UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Regulatory Impact Analysis for the Proposed Revised Cross-State Air Pollution Rule (CSAPR) Update for the 2008 Ozone NAAQS

ERRATA SHEET

After completion of the RIA, EPA received revised production cost projections for the proposed rule IPM run, which reduced the projected cost of the proposed rule. This Errata presents these technical corrections. The first table presents the changes in the text and is followed by sets of tables each showing the current table and corrected table.

Page numbers	Current Value	Corrected Value (Highlighted in yellow)
ES-15	The estimated social costs to implement the proposal, as described in this document, are approximately $21 million in 2021 and $6 million in 2025 (2016$).	The estimated social costs to implement the proposal, as described in this document, are approximately $20 million in 2021 and $1 million in 2025 (2016$).
ES-16	The annual net benefits of the proposal in 2021 (in 2016$) are approximately -$21 million using a 3 percent discount rate and a 7 percent real discount rate. The annual net benefits of the proposal in 2025 are approximately $27 million using a 3 percent real discount rate and approximately -$0.9 million using a 7 percent real discount rate.	The annual net benefits of the proposal in 2021 (in 2016$) are approximately -$20 million using a 3 percent discount rate and a 7 percent real discount rate. The annual net benefits of the proposal in 2025 are approximately $31 million using a 3 percent real discount rate and approximately $4 million using a 7 percent real discount rate.
ES-17	The present value (PV) of the net benefits, in 2016$ and discounted to 2021, is -$68 million when using a 7 percent discount rate and $14 million when using a 3 percent discount rate. The equivalent annualized value (EAV), an estimate of the annualized value of the net benefits consistent with the present value, is -$17 million per year when using a 7 percent	The present value (PV) of the net benefits, in 2016$ and discounted to 2021, is -$59 million when using a 7 percent discount rate and $23 million when using a 3 percent discount rate. The equivalent annualized value (EAV), an estimate of the annualized value of the net benefits consistent with the present value, is -$14 million per year when using a 7 percent

Page numbers	Current Value	Corrected Value (Highlighted in yellow)
	discount rate and $3 million when using a 3 percent discount rate.	discount rate and $5 million when using a 3 percent discount rate.
7-2	As shown in Chapter 4, the estimated annual compliance costs to implement the proposal, as described in this document, are approximately $21 million in 2021 and $6 million in 2025 (2016$).	As shown in Chapter 4, the estimated annual compliance costs to implement the proposal, as described in this document, are approximately $20 million in 2021 and $1 million in 2025 (2016$).
7-3	The annual net benefits of the proposal in 2021 (in 2016$) are approximately -$21 million using both a 3 percent and 7 percent real discount rate for the climate benefits. The annual net benefits of the proposal in 2025 are approximately $27 using a 3 percent real discount rate and -$0.9 million using a 7 percent real discount rate.	The annual net benefits of the proposal in 2021 (in 2016$) are approximately -$20 million using both a 3 percent and 7 percent real discount rate for the climate benefits. The annual net benefits of the proposal in 2025 are approximately $31 using a 3 percent real discount rate and $4 million using a 7 percent real discount rate.
7-5	The present value (PV) of the net benefits, in 2016$ and discounted to 2021, is -$68 million when using a 7 percent discount rate and $14 million when using a 3 percent discount rate. The equivalent annualized value (EAV), an estimate of the annualized value of the net benefits consistent with the present value, is -$17 million per year when using a 7 percent discount rate and $3 million when using a 3 percent discount rate.	The present value (PV) of the net benefits, in 2016$ and discounted to 2021, is -$59 million when using a 7 percent discount rate and $23 million when using a 3 percent discount rate. The equivalent annualized value (EAV), an estimate of the annualized value of the net benefits consistent with the present value, is -$14 million per year when using a 7 percent discount rate and $5 million when using a 3 percent discount rate.

Location: Page ES-10

Current Table:

Table ES-1. National Compliance Cost Estimates (millions of 2016$) for the Regulatory Control Alternatives

	Proposal	More-Stringent Alternative	Less-Stringent Alternative
2021-2025 (Annualized)	19.4	80.6	1.6
2021 (Annual)	20.9	37.2	3.8
2025 (Annual)	6.3	132.2	-12.0

The *2021-2025 (Annualized)* row reflects total estimated annual compliance costs levelized over the period 2021 through 2025, discounted using a 4.25 real discount rate. The *2021 (Annual)* and *2025 (Annual)* rows reflect annual estimates in each of those years.

Corrected Table (Corrections highlighted in yellow):

Table ES-2. National Compliance Cost Estimates (millions of 2016$) for the Regulatory Control Alternatives

	Proposal	More-Stringent Alternative	Less-Stringent Alternative
2021-2025 (Annualized)	17.4	80.6	1.6
2021 (Annual)	20.5	37.2	3.8
2025 (Annual)	1.5	132.2	-12.0

The *2021-2025 (Annualized)* row reflects total estimated annual compliance costs levelized over the period 2021 through 2025, discounted using a 4.25 real discount rate. The *2021 (Annual)* and *2025 (Annual)* rows reflect annual estimates in each of those years.

Location: Page ES-16

Current Table:

Table ES-7. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2021 for the U.S. (millions of 2016$)

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	0.31 +B	21	-21 +B
7%	0.05 +B		-21 +B
More Stringent Alternative			
3%	0.80 +B	37	-36 +B
7%	0.12 +B		-37 +B
Less Stringent Alternative			
3%	0.17 +B	4	-4 +B
7%	0.03 +B		-4 +B

Corrected Table (Corrections highlighted in yellow):

Table ES-7. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2021 for the U.S. (millions of 2016$)

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	0.31 +B	20	-20 +B
7%	0.05 +B		-20 +B
More Stringent Alternative			
3%	0.80 +B	37	-36 +B
7%	0.12 +B		-37 +B
Less Stringent Alternative			
3%	0.17 +B	4	-4 +B
7%	0.03 +B		-4 +B

Location: Pages ES16-17

Current Table:

Table ES-8. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2025 for the U.S. (millions of 2016$)

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	33 +B	6	27 +B
7%	5.4 +B		-0.9 +B
More Stringent Alternative			
3%	71.5 +B	132	-61 +B
7%	11.7 +B		-120 +B
Less Stringent Alternative			
3%	25 +B	-12	37 +B
7%	4.2 +B		16 +B

Corrected Table (Corrections highlighted in yellow):

Table ES-8. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2025 for the U.S. (millions of 2016$)

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	33 +B	1	31 +B
7%	5.4 +B		4 +B
More Stringent Alternative			
3%	71.5 +B	132	-61 +B
7%	11.7 +B		-120 +B
Less Stringent Alternative			
3%	25 +B	-12	37 +B
7%	4.2 +B		16 +B

Location: Page ES-18

Current Table:

Table ES-9. Summary of Present Values and Equivalent Annualized Values for the 2021-2025 Timeframe for Estimated Compliance Costs, Climate Benefits, and Net Benefits for the Proposed Rule (millions of 2016$, discounted to 2021)

		3% Discount Rate	7% Discount Rate
Present Value	Benefits[c,d]	101+β	15+β
	Climate Benefits[c]	101	15
	Compliance Costs[e]	87	83
	Net Benefits	**14+β**	**-68+β**
Equivalent Annualized Value			
	Benefits	22+b	4+b
	Climate Benefits	22	4
	Compliance Costs	19	20
	Net Benefits	**3+b**	**-17+b**

Corrected Table (Corrections highlighted in yellow):

		3% Discount Rate	7% Discount Rate
Present Value	Benefits[c,d]	101+β	15+β
	Climate Benefits[c]	101	15
	Compliance Costs[e]	78	74
	Net Benefits	**23+β**	**-59+β**
Equivalent Annualized Value			
	Benefits	22+b	4+b
	Climate Benefits	22	4
	Compliance Costs	17	18
	Net Benefits	**5+b**	**-14+b**

Location: Page 4-20

Current Table:

Table 4-6. National Compliance Cost Estimates (millions of 2016$) for the Regulatory Control Alternatives

	Revised CSAPR Update Proposal	More-Stringent Alternative	Less-Stringent Alternative
2021-2025 (Annualized)	19.4	80.6	1.6
2021 (Annual)	20.9	37.2	3.8
2022 (Annual)	29.7	49.2	12.8
2023 (Annual)	27.8	47.3	12.8
2024 (Annual)	6.3	132.2	-12.0
2025 (Annual)	6.3	132.2	-12.0

Corrected Table (Corrections highlighted in yellow):

Table 4-6. National Compliance Cost Estimates (millions of 2016$) for the Regulatory Control Alternatives

	Revised CSAPR Update Proposal	More-Stringent Alternative	Less-Stringent Alternative
2021-2025 (Annualized)	17.4	80.6	1.6
2021 (Annual)	20.5	37.2	3.8
2022 (Annual)	29.6	49.2	12.8
2023 (Annual)	27.7	47.3	12.8
2024 (Annual)	1.5	132.2	-12.0
2025 (Annual)	1.5	132.2	-12.0

Location: Page 7-3

Current Table:

Table 7-1. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2021 for the U.S. (millions of 2016$)

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	0.31 + B	21	-21 + B
7%	0.05 + B		-21 + B
More Stringent Alternative			
3%	0.80 + B	37	-36 + B
7%	0.12 + B		-37 + B
Less Stringent Alternative			
3%	0.17 + B	4	-4 + B
7%	0.03 + B		-4 + B

Corrected Table (Corrections highlighted in yellow):

Table 7-1. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2021 for the U.S. (millions of 2016$)

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	0.31 + B	20	-20 + B
7%	0.05 + B		-20 + B
More Stringent Alternative			
3%	0.80 + B	37	-36 + B
7%	0.12 + B		-37 + B
Less Stringent Alternative			
3%	0.17 + B	4	-4 + B
7%	0.03 + B		-4 + B

Location: Page 7-3

Current Table:

Table 7-2. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2025 for the U.S. (millions of 2016$)

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	33 + B	6	27 + B
7%	5.4 + B		-0.9 + B
More Stringent Alternative			
3%	71.5 + B	132	-61 + B
7%	11.7 + B		-120 + B
Less Stringent Alternative			
3%	25 + B	-12	37 + B
7%	4.2 + B		16 + B

Corrected Table (Corrections highlighted in yellow):

Table 7-2. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2025 for the U.S. (millions of 2016$)

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	33 + B	1	31 +B
7%	5.4 + B		4 +B
More Stringent Alternative			
3%	71.5 + B	132	-61 + B
7%	11.7 + B		-120 + B
Less Stringent Alternative			
3%	25 + B	-12	37 + B
7%	4.2 + B		16 + B

Location: Page 7-4

Current Table:

Table 7-3. Summary of Present Values and Equivalent Annualized Values for the 2021-2025 Timeframe for Estimated Compliance Costs, Climate Benefits, and Net Benefits for the Proposed Rule (millions of 2016$, discounted to 2021)

		3% Discount Rate	7% Discount Rate
Present Value	Climate Benefits[c,d]	101+β	15+β
	Compliance Costs[e]	87	83
	Net Benefits	**14+β**	**-68+β**
Equivalent Annualized Value			
	Climate Benefits	22+b	4+b
	Compliance Costs	19	20
	Net Benefits	**3+b**	**-17+b**

Corrected Table (Corrections highlighted in yellow):

Table 7-3. Summary of Present Values and Equivalent Annualized Values for the 2021-2025 Timeframe for Estimated Compliance Costs, Climate Benefits, and Net Benefits for the Proposed Rule (millions of 2016$, discounted to 2021)

		3% Discount Rate	7% Discount Rate
Present Value	Climate Benefits[c,d]	101+β	15+β
	Compliance Costs[e]	78	74
	Net Benefits	**23+β**	**-59+β**
Equivalent Annualized Value			
	Climate Benefits	22+b	4+b
	Compliance Costs	17	18
	Net Benefits	**5+b**	**-14+b**

EPA-452/P-20-003
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Regulatory Impact Analysis for the Proposed Revised Cross-State Air Pollution Rule (CSAPR) Update for the 2008 Ozone NAAQS

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Health and Environmental Impacts Division
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EXECUTIVE SUMMARY

Overview

This proposed action is taken in response to the United States Court of Appeals for the District of Columbia Circuit's (D.C. Circuit) September 13, 2019 remand of the Cross-State Air Pollution Rule (CSAPR) Update. The CSAPR Update finalized Federal Implementation Plans (FIPs) for 22 states to address their interstate pollution-transport obligations under the Clean Air Act (CAA) for the 2008 ozone National Ambient Air Quality Standards (NAAQS).[1] The D.C. Circuit found that the CSAPR Update, which was published on October 26, 2016 as a partial remedy to address upwind states' obligations prior to the 2018 Moderate area attainment date under the 2008 ozone NAAQS, was unlawful to the extent it allowed those states to continue their significant contributions to downwind ozone problems beyond the statutory dates by which downwind states must demonstrate their attainment of the air quality standards. This proposed rule, if finalized, will resolve 21 states' outstanding interstate ozone transport obligations with respect to the 2008 ozone NAAQS. [2]

This action proposes to find that for 9 of the 21 states with remanded FIPs (Alabama, Arkansas, Iowa, Kansas, Mississippi, Missouri, Oklahoma, Texas, and Wisconsin), their projected 2021 ozone season nitrogen oxides (NOx) emissions do not significantly contribute to a continuing downwind nonattainment and/or maintenance problem; therefore the CSAPR Update fully addresses their interstate ozone transport obligations with respect to the 2008 ozone NAAQS. This action also proposes to find that for the 12 remaining states (Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Virginia, and West Virginia), their projected 2021 ozone season NOx emissions significantly contribute to downwind states' nonattainment and/or maintenance problems for the 2008 ozone NAAQS.

EPA is proposing the creation of an additional geographic group and ozone season trading program comprised of these 12 upwind states with remaining linkages to downwind air

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[1] 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).

[2] In the CSAPR Update, EPA found that the finalized Tennessee emissions budget fully addressed Tennessee's good neighbor obligation with respect to the 2008 ozone NAAQS. As such, Tennessee is not considered in this proposal, and the number of states included is reduced from 22 to 21 states.

quality problems in 2021. This new group, Group 3, will be covered by a new CSAPR NO_X Ozone Season (May 1 – September 30) Group 3 trading program and will no longer be subject to Group 2 budgets. Aside from the removal of the 12 covered states from the current Group 2 program, this proposal leaves unchanged the budget stringency and geography of the existing CSAPR NO_X Ozone Season Group 1 and Group 2 trading programs. The electric generating units (EGUs) covered by the FIPs and subject to the budget are all fossil-fired EGUs with >25 megawatt (MW) capacity.

ES.1 Identifying Needed Emissions Reductions and Description of the Remedy

To reduce interstate emission transport under the authority provided in CAA section 110(a)(2)(D)(i)(I), this rule proposes to further limit ozone season NO_X emissions from EGUs in 12 states using the same framework used by EPA in developing the CSAPR (the interstate transport framework). The interstate transport framework provides a 4-step process to address the requirements of the good neighbor provision for ground-level ozone and fine particulate matter ($PM_{2.5}$) NAAQS: (1) identifying downwind receptors that are expected to have problems attaining or maintaining the NAAQS; (2) determining which upwind states contribute to these identified problems in amounts sufficient to “link” them to the downwind air quality problems (i.e., here, a 1 percent contribution threshold); (3) for states linked to downwind air quality problems, identifying upwind emissions that significantly contribute to downwind nonattainment or interfere with downwind maintenance of the NAAQS; and (4) for states that are found to have emissions that significantly contribute to nonattainment or interfere with maintenance of the NAAQS downwind, implementing the necessary emissions reductions through enforceable measures. In this proposed action, EPA applies this 4-step interstate transport framework to respond to the D.C. Circuit’s remand and revise the CSAPR Update with respect to the 2008 ozone NAAQS.

The remedy that emerges from the 4-step interstate transport framework is state emissions budgets implemented as a cap-and-trade program. This RIA evaluates how the EGUs covered by the proposed rule are expected to reduce their emissions in response to the requirements and flexibilities provided by the remedy implemented by the proposed Revised CSAPR Update and the benefits, costs, and impacts of doing so. The proposed rule sets EGU ozone season NO_X emissions budgets (allowable emission levels) for 2021 and future years. EPA proposes to implement these reductions through FIPs in any state that does not have an approved good neighbor SIP by the date this proposal is finalized. Furthermore, under the FIPs, affected EGUs would participate in the CSAPR NO_X ozone-season allowance trading program. The allowance trading program essentially converts the EGU NO_X emissions budget for each of the 12 states subject to the FIP into a limited number of NO_X ozone-season allowances that, on a ton basis, equal the state's ozone season emissions budget. Starting in 2021, emissions from affected EGUs in the 12 states cannot exceed the sum of emissions budgets but for the ability to use banked allowances from previous years for compliance. No further reductions in budgets occur after 2025, and budgets remain in place for future years. 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 states' emissions budget. Similar to the approach taken in the CSAPR Update, EPA is proposing a one-time conversion of banked Group 2 allowances according to a formula that ensures that emissions in the Group 3 trading program region in the first year of the program do not exceed a specified level (defined as emissions up to the sum of the states' seasonal emissions budgets and variability limits) as a result of the use of banked allowances from the Group 2 trading program.

For the proposed Revised CSAPR Update, the EGU ozone season NO_X budgets for each state reflect EGU NO_X reduction strategies that are widely available at a uniform cost of $1,600 per ton (2016$) of NO_X for affected EGUs.[3] Specifically, this uniform cost reflects turning on idled SCR and installing state-of-the-art combustion controls. Furthermore, this RIA analyzes regulatory control alternatives based on more and less stringent state emissions budgets based on uniform NO_X control costs of $9,600 per ton and $500 per ton, respectively. Table ES-1 shows the EGU NO_X ozone season emission budgets that are evaluated in this RIA.

Table ES-1. NO_X Ozone Season Emission Budgets (Tons) Evaluated

	Revised CSAPR Update Proposal				
State	**2021**	**2022**	**2023**	**2024**	**2025**
Illinois	9,444	9,415	8,397	8,397	8,397
Indiana	12,500	11,998	11,998	9,447	9,447

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[3] For details, please see EGU NO_X Mitigation Strategies Proposed Rule TSD available in the docket for this proposed rule.

Kentucky	14,384	11,936	11,936	11,936	11,936
Louisiana	15,402	14,871	14,871	14,871	14,871
Maryland	1,522	1,498	1,498	1,498	1,498
Michigan	12,727	11,767	9,803	9,614	9,614
New Jersey	1,253	1,253	1,253	1,253	1,253
New York	3,137	3,137	3,137	3,119	3,119
Ohio	9,605	9,676	9,676	9,676	9,676
Pennsylvania	8,076	8,076	8,076	8,076	8,076
Virginia	4,544	3,656	3,656	3,395	3,395
West Virginia	13,686	12,813	11,810	11,810	11,810
Total	106,280	100,096	96,111	93,092	93,092

Less-Stringent Alternative

State	2021	2022	2023	2024	2025
Illinois	9,667	9,632	8,579	8,599	8,579
Indiana	15,677	15,206	15,206	12,755	12,603
Kentucky	15,606	15,606	15,606	15,588	15,606
Louisiana	15,442	15,442	15,442	15,488	15,442
Maryland	1,565	1,565	1,565	1,565	1,565
Michigan	13,120	13,120	10,313	10,841	10,116
New Jersey	1,346	1,346	1,346	1,346	1,346
New York	3,182	3,182	3,182	3,169	3,163
Ohio	15,490	15,560	15,560	15,917	15,560
Pennsylvania	11,487	11,487	11,487	11,570	11,487
Virginia	4,588	4,172	4,172	3,912	3,908
West Virginia	15,017	15,017	13,272	13,407	13,272
Total	122,187	121,334	115,730	114,156	112,647

More-Stringent Alternative

State	2021	2022	2023	2024	2025
Illinois	9,444	9,415	8,397	7,142	7,142
Indiana	12,500	11,998	11,998	8,264	8,264
Kentucky	14,384	11,936	11,936	8,852	8,852
Louisiana	15,402	14,871	14,871	12,636	12,636
Maryland	1,522	1,498	1,498	1,239	1,239
Michigan	12,727	11,767	9,803	7,315	7,315
New Jersey	1,253	1,253	1,253	1,257	1,257
New York	3,137	3,137	3,137	3,020	3,020
Ohio	9,605	9,676	9,676	9,126	9,126
Pennsylvania	8,076	8,076	8,076	7,578	7,578

Virginia	4,544	3,656	3,656	3,022	3,022
West Virginia	13,686	12,813	11,810	9,569	9,569
Total	106,280	100,096	96,111	79,020	79,020

ES.2 Baseline and Analysis Years

The proposal sets forth the requirements for states to reduce states' significant contribution to downwind nonattainment or 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 and electricity sector and related fuel market conditions in the analysis year of 2021, taking into account currently on-the-books Federal regulations, substantial Federal regulatory proposals, enforcement actions, state regulations, population, expected electricity demand growth, and where possible, economic growth.[4] 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 proposal.

The analysis in this RIA focuses on benefits, costs and certain impacts in both 2021 and 2025. We focus on 2021 because it is by the 2021 ozone season, corresponding with the 2021 Serious area attainment date, that significant contribution from upwind states' must be eliminated to the extent possible. It is also the first year in which some EGU NOx mitigation technologies are available. In addition, impacts for 2023 to 2025 are important as these years reflect the next model years in which additional NOx mitigation technologies are first available.

Presenting benefits, costs, and certain impacts in 2025 reflects the time needed to make these retrofits on a regional scale and reflects full implementation of the proposed policy. Additional benefits and costs are expected to occur after 2025 as EGUs subject to this proposal

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[4] The technical support document (TSD) for the 2016v1 emissions modeling platform titled *Preparation of Emissions Inventories for 2016v1 North American Emissions Modeling Platform* is included in the docket for this proposed rule. The TSD includes additional discussion on mobile source rules included in the baseline. The future year onroad emission factors account for changes in activity data and the impact of on-the-books rules that are implemented into MOVES2014b. These rules include the Light Duty Vehicle GHG Rule for Model-Year 2017-2025 and the Tier 3 Motor Vehicle Emission and Fuel Standards Rule. Local inspection and maintenance (I/M) and other onroad mobile programs are included, such as California LEVIII, the National Low Emissions Vehicle (LEV) and Ozone Transport Commission (OTC) LEV regulations, local fuel programs, and Stage II refueling control programs. Regulations finalized after the year 2014 are not included, such as the Safer Affordable Fuel Efficient (SAFE) Vehicles Final Rule for Model Years 2021-2026 and the Final Rule for Phase 2 Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles.

continue to comply with the tighter allowance budget, which is below their baseline emissions. Because EPA did not estimate costs and benefits beyond 2025, the full costs and benefits of the proposed policy may be understated in this RIA.

ES.3 Emissions and Air Quality Modeling

The air quality spatial fields for this proposal were constructed using the method and air quality modeling data developed to support the regulatory impact analysis (RIA) for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units (U.S. EPA 2019), also referred to the Affordable Clean Energy (ACE) rule.[5] The foundational data from the ACE approach includes the ozone contributions from EGU emissions in each state based on the 2023 ACE EGU state-sector sector contribution modeling and the 2023 emissions for coal and non-coal fired EGUs that were input to that modeling.[6]

The air quality modeling used in the ACE analysis included annual model simulations for a 2011 base year and a 2023 future year to provide hourly concentrations of ozone and primary and secondarily formed $PM_{2.5}$ component species (*e.g.*, sulfate, nitrate, ammonium, elemental carbon (EC), organic aerosol (OA), and crustal material[7]) for both years nationwide. The photochemical modeling results for 2011 and 2023, in conjunction with modeling to characterize the air quality impacts from groups of emissions sources (*i.e.*, source apportionment modeling) and emissions data for the baseline and regulatory control alternatives, were used to construct the air quality spatial fields that reflect the influence of emissions changes between the baseline and the regulatory control alternatives.

The air quality model simulations (*i.e.*, model runs) were performed using the Comprehensive Air Quality Model with Extensions (CAMx) (Ramboll Environ 2016). Our CAMx nationwide modeling domain (*i.e.*, the geographic area included in the modeling) covers

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[5] Additional details on the ACE modeling and methodology for developing spatial fields of air quality for EGU control strategies are provided in Appendix 3A.

[6] The 2023 emissions used for the ACE modeling were derived from the 2011-based emissions platform whereas the emissions used in the air quality modeling to project ozone design values and contributions for this proposed rule were based on the more recent 2016 platform.

[7] Crustal material refers to metals that are commonly found in the earth's crust such as Aluminum, Calcium, Iron, Magnesium, Manganese, Potassium, Silicon, Titanium and the associated oxygen atoms.

all lower 48 states plus adjacent portions of Canada and Mexico using a horizontal grid resolution of 12 x 12 km.

To potentially calculate ozone-related benefits in 2021 and 2025 EPA applied the ACE approach using as input the ozone season EGU NOx emissions (tons) for the 2021 and 2025 baseline along with emissions for the proposal and each of the two other regulatory control alternatives. These emissions were applied using the ACE approach and source apportionment data to produce spatial fields of the May-September seasonal average MDA8 ozone and the April-October seasonal average MDA1 ozone concentrations as described in Chapter 3.[8] The emissions of SO_2 and directly emitted $PM_{2.5}$ in 2021 and 2025 for each of the regulatory alternatives do not change from the 2025 baseline.

ES.4 Control Strategies and Emissions Reductions

Before undertaking power sector analysis to evaluate compliance with the regulatory control alternatives, EPA first considered available EGU NOX mitigation strategies that could be implemented for the upcoming ozone season (i.e., the 2021 ozone season). EPA considered all widely-used EGU NOX control strategies: optimizing NOX removal by existing, operational selective catalytic reduction (SCRs) and turning on and optimizing existing idled SCRs;[9] turning on existing idled selective non-catalytic reduction (SNCRs); installation of (or upgrading to) state-of-the-art NOX combustion controls; shifting generation to units with lower NOX emission rates; and installing new SCRs and SNCRs. Similarly, as proposed, EPA determined that the power sector could implement all of these NOX mitigation strategies, except installation of new SCRs or SNCRs, for the 2021 ozone-season.

