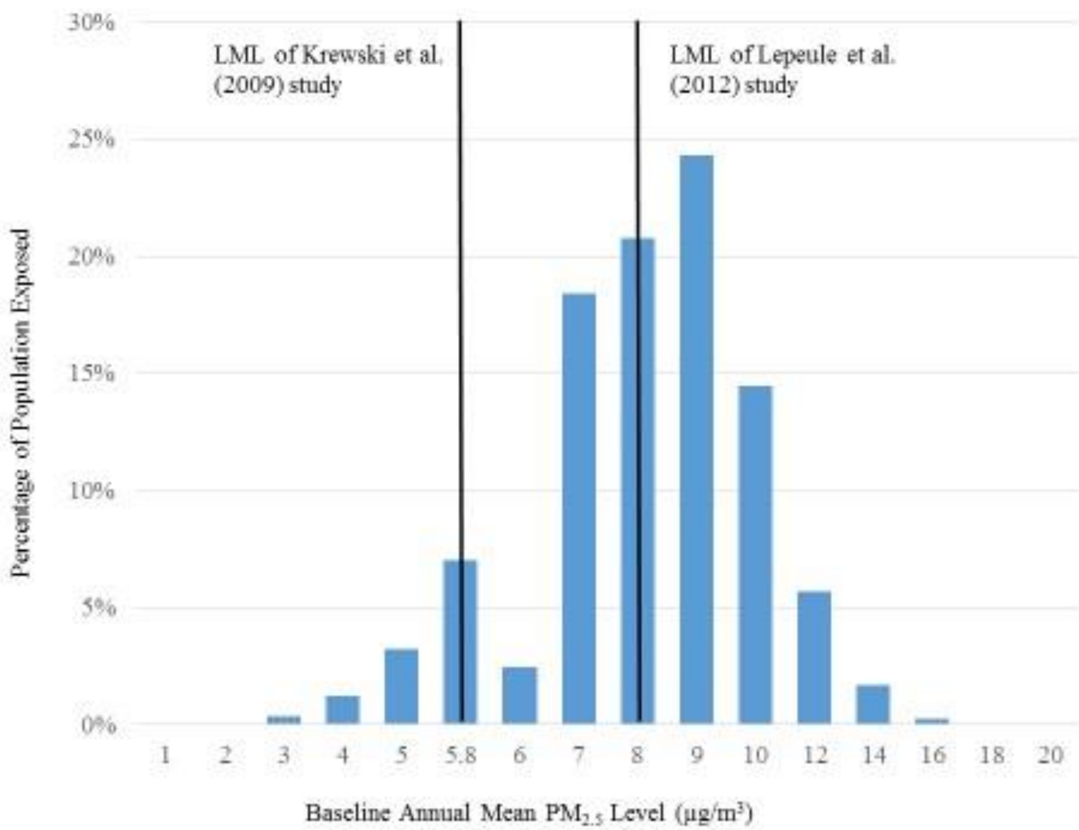
- **Avoided premature mortality according to baseline pollutant concentrations**: We recognize that, in estimating short-term ozone-related mortality, we are less confident in specifying the shape of the C-R function at lower ambient ozone concentrations (at and below 20 ppb, ozone ISA, section 2.5.4.4). Quantitative uncertainty analyses completed for the Ozone NAAQS RIA (U.S. EPA, 2015) found almost 100% of mortality reductions occurred above 20 ppb, where we are more confident in specifying the nature of the ozone-mortality effect (ozone ISA, section 2.5.4.4). However, as discussed in section 6B.7 of that RIA, care must be taken in interpreting these results since the ambient air metric used in modeling this endpoint is the mean 8-hour max value in each grid cell (and not the full distribution of 8-hour daily max values). Had the latter been used, then the distribution would have likely been wider.

For this analysis, policy-specific air quality data are not available, and the control scenarios are illustrative of what utilities may choose to do within the trading program. However, we believe that it is still important to characterize the distribution of exposure to baseline concentrations. As a surrogate measure of mortality impacts, we provide the percentage of the population exposed at each $PM_{2.5}$ concentration in the baseline of the air quality modeling used to calculate the benefit-per-ton estimates for this RIA using 12 km grid cells across the contiguous U.S.[95] It is important to note that baseline exposure is only one parameter in the health impact function, along with baseline incidence rates population and change in air quality. In other words, the percentage of the population exposed to air pollution below the LML is not the same as the percentage of the population experiencing health impacts as a result of a specific emission reduction policy. The most important aspect, which we are unable to quantify without rule-specific air quality modeling, is the shift in exposure anticipated by implementing the CSAPR update. Therefore, caution is warranted when interpreting the LML assessment in this

[95] As described in Chapter 3, the baseline for the air quality modeling used to calculate the benefit-per-ton values differs from the baseline used to estimate the benefits, costs, and impacts of this rulemaking. See Chapter 3 for more details about the differences between the two baselines.

RIA because these results are not consistent with results from RIAs that had air quality modeling.

Figure 5-3 shows a bar chart of the percentage of the population exposed to various air quality levels, including the LML concentration benchmarks in the illustrative control case modeling, and Figure 5-4 shows a cumulative distribution function of the same data. Both figures identify the LML for each of the major cohort studies.



Among the populations exposed to $PM_{2.5}$ in the baseline:

88% are exposed to $PM_{2.5}$ levels at or above the LML of the Krewski *et al.* (2009) study

47% are exposed to $PM_{2.5}$ levels at or above the LML of the Lepeule *et al.* (2012) study

Figure 5-2. Percentage of Adult Population (age 30+) by Annual Mean $PM_{2.5}$ Exposure in the Baseline used for the Air Quality Analysis in Chapter 3

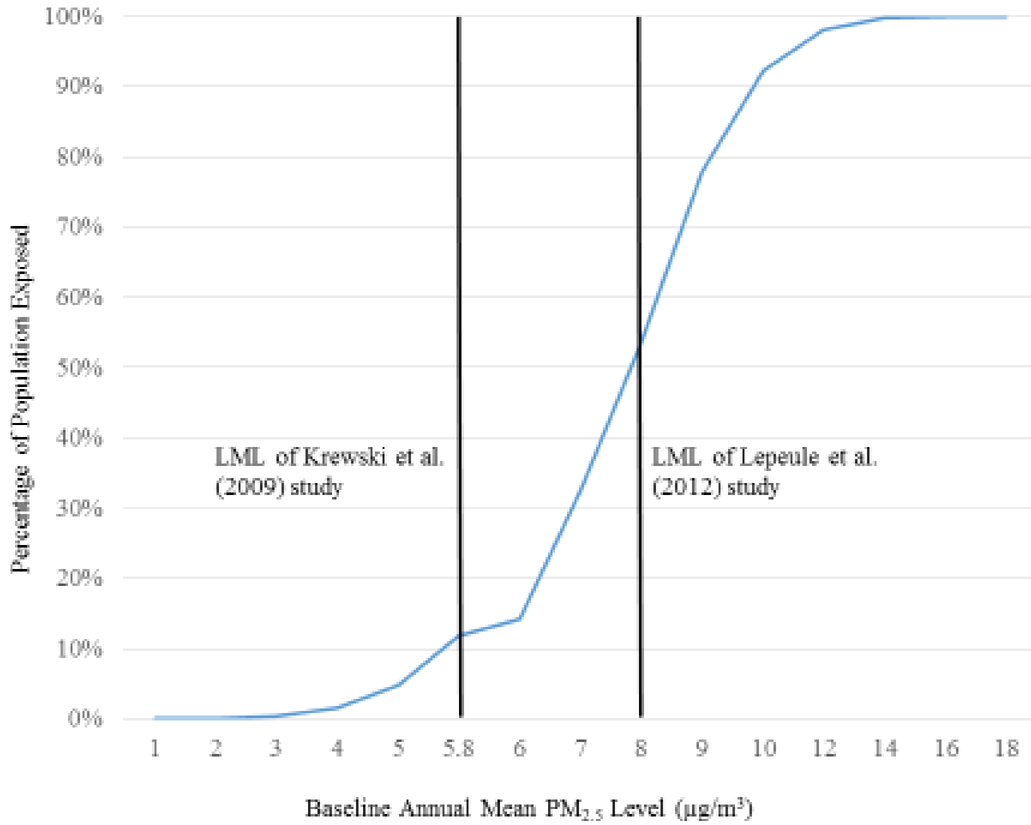


Figure 5-3. Cumulative Distribution of Adult Population (age 30+) by Annual Mean $PM_{2.5}$ Exposure in the Baseline used for the Air Quality Analysis in Chapter 3

5.3 Estimated Climate Co-Benefits from CO_2

A co-benefit of this proposal is reducing emissions of CO_2. In this section, we provide a brief overview of the 2009 Endangerment Finding and climate science assessments released since then. We also provide information regarding the economic valuation of CO_2 using the Social Cost of Carbon (SC-CO_2), a metric that estimates the monetary value of impacts associated with marginal changes in CO_2 emissions in a given year.

There are several important considerations in assessing the climate-related benefits for an ozone air quality-focused rulemaking. First, the estimated health benefits do not account for any climate-related air quality changes (e.g., increased ambient ozone associated with higher temperatures). Excluding climate-related air quality changes may underestimate ozone-related health benefits. It is unclear how $PM_{2.5}$-related health benefits would be affected by excluding climate-related air quality changes since the science is unclear as to how climate change may affect $PM_{2.5}$ exposure. Second, the estimated health benefits also do not consider temperature modification of $PM_{2.5}$ and ozone risks (Roberts 2004; Ren 2006a, 2006b, 2008a, 2008b). Third, the estimated climate co-benefits reported in this RIA reflect global benefits, while the estimated health benefits are calculated for the contiguous U.S. only. Excluding temperature modification of air pollution risks and international air quality-related health benefits likely leads to underestimation of quantified health benefits (Anenberg et al, 2009, Jhun et al, 2014). Fourth, we do not estimate the climate co-benefits associated with reductions in PM and ozone precursors.

5.3.1 Climate Change Impacts

Through the implementation of CAA regulations, the EPA addresses the negative externalities caused by air pollution. In 2009, the EPA Administrator found that elevated concentrations of greenhouse gases in the atmosphere may reasonably be anticipated both to endanger public health and to endanger public welfare. For health, these include the increased likelihood of heat waves, negative impacts on air quality, more intense hurricanes, more frequent and intense storms and heavy precipitation, and impacts on infectious and waterborne diseases. For welfare, these include reduced water supplies in some regions, increased water pollution, increased occurrences of floods and droughts, rising sea levels and damage to coastal infrastructure, increased peak electricity demand, changes in ecosystems, and impacts on indigenous communities.

Major scientific assessments released since the 2009 Endangerment Finding have improved scientific understanding of the climate, and provide even more evidence that GHG emissions endanger public health and welfare for current and future generations. The National Climate Assessment (NCA), in particular, assessed the impacts of climate change on human health in the United States, finding that Americans will be affected by “increased extreme weather events, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes and ticks.” These assessments also detail the risks to vulnerable groups such as children, the elderly and low income households. Furthermore, the assessments present an improved understanding of the impacts of climate change on public welfare, higher projections of future sea level rise than had been previously estimated, a better understanding of how the warmth in the next century may reach levels that would be unprecedented relative to the preceding millions of years of history, and new assessments of the impacts of climate change on permafrost and ocean acidification. The impacts of GHG emissions will be realized worldwide, independent of their location of origin, and impacts outside of the United States will produce consequences relevant to the United States.

5.3.2 Social Cost of Carbon

We estimate the global social benefits of CO_2 emission reductions expected from the final emission guidelines using the SC-CO_2 estimates presented in the *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (May 2013, Revised July 2015)* ("current TSD").[96] We refer to these estimates, which were developed by the U.S. government, as "SC-CO_2 estimates." The SC-CO_2 is a metric that estimates the monetary value of impacts associated with marginal changes in CO_2 emissions in a given year. It includes a wide range of anticipated climate impacts, such as net changes in agricultural productivity and human health, property damage from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning. It is typically used to assess the avoided damages as a result of regulatory actions (i.e., benefits of rulemakings that lead to an incremental reduction in cumulative global CO_2 emissions).

