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The Full Cost of Electricity (FCe-)

EPA's Valuation of Environmental Externalities from Electricity Production

PART OF A SERIES OF WHITE PAPERS

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THE FULL COST OF ELECTRICITY is an interdisciplinary initiative of the Energy Institute of the University of Texas to identify and quantify the full-system cost of electric power generation and delivery – from the power plant to the wall socket. The purpose is to inform public policy discourse with comprehensive, rigorous and impartial analysis.

The generation of electric power and the infrastructure that delivers it is in the midst of dramatic and rapid change. Since 2000, declining renewable energy costs, stringent emissions standards, low-priced natural gas (post-2008), competitive electricity markets, and a host of technological innovations promise to forever change the landscape of an industry that has remained static for decades. Heightened awareness of newfound options available to consumers has injected yet another element to the policy debate surrounding these transformative changes, moving it beyond utility boardrooms and legislative hearing rooms to everyday living rooms.

The Full Cost of Electricity (FCe-) study employs a holistic approach to thoroughly examine the key factors affecting the *total direct and indirect costs* of generating and delivering electricity. As an interdisciplinary project, the FCe- synthesizes the expert analysis and different perspectives of faculty across the UT Austin campus, from engineering, economics, law, and policy. In addition to producing authoritative white papers that provide comprehensive assessment and analysis of various electric power system options, the study team developed online calculators that allow policymakers and other stakeholders, including the public, to estimate the cost implications of potential policy actions. A framework of the research initiative, and a list of research participants and project sponsors are also available on the Energy Institute website: energy.utexas.edu

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This paper is one in a series of Full Cost of Electricity white papers that examine particular aspects of the electricity system.

Other white papers produced through the study can be accessed at the University of Texas Energy Institute website:
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EPA's Valuation of Environmental Externalities from Electricity Production

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ABSTRACT:

As part of the Energy Institute's Full Cost of Electricity Study, this white paper details how the Environmental Protection Agency (EPA) calculates the benefits associated with three recent regulations governing air emissions from fossil-fueled power plants: the Cross State Air Pollution Rule (CSAPR), the Mercury and Air Toxics Standards (MATS), and the Clean Power Plan (CPP). As mandated by Executive Order,[1] EPA must perform a Regulatory Impact Analysis (RIA) for all regulations expected to have annual economic costs exceeding $100 million (so-called "major rules"), estimating the dollar value of both the costs of compliance and the benefits of reducing emissions. This document will describe the general process by which EPA calculates these benefits based on federal guidelines, and will then introduce the specifics for MATS, CPP, and CSAPR.

1 Exec. Order No. 12866, 58 Fed. Reg. (Oct. 4, 1993). Accessed July 15, 2015. http://www.archives.gov/federal-register/executive-orders/pdf/12866.pdf.

1 | QUANTIFYING BENEFITS FOR REGULATORY IMPACT ASSESSMENTS

The benefits of EPA rules include both the human health impacts and environmental impacts of reduced emissions. EPA must employ various techniques to convert these effects into dollar values. Since many of its regulations reduce emissions of more than one pollutant, the agency faces challenges in making sure they include all potential effects without double counting. This challenge is compounded by the fact that EPA does not have many resources to perform independent research so must rely on existing research to create its benefit/cost analysis.

To ensure a thorough review, EPA first identifies all of the significant benefits of different policy options (e.g., lives saved, hospitalizations avoided, crop damages averted, etc.) and the extent to which each benefit can be realized through each new regulation. EPA then assigns a dollar value to these benefits, when possible. EPA's estimate of the magnitude of the health and environmental benefits is guided by the existing scientific literature, and its assignment of dollar values to those benefits is guided by the existing economic literature. These benefit valuation techniques and their application are described in EPA's *Guidelines for Preparing Economic Analyses*, written and regularly updated by EPA Science Advisory Board's Environmental Economics Advisory Committee.[2]

Since human health and environmental damages are not commodities easily traded on an open market, economists use willingness to pay (WTP) as a standard method for converting environmental benefits to dollars. Economists use a variety of methods to quantify WTP which often results in a variety of WTP values for the same reductions in emissions (EPA, 2014a). In cases where EPA uses multiple resources to determine the benefits of pollution reductions, the Regulatory Impact Assessments (RIAs) generally show a range for the benefits values.

Double counting is a major challenge that EPA must avoid. EPA evaluates multiple studies which use a variety of methods to reduce the amount of uncertainty in their analysis. In addition, EPA only assigns dollar values to impacts when the dollar estimate is supported by well-established studies; consequently, some benefits of regulations are discussed only qualitatively, and their dollar value excluded from the estimate of total benefits.

Monetizing Human Health Benefits

EPA uses mortality and morbidity (non-fatal declines in health) factors to monetize policy effects on human life. The method by which EPA estimates the economic value of mortality, "value of statistical life" (VSL), is a linear extrapolation of empirical estimates of marginal WTP for small reductions in the risk of death (or, conversely, willingness to accept (WTA) compensation for small increases in that risk). The VSL is not the value of a person's life. It is also not the amount an individual would be willing to pay to avoid certain death in any given year or the amount an individual would be willing to accept to face certain death. Rather, it is an estimate derived from studies of WTP and WTA behavior.

EPA currently uses a default VSL of $8.7 million (in 2014$).[3,4] This means that a person would be

2 Mortality and morbidity estimates are drawn from the toxicology and epidemiology literature. Some of that literature is based on animal toxicology studies, and some is based upon natural experiments inferring effects from observed pollution levels and observed levels of human mortality and morbidity. Each type of study relies in part on assumptions that can be challenged. Scholars sometimes challenge extrapolation to humans of health effects observed in animals. Similarly, observational studies struggle to control for other factors, such as smoking, genetic predisipositions toward certain health effects, etc. (Bell et al. (2006) and Dockery, et al. (1993)).

3 Most dollar values have been converted to 2014$ for this paper for sake of consistency. The conversions were made using annual price index average from the Bureau of Labor Statistics. Only the social cost of carbon has not been converted in this paper.

4 The original value used in EPA reports is $7.9 million in 2007$.

willing to pay, on average, $870 (in 2014$) to avoid a 1:10,000 risk of death. EPA uses the VSL figure as follows. First, EPA must determine how many people will be affected by projected emissions reductions, and how reduced exposure to pollutants influences the probability of death – for example, from cardiovascular or respiratory ailments due to pollution exposure. This probability is multiplied by the number of people affected to obtain the number of statistical lives lost. The number of statistical lives lost is then multiplied by the VSL to calculate the final dollar value for mortality. Note that this approach does not attempt to assign different values to different lives lost based upon age, earning power, etc.; rather, it assigns the same default VSL to each life.[5]

This default VSL, just like many other economic values used by EPA, is not independently determined by EPA but is based upon 26 published VSL studies. These studies determine VSL using various valuation methods. They include (i) the hedonic wage method, which estimates the rate at which workers are willing to trade-off health risks for wages, (ii) the averting behavior method, which looks at how much money people actually spend to reduce risks, and (iii) the stated preference method, which uses simulated markets (in surveys) to ask individuals to value how much they would be willing to spend to reduce risk. The variety of ways in which VSL can be calculated results in a wide range of values. In the 26 studies used, the values range from $1.0 million to $23.25 million (in 2014$)[6] with the average being $8.7 million (in 2014$) (EPA, 2014a).

EPA also values the incidence of non-fatal illnesses, known as morbidity. Economists use similar economic methods to determine morbidity benefits. The most commonly used methods are stated preference, averting behavior method, and cost-of-illness method (COI). The COI method estimates the cost to deal with the illness after contraction and does not consider any costs associated with preventing illness.[7] Major morbidity and mortality risks are generally included in the dollar estimate of the benefits of an air regulation so long as EPA can justify the uncertainties and assumptions made.

Monetizing Ecological Benefits

Economists use a different set of valuation methods to quantify ecological benefits. Some of these benefits can be estimated in a straightforward manner from market data – for example, changes in the production of crops, timber, and commercial fish can be valued at their market prices. However, non-market ecological benefits are more difficult to quantify than health benefits, in part because there is sometimes disagreement over the value that ought to be measured. *Use values* are attributes of an environment that can be enjoyed by the population, such as recreational or consumable attributes. *Non-use values* are to attributes that are not directly enjoyed by the population. This could include preservation of reserved lands or endangered species for the sake of preservation. Use values are easier to quantify than non-use values. The only methods for monetizing non-use values are stated preference methods, involving surveys which are controversial and costly to implement. While EPA has some guidelines for how to assess ecological benefits, most of the RIAs for air regulations do not include ecological benefits in the dollar estimate and only provide a qualitative discussion on how regulatory action could affect ecological systems.

One environmental effect that has been quantified in RIAs is visibility. Suspended particles such as sulfur dioxide (SO_2), nitrogen oxide (NO_2), and other particulate matter (PM) scatter and absorb light which reduces visibility and, subsequently, people's aesthetic enjoyment (of views, for example). As a result of decreased visibility, the visual range in eastern national parks has decreased from 90 miles to 15-25 miles. The visual range in

5 While evidence from the empirical economics literature suggests that VSL does vary with age (Viscusi & Aldy 2007, Aldy & Viscusi 2008, O'Brien 2013), EPA does not currently adjust VSL to account for age or any other individual characteristic. During the George W. Bush administration, an effort was made to incorporate age-adjusted VSL into regulatory impact analysis, but the ensuing political controversy over what came to be called the "senior discount" caused the U.S. Congress to include a prohibition on funding analyses made using age-adjusted VSL estimates in the 2004 Appropriations Bill (Robinson 2007). The ban remains in place.