The EGU NOX mitigation strategies that are assumed to operate or are available to reduce NOX in order to comply with each of the regulatory control alternatives are shown in Table ES-2.

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[8] MDA8 is defined as maximum daily 8-hour average ozone concentration, and MDA1 is defined as the maximum daily 1-hour ozone concentration.

[9] Units may choose to idle SCRs in order to avoid fixed operation and maintenance (FOM) and variable operation and maintenance (VOM) costs such as auxiliary fan power, catalyst costs, and additional administrative costs (labor), depending on the prevailing CSAPR allowance price for those units otherwise not required to attain a NOx emission rate that would require operating their SCRs more intensively.

Table ES-2. NO$_X$ Mitigation Strategies Implemented for Compliance with the Regulatory Control Alternatives

Regulatory Control Alternative	NO$_X$ Controls Implemented
Less Stringent Alternative	(1) Shift generation to minimize costs (costs estimated within IPM)
Revised CSAPR Update Proposed Rule	(All controls above) (2) Fully operating existing SCRs to achieve 0.08 lb/MMBtu NOx emission rate (costs estimated outside IPM) (3) Turn on idled SCRs (costs estimated outside IPM) and fully operate akin to (2) (4) Install state of the art combustion controls.
More Stringent Alternative	(All controls above) (5) In 2025, turn on idled SNCRs (costs estimated outside IPM) (6) In 2025, install new SCRs (costs estimated outside IPM)

For the NO$_X$ controls identified in Table ES-2, under the proposed rule and the more stringent alternative, 60 units are projected to fully operate existing SCRs and 4 units are projected to turn on idled SCRs. Under the less stringent alternative, no units are projected to either fully operate existing SCRs or turn on idled SCRs. Under the proposed rule and the more stringent alternative, 27 units are projected to install state-of-the-art combustion controls, and under the less stringent alternative no units are projected to install state-of-the-art combustion controls. The book-life of the controls is assumed to be 15 years. Under the proposed rule and the less stringent alternative, no units are projected to install new SCRs, and under the more stringent alternative, 48 units are projected to install new SCRs. The book-life of the new SCRs is assumed to be 15 years. For the final rule, EPA will provide analytic results for the years 2021 through 2040. In addition, EPA will provide information on the stream of costs and, as feasible, information on the stream of benefits for these analytical years for all scenarios that are both discounted and undiscounted to provide a more complete picture of the effects estimated to take place. For additional details, see the EGU NO$_X$ Mitigation Strategies Proposed Rule TSD.

Table ES-3 shows the emissions reductions expected from the proposal in 2021 and 2025, as well as the more and less stringent alternatives analyzed.

Table ES-3. Estimated 2021 and 2025[a] EGU Emissions Reductions in the 12 States of NOx, SO$_2$, and CO$_2$ and More and Less Stringent Alternatives (Tons)[b,c]

2021	Proposal	More Stringent Alternative	Less Stringent Alternative
NOx (annual)	17,000	17,000	2,000
NOx (ozone season)	17,000	17,000	2,000
SO$_2$ (annual)	--	--	--

2021	Proposal	More Stringent Alternative	Less Stringent Alternative
CO_2 (annual, thousand metric)	--	--	--
2025			
NOx (annual)	27,000	41,000	2,000
NOx (ozone season)	21,000	35,000	2,000
SO_2 (annual)	--	--	--
CO_2 (annual, thousand metric)	4,000	10,000	3,000

[a] The 2021 emissions reductions estimates are based on IPM projections for 2021 and engineering analysis. For more information, see the Ozone Transport Policy Analysis TSD.

[b] NO_x emissions are reported in English (short) tons; CO_2 is reported in metric tons.

[c] In addition to no annual SO_2 emissions reductions as shown in the table above, there are no annual direct $PM_{2.5}$ emissions reductions.

The results of EPA's analysis show that, with respect to compliance with the EGU NO_X emission budgets in 2021, maximizing the use of existing operating SCRs provides the largest amount of ozone season NO_X emission reductions (52 percent, affecting 60 units), and turning on idled SCRs produces an additional 34 percent (affecting 4 units) of the total ozone season NO_X reductions. Generation shifting primarily from coal to gas generation (14 percent) makes up the remainder of the ozone season NO_X reductions.

ES.5 Cost Impacts

EPA analyzed ozone-season NO_X emission reductions and the associated costs to the power sector of implementing the EGU NO_X ozone-season emissions budgets in each of the 12 states using the Integrated Planning Model (IPM) and its underlying data and inputs. The estimates of the changes in the cost of supplying electricity for the regulatory control alternatives are presented in Table ES-4. Since the rule does not result in any additional recordkeeping, monitoring or reporting requirements, the costs associated with compliance with monitoring, recordkeeping, and reporting requirements are not included within the estimates in this table and can be found in preamble section VIII.C.6.

There are several notable aspects of the results presented in Table ES-4. The most notable result is that the estimated annual compliance cost for the less stringent alternative is negative (i.e., a cost reduction) in 2025, although this regulatory control alternative reduces NO_X emissions by over 2,000 tons as shown in Table ES-3. 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. 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 or economic retirement that 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. Since the less-stringent alternative is designed to include only generation shifting, it does not necessitate full operation of existing controls, or installation of new controls, leading to a negative cost point estimate in 2025.

Table ES-4. National Compliance Cost Estimates (millions of 2016$) for the Regulatory Control Alternatives

	Proposal	More-Stringent Alternative	Less-Stringent Alternative
2021-2025 (Annualized)	19.4	80.6	1.6
2021 (Annual)	20.9	37.2	3.8
2025 (Annual)	6.3	132.2	-12.0

The *2021-2025 (Annualized)* row reflects total estimated annual compliance costs levelized over the period 2021 through 2025, discounted using a 4.25 real discount rate.[10] The *2021 (Annual)* and *2025 (Annual)* rows reflect annual estimates in each of those years.

Under the Revised CSAPR Update proposed rule, fully operating existing SCR controls provides a large share of the total emissions reductions. These options are selected in 2021, while upgrading to state-of-the-art combustion controls is assumed to begin in 2022. Generation shifting costs are positive in 2021, but negative in 2025. The result is that the costs in 2021 are higher than costs in 2025.

ES.6 Benefits

The proposed Revised CSAPR Update is expected to reduce concentrations of ground-level ozone, $PM_{2.5}$, and CO_2 in the atmosphere (see Chapter 3 for discussion). EPA historically has used evidence reported in the Integrated Science Assessment (ISA) for the most recent NAAQS review to inform its approach for quantifying air pollution-attributable health, welfare, and environmental impacts associated with that pollutant. The ISA synthesizes the

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[10] This table reports compliance costs consistent with expected electricity sector economic conditions. An NPV of costs was calculated using a 4.25% real discount rate consistent with the rate used in IPM's objective function for cost-minimization. The NPV of costs was then used to calculate the levelized annual value over a 5-year period (2021-2025) using the 4.25% rate as well. Tables ES-9 and 7-3 report the NPV of the annual stream of costs from 2021-2025 using 3% and 7% consistent with OMB guidance.

epidemiologic, controlled human exposure and experimental evidence "…useful in indicating the kind and extent of identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in ambient air."

The ISA uses a weight of evidence approach to assess the extent to which each criteria pollutant causes a given health outcome. EPA generally estimates the number and economic value of the effects for which the ISA identifies the pollutant as having "causal" or "likely to be causal" relationship. The endpoints for which the 2020 final Ozone ISA and the 2019 final PM ISA identified as being causal or likely causal differed in some cases from the endpoints for which those pollutants were identified as being causal or likely causal in the Ozone and PM ISAs completed for the previous NAAQS reviews (see Chapter 5, Tables 5-5 and 5-6). In addition to statements of causality, each new ISA identifies an extensive number of epidemiologic studies that may be suitable for supporting a PM or ozone benefits analysis.[11]

When updating its approach for quantifying the benefits of changes in $PM_{2.5}$ and ozone, the Agency will incorporate evidence reported in these two ISAs and account for forthcoming recommendations from the Science Advisory Board on this issue. When updating the evidence for a given endpoint, EPA will consider the extent to which there is a causal relationship, whether suitable epidemiologic evidence exists to quantify the effect and whether the economic value of the effect may be estimated. Carefully and systematically reviewing the full breadth of this information requires significant time and resources. EPA intends to conduct the necessary updates in time to report the number and economic value of $PM_{2.5}$ and ozone health effects resulting from this proposed rulemaking in the final Revised CSAPR Update RIA. However, to provide perspective regarding the scope of the estimated benefits, Appendix 5B illustrates the potential health effects associated with the change in $PM_{2.5}$ and ozone concentrations as

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[11] In particular, the 2020 Ozone ISA concludes that the currently available evidence for cardiovascular effects and total mortality is suggestive of, but not sufficient to infer, a causal relationship with short-term (as well as long-term) ozone exposures (U.S. EPA, 2020b, sections IS.4.3.4 and IS.4.3.5). As such, EPA is in the process of recalibrating its benefits estimates to quantify only premature mortality from respiratory causes (i.e., non-respiratory causes of premature mortality associated with ozone exposure would no longer be estimated). Similarly, the 2019 PM ISA concludes that the currently available evidence for nervous system effects and cancer is likely to be a causal relationship with long term $PM_{2.5}$ exposure. EPA is in the process of evaluating nervous system effects from long term $PM_{2.5}$ exposure and evaluating the relationship between long term $PM_{2.5}$ exposure and cancer. Furthermore, the ISA references a variety of additional studies for consideration in quantifying the health implications of changes in $PM_{2.5}$ and ozone exposure. EPA is updating the estimates for several other health endpoints to account for this new scientific literature.

calculated using methods developed prior to the 2019 PM ISA and 2020 Ozone ISA. The values of these estimated benefits are not reflected in the estimated net benefits reported below.

The proposal is expected to reduce emissions of ozone season NO_X. Reducing NO_X emissions generally reduces human exposure to ozone and the incidence of ozone-related health effects, though the degree to which ozone is reduced will depend in part on local levels of VOCs as discussed in Chapter 3. The proposal would 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 reduce human exposure to ambient $PM_{2.5}$ throughout the year and would reduce the incidence of $PM_{2.5}$-attributable health effects.[12] Reducing emissions of NO_X would also reduce ambient exposure to NO_2 and its associated health effects.

ES.6.1 Climate Benefits Estimates

We estimate the climate benefits for this proposed rulemaking using a measure of the domestic social cost of carbon (SC-CO_2). The SC-CO_2 is a metric that estimates the monetary value of projected impacts associated with marginal changes in CO_2 emissions in a specific year. The SC-CO_2 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, including reduced costs for heating and increased costs for air conditioning. The metric 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 CO_2 estimates presented in this RIA focus on the projected impacts of climate change that are anticipated to directly occur within U.S. borders. Table ES-5 shows the estimated monetary value of the estimated changes in CO_2 emissions in 2021 and 2025 for the Revised CSAPR Update proposal, the more stringent alternative, and the less stringent alternative.

Table ES-5. Estimated Domestic Climate Benefits from Changes in CO_2 Emissions for Selected Years (Millions of 2016$)

Regulatory Option	Year	3% Discount Rate	7% Discount Rate
Proposal	2021	0.3	0.0

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[12] This RIA does not quantify $PM_{2.5}$-related benefits associated with SO_2 emission reductions. As discussed in Chapter 4, EPA does not estimate significant SO_2 emission reductions as a result of this proposal. Additionally, this RIA does not estimate changes in emissions of directly emitted particles.

Table ES-5. Estimated Domestic Climate Benefits from Changes in CO_2 Emissions for Selected Years (Millions of 2016$)

	2025	32.9	5.4
More Stringent Alternative	2021	0.8	0.1
	2025	71.5	11.7
Less Stringent Alternative	2021	0.2	0.0
	2025	25.5	4.2

Table ES-6 shows the total annualized monetary values associated with changes in CO_2 emissions for the three regulatory options. The annualized values for the proposed Revised CSAPR Update are $22 million and $3.6 million, using discount rates of 3 and 7 percent, respectively.

Table ES-6. Estimated Total Annualized Domestic Climate Benefits (2021-25) from Changes in CO_2 Emissions (Millions of 2016$)

Regulatory Option	3% Discount Rate	7% Discount Rate
Proposal	22.1	3.6
More Stringent Alternative	38.9	6.3
Less Stringent Alternative	15.3	2.5

ES.6.2 Unquantified Health and Welfare Benefits Categories

The monetized benefits estimated in this RIA reflect a subset of benefits attributable to the climate benefits from reductions associated with CO_2. The proposal is also expected to reduce emissions of ozone season NO_X. In the presence of sunlight, NO_X and volatile organic compounds (VOCs) can undergo a chemical reaction in the atmosphere to form ozone. Reducing NO_X emissions generally reduces human exposure to ozone and the incidence of ozone-related health effects, though the degree to which ozone is reduced will depend in part on local levels of VOCs. The proposal would 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 reduce human exposure to ambient $PM_{2.5}$ throughout the year and would reduce the incidence of $PM_{2.5}$-attributable health effects. Reducing emissions of NO_X would also reduce ambient exposure to NO_2 and its associated health effects.

Data, time, and resource limitations prevented EPA from quantifying the estimated impacts or monetizing estimated benefits , including benefits associated with exposure to ozone, $PM_{2.5}$, and NO_2 (independent of the role NO_2 plays as precursors to $PM_{2.5}$), as well as ecosystem effects, and visibility impairment due to the absence of air quality modeling data for these pollutants in this analysis. In Chapter 5, (Table 5-4), we provide a qualitative description of these benefits.

ES.6.3 Approach for Updating Health Effects from $PM_{2.5}$ and Ozone

EPA is reviewing this evidence and is following a five-step approach as it updates its methods for quantifying and monetizing ozone and $PM_{2.5}$ attributable health endpoints:

1. Identify Ozone- and $PM_{2.5}$-attributable health effects for which the ISA reports the strongest evidence. EPA will consider the ISA-reported evidence for each endpoint, including the extent to which the ISA identifies that endpoint as either causally, or likely-to-be-causally, related to each pollutant.
2. Identify health outcomes that may be quantified in a benefits assessment. We would select among clinically significant outcomes (e.g. premature mortality and hospital admissions) for which endpoint-specific baseline incidence data are available.
3. Choose concentration-response parameters characteristic of the literature reviewed in the ISA. We would weigh criteria including study design, location, population characteristics, and other attributes. In some cases we will need to identify and select new rates of baseline disease to quantify these effects.
4. Choose economic unit values. For each health endpoint we would identify a corresponding willingness-to-pay or cost-of-illness measure to express the economic value of the adverse effect.
5. Develop methods for characterizing uncertainty associated with quantified benefits estimates. Building on EPA's current methods for characterizing uncertainty, these approaches will include, among others, reporting confidence intervals calculated from concentration-response parameter estimates and separate quantification using multiple studies and concentration response parameters for particularly influential endpoints (e.g., mortality risk), and potentially approaches for aggregating and representing the results of multiple studies evaluating a particular health endpoint.

At each of the four stages above, the Agency would report a Preferred Reporting Item for System Reviews (PRISMA) diagram, detailing for each endpoint, study and concentration-response (effect coefficients), which are included and excluded and the rationale for applying or excluding this information.

ES.7 Results of Benefit-Cost Analysis

In applying the multi-factor test, EPA evaluated whether reductions resulting from emitting at the level of the proposed emissions budgets for EGUs in 2021 and 2022 would resolve any downwind nonattainment or maintenance problems. The assessment showed that the emission budgets reflecting $1,600 per ton would change the status of one of the two nonattainment receptors (first shifting the Stratford, Connecticut monitor to a maintenance-only receptor in 2021 and then shifting that monitor to attainment in 2022); however, no other nonattainment or maintenance problems would be resolved in 2021 or 2022. EPA's assessment shows that none of the 11 states are solely linked to the Stratford receptor that is resolved at the $1,600 per ton level of control stringency in 2022. In addition, reductions resulting from the $1,600 per ton emission budgets would shift the Houston receptor in Harris County, Texas from maintenance to attainment in 2023. These emission reductions would also shift the last remaining nonattainment receptor (the Westport receptor in Fairfield, Connecticut) to a maintenance-only receptor in 2024. No nonattainment or maintenance receptors would remain after 2024.

Below in Table ES-7 and Table ES-8, we present the annual costs and benefits estimates for 2021 and 2025, respectively. This analysis uses annual compliance costs reported above as a proxy for social costs. The net benefits of the proposal and more and less stringent alternatives reflect the climate benefits of implementing EGU emissions reductions strategies for the affected 12 states via the proposed FIPs minus the costs of those emissions reductions. We represent the present annual value of non-monetized benefits from reductions in ozone, $PM_{2.5}$ and NO_2 exposure as a B. The annual value of B will differ across discount rates, year of analysis, and the regulatory alternatives analyzed. The estimated social costs to implement the proposal, as described in this document, are approximately $21 million in 2021 and $6 million in 2025 (2016$).

The estimated climate benefits from implementation of the proposal are approximately $0.31 million and $0.05 million in 2021 (2016$, based on a real discount rate of 3 percent and 7 percent for climate benefits). For 2025, the estimated climate benefits from implementation of the proposal are approximately $33 million and $5.4 million (2016$, based on a real discount rate of 3 percent and 7 percent for climate benefits). As discussed in Chapter 5, the monetized benefits presented in this proposal RIA are those for climate (from CO_2 emissions reductions). The non-monetized benefits for ozone and $PM_{2.5}$ are discussed qualitatively in Chapter 5.

EPA calculates the net benefits of the proposal by subtracting the estimated social costs from the estimated benefits in both 2021 and 2025. The annual net benefits of the proposal in 2021 (in 2016$) are approximately -$21 million using a 3 percent discount rate and a 7 percent real discount rate. The annual net benefits of the proposal in 2025 are approximately $27 million using a 3 percent real discount rate and approximately -$0.9 million using a 7 percent real discount rate. Table ES-7 presents a summary of the climate benefits, costs, and net benefits of the proposal and the more and less stringent alternatives for 2021. Table ES-8 presents a summary of these impacts for the proposal and the more and less stringent alternatives for 2025.

Table ES-7. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2021 for the U.S. (millions of 2016$)[a,b,c,d]

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	0.31 +B	21	-21 +B
7%	0.05 +B		-21 +B
More Stringent Alternative			
3%	0.80 +B	37	-36 +B
7%	0.12 +B		-37 +B
Less Stringent Alternative			
3%	0.17 +B	4	-4 +B
7%	0.03 +B		-4 +B

[a] We focus results to provide a snapshot of costs and benefits in 2021, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates.
[b] Benefits ranges represent discounting of climate benefits at a real discount rate of 3 percent and 7 percent. Climate benefits are based on changes (reductions) in CO_2 emissions. The costs presented in this table are 2021 annual estimates for each alternative analyzed.
[c] All costs and benefits are rounded to two significant figures; rows may not appear to add correctly.
[d] B is the sum of all unquantified ozone, $PM_{2.5}$, and NO_2 benefits. The annual value of B will differ across discount rates, year of analysis, and the regulatory alternatives analyzed. While EPA did not estimate these benefits in this RIA, Appendix 5B presents $PM_{2.5}$ and ozone estimates quantified using methods consistent with the previously published ISAs to provide information regarding the potential magnitude of the benefits of this proposed rule.

Table ES-8. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2025 for the U.S. (millions of 2016$)[a,b,c,d]

Discount Rate	Benefits	Costs	Net Benefits
Proposal			

3%	33 +B	6	27 +B
7%	5.4 +B		-0.9 +B
More Stringent Alternative			
3%	71.5 +B	132	-61 +B
7%	11.7 +B		-120 +B
Less Stringent Alternative			
3%	25 +B	-12	37 +B
7%	4.2 +B		16 +B

[a] We focus results to provide a snapshot of costs and benefits in 2025, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates.

[b] Benefits ranges represent discounting of climate benefits at a real discount rate of 3 percent and 7 percent. Climate benefits are based on changes (reductions) in CO_2 emissions. The costs presented in this table are 2025 annual estimates for each alternative analyzed.

[c] All costs and benefits are rounded to two significant figures; rows may not appear to add correctly.

[d] B is the sum of all unquantified ozone, $PM_{2.5}$, and NO_2 benefits. The annual value of B will differ across discount rates, year of analysis, and the regulatory alternatives analyzed. While EPA did not estimate these benefits in this RIA, Appendix 5B presents $PM_{2.5}$ and ozone estimates quantified using methods consistent with the previously published ISAs to provide information regarding the potential magnitude of the benefits of this proposed rule.

Also, as part of fulfilling analytical guidance with respect to E.O. 12866, EPA presents estimates of the present value of the benefits and costs over the five-year period of 2021 to 2025, which is the analytical period for this proposal. To calculate the present value of the social net-benefits of the proposed Revised CSAPR Update, annual benefits and costs are discounted to 2021 at 3 percent and 7 discount rates as directed by OMB's Circular A-4. The present value (PV) of the net benefits, in 2016$ and discounted to 2021, is -$68 million when using a 7 percent discount rate and $14 million when using a 3 percent discount rate.[13] The equivalent annualized value (EAV), an estimate of the annualized value of the net benefits consistent with the present value, is -$17 million per year when using a 7 percent discount rate and $3 million when using a 3 percent discount rate. The EAV represents a flow of constant annual values that, had they occurred in each year from 2021 to 2025, would yield a sum equivalent to the PV. The EAV represents the value of a typical cost or benefit for each year of the analysis, in contrast to the year-specific estimates mentioned earlier in the RIA for the analysis years 2021 and 2025. The comparison of benefits and costs in PV and EAV terms for the proposal can be found in Table ES-9. Estimates in the table are presented as rounded values. The table represents the present

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[13] In annualizing compliance costs using social discount rates, this analysis treats the annual compliance costs as reflecting the use of real resources in a particular year. In practice, annual costs from IPM and costs of NOx controls estimated outside of IPM (e.g., capital costs of combustion controls) reflect annual payments for financed capital and not solely the change in the use of real resources in a particular year (i.e., the opportunity cost of those resources).

value of non-monetized benefits from ozone, $PM_{2.5}$ and NO_2 reductions as a β, while b represents the equivalent annualized value of these non-monetized benefits. These values will differ across the discount rates and depend on the values of the B's in the previous tables.

Table ES-9. Summary of Present Values and Equivalent Annualized Values for the 2021-2025 Timeframe for Estimated Compliance Costs, Climate Benefits, and Net Benefits for the Proposed Rule (millions of 2016$, discounted to 2021)[a,b]

		3% Discount Rate	7% Discount Rate
Present Value	Benefits[c,d]	101+β	15+β
	Climate Benefits[c]	101	15
	Compliance Costs[e]	87	83
	Net Benefits	**14+β**	**-68+β**
Equivalent Annualized Value			
	Benefits	22+b	4+b
	Climate Benefits	22	4
	Compliance Costs	19	20
	Net Benefits	**3+b**	**-17+b**

[a] All estimates in this table are rounded to two significant figures, so numbers may not sum due to independent rounding.

[b] The annualized present value of costs and benefits are calculated over a 5 year period from 2021 to 2025.

[c] Benefits ranges represent discounting of climate benefits at a real discount rate of 3 percent and 7 percent. Climate benefits are based on changes (reductions) in CO_2 emissions.

[d] β and b is the sum of all unquantified ozone, $PM_{2.5}$, and NO_2 benefits. The annual values of β and b will differ across discount rates. While EPA did not estimate these benefits in this RIA, Appendix 5B presents $PM_{2.5}$ and ozone estimates quantified using methods consistent with the previously published ISAs to provide information regarding the potential magnitude of the benefits of this proposed rule.

[e] The costs presented in this table reflect annualized present value compliance costs calculated over a 5 year period from 2021 to 2025.

CHAPTER 1: INTRODUCTION AND BACKGROUND

Overview

EPA originally published the Cross-State Air Pollution Rule (CSAPR) on August 8, 2011, to address interstate transport of ozone pollution under the 1997 ozone National Ambient Air Quality Standards (NAAQS).[1] On October 26, 2016, EPA published the CSAPR Update, which finalized Federal Implementation Plans (FIPs) for 22 states that EPA found failed to submit a complete good neighbor State Implementation Plan (SIP) (15 states)[2] or for which EPA issued a final rule disapproving their good neighbor SIP (7 states).[3] The FIPs promulgated for these states included new electric generating unit (EGU) oxides of nitrogen (NO_X) ozone season emission budgets to reduce interstate transport for the 2008 ozone NAAQS.[4] These emission budgets took effect in 2017 in order to assist downwind states with attainment of the 2008 ozone NAAQS by the 2018 Moderate area attainment date. EPA acknowledged at the time that the FIPs promulgated for 21 of the 22 states only partially addressed good neighbor obligations under the 2008 ozone NAAQS.[5]

This proposed action is taken in response to the United States Court of Appeals for the District of Columbia Circuit's (D.C. Circuit) September 13, 2019 remand of the CSAPR Update.[6] The D.C. Circuit found that the CSAPR Update, which was a partial remedy, was unlawful to the extent it allowed those states to continue their significant contributions to downwind ozone problems beyond the statutory dates by which downwind states must demonstrate their attainment of the air quality standards. This proposed rule, if finalized, will

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

[2] Alabama, Arkansas, Illinois, Iowa, Kansas, Maryland, Michigan, Mississippi, Missouri, New Jersey, Oklahoma, Pennsylvania, Tennessee, Virginia, and West Virginia.

[3] Indiana, Kentucky, Louisiana, New York, Ohio, Texas, and Wisconsin.

[4] 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).

[5] In the CSAPR Update, EPA found that the finalized Tennessee emission budget fully addressed Tennessee's good neighbor obligation with respect to the 2008 ozone NAAQS. As such, Tennessee is not considered in this proposal, and the number of states included is reduced from 22 to 21 states.