The SC-CO_2 estimates used in this analysis were developed over many years, using the best science available, and with input from the public. Specifically, an interagency working group (IWG) that included the EPA and other executive branch agencies and offices used three integrated assessment models (IAMs) to develop the SC-CO_2 estimates and recommended four global values for use in regulatory analyses. The SC-CO_2 estimates were first released in February 2010 and updated in 2013 using new versions of each IAM. The 2013 update did not

[96] Docket ID EPA-HQ-OAR-2013-0495, Technical Support Document: *Technical Update of the 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 (May 2013, Revised July 2015). Available at: <https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf> Accessed 7/11/2015.

revisit the 2010 modeling decisions with regards to the discount rate, reference case socioeconomic and emission scenarios, and equilibrium climate sensitivity distribution. Rather, improvements in the way damages are modeled are confined to those that have been incorporated into the latest versions of the models by the developers themselves and published in the peer-reviewed literature. The 2010 SC-CO_2 Technical Support Document (2010 SC-CO_2 TSD) provides a complete discussion of the methods used to develop these estimates and the current SC-CO_2 TSD presents and discusses the 2013 update (including recent minor technical corrections to the estimates).[97] One key methodological aspect discussed in the SC-CO2 TSDs is the global scope of the estimates. The SC-CO_2 estimates represent global measures because of the distinctive nature of climate change, which is highly unusual in at least three respects. First, emissions of most GHGs contribute to damages around the world independent of the country in which they are emitted. Second, the U.S. operates in a global and highly interconnected economy, such that impacts on the other side of the world can affect our economy. This means that the true costs of climate change to the U.S. are much larger than the direct impacts that simply occur within the U.S. Third, climate change represents a classic public goods problem because each country's greenhouse gas emissions reductions benefit everyone else and no country can be excluded from enjoying the benefits of other countries' reductions, even if it provides no reductions itself. In this situation, the only way to achieve an economically efficient level of emissions reductions is for countries to cooperate in providing mutually beneficial reductions beyond the level that would be justified only by their own domestic benefits. In reference to the public good nature of mitigation and its role in foreign relations, thirteen prominent academics noted that these "are compelling reasons to focus on a global SCC" in a recent article on the SCC (Pizer et al., 2014). In addition, the IWG recently noted that there is no bright line between domestic and global damages. Adverse impacts on other countries can have spillover effects on the United States, particularly in the areas of national security, international trade, public health and humanitarian concerns.[98]

[97] Both the 2010 SC-CO_2 TSD and the current SC-CO_2 TSD are available at: https://www.whitehouse.gov/omb/oira/social-cost-of-carbon

[98] See *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon*, July 2015, page 31. https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-response-to-comments-final-july-2015.pdf

The 2010 TSD noted a number of limitations to the SC-CO_2 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. Currently integrated assessment models do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature due to a lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research.[99] The limited amount of research linking climate impacts to economic damages makes the modeling exercise even more difficult. These individual limitations do not all work in the same direction in terms of their influence on the SC-CO_2 estimates, though taken together they suggest that the SC-CO_2 estimates are likely conservative. In particular, the IPCC Fourth Assessment Report (2007), which was the most current IPCC assessment available at the time of the IWG's 2009-2010 review, concluded that "It is very likely that [SC-CO_2 estimates] underestimate the damage costs because they cannot include many non-quantifiable impacts." Since then, the peer-reviewed literature has continued to support this conclusion. For example, the IPCC Fifth Assessment report (2014) observed that SC-CO_2 estimates continue to omit various impacts, such as "the effects of the loss of biodiversity among pollinators and wild crops on agriculture." Nonetheless, these estimates and the discussion of their limitations represent the best available information about the social benefits of CO_2 reductions to inform benefit-cost analysis. The new versions of the models used to estimate the values presented below offer some improvements in these areas, although further work is warranted.

The EPA and other agencies have continued to consider feedback on the SC-CO_2 estimates from stakeholders through a range of channels, including public comments on rulemakings that use the SC-CO_2 in supporting analyses and through regular interactions with stakeholders and research analysts implementing the SC-CO_2 methodology used by the interagency working

[99] Climate change impacts and SCC modeling is an area of active research. For example, see: (1) Howard, Peter, "Omitted Damages: What's Missing from the Social Cost of Carbon." March 13, 2014, http://costofcarbon.org/files/Omitted_Damages_Whats_Missing_From_the_Social_Cost_of_Carbon.pdf; and (2) Electric Power Research Institute, "Understanding the Social Cost of carbon: A Technical Assessment," October 2014, www.epri.com.

group. In addition, OMB's Office of Information and Regulatory Affairs issued a separate request for public comment on the approach used to develop the estimates.[100] After careful evaluation of the full range of comments submitted to OMB's Office of Information and Regulatory Affairs, the IWG continues to recommend the use of these SC-CO_2 estimates in regulatory impact analysis. With the release of the response to comments[101], the IWG announced plans to obtain expert independent advice from the National Academies of Sciences, Engineering, and Medicine (Academies) to ensure that the SC-CO_2 estimates continue to reflect the best available scientific and economic information on climate change.[102] The Academies' process will be informed by the public comments received and focuses on the technical merits and challenges of potential approaches to improving the SC-CO_2 estimates in future updates.[103]

Accordingly, EPA and other agencies continue to engage in research on modeling and valuation of climate impacts with the goal to improve these estimates. The EPA and other federal agencies also continue to consider feedback on the SC-CO_2 estimates from stakeholders through a range of channels, including public comments on Agency rulemakings that use the SC-CO_2 in supporting analyses and through regular interactions with stakeholders and research analysts implementing the SC-CO_2 methodology used by the IWG. In addition, OMB sought public comment on the approach used to develop the SC-CO_2 estimates through a separate comment period and published a response to those comments in 2015.

After careful evaluation of the full range of comments submitted to OMB, the IWG continues to recommend the use of the SC-CO_2 estimates in regulatory impact analysis. With the July 2015 release of the response to comments, the IWG announced plans to obtain expert independent advice from the National Academies of Sciences, Engineering and Medicine to

[100] See https://www.federalregister.gov/articles/2013/11/26/2013-28242/technical-support-document-technical-update-of-the-social-cost-of-carbon-for-regulatory-impact

[101] See https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-response-to-comments-final-july-2015.pdf

[102] See https://www.whitehouse.gov/blog/2015/07/02/estimating-benefits-carbon-dioxide-emissions-reductions.

[103] See http://sites.nationalacademies.org/DBASSE/BECS/CurrentProjects/DBASSE_167526?utm_source=All%20DBASSE%20Newsletters&utm_campaign=e84c13e8c4-New_Project_the_Social_Cost_of_Carbon&utm_medium=email&utm_term=0_e16023964e-e84c13e8c4-267347161 for more information about the National Academies process and the status of the project.

ensure that the SC-CO_2 estimates continue to reflect the best available scientific and economic information on climate change. The Academies then convened a committee, "Assessing Approaches to Updating the Social Cost of Carbon," (Committee) which is reviewing the state of the science on estimating the SC-CO_2, and will provide expert, independent advice on the merits of different technical approaches for modeling and highlight research priorities going forward. EPA will evaluate its approach based upon any feedback received from the Academies' panel.

To date, the Committee has released an interim report, which recommended against doing a near term update of the SC-CO_2 estimates. For future revisions, the Committee recommended the IWG move efforts towards a broader update of the climate system module consistent with the most recent, best available science, and also offered recommendations for how to enhance the discussion and presentation of uncertainty in the SC-CO_2 estimates. Specifically, the Committee recommended that "the IWG provide guidance in their technical support documents about how [SC-CO_2] uncertainty should be represented and discussed in individual regulatory impact analyses that use the [SC-CO_2]" and that the technical support document for each update of the estimates present a section discussing the uncertainty in the overall approach, in the models used, and uncertainty that may not be included in the estimates. At the time of this writing, the IWG is reviewing the interim report and considering the recommendations. EPA looks forward to working with the IWG to respond to the recommendations and will continue to follow IWG guidance on SC-CO_2.

The four SC-CO_2 estimates are as follows: $12, $41, $63, and $120 per metric ton of CO_2 emissions in the year 2017 (2011$).[104] The first three values are based on the average SC-CO_2 from the three IAMs, at discount rates of 5, 3, and 2.5 percent, respectively. SC-CO_2 estimates for several discount rates are included because the literature shows that the SC-CO_2 is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context (where costs and benefits are incurred by different generations). The fourth value is the 95th percentile of the SC-CO_2 from all three

[104] The current version of the TSD is available at: https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf. The 2010 and 2013 TSDs present SC-CO_2 in 2007$ per metric ton. The unrounded estimates from the current TSD were adjusted to 2011$ using GDP Implicit Price Deflator (1.061374), http://www.bea.gov/iTable/index_nipa.cfm. The estimates presented here have been rounded to two significant digits.

models at a 3 percent discount rate. It is included to represent lower probability but higher impact outcomes from climate change, which are captured further out in the tail of the SC-CO_2 distribution, and while less likely than those reflected by the average SC-CO_2 estimates, would be much more harmful to society and therefore, are relevant to policy makers.

Table 5-7 presents the global SC-CO_2 estimates in metric tons for the years 2015 to 2050. In order to calculate the dollar value for emission reductions, the SC-CO_2 estimate for each emissions year would be applied to changes in CO_2 emissions for that year, and then discounted back to the analysis year using the same discount rate used to estimate the SC-CO_2.[105, 106] The SC-CO_2 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 climate change. Note that the interagency group estimated the growth rate of the SC-CO_2 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 modeling assumptions. Table 5-8 reports the incremental climate co-benefits from CO_2 emission impacts estimated for the final CSPAR update and more and less stringent alternatives for the 2017 analysis year.

Table 5-7. Social Cost of CO_2, 2015-2050 (in 2011$ per metric ton)*

	Discount Rate and Statistic			
Year	5% Average	3% Average	2.5% Average	3% (95th percentile)
2015	$12	$38	$59	$110
2017	$12	$41	$63	$120
2020	$13	$45	$66	$130
2025	$15	$49	$72	$150
2030	$17	$53	$77	$160
2035	$19	$58	$83	$180
2040	$22	$64	$89	$190
2045	$24	$68	$94	$210
2050	$28	$73	$100	$230

* These SC-CO_2 values are stated in $/metric ton and rounded to two significant figures. The estimates vary depending on the year of CO_2 emissions and are defined in real terms, i.e., adjusted for inflation using the GDP implicit price deflator.

[105] CO_2 emission impacts for this rulemaking are shown for the year 2017 and are calculated in metric tons.

[106] This analysis considered the climate impacts of only CO_2 emission change. As discussed below, the climate impacts of other pollutants were not calculated for the final CSAPR Update. While CO_2 is the dominant GHG emitted by the sector, we recognize the representative facilities within these comparisons may also have different emission rates for other climate forcers that will serve a minor role in determining the overall social cost of generation.

Table 5-8. Estimated Global Climate Co-benefits of CO_2 Reductions for the CSAPR Update and More and Less Stringent Alternatives for 2017 (millions of 2011$)*

Discount rate and statistic	CSPAR Update	More Stringent Alternative	Less Stringent Alternative
Million metric tons of CO_2 reduced	1.6	2.1	1.3
5% (average)	$19	$25	$15
3% (average)	$66	$87	$54
2.5% (average)	$100	$130	$81
3% (95th percentile)	$190	$250	$150

* The SC-CO_2 values are dollar-year and emissions-year specific. SC-CO_2 values represent only a partial accounting of climate impacts.

It is important to note that the climate co-benefits presented above are associated with changes in CO_2 emissions only. Implementing the CSAPR update, however, will have an impact on the emissions of other pollutants that would affect the climate. Both predicting reductions in emissions and estimating the climate impacts of these other pollutants, however, is complex. The climate impacts of these other pollutants have not been calculated for the rule.[107]

5.4 Combined Health Benefits and Climate Co-Benefits Estimates

In this analysis, we were able to monetize the estimated benefits associated with the reduced exposure to ozone and $PM_{2.5}$ and co-benefits of decreased emissions of CO_2, but we were unable to monetize the co-benefits associated with reducing exposure to mercury, carbon monoxide, and NO_2, as well as ecosystem effects and visibility impairment. In addition, there are expected to be unquantified health and welfare impacts associated with changes in hydrogen chloride. Specifically, we estimated combinations of health benefits at discount rates of 3 percent and 7 percent (as recommended by the EPA's *Guidelines for Preparing Economic Analyses* [U.S. EPA, 2014] and OMB's *Circular A-4* [OMB, 2003]) and climate co-benefits at estimates of the SC-CO_2 (average SC-CO_2 at each of three discount rates—5 percent, 3 percent, 2.5 percent—and the 95th percentile SC-CO_2 at 3 percent) (as recommended by the IWG).