6 The original values used in EPA reports are $0.85 million to $19.8 million in 2006$.

7 EPA collects and evaluates published estimates for morbidity in its Handbook for Non-Cancer Valuation and Cost of Illness Handbook.

western national parks has decreased from 140 to 35 - 90 miles. Reduction in visibility in Class I areas affect all households in the U.S. and not just populations that reside around the parks.

Standardized Benefit-per-ton Estimates

For certain pollutants that are frequently the subject of EPA RIAs, EPA has already calculated a benefit-per-ton (BPT) of reduced emissions. This is the case for reductions in emissions of $PM_{2.5}$,[8] which are included among the benefits of all three of the EPA rules addressed in this white paper. The EPA determines the BPT by determining the amount of $PM_{2.5}$ emitted from certain sectors in the U.S.. These sectors also have associated estimates for health impacts determined by Benefits Mapping and Analysis Program (BenMAP). BenMAP models health impacts based on the difference between post-policy air quality and baseline air quality. While running a BenMAP model provides valuable, granular information on the overall health impacts of a new regulation, the process is very time and resource intensive. As a result, EPA divides the dollar value of health impacts by the previously determined emissions amount to come up with a BPT (EPA, 2011a). Use of BPT estimates simplifies the benefit valuation portion of individual RIAs, and allows standardization across these studies, as well.

BPT Estimates for $PM_{2.5}$

EPA can model the changes in emissions of fine particulate matter ($PM_{2.5}$) and determine the number of people exposed to $PM_{2.5}$. However, the health impact of $PM_{2.5}$ reduction varies by location and conditions such as climate, stack height, and population density. As a result of heterogeneity in the system, EPA would have to run time and resource intensive models for each change in emissions if it did not have a BPT estimate. Instead, EPA can assume changes in health impact (Δy) from the base case (y_0) by using a function such as the following:

(1)

$$\Delta y = y_0 \times (e^{\beta \Delta x} - 1)$$

EPA estimates the effects on estimated mortality and morbidity incidences (β) as a result of changes in $PM_{2.5}$ emissions (Δx) by using values found in epidemiological studies.[9] The calculated changes in health benefits can then be multiplied by VSL or by morbidity economic estimates depending on the health impact being analyzed. EPA then calculates the BPT by dividing this value by the emission reduction assumed. EPA can then apply the BPT for more and less stringent cases so that it does not have to run models for each emissions reduction scenario.

Social Cost of Carbon

Another pollutant for which EPA relies on a standardized BPT is carbon dioxide. The U.S. Government created an interagency group to determine the benefits of carbon dioxide (CO_2) emission reductions. The group estimated the social cost of carbon (SC-CO_2) by considering damages including "net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning."[10] Climate change is a global problem, which distinguishes CO_2 from other pollutants, the effects of which are more localized. As a result, most of the studies surrounding CO_2 effects calculate its cost based on global GDP rather than national or local effects. To determine the effects from just the United States, the interagency group multiplies the global GDP effect by the percentage

8 $PM_{2.5}$ is particulate matter (fine particles) 2.5 microns or smaller.

9 For the MATS and CSAPR rules, EPA used two studies (Pope et al. (2002) and Laden et al. (2006)) to determine the relationship between emissions and health impacts. The Pope study applied to levels of $PM_{2.5}$ above 10 µg/m3, and the Laden study applied to levels of $PM_{2.5}$ above 7.5 µg/m3. The CSPAR RIA sample showed that 96% of the avoided deaths studied were above or at 7.5 µg/m3 and 69% were above or at 10 µg/m3. The MATS RIA sample showed that 73% of the avoided premature deaths studied were above or at 7.5 µg/m3 and 11% were above or at 10 µg/m3. The EPA assumed that using the results of these studies was within a reasonable amount of uncertainty since evidence shows that even small concentrations of $PM_{2.5}$ can still be detrimental to human health.

EPA updated the epidemiological studies used in the CPP (Krewski et al., (2009) and Lepeule et al, (2012)). For CPP, 88% of the population is exposed to limits at or above the level found in the Krewski study. 46% of the population is exposed to limits at or above the level found in the Lepeule study.

10 The EPA recognizes the challenges associated with putting a cost on carbon and notes "any assessment will suffer from uncertainty, speculation, and lack of information… As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics and ethics and should be viewed as provisional."

TABLE 1:

U.S. Social Cost of Carbon in $ / short ton from 2015 to 2050 in (in 2011$)

Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% (95th Percentile)
	$ / short ton of CO_2 (in 2011$)[a]			
2015	11	35	54	100
2020	12	40	60	120
2025	13	44	65	130
2030	15	48	70	150
2035	17	53	75	160
2040	20	58	81	180
2045	22	62	86	190
2050	25	66	91	200

(From EPA, 2015a) a: The SC-CO_2 values listed in this table have not been converted to 2014$ since the table includes future projections of SC-CO_2.

share of global GDP attributable to the U.S. to determine the cost per ton of CO_2 emissions in a given year.

The SC-CO_2 does not include certain climate-related impacts which are especially difficult to measure or value. For example, the SC-CO_2 does not include ocean acidification, effects on sensitive ecosystems, or climate effects from greenhouse gases other than CO_2. It also does not include climate-related effects on ozone or $PM_{2.5}$ levels. As a result, the current U.S. SC-CO_2 could be underestimating the benefits of CO_2 reduction.

The economic damage of climate change is calculated using so-called Integrated Assessment Models (IAMs), which model the relationship between changes in the climate and the global economy.[11] The interagency group used climate sensitivity, socio-economic and emissions trajectories, and discount rates as inputs for these models and left all other aspects of the models constant.[12] The SC-CO_2 from 2015 to 2050 are shown in the Table 1 for various discount rates and scenarios.

The SC-CO_2 associated with each year in the table measures the present (2011$) discounted value of a ton of CO_2 emissions in that year. For example, the 2011 marginal damage from a ton of CO_2 emitted in 2015 (assuming a discount rate of 3%) is $35. The same ton emitted in 2030 would cause damages with a present value of $48 (in 2011$), because the marginal damages from CO_2 emissions are expected to increase over time, as the stock of CO_2 continues to increase in the upper atmosphere. Since the model inputs include climate sensitivity and socio-economic and emissions trajectories, the model includes a range of potential outcomes. The first three columns in Table 1 report average SC-CO_2 values at different discount rates, while the fourth column reports values that put relatively more weight on the possibility of catastrophic climate outcomes. Though EPA calculates the four values (average scenario at 2.5%, 3%, and 5% discount rates and 95th percentile scenario), it only uses the average scenario at 3% discount rate to compare benefits to costs of emissions reductions.

As can be seen from Table 1, the chosen discount rate greatly influences the SC-CO_2.[13] Note that there is considerable disagreement, even among economists, regarding the appropriate rate at which to discount future climate damages. A 5% discount

11 The three main IAMs are DICE, PAGE, and FUND. Each model converts emissions to dollars slightly differently, and the EPA uses all three models to determine SC-CO_2 for RIAs (EPA, 2015b). The larger IAM literature has produced a broad range of SCC estimates, from slightly negative values to values well in excess of $100/ton. The last column in Table 3 reflects that wide range of estimates.

12 The interagency group considered average and 95th percentile damage rates and 2.5%, 3%, and 5% discount rates. These inputs have not changed since the first interagency report in 2010. However, the SC-CO_2 values were updated in 2013 as a result of updated IAMs.

13 Discounting is usually used to compare alternative capital investment options over a period of time. For SC-CO_2, a discount rate of 0% assumes that each year, or generation, is equally important so climate change should be dealt with more stringently and as soon as possible. A positive discount rate puts greater emphasis on the preferences of the current generation over future generations. The higher the discount rate, the greater the shift in responsibility to future generations. This trend can be seen in the figure above. A higher discount rate results in a lower SC-CO_2 while a lower discount rate correlates with a higher SC-CO_2.

rate is closer to returns seen in capital investments. The lower discount rate of 2.5% is closer to the choice to treat each generation as equally important and takes into consideration the high uncertainty of interest rates over time. The 3% discount rate is in line with the OMB recommendation for regulations that affect consumption of individuals and is used regularly in air regulation RIAs (EPA, 2010).

EPA plans to continually update the SC-CO_2 as new research results suggest that changes need to be made (EPA, 2010). In the discussion of specific air regulations, the Clean Power Plan (CPP) uses the values shown in Table 1, but CSAPR and MATS use older values since their corresponding RIAs were published before the new 2015 report.

2 | ASSUMPTIONS IN EXISTING AIR REGULATIONS

To illustrate how EPA uses these benefit estimates in practice, we use RIAs for three recent EPA regulations issued under the agency's Clean Air Act authority: the Cross State Air Pollution Rule (CSAPR), the Mercury and Air Toxics Standards (MATS), and the Clean Power Plan (CPP).