[6] EPA is taking this action to address the remand of the CSAPR Update in *Wisconsin v. EPA*, 938 F.3d 303 (D.C. Cir. 2019). The court remanded but did not vacate the CSAPR Update, finding that vacatur of the rule could cause harm to public health and the environment or disrupt the trading program EPA had established and that the obligations imposed by the rule may be appropriate and sustained on remand.

resolve 21 states' outstanding interstate ozone transport obligations with respect to the 2008 ozone NAAQS.

This action, the Revised CSAPR Update proposal, finds that for 9 of the 21 states with remanded FIPs (Alabama, Arkansas, Iowa, Kansas, Mississippi, Missouri, Oklahoma, Texas, and Wisconsin), their projected 2021 ozone season nitrogen oxides (NOx) emissions do not significantly contribute to a continuing downwind nonattainment and/or maintenance problem; therefore the CSAPR Update fully addresses their interstate ozone transport obligations with respect to the 2008 ozone NAAQS. This action also proposes to find that for the 12 remaining states (Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Virginia, and West Virginia), their projected 2021 ozone season NOx emissions significantly contribute to downwind states' nonattainment and/or maintenance problems for the 2008 ozone NAAQS. For these 12 states, EPA proposes to amend their FIPs to revise the existing CSAPR NOx Ozone Season Group 2 emissions budgets for EGUs and implement the revised budgets via a new CSAPR NOx Ozone Season Group 3 Trading Program.[7] EPA is proposing implementation of the revised emission budgets starting with the 2021 ozone season (May 1 – September 30), as outlined in section VIII of the preamble.

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 allowance trading program is the proposed remedy in the FIPs that achieves the ozone season NO_X emission reductions proposed by the rule. The allowance trading program essentially converts the EGU NO_X emission budget for each of the 12 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 can 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. The EGUs covered by the FIPs and subject to the budget are all fossil-fired EGUs with >25MW capacity. The 12 Group 3 states may not use

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[7] The CSAPR Update established a second NO_X ozone season trading program for the 22 states determined to have good neighbor obligations with respect to the 2008 ozone NAAQS – the CSAPR NO_X Ozone Season Group 2 trading program.

allowances allocated under the CSAPR Update for compliance in 2021 and later.[8] Also, allowances allocated under the Revised CSAPR Update may not be used for compliance in the 10 Group 2 states that remain subject to the budgets established in the CSAPR Update.

Consistent with OMB Circular A-4 and EPA's *Guidelines for Preparing Economic Analyses* (2010), this Regulatory Impact Analysis (RIA) presents the benefits and costs of the proposal and compares the benefits and the costs of the proposed rule in 2021 and 2025. The estimated benefits are those health benefits expected to arise from reduced air pollution and the estimated costs are the increased costs of producing electricity and any state reporting requirements as a result of this rule. Unquantified benefits and costs are described qualitatively. The RIA also provides (i) estimates of other impacts of the proposed rule including its effect on retail electricity prices and fuel production and (ii) an assessment of how expected compliance with the proposed rule would affect concentrations at nonattainment and maintenance receptors. This chapter contains background information relevant to the rule and an outline of the chapters of this RIA.

1.1 Background

Clean Air Act (CAA or the Act) section 110(a)(2)(D)(i)(I), which is also known as the "good neighbor provision," requires states to prohibit emissions that will contribute significantly to nonattainment or interfere with maintenance in any other state with respect to any primary or secondary NAAQS. The statute vests states with the primary responsibility to address interstate emission transport through the development of good neighbor State Implementation Plans (SIPs), which are one component of larger SIP submittals typically required three years after EPA promulgates a new or revised NAAQS. These larger SIPs are often referred to as "infrastructure" SIPs or iSIPs. *See* CAA section 110(a)(1) and (2). EPA supports state efforts to submit good neighbor SIPs for the 2008 ozone NAAQS and has shared information with states to facilitate such SIP submittals. However, the CAA also requires EPA to fill a backstop role by issuing FIPs where states fail to submit good neighbor SIPs or EPA disapproves a submitted good neighbor SIP.

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[8] EGUs can still use converted banked allowances from the CSAPR Update to comply with this proposed rule.

As described in the preamble for the proposal, to reduce interstate emission transport under the authority provided in CAA section 110(a)(2)(D)(i)(I), this rule proposes to further limit ozone season (May 1 through September 30) NOx emissions from EGUs in 12 states using the same framework used by EPA in developing the original CSAPR (the Interstate Transport Framework). The Interstate Transport Framework provides a 4-step process to address the requirements of the good neighbor provision for ground-level ozone and fine particulate matter ($PM_{2.5}$) NAAQS: (1) identifying downwind receptors that are expected to have problems attaining or maintaining the NAAQS; (2) determining which upwind states contribute to these identified problems in amounts sufficient to "link" them to the downwind air quality problems (*i.e.*, here, a 1 percent contribution threshold); (3) for states linked to downwind air quality problems, identifying upwind emissions that significantly contribute to downwind nonattainment or interfere with downwind maintenance of the NAAQS; and (4) for states that are found to have emissions that significantly contribute to nonattainment or interfere with maintenance of the NAAQS downwind, implementing the necessary emissions reductions through enforceable measures. Details on the methods and results of applying this process can be found in the preamble for this proposal.

1.1.1 Role of Executive Orders in the Regulatory Impact Analysis

Several statutes and executive orders apply to any public document. The analyses required by these statutes, along with a brief discussion of several executive orders, are presented in Chapter 6. Below we briefly discuss the requirements of Executive Orders 12866, 13563, and 13771 and the guidelines of the Office of Management and Budget (OMB) Circular A-4 (U.S. OMB, 2003).

Executive Order 13771 directs all federal agencies to repeal at least two existing regulations for each new regulation issued in fiscal year (FY) 2017 and thereafter. It further directs agencies that the "total incremental costs of all regulations should be no greater than zero" in FY 2017. For FY 2018 and beyond, the director of the OMB is to provide agencies with a total amount of incremental costs that will be allowed.

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 emissions reductions for compliance with the Revised CSAPR Update proposal. OMB Circular A-4 requires analysis of one potential regulatory control alternative more stringent than the proposal and one less stringent than the proposal. This RIA evaluates the benefits, costs, and certain impacts of a more and a less stringent alternative to the primary alternative in this proposal.

1.1.2 Alternatives Analyzed

EPA proposes to amend FIPs for 12 states to revise the existing CSAPR NOx Ozone Season Group 2 emissions budgets for EGUs and implement the revised budgets via a new CSAPR NOx Ozone Season Group 3 Trading Program. Note that EGUs have flexibility in determining how they will comply with the allowance trading program. EPA is proposing implementation of the revised emission budgets starting with the 2021 ozone season.

In response to OMB Circular A-4, this RIA analyzes the Revised CSAPR Update proposed emission budgets as well as a more and a less stringent alternative to the Revised CSAPR Update proposal. The more and less stringent alternatives differ from the Revised CSAPR Update proposal in that they set different EGU NOX ozone season emission budgets for the affected EGUs. The less-stringent scenario uses emission budgets that were developed using uniform control stringency represented by $500 per ton (2016$). The more-stringent scenario uses emission budgets that were developed using uniform control stringency represented by $9,600 per ton (2016$). See section VIII of the preamble, and the EGU NOX Mitigation Strategies Proposed Rule TSD, in the docket for this proposed rule[9] for further details of these emission budgets.

1.1.3 The Need for Air Quality or Emissions Regulation

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.

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[9] Docket ID No. EPA-HQ-OAR-2020-0272

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, achieving emissions reductions (i.e., by establishing the EGU NO_X ozone-season emissions budgets in this proposal) through a market-based mechanism is a straightforward and cost-effective remedy to address an externality in which firms emit pollutants, resulting in health and environmental problems without compensation for those incurring the problems. Capping emissions through allowance allocations incentivizes 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 Needed Reductions

In order to apply the first and second steps of the CSAPR 4-step Interstate Transport Framework to interstate transport for the 2008 ozone NAAQS, EPA first performed air quality modeling coupled with ambient measurements in an interpolation technique to project ozone concentrations at air quality monitoring sites in 2021. EPA evaluated 2021 projected ozone concentrations at individual monitoring sites and considered current ozone monitoring data at these sites to identify receptors that are anticipated to have problems attaining or maintaining the 2008 ozone NAAQS. In this analysis, downwind air quality problems are defined by receptors that are projected to be unable to attain (i.e., nonattainment receptor) or maintain (i.e., maintenance receptor) the 2008 ozone NAAQS.

To apply the second step of the Interstate Transport Framework, EPA used air quality modeling to quantify the contributions from upwind states to ozone concentrations in 2021 at downwind receptors. Once quantified, EPA then evaluated these contributions relative to a screening threshold of 1 percent of the NAAQS. States with contributions that equal or exceed 1 percent of the NAAQS are identified as warranting further analysis for significant contribution to nonattainment or interference with maintenance.[10] States with contributions below 1 percent of the NAAQS are considered to not significantly contribute to nonattainment or interfere with maintenance of the NAAQS in downwind states.

To apply the third step of the Interstate Transport Framework, EPA applied a multi-factor test to evaluate cost, available emission reductions, and downwind air quality impacts to determine the appropriate level of uniform NOx control stringency that addresses the impacts of interstate transport on downwind nonattainment or maintenance receptors. EPA used this multi-factor assessment to gauge the extent to which emission reductions are needed, and to ensure any required reductions do not result in over-control.

Using the multi-factor test, EPA identified a control strategy for EGUs at a stringency level that maximizes cost-effective emission reductions.[11] This control strategy reflects the optimization of existing selective catalytic reduction (SCR) controls and installation of state-of-the-art NOx combustion controls, with an estimated marginal cost of $1,600 per ton (2016$).[12] It is at this control stringency where incremental EGU NOx reduction potential and corresponding downwind ozone air quality improvements are maximized relative to the alternative options analyzed. This strategy maximizes the ratio of emission reductions to marginal cost and the ratio of ozone improvements to marginal cost. EPA finds that these cost-effective EGU NOx reductions will make meaningful and timely improvements in downwind ozone air quality to address interstate ozone transport for the 2008 ozone NAAQS, as discussed in Section VII.D.1 of the preamble. Further, this evaluation shows that emission budgets reflecting the $1,600 per ton cost threshold do not over-control upwind states' emissions relative to either the downwind air

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[10] EPA assessed the magnitude of the maximum projected design value for 2021 at each receptor in relation to the 2008 ozone NAAQS. Where the value exceeds the NAAQS, EPA determined that receptor to be a maintenance receptor for purposes of defining interference with maintenance. That is, monitoring sites with a maximum design value that exceeds the NAAQS are projected to have a maintenance problem in 2021.

[11] EPA's *Guidelines for Preparing Economic Analysis* states "[a] policy is cost-effective if it meets a given goal at least cost, but cost-effectiveness does not encompass an evaluation of whether that goal has been set appropriately to maximize social welfare. … A policy is considered cost-effective when marginal abatement costs are equal across all polluters. In other words, for any level of total abatement, each polluter has the same cost for their last unit abated." (USEPA 2010, p 4-2). That is not the sense in which the term "cost-effective" is used in this paragraph. For the sense of what this term means, and in particular what "maximize cost-effective reductions" means in the context of this proposed rulemaking, see Section VII.D.1 of the preamble.

[12] EGU NO_X Mitigation Strategies Proposed Rule TSD, in the docket for this proposed rule (Docket ID No. EPA-HQ-OAR-2020-0272).

quality problems to which they are linked at step 1 or the 1 percent contribution threshold that triggers further evaluation at step 2 of the 4-step Interstate Transport Framework for the 2008 ozone NAAQS.

In applying the multi-factor test, EPA evaluated whether reductions resulting from the proposed emissions budgets for EGUs in 2021 and 2022 would resolve any downwind nonattainment or maintenance problems. The assessment showed that the emission budgets reflecting $1,600 per ton would change the status of one of the two nonattainment receptors (first shifting the Stratford, Connecticut monitor to a maintenance-only receptor in 2021, then shifting that receptor to attainment in 2022); however, no other nonattainment or maintenance problems would be resolved in 2021 or 2022. EPA's assessment shows that none of the 11 states are solely linked to the Stratford receptor that is resolved at the $1,600 per ton level of control stringency in 2022. In addition, reductions resulting from the $1,600 per ton emission budgets would shift the Houston receptor in Harris County, Texas from maintenance to attainment in 2023. These emission reductions would also shift the last remaining nonattainment receptor (the Westport receptor in Fairfield, Connecticut) to a maintenance-only receptor in 2024. No nonattainment or maintenance receptors would remain after 2024.

1.2.2 States Covered by the Proposed Rule

This rule proposes to find that the following 12 states require further ozone season NOx emission reductions to address the good neighbor provision as to the 2008 ozone NAAQS: Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Virginia, and West Virginia.[13] As such, EPA proposes to promulgate FIPs for these states that include new EGU NOx ozone season emission budgets, with implementation of these emission budgets beginning with the 2021 ozone season. EPA also proposes to adjust states' emission budgets for each ozone season thereafter to incentivize ongoing operation of

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[13] This action proposes to find that for 9 of the 21 states with remanded FIPs (Alabama, Arkansas, Iowa, Kansas, Mississippi, Missouri, Oklahoma, Texas, and Wisconsin), their projected 2021 ozone season NOx emissions do not significantly contribute to a continuing downwind nonattainment and/or maintenance problem; therefore the CSAPR Update fully addresses their interstate ozone transport obligations with respect to the 2008 ozone NAAQS. In addition, in the CSAPR Update EPA found that the finalized Tennessee emission budget fully addressed Tennessee's good neighbor obligation with respect to the 2008 ozone NAAQS, and Tennessee is also not considered in this proposal. Allowances allocated under the Revised CSAPR Update may not be used for compliance in these 10 Group 2 states that remain subject to the budgets established in the CSAPR Update.

identified emission controls to address significant contribution, until such time that our air quality projections demonstrate anticipated resolution of the downwind nonattainment and/or maintenance problems for the 2008 ozone NAAQS.

1.2.3 Regulated Entities

The proposed rule affects EGUs in these 12 states and regulates utilities (electric, natural gas, other systems) classified as code 221112 by the North American Industry Classification System (NAICS) and have a nameplate capacity of greater than 25 megawatts (MWe).

1.2.4 Baseline and Analysis Years

As described in the preamble, EPA proposes to align implementation of this rule with relevant attainment dates for the 2008 ozone NAAQS. EPA's final 2008 Ozone NAAQS SIP Requirements Rule established the attainment deadline of July 20, 2021 for ozone nonattainment areas currently designated as Serious, and EPA proposes to establish emission budgets and implementation of these emission budgets starting with the 2021 ozone season.

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 2021, taking into account currently on-the-books Federal regulations, substantial Federal regulatory proposals, enforcement actions, state regulations, population, and where possible, economic growth.[14] 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 proposed transport rule.

The baseline for this analysis does not assume states will adopt any emissions reduction methods in and around the Air Quality Control Regions where the nonattainment and

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[14] The technical support document (TSD) for the 2016v1 emissions modeling platform titled *Preparation of Emissions Inventories for 2016v1 North American Emissions Modeling Platform* is included in the docket for this proposed rule. The TSD includes additional discussion on mobile source rules included in the baseline. The future year onroad emission factors account for changes in activity data and the impact of on-the-books rules that are implemented into MOVES2014b. These rules include the Light Duty Vehicle GHG Rule for Model-Year 2017-2025 and the Tier 3 Motor Vehicle Emission and Fuel Standards Rule. Local inspection and maintenance (I/M) and other onroad mobile programs are included, such as California LEVIII, the National Low Emissions Vehicle (LEV) and Ozone Transport Commission (OTC) LEV regulations, local fuel programs, and Stage II refueling control programs. Regulations finalized after the year 2014 are not included, such as the Safer Affordable Fuel Efficient (SAFE) Vehicles Final Rule for Model Years 2021-2026 and the Final Rule for Phase 2 Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles.

maintenance receptors are located to reduce ozone other than those already taken into account. In these areas that do not meet the NAAQS in the baseline that see decreased concentrations of ozone, the states where these receptors are located may be able to avoid applying other measures to assure NAAQS attainment. As a result, there would be benefits from avoided compliance costs in these areas and the ozone and $PM_{2.5}$ concentrations changes, and their associated health and ecological benefits, would likely be lower relative to the projections in this RIA. The baseline in this RIA respects that reductions are required of upwind states in order to improve air quality at the nonattainment and maintenance receptors.

The analysis in this RIA focuses on benefits, costs and certain impacts in both 2021 and 2025. We focus on 2021 because it is by the 2021 ozone season, corresponding with the 2021 Serious area attainment date, that significant contribution from upwind states' must be eliminated to the extent possible. In addition, impacts for 2023 to 2025 are important because it is in this period that additional NOx control technologies could potentially be installed. EPA's analysis for the third step of the Interstate Transport Framework indicates that by 2023 the remaining ozone receptors in the two downwind states (Connecticut and Texas) are expected to shift from nonattainment or maintenance status to meeting the NAAQS with application of certain EGU controls beginning in 2021, except for one receptor in Westport, Connecticut.[15] This receptor is estimated to shift from nonattainment status to meeting the NAAQS in 2025 with the application of additional EGU controls. Presenting benefits, costs and certain impacts in 2025 reflects the time needed to make these retrofits on a regional scale and reflects full implementation of the proposed policy. Additional benefits and costs are expected to occur after 2025 as EGUs subject to this proposal continue to comply with the tighter allowance budget, which is below their baseline emissions.[16] Because EPA did not estimate costs and benefits beyond 2025, the full costs and benefits of the proposed policy may be understated in this RIA.

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[15] This RIA also provides an assessment of how expected compliance with the proposed rule would affect concentrations at nonattainment and maintenance receptors.

[16] EPA designed the analysis for the RIA to be consistent with the methodology adopted in the CSAPR Update rule. As such, the analytical timeframe chosen was 2021-25, which is the period between when the proposed rule would begin to take effect and the date by which all linked receptors are projected to come clean.

1.2.5 Emissions Controls, Emissions, and Cost Analysis Approach

EPA estimated the control strategies and compliance costs of the proposed rule 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 purchasing, installing, and operating NO_X control technology, changes in fuel costs, and changes in the generation mix.[17] 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. This analysis also provides estimates of NO_X emissions changes during ozone season and year-round, as well as emissions changes in carbon dioxide (CO_2) due to changes in power sector operation.

1.2.6 Benefits Analysis Approach

Implementing the Revised CSAPR Update proposed rule is expected to reduce emissions of NO_X and provide ozone reductions, as well as consequent reductions in $PM_{2.5}$ concentrations and CO_2 emissions. Data, resource, and methodological limitations prevent EPA from monetizing health benefits from reducing concentrations of ozone and $PM_{2.5}$, as well as the benefits of reducing direct exposure to NO_2, ecosystem effects and visibility impairment as well as benefits from reductions in other pollutants, such as hazardous air pollutants (HAP). For more details on these limitations and a qualitative discussion of the unquantified benefits, see Chapter 5. EPA estimated the climate benefits of the proposal, and a description of the methodologies used to estimate the climate benefits is also contained in Chapter 5.

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

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[17] Under the proposed rule and the more stringent alternative, 27 units are projected to install state-of-the-art combustion controls; under the less stringent alternative, no units are projected to install state-of-the-art combustion controls. Under the more stringent alternative, 48 units are projected to install new SCRs; under the proposed rule and the less stringent alternative, no units are projected to install new SCRs.

post-processing techniques used to produce a number of air quality metrics for input into the analysis of benefits and costs.

- *Chapter 4: Cost, Emissions, and Energy Impacts.* The chapter summarizes the data sources and methodology used to estimate the costs and other impacts incurred by the power sector.
- *Chapter 5: Benefits*. The chapter qualitatively discusses the health-related benefits of the ozone-related air quality improvements associated with the three regulatory control alternatives analyzed.
- *Chapter 6*: *Statutory and Executive Order Impact Analyses*. The chapter summarizes the Statutory and Executive Order impact analyses.
- *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 the Revised CSAPR Update proposal with respect to the interstate transport of emissions of nitrogen oxides (NOx) 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[1] and provides background on the power sector and electricity generating units (EGUs). In addition, this chapter provides some historical background on recent trends 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, specifically the increased natural gas supply and subsequent relatively low natural gas prices, have resulted in more natural gas being used as base load energy in addition to supplying electricity during peak load. This chapter presents data on the evolution of the power sector from 2014 through 2018. Projections of future power sector behavior and the impact of this proposed rule are discussed in more detail in Chapter 4 of this RIA.

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[1] Only coal-fired EGUs will be directly affected (i.e., have to reduce NOx emissions) by this proposal.

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 2014 and 2018.

In 2018 the power sector consisted of over 22,000 generating units with a total capacity[2] of 1,095 GW, an increase of 26 GW (or 2 percent) from the capacity in 2014 (1,068 GW). The 26 GW increase consisted primarily of natural gas fired EGUs (38 GW), and wind (30 GW) and solar generators (22 GW), and the retirement/re-rating of 56 GW of coal capacity. Substantially smaller net increases and decreases in other types of generating units also occurred.

Table 2-1. Total Net Summer Electricity Generating Capacity by Energy Source, 2014 and 2018

	2014		2018		Change Between '14 and '18		
Energy Source	**Net Summer Capacity (MW)**	**% Total Capacity**	**Net Summer Capacity (MW)**	**% Total Capacity**	**% Increase**	**Capacity Change (MW)**	**% of Total Capacity Increase**
Coal	299,094	28%	242,786	22%	-19%	-56,309	-214%
Natural Gas	432,150	40%	470,237	43%	9%	38,087	145%
Nuclear	98,569	9%	99,433	9%	0.9%	864	3.3%
Hydro	102,162	9.56%	102,702	9.38%	0.5%	540	2.1%
Petroleum	41,135	3.85%	32,218	2.94%	-22%	-8,917	-34%
Wind	64,232	6.01%	94,418	8.62%	47%	30,186	115%
Solar	10,323	0.97%	31,878	2.91%	209%	21,555	82%
Other Renewable	16,049	2%	16,178	1%	1%	129	0%
Misc	4,707	0.44%	4,891	0.45%	4%	184	1%
Total	1,068,422	100%	1,094,740	100%	2%	26,318	100%

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[2] 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).

Note: This table presents generation capacity. Actual net generation is presented in Table 2-2.
Source: EIA. Electric Power Annual 2014 and 2018, Table 4.3

The 2 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 2014 to 2018, a total of 98 GW of new generating capacity was built and brought online, and 74 GW of existing units were retired. The net effect of the re-rating of existing units reduced the total capacity by 9.4 GW. The overall net change in capacity was an increase of 26 GW, as shown in Table 2-1.

The newly built generating capacity was primarily natural gas (44 GW), which was partially offset by gas retirements (24 GW). Wind capacity was the second largest type of new builds (30 GW), augmented by solar (21 GW). The largest decline was from coal retirements and re-rating, which amounted to 56 GW over this period. The overall mix of newly built and retired capacity, along with the net effect, is shown on Figure 2-1. The data for Figure 2-1 is from Form EIA-860. Figure 2-1 does not show wind and solar retirements of 568 MW.

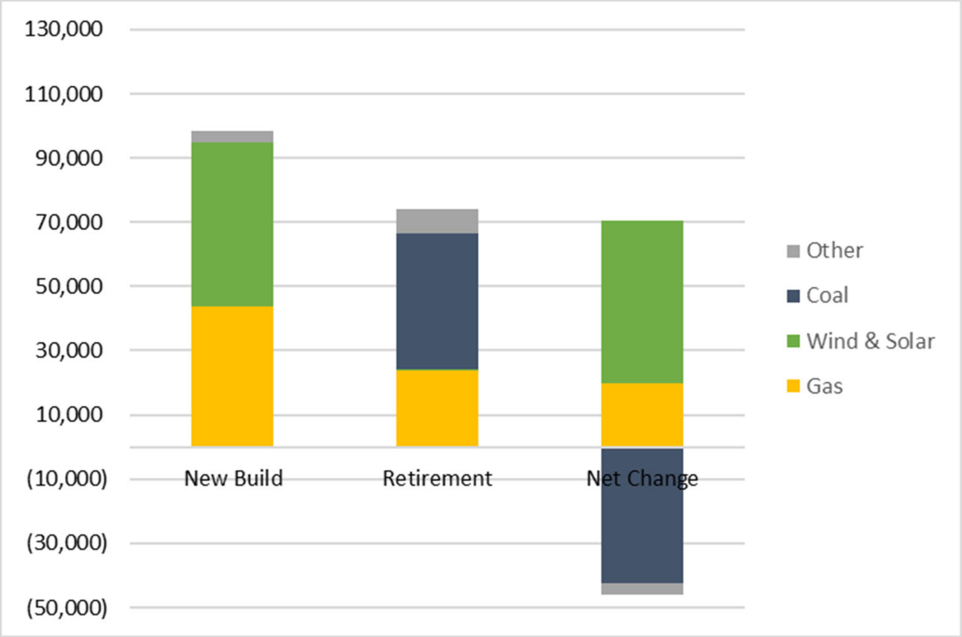

Figure 2-1. National New Build and Retired Capacity (MW) by Fuel Type, 2014-2018

The information in Table 2-1 and Figure 2-1 present information about the generating capacity in the entire U.S. The CSAPR Update, however, directly affected EGUs in 23 eastern states (i.e., the CSAPR 2008 Ozone Region. The share of generating capacity from each major type of generation differs between the CSAPR 2008 Ozone Region and the rest of the U.S. (non-region). Figure 2-2 shows the mix of generating capacity for each region. In 2018, the overall capacity in the CSAPR 2008 Ozone Region is 59 percent 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 (26 percent) than it does in the rest of the country (17 percent). The share of natural gas in the CSAPR 2008 Ozone Region is 45 percent as compared to 40 percent 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.