[107] The SC-CO_2 estimates used in this analysis are designed to assess the climate benefits associated with changes in CO_2 emissions only.

Different discount rates are applied to SC-CO_2 than to the health benefit estimates because CO_2 emissions are long-lived and subsequent damages occur over many years. Moreover, several rates are applied to SC-CO_2 because the literature shows that it is sensitive to assumptions about discount rate and because no consensus exists on the appropriate rate to use in an intergenerational context. The SC-CO_2 interagency group centered its attention on the 3 percent discount rate but emphasized the importance of considering all four SC-CO_2 estimates.[108] The EPA has evaluated the range of potential impacts by combining all SC-CO_2 values with health benefits values at the 3 percent and 7 percent discount rates. Combining the 3 percent SC-CO_2 values with the 3 percent health benefit values assumes that there is no difference in discount rates

Table 5-9 provides the combined health and climate benefits for the CSAPR update and more and less stringent alternatives for the 2017 analysis year.

[108] See the 2010 SCC TSD. Docket ID EPA-HQ-OAR-2009-0472-114577 or http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf for details.

Table 5-9. Combined Health Benefits and Climate Co-Benefits for the CSAPR update and More and Less Stringent Alternatives for 2017 (millions of 2011$)*

$SC\text{-}CO_2$ Discount Rate**	Health and Climate Benefits (Discount Rate Applied to Health Co-Benefits) 3%	7%	Climate Co-Benefits Only
CSAPR Update			
5%	$480 to $830	$470 to $810	$19
3%	$530 to $880	$520 to $860	$66
2.5%	$560 to $910	$550 to $890	$100
3% (95th percentile)	$650 to $1,000	$640 to $980	$190
More Stringent Alternative			
5%	$520 to $900	$510 to $870	$25
3%	$580 to $960	$570 to $940	$87
2.5%	$630 to $1,000	$620 to $980	$130
3% (95th percentile)	$750 to $1,100	$740 to $1,100	$250
Less Stringent Alternative			
5%	$210 to $360	$210 to $350	$15
3%	$250 to $400	$250 to $390	$54
2.5%	$280 to $420	$270 to $420	$81
3% (95th percentile)	$350 to $500	$350 to $490	$150

*All estimates are rounded to two significant figures. Climate benefits are based on reductions in CO_2 emissions. Health benefits are based on benefit-per-ton estimates. Benefits for ozone are based on ozone season NOx emissions. Ozone benefits occur in analysis year, so they are the same for all discount rates. The health benefits reflect the sum of the ozone benefits and $PM_{2.5}$ co-benefits and reflect the range based on adult mortality functions (e.g., from Krewski *et al.* (2009) with Smith *et al.* (2009) to Lepeule *et al.* (2012) with Zanobetti and Schwartz (2008)). The monetized health benefits do not include reduced health effects from direct exposure to NO_2 as well as ecosystem effects and visibility impairment associated with reductions in NO_X.
**As discussed in section 5.3, the $SC\text{-}CO_2$ estimates are calculated with four different values of a one metric ton reduction.

5.5 Unquantified Benefits and Co-benefits

The monetized co-benefits estimated in this RIA reflect a subset of benefits and co-benefits attributable to the health effect reductions associated with ambient ozone and fine particles. Data, time, and resource limitations prevented the EPA from quantifying the impacts to, or monetizing the co-benefits from several important benefit categories as well as ecosystem effects and visibility impairment associated with reductions in NOx due to the absence of air quality modeling data for these pollutants in this analysis. This does not imply that there are no co-benefits associated reductions in exposures to NO_2. In this section, we provide a qualitative description of these benefits, which are listed in Table 5-10.

Table 5-10. Unquantified Health and Welfare Benefit and Co-benefit Categories

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Improved Human Health				
Reduced incidence of morbidity from exposure to NO_2	Asthma hospital admissions (all ages)	—	—	NO_2 ISA[1]
	Chronic lung disease hospital admissions (age > 65)	—	—	NO_2 ISA[1]
	Respiratory emergency department visits (all ages)	—	—	NO_2 ISA[1]
	Asthma exacerbation (asthmatics age 4–18)	—	—	NO_2 ISA[1]
	Acute respiratory symptoms (age 7–14)	—	—	NO_2 ISA[1]
	Premature mortality	—	—	NO_2 ISA[1,2,3]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	—	—	NO_2 ISA[2,3]
Improved Environment				
Reduced visibility impairment	Visibility in Class 1 areas	—	—	PM ISA[1]
	Visibility in residential areas	—	—	PM ISA[1]
Reduced effects on materials	Household soiling	—	—	PM ISA[1,2]
	Materials damage (e.g., corrosion, increased wear)	—	—	PM ISA[2]
Reduced effects from PM deposition (metals and organics)	Effects on individual organisms and ecosystems	—	—	PM ISA[2]
Reduced vegetation and ecosystem effects from exposure to ozone	Visible foliar injury on vegetation	—	—	Ozone ISA[1]
	Reduced vegetation growth and reproduction	—	—	Ozone ISA[1]
	Yield and quality of commercial forest products and crops	—	—	Ozone ISA[1]
	Damage to urban ornamental plants	—	—	Ozone ISA[2]
	Carbon sequestration in terrestrial ecosystems	—	—	Ozone ISA[1]
	Recreational demand associated with forest aesthetics	—	—	Ozone ISA[2]
	Other non-use effects			Ozone ISA[2]
	Ecosystem functions (e.g., water cycling, biogeochemical cycles, net primary productivity, leaf-gas exchange, community composition)	—	—	Ozone ISA[2]
Reduced effects from acid deposition	Recreational fishing	—	—	NO_x SO_x ISA[1]
	Tree mortality and decline	—	—	NO_x SO_x ISA[2]
	Commercial fishing and forestry effects	—	—	NO_x SO_x ISA[2]
	Recreational demand in terrestrial and aquatic ecosystems	—	—	NO_x SO_x ISA[2]
	Other non-use effects			NO_x SO_x ISA[2]
	Ecosystem functions (e.g., biogeochemical cycles)	—	—	NO_x SO_x ISA[2]
Reduced effects from nutrient enrichment	Species composition and biodiversity in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[2]
	Coastal eutrophication	—	—	NO_x SO_x ISA[2]
	Recreational demand in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[2]
	Other non-use effects			NO_x SO_x ISA[2]
	Ecosystem functions (e.g., biogeochemical cycles, fire regulation)	—	—	NO_x SO_x ISA[2]

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Reduced vegetation effects from ambient exposure to NO_x	Injury to vegetation from NO_x exposure	—	—	NO_x SO_x ISA[2]

[1] We assess these co-benefits qualitatively due to data and resource limitations for this RIA.

[2] We assess these co-benefits qualitatively because we do not have sufficient confidence in available data or methods.

[3] We assess these co-benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

5.5.2 Additional NO_2 Health Co-Benefits

NO and NO_2 are often grouped together into their own group or family, which the atmospheric sciences community refers to as NOx (U.S. EPA, 2016). In addition to being a precursor to $PM_{2.5}$ and ozone, NOx/NO_2 emissions—which emanate from a variety of sources including EGU's—are also linked to a variety of adverse health effects associated with direct exposure. We were unable to estimate the health co-benefits associated with reduced NO_2 exposure in this analysis for two reasons. First, we lacked a reliable reduced-form approach for quantifying NO_2-attributable benefits. A second, and related reason, is that it is generally necessary to perform air quality modeling that characterizes well the near-field gradient associated with NO_2 concentrations—particularly from the mobile sector (U.S. EPA, 2016); such an analysis was not performed for this rule. Therefore, this analysis only quantified and monetized the ozone benefits and $PM_{2.5}$ co-benefits associated with the reductions in NO_2 emissions.

Following a comprehensive review of health evidence from epidemiologic and laboratory studies, the *Integrated Science Assessment for Oxides of Nitrogen —Health Criteria* (NOx ISA) (U.S. EPA, 2016) concluded that there is a causal relationship between respiratory health effects and short-term exposure to NO_2. These epidemiologic and experimental studies encompass a number of endpoints including emergency department visits and hospitalizations, respiratory symptoms, airway hyperresponsiveness, airway inflammation, and lung function. The NOx ISA also 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 NOx 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.

5.5.4 *Additional NO_2 Welfare Co-Benefits*

As described in the *Integrated Science Assessment for Oxides of Nitrogen and Sulfur — Ecological Criteria* (NOx/SOx ISA) (U.S. EPA, 2008d), NOx emissions also contribute to a variety of adverse welfare effects, including those associated with acidic deposition, visibility impairment, and nutrient enrichment. Deposition of nitrogen causes acidification, which can cause a loss of biodiversity of fishes, zooplankton, and macro invertebrates in aquatic ecosystems, as well as a decline in sensitive tree species, such as red spruce (Picea rubens) and sugar maple (Acer saccharum) in terrestrial ecosystems. In the northeastern U.S., the surface waters affected by acidification are a source of food for some recreational and subsistence fishermen and for other consumers and support several cultural services, including aesthetic and educational services and recreational fishing. Biological effects of acidification in terrestrial ecosystems are generally linked to aluminum toxicity, which can cause reduced root growth, restricting the ability of the plant to take up water and nutrients. These direct effects can, in turn, increase the sensitivity of these plants to stresses, such as droughts, cold temperatures, insect pests, and disease leading to increased mortality of canopy trees.

Deposition of nitrogen is also associated with aquatic and terrestrial nutrient enrichment. In estuarine waters, excess nutrient enrichment can lead to eutrophication. Eutrophication of estuaries can disrupt an important source of food production, particularly fish and shellfish production, and a variety of cultural ecosystem services, including water-based recreational and aesthetic services. Terrestrial nutrient enrichment is associated with changes in the types and number of species and biodiversity in terrestrial systems. Excessive nitrogen deposition upsets the balance between native and nonnative plants, changing the ability of an area to support biodiversity. When the composition of species changes, then fire frequency and intensity can also change, as nonnative grasses fuel more frequent and more intense wildfires (U.S. EPA, 2008d).

Reductions in emissions of NO_2 will improve the level of visibility throughout the United States because these gases (and the particles of nitrate formed from this gas as discussed below) impair visibility by scattering and absorbing light (U.S. EPA, 2009). 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, 2009). 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 (U. S. EPA, 2009).

5.5.5 Ozone Welfare Benefits

Exposure to ozone has been associated with a wide array of vegetation and ecosystem effects in the published literature (U.S. EPA, 2013b). Sensitivity to ozone is highly variable across species, with over 65 plant species identified as “ozone-sensitive”, many of which occur in state and national parks and forests. These effects include those that damage or impair the intended use of the plant or ecosystem. Such effects can include reduced growth and/or biomass production in sensitive plant species, including forest trees, reduced yield and quality of crops, visible foliar injury, species composition shift, and changes in ecosystems and associated ecosystem services.

5.5.6 $PM_{2.5}$ Visibility Impairment Co-Benefits

Reducing secondary formation of $PM_{2.5}$ would improve levels of visibility in the U.S. because suspended particles and gases degrade visibility by scattering and absorbing light (U.S. EPA, 2009b). Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil (Sisler, 1996). Visibility has direct significance to people’s enjoyment of daily activities and their overall sense of wellbeing. Good visibility increases the quality of life where individuals live and work, and where they engage in recreational activities. Particulate sulfate is the dominant source of regional haze in the eastern U.S. and particulate nitrate is an important contributor to light extinction in California and the upper Midwestern U.S., particularly during winter (U.S. EPA, 2009b). Previous analyses (U.S. EPA, 2011a) show that visibility co-benefits can be a significant welfare benefit category. Without air quality modeling, we are unable to estimate visibility-related benefits, and we are also unable to determine whether the emission reductions associated with the final CSAPR Update would be likely to have a significant impact on visibility in urban areas or Class I areas.

5.6 References

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CHAPTER 6: ECONOMIC IMPACTS

Overview

This chapter addresses economic impacts on small entities, other government entities, and employment.