Cross State Air Pollution Rule

The Cross State Air Pollution Rule (CSAPR, also known as the Transport Rule) seeks to reduce the amount of SO_2 and NO_x that traverses across state lines.[14] These traveling pollutants are precursors to ozone and $PM_{2.5}$[15] and contribute to neighboring states' inability to attain ozone and $PM_{2.5}$ limitations set by the National Ambient Air Quality Standards (NAAQS). In total, 27 states will be affected by this rule since they contributed significantly to neighboring states' 24-hour $PM_{2.5}$ NAAQS, annual $PM_{2.5}$ NAAQS, and 8-hour ozone NAAQS.[16] The overall benefit of CSAPR according to the RIA ranges from $137 billion to $320 billion using a 3% discount rate and $126 billion to $286 billion using a 7% discount rate (in 2014$).[17] The expected social cost[18] equals about $1.6 billion (in 2014$)[19] in 2012 and $0.9 billion (in 2014$)[20] in 2014 (EPA, 2011a). Table 2 shows the effects included in the dollar value along with their estimated cost.

EPA models the post-policy air quality and compares it with the baseline air quality to find the overall change in quality. Since CSAPR replaced the Clean Air Interstate Rule (CAIR), the baseline air quality used in the CSAPR model assumes that CAIR was not in effect. However, states did implement CAIR so the baseline emissions levels used in the model may be modestly different than what they actually are. CAIR cannot be included in the baseline, however, because the EPA cannot assume "that the reductions required by CAIR will continue to be achieved" (EPA, 2011a).[21]

The largest benefit contributor is the reduction of premature mortality for adults.[22] EPA calculates the benefit of reductions of $PM_{2.5}$ and ozone (O_3) by determining changes in local air quality and population, determining how these air quality changes affect health, and then converting the health impacts into dollar values. To prepare the RIA for CSAPR and MATS, EPA calculated air quality and meteorological changes in 12 km x 12 km blocks in the Eastern United States and in 36 km x 36 km for the rest of the country.[23] EPA overlays the emission modeling with population models to determine the reduction of exposure on various groups. This information is then inputted into BenMAP models to calculate the health impact of emission reduction. Once changes in mortality rates are determined, EPA uses the VSL to determine the final dollar value after a policy is implemented. Based on EPA's assessment, CSAPR will reduce the number of premature deaths by 13,000 (according to the Pope study) to 34,000 (according to the Laden study) deaths per year. This correlates to $114 billion to $308 billion (in 2014$) at a discount rate of 3% and $107 billion to $274 billion (in 2014$) at a discount rate of 7% (EPA, 2011a).

14 As mandated by Clean Air Act Section 110(a)(2)(D)(i)(I).

15 SO_2 and nitrogen oxides (NOx) become particulate sulfate and particulate nitrate which are considered $PM_{2.5}$.

16 The effected states include: Alabama, Arkansas, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

17 The original values used in CSAPR RIA are $120 billion to $280 billion using a 3% discount rate and $110 billion to $250 billion in 2007$.

18 The social cost includes the cost of reduced levels of electricity demand as a result of changes in electricity prices.

19 The original value used in CSPAR RIA is $1.4 billion in 2007$.

20 The original value used in CSAPR RIA is $0.8 billion in 2007$.

21 The D.C. Circuit Court found CAIR to be unlawful in July 2008. However, it allowed CAIR to remain in effect until it was replaced by a new, lawful rule. Since CAIR was allowed to remain in effect, it actually did reduce emissions in many states. Some states covered in CAIR are not covered in CSAPR so there is a chance that emissions would increase in those states once CAIR is vacated.

22 EPA found that $PM_{2.5}$ responsible for 130,000 to 320,000 premature deaths in 2005, and that ozone was responsible for 4,700 premature deaths in 2005. Combined, they made up 6.1% of total deaths in the U.S. (EPA, 2011b)

23 The model also calculates pre- and post-policy emission levels at 14 different vertical layers. The Eastern United States is modeled at a finer level since these are the states that are most affected by the rule.

TABLE 2:

Benefit Categories for CSAPR with Dollar Estimates

Benefit Category	Specific Effect	Total Cost at 95% conf. in billions of 2014$[b] (discount rate)
$PM_{2.5}$ and O_3		
Premature Mortality	Adults	114 – 308 (3%) 107 – 274 (7%) *lower values in range by Pope et al., 2002 for PM and Bell et al. 2004 for ozone; higher values by Laden et al., 2006 for PM and Levy et al., 2004 for ozone
Morbidity	Hospital admissions – respiratory	0.05
	Emergency room visits for asthma	0.003
	Minor restricted-activity Days	0.8
$PM_{2.5}$		
Morbidity	Non-fatal heart attacks	1.9 (3%) 1.5 (7%)
	Hospital admissions – cardiovascular	0.1
	Acute bronchitis	0.009
	Lower respiratory symptoms	0.005
	Upper respiratory symptoms	0.006
	Asthma exacerbation	0.02
	Lost work days	0.2
	Chronic bronchitis	4.8
Recreational	Recreational visibility, Class I areas	4.7
O_3		
Morbidity	School loss days	0.01
CO_2		
Climate Effects	Social cost of carbon	0.7 (3%, 2014 value)

(From EPA, 2011a)

b: All values in the table have been converted from 2007$ to 2014$.

EPA used the same methodology to calculate the morbidity effects of $PM_{2.5}$ and ozone. These effects are much smaller in economic magnitude than mortality effects but may occur much more frequently. For example, reduction of lost work days contributes $0.2 billion (in 2014$) to the total benefits. However, work loss days occur 100 times more often than premature mortalities. The economic value of each incidence is minute compared to the VSL.

EPA also includes recreational visibility for Class I (national parks) areas as a monetized benefit of the CSAPR. Visibility was not included in BPT estimates, however, and so while CPP and MATS also increase visibility as a result of $PM_{2.5}$ emission reduction, the RIAs do not compare the benefits of increased visibility with the cost related to implementation of MATs or CPP.

EPA also considers reductions in CO_2 as part of its CSAPR benefit calculation. The SC-CO_2 used for CSAPR and MATS was released prior to the values shown in Table 1. The SC-CO_2 used for CSAPR in 2014 ranged from $6.3 to $81.3 per metric ton of CO_2 (in 2014$)[24], consistent with the SC-CO_2 determined in the 2010 interagency study (EPA, 2010).

24 The original values used in CSAPR RIA are $5.5 to $71.2 per metric ton of CO_2 in 2007$.

TABLE 3:

Benefit Categories for MATS with Dollar Estimates

Benefit Category	Specific Effect	Total Benefit at 95% conf. in billions of 2014$[c] (discount rate)
$PM_{2.5}$		
Premature Mortality	Adults	39 – 99 (3%) 34 – 89 (7%) *lower values in range by Pope et al., 2002; higher values by Laden et al., 2006
	Infants	0.2
Morbidity	Non-fatal heart attacks	0.6 (3%) 0.5 (7%)
	Hospital admissions – respiratory	0.01
	Hospital admissions – cardiovascular	0.03
	Emergency room visits for asthma	<0.01
	Acute bronchitis	<0.01
	Lower respiratory symptoms	<0.01
	Upper respiratory symptoms	<0.01
	Asthma exacerbation	<0.01
	Lost work days	0.1
	Minor restricted-activity Days	0.2
	Chronic bronchitis	1.6
Mercury		
Morbidity	Exposure to MeHg, neurologic effects – IQ Loss	0.005 - $0.007 (3%) 0.0006 - $0.001 (7%)
CO_2		
Climate Effects	Global climate impacts from CO_2	0.41 (3%)

(From EPA, 2011b)

c: All values in the table have been converted from 2007$ to 2014$.

Mercury and Air Toxics Standards

The Mercury and Air Toxics Standard (MATS) requires coal-fired power plants to reduce their emissions of hazardous air pollutants (HAPs) including mercury (Hg), arsenic, cadmium, lead, nickel, and other pollutants. The control technologies required to reduce HAPs will also reduce sulfur dioxide (SO_2) and fine particulate matter ($PM_{2.5}$). The estimated benefit of MATS according to the RIA ranges from $42 billion to $103 billion using a 3% discount rate and $38 billion to $93 billion using a 7% discount rate (in 2014$).[25] The expected compliance cost is about $11.0 billion (in 2014$), representing mostly the capital cost of installating mercury controls (which differ by plant type) and equipment operational costs.[26] The table below shows the effects included in the dollar value along with their estimated benefit.

As can be seen from Table 3, mercury effects make up a very small portion of the total benefits of MATS; most of the benefits are associated with reductions in emissions of $PM_{2.5}$. At the same time, it should also be noted that some of the benefits associated with reduced exposure to mercury were omitted from the cost-benefit analysis. The only monetized benefit of mercury reduction is associated with reduced exposure to methyl mercury (MeHg) found in fish, and includes dollar estimates only for the effects of recreationally

25 The original values used in MATS RIA are $37 billion to $90 billion using a 3% discount rate and $33 billion to $81 billion using a 7% discount rate in 2007$.

26 The original value used in MATS RIA is $9.6 billion in 2007$.

caught fish which account for between 10 to 17% of U.S. fish consumption. The RIA excludes (i) some health effects of mercury exposure that could not be quantified, including cardiovascular, genetic, other neurologic (impaired cognitive development, problems with language, abnormal social development), and carcinogenic effects, in part because there are few, high-quality studies that monetize these effects, and (ii) some pathways of mercury exposure, including consumption of commercially caught fish, which account for the majority of fish consumption in the U.S. . Finally, ecological benefits are also not monetized since much of the research conducted so far is heavily generalized and not necessarily a realistic representation of the regulation's impacts.