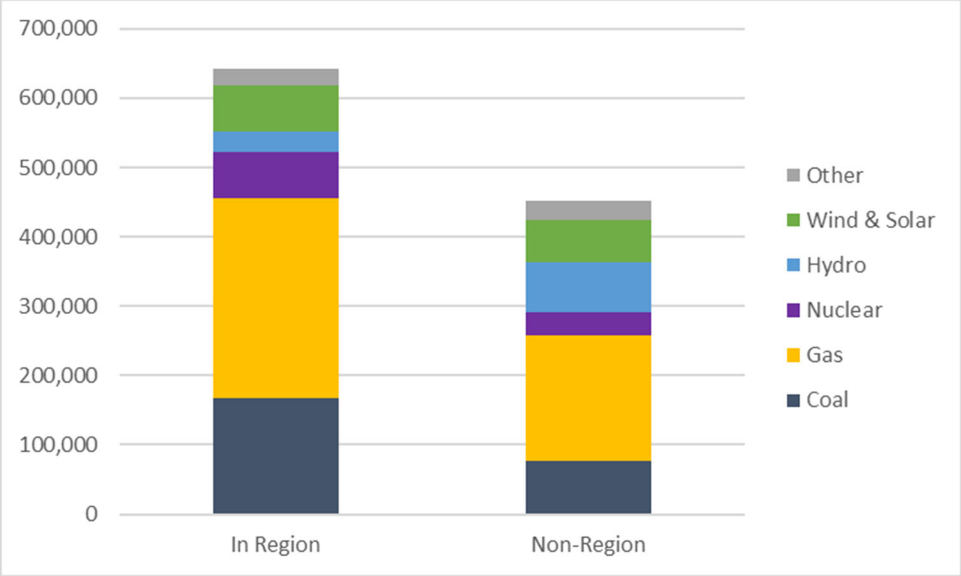

Figure 2-2. Regional Differences in Generating Capacity (MW), 2018

Source: Form EIA-860. Note: "Other" includes petroleum, geothermal, other renewable, waste materials and miscellaneous.

In 2018, electric generating sources produced a net 4,204 TWh to meet national electricity demand, a 2 percent increase from 2014. As presented in Table 2-2, 62 percent of electricity in 2018 was produced through the combustion of fossil fuels, primarily coal and natural gas, with natural gas accounting for the largest single share. Although the share of the total generation from fossil fuels in 2018 (62 percent) was only modestly smaller than the total fossil share in 2014 (66 percent), the mix of fossil fuel generation changed substantially during that period. Coal generation declined by 28 percent and petroleum generation by 17 percent, while natural gas generation increased by 30 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 and solar generation also grew from 5 percent of the mix in 2014 to 8 percent in 2018.

Table 2-2. Net Generation in 2014 and 2018 (Trillion kWh = TWh)

	2014		**2018**		**Change Between '14 and '18**	
	Net Generation (TWh)	**Fuel Source Share**	**Net Generation (TWh)**	**Fuel Source Share**	**Net Generation Change (TWh)**	**% Change in Net Generation**
Coal	1,582	39%	1,146	27%	-436	-440%
Natural Gas	1,127	27%	1,469	35%	342	345%
Nuclear	797	19%	807	19%	10	10%
Hydro	253	6%	287	7%	33	34%
Petroleum	30	1%	25	1%	-5	-5%
Wind	182	4%	273	6%	91	92%
Solar	18	0%	64	2%	46	47%
Other Renewable	91	2%	107	3%	16	16%
Misc	25	1%	26	1%	1	1%
Total	4,105	100%	4,204	100%	99	100%

Source: EIA 2014 and 2018 Electric Power Annual, Tables 3.2 and 3.3.

Coal-fired and nuclear generating units have historically supplied “base load” electricity, the portion of electricity loads that 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 18 percent of the total number of coal-fired units, but only 2 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 66 percent of the coal EGU fleet capacity is over 500 MW per unit, 82 percent of the gas fleet is between 50 and 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 2018

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	37	7%	50	12	427	0%	11,948
25 – 49	39	7%	34	36	1,404	1%	12,386
50 – 99	26	5%	39	76	1,987	1%	12,027
100 - 149	39	7%	48	122	4,757	2%	11,223
150 - 249	73	13%	50	192	14,040	7%	10,882
250 - 499	142	25%	41	364	51,748	24%	10,659
500 - 749	143	26%	39	608	87,005	40%	10,310
750 - 999	49	9%	35	827	40,521	19%	10,057
1000 - 1500	11	2%	41	1,257	13,831	6%	9,802
Total Coal	559	100%	41	386	215,720	100%	10,838
NATURAL GAS							
0 – 24	3,910	51%	32	5	20,540	4%	14,015
25 – 49	931	12%	26	41	37,792	8%	11,999
50 – 99	1,032	14%	26	71	73,129	15%	12,315
100 - 149	418	5%	22	127	52,927	11%	9,442
150 - 249	1,018	13%	16	179	181,772	38%	8,192
250 - 499	247	3%	22	332	82,114	17%	8,296
500 - 749	38	0%	39	577	21,910	5%	10,583
750 - 1000	9	0%	44	834	7,510	2%	11,625
Total Gas	7,603	100%	28	63	477,693	100%	12,301

Source: National Electric Energy Data System (NEEDS) v.6

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 2018 or earlier and excludes those units in NEEDS with planned retirements in 2019 or 2020.

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 2-3 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.

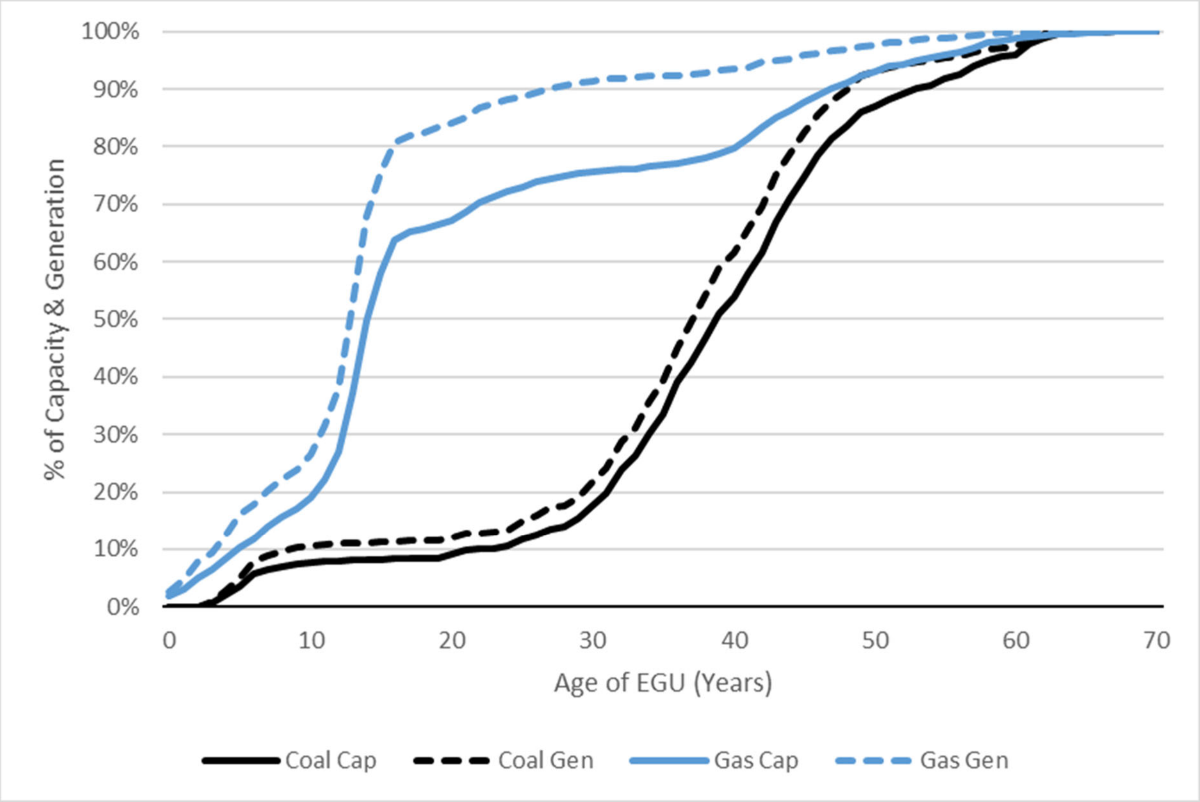

Figure 2-3. Cumulative Distribution in 2018 of Coal and Natural Gas Electricity Capacity and Generation, by Age

Source: eGRID 2018 (March 2020 release from EPA eGRID website). Figure presents data from generators that came online between 1949 and 2018 (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. Figure is limited to coal-steam units in NEEDS v6 in operation in 2018 or earlier.

The locations of existing fossil units in EPA's National Electric Energy Data System (NEEDS) v.6 are shown in Figure 2-4.

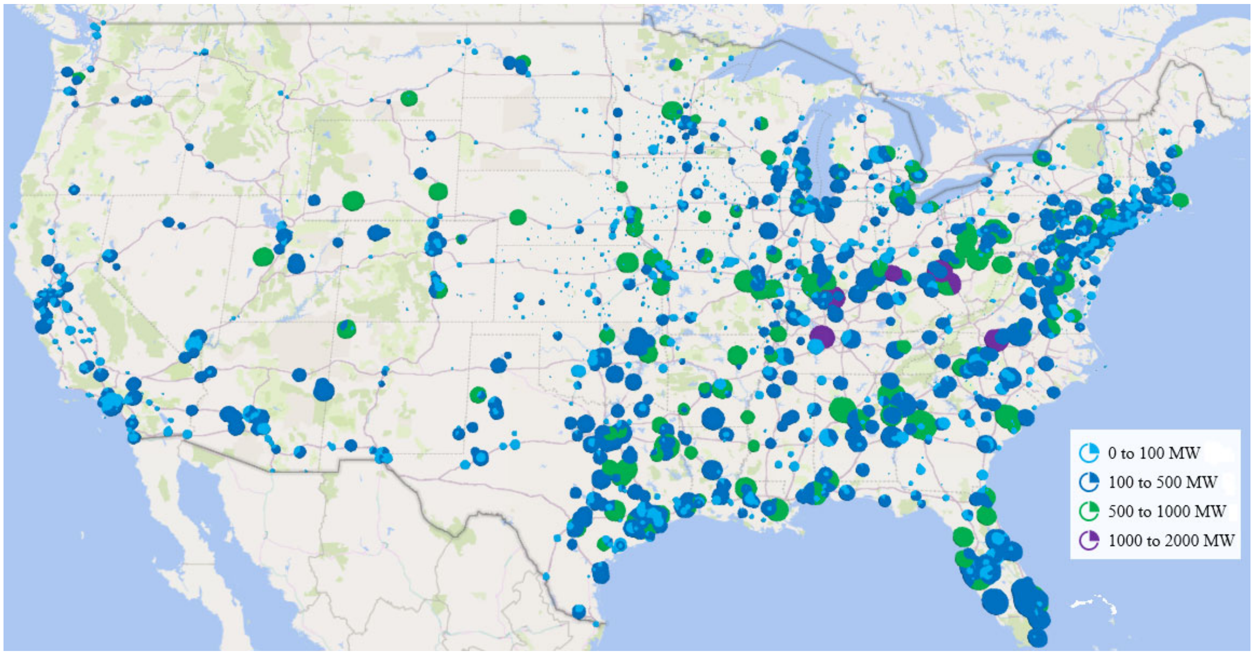

Figure 2-4. Fossil Fuel-Fired Electricity Generating Facilities, by Size

Source: National Electric Energy Data System (NEEDS) v.6

Note: This map displays fossil capacity at facilities in the NEEDS v.6 IPM frame. NEEDS v.6 reflects generating capacity expected to be on-line at the end of 2021. 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,[3] each operating synchronously. Within each of these transmission networks, there are multiple areas where the operation of power plants is monitored 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

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[3] 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 https://www.nerc.com/AboutNERC/keyplayers/PublishingImages/NERC%20Interconnections.pdf.

regional operator;[4] in others, individual utilities[5] 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.

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

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[4] For example, PMJ Interconnection, LLC, Western Area Power Administration (which comprises 4 sub-regions).
[5] For example, Los Angeles Department of Power and Water, Florida Power and Light.

to a third of the total electricity produced[6] (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 2014 and 2018.

Table 2-4. Total U.S. Electric Power Industry Retail Sales, 2014 and 2018 (billion kWh)

		2014		2018	
		Sales/Direct Use (Billion kWh)	**Share of Total End Use**	**Sales/Direct Use (Billion kWh)**	**Share of Total End Use**
Sales	Residential	1,407	36%	1,469	37%
	Commercial	1,352	35%	1,382	35%
	Industrial	998	26%	1,001	25%
	Transportation	8	0%	8	0%
Total		3,765	96%	3,859	96%
Direct Use		139	4%	144	4%
Total End Use		3,903	100%	4,003	100%

Source: Table 2.2, EIA Electric Power Annual, 2014 and 2018
Notes: Retail sales are not equal to net generation (Table 2-2) because net generation includes net imported electricity and loss of electricity that occurs through transmission and distribution, along with data collection frame differences and non-sampling error. Direct Use represents commercial and industrial facility use of onsite net electricity generation; electricity sales or transfers to adjacent or co-located facilities; and barter transactions.

2.3.1 Electricity Prices

Electricity prices vary substantially across the United States, differing both between the ultimate customer categories and 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 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

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

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 2018, the national average retail electricity price (all sectors) was 10.53 cents/KWh, with a range from 7.71 cents (Louisiana) to 29.18 (Hawaii).[7]

Average national retail electricity prices decreased between 2014 and 2018 by 5 percent in real terms (2018$).[8] The amount of decrease differed for the three major end use categories (residential, commercial and industrial). National average industrial prices decreased the most (9 percent), and residential prices decreased the least (4 percent). The real year prices for 2014 through 2018 are shown in Figure 2-5.

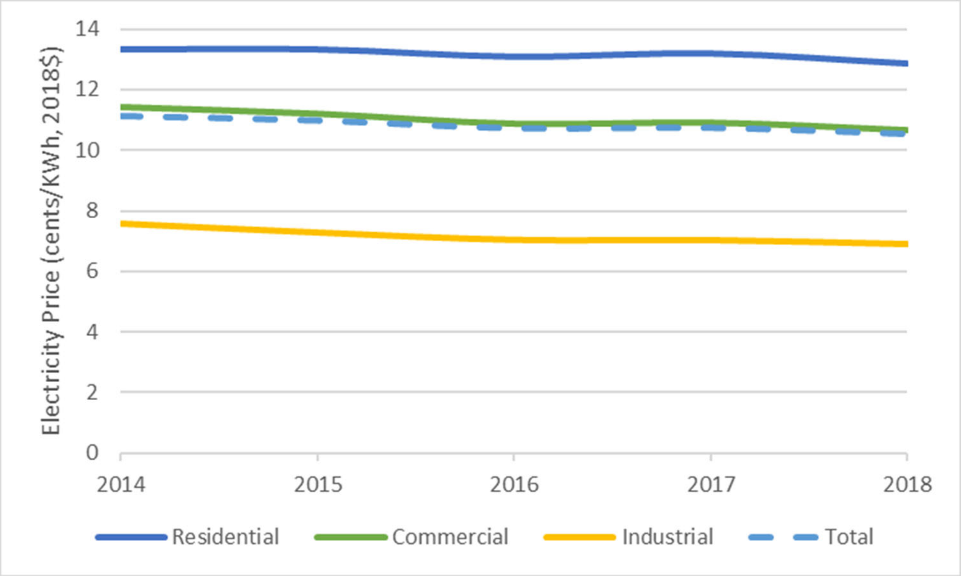

Figure 2-5. Real National Average Electricity Prices (including taxes) for Three Major End-Use Categories

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[7] EIA State Electricity Profiles with Data for 2018 (http://www.eia.gov/electricity/state/)

[8] All prices in this section are estimated as real 2018 prices adjusted using the GDP implicit price deflator unless otherwise indicated.

Source: EIA Monthly Energy Review (May 2020), Table 9.8.

Most of these electricity price decreases occurred between 2014 and 2015, when nominal residential electricity prices followed inflation trends, while nominal commercial and industrial electricity prices declined. The years 2016 and 2017 saw an increase in nominal commercial and industrial electricity prices, while 2018 saw flattening of this growth. 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.

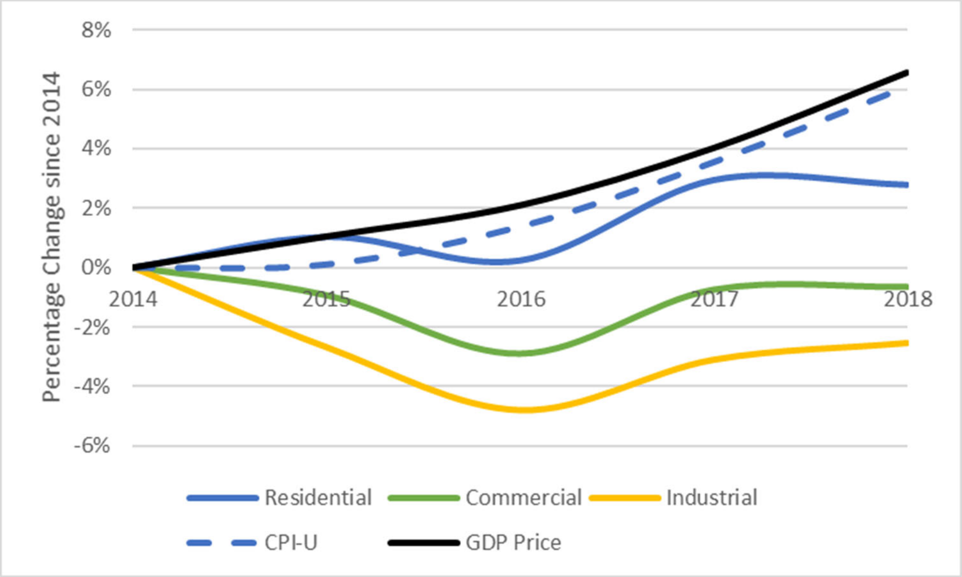

Figure 2-6. Relative Increases in Nominal National Average Electricity Prices for Major End-Use Categories (including taxes), With Inflation Indices

Source: EIA Monthly Energy Review (May 2020), Table 9.8.

For a longer-term perspective, Figure 2-7 shows real[9] (2018$) 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

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[9] All prices in this section are estimated as real 2018 prices adjusted using the GDP implicit price deflator unless otherwise indicated.

2018 was relatively unchanged from 1960 (5 percent lower), residential and commercial real prices are 25 percent and 33 percent lower respectively than in 1960.

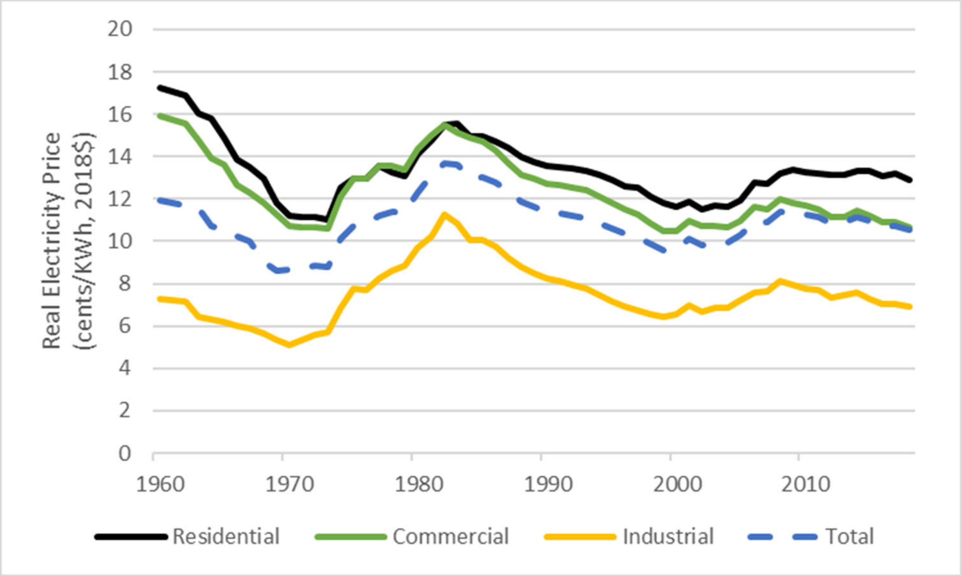

Figure 2-7. Real National Average Electricity Prices for Three Major End-Use Categories (including taxes), 1960-2018 (2018$)

Source: EIA Monthly Energy Review, May 2020, Table 9.8

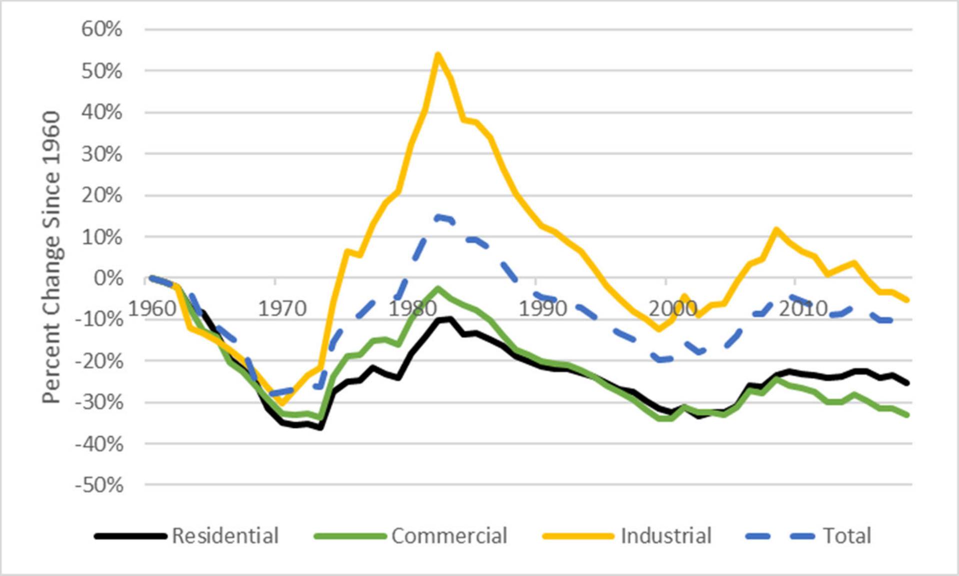

Figure 2-8. Relative Change in Real National Average Electricity Prices (2018$) for Three Major End-Use Categories (including taxes)

Source: EIA Monthly Energy Review, May 2020, 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[10] for the three major fossil fuels used in electricity generation; coal, natural gas and petroleum products. Relative to real prices in 2014, the national average real price (in 2018$) of coal delivered to EGUs in 2018 had decreased by 18 percent, while the real price of natural gas decreased by 33 percent. The real price of delivered petroleum products also decreased by 22 percent, but with petroleum products declining as an EGU fuel (in 2018 petroleum products generated 1 percent of electricity) the higher delivered oil prices had little overall impact in the electricity market. The combined real delivered price of all fossil fuels in 2014 decreased by 20 percent over 2014 prices. Figure 2-9 shows the relative changes in real price of all 3 fossil fuels between 2014 and 2018.

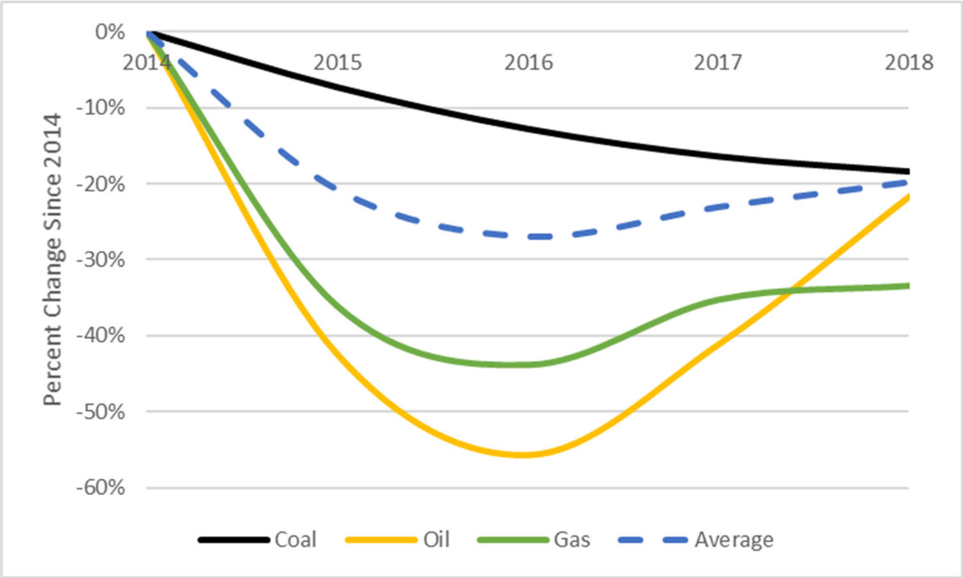

Figure 2-9. Relative Real Prices of Fossil Fuels for Electricity Generation; Change in National Average Real Price per MMBtu Delivered to EGU

Source: EIA Monthly Energy Review, May 2020, Table 9.9.

2.3.3 *Changes in Electricity Intensity of the U.S. Economy from 2014 to 2018*

An important aspect of the changes in electricity generation (i.e., electricity demand) between 2014 and 2018 is that while total net generation increased by 2 percent over that period,

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

the demand growth for generation was lower than both the population growth (3 percent) and real GDP growth (10 percent). Figure 2-10 shows the growth of electricity generation, population and real GDP during this period.