6.1 Impacts on Small Entities

The EPA certifies that this action will not have a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act (RFA). The small entities subject to the requirements of this action are small businesses, small organizations, and small governmental jurisdictions. The EPA has determined that 1 entity (of 11 small entities identified as potentially affected) may experience an impact of greater than 3 percent of annual revenues. Details of this analysis are presented below.

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 final rulemaking, it must prepare and make available an final regulatory flexibility analysis, unless it certifies that the final rule 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.

The EPA conducted regulatory flexibility analysis at the ultimate (i.e., highest) level of ownership, evaluating parent entities with the largest share of ownership in at least one potentially-affected EGU included in EPA's base case using the IPM v.5.15, used in this RIA.[109] This analysis draws on the "parsed" unit-level estimates using IPM results for 2018,[110] as well as ownership, employment, and financial information for the potentially affected small entities drawn from other resources described in more detail below.

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[109] Detailed documentation for IPM v.5.15 is available at: http://www.epa.gov/airmarkets/powersectormodeling.html.

[110] For this analysis, the 2018 parsed file is used to represent 2017 for the purposes of RIA analysis.

The EPA identified the size of ultimate parent entities by using the Small Business Administration (SBA) size threshold guidelines.[111] The criteria for size determination vary by the organization/operation category of the ultimate parent entity, as follows:

- Privately-owned (non-government) entities (see Table 6-1)
    - Privately-owned entities include investor-owned utilities, non-utility entities, and entities with a primary business other than electric power generation.
    - For entities with electric power generation as a primary business, small entities are those with less than the threshold number of employees specified by SBA for each of the relevant North American Industry Classification System (NAICS) sectors (NAICS 2211).
    - For entities with a primary business other than electric power generation, the relevant size criteria are based on revenue, assets, or number of employees by NAICS sector.[112]
- Publicly-owned entities
    - Publicly-owned entities include federal, state, municipal, and other political subdivision entities.
    - The federal and state governments were considered to be large. Municipalities and other political units with population fewer than 50,000 were considered to be small.
- Rural Electric Cooperatives
    - Small entities are those with fewer than the threshold level of employees or revenue specified by SBA for each of the relevant NAICS sectors.

[111] U.S. Small Business Administration (SBA). 2014. Small Business Size Standards. Effective as of July 14, 2014. See: http://www.sba.gov/sites/default/files/Size_Standards_Table.pdf.

[112] Certain affected EGUs are owned by ultimate parent entities whose primary business is not electric power generation.

6.1.1 Identification of Small Entities

In this analysis, the EPA considered EGUs which meet the following five criteria: 1) EGU is represented in NEEDS v5.15; 2) EGU is fossil fuel-fired; 3) EGU is located in a state covered by this rule; 4) EGU is neither a cogeneration unit nor solid waste incineration unit; 5) EGU capacity is 25MW or larger. The EPA next refined this list of EGUs, narrowing it to those that exhibit at least one of the following changes under the CSAPR Update scenario, in comparison to the baseline.

- Summer fuel use (BTUs) changes by +/- 1% or more
- Summer generation (GWh) changes by +/- 1% or more
- NOx summer emissions (tons) changes by +/- 1% or more

Based on these criteria, the EPA identified a total of 365 potentially affected EGUs warranting examination in this RFA analysis. Next, we determined power plant ownership information, including the name of associated owning entities, ownership shares, and each entity's type of ownership. We primarily used data from SNL and Ventyx, supplemented by limited research using publicly available data.[113] Majority owners of power plants with affected EGUs were categorized as one of the seven ownership types.[114] These ownership types are:

1. **Investor-Owned Utility (IOU)**: Investor-owned assets (e.g., a marketer, independent power producer, financial entity) and electric companies owned by stockholders, etc.
2. **Cooperative (Co-Op)**: Non-profit, customer-owned electric companies that generate and/or distribute electric power.
3. **Municipal**: A municipal utility, responsible for power supply and distribution in a small region, such as a city.

[113] SNL Financial data covers the energy market and other industries, and includes detailed immediate and ultimate ownership at the EGU level. For more information, see: www.snl.com. The Ventyx Energy Velocity Suite database consists of detailed ownership and corporate affiliation information at the EGU level. For more information, see: www.ventyx.com.

[114] Throughout this analysis, the EPA refers to the owner with the largest ownership share as the "majority owner" even when the ownership share is less than 51 percent.

4. **Sub-division**: Political subdivision utility is a county, municipality, school district, hospital district, or any other political subdivision that is not classified as a municipality under state law.
5. **Private**: Similar to an investor-owned utility, however, ownership shares are not openly traded on the stock markets.
6. **State**: Utility owned by the state.
7. **Federal**: Utility owned by the federal government.

Next, the EPA used both the Hoover's online database and the SNL database to identify the ultimate owners of power plant owners identified in the SNL and Ventyx databases. This was necessary, as many majority owners of power plants (listed in SNL or Ventyx) are themselves owned by other ultimate parent entities (listed in Hoover's or SNL).[115] In these cases, the ultimate parent entity was identified via Hoover's or SNL, whether domestically or internationally owned.

The EPA followed SBA size standards to determine which non-government ultimate parent entities should be considered small entities in this analysis. These SBA size standards are specific to each industry, each having a threshold level of either employees, revenue, or assets below which an entity is considered small. SBA guidelines list all industries, along with their associated NAICS code and SBA size standard. Therefore, it was necessary to identify the specific NAICS code associated with each ultimate parent entity in order to understand the appropriate size standard to apply. Data from Hoover's was used to identify the NAICS codes for most of the ultimate parent entities. In many cases, an entity that is a majority owner of a power plant is itself owned by an ultimate parent entity with a primary business other than electric power generation. Therefore, it was necessary to consider SBA entity size guidelines for the range of NAICS codes listed in Table 6-1. This table represents the range of NAICS codes and areas of primary business of ultimate parent entities which are majority owners of potentially affected EGUs in the EPA's IPM base case.

[115] The Hoover's Inc. online platform includes company records that can contain NAICS codes, number of employees, revenues, and assets. For more information, see: http://www.hoovers.com

Table 6-1. SBA Size Standards by NAICS Code

NAICS Code	NAICS Description	SBA Size Standard
221112	Fossil Fuel Electric Power Generation	750 employees
221118	Other Electric Power Generation	250 employees
221122	Electric Power Distribution	1,000 employees
221210	Natural Gas Distribution	1,000 employees
238210	Electrical Contractors and Other Wiring Installation Contractors	$15 million in revenue
324110	Petroleum Refineries	1,500 employees
325180	Other Basic Inorganic Chemical Manufacturing	1,000 employees
325320	Pesticide and Other Agricultural Chemical Manufacturing	1,000 employees
331313	Alumina Refining and Primary Aluminum Production	1,000 employees
333613	Mechanical Power Transmission Equipment Manufacturing	750 employees
424720	Petroleum and Petroleum Products Merchant Wholesalers (except Bulk Stations and Terminals)	200 employees
486210	Pipeline Transportation of Natural Gas	$27.5 million in revenue
522110	Commercial Banking	$550 million in assets
522220	Sales Financing	$38.5 million in revenue
523120	Securities Brokerage	$38.5 million in revenue
523910	Miscellaneous Intermediation	$38.5 million in revenue
523930	Investment Advice	$38.5 million in revenue
524126	Direct Property and Casualty Insurance Carriers	1,500 employees
525120	Health and Welfare Funds	$32.5 million in revenue
525990	Other Financial Vehicles	$32.5 million in revenue
541611	Administrative Management and General Management Consulting Services	$15 million in revenue
551112	Offices of Other Holding Companies	$20.5 million in revenue

Note: Based on size standards effective at the time the EPA conducted this analysis (SBA size standards, effective February 26, 2016)
Source: SBA, 2016

The EPA compared the relevant entity size criterion for each ultimate parent entity to the SBA threshold value noted in Table 6-1. We used the following data sources and methodology to estimate the relevant size criterion values for each ultimate parent entity:

1. **Employment, Revenue, and Assets**: The EPA used the Hoover's database as the primary source for information on ultimate parent entity employee numbers, revenue, and assets.[116] In parallel, the EPA also considered estimated revenues from affected EGUs based on analysis of parsed-file estimates for the final rule. The EPA assumed that the ultimate parent entity revenue was the larger of the two revenue estimates. In limited

[116] Estimates of sales were used in lieu of revenue estimates when revenue data was unavailable.

instances, supplemental research was also conducted to estimate an ultimate parent entity's number of employees, revenue, or assets.

2. **Population**: Municipal entities are defined as small if they serve populations of less than 50,000. The EPA primarily relied on data from the Ventyx database and the U.S. Census Bureau to inform this determination. Supplemental research of individual municipalities was also conducted in some instances.

Ultimate parent entities for which the relevant measure is less than the SBA size criterion were identified as small entities and carried forward in this analysis. In the case of one entity, data limitations prevented the comparison of the entity against its appropriate SBA size standard. For the purposes of this analysis, the EPA assumed that this entity is a small entity. Overall, the EPA identified 30 potentially affected EGUs owned by 11 small entities included in the EPA's Base Case.

6.1.2 Overview of Analysis and Results

This section presents the methodology and results for estimating the impact of the CSAPR Update to small entities in 2017 based on the following endpoints:

- annual economic impacts of the CSAPR Update on small entities, and
- ratio of small entity impacts to revenues from electricity generation.

6.1.2.1 Methodology for Estimating Impacts of the CSAPR Update on Small Entities

An entity can comply with the CSAPR Update through some combination of the following: optimizing existing SCR, turning on idled SCR or SNCR controls, upgrading to state of the art combustion controls, using allocated allowances, purchasing allowances, 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, the 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 CSAPR Update in 2017. This analysis is based on the NO_X budgets and modeling results presented in Chapter 4.

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 CSAPR Update, 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 CSAPR Update. On the other hand, those 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). 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, the EPA used IPM-parsed output 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 CSAPR Update 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 CSAPR Update, the EPA identified units that install control technology under the policy, and what technology was installed. The equations for calculating retrofit costs were adopted from the 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 annual cost for units projected to turn on existing idled SCR, fully operate existing SCR, or turn on existing idled SNCR.

(2) **Sale or purchase of allowances:** To estimate the value of allowances holdings, allocated allowances were subtracted from projected emissions, and the difference was then multiplied by $1,400 per ton. $1,400 per ton is the marginal cost of NO_X reductions used to set the budgets in the final rule. While this is a reasonable approximation, it is possible that the actual allowance price could be lower. Units were assumed to purchase or sell allowances to exactly cover their projected emissions under the policy.

(3) **Fuel costs:** The change in fuel expenditures under the policy was estimated by taking the difference in projected fuel expenditures between the IPM estimates for the CSAPR Update and the base case.

(4) **Value of electricity generated:** To estimate the value of electricity generated, the projected level of electricity generation is multiplied by the regional-adjusted retail electricity price ($/MWh) estimate, for all entities except those categorized as Private in Ventyx. For private entities, the EPA used segmental 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.

(5) **Administrative costs:** Because most affected units are already monitored as a result of other regulatory requirements, the EPA considered the primary administrative cost to be transaction costs related to purchasing or selling allowances. The EPA assumed that transaction costs were equal to 1.5 percent of the total absolute value of the difference between a unit’s allocation and projected NO_X emissions. This assumption is based on market research by ICF International.

6.1.2.2 Results

The potential impacts of the CSAPR Update on small entities are summarized in Table 6-2. All costs are presented in $2011. The EPA estimated the annual net compliance cost to small entities to be approximately $23.9 million in 2017. At a plant level, the net compliance costs for all entities includes net savings at a number of plants in this analysis. These net savings are driven by entities that are able to increase their revenues by increasing generation.

Table 6-2. Projected Impact of the CSAPR Update on Small Entities in 2017

EGU Ownership Type	Number of Potentially Affected Entities	Total Net Compliance Cost ($2011 millions)	Number of Small Entities with Compliance Costs >1% of Generation Revenues	Number of Small Entities with Compliance Costs >3% of Generation Revenues
Cooperative	3	24.1	1	1
Municipal	3	0.0	0	0
Private	5	-0.2	0	0
Total	11	23.9	1	1

Note: 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 CSAPR Update.

Source: IPM analysis

The 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 the 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, the 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.