EPA quantifies the effects of MeHg exposure by projecting reductions in the IQ and earning potential of unborn children of women who consume fish. EPA calculates the number of IQ points lost by first determining the number of people affected by MeHg exposure. EPA determined the number of pregnant women who eat recreationally caught fish from rivers and lakes. EPA also determined the concentration of MeHg in these bodies of water by assuming that MeHg proportionally decreases with emissions from electricity generating units (EGUs).[27] The agency then estimated daily mercury ingestion rates by the affected population. The IQ of unborn children decreases as their pregnant mothers ingest higher quantities of MeHg found in fish. Once MATS goes into effect, Hg concentration will decrease, and IQ loss in exposed children will also decrease. Using existing studies that tie IQ with income,[28] the estimated decrease in IQ points lost due to MATS correlates to an estimated benefit of $4.8 million to $7.1 million (in 2014$) at a 3% discount rate and $0.54 million to $1.1 million (in 2014$)[29] at a 7% discount rate (EPA, 2011b).[30]

It is evident that, as with CSAPR, most of the benefits of the mercury rule come from $PM_{2.5}$ reduction, since mercury control technologies also affect $PM_{2.5}$. The method by which EPA determined the dollar estimate is the same as was described in the benefit per ton CSAPR section of this paper. Since CSAPR was passed during the creation of the MATS RIA, the MATS RIA considers CSAPR as part of its baseline analysis, thereby avoiding double counting of those effects.[31] The resulting benefits estimate of $PM_{2.5}$ reduction is between $39 billion to $99 billion (in 2007$) at a 3% discount rate and between $34 billion to $89 billion (in 2007$)[32] at a 7% discount rate.

Although the MATS Rule will increase visibility, EPA did not include visibility as part of the benefit estimate compared to costs. The MATS Rule does consider reductions in CO_2 as part of its benefit. The SC-CO_2 used for MATS was released prior to the values in Table 1. The SC-CO_2 used for MATS for 2016 is consistent with the estimates in the 2010 interagency study (EPA, 2010).

Clean Power Plan

In accordance with CAA Section 111(d), EPA finalized the Clean Power Plan (CPP) on August 5, 2015 and released an updated RIA the same month. The CPP regulates the amount of greenhouse gas emissions from fossil fuel-fired electric steam generating units and stationary combustion turbines for each state. While the main target

27 The EPA uses a modeling program called Mercury Maps (MMaps) to estimate the changes in Hg accumulation in bodies of water located near EGUs. MMaps only considers EGUs as a source for mercury and does not take into consideration ecosystem effects that may alter the concentration of MeHg in fish. This is, however, currently the best method for estimating MeHg concentrations (EPA, 2011a).

28 The EPA determined the potential lost future earnings as a result of MeHg exposure. Based on existing research, a 1-point increase in IQ can increase lifetime earnings by 1.76% to 2.379%. The EPA also assumes that a 1-point increase in IQ increases the years of schooling by 0.131 years. The net loss per change in IQ point ranged from $893 to $1,958 (EPA, 2011a).

29 The original values in MATS RIA are $4.2 million to $6.2 million at a 3% discount rate and $0.47 billion to $1.0 billion at a 7% discount rate in 2007$.

30 The studies that link IQ to economic valuation have noted that IQ is not very sensitive to changes in MeHg concentrations and likely undervalues the impact of MeHg on cognitive abilities. Additionally, these studies assume that the economic value of IQ loss is correlated with losses in future earnings. However, a parent's WTP to avoid IQ loss in their children may be much higher. As a result, the value of IQ loss avoidance may be much higher than assumed in the MATS RIA.

31 In doing so, it does not assume the same benefits for reductions in $PM_{2.5}$, SO_2, or NOx. However, additional changes were made to the CSAPR that affected the levels of SO_2 emission reductions. This change was not reflected in the CSAPR or MATS RIA (EPA, 2011a).

32 The original values in MATS RIA are $34 billion to $87 billion at a 3% discount rate and between $30 billion to $78 billion at a 7% discount rate in 2007$.

of the CPP is to reduce CO_2 emissions, the CPP will also reduce SO_2, NO_2, $PM_{2.5}$, and ozone. EPA determined each state's specific goal by using the following three building blocks:

(1) Improving heat rate at affected coal-fired steam electric generating units (EGUs).

(2) Substituting increased generation from lower-emitting existing natural gas combined cycle units for reduced generation from higher-emitting affected steam generating units.

(3) Substituting increased generation from new zero-emitting generating capacity for reduced generation from affected fossil fuel-fired generating units (EPA, 2015a).

EPA has provided rate-based and mass-based CO_2 emissions limits for all states and established a final emission goal to be met by 2030 and an interim goal for 2022 to 2029. Each state must choose one approach, and thus, the two options provide states flexibility for how to reach the established goals. The mass-based approach will reduce emissions sooner than the rate-based approach. For both the rate-based and mass-based approaches, national CO_2 emissions will be reduced by 32% from the base case scenario if all states meet their targets. Since the reduction changes throughout the time period, EPA provided cost benefit information for 2020, 2025, and 2030 in the RIA.

Because EPA grants states flexibility in determining the means of compliance with these mandated reductions, it is very difficult to estimate both the costs and the benefits of the rule, and EPA's estimates must be considered with that proviso. EPA estimated that the compliance cost for the rate-based approach would be $2.5 billion (in 2011$) in 2020, $1.0 billion (in 2011$) in 2025, and $8.4 billion (in 2011$) in 2030. The compliance cost for the mass-based approach would be $1.4 billion (in 2011$) in 2020, $3.0 billion (in 2011$) in 2025, and $5.1 billion (in 2011$) in 2030. The compliance cost was calculated based on "estimated incremental electric utility generating costs changes from the base case plus the estimates of demand-side energy efficiency program costs (which are paid by electric utilities), demand-side energy efficiency participant costs (which are paid by electric utility consumers), and [monitoring, reporting, and recordkeeping requirements (MR&R)] costs" (EPA, 2015a).

The monetized benefits of CPP derive from the federal government's SC-CO_2 values, as shown in

TABLE 4:

Benefit Categories for CPP with Dollar Estimates for Rate-based Approach

Benefit Category	Total Benefit at 95% conf. in billions of 2011$ (discount rate, scenario)		
	2020	2025	2030
SO_2	0.44 to 0.99 (3%) 0.39 to 0.89 (7%)	6.4 to 14 (3%) 5.7 to 13 (7%)	12 to 28 (3%) 11 to 25 (7%)
NOx (as $PM_{2.5}$)	0.14 to 0.33 (3%) 0.13 to 0.30 (7%)	0.56 to 1.3 (3%) 0.50 to 1.1 (7%)	1.0 to 2.3 (3%) 0.93 to 2.1 (7%)
NOx (as Ozone)	0.12 to 0.52 (3%) 0.12 to 0.52 (7%)	0.49 to 2.1 (3%) 0.49 to 2.1 (7%)	0.86 to 3.7 (3%) 0.86 to 3.7 (7%)
Total non-CO_2	0.70 to 1.8 (3%) 0.64 to 1.7 (7%)	7.4 to 18 (3%) 6.7 to 16 (7%)	14 to 34 (3%) 13 to 31 (7%)
CO_2			
Climate Effects	0.80 (5%, avg) 2.8 (3%, avg) 4.1 (2.5%, avg) 8.2 (3%, 95^{th})	3.1 (5%, avg) 10 (3%, avg) 15 (2.5%, avg) 31 (3%, 95^{th})	6.4 (5%, avg) 20 (3%, avg) 29 (2.5%, avg) 61 (3%, 95^{th})

(From EPA, 2015a)

TABLE 5:

Benefit Categories for CPP with Dollar Estimates for Mass-based Approach

Benefit Category	Total Benefit at 95% conf. in billions of 2011$ (discount rate, scenario)		
	2020	2025	2030
SO_2	1.7 to 3.8 (3%) 1.5 to 3.4 (7%)	6.0 to 13 (3%) 5.4 to 12 (7%)	10 to 23 (3%) 9.0 to 20 (7%)
NOx (as $PM_{2.5}$)	0.17 to 0.39 (3%) 0.16 to 0.36 (7%)	0.58 to 1.3 (3%) 0.52 to 1.2 (7%)	0.87 to 2.0 (3%) 0.79 to 1.8 (7%)
NOx (as Ozone)	0.14 to 0.61 (3%) 0.14 to 0.61 (7%)	0.56 to 2.4 (3%) 0.56 to 2.4 (7%)	0.82 to 3.5 (3%) 0.82 to 3.5 (7%)
Total non-CO_2	2.0 to 4.8 (3%) 1.8 to 4.4 (7%)	7.1 to 17 (3%) 6.5 to 16 (7%)	12 to 28 (3%) 11 to 26 (7%)
CO_2			
Climate Effects	0.94 (5%, avg) 3.3 (3%, avg) 4.9 (2.5%, avg) 9.7 (3%, 95th)	3.6 (5%, avg) 12 (3%, avg) 17 (2.5%, avg) 35 (3%, 95th)	6.4 (5%, avg) 20 (3%, avg) 29 (2.5%, avg) 60 (3%, 95th)

(From EPA, 2015a)

Table 1, as well as co-benefits from reduced ozone levels and $PM_{2.5}$ emissions. The co-benefits of the CPP only include non-climate-related benefits, and as with the MATS rule, these are calculated so to avoid double counting benefits created by prior rules (including CSAPR and MATS).[33] For ozone, the CPP benefit includes avoided premature deaths and morbidity as a result of ozone exposure, calculated using the method described in earlier sections. The dollar values associated with the co-benefits are calculated at 3% and 7% discount rates which are different from the discount rates used to calculate SC-CO_2 since the effects are not as long lived as that of CO_2. Benefit estimates for $PM_{2.5}$ and ozone follow the same BPT approach as described for the MATS estimate. It is evident from Table 4 that, as was the case with MATS, the co-benefits from reductions in associated local and regional pollutants represent a large portion (though not as large a portion) of the total monetized benefits.