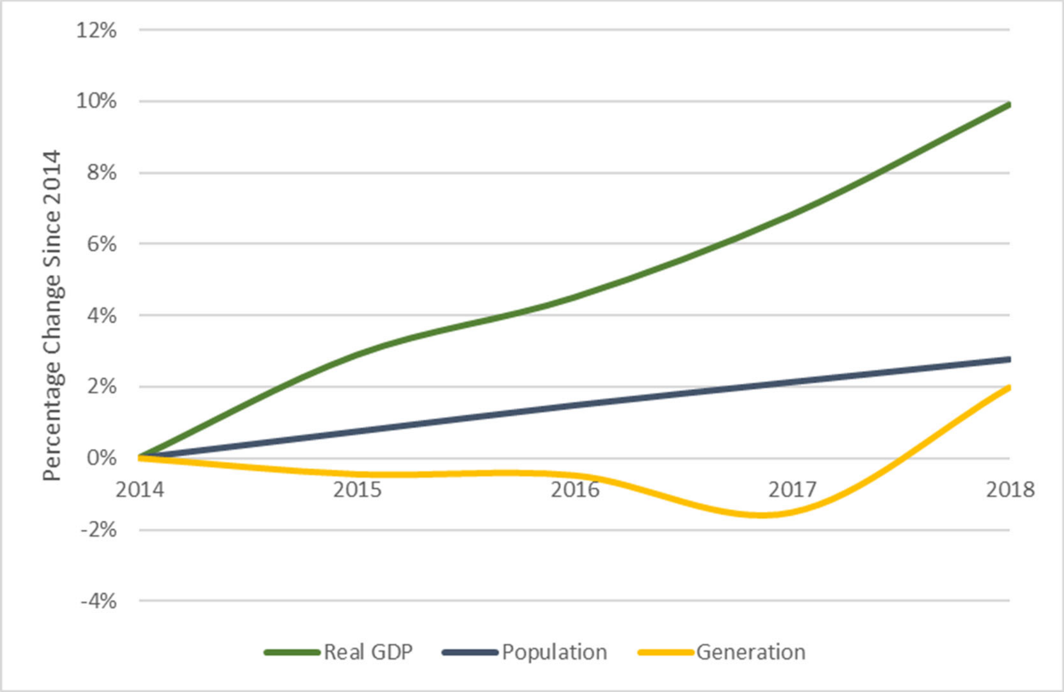

Figure 2-10. Relative Growth of Electricity Generation, Population and Real GDP Since 2014

Sources: Generation: U.S. EIA Monthly Energy Review, May 2020. Table 7.2a Electricity Net Generation: Total (All Sectors). Population: U.S. Census. Real GDP: 2019 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 2014 to 2018. On a per capita basis, real GDP per capita grew by 7 percent between 2014 and 2018. At the same time electricity generation per capita decreased by 1 percent. The combined effect of these two changes improved the overall electricity generation efficiency in the U.S. market economy. Electricity generation per dollar of real GDP decreased 7 percent. These relative changes are shown in Figure 2-11.

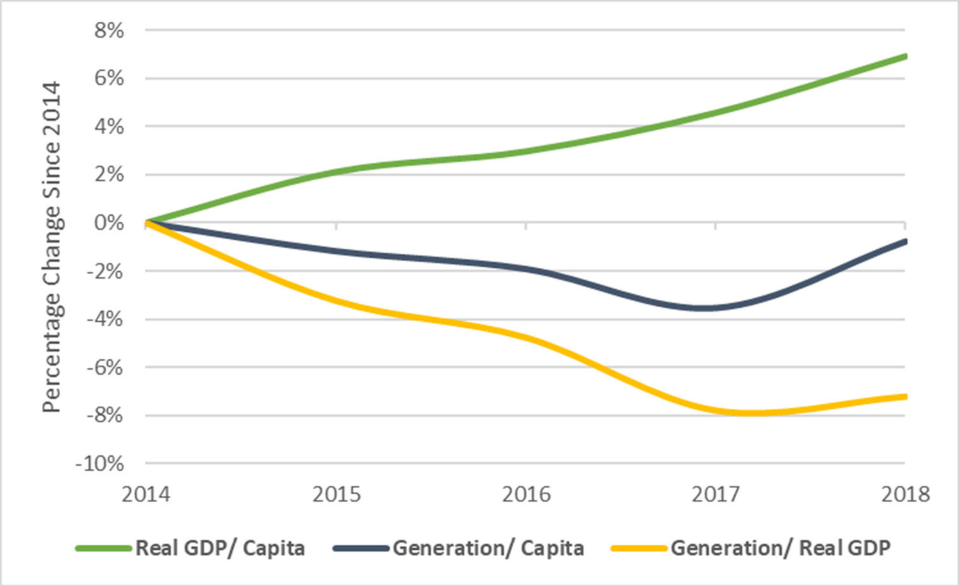

Figure 2-11. Relative Change of Real GDP, Population and Electricity Generation Intensity Since 2014

Sources: Generation: EIA Monthly Energy Review, May 2020. Table 7.2a Electricity Net Generation: Total (All Sectors). Population: U.S. Census. Real GDP: 2019 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 2-12). Currently, there are 15 states plus the District of Columbia where price deregulation of generation (restructuring) has occurred (“Active” in Figure 2-12). 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.

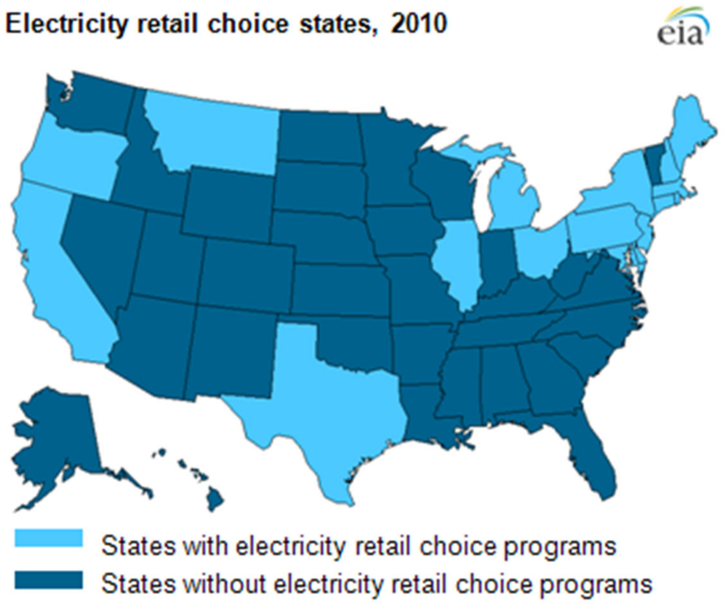

Figure 2-12. Status of State Electricity Industry Restructuring Activities

Source: EIA 2010. “Status of Electricity Restructuring by State.” Available online at: <https://www.eia.gov/todayinenergy/detail.php?id=6250>.

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 2014, traditional utilities owned 61 percent of U.S. generating capacity (MW) while IPPs[11] owned 39 percent of U.S. generating capacity, respectively. The mix of electricity generated (MWh) was more heavily weighted towards the utilities, with a distribution in 2014 of 61 percent, and 39 percent for IPPs.

In 2018, the share of capacity (59 percent utility, 41 percent IPPs) and generation (58 percent utility, 42 percent IPP) has remained relatively stable relative to 2014 levels.

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

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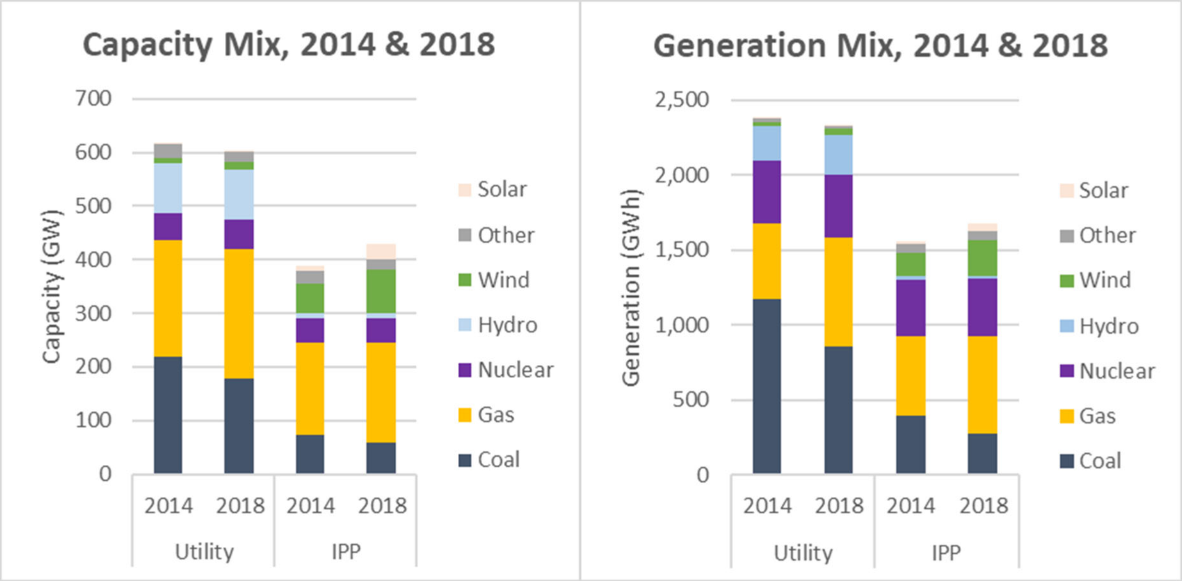
[11] IPP data presented in this section include both combined and non-combined heat and power plants.



Figures 2-13. and 2-14. Capacity and Generation Mix by Ownership Type, 2014 & 2018

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.

CHAPTER 3: EMISSIONS AND AIR QUALITY IMPACTS

Overview

This Chapter describes the methods for developing spatial fields of air quality concentrations for the baseline and regulatory control alternatives in 2021 and 2025. These spatial fields provide the air quality inputs to potentially calculate health benefits for the proposed Revised CSAPR Update. The spatial fields for this proposal were constructed using the method and air quality modeling developed to support the regulatory impact analysis (RIA) for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units (U.S. EPA 2019), also referred to as the Affordable Clean Energy (ACE) rule.[1]

In Section 3.1 we describe the ACE air quality modeling platform; in Section 3.2 we describe the ACE approach for processing the air quality modeling outputs to create inputs for estimating benefits; in Section 3.3 we describe how the ACE approach was applied in the proposed Revised CSAPR Update, in Section 3.4 we present maps showing the impacts on ozone and $PM_{2.5}$ concentrations of each of the three regulatory control alternatives compared to the corresponding baseline; and in Section 3.5 we identify uncertainties and limitations in the application of the ACE approach for generating spatial fields of pollutant concentrations.

3.1 ACE Air Quality Modeling Platform

The air quality modeling for the ACE analysis utilized a 2011-based modeling platform which included meteorology and base year emissions from 2011 and projected emissions for 2023. The air quality modeling included annual photochemical model simulations for a 2011 base year and a 2023 future year to provide hourly concentrations of ozone and primary and secondarily formed $PM_{2.5}$ component species (*e.g.*, sulfate, nitrate, ammonium, elemental carbon (EC), organic aerosol (OA), and crustal material[2]) for both years nationwide. In particular, source apportionment modeling was performed for 2023 to quantify the contributions to ozone and $PM_{2.5}$ component species from coal-fired and non-coal EGUs on a state-by-state or multi-

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[1] Additional details on the ACE modeling and methodology for developing spatial fields of air quality for EGU control strategies are provided in Appendix 3A.

[2] Crustal material refers to metals that are commonly found in the earth's crust such as Aluminum, Calcium, Iron, Magnesium, Manganese, Potassium, Silicon, Titanium and the associated oxygen atoms.

state basis. As described below, the modeling results for 2011 and 2023, in conjunction with emissions data for the baseline and regulatory control alternatives, were used to construct the air quality spatial fields that reflect the influence of emissions changes between the baseline and the regulatory control alternatives.

The air quality model simulations (*i.e.*, model runs) were performed using the Comprehensive Air Quality Model with Extensions (CAMx) (Ramboll Environ 2016). Our CAMx nationwide modeling domain (*i.e.*, the geographic area included in the modeling) covers all lower 48 states plus adjacent portions of Canada and Mexico using a horizontal grid resolution of 12 x 12 km shown in Figure 3-1.

Figure 3-1. Air Quality Modeling Domain

The impact of specific emissions sources on ozone and $PM_{2.5}$ in the 2023 modeled case was tracked using a tool called “source apportionment.” In general, source apportionment modeling quantifies the air quality concentrations formed from individual, user-defined groups of emissions sources or “tags”. These source tags are tracked through the transport, dispersion, chemical transformation, and deposition processes within the model to obtain hourly gridded[3] contributions from the emissions in each individual tag to hourly modeled concentrations of ozone and $PM_{2.5}$.[4] Thus, the source apportionment method provides an estimate of the effect of

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[3] Hourly contribution information is provided for each grid cell to provide spatial patterns of the contributions from each tag.

[4] Note that the sum of the contributions in a model grid cell from each tag for a pollutant equals the total concentration of that pollutant in the grid cell.

changes in emissions from each group of emissions sources (*i.e.*, each tag) to changes in ozone and $PM_{2.5}$ concentrations. For this analysis we applied outputs from source apportionment modeling for ozone and $PM_{2.5}$ using the 2023 modeled case to obtain the contributions from EGU emissions as well as other sources to ozone and to $PM_{2.5}$ component species concentrations.[5] Ozone contributions were modeled using the Ozone Source Apportionment Technique/Anthropogenic Precursor Culpability Assessment (OSAT/APCA) tool and $PM_{2.5}$ component species contributions were modeled using the Particulate Source Apportionment Technique (PSAT) tool.[6] The source apportionment modeling, which was already available from analysis performed to support the ACE rule RIA (U.S. EPA, 2019) was used to quantify the contributions from EGU emissions on a state-by-state or, in some cases, on a multi-state basis. For ozone, we modeled the contributions from the 2023 EGU sector emissions of NO_X and VOC to hourly ozone concentrations for the period April through October to provide data for developing spatial fields for two seasonal ozone benefits metrics identified above (i.e., for the May-September seasonal average of the maximum daily 8-hour average (MDA8) ozone and the April-October seasonal average of the maximum daily 1-hour average (MDA1) ozone). For $PM_{2.5}$, we modeled the contributions from the 2023 EGU sector emissions of SO_2, NO_X, and directly emitted $PM_{2.5}$ for the entire year to inform the development of spatial fields of annual mean $PM_{2.5}$. For each state, or multi-state group, we separately tagged EGU emissions depending on whether the emissions were from coal-fired units or non-coal units.[7] In addition to tagging coal-fired and non-coal EGU emissions we also tracked the ozone and $PM_{2.5}$ contributions from all other sources.

3.2. Applying Modeling Outputs to Create Spatial Fields

In this section we describe the ACE approach for creating spatial fields based on the 2011 and 2023 modeling performed for the ACE rule. The foundational data from ACE include the ozone contributions from EGU emissions in each state based on the 2023 ACE EGU state-sector sector contribution modeling and the 2023 emissions for coal and non-coal fired EGUs that were

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[5] In the source apportionment modeling for $PM_{2.5}$ we tracked the source contributions from primary, but not secondary organic aerosols (SOA). The method for treating SOA concentrations is described in U.S. EPA, 2019 chapter 8.

[6] OSAT/APCA and PSAT tools are described in Ramboll Environ (2016).

[7] For the purposes of this analysis non-coal fuels include emissions from natural gas, oil, biomass, municipal waste combustion and waste coal EGUs.

input to that modeling. These data are used to generate spatial fields based on ozone season EGU NOx emissions (tons) and annual total EGU emissions of NOx, SO2 and $PM_{2.5}$. The inputs for this method include emissions for each state with a breakout of emissions for coal-fired and non-coal EGUs. The ozone season NOx emissions are used to prepare spatial fields of the May-September seasonal average MDA8 ozone and the April-October seasonal average MDA1 ozone concentration and the annual emissions are used to prepare spatial fields of annual $PM_{2.5}$ concentrations. This method calculates the scaling ratios, described below, that are used to prepare the air quality spatial fields.

To create the spatial fields for each future emissions scenario the 2023 state-sector source apportionment modeling outputs from the ACE modeling described above are used in combination with the EGU SO_2, NO_x, and $PM_{2.5}$ emissions for each scenario. Contributions from each state-sector contribution "tag" were scaled based on the ratio of emissions in the year/scenario being evaluated to the emissions in the modeled ACE 2023 scenario. In this approach, scaling ratios for $PM_{2.5}$ components that are emitted directly from the source (OA, EC, crustal) are based on relative changes in annual primary $PM_{2.5}$ emissions between the modeled ACE 2023 emissions scenario and the specific baseline or control scenario being analyzed. Also the scaling ratios for components that are formed through chemical reactions in the atmosphere were created as follows: scaling ratios for sulfate were based on relative changes in annual SO_2 emissions; scaling ratios for nitrate were based on relative changes in annual NO_X emissions; and scaling ratios for ozone formed in NO_X-limited regimes[8] ("O3N") were based on relative changes in ozone season (May-September) NO_X emissions. Tags representing sources other than EGUs are held constant at 2023 ACE baseline levels for emissions scenarios analyzed by the user. For each control scenario analyzed, the scaled contributions from all sources were summed together to create a gridded surface of total modeled ozone or total modeled $PM_{2.5}$. Finally, spatial fields of ozone and $PM_{2.5}$ are created based on "fusing" modeled data with measured concentrations at air quality monitoring locations. The process is described in a step-by-step manner below.

(1) The EGU annual SO_2, NO_X, and directly emitted $PM_{2.5}$ emissions for the control scenario of interest and the corresponding 2023 SO_2, NO_X, and directly emitted $PM_{2.5}$ emissions

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[8] The CAMx model internally determines whether the ozone formation regime is NO_X-limited or VOC-limited depending on predicted ratios of indicator chemical species.

used in the ACE modeling to calculate the ratio of control case emissions to the ACE emissions for each of these pollutants for each EGU tag.

(2) The tag-specific 2025 to 2023 EGU emissions-based scaling ratios from step (1) are multiplied by the corresponding 365 gridded daily 24-hour average $PM_{2.5}$ component species contributions from the 2023 contribution modeling. The emissions ratios for SO_2 are applied to sulfate contributions; ratios for annual NO_X are applied to nitrate contributions; and ratios for directly emitted $PM_{2.5}$ are applied to the EGU contributions to primary OA, EC and crustal material. This step results in 365 adjusted gridded daily $PM_{2.5}$ component species contributions for each EGUs tag that reflects the emissions in the control scenario.

(3) For each individual $PM_{2.5}$ component species, the adjusted gridded contributions for each EGU tag from step (2) are added together to produce a gridded daily EGU tag total.

(4) The daily total EGU contributions for each $PM_{2.5}$ component species from step (3) are then combined with the species contributions from source tags representing all other sources of $PM_{2.5}$. As part of this step we also add the total secondary organic aerosol concentrations from the 2023 ACE modeling to the net EGU contributions of primary OA. Note that the secondary organic aerosol concentration does not change between scenarios. This step results in 24-hour average $PM_{2.5}$ component species concentrations for the control scenario in each model grid cell, nationwide for each day in the year.

(5) For each $PM_{2.5}$ component species, the daily concentrations from step (4) are averaged for each quarter of the year.

(6) The quarterly average $PM_{2.5}$ component species concentrations from step (5)[9] are divided by the corresponding quarterly average species concentrations from the base period air quality model run. This step provides a Relative Response Factor (i.e., RRF) between the base period and the control scenario for each species in each model grid cell.

(7) The species-specific quarterly RRFs from step (6) are then multiplied by the corresponding species-specific quarterly average concentrations from the base period

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[9] Ammonium concentrations are calculated assuming that the degree of neutralization of sulfate ions remains at 2011 levels (see Chapter 8 of U.S. EPA, 2019 for details).

fused surfaces to produce quarterly average species concentrations for the control scenario.

(8) The quarterly average species concentrations from step (7) are summed over the species to produce total $PM_{2.5}$ concentrations for each quarter. Finally, total $PM_{2.5}$ concentrations for the four quarters of the year are averaged to produce the spatial field of annual average $PM_{2.5}$ concentrations for the 2025 baseline.

To generate the spatial fields for each of the two ozone concentration metrics (i.e., April-October MDA1 and May-September MDA8) we follow the steps similar to those above for $PM_{2.5}$.

(1) The EGU May through September (i.e., Ozone Season - OS) NO_X for the control scenario and the corresponding modeled 2023 OS NO_X emissions are used to calculate the ratio of control scenario emissions to 2023 ACE emissions for each EGU tag (i.e. an ozone-season scaling factor for each tag).

(2) The source apportionment modeling provided separate ozone contributions for ozone formed in VOC-limited chemical regimes (O_3V) and ozone formed in NO_X-limited chemical regimes (O_3N).[10] The EGU OS NOx emissions for the control scenario and the 2023 ACE OS NOx baseline emissions are used to calculate the ratio of the control scenario emissions to the 2023 ACE emission to create the EGU NOx emissions scaling ratios. The emissions scaling ratios are multiplied by the corresponding O_3N gridded daily contributions to MDA1 and MDA8 concentrations. This step results in adjusted gridded daily MDA1 and MDA8 contributions due to NO_X changes for each EGUs tag that reflect the emissions in the 2025 baseline.

(3) For MDA1 and MDA8, the adjusted contributions for each EGU tag from step (2) are added together to produce a daily adjusted EGU tag total. Since IPM does not output VOC from EGUs, there are no predicted changes in VOC emissions in these scenarios so the O_3V contributions remain unchanged. The contributions from the unaltered O_3V tags from the 2023 ACE modeling are added to the summed adjusted O_3N EGU tags.

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[10] Information on the treatment of ozone contributions under NOx-limited and VOC-limited chemical regimes in the CAMx APCA source apportionment technique can be found in the CAMx v6.40 User's Guide (Ramboll, 2016).

(4) The daily total EGU contributions for MDA1 and MDA8 from step (3) are then combined with the contributions to MDA1 and MDA8 from all other sources. This step results in MDA1 and MDA8 concentrations for the control scenario in each model grid cell, nationwide for each day in the ozone season.

(5) For MDA1, we average the daily concentrations from step (4) across all the days in the period April 1 through October 31. For MDA8, we average the daily concentrations across all days in the period May 1 through September 30.

(6) The seasonal mean concentrations from step (5) are divided by the corresponding seasonal mean concentrations from the base period air quality model run. This step provides a Relative Response Factor (i.e., RRF) between the base period and control scenario for MDA1 and MDA8 in each model grid cell.

(7) Finally, the RRFs for the seasonal mean metrics from step (6) are then multiplied by the corresponding seasonal mean concentrations from the base period MDA1 and MDA8 fused surfaces to produce seasonal mean concentrations for MDA1 and MDA8 for the control scenario that are input to BenMAP-CE.

3.3 Application of ACE Approach for the Revised CSAPR Update

In this section we describe how we applied the ACE approach to generate spatial fields of seasonal ozone and annual $PM_{2.5}$ concentrations associated with the regulatory control alternatives (i.e., the proposal and the less stringent and more stringent alternatives) in this proposed rule RIA. The data for creating the Revised CSAPR Update spatial fields include EGU emissions for the 2021 and 2025 baseline and the regulatory control alternatives. The EGU emissions include OS NOx and annual NOx, SO2, and $PM_{2.5}$ for coal-fired and non-coal units in each state in the continental U.S. These EGU emissions are taken from the electricity sector analysis described in Chapter 4. In the case of the Revised CSAPR Update proposal analysis, there are no impacts on SO_2 or $PM_{2.5}$ emissions in the regulatory control scenarios compared to the 2025 baseline.

To potentially calculate ozone-related benefits in 2021 and 2025 we used the ozone season EGU NOx emissions (tons) for the 2021 and 2025 baseline along with emissions for the proposal, and each of the two other regulatory control alternatives. These emissions were applied using the ACE approach and source apportionment data to produce spatial fields of the May-

September seasonal average MDA8 ozone and the April-October seasonal average MDA1 ozone concentrations as described in the previous section.

In 2021, the only control measure expected to be adopted for compliance in each of the regulatory control alternatives is optimization of existing SCRs beginning in May of 2021, and this measure will operate only during the ozone season. This is relevant because NOx reductions in the ozone season provide minimal $PM_{2.5}$ reductions since $PM_{2.5}$ nitrate concentrations, which result from conversion of NOx emissions to nitrate, are minimal during the warmer temperatures during the ozone season. Conversely, the conversion of nitrates to $PM_{2.5}$ is much greater in cooler (non-ozone season) months, and thus it would be considered worthwhile to estimate $PM_{2.5}$ benefits from NOx reductions in those months (Hand et al., 2012). In 2025, the presence of additional control measures that operate year-round and other changes in market conditions as a result of the proposed rule lead to notable NOx reductions in the winter months.

To create spatial fields for $PM_{2.5}$ we pre-processed the 2025 coal and non-coal fired EGU emissions in order to obtain annual emissions of NOx, SO2, and directly emissions $PM_{2.5}$ in a manner that is appropriate for assessing the impacts on annual average $PM_{2.5}$ concentrations. This additional pre-processing was needed because the vast majority of the emissions reductions are expected to occur during the ozone season but, as noted above, $PM_{2.5}$ nitrate concentrations are lowest during that time of year. In this regard, simply treating the summer emissions reductions as if they were abated proportionately throughout the year would overstate the impacts of the emissions reductions on $PM_{2.5}$ and therefore overstate benefits associated with reducing exposure to $PM_{2.5}$.[11] For those states in which there are NOx emissions reductions during the ozone season only, we reset the annual NOx emission in the regulatory alternative to be equivalent to the corresponding baseline emissions to avoid distributing the ozone season reductions across the entire year. That is, we assumed that there would be no impact on $PM_{2.5}$ nitrate concentrations of NOx reductions in the ozone season. For those states in which there are NOx emissions changes between the baseline and regulatory control alternative outside of the ozone season, we accounted for those reductions by "annualizing" the EGU emissions for the

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[11] The FAST-CE model described above essentially treats a ton of abated NOx emissions as if it were abated in equal proportions per time (e.g., day) throughout the year when projecting $PM_{2.5}$ fields. Therefore, when NOx abatement is heavily concentrated in a particular time of the year, as in the proposed Revised CSAPR Update, the inputs to the model need to be adjusted to avoid overestimating (as for this proposed rule) or underestimating (if reductions were greater in the winter months) the change in annual $PM_{2.5}$ concentrations and benefits from changes in $PM_{2.5}$ exposure.

period outside the ozone season in the regulatory alternative as well as the corresponding baseline. This method essentially applies the change in NO_X tons outside the ozone season on a daily basis to changes in NOx emissions tons within the ozone season.[12] With this adjustment the impact of the regulatory control alternative on annual average $PM_{2.5}$ concentrations reflects the emissions reductions that will occur outside the ozone season when $PM_{2.5}$ nitrate concentrations are highest. The emissions of SO_2 and directly emitted $PM_{2.5}$ in 2025 for each of the regulatory alternatives do not change from the 2025 baseline. That is, the regulatory control alternatives analyzed in this RIA reduce emissions of NOx, but do not impact emissions of SO_2 and directly emitted $PM_{2.5}$.