Of the 11 small entities considered in this analysis, 1 entity may experience compliance costs greater than 1 percent of generation revenues in 2017, and only 2 entities may experience net positive compliance costs. The other 9 entities may experience negative net costs under the CSAPR Update. The 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 6-2.

The distribution across entities of economic impacts as a share of base case revenue is summarized in Table 6-3. Since there are few potentially-impacted small entities included in this analysis, the distributions of economic impacts on each ownership type are in general fairly tight.

Table 6-3. Summary of Distribution of Economic Impacts of the CSAPR Update on Small Entities in 2017

EGU Ownership Type	Capacity-Weighted Average Economic Impacts as a % of Generation Revenues	Min	Max
Cooperative	9.0%	-7.8%	9.0%
Municipal	-0.8%	-11.9%	0.2%
Private	-1.9%	-11.7%	-0.1%

Source: IPM analysis

The separate components of annual costs to small entities under the CSAPR Update are summarized in Table 6-4. The most significant components of incremental cost to these entities under the CSAPR Update are due to lower electricity revenues. The vast majority of the decreased electricity revenue component is attributable to the single entity that may experience compliance costs greater than 1 percent of generation revenues in 2017. Since this one entity represents a large share of generation in this category, the projected reduction in generation at this single entity relative to the base case leads to higher net costs for the entire category. The fuel costs decreases are largely attributable to a few entities that are projected to decrease generation relative to the base case, which translates to lower fuel costs for the whole group. However, many of these entities are projected to increase generation relative to the base case and thus counterbalance this overall impact. Additionally, increases in electricity generation revenue, shown as cost savings or negative costs are experienced by cooperative, municipal, and private entities. This is due largely to the projected increase in generation at these entities under the CSAPR Update.

Table 6-4. Incremental Annual Costs under the CSAPR Update Summarized by Ownership Group and Cost Category in 2017 (2011$ millions)

EGU Ownership Type	Operating Cost	Net Purchase of Allowances	Fuel Cost	Lost Electricity Revenue	Administrative Cost
Cooperative	-$1.8	$1.5	-$6.6	$31.0	$0.02
Municipal	$0.5	$0.3	$0.3	-$1.1	$0.00
Private	$0.4	-$0.6	-$0.1	$0.0	$0.01

Source: IPM analysis

6.1.3 Summary of Small Entity Impacts

The 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 11 small entities potentially affected, 1 may experience compliance costs in excess of 1 percent of revenues in 2017, 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 CSAPR Update.

The EPA has lessened the impacts for small entities by excluding all units smaller than 25 MW. This exclusion, in addition to the exemptions for cogeneration units and solid waste incineration units, eliminates the burden of higher costs for a substantial number of small entities located in the 22 states for which the EPA is finalzing FIPs. Additionally, the CSAPR Update allows for the flexibility of trading, which greatly reduces compliance burden. For further information, see the evaluation completed for the original CSAPR, available at 76 FR 48272-48273 (August 8, 2011).

6.2 Unfunded Mandates Reform Act

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, the 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 the 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. Moreover, section 205 allows the 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 the EPA stated in the preamble, the EPA is not directly establishing any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments. Thus, under the CSAPR Update, the EPA is not obligated to develop under Section 203 of the UMRA a small government agency plan.

The EPA did analyze the economic impacts of the CSAPR Update on government entities, however. This analysis does not examine potential indirect economic impacts associated with the CSAPR Update, such as employment effects in industries providing fuel and pollution control equipment, or the potential effects of electricity price increases on industries and households.

6.2.1 *Identification of Government-Owned Entities*

In this analysis, the EPA considered EGUs which meet the following five criteria: 1) EGU is represented in NEEDS v5.15; 2) EGU is fossil-fuel fired; 3) EGU is located in a state covered by this rule; 4) EGU is neither a cogeneration unit nor solid waste incineration unit; and 5) EGU capacity is 25 MW or larger.

The EPA next refined this list of EGUs, narrowing it to those that exhibit at least one of the following changes under the final rule, in comparison to the base case.

- Summer fuel use (BTUs) changes by +/- 1% or more
- Summer generation (GWh) changes by +/- 1% or more
- NOx summer emissions (tons) changes by +/- 1% or more

From the inventory of units meeting the criteria above, the EPA used Ventyx data to identify state and municipality-owned utilities and subdivisions in the CSAPR Update region. The EPA then used IPM-parsed output to associate these plants with individual generating units. The EPA identified 12 municipality-owned utilities that are potentially affected by the CSAPR Update.

6.2.2 *Overview of Analysis and Results*

After identifying potentially affected government entities, the EPA estimated the impact of the CSAPR Update in 2017 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 CSAPR Update is composed of compliance and administrative costs. This section outlines the compliance and administrative costs for the 12 potentially affected government-owned units in the CSAPR Update region.

6.2.2.1 Methodology for Estimating Impacts of the CSAPR Update on Government Entities

An entity can comply with the CSAPR Update through any combination of the following: optimizing existing SCR, turning on idled SCR or SNCR controls, upgrading to state of the art combustion controls, using allocated allowances, purchasing allowances, or reducing emissions through a reduction in generation or improved efficiency. 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, the 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 CSAPR Update, for example, some units will forgo some level of electricity generation (and thus revenues) to comply, this impact will be lessened on these entities by the projected increase in electricity prices under the policy, while those not reducing generation levels will see an increase in electricity revenues. 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.

In this analysis, the EPA used IPM-parsed output for the base case and the CSAPR Update to estimate compliance cost at the unit level. These costs were then summed for each 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 CSAPR Update relative to the base case. These components of compliance cost were estimated as follows:

(1) **Operating and retrofit costs:** Using the IPM-parsed output for the base case and the CSAPR Update, the EPA identified units that install control technology under the policy and the technology installed. The equations for calculating retrofit costs were adopted from the 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 annual cost for units projected to turn on existing idled SCR, fully operate existing SCR, or turn on existing idled SNCR.

(2) **Sale or purchase of allowances:** To estimate the value of allowances holdings, allocated allowances were subtracted from projected emissions, and the difference was then multiplied by $1,400 per ton. $1,400 per ton is the marginal annualized cost of NO_X reductions used to set the budgets. While this is a reasonable approximation, it is possible that the actual allowance price could be lower. Units were assumed to purchase or sell allowances to exactly cover their projected emissions under the CSAPR Update.

(3) **Fuel costs:** The change in fuel expenditures under the policy was estimated by taking the difference in projected fuel expenditures between the illustrative CSAPR Update and the base case.

(4) **Value of electricity generated:** To estimate the value of electricity generated, the projected level of electricity generation is multiplied by the regional-adjusted retail electricity price ($/MWh) estimate, for all entities except those categorized as Private in Ventyx. For private entities, the 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.

(5) **Administrative costs:** Because most affected units are already monitored as a result of other regulatory requirements, the EPA considered the primary administrative cost to be transaction costs related to purchasing or selling allowances. The EPA assumed that transaction costs were equal to 1.5 percent of the total absolute value of the difference between a unit's allocation and projected NO_X emissions. This assumption is based on market research by ICF International.

6.2.2.2 Results

A summary of economic impacts on government owned entities is presented in Table 6-5. According to the EPA's analysis, the total net economic impact on government-owned entities (state- and municipality-owned utilities and subdivisions) is expected to be $20.5 million in 2017.[117]

Table 6-5. Summary of Potential Impacts on Government Entities under the CSAPR Update in 2017

EGU Ownership Type	Potentially Affected Entities	Projected Annualized Costs ($2011 millions)	Number of Government Entities with Compliance Costs >1% of Generation Revenues	Number of Government Entities with Compliance Costs >3% of Generation Revenues
Municipal	11	$14.7	2	2
State	1	$5.8	1	1
Total	**12**	**$20.5**	**3**	**3**

Note: The total number of entities with costs greater than 1 percent or 3 percent of revenues includes only entities experiencing positive costs

As was done for the small entities analysis, the 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

[117] All costs are reported in 2011 dollars.

measure is greater than 1 percent.[118] The EPA projects that 3 government entities may have compliance costs greater than 1 percent of revenues from electricity generation in 2017. The majority of the units that have higher costs are not expected to make operational changes as a result of this rule (e.g., turn on controls). Their increased costs are largely due to a change in generation level, which results in a decrease in electricity revenue. 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 CSAPR Update through rate increases. Given this, the 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.

For municipality- and state-owned entities, the capacity-weighted average economic impact as a share of base case revenue is slightly less than zero percent. This average reflects the fact that 6 of the 12 entities are projected to experience a negative economic impact as a share of base case revenue, which implies that this group of 5 entities experiences a net savings under the CSAPR Update.

The various components of annual incremental cost under the CSAPR Update to government entities are summarized in Table 6-6. In 2017, state and municipal entities are a net purchaser of allowances, and experience both a decrease in fuel expenditures and a decrease in electricity revenue under the CSAPR Update. Incremental fuel costs are negative because most of these entities are projected to decrease generation

Table 6-6. Incremental Annual Costs under the CSAPR Update Summarized by Ownership Group and Cost Category (2011$ millions) in 2017

EGU Ownership Type	Retrofit + Operating Cost	Net Purchase of Allowances	Fuel Cost	Lost Electricity Revenue	Administrative Cost
Municipal	-$0.8	$1.0	-$5.8	-$20.2	$0.1
State	-$1.4	$0.9	-$5.2	-$11.6	$0.0

[118] Neither the costs nor the revenues of units that retire under the illustrative CSAPR Update are included in this portion of the analysis. Because these units are better off retiring under the policy than continuing operation, the true cost of the rule on these units is not represented by our modeling. The true cost of the policy for these units is the differential between their costs in the base case and the costs of meeting their customers' demand under the rule.

Source: IPM analysis

6.2.3 Summary of Government Entity Impacts

The EPA examined the potential economic impacts on government-owned entities associated with this rulemaking based on assumptions of how the affected states will implement control measures to meet their emissions. According to the EPA's analysis, the total net economic impact on government-owned entities is expected to be $20.5 million in 2017. This does not mean that each government entity will experience net cost as the overall net savings is driven by some entities garnering savings. Of the 12 government entities considered in this analysis, three may experience compliance costs in excess of 1 percent of revenues in 2017, 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 CSAPR Update. However, as noted above, it is the EPA's position that because these government entities can pass on their costs of compliance to rate-payers, they will not be significantly affected.

6.3 Employment

Executive Order 13563 directs federal agencies to consider regulatory impacts on job creation and employment. According to the Executive Order, "our regulatory system must protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation. It must be based on the best available science" (Executive Order 13563, 2011). Although standard benefit-cost analyses have not typically included a separate analysis of regulation-induced employment impacts,[119] we typically conduct employment analyses for economically significant rules. This section discusses and projects potential employment impacts related to today's final rule.[120]

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[119] Labor expenses do, however, contribute toward total costs in the EPA's standard benefit-cost analyses.

[120] The employment analysis in this RIA is part of EPA's ongoing effort to "conduct continuing evaluations of potential loss or shifts of employment which may result from the administration or enforcement of [the Act]" pursuant to CAA section 321(a).

Section 6.3.1 describes the theoretical framework used to analyze regulation-induced employment impacts, discussing how economic theory alone cannot predict whether such impacts are positive or negative. Section 6.3.2 presents an overview of the peer-reviewed literature relevant to evaluating the effect of environmental regulation on employment. Section 6.3.3 provides background regarding recent employment trends in the electricity generation, coal and natural gas extraction sectors. Section 6.3.4 discusses the potential direct employment impacts in these sectors.

6.3.1 Economic Theory and Employment

Regulatory employment impacts are difficult to disentangle from other economic changes affecting employment decisions over time and across regions and industries. Labor market responses to regulation are complex. They depend on labor demand and supply elasticities and possible labor market imperfections (e.g., wage stickiness, long-term unemployment, etc.). The unit of measurement (e.g., number of jobs, types of jobs, hours worked, and earnings) may affect observability of those responses. Net employment impacts are composed of a mix of potential declines and gains in different areas of the economy (e.g., the directly regulated sector, the environmental protection sector, upstream and downstream sectors, etc.) over time. In light of these difficulties, economic theory provides a constructive framework for analysis.