Unlike CSAPR and MATS, CPP does not dictate emission reductions at specific plants. This makes air quality modeling more difficult. It will be up to the states to decide how to comply with their overall targets, and states' choice of policy approaches will determine the distribution of abatement across plants.

BPT estimates are used to determine the co-benefits. SO_2 in Table 4 and Table 5 is associated with $PM_{2.5}$ formation. Similarly, the CPP RIA shows $PM_{2.5}$ and ozone effects resulting from NO_x. $PM_{2.5}$ has a greater relation with SO_2 concentrations and so the benefits of SO_2 reduction are much higher than the benefits of NO_x reduction. The rate-based approach and mass-based approaches result in comparable monetized benefits from 2020 to 2030, but the mass-based approach has slightly lower climate impacts than the rate-based approach. In 2030, the climate effects are almost identical except for the 95th percentile scenario. Non-CO_2 benefits are higher for the mass-based approach in 2020 but higher for the rate-based approach in 2025 and 2030.

33 For example, the dollar estimate of ozone benefits does not include ozone effects mitigated by reduction in temperature.

3 CONCLUSION

Since EPA lacks resources to conduct much independent research, it often relies on peer-reviewed journal articles that correlate environmental pollution with social benefits, both monetized and not. Well-respected, peer-reviewed studies are used repeatedly across EPA's various air regulations, to ensure consistency in benefit estimates across rules. EPA takes great strides to ensure that the values used to calculate the dollar estimate of air regulation benefits do not double count reduced air pollution damages either across impacts (e.g., reductions in $PM_{2.5}$ from SO_2 and NO_x reductions) or across regulations (e.g., MATS vs. CPP). While the inputs to RIAs are imperfect, EPA clearly explains its procedures, assumptions, and sources of information in the reviewed RIAs. These documents and the benefit estimation methods they employ clearly play an important role in air pollution regulation policy debates. ■

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APPENDIX A – VALUE OF STATISTICAL LIFE STUDIES USED BY EPA

Table B.1 - Value of Statistical Life Estimates (mean values in millions of 2006 dollars)

Study	Method	Value of Statistical Life
Kniesner and Leeth (1991 - US)	Labor Market	$0.85
Smith and Gilbert (1984)	Labor Market	$0.97
Dillingham (1985)	Labor Market	$1.34
Butler (1983)	Labor Market	$1.58
Miller and Guria (1991)	Contingent Valuation	$1.82
Moore and Viscusi (1988)	Labor Market	$3.64
Viscusi, Magat, and Huber (1991)	Contingent Valuation	$4.01
Marin and Psacharopoulos (1982)	Labor Market	$4.13
Gegax et al. (1985)	Contingent Valuation	$4.86
Kniesner and Leeth (1991 - Australia)	Labor Market	$4.86
Gerking, de Haan, and Schulze (1988)	Contingent Valuation	$4.98
Cousineau, Lecroix, and Girard (1988)	Labor Market	$5.34
Jones-Lee (1989)	Contingent Valuation	$5.59
Dillingham (1985)	Labor Market	$5.71
Viscusi (1978)	Labor Market	$6.07
R.S. Smith (1976)	Labor Market	$6.80
V.K. Smith (1983)	Labor Market	$6.92
Olson (1981)	Labor Market	$7.65
Viscusi (1981)	Labor Market	$9.60
R.S. Smith (1974)	Labor Market	$10.57
Moore and Viscusi (1988)	Labor Market	$10.69
Kniesner and Leeth (1991 - Japan)	Labor Market	$11.18
Herzog and Schlottman (1987)	Labor Market	$13.36
Leigh and Folsom (1984)	Labor Market	$14.21
Leigh (1987)	Labor Market	$15.31
Garen (1988)	Labor Market	$19.80

Derived from U.S. EPA (1997a) and Viscusi (1992). Updated to 2006$ with GDP deflator.

Source: (EPA, 2014b)

APPENDIX B – BENEFITS AND VALUATION METHODS USED BY EPA

Table 7.1 - Types of Benefits Associated With Environmental Policies: Categories, Examples, and Commonly Used Valuation Methods

Benefit Category	Examples	Commonly Used Valuation Methods
Human Health Improvements		
Mortality risk reductions	Reduced risk of: Cancer fatality Acute fatality	Averting behaviors Hedonics Stated preference
Morbidity risk reductions	Reduced risk of: Cancer Asthma Nausea	Averting behaviors Cost of illness Hedonics Stated preference
Ecological Improvements		
Market products	Harvests or extraction of: Food Fuel Fiber Timber Fur and Leather	Production function
Recreation activities and aesthetics	Wildlife viewing Fishing Boating Swimming Hiking Scenic views	Production function Averting behaviors Hedonics Recreation demand Stated preference
Valued ecosystem functions	Climate moderation Flood moderation Groundwater recharge Sediment trapping Soil retention Nutrient cycling Pollination by wild species Biodiversity, genetic library Water filtration Soil fertilization Pest control	Production function Averting behaviors Stated preference
Non-use values	Relevant species populations, communities, or ecosystems	Stated preference
Other Benefits		
Aesthetic improvements	Visibility Taste Odor	Averting behaviors Hedonics Stated preference
Reduced materials damages	Reduced soiling Reduced corrosion	Averting behaviors Production / cost functions

Note: "Stated preference" refers to all valuation studies based on hypothetical choices, as distinguished from "revealed preference," which refers to valuation studies based on observations of actual choices.

Source: (EPA, 2014b)

APPENDIX C – CROSS-STATE AIR POLLUTION RULE (CSAPR)

CSAPR List of All Health Effects

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

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

Source: (EPA, 2011a)

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CSAPR List of All Health Effects

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

Source: (EPA, 2011a)

Projected Emissions with and without CSAPR

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

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

* In this table, man-made emissions includes average fires.

Source: (EPA, 2011a)

CSAPR Benefits and Costs Estimate

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

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

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

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

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

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

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

Source: (EPA, 2011a)

APPENDIX D – MATS RULE

MATS List of All Effects

Table ES-5. Human Health Effects of Pollutants Affected by the Mercury and Air Toxics Standards

Benefits Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information[a]
Improved Human Health				
Reduced incidence of premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimates and expert elicitation estimates (age >25 or age >30)	✓	✓	Section 5.4
	Infant mortality (age <1)	✓	✓	Section 5.4
Reduced incidence of morbidity from exposure to $PM_{2.5}$	Non-fatal heart attacks (age > 18)	✓	✓	Section 5.4
	Hospital admissions—respiratory (all ages)	✓	✓	Section 5.4
	Hospital admissions—cardiovascular (age >18)	✓	✓	Section 5.4
	Emergency room visits for asthma (age <18)	✓	✓	Section 5.4
	Acute bronchitis (age 8–12)	✓	✓	Section 5.4
	Lower respiratory symptoms (age 7–14)	✓	✓	Section 5.4
	Upper respiratory symptoms (asthmatics age 9-11)	✓	✓	Section 5.4
	Asthma exacerbation (asthmatics age 6–18)	✓	✓	Section 5.4
	Lost work days (age 18-65)	✓	✓	Section 5.4
	Minor restricted-activity days (age 18–65)	✓	✓	Section 5.4
	Chronic bronchitis (age >26)	✓	✓	Section 5.4
	Other cardiovascular effects (e.g., other ages)	—	—	PM ISA[c]
	Other respiratory effects (e.g., pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA[c]
	Reproductive and developmental effects (e.g., low birth weight, pre-term births, etc)	—	—	PM ISA[c, d]
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA[c, d]
Reduced incidence of mortality from exposure to ozone	Premature mortality based on short-term study estimates (all ages)	—	—	Ozone CD, Draft Ozone ISA[b]
	Premature mortality based on long-term study estimates (age 30–99)	—	—	Ozone CD, Draft Ozone ISA[b]
Reduced incidence of morbidity from exposure to ozone	Hospital admissions—respiratory causes (age > 65)	—	—	Ozone CD, Draft Ozone ISA[b]
	Hospital admissions—respiratory causes (age <2)	—	—	Ozone CD, Draft Ozone ISA[b]
	Emergency room visits for asthma (all ages)	—	—	Ozone CD, Draft Ozone ISA[b]
	Minor restricted-activity days (age 18–65)	—	—	Ozone CD, Draft Ozone ISA[b]

Source: (EPA, 2011b)

Continued on next page

MATS List of All Effects

Continued from previous page

Table ES-5. Human Health Effects of Pollutants Affected by the Mercury and Air Toxics Standards (continued)