3.4 Spatial Distribution of Air Quality Impacts

Below we present the estimated impacts on May-September MDA8 ozone[13] between the baseline and each of the regulatory control alternatives for 2021 and 2025 as well as the estimated impacts on annual mean $PM_{2.5}$ concentrations between the baseline and the regulatory control alternatives in 2025 (Figure 3-2 through Figure 3-10). The data shown in these figures are calculated as the baseline minus the regulatory control alternative concentrations (i.e., positive values indicate reductions in pollutant concentrations). The spatial patterns of the impacts of emissions reductions are a result of (1) the spatial distribution of EGU sources that are predicted to have changes in emissions and (2) the physical or chemical processing that the model simulates in the atmosphere.

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[12] In all states the actual tons reduced in the ozone season is greater than or equal to the change outside the ozone season between the baseline and the regulatory alternatives.

[13] The estimated impacts on April-October 2021 and 2025 ozone for each scenario are not shown but are similar to May-September impacts available in Figure 12-20.

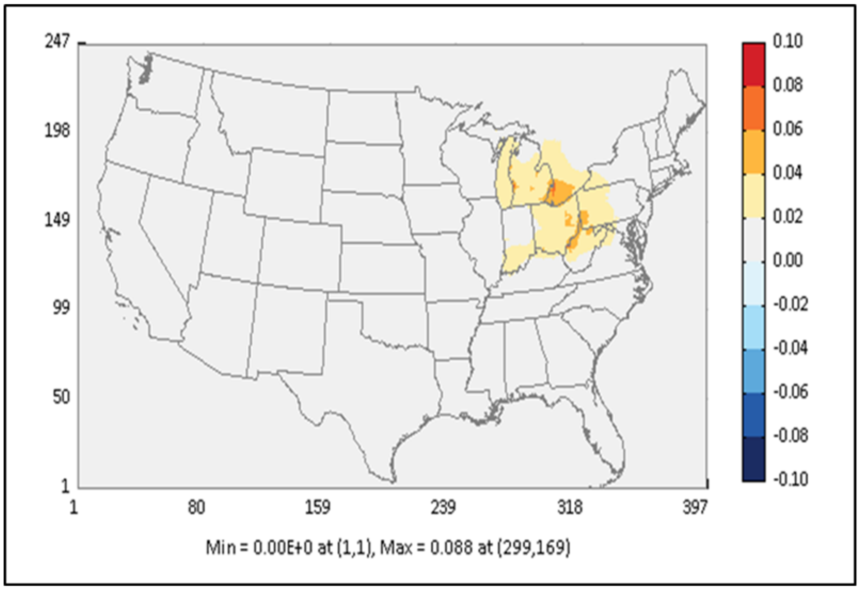

Figure 3-2. Map of change in May-September MDA8 ozone (ppb): 2021 baseline – less stringent regulatory alternative (scale: ± 0.10 ppb)

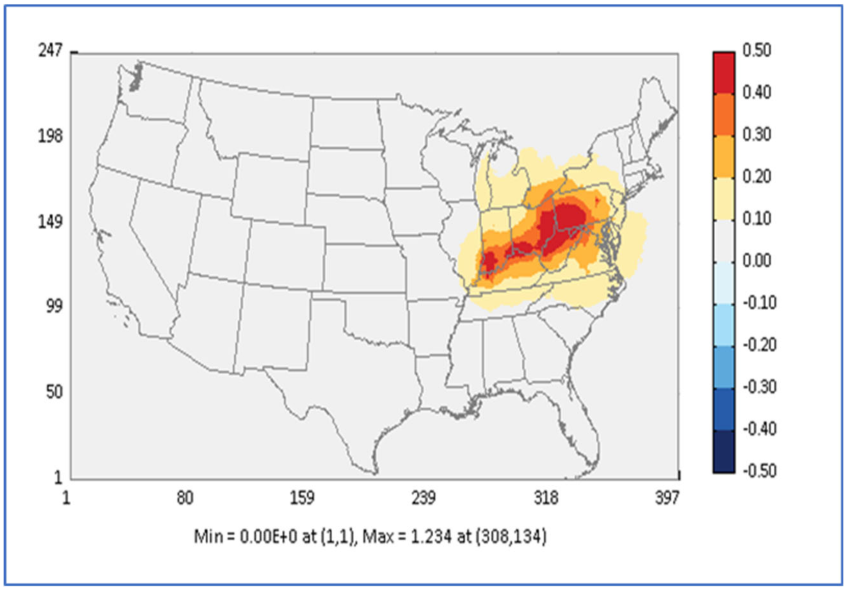

Figure 3-3. Map of change in May-September MDA8 ozone (ppb): 2021 baseline – proposal (scale: ± 0.50 ppb)

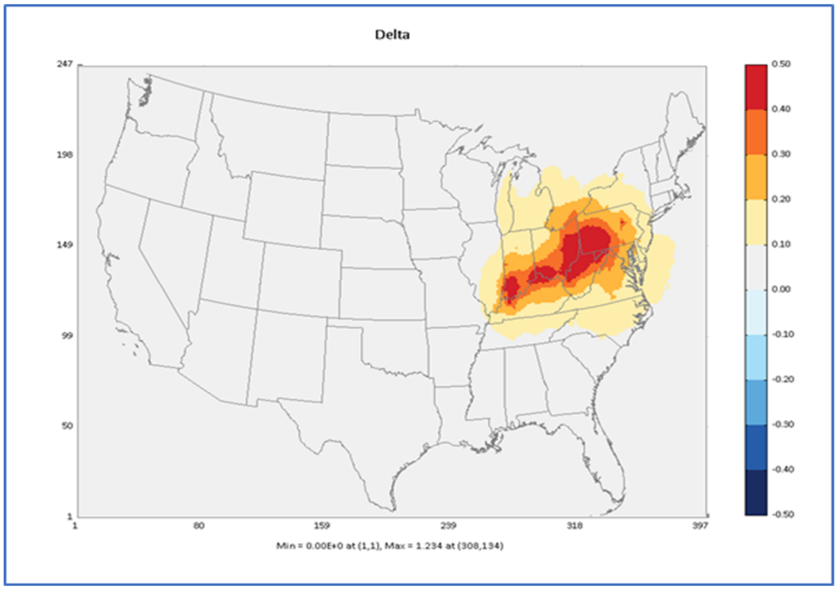

Figure 3-4. Map of change in May-September MDA8 ozone (ppb): 2021 baseline – more stringent regulatory alternative (scale: ± 0.50 ppb)

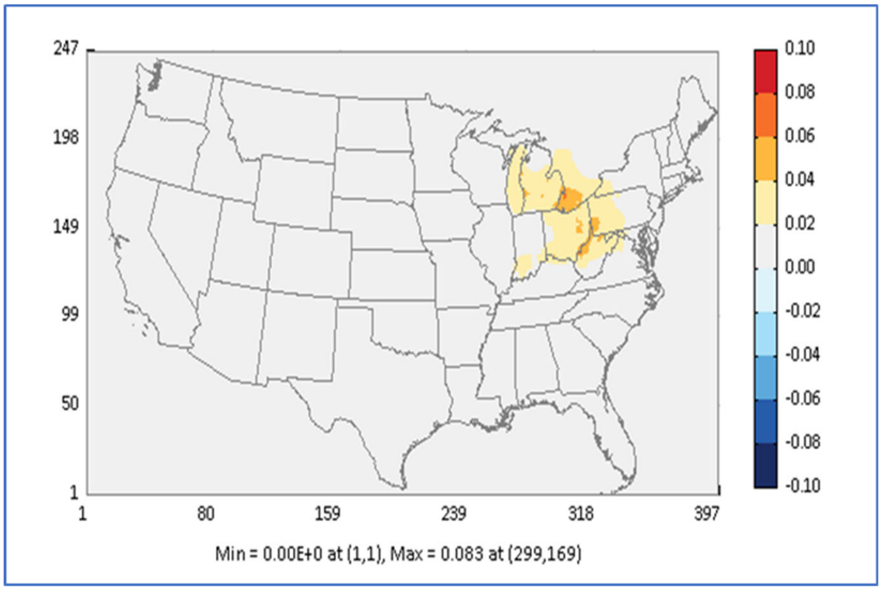

Figure 3-5. Map of change in May-September MDA8 ozone (ppb): 2025 baseline – less stringent regulatory alternative (scale: ± 0.10 ppb)

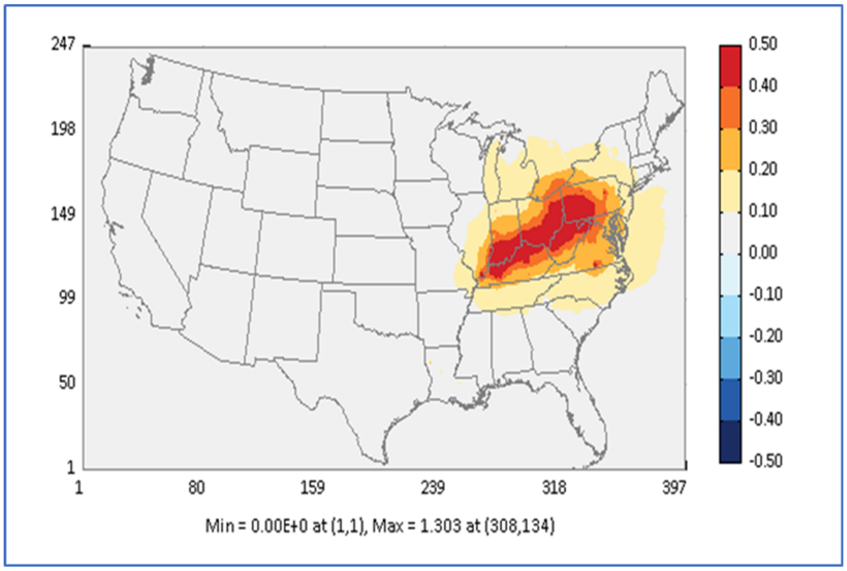

Figure 3-6. Map of change in May-September MDA8 ozone (ppb): 2025 baseline – proposal (scale: ± 0.50 ppb)

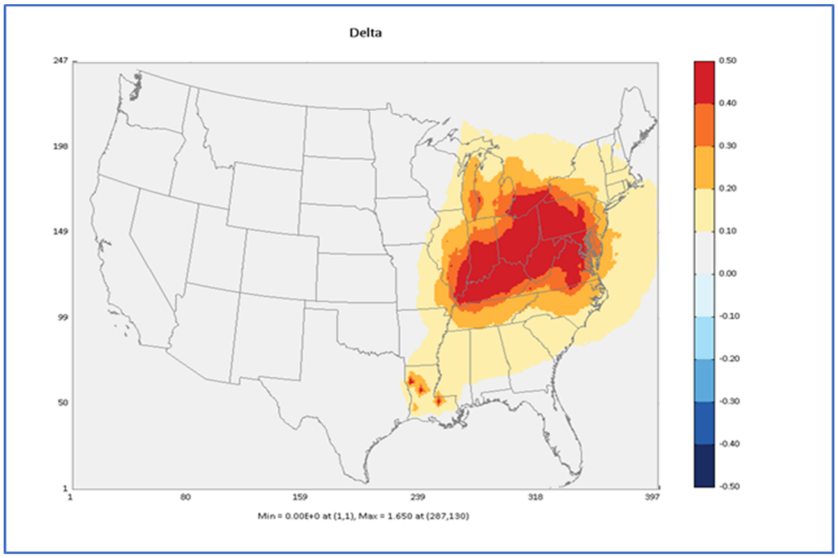

Figure 3-7. Map of change in May-September MDA8 ozone (ppb): 2025 baseline – more stringent regulatory alternative (scale: ± 0.50 ppb)

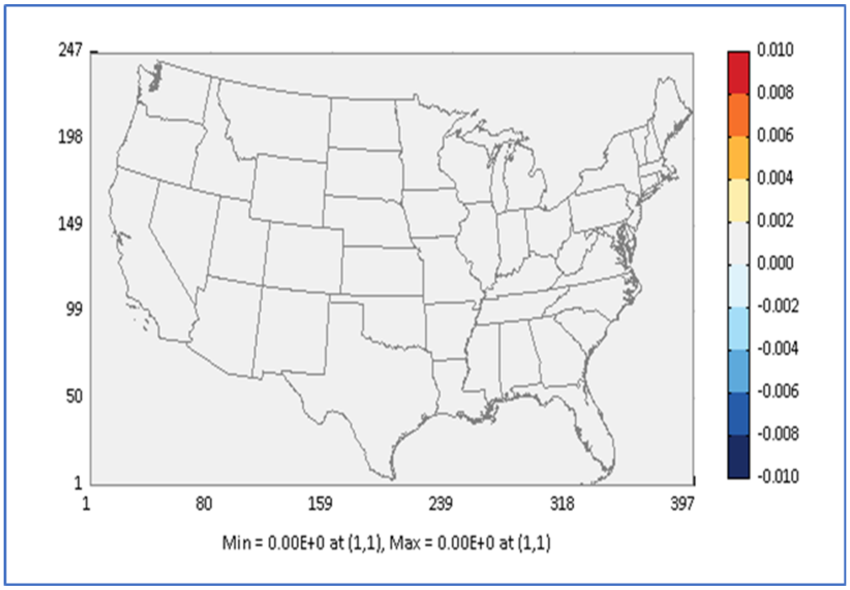

Figure 3-8. Map of change in annual mean PM2.5 (µg/m³): 2025 baseline – less stringent regulatory alternative (scale: ± 0.01 µg/m³)

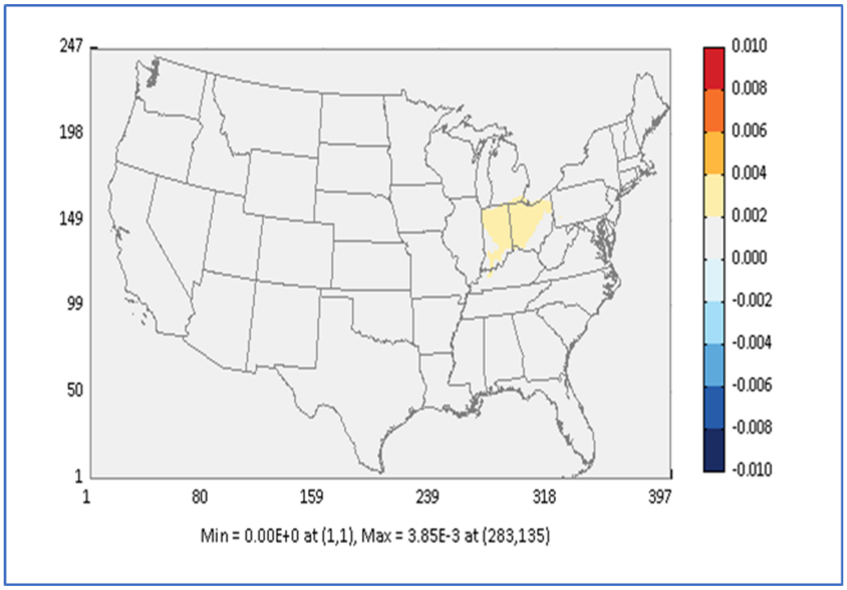

Figure 3-9. Map of change in annual mean PM2.5 (µg/m³): 2025 baseline – proposal (scale: ± 0.01 µg/m³)

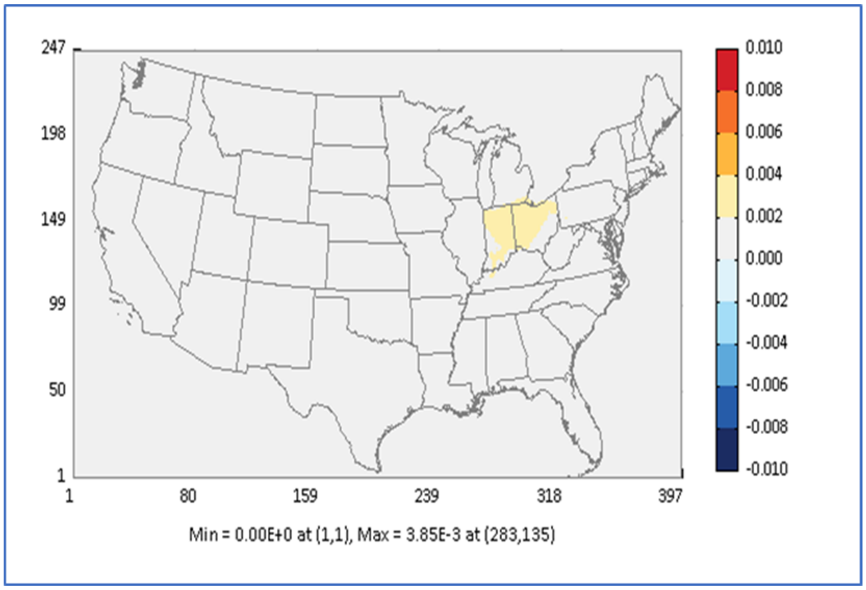

Figure 3-10. Map of change in annual mean $PM_{2.5}$ (µg/m^3):
2025 baseline – more stringent regulatory alternative (scale: ± 0.01 µg/m^3)

3.5 Uncertainties and Limitations of ACE Approach

One limitation of the scaling methodology for creating $PM_{2.5}$ surfaces associated with the baseline and regulatory alternatives described above is that it treats air quality changes from the tagged sources as linear and additive. It therefore does not account for nonlinear atmospheric chemistry and does not account for interactions between emissions of different pollutants and between emissions from different tagged sources. This is consistent with how air quality estimations have been treated in past regulatory analyses (U.S. EPA 2012; 2019; 2020b). We note that air quality is calculated in the same manner for the baseline and the regulatory alternatives, so any uncertainty associated with these assumptions is carried through both sets of scenarios in the same manner and is thus not expected to impact the air quality differences between scenarios. In addition, emissions changes between baseline and the regulatory alternatives are relatively small compared to modeled 2023 emissions that form the basis of the ACE source apportionment approach. Previous studies have shown that air pollutant concentrations generally respond linearly to small emissions changes of up to 30 percent (Dunker et al., 2002; Cohan et al., 2005; Napelenok et al., 2006; Koo et al., 2007; Zavala et al., 2009; Cohan and Napelenok, 2011) and that linear scaling from source apportionment can do a reasonable job of representing impacts of 100 percent of emissions from individual sources (Baker and Kelly 2014). Therefore, while simplistic, it is reasonable to expect that the emissions concentration differences between the baseline and regulatory control alternatives can be adequately represented using this methodology and any uncertainty should be weighed against the speed in which this method may be used to account for spatial differences in the effect of EGU emissions on ozone and $PM_{2.5}$ concentrations.

A second limitation is that the source apportionment $PM_{2.5}$ contributions represent the spatial and temporal distribution of the emissions from each source tag as they occur in the 2023 modeled case. Thus, the contribution modeling results do not allow us to represent any changes to "within tag" spatial distributions. As a result, the method does not account for any changes of spatial patterns that would result from changes in the relative magnitude of sources within a source tag in the scenarios investigated here. As described above, the EGU tags are generally by state and by two EGU types; one for coal-fired units and one for non-coal units.

In addition, the 2023 CAMx-modeled concentrations themselves have some uncertainty. While all models have some level of inherent uncertainty in their formulation and inputs, the base-year 2011 model outputs have been evaluated elsewhere against ambient measurements (U.S. EPA 2017; 2019) and have been shown to adequately reproduce spatially and temporally varying ozone and $PM_{2.5}$ concentrations.

The regulatory alternatives lead to decreased concentrations of ozone and $PM_{2.5}$, the extent to which varies by location, relative to the baseline. However, the analysis does not account for how interaction with NAAQS compliance would affect the benefits and costs of the regulatory alternatives, which introduces uncertainty in the benefits and costs of the alternatives. To the extent the Revised CSAPR Update proposal will decrease NO_X and consequentially ozone and $PM_{2.5}$, these changes may affect compliance with existing NAAQS standards and subsequently affect the actual benefits and costs of the proposed rule. In areas not projected to attain the 2015 ozone NAAQS without further emissions reductions from the baseline, states may be able avoid applying some emissions control measures to reduce emissions from local sources as a result of this proposed rule. If compliance behavior with the 2015 ozone NAAQS were accounted for in the baseline in this RIA there may be additional benefits from reduced compliance costs, while the level and spatial pattern of changes in ozone and $PM_{2.5}$ concentrations, and their associated health and ecological benefits, would differ.

Similarly, the regulatory alternatives may project decreases in ozone and $PM_{2.5}$ concentrations in areas attaining the NAAQS in the baseline. In practice, these potential changes in concentrations may influence NAAQS compliance plans in these areas, which in turn would further influence concentrations and the cost of complying with the NAAQS. However, such behavior will be mitigated by NAAQS requirements such as Prevention of Significant Deterioration (PSD) requirements. This RIA does not account for how interaction with NAAQS compliance would affect the benefits and costs of the regulatory alternatives.

3.6 References

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APPENDIX 3A: METHODOLOGY FOR DEVELOPING AIR QUALITY SURFACES

In this appendix we describe the air quality modeling platform and methodology that was leveraged to prepare the air quality surfaces that could inform the calculation of health benefits of the proposed Revised CSAPR Update. The modeling and methodology described here were developed to support the Regulatory Impact Analysis for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units (U.S. EPA 2019), also referred to the Affordable Clean Energy (ACE) rule. The foundational data in the ACE approach include the 2023 ACE baseline EGU emissions and the 2023 ACE EGU air quality contribution data described below. To generate spatial fields for alternative EGU scenarios, such as the scenarios analyzed for the Revised CSPR Update proposal, the user provides as input EGU emissions for coal-fired and non-coal units for each state, separately. Ozone season EGU NOx emissions (tons) are used to prepare spatial fields of the May-September seasonal average MDA8 ozone and the April-October seasonal average MDA1 ozone concentrations and annual total EGU emissions of NOx, SO2 and $PM_{2.5}$ are used to prepare spatial fields of annual $PM_{2.5}$ concentrations. Emissions scaling ratios, described below, that are used to prepare the air quality spatial fields.

3A.1 Air Quality Modeling Platform for the ACE Rule

As part of the ACE assessment we used existing air quality modeling for 2011 and 2023 to estimate $PM_{2.5}$ and ozone concentrations in the future years analyzed for the ACE final rule. The modeling platform consists of several components including the air quality model, meteorology, estimates of international transport, and base year and future year emissions from anthropogenic and natural sources. An overview of each of these platform comments is provided in the subsections below.

3A.1.1 Air Quality Model, Meteorology and Boundary Conditions

We used the Comprehensive Air Quality Model with Extensions (CAMx version 6.40) with the Carbon Bond chemical mechanism CB6r4 for modeling base year and future year ozone and $PM_{2.5}$ concentrations (Ramboll, 2016). CAMx is a three-dimensional grid-based photochemical air quality model designed to simulate the formation and fate of oxidant precursors, primary and secondary particulate matter concentrations, and deposition over national, regional and urban spatial scales. Consideration of the different processes (e.g., transport and deposition) that affect primary (directly emitted) and secondary (formed by atmospheric processes) pollutants in different locations is fundamental to understanding and assessing the effects of emissions on air quality concentrations.

The geographic extent of the modeling domain covers the 48 contiguous states along with the southern portions of Canada and the northern portions of Mexico as shown in Figure1. This modeling domain contains 25 vertical layers with a top at about 17,550 meters[1] and horizontal grid resolution of 12 km x 12 km. The model simulations produce hourly air quality concentrations for each 12-km grid cell across the modeling domain.

Figure 3A-1. Air Quality Modeling Domain

The 2011 meteorological data for air quality modeling were derived from running Version 3.4 of the Weather Research Forecasting Model (WRF) (Skamarock, et al., 2008). 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 vertical layer in each grid cell. The 2011 meteorology was used for both the 2011 base year and 2023 future year air quality modeling. Details of the annual 2011 meteorological model simulation and evaluation are provided in a separate technical support document (US EPA,

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[1] Since the model top is defined based on atmospheric pressure, the actual height of the model top varies somewhat with time and location.

2014a) which can be obtained at:
http://www.epa.gov/ttn/scram/reports/MET_TSD_2011_final_11-26-14.pdf

The lateral boundary and initial species condition concentrations are provided by a three-dimensional global atmospheric chemistry model, GEOS-Chem (Yantosca, 2004) standard version 8-03-02 with 8-02-01 chemistry. The global GEOS-Chem model simulates atmospheric chemical and physical processes driven by assimilated meteorological observations from the NASA's Goddard Earth Observing System (GEOS-5).[2] GEOS-Chem was run for 2011 with a grid resolution of 2.0 degrees x 2.5 degrees (latitude-longitude). The predictions were used to provide one-way dynamic boundary condition concentrations at three-hour intervals and an initial concentration field for the CAMx simulations. The 2011 boundary concentrations from GEOS-Chem were used for both the 2011 and 2023 model simulations. The procedures for translating GEOS-Chem predictions to initial and boundary concentrations are described elsewhere (Henderson, 2014). More information about the GEOS-Chem model and other applications using this tool is available at: http://www-as.harvard.edu/chemistry/trop/geos.