Microeconomic theory describes how firms adjust their use of inputs in response to changes in economic conditions.[121] Labor is one of many inputs to production, along with capital, energy, and materials. In competitive markets, firms choose inputs and outputs to maximize profit as a function of market prices and technological constraints.[122,123] Berman and Bui (2001) adapt this model to analyze how environmental regulations affect labor demand.[124] They model environmental regulation as effectively requiring certain factors of production, such as pollution abatement capital, at levels that firms would not otherwise choose. Berman and Bui (2001)

[121] See Layard and Walters (1978), a standard microeconomic theory textbook, Chapter 9, for a discussion.

[122] See Hamermesh (1993), Chapter 2, for a derivation of the firm's labor demand function from cost-minimization.

[123] In this framework, labor demand is a function of quantity of output and prices (of both outputs and inputs).

[124] Morgenstern, Pizer, and Shih (2002) develop a similar model.

model two components that drive changes in firm-level labor demand: output effects and substitution effects.[125] Regulation affects the profit-maximizing quantity of output by changing the marginal cost of production. If a regulation causes marginal production cost to increase, it will place upward pressure on output prices, leading to a decrease in quantity demanded, and resulting in a decrease in production. The output effect describes how, holding labor intensity constant, a decrease in production causes a decrease in labor demand. As noted by Berman and Bui, although many assume that regulations must increase marginal cost, in some cases they may decrease it. A regulation could induce a firm to upgrade to less polluting and more efficient equipment that lowers the marginal cost of production. In such a case, output could increase after firms comply with the regulation. An unregulated profit-maximizing firm may not have chosen to install such an efficiency-improving technology if the return on investment were too low, but once the technology is in place it lowers marginal production costs.

The substitution effect describes how, holding output constant, regulation affects the labor-intensity of production. Although increased environmental regulation may increase use of pollution control equipment and energy to operate that equipment, the impact on labor demand is ambiguous. For example, equipment inspection requirements, specialized waste handling, completing required paperwork, or pollution technologies that alter the production process may affect the number of workers necessary to produce a unit of output. Berman and Bui (2001) model the substitution effect as the effect of regulation on pollution control equipment and expenditures required by the regulation and the corresponding change in the labor-intensity of production.

In summary, as output and substitution effects may be positive or negative, economic theory alone cannot predict the direction of the net effect of regulation on labor demand. In addition, the empirical literature illustrates difficulties with estimation of net employment impacts. The most commonly used empirical methods, for example, Greenstone (2002), likely overstate employment impacts because they rely on relative comparisons between more

[125] The authors also discuss a third component, the impact of regulation on factor prices, but conclude that this effect is unlikely to be important for large competitive factor markets, such as labor and capital. Morgenstern, Pizer and Shih (2002) use a very similar model, but they break the employment effect into three parts: 1) a demand effect; 2) a cost effect; and 3) a factor-shift effect.

regulated and less regulated counties, which can lead to “double counting” of impacts when production and employment shift from more regulated towards less regulated areas. Thus these empirical methods cannot be used to estimate net employment effects.[126]

The conceptual framework described thus far focused on regulatory effects on plant-level decisions within a regulated industry, but employment impacts at an individual plant do not necessarily represent impacts for the sector as a whole. At the industry-level, labor demand is more responsive if: (1) the price elasticity of demand for the product is high, (2) other factors of production can be easily substituted for labor, (3) the supply of other factors is highly elastic, or (4) labor costs are a large share of total production costs.[127] For example, if all firms in an industry are faced with the same regulatory compliance costs and product demand is inelastic, then industry output may not change much, and output of individual firms may change slightly.[128]

In addition to changes to labor demand in the regulated industry, net employment impacts encompass changes in other related sectors such as the environmental protection sector. This final rule may increase demand for the nitrogenous reagent (typically ammonia or urea) used in SCRs and SNCRs to reduce NOx, which may increase revenue and employment in the firms providing these chemicals.

If the U.S. economy is at full employment, even a large-scale environmental regulation is unlikely to have a noticeable impact on aggregate net employment.[129] Instead, labor in affected sectors would primarily be reallocated from one productive use to another (e.g., from producing electricity to manufacturing, installing, or operating and maintaining pollution-abatement equipment), and net national employment effects from environmental regulation would be small and transitory (e.g., as workers move from one job to another).[130] Some workers may retrain or

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[126] See Greenstone (2002) p. 1212.

[127] See Ehrenberg & Smith (2000), p. 108.

[128] This example is from Berman and Bui (2001), pp. 293.

[129] Full employment is a conceptual target for the economy where everyone who wants to work and is available to do so at prevailing wages is actively employed. The unemployment rate at full employment is not zero.

[130] Arrow *et al.* (1996); see discussion on bottom of p. 8. In practice, distributional impacts on individual workers can be important, as discussed in later paragraphs of this section.

relocate in anticipation of new requirements or require time to search for new jobs, while shortages in some sectors or regions could bid up wages to attract workers. These adjustment costs can lead to local labor disruptions.

If, on the other hand, the economy is operating at less than full employment, economic theory does not clearly indicate the direction or magnitude of the net impact of environmental regulation on employment; it could cause either a short-run net increase or short-run net decrease (Schmalansee and Stavins, 2011). For example, the Congressional Budget Office considered EPA's MATS and regulations for industrial boilers and process heaters as potentially leading to short-run net increases in economic growth and employment, driven by capital investments for compliance with the regulations (Congressional Budget Office, 2011). Environmental regulation may also affect labor supply and productivity. In particular, reducing pollution and other environmental risks may improve labor productivity or employees' ability to work.[131] While the theoretical framework for analyzing labor supply effects is analogous to that for labor demand, it is more difficult to study empirically. There is a small emerging literature that uses detailed labor and environmental data to assess these impacts.

To summarize, economic theory provides a framework for analyzing the impacts of environmental regulation on employment. The net employment effect incorporates expected employment changes (both positive and negative) in the regulated sector and other related sectors including the environmental protection sector. Labor demand impacts for regulated firms, and also for the regulated industry, can be decomposed into output and substitution effects which may be either negative or positive. Estimation of net employment effects for regulated sectors is possible when data of sufficient detail and quality are available. Finally, economic theory suggests that labor supply effects are also possible. In the next section, we discuss the empirical literature.

6.3.1.1 Current State of Knowledge Based on the Peer-Reviewed Literature

The peer-reviewed empirical literature specifically estimating employment effects of environmental regulations is limited but growing. We summarize it briefly in this section.

[131] E.g. Graff Zivin and Neidell (2012).

6.3.1.2 Regulated Sector

Several empirical studies, including Berman and Bui (2001) and Ferris, Shadbegian, and Wolverton (2014), suggest that regulation-induced net employment impacts may be zero or slightly positive, but small in the regulated sector. Gray et al (2014) find that pulp mills that had to comply with both the air and water regulations in EPA's 1998 "Cluster Rule" experienced relatively small, and not always statistically significant, decreases in employment. Other research on regulated sectors suggests that employment growth may be lower in more regulated areas (Greenstone 2002, Walker 2011, 2013). However, since these latter studies compare more regulated to less regulated counties, this methodological approach likely overstates employment impacts to the extent that regulation causes plants to locate in one area of the country rather than another, which would lead to "double counting" of the employment impacts. List *et al.* (2003) find some evidence that this type of geographic relocation may be occurring.

6.3.1.3 Economy-Wide

Given the difficulty with estimating national impacts of regulations, EPA has not generally estimated economy-wide employment impacts of its regulations in its benefit-cost analyses. However, in its continuing effort to advance the evaluation of costs, benefits, and economic impacts associated with environmental regulation, EPA has formed a panel of experts as part of EPA's Science Advisory Board (SAB) to advise EPA on the technical merits and challenges of using economy-wide economic models to evaluate the impacts of its regulations, including the impact on net national employment.[132] Once EPA receives guidance from this panel, it will carefully consider this input and then decide if and how to proceed on economy-wide modeling of employment impacts of its regulations.

6.1.4 Labor Supply Impacts

The empirical literature on environmental regulatory employment impacts focuses primarily on labor demand. However, there is a nascent literature focusing on regulation-induced effects on labor supply.[133] Although this literature is limited by empirical challenges, researchers

[132] For further information see: http://yosemite.epa.gov/sab/sabproduct.nsf/0/07E67CF77B54734285257BB0004F87ED?OpenDocument

[133] For a recent review see Graff-Zivin and Neidell (2013).

have found that air quality improvements lead to reductions in lost work days (e.g., Ostro, 1987). Limited evidence suggests worker productivity may also improve when pollution is reduced. Graff Zivin and Neidell (2012) used detailed worker-level productivity data from 2009 and 2010, paired with local ozone air quality monitoring data for one large California farm growing multiple crops, with a piece-rate payment structure. Their quasi-experimental structure identifies an effect of daily variation in monitored ozone levels on productivity. They find "ozone levels well below federal air quality standards have a significant impact on productivity: a 10 parts per billion (ppb) decreases in ozone concentrations increases worker productivity by 5.5 percent." (Graff Zivin and Neidell, 2012, p. 3654).[134]

6.3.1.5 Conclusion

This section has outlined the challenges associated with estimating regulatory effects on both labor demand and supply for specific sectors. These challenges make it difficult to estimate net national employment estimates that would appropriately capture the way in which costs, compliance spending, and environmental improvements propagate through the macro-economy.

6.3.2 Recent Employment Trends

The U.S. electricity system includes employees that support electric power generation, transmission and distribution; the extraction of fossil fuels; and supply-side and demand-side energy efficiency. This section describes recent employment trends in the electricity system.

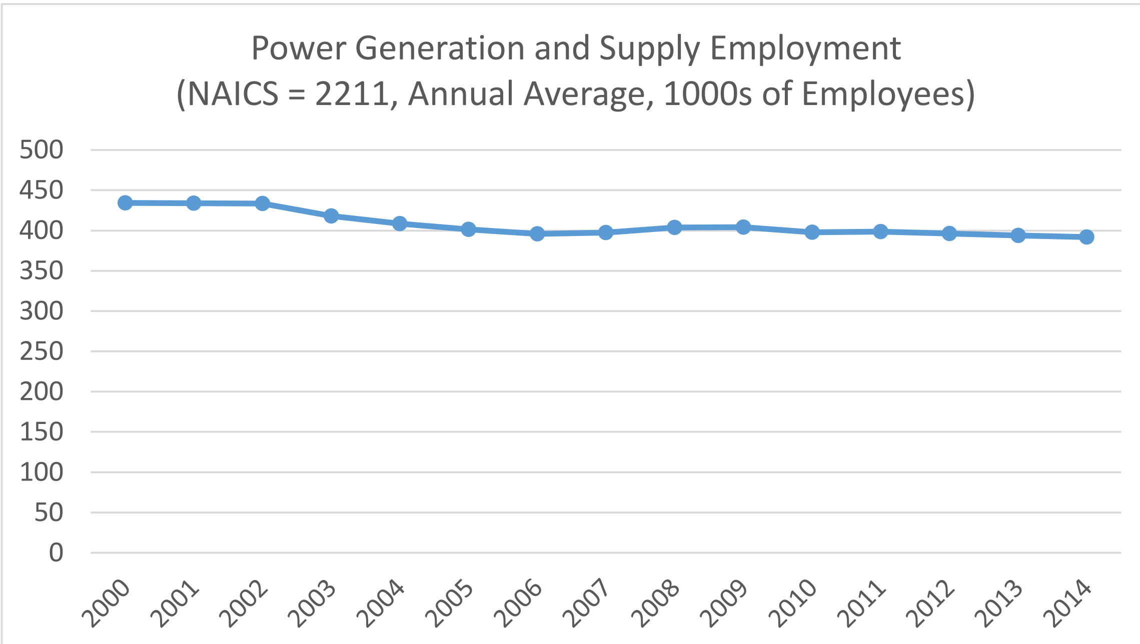
6.3.2.1 Electric Power Generation

In 2014, the electric power generation, transmission and distribution sector (NAICS 2211) employed about 390,000 workers (U.S. BLS, 2015) in the U.S. Installation, maintenance, and repair occupations accounted for the largest share of workers (25 percent) (U.S. BLS, 2014). These categories include inspection, testing, repairing and maintaining of electrical equipment and/or installation and repair of cables used in electrical power and distribution systems. Other major occupation categories include office and administrative support (18 percent), production occupations (16 percent), architecture and engineering (10 percent), business and financial

[134] The EPA is not quantifying productivity impacts of reduced pollution in this rulemaking using this study. In light of this recent research, however, the EPA is considering how best to incorporate possible productivity effects in the future.

operations (7 percent) and management (7 percent). Asd shown in Figure 6-1, employment in the electric power industry averaged about 420,000 workers from 2000 to 2005, declining to an average of about 400,000 workers for the rest of the decade, and then declining to about 390,000 workers in 2014.