Benefits Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
	School absence days (age 5–17)	—	—	Ozone CD, Draft Ozone ISA[b]
	Decreased outdoor worker productivity (age 18-65)	—	—	Ozone CD, Draft Ozone ISA[b]
	Other respiratory effects (e.g., premature aging of lungs)	—	—	Ozone CD, Draft Ozone ISA[c]
	Cardiovascular and nervous system effects	—	—	Ozone CD, Draft Ozone ISA[d]
	Reproductive and developmental effects	—	—	Ozone CD, Draft Ozone ISA[d]
Reduced incidence of morbidity from exposure to NO_2	Asthma hospital admissions (all ages)	—	—	NO_2 ISA[b]
	Chronic lung disease hospital admissions (age > 65)	—	—	NO_2 ISA[b]
	Respiratory emergency department visits (all ages)	—	—	NO_2 ISA[b]
	Asthma exacerbation (asthmatics age 4–18)	—	—	NO_2 ISA[b]
	Acute respiratory symptoms (age 7–14)	—	—	NO_2 ISA[b]
	Premature mortality	—	—	NO_2 ISA[c,d]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	—	—	NO_2 ISA[c,d]
Reduced incidence of morbidity from exposure to SO_2	Respiratory hospital admissions (age > 65)	—	—	SO_2 ISA[b]
	Asthma emergency room visits (all ages)	—	—	SO_2 ISA[b]
	Asthma exacerbation (asthmatics age 4–12)	—	—	SO_2 ISA[b]
	Acute respiratory symptoms (age 7–14)	—	—	SO_2 ISA[b]
	Premature mortality	—	—	SO_2 ISA[c,d]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	—	—	SO_2 ISA[c,d]
Reduced incidence of morbidity from exposure to methyl mercury (through reduced mercury deposition as well as the role of sulfate in methylation)	Neurologic effects—IQ loss	✓	✓	IRIS; NRC, 2000[b]
	Other neurologic effects (e.g., developmental delays, memory, behavior)	—	—	IRIS; NRC, 2000c
	Cardiovascular effects	—	—	IRIS; NRC, 2000[c,d]
	Genotoxic, immunologic, and other toxic effects	—	—	IRIS; NRC, 2000[c,d]

[a] For a complete list of references see Chapter 5.
[b] We assess these benefits qualitatively due to time and resource limitations for this analysis.
[c] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.
[d] We assess these benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

Source: (EPA, 2011b)

Table ES-6. Environmental Effects of Pollutants Affected by the Mercury and Air Toxics Standards

Benefits Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information[a]
Improved Environment				
Reduced visibility impairment	Visibility in Class I areas in SE, SW, and CA regions	—	—	PM ISA[b]
	Visibility in Class I areas in other regions	—	—	PM ISA[b]
	Visibility in residential areas	—	—	PM ISA[b]
Reduced climate effects	Global climate impacts from CO_2	—	✓	Section 5.6
	Climate impacts from ozone and PM	—	—	Section 5.6
	Other climate impacts (e.g., other GHGs, other impacts)	—	—	IPCC[c]
Reduced effects on materials	Household soiling	—	—	PM ISA[c]
	Materials damage (e.g., corrosion, increased wear)	—	—	PM ISA[c]
Reduced effects from PM deposition (metals and organics)	Effects on Individual organisms and ecosystems	—	—	PM ISA[c]
Reduced vegetation and ecosystem effects from exposure to ozone	Visible foliar injury on vegetation	—	—	Ozone CD, Draft Ozone ISA[c]
	Reduced vegetation growth and reproduction	—	—	Ozone CD, Draft Ozone ISA[b]
	Yield and quality of commercial forest products and crops	—	—	Ozone CD, Draft Ozone ISA[b,d]
	Damage to urban ornamental plants	—	—	Ozone CD, Draft Ozone ISA[c]
	Carbon sequestration in terrestrial ecosystems	—	—	Ozone CD, Draft Ozone ISA[c]
	Recreational demand associated with forest aesthetics	—	—	Ozone CD, Draft Ozone ISA[c]
	Other non-use effects			Ozone CD, Draft Ozone ISA[c]
	Ecosystem functions (e.g., water cycling, biogeochemical cycles, net primary productivity, leaf-gas exchange, community composition)	—	—	Ozone CD, Draft Ozone ISA[c]

Source: (EPA, 2011b)

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Table ES-6. Environmental Effects of Pollutants Affected by the Mercury and Air Toxics Standards (continued)

Benefits Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Reduced effects from acid deposition	Recreational fishing	—	—	NO_x SO_x ISA[b]
	Tree mortality and decline	—	—	NO_x SO_x ISA[c]
	Commercial fishing and forestry effects	—	—	NO_x SO_x ISA[c]
	Recreational demand in terrestrial and aquatic ecosystems	—	—	NO_x SO_x ISA[c]
	Other nonuse effects			NO_x SO_x ISA[c]
	Ecosystem functions (e.g., biogeochemical cycles)	—	—	NO_x SO_x ISA[c]
Reduced effects from nutrient enrichment	Species composition and biodiversity in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[c]
	Coastal eutrophication	—	—	NO_x SO_x ISA[c]
	Recreational demand in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[c]
	Other non-use effects			NO_x SO_x ISA[c]
	Ecosystem functions (e.g., biogeochemical cycles, fire regulation)	—	—	NO_x SO_x ISA[c]
Reduced vegetation effects from ambient exposure to SO_2 and NO_x	Injury to vegetation from SO_2 exposure	—	—	NO_x SO_x ISA[c]
	Injury to vegetation from NO_x exposure	—	—	NO_x SO_x ISA[c]
Reduced incidence of morbidity from exposure to methyl mercury (through reduced mercury deposition as well as the role of sulfate in methylation)	Effects on fish, birds, and mammals (e.g., reproductive effects)	—	—	Mercury Study RTC[c,d]
	Commercial, subsistence and recreational fishing	—	—	Mercury Study RTC[c]

[a] For a complete list of references see Chapter 5.
[b] We assess these benefits qualitatively due to time and resource limitations for this analysis.
[c] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.
[d] We assess these benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

Source: (EPA, 2011b)

MATS Emission Limitations

Table 1-1. Emission Limitations for Coal-Fired and Solid Oil-Derived Fuel-Fired EGUs

Subcategory	Filterable Particulate Matter	Hydrogen Chloride	Mercury
Existing Unit designed for not low rank virgin coal	0.030 lb/MMBtu (0.30 lb/MWh)	0.0020 lb/MMBtu (0.020 lb/MWh)	1.2 lb/TBtu (0.020 lb/GWh)
Existing Unit designed for low rank virgin coal	0.030 lb/MMBtu (0.30 lb/MWh)	0.0020 lb/MMBtu (0.020 lb/MWh)	4.0 lb/TBtu[a] (0.040 lb/GWh[a])
Existing - IGCC	0.040 lb/MMBtu (0.40 lb/MWh)	0.00050 lb/MMBtu (0.0050 lb/MWh)	2.5 lb/TBtu (0.030 lb/GWh)
Existing – Solid oil-derived	0.0080 lb/MMBtu (0.090 lb/MWh)	0.0050 lb/MMBtu (0.080 lb/MWh)	0.20 lb/TBtu (0.0020 lb/GWh)
New unit designed for not low rank virgin coal	0.0070 lb/MWh	0.00040 lb/MWh	0.00020 lb/GWh
New unit designed for coal low rank virgin coal	0.0070 lb/MWh	0.00040 lb/MWh	0.040 lb/GWh
New – IGCC	0.070 lb/MWh[b] 0.090 lb/MWh[c]	0.0020 lb/MWh[d]	0.0030 lb/GWh[e]
New – Solid oil-derived	0.020 lb/MWh	0.00040 lb/MWh	0.0020 lb/GWh

Note: In some cases, affected units may comply with either an input-based standard or an output-based standard, shown in parentheses below the input-based standard.

lb/MMBtu = pounds pollutant per million British thermal units fuel input

lb/TBtu = pounds pollutant per trillion British thermal units fuel input

lb/MWh = pounds pollutant per megawatt-hour electric output (gross)

lb/GWh = pounds pollutant per gigawatt-hour electric output (gross)

[a] Beyond-the-floor limit. The MACT floor for this subcategory is 11.0 lb/TBtu (0.20 lb/GWh)

[b] Duct burners on syngas; based on permit levels in comments received

[c] Duct burners on natural gas; based on permit levels in comments received

[d] Based on best-performing similar source

[e] Based on permit levels in comments received

Source: (EPA, 2011b)

Table 1-2. Emission Limitations for Liquid Oil-Fired EGUs

Subcategory	Filterable PM	Hydrogen Chloride	Hydrogen Fluoride
Existing – Liquid oil-continental	0.030 lb/MMBtu (0.30 lb/MWh)	0.0020 lb/MMBtu (0.010 lb/MWh)	0.00040 lb/MMBtu (0.0040 lb/MWh)
Existing – Liquid oil-non-continental	0.030 lb/MMBtu (0.30 lb/MWh)	0.00020 lb/MMBtu (0.0020 lb/MWh)	0.000060 lb/MMBtu (0.00050 lb/MWh)
New – Liquid oil - continental	0.070 lb/MWh	0.00040 lb/MWh	0.00040 lb/MWh
New – Liquid oil - non-continental	0.20 lb/MWh	0.0020 lb/MWh	0.00050 lb/MWh

Note: In some cases, affected units may comply with either an input-based standard or an output-based standard, shown in parentheses below the input-based standard.