3A.1.2 2011 and 2023 Emissions

The purpose of the 2011 base year modeling is to represent the year 2011 in a manner consistent with the methods used in the 2023 future year base case. The emissions data in this platform are primarily based on the 2011 National Emissions Inventory (NEI) v2 for point sources, nonpoint sources, commercial marine vessels, nonroad mobile sources and fires.[3] The onroad mobile source emissions are similar to those in the 2011 NEIv2, but were generated using the 2014a version of the Motor Vehicle Emissions Simulator (MOVES2014a) (http://www.epa.gov/otaq/models/moves/). The 2011 and 2023 emission inventories incorporate revisions implemented based on comments received on the Notice of Data Availability (NODA)

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[2] Additional information is available at:
http://gmao.gsfc.nasa.gov/GEOS/ and http://wiki.seas.harvard.edu/geos-chem/index.php/GEOS-5).

[3] Note that EPA used a more recent 2016-based emissions platform for air quality modeling to provide the foundational data needed to identify receptors and interstate contributions for the proposed rule. The 2016-based mobile emissions platform data were based on MOVES2014b. The 2016-based emissions platform is described in the Emissions Modeling Technical Support Document available at: https://www.epa.gov/air-emissions-modeling/2016v1-platform. Although the modeling data in the ACE approach are based on the 2011 platform (and the 2011-based platform mobile emissions data were developed using MOVES2014a), the state-EGU contribution modeling data, as described in this appendix, provide a means to develop spatial fields of air quality for the 2021 and 2025 baseline and the proposal and alternative control scenarios analyzed in this RIA.

issued in January 2017 “Preliminary Interstate Ozone Transport Modeling Data for the 2015 Ozone National Ambient Air Quality Standard” (82 FR 1733), along with revisions made from prior notices and rulemakings on earlier versions of the 2011 platform. The preparation of the emission inventories for air quality modeling is described in the Technical Support Document (TSD) Additional Updates to Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform for the Year 2023 (US EPA, 2017a). Electronic copies of the emission inventories and ancillary data used to produce the emissions inputs to the air quality model are available from the 2011en and 2023 en section of the EPA Air Emissions Modeling website for the 2011v6.3 emissions modeling platform: https://www.epa.gov/air-emissions-modeling/2011-version-63-platform.

The emission inventories for the 2023 ACE future year were developed using projection methods that are specific to the type of emission source. Future emissions are projected from the 2011 current 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)[4], 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. For sectors which depend strongly on meteorology (such as biogenic and fires), the same emissions are used in the base and future years to be consistent with the 2011 meteorology used when modeling 2023. 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. Emissions inventories for neighboring countries used in our modeling are included in this platform, specifically 2011 and 2023 emissions inventories for Mexico, and 2013 and 2025 emissions inventories for Canada. The meteorological data used to create and temporalize emissions for the future year cases is held constant and represents the year 2011. The same ancillary data files[5] are used to prepare the future year emissions inventories for air quality modeling as were used to prepare the 2011 base year inventories with the exception of chemical speciation profiles for mobile sources and temporal profiles for EGUs.

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[4] California provided emissions for the modeling platform. As such, onroad mobile source emissions for California were consistent with the emissions provided by the state.

[5] Ancillary data files include temporal, spatial, and VOC/$PM_{2.5}$ chemical speciation surrogates.

The projected EGU emissions reflect the emissions reductions expected due to the Final Mercury and Air Toxics (MATS) rule announced on December 21, 2011, the Cross-State Air Pollution Rule (CSAPR) issued July 6, 2011, and the CSAPR Update issued October 26, 2016. The 2023 EGU projected inventory was developed using an engineering analysis approach. EPA started with 2016 reported, seasonal, historical emissions for each unit. The emissions data for NO_X and SO_2 for units that report data under either the Acid Rain Program (ARP) and/or the CSAPR were aggregated to the summer/ozone season period (May-September) and winter/non-ozone period (January-April and October-December).[6] Adjustments to 2016 levels were made to account for retirements, coal to gas conversion, retrofits, state-of-the-art combustion controls, along with other unit-specific adjustments. Details and these adjustments, and information about handling for units not reporting under Part 75 and pollutants other than NO_X and SO_2 are described in the emissions modeling TSD (US EPA, 2017a).

The 2023 non-EGU stationary source emissions inventory includes impacts from 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 the January 2017 NODA, along with emissions reductions due to national and local rules, control programs, plant closures, consent decrees and settlements. Growth and control factors provided by states and by regional organizations on behalf of states were applied. Reductions to criteria air pollutant (CAP) emissions from stationary engines resulting as co-benefits to the Reciprocating Internal Combustion Engines (RICE) National Emission Standard for Hazardous Air Pollutants (NESHAP) are included. Reductions due to the New Source Performance Standards (NSPS) VOC controls for oil and gas sources, and the NSPS for process heaters, internal combustion engines, and natural gas turbines were also included.

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[6] EPA notes that historical state-level ozone season EGU NO_X emission rates are publicly available and quality assured data. They are monitored using continuous emissions monitors (CEMs) data and are reported to EPA directly by power sector sources. They are reported under Part 75 of the CAA.

For point and nonpoint oil and gas sources, state projection factors were generated using state-specific historical oil and gas production data available from EIA for 2011 to 2015 and information from regional factors based AEO 2017 to project the emission to the year 2023. Co-benefits of stationary engines CAP reductions (RICE NESHAP) and controls from New Source Performance Standards (NSPS) are reflected for select source categories. Mid-Atlantic Regional Air Management Association (MARAMA) factors for the year 2023 were used where applicable. Projection factors for other nonpoint sources such as stationary source fuel combustion, industrial processes, solvent utilization, and waste disposal, reflect emissions reductions due to control programs along with comments on the growth and control of these sources as a result of the January 2017 NODA and information gathered from prior rulemakings and outreach to states on emission inventories.

The MOVES2014a-based 2023 onroad mobile source 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 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards (LD GHG), the Renewable Fuel Standard (RFS2), the Mobile Source Air Toxics Rule, the Light Duty Green House Gas/Corporate Average Fuel Efficiency (CAFE) standards for 2012-2016, the Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, the Light-Duty Vehicle Tier 2 Rule, and the Heavy-Duty Diesel Rule. The MOVES-based emissions also include state rules related to the adoption of LEV standards, inspection and maintenance programs, Stage II refueling controls, and local fuel restrictions.

The nonroad mobile 2023 emissions, including 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 percent sulfur fuel in the Emissions Control Area (ECA) zone, the 2012-2015 Tier 2 NO_X controls, the 2016 0.1 percent 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 2025 using consistent methods that incorporated controls based on ECA and IMO global NO_X and SO_2 controls.

3A.1.3 2011 Model Evaluation for Ozone and $PM_{2.5}$

An operational model performance evaluation was conducted to examine the ability of the 2011 base year model run to simulate the corresponding 2011 measured ozone and $PM_{2.5}$ concentrations. This evaluation focused on four statistical metrics comparing model predictions to the corresponding observations. The performance statistics include mean bias, mean error, normalized mean bias, and normalized mean error. Mean bias (MB) is the sum of the difference (predicted – observed) divided by the total number of replicates (*n*). Mean bias is given in units of ppb and is defined as:

$$\text{MB} = \frac{1}{n}\sum_1^n (P-O) \qquad \text{(Eq-1)}$$

Where:

- P is the model-predicted concentration;
- O is the observed concentrations; and
- n is the total number of observations

Mean error (ME) calculates the sum of the absolute value of the difference (predicted - observed) divided by the total number of replicates (*n*). Mean error is given in units of ppb and is defined as:

$$\text{ME} = \frac{1}{n}\sum_1^n |P-O| \qquad \text{(Eq-2)}$$

Normalized mean bias (NMB) is the sum of the difference (predicted - observed) over the sum of observed values. NMB is a useful model performance indicator because it avoids over inflating the observed range of values, especially at low concentrations. Normalized mean bias is given in percentage units and is defined as:

$$\text{NMB} = \frac{\sum_1^n (P-O)}{\sum_1^n (O)} * 100 \qquad \text{(Eq-3)}$$

Normalized mean error (NME) is the sum of the absolute value of the difference (predicted - observed) divided by the sum of observed values. Normalized mean error is given in percentage units and is defined as:

$$\text{NME} = \frac{\sum_1^n |P-O|}{\sum_1^n (O)} * 100 \qquad \text{(Eq-4)}$$

For $PM_{2.5}$, performance statistics were calculated for modeled and observed 24-hour average concentrations paired by day and location for the entire year. Performance statistics were calculated for monitoring data in the Chemical Speciation Network (CSN)[7] and, separately, for monitoring data in the Interagency Monitoring of Protected Visual Environments (IMPROVE)[8] network. For ozone, performance statistics were calculated for modeled concentrations with observed 8-hour daily maximum (MDA8) ozone concentrations at or above 60 ppb[9] over the period May through September for monitoring sites in the Air Quality System (AQS)[10,11] network. For both $PM_{2.5}$ and ozone, the modeled and predicted pairs of data were aggregated by 9 regions across the U.S. for the calculation of model performance statistics. These 9 regions are shown in Figure 3A-2.[12]

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[7] Additional information on the measurements made at CSN monitoring sites can be found at the following web link: https://www.epa.gov/amtic/chemical-speciation-network-csn.

[8] Additional information on the measurements made at IMPROVE monitoring sites can be found at the following web link: https://www3.epa.gov/ttnamti1/visdata.html.

[9] Performance statistics are calculated for days with measured values at or above 60 ppb in order to focus the evaluation on days with high rather than low concentrations.

[10] Additional information on the measurements made at AQS monitoring sites can be found at the following web link: https://www.epa.gov/aqs.

[11] Note that the AQS data base also includes measurements made at monitoring sites in the Clean Air Status and Trends Network (CASTNet).

[12] Source: http://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php#references.

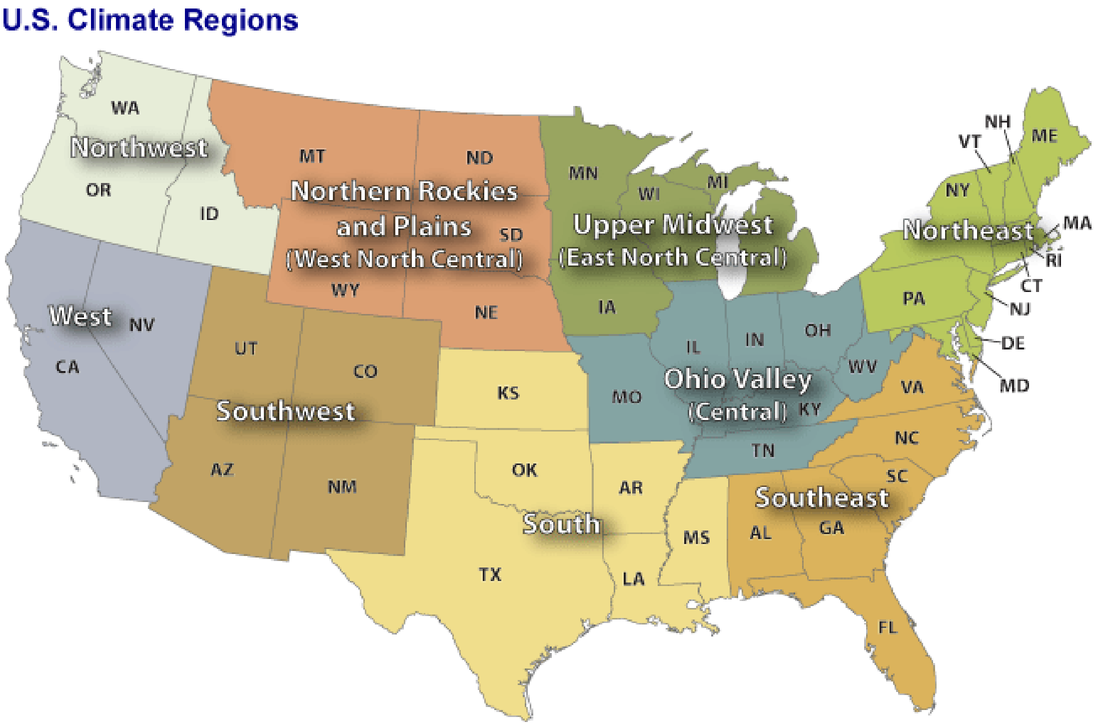

Figure 3A-2. NOAA Climate Regions

Model performance statistics for $PM_{2.5}$ for each region are provided in Table 3A.1. These data indicate that over the year as a whole, $PM_{2.5}$ is over predicted in the Northeast, Ohio Valley, Upper Midwest, Southeast, and Northwest regions and under predicted in the South and Southwest regions. Normalized mean bias is within ±30 percent in all regions except the Northwest which has somewhat larger model over-predictions. Model performance for $PM_{2.5}$ for the 2011 modeling platform is similar to the model performance results for other contemporary, state of the science photochemical model applications (Simon et al., 2012). Additional details on $PM_{2.5}$ model performance for the 2011 base year model run can be found in the Technical Support Document for EPA's preliminary regional haze modeling (US EPA, 2017b).

Table 3A.1. Model Performance Statistics by Region for $PM_{2.5}$

Region	Network	No. of Obs	MB ($\mu g/m^3$)	ME ($\mu g/m^3$)	NMB (%)	NME (%)
Northeast	IMPROVE	1577	0.87	2.21	17.70	44.90
	CSN	2788	0.97	4.04	9.70	40.40
Ohio Valley	IMPROVE	680	0.10	2.96	1.20	35.50
	CSN	2475	0.13	3.85	1.10	32.80
Upper Midwest	IMPROVE	700	0.83	2.37	14.20	40.40
	CSN	1343	1.37	3.66	13.60	36.30
Southeast	IMPROVE	1172	0.52	3.54	6.30	43.20
	CSN	1813	0.19	3.92	1.70	34.20
South	IMPROVE	933	-0.47	2.69	-6.50	37.40
	CSN	962	-0.08	4.48	-0.75	39.50
Southwest	IMPROVE	3695	-1.12	1.86	-28.00	46.30
	CSN	746	-0.08	3.93	-1.00	47.10
N. Rockies/ Plains	IMPROVE	1952	0.07	1.39	2.40	44.90
	CSN	275	-2.07	4.18	-21.80	43.90
Northwest	IMPROVE	1901	1.19	2.28	43.20	82.90
	CSN	668	5.77	7.25	69.90	87.90
West	IMPROVE	1782	-1.08	2.08	-25.30	48.50
	CSN	936	-2.92	5.08	-23.10	40.30

Model performance statistics for May through September MDA8 ozone concentrations for each region are provided in Table 3A.2. Overall, measured ozone is under predicted in most regions, except for the Northeast and Southeast where over prediction is found. Normalized mean bias is within ±15 percent in all regions. Model performance for ozone for the 2011 modeling platform is similar to the model performance results for other contemporary, state of the science photochemical model applications (Simon et al., 2012). Additional details on ozone model performance for the 2011 base year model run can be found in the Air Quality Technical Support Document for EPA’s preliminary interstate ozone transport modeling for the 2015 ozone National Ambient Air Quality Standard (US EPA, 2017c).

Table 3A.2. Model Performance Statistics by Region for Ozone on Days Above 60 ppb (May-Sep)

Region	No. of Obs	MB (ppb)	ME (ppb)	NMB (%)	NME (%)
Northeast	4085	1.20	7.30	1.80	10.70
Ohio Valley	6325	-0.60	7.50	-0.90	11.10
Upper Midwest	1162	-4.00	7.60	-5.90	11.10
Southeast	4840	2.30	6.80	3.40	10.20
South	5694	-5.30	8.40	-7.60	12.20
Southwest	6033	-6.20	8.50	-9.40	12.90
N. Rockies/Plains	380	-7.20	8.40	-11.40	13.40
Northwest	79	-5.60	9.00	-8.70	14.00
West	8655	-8.60	10.30	-12.20	14.50

Thus, the model performance results demonstrate the scientific credibility of our 2011 modeling platform for predicting $PM_{2.5}$ and ozone concentrations. These results provide confidence in the ability of the modeling platform to provide a reasonable projection of expected future year ozone concentrations and contributions.

3A.2 Source Apportionment Tags

CAMx source apportionment modeling was used to track ozone and $PM_{2.5}$ component species impacts from pre-defined groups of emissions sources (source tags). Separate tags were created for state-level EGUs split by fuel type (coal units versus non-coal units[13]). For some states with low EGU emissions, EGUs are grouped with nearby states that also have low EGU emissions. In addition, there are no coal EGUs operating in the 2023 emissions case for the following states: Idaho, Oregon, and Washington. Therefore, there is no coal EGU tag for those states. Similarly, there were no EGUs (coal or non-coal) in Washington D.C. in the 2023 emissions scenario, so there were no EGU tags for Washington D.C. There were also several domain-wide tags for sources other than EGUs. Table 3A.3 provides a full list of the emissions group tags that were tracked in the source apportionment modeling.

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[13] For the purposes of this analysis non-coal fuels include emissions from natural gas, oil, biomass, and waste coal-fired EGUs.

Table 3A.3. Source Apportionment Tags

Coal-fired EGU tags	Non-coal EGU tags	Domain-wide tags
• Alabama • Arizona • Arkansas • California • Colorado • Connecticut + Rhode Island • Delaware + New Jersey • Florida • Georgia • Illinois • Indiana • Iowa • Kansas • Kentucky • Louisiana • Maine + Mass. + New Hamp. + Vermont • Maryland • Michigan • Minnesota • Mississippi • Missouri • Montana • Nebraska • Nevada • New Mexico • New York • North Carolina • North Dakota + South Dakota • Ohio • Oklahoma • Pennsylvania • South Carolina • Tennessee • Texas • Utah • Virginia • West Virginia • Wisconsin • Wyoming • Tribal Data*	• Alabama • Arizona • Arkansas • California • Colorado • Connecticut + Rhode Island • Delaware + New Jersey • Florida • Georgia • Idaho + Oregon + Washington • Illinois • Indiana • Iowa • Kansas • Kentucky • Louisiana • Maine + Mass. + New Hamp. + Vermont • Maryland • Michigan • Minnesota • Mississippi • Missouri • Montana • Nebraska • Nevada • New Mexico • New York • North Carolina • North Dakota + South Dakota • Ohio • Oklahoma • Pennsylvania • South Carolina • Tennessee • Texas • Utah • Virginia • West Virginia • Wisconsin • Wyoming • Tribal Data[14]	• EGU retirements through 2025 • EGU retirements 2026-2030 • All U.S. anthropogenic emissions from source sectors other than EGUs • International within-domain emissions (sources occurring in Canada, Mexico, and from offshore marine vessels and drilling platforms) • Fires (wildfires and prescribed fires) • Biogenic sources • Boundary conditions

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[14] EGUs operating on tribal lands were tracked together in a single tag. There are EGUs on tribal land in the following states: Utah (coal), New Mexico (coal), Arizona (coal and non-coal), Idaho (non-coal). EGU emissions occurring on tribal lands were not included in the state-level EGU source tags.

The contributions represent the spatial and temporal distribution of the emissions within each source tag. Thus, the contribution modeling results do not allow us to represent any changes to any "within tag" spatial distributions. For example, the location of coal-fired EGUs in Michigan are held in place based on locations in the 2023 emissions. Additionally, the relative magnitude of sources within a source tag do not change from what was modeled with the 2023 emissions inventory.

3A.3 Applying Source Apportionment Contributions to Create Air Quality Fields

We created air quality surfaces for the ACE future year baseline and illustrative policy scenarios by scaling the EGU sector tagged contributions from the 2023 modeling based on relative changes in EGU emissions associated with each tagged category between the 2023 emissions case and the ACE scenarios. Below, we provide equations used to apply these scaling ratios along with tables of the ratios.

3A.3.2 Scaling Ratio Applied to Source Apportionment Tags

Scaling ratios for $PM_{2.5}$ components that are emitted directly from the source (OA, EC, crustal) were based on relative changes in annual primary $PM_{2.5}$ emissions between the 2023 emissions case and the ACE baseline and the illustrative policy scenario. Scaling ratios for components that are formed through chemical reactions in the atmosphere were created as follows: scaling ratios for sulfate were based on relative changes in annual SO_2 emissions; scaling ratios for nitrate were based on relative changes annual NO_X emissions; and scaling ratios for ozone formed in NO_X-limited regimes[15] ("O3N") were based on relative changes in ozone season (May-September) NO_X emissions. The scaling ratios that were determined based on emissions provided for each scenario.

Scaling ratios were applied to create air quality surfaces for ozone using equation (9):

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[15] The CAMx model internally determines whether the ozone formation regime is NO_X-limited or VOC-limited depending on predicted ratios of indicator chemical species.

$$Ozone_{m,g,d,i,y} = C_{m,g,d,BC} + C_{m,g,d,int} + C_{m,g,d,bio} + C_{m,g,d,fires} + C_{m,g,d,USanthro} + C_{m,g,d,y,EGUret} + \sum_{t=1}^{T} C_{VOC,m,g,d,t} + \sum_{t=1}^{T} C_{NOx,m,g,d,t} S_{t,i,y} \quad \text{(Eq-9)}$$

where:

- $Ozone_{m,g,d,i,y}$ is the estimated ozone for metric, “m” (MDA8 or MDA1), grid-cell, “g”, day, “d”, scenario, “i”, and year, “y”;
- $C_{m,g,d,BC}$ is the total ozone contribution from the modeled boundary inflow; $C_{m,g,d,int}$ is the total ozone contribution from international emissions within the model domain;
- $C_{m,g,d,bio}$ is the total ozone contribution from biogenic emissions;
- $C_{m,g,d,fires}$ is the total ozone contribution from fires;
- $C_{m,g,d,USanthro}$ is the total ozone contribution from U.S. anthropogenic sources other than EGUs;
- $C_{m,g,d,y,EGUret}$ is the total ozone contribution from retiring EGUs after year, “y” (this term is equal to 0 in 2030 and 2035);
- $C_{VOC,m,g,d,t}$ is the ozone contribution from EGU emissions of VOCs from tag, “t”;
- $C_{NOx,m,g,d,t}$ is the ozone contribution from EGU emissions of NO_X from tag, “t”; and
- $S_{t,i,y}$ is the ozone scaling ratio for tag, “t”, scenario, “i”, and year, “y”.

Scaling ratios were applied to create air quality surfaces for $PM_{2.5}$ species using equation (10) (for sulfate, nitrate, EC or crustal material) or using equation (11) (for OA):

$$PM_{s,g,d,i,y} = C_{s,g,d,BC} + C_{s,g,d,int} + C_{s,g,d,bio} + C_{s,g,d,fires} + C_{s,g,d,USanthro} + C_{s,g,d,y,EGUret} + \sum_{t=1}^{T} C_{s,g,d,t} S_{s,t,i,y} \quad \text{(Eq-10)}$$

$$OA_{g,d,i,y} = C_{POA,g,d,BC} + C_{POA,g,d,int} + C_{POA,g,d,bio} + C_{POA,g,d,fires} + C_{POA,g,d,USanthro} + C_{POA,g,d,y,EGUret} + SOA_{g,d} + \sum_{t=1}^{T} C_{POA,g,d,t} S_{pri,t,i,y} \quad \text{(Eq-11)}$$

where:

- $PM_{s,g,d,i,y}$ is the estimated concentration for species, "s" (sulfate, nitrate, EC, or crustal material), grid-cell, "g", day, "d", scenario, "i", and year, "y";
- $C_{s,g,d,BC}$ is the species contribution from the modeled boundary inflow;
- $C_{s,g,d,int}$ is the species contribution from international emissions within the model domain;
- $C_{s,g,d,bio}$ is the species contribution from biogenic emissions;
- $C_{s,g,d,fires}$ is the species contribution from fires;
- $C_{s,g,d,USanthro}$ is the species contribution from U.S. anthropogenic sources other than EGUs;
- $C_{s,g,d,y,EGUret}$ is the species contribution from retiring EGUs after year, "y" (this term is equal to 0 in 2030 and 2035);
- $C_{s,g,d,t}$ is the species contribution from EGU emissions from tag, "t"; and
- $S_{s,t,i,y}$ is the scaling ratio for species, "s", tag, "t", scenario, "i", and year, "y".

Similarly, for Equation (11):

- $OA_{g,d,i,y}$ is the estimated OA concentration for grid-cell, “g”, day, “d”, scenario, “i”, and year, “y”;
- Each of the contribution terms refers to the contribution to primary OA (POA); and
- $SOA_{g,d}$ represents the modeled secondary organic aerosol concentration for gird-cell, “g”, and day, “d”, which does not change among scenarios

3A.4 Creating Fused Fields Based on Observations and Model Surfaces

In this section we describe steps taken to estimate $PM_{2.5}$ and ozone gridded surfaces associated with the baseline and the illustrative policy scenario for every year. For $PM_{2.5}$, (daily gridded $PM_{2.5}$ species were processed into annual average surfaces which combine observed values with model predictions using the enhanced Veronoi Neighbor Average (eVNA) method (Gold et al., 1997; US EPA, 2007; Ding et al., 2015). These steps were performed using EPA’s software package, Software for the Modeled Attainment Test – Community Edition (SMAT-CE)[16] and have been previously documented both in the user’s guide for the predecessor software (Abt, 2014) and in EPA’s modeling guidance document (U.S. EPA, 2014b). First, we create a 2011 eVNA surface for each PM component species. To create the 2011 eVNA surface, SMAT-CE first calculates quarterly average values (January-March; April-June; July-September; October-December) for each $PM_{2.5}$ component species at each monitoring site with available measured data. For this calculation we used 3 years of monitoring data (2010-2012)[17]. SMAT-CE then creates an interpolated field of the quarterly-average observed data for each $PM_{2.5}$ component species using inverse distance squared weighting resulting in a separate 3-year average interpolated observed field for each $PM_{2.5}$ species and each quarter. The interpolated observed fields are then adjusted to match the spatial gradients from the modeled data. These two steps can be calculated using Equation (12):

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[16] Software download and documentation available at https://www.epa.gov/scram/photochemical-modeling-tools

[17] Three years of ambient data is used to provide a more representative picture of air pollution concentrations.

$$eVNA_{g,s,q,2011} = \sum Weight_x Monitor_{x,s,q,2010-2012} \frac{Model_{g,s,q,2011}}{Model_{x,s,q,2011}} \quad \text{(Eq-12)}$$

Where:

- $eVNA_{g,s,q,current}$ is the gradient adjusted quarterly-average eVNA value at grid-cell, g, for PM component species, s, during quarter, q for the year 2011;
- $Weight_x$ is the inverse distance weight for monitor x at the location of grid-cell, g;
- $Monitor_{x,s,q,2010-2012}$ is the 3-year (2010-2012) average of the quarterly monitored concentration for species, s, at monitor, x, during quarter, q;
- $Model_{g,s,q,2011}$ is the 2011 modeled quarterly-average concentrations of species, s, at grid cell, g, during quarter, q; and
- $Model_{x,s,q,2011}$ is the 2011 modeled quarterly-average concentration of species, s, at the location of monitor, x, during quarter q.