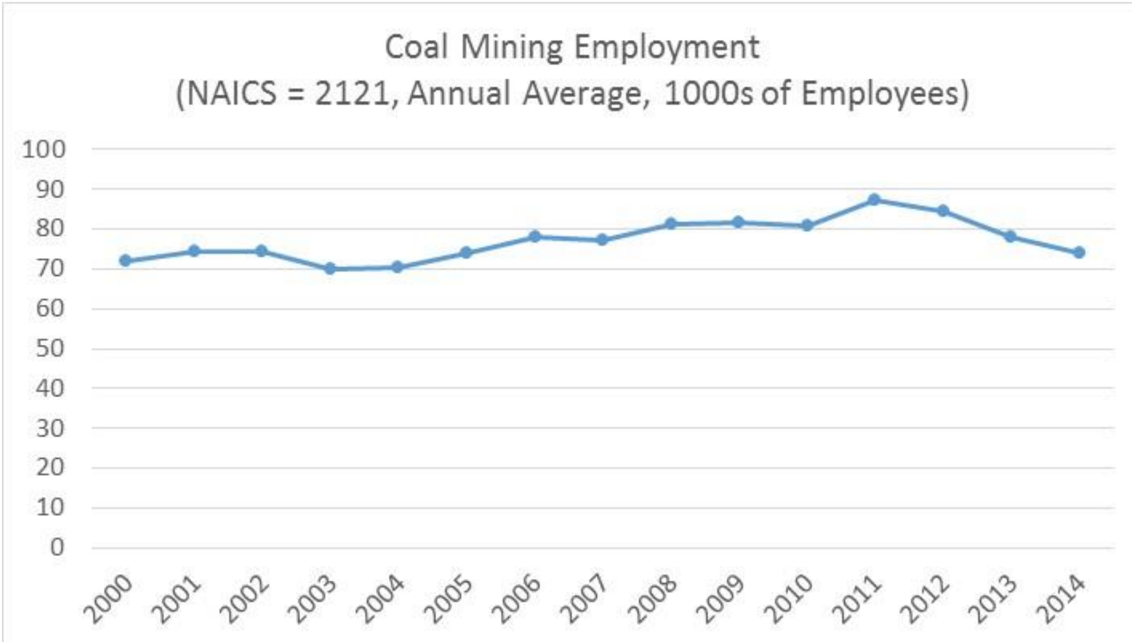
Figure 6-1. Electric Power Industry Employment



6.3.2.2 Fossil Fuel Extraction

Coal Mining. The coal mining sector (NAICS 2121) is primarily engaged in coal mining and coal mine site development, excluding metal ore mining and nonmetallic mineral mining and quarrying. In 2014, BLS reported about 74,000 coal mining employees (Figure 6-2). During the 2000 to 2014 period, coal mining employment peaked in 2011 at about 87,000 employees.

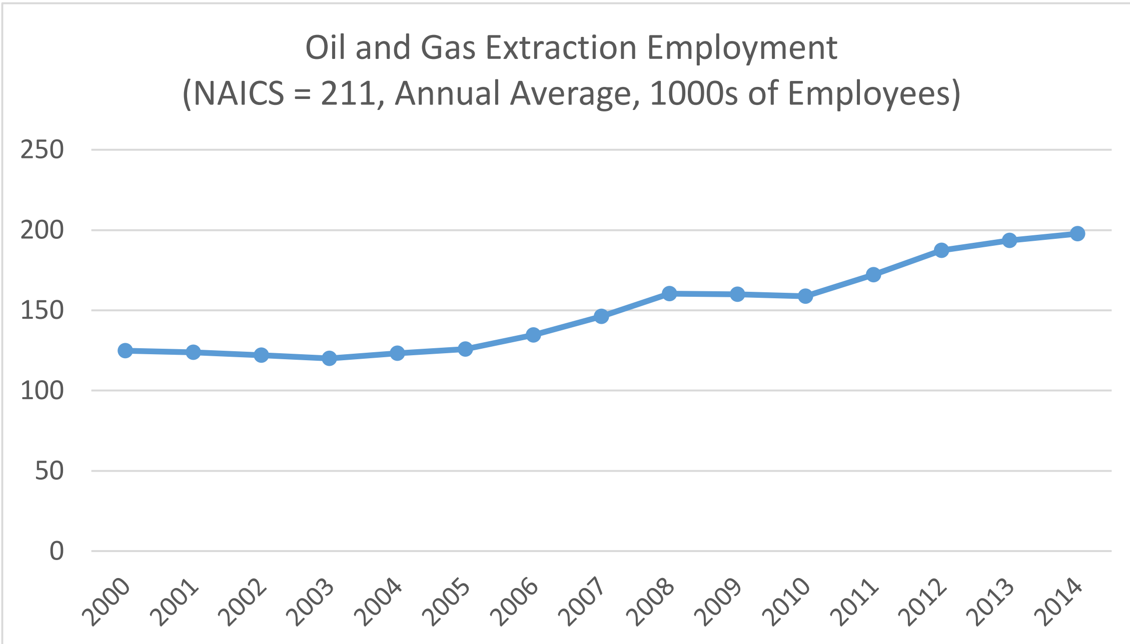
Figure 6-2. Coal Production Employment



Source: BLS (2014a)

Oil and Gas Extraction. In 2014, there were close to 200,000 employees in the oil and gas extraction sector (NAICS 211). This sector includes production of crude petroleum, oil from oil shale and oil sands, production of natural gas, sulfur recovery from natural gas, and recovery of hydrocarbon liquids. Activities include the development of gas and oil fields, exploration activities for crude petroleum and natural gas, drilling, completing, and equipping wells, and other production activities. In contrast with coal, Figure 6-3 shows there has been a sharp increase in employment in this sector over the past decade.

Figure 6-3 Oil and Gas Extraction Employment



Source: BLS (2014b)

6.3.3 Power and Fuels Sector Direct Employment Impacts

As described above, affected EGUs may respond to the CSAPR Update by upgrading or improving performance of existing combustion controls, or by upgrading, improving, or utilizing post-combustion NO_X systems already in place. In addition, some generation may shift from higher NO_X-emitting EGUs to units with lower or zero NO_X emission rates. All of these NOx-related changes will likely result in changes in the amount of the various types of amount of labor needed in different parts of the fuels and utility power sectors. There also may be other labor impacts in sectors that provide products and materials used in reducing NO_X emissions at EGUs, such as catalysts used in SCR control systems. These direct labor impacts will likely include both increased demand for certain types of labor in some portions of the affected sectors, and reduced demand for labor in other portions of the affected sectors.

Installing and operating new equipment could change labor demand in the electricity generating sector itself, as well as associated equipment and services sectors. Specifically, the direct employment effects in the power sector that could occur because of actions taken by the 2017 ozone season include:

- Optimizing NO_X removal from existing and operational SCR systems;
- Turning on and optimizing idled SCR and SNCR systems;
- Installing, optimizing or upgrading combustion-side improvements resulting in reduced NO_X emissions;
- Shifting generation from units with higher NO_X emission rates to units with lower or zero emission rates.

In addition, there could be directly induced employment impacts (both positive and negative) in the labor demand in the industries supplying fossil fuels to the power sector and industries supplying materials used by the NO_X reduction systems. Once implemented, both the potential increases in operating efficiency of NO_X reductions, as well as shifting generation to lower NO_X-emitting or zero-emitting EGUs, could impact the utility power sector's demand for fossil fuels, and hence the demand for labor needed in the coal mining and gas extraction sectors.

The direct net employment impacts of the final rule, in terms of the power sector and fuels sector, however, are anticipated to be relatively small. This is consistent with the relatively small estimated changes in the power sector's overall cost of generation, as well as relatively small changes in generation, fuel use, capacity, and the percent of total generation produced by each type of fuel.

For example, for the final rule in 2017, the estimated impacts relevant to changes in labor demand include:

- The overall total national cost of generation in 2017 decreases by 0.01 percent;
- Total net generation increases by 0.001 percent (coal generation decreases by 0.17 percent, and natural gas generation increases by 0.18 percent);
- The power sector's total tons of coal used for electricity generation decreases by 0.25 percent (or 0.19 percent decrease in BTUs);
- Total natural gas use increases by 0.20 percent.

The results of the power sector modeling suggest that because of the very small changes in the power and fuels sector, the direction and magnitude of the potential labor impacts are very small in all three regulatory alternatives analyzed. To illustrate this point, the direct labor impacts are quantified for the final regulation for 2017 and 2020. The labor impacts for the more and less stringent alternatives have not been quantified.

Affected EGUs may respond to the requirement for EGUs in 22 eastern states to reduce NO_X emissions during the ozone season by improving and optimizing existing NO_X emission control systems or to shift generation to lower NO_X-emitting or zero-emitting EGUs. Meeting the new EGU ozone season NO_X budget limits will result in changes in the amount of labor needed in different parts of the utility power sector. Installing and operating new equipment, upgrading combustion control operations to reduce NO_X emissions, and shifting generation to other sources could affect labor demand in the electricity generating sector itself, as well as associated equipment and services sectors. Specifically, the direct employment effects of initiatives at existing fossil EGUs would include increases in labor demand during the implementation phase for manufacturing, installing, and operating the NO_X emissions controls at existing fossil units. Once implemented, reductions in NO_X emissions from existing EGUs and shifting generation to existing generation resources will impact the utility power sector's demand for fossil fuels and potentially plans for EGU retirement.

The employment analysis uses the cost projections from IPM to project labor demand impacts of the final CSAPR Update on affected EGUs in the electricity power sector and the fuel production sector (coal and natural gas). These projections include effects attributable to installing and improving the NO_X control performance of combustion control systems, optimizing the operation of post-combustion NOx control systems, generation shifts, and changes in fuel use. The following section presents the EPA's quantitative projections of potential employment impacts in the electricity generation sector, as well as the impacts in the coal and natural gas fuel sectors.

6.3.3.1 Methods Used to Estimate Changes in Employment in Electricity Generation and Fuel Supply

The analytical approach used in this analysis is a bottom-up engineering method combining the EPA's cost analysis of compliance with the NO_X emissions budgets with data on labor productivity, engineering estimates of the amount and types of labor needed to manufacture, construct, and operate different types of NO_X control systems, and prevailing wage rates for skilled and general labor categories. Lacking robust peer-reviewed methods to estimate economy-wide impacts, the engineering-based analysis focuses on the supply-side direct impact on labor demand in industries closely involved with electricity generation. The engineering approach projects labor changes measured as the change in each analysis year in job-years employed in the utility power sector and directly related sectors (e.g., emission control equipment manufacturing and fuel supply). Some of the quantified employment impacts in this analysis are one-time impacts, such as changes associated with upgrading the combustion controls. Other labor impacts will continue, such as changes associated with operating and maintaining generating units that will be constructed or retired, shifting generation to lower emitting generating units, and changes in the demand for labor providing the fuels supplied to the affected fossil-fired EGUs. All of these continuing labor impacts are estimated as annual impacts on employment.

The methods the EPA uses to estimate the labor impacts are based on the analytical methods used in many previous EPA regulatory analyses. The methods used in this analysis to estimate many of the labor impacts (e.g., labor associated with changes in operating and maintaining generating units, as well as labor needed to mine coal and natural gas) are the same as we used in the Clean Power Plan (CPP) (U.S. EPA, 2015) and CSAPR (U.S. EPA, 2011), with updated data where available. In addition, a central feature of the labor analysis for this RIA, involves the labor needs of upgrading and optimizing NOx control systems on existing EGUs in the affected 22-state region. In addition to the changes at EGUs within the 22-state region, there are also estimated changes in the utilization of existing generating units in other states, as well as changes in the gas and coal supply sectors.