Source: (EPA, 2011b)

Projected Emissions with and without MATS

Table 3-4. Projected Emissions of SO_2, NO_X, Mercury, Hydrogen Chloride, PM, and CO_2 with the Base Case and with MATS, 2015

		Million Tons		Mercury	Thousand Tons		CO_2
		SO_2	NO_x	(Tons)	HCl	$PM_{2.5}$	(Million Metric Tonnes)
Base	All EGUs	3.4	1.9	28.7	48.7	277	2,230
	Covered EGUs	3.3	1.7	26.6	45.3	270	1,906
MATS	All EGUs	2.1	1.9	8.8	9.0	227	2,215
	Covered EGUs	1.9	1.7	6.6	5.5	218	1,882

Source: Integrated Planning Model run by EPA, 2011

Source: (EPA, 2011b)

MATS BENEFITS AND COSTS

Table ES-1. Summary of EPA's Estimates of Annualized[a] Benefits, Costs, and Net Benefits of the Final MATS in 2016[b] (billions of 2007$)

Description	Estimate (3% Discount Rate)	Estimate (7% Discount Rate)
Costs[c]	$9.6	$9.6
Benefits[d,e,f]	$37 to $90 + B	$33 to $81 + B
Net benefits (benefits-costs)[g]	$27 to $80 + B	$24 to $71 + B

[a] All estimates presented in this report represent annualized estimates of the benefits and costs of the final MATS in 2016 rather than the net present value of a stream of benefits and costs in these particular years of analysis.

[b] Estimates rounded to two significant figures and represent annualized benefits and costs anticipated for the year 2016.

[c] Total social costs are approximated by the compliance costs. Compliance costs consist of IPM projections, monitoring/reporting/recordkeeping costs, and oil-fired fleet analysis costs. For a complete discussion of these costs refer to Chapter 3. Costs were annualized using a 6.15% discount rate.

[d] Total benefits are composed primarily of monetized PM-related health benefits. The reduction in premature fatalities each year accounts for over 90% of total monetized benefits. Benefits in this table are nationwide and are associated with directly emitted $PM_{2.5}$ and SO_2 reductions. The estimate of social benefits also includes CO_2-related benefits calculated using the social cost of carbon, discussed further in Chapter 5.

[e] Not all possible benefits or disbenefits are quantified and monetized in this analysis. B is the sum of all unquantified benefits and disbenefits. Data limitations prevented us from quantifying these endpoints, and as such, these benefits are inherently more uncertain than those benefits that we were able to quantify. Estimates here are subject to uncertainties discussed further in the body of the document. Potential benefit categories that have not been quantified and monetized are listed in Table ES-5.

[f] Mortality risk valuation assumes discounting over the SAB-recommended 20-year segmented lag structure. Results reflect the use of 3% and 7% discount rates consistent with EPA and OMB guidelines for preparing economic analyses (EPA, 2000; OMB, 2003).

[g] Net benefits are rounded to two significant figures. Columnar totals may not sum due to rounding.

Source: (EPA, 2011b)

MATS Mortality Benefits in Total and per Ton Basis

Table 5C-3. Estimated Economic Value of Adult Mortality Benefits by Pollutant, in Total and Per Ton of Emissions Reduced Interim Modeled Mercury and Air Toxics Standard in 2016 (95% confidence intervals, 2007$)

Pollutant and Source of Adult Mortality Estimate	Total Monetized Benefits (billions)		BPT (thousands)	
	Eastern U.S.[a]	Western U.S.	Eastern U.S.[a]	Western U.S.
SO_2 emissions (tons)[b]	1,268,961	146,155		
Pope et al. (2002) estimate	$36 ($2.9—$110)	$1.2 ($0.1—$3.7)	$29 ($2.3-$87)	$8.3 ($0.1-$25)
Laden et al. (2006) estimate	$93 ($8.2—$270)	$3.1 ($0.3—$9.0)	$73 ($6.4-$210)	$21 ($1.9-$62)
Carbonaceous $PM_{2.5}$ emissions (tons)[b]	5,860	231		
Pope et al. (2002) estimate[c]	$1.3 ($0.1—$3.9)	<-$0.01	$220 ($17-$670)	-$66 (-$450-$210)
Laden et al. (2006) estimate[c]	$3.3 ($0.3—$9.6)	<-$0.01	$560 ($49-$1,600)	-$170 (-$960-$350)
Crustal $PM_{2.5}$ emissions (tons)[b]	34,742	29,148		
Pope et al. (2002) estimate	$0.6 (<$0.01—$1.9)	$0.1 (<$0.01—$0.2)	$18 ($1.4-$55)	$9.6 ($0.1-$31)
Laden et al. (2006) estimate	$1.6 ($0.1—$4.7)	$0.1 (<$0.01—$0.4)	$47 ($4.1-$140)	$25 ($2.1-$74)

[a] Includes Texas and those states to the north and east.

[b] Emission reductions are reported for the modeled interim policy case, from which the BPT values were generated.

[c] Directly emitted carbonaceous $PM_{2.5}$ increased slightly in some locations in the Western U.S. for the interim policy scenario relative to the interim baseline, which overall resulted in negative BPT values for the West. However, since the magnitudes of the emission and concentration changes are small relative to the changes in SO_2 emissions and sulfate concentrations, the resulting increase in premature mortality is only 0.04% of the total health impact of the rule.

Source: (EPA, 2011b)

APPENDIX E – CLEAN POWER PLAN

CPP List of All Benefits

Table ES-6. Quantified and Unquantified Benefits

Benefits Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information
Improved Environment				
Reduced climate effects	Global climate impacts from CO_2	—[1]	✔	SC-CO_2 TSD
	Climate impacts from ozone and black carbon (directly emitted PM)	—	—	Ozone ISA, PM ISA[2]
	Other climate impacts (e.g., other GHGs such as methane, aerosols, other impacts)	—	—	IPCC[2]
Improved Human Health (co-benefits)				
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[2]
	Emergency room visits for cardiovascular effects (all ages)	—	—	PM ISA[2]
	Strokes and cerebrovascular disease (age 50-79)	—	—	PM ISA[2]
	Other cardiovascular effects (e.g., other ages)	—	—	PM ISA[3]
	Other respiratory effects (e.g., pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA[3]
	Reproductive and developmental effects (e.g., low birth weight, pre-term births, etc)	—	—	PM ISA[3,4]
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA[3,4]
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[2]
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[2]
	Other respiratory effects (e.g., premature aging of lungs)	—	—	Ozone ISA[3]
	Cardiovascular and nervous system effects	—	—	Ozone ISA[3]
	Reproductive and developmental effects	—	—	Ozone ISA[3,4]

Source: (EPA, 2015)

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CPP List of All Benefits

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Table ES-6. Continued

Reduced incidence of morbidity from exposure to NO_2	Asthma hospital admissions (all ages)	—	—	NO_2 ISA[2]
	Chronic lung disease hospital admissions (age > 65)	—	—	NO_2 ISA[2]
	Respiratory emergency department visits (all ages)	—	—	NO_2 ISA[2]
	Asthma exacerbation (asthmatics age 4–18)	—	—	NO_2 ISA[2]
	Acute respiratory symptoms (age 7–14)	—	—	NO_2 ISA[2]
	Premature mortality	—	—	NO_2 ISA[2,3,4]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	—	—	NO_2 ISA[3,4]
Reduced incidence of morbidity from exposure to SO_2	Respiratory hospital admissions (age > 65)	—	—	SO_2 ISA[2]
	Asthma emergency department visits (all ages)	—	—	SO_2 ISA[2]
	Asthma exacerbation (asthmatics age 4–12)	—	—	SO_2 ISA[2]
	Acute respiratory symptoms (age 7–14)	—	—	SO_2 ISA[2]
	Premature mortality	—	—	SO_2 ISA[2,3,4]
	Other respiratory effects (e.g., airway hyperresponsiveness and inflammation, lung function, other ages and populations)	—	—	SO_2 ISA[2,3]
Reduced incidence of morbidity from exposure to methylmercury	Neurologic effects—IQ loss	—	—	IRIS; NRC, 2000[2]
	Other neurologic effects (e.g., developmental delays, memory, behavior)	—	—	IRIS; NRC, 2000[3]
	Cardiovascular effects	—	—	IRIS; NRC, 2000[3,4]
	Genotoxic, immunologic, and other toxic effects	—	—	IRIS; NRC, 2000[3,4]
Improved Environment (co-benefits)				
Reduced visibility impairment	Visibility in Class 1 areas	—	—	PM ISA[2]
	Visibility in residential areas	—	—	PM ISA[2]
Reduced effects on materials	Household soiling	—	—	PM ISA[2,3]
	Materials damage (e.g., corrosion, increased wear)	—	—	PM ISA[3]
Reduced PM deposition (metals and organics)	Effects on Individual organisms and ecosystems	—	—	PM ISA[3]
Reduced vegetation and ecosystem effects from exposure to ozone	Visible foliar injury on vegetation	—	—	Ozone ISA[2]
	Reduced vegetation growth and reproduction	—	—	Ozone ISA[2]
	Yield and quality of commercial forest products and crops	—	—	Ozone ISA[2]
	Damage to urban ornamental plants	—	—	Ozone ISA[3]
	Carbon sequestration in terrestrial ecosystems	—	—	Ozone ISA[2]
	Recreational demand associated with forest aesthetics	—	—	Ozone ISA[3]
	Other non-use effects			Ozone ISA[3]
	Ecosystem functions (e.g., water cycling, biogeochemical cycles, net primary productivity, leaf-gas exchange, community composition)	—	—	Ozone ISA[3]
Reduced effects from acid deposition	Recreational fishing	—	—	NO_x SO_x ISA[2]
	Tree mortality and decline	—	—	NO_x SO_x ISA[3]
	Commercial fishing and forestry effects	—	—	NO_x SO_x ISA[3]
	Recreational demand in terrestrial and aquatic ecosystems	—	—	NO_x SO_x ISA[3]
	Other non-use effects			NO_x SO_x ISA[3]
	Ecosystem functions (e.g., biogeochemical cycles)	—	—	NO_x SO_x ISA[3]

Source: (EPA, 2015)

Projected Emissions with and without CPP for Rate-based Approach

Table ES-2. Climate and Air Pollutant Emission Reductions for the Rate-Based Illustrative Plan Approach[1]

	CO_2 (million short tons)	SO_2 (thousand short tons)	Annual NO_X (thousand short tons)
2020 Rate-Based Approach			
Base Case	2,155	1,311	1,333
Final Guidelines	2,085	1,297	1,282
Emissions Change	-69	-14	-50
2025 Rate-Based Approach			
Base Case	2,165	1,275	1,302
Final Guidelines	1,933	1,097	1,138
Emissions Change	-232	-178	-165
2030 Rate-Based Approach			
Base Case	2,227	1,314	1,293
Final Guidelines	1,812	996	1,011
Emission Change	-415	-318	-282

Source: Integrated Planning Model, 2015. Emissions change may not sum due to rounding.
[1] CO_2 emission reductions are used to estimate the climate benefits of the guidelines. SO_2, and NO_X reductions are relevant for estimating air quality health co-benefits of the final guidelines. The final guidelines are also expected to achieve reductions in directly emitted $PM_{2.5}$, which we were not able to estimate for this RIA.

Source: (EPA, 2015)

Projected Emissions with and without CPP for Mass-based Approach

Table ES-3. Climate and Air Pollutant Emission Reductions for the Mass-Based Illustrative Plan Appproach[1]

	CO_2 (million short tons)	SO_2 (thousand short tons)	Annual NO_X (thousand short tons)
2020 Mass-Based Approach			
Base Case	2,155	1,311	1,333
Final Guidelines	2,073	1,257	1,272
Emissions Change	-82	-54	-60
2025 Mass-Based Approach			
Base Case	2,165	1,275	1,302
Final Guidelines	1,901	1,090	1,100
Emissions Change	-264	-185	-203
2030 Mass-Based Approach			
Base Case	2,227	1,314	1,293
Final Guidelines	1,814	1,034	1,015
Emission Change	-413	-280	-278

Source: Integrated Planning Model, 2015. Emissions change may not sum due to rounding.
[1] CO_2 emission reductions are used to estimate the climate benefits of the guidelines. SO_2, and NO_X reductions are relevant for estimating air quality health co-benefits of the final guidelines. The final guidelines are also expected to achieve reductions in directly emitted $PM_{2.5}$, which we were not able to estimate for this RIA.

Source: (EPA, 2015)

Benefits and Costs Estimate for the Rate-based Approach

Table ES-9. Monetized Benefits, Compliance Costs, and Net Benefits Under the Rate-based Illustrative Plan Approach (billions of 2011$) [a]

	Rate-Based Approach					
	2020		2025		2030	
Climate Benefits [b]						
5% discount rate	$0.80		$3.1		$6.4	
3% discount rate	$2.8		$10		$20	
2.5% discount rate	$4.1		$15		$29	
95th percentile at 3% discount rate	$8.2		$31		$61	
	Air Quality Co-benefits Discount Rate					
	3%	7%	3%	7%	3%	7%
Air Quality Health Co-benefits [c]	$0.70 to $1.8	$0.64 to $1.7	$7.4 to $18	$6.7 to $16	$14 to $34	$13 to $31
Compliance Costs [d]	$2.5		$1.0		$8.4	
Net Benefits [e]	$1.0 to $2.1	$1.0 to $2.0	$17 to $27	$16 to $25	$26 to $45	$25 to $43
Non-Monetized Benefits	Non-monetized climate benefits					
	Reductions in exposure to ambient NO_2 and SO_2					
	Reductions in mercury deposition					
	Ecosystem benefits associated with reductions in emissions of NO_X, SO_2, PM, and mercury					
	Visibility impairment					

[a] All are rounded to two significant figures, so figures may not sum.

[b] The climate benefit estimate in this summary table reflects global impacts from CO_2 emission changes and does not account for changes in non-CO_2 GHG emissions. Also, different discount rates are applied to SC-CO_2 than to the other estimates because CO_2 emissions are long-lived and subsequent damages occur over many years. The benefit estimates in this table are based on the average SC-CO_2 estimated for a 3 percent discount rate, however we emphasize the importance and value of considering the full range of SC-CO_2 values. As shown in the RIA, climate benefits are also estimated using the other three SC-CO_2 estimates (model average at 2.5 percent discount rate, 3 percent, and 5 percent; 95th percentile at 3 percent). The SC-CO_2 estimates are year-specific and increase over time.

[c] The air quality health co-benefits reflect reduced exposure to $PM_{2.5}$ and ozone associated with emission reductions of SO_2 and NO_X. The co-benefits do not include the benefits of reductions in directly emitted $PM_{2.5}$. These additional benefits would increase overall benefits by a few percent based on the analyses conducted for the proposed rule. The range reflects the use of concentration-response functions from different epidemiology studies. The reduction in premature fatalities each year accounts for over 98 percent of total monetized co-benefits from $PM_{2.5}$ and ozone. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. Estimates in the table are presented for three analytical years with air quality co-benefits calculated using two discount rates. The estimates of co-benefits are annual estimates in each of the analytical years, reflecting discounting of mortality benefits over the cessation lag between changes in $PM_{2.5}$ concentrations and changes in risks of premature death (see RIA Chapter 4 for more details), and discounting of morbidity benefits due to the multiple years of costs associated with some illnesses. The estimates are not the present value of the benefits of the rule over the full compliance period.

[d] Total costs are approximated by the illustrative compliance costs estimated using the Integrated Planning Model for the final emission guidelines and a discount rate of approximately 5 percent. This estimate also includes monitoring, recordkeeping, and reporting costs and demand-side energy efficiency program and participant costs.

[e] The estimates of net benefits in this summary table are calculated using the global SC-CO_2 at a 3 percent discount rate (model average). The RIA includes combined climate and health estimates based on additional discount rates.

Source: (EPA, 2015)

Benefits and Costs Estimate for the Mass-based Approach

Table ES-10. Monetized Benefits, Compliance Costs, and Net Benefits under the Mass-based Illustrative Plan Approach (billions of 2011$) [a]

	Mass-Based Approach					
	2020		2025		2030	
Climate Benefits [b]						
5% discount rate	$0.94		$3.6		$6.4	
3% discount rate	$3.3		$12		$20	
2.5% discount rate	$4.9		$17		$29	
95th percentile at 3% discount rate	$9.7		$35		$60	
	Air Quality Co-benefits Discount Rate					
	3%	7%	3%	7%	3%	7%
Air Quality Health Co-benefits [c]	$2.0 to $4.8	$1.8 to $4.4	$7.1 to $17	$6.5 to $16	$12 to $28	$11 to $26
Compliance Costs [d]	$1.4		$3.0		$5.1	
Net Benefits [e]	$3.9 to $6.7	$3.7 to $6.3	$16 to $26	$15 to $24	$26 to $43	$25 to $40
Non-Monetized Benefits	Non-monetized climate benefits Reductions in exposure to ambient NO_2 and SO_2 Reductions in mercury deposition Ecosystem benefits associated with reductions in emissions of NO_X, SO_2, PM, and mercury Visibility improvement					

[a] All are rounded to two significant figures, so figures may not sum.
[b] The climate benefit estimate in this summary table reflects global impacts from CO_2 emission changes and does not account for changes in non-CO_2 GHG emissions. Also, different discount rates are applied to SC-CO_2 than to the other estimates because CO_2 emissions are long-lived and subsequent damages occur over many years. The benefit estimates in this table are based on the average SC-CO_2 estimated for a 3 percent discount rate, however we emphasize the importance and value of considering the full range of SC-CO_2 values. As shown in the RIA, climate benefits are also estimated using the other three SC-CO_2 estimates (model average at 2.5 percent discount rate, 3 percent, and 5 percent; 95th percentile at 3 percent). The SC-CO_2 estimates are year-specific and increase over time.
[c] The air quality health co-benefits reflect reduced exposure to $PM_{2.5}$ and ozone associated with emission reductions of, SO_2 and NO_X. The co-benefits do not include the benefits of reductions in directly emitted $PM_{2.5}$. These additional benefits would increase overall benefits by a few percent based on the analyses conducted for the proposed rule. The range reflects the use of concentration-response functions from different epidemiology studies. The reduction in premature fatalities each year accounts for over 98 percent of total monetized co-benefits from $PM_{2.5}$ and ozone. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. Estimates in the table are presented for three analytical years with air quality co-benefits calculated using two discount rates. The estimates of co-benefits are annual estimates in each of the analytical years, reflecting discounting of mortality benefits over the cessation lag between changes in PM2.5 concentrations and changes in risks of premature death (see RIA Chapter 4 for more details), and discounting of morbidity benefits due to the multiple years of costs associated with some illnesses. The estimates are not the present value of the benefits of the rule over the full compliance period.
[d] Total costs are approximated by the illustrative compliance costs estimated using the Integrated Planning Model for the final emission guidelines and a discount rate of approximately 5 percent. This estimate also includes monitoring, recordkeeping, and reporting costs and demand-side energy efficiency program and participant costs.
[e] The estimates of net benefits in this summary table are calculated using the global SC-CO_2 at a 3 percent discount rate (model average). The RIA includes combined climate and health estimates based on additional discount rates.

Source: (EPA, 2015)

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