The methods and data used to estimate the labor associated with upgrading combustion control systems to reduce NOx emissions rely on three critical components:

- The mix of labor categories needed to implement the NO_X combustion control upgrades (i.e., the share of the labor cost of the upgrades apportioned to general construction, boilermaker, engineering and management labor) is the same as was used for heat rate improvement combustion control upgrades needed in the final CPP RIA analysis.

- The fully loaded labor cost of each labor category is the same as was used for the NO_X control upgrades and is the same labor cost assumed for heat rate improvements in the CPP final RIA.

- The amount of labor needed to implement the NO_X combustion control upgrades is derived from the total costs of the NO_X combustion upgrades estimated by IPM. The labor analysis relies on an estimate (McAdams et al., 2001) that the labor needed to install the combustion upgrades accounts for 30% of the total cost, and the remaining 70% of the total cost is for capital expenditures on equipment.[135]

6.3.3.2 Estimates of the Changes in Employment in Electricity Generation and Fuel Supply

The estimated labor impacts of the revisions to the NO_X budgets from EGUs in the 22-state region are presented in Table 6-7. Given the methods the EPA uses to estimate labor impacts, it is not possible to directly separate the labor impacts that occur within the 22-state region from the labor impacts in the states not in the region. However, all the labor changes associated with combustion control upgrades, and optimization of existing post-combustion NOx control systems, will occur within the 22-state region. The fuel supply labor impacts, however, will occur both within the 22-state region and in other states. This occurs for two reasons. First, coal and natural gas used at EGUs throughout the United States are both extracted within the 22-state region and in other states. Second, the shifts in fossil-fired generation will also occur both within the 22-state region and in other states.

[135] In the RIA for the proposed CASPR Update, labor was assumed to account for 40% of the total cost. The 40% estimate was consistent with the labor share of cost for heat rate improvements used in the CPP RIA. The 30% labor share estimate used in this final CSAPR Update analysis comes from a published article (McAdams et al., 2001), which specifically examined the labor and capital costs of improving NOx emission rates at industrial boilers by retrofitting flue gas recirculation systems and upgraded low-NOx burners.

Table 6-7. Annual Net Employment Impacts for Power and Fuels Sectors in 2017 & 2020

	2017	**2020**
Upgrades and Optimization		
SCR	11	14
SNCR*	0	0
Combustion Control	55	66
Upgrades & Optimization Sub-Total	**65**	**80**
Plant Retirement		
Coal	0	-366
Fuel Use Change		
Coal	-95	-339
Natural Gas	87	128
Fuel Use Sub-Total	**-8**	**-211**
Net Employment Impact	**58**	**-497**

*All results in this table are those for the CSAPR Update alternative only. Turning on idled SNCR takes place only in the more stringent alternative. Job-year estimates are derived from IPM investment and upgrade estimates, as well as IPM fuel use estimates (tons coals or MMBtu gas). Employment impacts in the upgrades and optimization category includes both employment on-site (e.g., installing improved combustion control systems) and employment involved in manufacturing the improved combustion control systems. All job-year estimates are full-time equivalent (FTE) jobs.

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CHAPTER 7: COMPARISON OF BENEFITS AND COSTS

Overview

The EPA performed an illustrative analysis to estimate the costs, human health benefits, and climate co-benefits of compliance with the proposed and more and less stringent alternatives and is finalizing EGU NOx ozone season emissions budgets for 22 states.[136] The emissions reductions evaluated in the CSAPR update reflect EGU NO_X reduction strategies that are achievable for the 2017 ozone season. The EPA has quantified EGU NO_X ozone-season emissions budgets reflecting EGU NO_X reduction strategies that are widely available at a uniform annualized cost of $1,400 per ton (2011$). For the RIA, in order to implement the OMB Circular A-4 requirement to assess at least one less stringent and one more stringent alternative to the CSAPR update, the EPA has also analyzed EGU NO_X ozone season emissions budgets reflecting NO_X reduction strategies that are widely available at a uniform annualized cost of $800 per ton (2011$) and strategies that are widely available at a uniform annualized cost of $3,400 per ton (2011$). This chapter summarizes these results.

7.1 Results

As shown in Chapter 4, the estimated annualized costs to implement the CSAPR update, are approximately $68 million (2011 dollars, rounded to two significant figures). As shown in Chapter 5, the total estimated combined benefits from implementation of the CSAPR update are approximately $530 million to $880 million in 2017 (2011 dollars, rounded to two significant figures). EPA can thus calculate the net benefits of the CSAPR update by subtracting the estimated annualized costs from the estimated benefits in 2017. The net benefits of the CSAPR update are approximately $460 to $810 million (based on air quality benefits discounted at 3 percent, the central estimate of CO_2 co-benefits, and annualized cost estimates). Therefore, the 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

[136] Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

estimated net benefits of the rule. Table 7-1 presents a summary of the benefits, costs, and net benefits of the CSAPR update and also the more and less stringent alternatives.

Table 7-1. Total Costs, Total Monetized Benefits, and Net Benefits of the CSAPR Update and More and Less Stringent Alternatives in 2017 for U.S. (millions of 2011$)[a,b,c,d]

	CSAPR Update	More Stringent Alternative Alternative	Less Stringent Alternative
Climate Co-Benefits	$66	$87	$54
Air Quality Health Benefits	$450 to $790	$490 to $850	$190 to $330
Total Benefits	$520 to $860	$580 to $940	$240 to $390
Annualized Compliance Costs	$68	$82	$8
Net Benefits	$450 to $790	$490 to $850	$240 to $380
Non-Monetized Benefits[e]	Non-monetized climate benefits		
	Reductions in exposure to ambient NO_2		
	Ecosystem benefits and visibility improvments assoc. with reductions in emissions of NOx		

[a] Estimating multiple years of costs and benefits is limited for this RIA by data and resource limitations. As a result, we provide compliance costs and social benefits in 2017, using the best available information to approximate compliance costs and social benefits recognizing uncertainties and limitations in those estimates.
[b] Benefits ranges represent discounting of health benefits and climate co-benefits at a discount rate of 7 percent. See Chapter 5 for additional detail and explanation. The costs presented in this table reflect compliance costs annualized at a 4.77 percent discount rate and do not include monitoring, recordkeeping, and reporting costs, which are reported separately. See Chapter 4 for additional detail and explanation.
[c] All costs and benefits are rounded to two significant figures; columns may not appear to add correctly.
[d] Ozone and $PM_{2.5}$ benefits from NO_X emission reductions are for the 22-state region only.
[e] Non-monetized benefits descriptions are for all three alternatives and are qualitative.

In accordance with Circular A-4 Guidance (OMB, 2003), the EPA also analyzed the costs and benefits of two regulatory control alternatives that impose relatively more stringent and relatively less stringent EGU NOx emissions budgets, compared to the CSAPR Update. They are designed to show the effects of more stringent and less stringent NOx reduction requirements in a regulatory structure that is otherwise the same as the final NOx emissions budgets. Table 7-2 presents the projected emissions reductions for ozone season NOx, as well as reductions in co-pollutant annual NO_X, annual SO_2, and annual CO_2, in 2017 under the CSAPR update and the more and less stringent alternatives.

Table 7-2. Projected 2017* Changes in Emissions of NOxand CO_2 with the proposed NOx Emissions Budgets and More or Less Stringent Alternatives (Tons)

	CSAPR update	More Stringent Alternative	Less Stringent Alternative
NOx (annual)	-75,000	-79,000	-27,000
NOx (ozone season)	-61,000	-66,000	-27,000
CO_2 (annual short tons)	-1,600,000	-2,000,000	-1,300,000

*Annual reductions are based on 2018 IPM direct model outputs relied upon in this RIA to represent 2017 co-pollutant reductions

In this RIA, we quantify an array of adverse health impacts attributable to ozone and $PM_{2.5}$. The Integrated Science Assessment for Ozone and Related Photochemical Oxidants ("Ozone ISA") (U.S. EPA, 2013a) identifies the human health effects associated with ozone exposure, which include premature death and a variety of illnesses associated with acute (days-long) and chronic (months to years-long) exposures. Similarly, the Integrated Science Assessment for Particulate Matter ("PM ISA") (U.S. EPA, 2009) identifies the human health effects associated with ambient particles, which include premature death and a variety of illnesses associated with acute and chronic exposures.

The EPA believes that providing comparisons of social costs and social benefits at discount rates of 3 and 7 percent is appropriate to the extent this is possible given available models and techniques. The four different uses of discounting in the RIA – (i) construction of annualized costs, (ii) adjusting the value of mortality risk for lags in mortality risk decreases, (iii) adjusting the cost of illness for non-fatal heart attacks to adjust for lags in follow up costs, and (iv) discounting climate co-benefits -- are all appropriate. We explain our discounting of benefits in Chapter 5 of the RIA, specifically the application of 3 and 7 percent to air quality benefits and 2.5, 3, and 5 percent to climate co-benefits; we explain our discounting of costs, in which we use a single discount rate of 4.77 percent, in Chapter 4. Our estimates of net benefits are the approximations of the net value (in 2017) of benefits attributable to emissions reductions needed to attain just for the year 2017.

The EPA presents annualized costs and benefits in a single year for comparison in this RIA because there are a number of methodological complexities associated with calculating the net present value (NPV) of a stream of costs and benefits for a NAAQS. While NPV analysis allows evaluation of alternatives by summing the present value of all future costs and benefits, insights into how costs will occur over time, necessary for a NPV calculation, are limited by underlying assumptions and data. Calculating a present value (PV) of the stream of future benefits also poses special challenges, which we describe below. In addition, calculating NPV requires definition of the length of the future time period considered, which is not straightforward for this analysis and subject to uncertainty. We provide annualized costs of compliance instead of using NPV or alternatives in this RIA, and our explanation for this is in Chapter 4.

The theoretically appropriate approach for characterizing the PV of benefits is the life table approach. The life table, or dynamic population, approach explicitly models the year-to-year influence of air pollution on baseline mortality risk, population growth and the birth rate—typically for each year over the course of a 50-to-100 year period (U.S. EPA SAB, 2010; Miller, 2003). In contrast to the pulse approach[137], a life table models these variables endogenously by following a population cohort over time. For example, a life table will "pass" the air pollution-modified baseline death rate and population from year to year; impacts estimated in year 50 will account for the influence of air pollution on death rates and population growth in the preceding 49 years.

Calculating year-to-year changes in mortality risk in a life table requires some estimate of the annual change in air quality levels. It is both impractical and challenging to model air quality levels for each year and to account for changes in federal, state and local policies that will affect the annual level and distribution of pollutants. For each of these reasons, the EPA has not generally reported the PV of benefits for air rules but has instead pursued a pulse approach. While we agree that providing the NPV of a stream of costs and benefits could be informative, based on the challenges with calculating NPV outlined above, we are not able to provide the NPV of a stream of costs and benefits in this RIA.

Finally, with regard to the increment of impacts attributable to the CSAPR Update and the original CSAPR, the EPA does not believe that the costs and benefits for the original CSAPR and the CSAPR Update are entirely additive. The EPA recognizes that the majority of the benefits of the original CSAPR were derived from reductions in SO_2 and annual NOx emissions, and the benefits of the CSAPR Update are primarily based on ozone-season NOx emissions

[137] The pulse approach assumes changes in air pollution in a single year and affects mortality estimates over a 20-year period.

reductions. However, five years have passed between promulgation of the original CSAPR and the CSAPR Update, and the two rules have different baselines. In the intervening five years, changes in the power sector that are independent of these rules, such as changes in fuel costs and electricity markets as well as other federal and state level actions, which creates challenges when estimating the sum of the costs and benefits of these two rules. In addition, implementation of the original CSAPR was delayed such that its two phases were implemented as phase I – limits to be met by 2015, and phase II – limits to be met by 2017. The reductions estimated for the CSAPR Update in 2017, given that it replaces remanded original CSAPR budgets, may overlap with reductions that would have otherwise occurred for phase II. However, the benefits and costs of CSAPR are still notable given the enduring original CSAPR ozone season NOx budgets, annual NOx budgets, and SO_2 budgets. While the EPA did remove the remanded ozone season NOx budgets for three states, two of these states (North Carolina and South Carolina) remain subject to annual NOx requirements. These original CSAPR budgets are all present in EPA's modeling of the baseline and policy alternatives.

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Health and Environmental Impacts Division Research Triangle Park, NC	Publication No. EPA-452/R-16-004 September, 2016