The 2011 eVNA field serves as the starting point for future-year projections. To create a gridded future-year eVNA surfaces for the baseline and ACE illustrative policy, we take the ratio of the modeled future year[18] quarterly average concentration to the modeled 2011 concentration in each grid cell and multiply that by the corresponding 2011 eVNA quarterly $PM_{2.5}$ component species value in that grid cell (Equation 13).

$$eVNA_{g,s,q,future} = \left(eVNA_{g,s,q,2011}\right) \times \frac{Model_{g,s,q,future}}{Model_{g,s,q,2011}} \quad \text{(Eq-13)}$$

This results in a gridded future-year projection which accounts for adjustments to match observations in the 2011 modeled data.

Finally, particulate ammonium concentrations are impacted both by emissions of precursor ammonia gas as well as ambient concentrations of particulate sulfate and nitrate.

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[18] In this analysis the "future year" modeled concentration is the result of Equations 9, 10 or 11 that represents either the ACE scenarios.

Because of uncertainties in ammonium speciation measurements combined with sparse ammonium measurements in rural areas, the SMAT-CE default is to calculate ammonium values using the degree of sulfate neutralization (i.e., the relative molar mass of ammonium to sulfate with the assumption that all nitrate is fully neutralized). Degree of neutralization values are mainly available in urban areas while sulfate measurements are available in both urban and rural areas. Ammonium is thus calculated by multiplying the interpolated degree of neutralization value by the interpolated sulfate value at each grid-cell location which allows the ammonium fields to be informed by rural sulfate measurements in locations where no rural ammonium measurements are available. The degree of neutralization is not permitted to exceed the maximum theoretical molar ratio of 2:1 for ammonium:sulfate. When creating the future year surface for particulate ammonium, we use the default SMAT-CE assumption that the degree of neutralization for the aerosol remains at 2011 levels.

A similar method for creating future-year eVNA surfaces is followed for the two ozone metrics with a few key differences. First, while $PM_{2.5}$ is split into quarterly averages and then averaged up to an annual value, we look at ozone as a summer-season average using definitions that match metrics from epidemiology studies (May-Sep for MDA8 and Apr-Oct for MDA1). The other main difference in the SMAT-CE calculation for ozone is that the spatial interpolation of observations uses an inverse distance weighting rather than an inverse distance squared weighting. This results in interpolated observational fields that better replicate the more gradual spatial gradients observed in ozone compared to $PM_{2.5}$.

3A.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 Revised CSAPR Update proposed rule. EPA used the Integrated Planning Model (IPM) to conduct most of the analysis discussed in this chapter. As explained in detail below, this chapter presents analysis for three regulatory control alternatives that differ in the level of electric generating units (EGU) nitrogen oxides (NO_X) ozone season emissions budgets in 12 states subject to this action.[1] These regulatory control alternatives impose different budget levels based on alternative assumptions about the possible actions that EGUs may be able to pursue to reduce their NO_X emissions.

The chapter is organized as follows: following a summary of the regulatory control alternatives analyzed and a summary of 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.

4.1 Regulatory Control Alternatives

Of the 22 states currently covered by the Cross-State Air Pollution Rule (CSAPR) NO_X Ozone Season Group 2 trading program, EPA is proposing to establish revised budgets for 12 states. Therefore, EPA is proposing the creation of an additional geographic group and ozone season trading program comprised of these 12 upwind states with remaining linkages to downwind air quality problems in 2021. This new group, Group 3, will be covered by a new CSAPR NO_X Ozone Season Group 3 trading program and will no longer be subject to Group 2 budgets. Aside from the removal of the 12 covered states from the current Group 2 program, this proposal leaves unchanged the budget stringency and geography of the existing CSAPR NO_X Ozone Season Group 1 and Group 2 trading programs. The EGUs covered by the FIPs and subject to the budget are all fossil-fired EGUs with >25 megawatt (MW) capacity.

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[1] The 12 states for which EPA is proposing to promulgate FIPs to reduce interstate ozone transport for the 2008 ozone NAAQS are listed in Table I.A-2 of the preamble and include Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, New York, New Jersey, Ohio, Pennsylvania, Virginia, and West Virginia.

This RIA evaluates the benefits, costs and certain impacts of compliance with three regulatory control alternatives: the Revised CSAPR Update proposed rule, a less-stringent alternative, and a more-stringent alternative. For details on the derivation of these budgets, please see Section VII of the preamble. 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 emissions budgets analyzed.

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 Revised CSAPR Update proposed rule. The Revised CSAPR Update proposed emission budgets in this RIA represent EGU NO_X ozone season emission budgets for each state that were developed using uniform control stringency represented by $1,600 per ton of NO_X (2016$).[2] This RIA analyzes the Revised CSAPR Update proposed emission budgets, as well as a more and a less stringent alternative to the Revised CSAPR Update proposal. The more and less stringent alternatives differ from the Revised CSAPR Update proposal in that they set different 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 $500 per ton of NO_X (2016$). The more-stringent scenario uses emission budgets that were developed using uniform control stringency represented by $9,600 per ton of NO_X (2016$). For details, please see EGU NO_X Mitigation Strategies Proposed Rule TSD, in the docket for this proposed rule.[3]

Table 4-1 reports the EGU NO_X ozone season emission budgets that are evaluated in this RIA. As described above, starting in 2021, emissions from affected EGUs in the 12 states cannot exceed the sum of emissions budgets but for the ability to use banked allowances from previous years for compliance. No further reductions in budgets occur after 2024, and budgets remain in place for future years. Furthermore, emissions from affected EGUs in a particular state are subject to the CSAPR assurance provisions, which require additional allowance surrender

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[2] The budget setting process is described in section VIII of the preamble and in detail in the Ozone Transport Policy Analysis Technical Support Document (TSD).

[3] Docket ID No. EPA-HQ-OAR-2020-0272

penalties (a total of 3 allowances per ton of emissions) on emissions that exceed a state's CSAPR NOX ozone season assurance level, or 121 percent of the emissions budget. Similar to the approach taken in the CSAPR Update, EPA is proposing a one-time conversion of banked Group 2 allowances according to a formula. The size of the initial bank would be set at a level that would ensure that the use of these converted allowances, in addition to the allowances provided in the states' emissions budgets under the Group 3 trading program, would not authorize emissions in the trading program region in the first year of the program to exceed the sum of the states' budgets by more than the sum of the states' variability limits. The CSAPR NOX ozone season allowance trading program is described in further detail in Section VIII of the preamble.

Table 4-1. NOX Ozone Season Emission Budgets (Tons) Evaluated

Revised CSAPR Update Proposal

State	2021	2022	2023	2024	2025
Illinois	9,444	9,415	8,397	8,397	8,397
Indiana	12,500	11,998	11,998	9,447	9,447
Kentucky	14,384	11,936	11,936	11,936	11,936
Louisiana	15,402	14,871	14,871	14,871	14,871
Maryland	1,522	1,498	1,498	1,498	1,498
Michigan	12,727	11,767	9,803	9,614	9,614
New Jersey	1,253	1,253	1,253	1,253	1,253
New York	3,137	3,137	3,137	3,119	3,119
Ohio	9,605	9,676	9,676	9,676	9,676
Pennsylvania	8,076	8,076	8,076	8,076	8,076
Virginia	4,544	3,656	3,656	3,395	3,395
West Virginia	13,686	12,813	11,810	11,810	11,810
Total	106,280	100,096	96,111	93,092	93,092

Less-Stringent Alternative

State	2021	2022	2023	2024	2025
Illinois	9,667	9,632	8,579	8,599	8,579
Indiana	15,677	15,206	15,206	12,755	12,603
Kentucky	15,606	15,606	15,606	15,588	15,606
Louisiana	15,442	15,442	15,442	15,488	15,442
Maryland	1,565	1,565	1,565	1,565	1,565
Michigan	13,120	13,120	10,313	10,841	10,116
New Jersey	1,346	1,346	1,346	1,346	1,346
New York	3,182	3,182	3,182	3,169	3,163

Ohio	15,490	15,560	15,560	15,917	15,560
Pennsylvania	11,487	11,487	11,487	11,570	11,487
Virginia	4,588	4,172	4,172	3,912	3,908
West Virginia	15,017	15,017	13,272	13,407	13,272
Total	122,187	121,334	115,730	114,156	112,647

More-Stringent Alternative

State	2021	2022	2023	2024	2025
Illinois	9,444	9,415	8,397	7,142	7,142
Indiana	12,500	11,998	11,998	8,264	8,264
Kentucky	14,384	11,936	11,936	8,852	8,852
Louisiana	15,402	14,871	14,871	12,636	12,636
Maryland	1,522	1,498	1,498	1,239	1,239
Michigan	12,727	11,767	9,803	7,315	7,315
New Jersey	1,253	1,253	1,253	1,257	1,257
New York	3,137	3,137	3,137	3,020	3,020
Ohio	9,605	9,676	9,676	9,126	9,126
Pennsylvania	8,076	8,076	8,076	7,578	7,578
Virginia	4,544	3,656	3,656	3,022	3,022
West Virginia	13,686	12,813	11,810	9,569	9,569
Total	106,280	100,096	96,111	79,020	79,020

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 Revised CSAPR Update proposal.

IPM, developed by ICF, 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.[4] EPA has used IPM for almost three decades to better understand power sector behavior under future business-as-usual conditions and to evaluate the economic and emissions impacts of prospective environmental policies. The model is designed to reflect electricity markets as accurately as possible. 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.[5]

The model incorporates a detailed representation of the fossil-fuel supply system that is used to estimate equilibrium fuel prices. The model uses natural gas fuel supply curves and regional gas delivery costs (basis differentials) to simulate the fuel price associated with a given level of gas consumption within the system. These inputs are derived using ICF's Gas Market Model (GMM), a supply/demand equilibrium model of the North American gas market.[6]

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

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[4] Due to the compliance timing for the Revised CSAPR Update proposal, 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 through 2025. EPA's compliance modeling does allow for new combustion controls, which represent the most likely potential capital expenditure in the 2021 analysis year.

[5] Detailed information and documentation of EPA's Base Case using IPM (v6), including all the underlying assumptions, data sources, and architecture parameters can be found on EPA's website at: http://www.epa.gov/airmarkets/powersectormodeling.html.

[6] See Chapter 8 of EPA's Base Case using IPM v6 documentation, available at: https://www.epa.gov/airmarkets/power-sector-modeling-platform-v6-may-2019.

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.[7]

To estimate the annualized costs of additional capital investments in the power sector, 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.[8] 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.

EPA has used IPM extensively over the past three 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), the Carbon Pollution Standards for New Power Plants (U.S. EPA, 2015), the Affordable Clean Energy Rule (U.S. EPA, 2019), and the Clean Power Plan Repeal (U.S. EPA, 2019). 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 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

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[7] See Chapter 7 of the IPM v.6 documentation. The documentation for EPA's Base Case v.6 using IPM consists of a comprehensive document for the November 2018 release of IPM v. 6, and incremental update documents for subsequent releases: http://www.epa.gov/airmarkets/powersectormodeling.html.

[8] See Chapter 10 of EPA's Base Case using IPM (v6) documentation, available at: http://www.epa.gov/airmarkets/powersectormodeling.html

assumptions, model representation, and modeling results. IPM has received extensive review by energy and environmental modeling experts in a variety of contexts. For example, in October 2014 U.S. EPA commissioned a peer review[9] of EPA Base Case version 5.13 using the Integrated Planning Model. Additionally, and in the late 1990s, the Science Advisory Board reviewed IPM as part of the CAA Amendments Section 812 prospective studies[10] that are periodically conducted. 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 the Regional Greenhouse Gas Initiative, 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 proposed rule. As such, an IPM base case represents an element of the baseline for this RIA.[11] EPA frequently updates the IPM base case to reflect the latest available electricity demand forecasts from the U.S. Energy Information Administration (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 Base Case v.6

For our analysis of the Revised CSAPR Update proposed rule, EPA used the January 2020 release of IPM version 6 to provide power sector emissions data for air quality modeling, as well as a companion updated database of EGU units (the National Electricity Energy Data System, or NEEDS v.6 rev: 1-8-2020[12]) that is used in EPA's modeling applications of IPM. The IPM Base

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[9] See Response and Peer Review Report EPA Base Case Version 5.13 Using IPM, available at: https://www.epa.gov/airmarkets/response-and-peer-review-report-epa-base-case-version-513-using-ipm.

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

[11] 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).

[12] https://www.epa.gov/airmarkets/national-electric-energy-data-system-needs-v6

Case includes the Affordable Clean Energy (ACE) Rule consistent with the RIA for the final rule and includes both the CSAPR rule and CSAPR Update rule. The Base Case includes the 2015 Effluent Limitation Guidelines (ELG) and the 2015 Coal Combustion Residuals (CCR), but does not include the recently finalized 2020 ELG and CCR rules.[13] The analysis of cost and impacts presented in this chapter is based on a single IPM base case, and represents incremental impacts projected solely as a result of compliance with the emissions budgets presented in Table 4-1 above.

4.3.2. Methodology for Evaluating the Regulatory Control Alternatives

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

Before undertaking power sector analysis to evaluate compliance with the regulatory control alternatives, EPA first considered available EGU NOX mitigation strategies that could be implemented for the upcoming ozone season (i.e., the 2021 ozone season). EPA considered all widely-used EGU NOX control strategies: optimizing NOX removal by existing, operational selective catalytic reduction (SCRs) and turning on and optimizing existing idled SCRs; turning on existing idled selective non-catalytic reduction (SNCRs); installation of (or upgrading to) state-of-the-art NOX combustion controls; shifting generation to units with lower NOX emission rates; and installing new SCRs and SNCRs. EPA determined that affected EGUs within the 12 states could implement all of these NOX mitigation strategies, except installation of new SCRs or SNCRs and state of the art combustion controls for the 2021 ozone season. After assessing the available NOx mitigation methods for complying with the annual budgets, this RIA projects that the system-wide least-cost strategies for compliance with the proposed Revised CSAPR Update and the more and less stringent regulatory alternatives lead to the application of the same

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[13] For a full list of modeled policy parameters, please see: https://www.epa.gov/sites/production/files/2020-02/documents/incremental_documentation_for_epa_v6_january_2020_reference_case.pdf

controls at the same sources as in the analysis used to calculate the budgets for these alternatives. As a consequence, the sectoral analyses used to establish the budgets are the same analyses used to estimate the compliance cost, benefits, and impacts of the proposed Revised CSAPR Update and the more and less stringent alternatives. In the analysis of the proposed rule presented in this RIA, in each year of the analysis period (2021-2025) and in each of the 12 states subject to tighter seasonal NOx budgets, seasonal NOx emissions from the sources subject to the proposed rule equal the seasonal NOx budget. For more details on these assessments, including the assessment of EGU NO_X mitigation costs and feasibility, please refer to the EGU NO_X Mitigation Strategies Proposed Rule TSD, in the docket for this proposed rule.[14]

These mitigation strategies are primarily captured within the model. However, due to limitations on model size, IPM v.6 does not have the ability to endogenously determine whether or not to operate existing EGU post-combustion NO_X controls (i.e., SCR or SNCR) in response to a regulatory emissions requirement.[15] The operating status of existing post-combustion NO_X controls at a particular EGU in a model scenario is determined by the model user. In order to evaluate compliance with the regulatory alternatives, EPA determined outside of IPM whether or not operation of existing controls that are idle in the baseline would be reasonably expected for compliance with each of the evaluated regulatory alternatives and for which model years they can feasibly be applied. IPM includes optimization and perfect foresight in solving for least cost dispatch. Given that the final rule will likely become effective either immediately prior to or slightly after the start of the 2021 ozone season, to avoid overstating optimization and dispatch decisions that are not possible in the short time frame, EPA complemented the projected IPM EGU outlook with historical (e.g., engineering analytics) perspective based on historical data that only factors in known changes to the fleet. This analysis forms the basis for the climate benefits calculations presented in this RIA.

EPA considers a unit to have optimized use of an SCR if emissions rates are equal to (or below) the "widely achievable" rate of 0.08 lbs/MMBtu.[16] Within IPM, units with extant SCRs are defined as SCR-equipped units with ozone season NO_X emission rates less than 0.20 lbs/

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[14] Docket ID No. EPA-HQ-OAR-2020-0272

[15] 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.

[16] For details on the derivation of this standard, please see preamble Section VII.B.1.

MMBtu in the Base Case. These units had their emission rates lowered to the lower of their mode 4[17] NOx rate in NEEDS and the "widely achievable" optimized emissions rate of 0.08 lbs/ MMBtu in the Revised CSAPR Update proposal. Units equipped with SCRs with an emissions rate exceeding 0.20 lbs/ MMBtu were considered to have idled SCRs. These units had their emission rates lowered to the lower of their mode 4 NOx rate in NEEDS and the "widely achievable" optimized emissions rate of 0.08 lbs/ MMBtu in the Revised CSAPR Update proposal. These control options are achievable in 2021 and were associated with a uniform control cost of $800 per ton and $1,600 per ton respectively. No further adjustments were made to the variable and fixed operating cost of these units, and their heat rates were also not adjusted to reflect energy requirements from increasing SCR removal efficiency within IPM. Under the proposed rule, 60 units are projected to fully run existing SCR controls, while 4 units are projected to turn on idled SCR controls.

Finally, unit combustion control configurations listed in NEEDS were compared against Table 3-11 in the Documentation for EPA Base Case v.5.13 Using the Integrated Planning Model IPM v.6, which lists state-of-the-art combustion control configurations based on unit firing type. This allowed EPA to identify units that would receive state-of-the-art combustion control upgrades in IPM. EPA then followed the procedure in the EGU NOx Mitigation Strategies Proposed Rule TSD to calculate each of these unit's new NOx emission rate. These upgrades were assumed to occur in 2022 and were assigned a uniform control cost of $1,600 per ton. No further adjustments were made to the variable and fixed operating cost of these units, and their heat rates were also not adjusted to reflect increased energy input requirements at a given load from the use of additional combustion controls, within IPM. Under the proposed rule, 27 units are projected to install state-of-the-art combustion controls.

The EGU NOx mitigation strategies that are assumed to operate or are available to reduce NOx in order to comply with each of the regulatory control alternatives are shown in Table 4-2;

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[17] NEEDS includes four possible states of NOx control operations, designated Modes 1-4. For details, please see Chapter 3.9.3 of IPM v6 documentation available at: https://www.epa.gov/sites/production/files/2018-08/documents/epa_platform_v6_documentation_-_all_chapters_august_23_2018_updated_table_6-2.pdf.

more information about the estimated costs of these controls can be found in the EGU NO_X Mitigation Strategies Proposed Rule TSD.

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) Shift generation to minimize costs (costs estimated within IPM)
Revised CSAPR Update Proposed Rule	(All controls above) (2) Fully operating existing SCRs to achieve 0.08 lb/MMBtu NO_x emission rate (costs estimated outside IPM) (3) Turn on idled SCRs (costs estimated outside IPM) and fully operate akin to (2) (4) Install state of the art combustion controls.
More Stringent Alternative	(All controls above) (5) In 2025, turn on idled SNCRs (costs estimated outside IPM) (6) In 2025, install new SCRs (costs estimated outside IPM)

For the NO_X controls identified in Table 4-2, under the proposed rule and the more stringent alternative, 60 units are projected to fully operate existing SCRs and 4 units are projected to turn on idled SCRs. Under the less stringent alternative, no units are projected to either fully operate existing SCRs or turn on idled SCRs. Under the proposed rule and the more stringent alternative, 27 units are projected to install state-of-the-art combustion controls, and under the less stringent alternative no units are projected to install state-of-the-art combustion controls. The book-life of the controls is assumed to be 15 years. Under the proposed rule and the less stringent alternative, no units are projected to install new SCRs, and under the more stringent alternative, 48 units are projected to install new SCRs. The book-life of the new SCRs is assumed to be 15 years.

In addition to the limitation on ozone season NO_X emissions required by the EGU emissions budgets for the 12 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, including: 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 pre-2021 vintage NO_X ozone season allowances issued under the CSAPR

Update program now being revised under this proposal. 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 NOX emissions across affected EGUs is generally governed by this cost-minimizing behavior in the analysis. The total ozone season NOX emissions from affected EGUs in this analysis are limited to the amount allowed by the sum of the NOX budgets across the 12 states. Furthermore, allowances may be banked for future use. The number of banked allowances is influenced by the determination, outside the model, of whether (i) existing controls that are idle in the base case are turned on and (ii) it is less costly to abate ozone season NOX emissions in a current ozone season than to abate emissions in a later ozone season. Affected EGUs are expected to bank NOX ozone season allowances in the 2021 ozone season for use in a later ozone season. The model starts with an assumed bank level in 2021 and endogenously determines the bank in each subsequent year. Based on observation, EPA believes that this is a reasonable compliance path for EGUs, even though there may be other non-economic reasons, such as being prepared for future variability in power sector operations, that can potentially influence this decision.

While there are no explicit limits on the exchange of allowances between affected EGUs and on the banking of 2021 and future vintage NOX ozone season allowances, the assurance provisions limit the amount of seasonal NOX emissions by affected EGUs in each of the 12 states. The assurance level limits affected EGU emissions over an ozone season to the state’s NOX ozone season emissions budget plus an increment equal to 21 percent of each state’s emissions budget. This increment is called the variability limit. See Section VIII.C.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 VIII.C.4 of the preamble also explains how 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 NOX 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 VIII.D.4 of the preamble, the rule allows pre-2021 vintage NO_X ozone season allowances (that had been issued under the CSAPR Update program now being revised under this proposal) to be used for compliance with this proposed rule, following a one-time conversion that reduces the overall quantity of banked allowances from that time period. Based on EPA's expectation of the size of the NO_X allowance bank after the one-time conversion carried out pursuant to the terms of this proposed rule, the treatment of these banked allowances is represented in the modeling as an additional 21,020 tons of NO_X allowances, the equivalent of one year of the variability limit associated with the emission budgets, that may be used by affected EGUs during the 2021 ozone season or in later ozone seasons under the Revised CSAPR Update rule. Under the more stringent and less stringent alternatives an additional 21,020 tons and 25,480 tons respectively may be used by affected EGUs during the 2021 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 shifting generation to lower-NO_X emitting EGUs. The costs of increasing the use and optimizing the performance of existing and operating SCRs,[18] 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 engineering analytics emissions projections and use 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 EPA's methodology for estimating the component of compliance costs that are calculated outside of the model for the Revised CSAPR Update proposal alternative[19]:

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

[19] For more information on the derivation of costs and useful life of combustion controls, please see EGU NO_X Mitigation Strategies Proposed Rule TSD.

(1) In the model projections, identify all EGUs in the 12 states that can adopt the following NO_X mitigation strategies:

- Fully operating existing SCRs
- Installing state of the art combustion controls

(2) Estimate the total NO_X reductions that are attributable to each of these strategies:[20]

- Fully operating existing SCRs (SCRs operating in base case): 9,154 tons
- Fully operating existing SCRs (SCRs not operating in base case): 5,870 tons
- Installing state-of-the-art combustion controls (not available in 2021): 0 tons

(3) Estimate the average cost associated with each of these strategies:[21]

- Fully operating existing SCRs (SCRs operating in base case): \$800/ton
- Fully operating existing SCRs (SCRs not operating in base case): \$1,600/ton
- Installing state-of-the-art combustion controls: \$1,600/ton

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

Table 4-3 summarizes the results of this methodology for the Revised CSAPR Update proposal alternative in 2021.

Table 4-3. Summary of Methodology for Calculating Compliance Costs Estimated Outside of IPM for Revised CSAPR Update Proposal, 2021 (2016$)

NO_X Mitigation Strategy	NO_X Ozone Season Emissions (Tons)	Average Cost ($/ton)	Total Cost ($MM)
Optimize existing SCRs	9,154	800	7
Operate existing SCRs	5,870	1,600	9

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[20] For more information on how NO_X reductions were attributed to strategies, see the Ozone Transport Policy Analysis TSD.

[21] 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.

EPA exogenously updated the emissions rates for the identified EGUs within the 12 states consistent with the set of controls determined for 2021-2025 within IPM. The model was updated to incorporate the emissions budgets identified for each case, and the first-year bank adjustment as outlined in Section 4.3.2. The Group 2 regional trading program was updated to exclude the 12-state Group 3 regional trading program, and budgets for the remaining Group 2 states were left otherwise unchanged. The change in the reported power system production cost between this model run and the base run was used to capture the cost of generation shifting. 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 1, EPA determined that NOX emissions in 12 eastern states affect the ability of downwind states to attain and maintain the 2008 ozone NAAQS. For these 12 eastern states, EPA is issuing Federal Implementation Plans (FIPs) that generally update the existing CSAPR Update NOX ozone-season emission budgets for EGUs and implement these budgets via the CSAPR NOX ozone-season allowance trading program.

As indicated in Chapter 1, the NOX emissions reductions are presented in this RIA for two time periods: 2021 and 2025. The 2021 emissions estimates are based on IPM projections for 2021, and adjustments to account for historical data. For more information on these and other adjustments, see the Ozone Transport Policy Analysis TSD.

Table 4-4 presents the estimated reduction in power sector NOX emissions resulting from compliance with the evaluated regulatory control alternatives (i.e., emissions budgets) in the 12 states, as well as the impact on other states. The emission reductions follow an expected pattern: the less stringent alternative produces substantially smaller emissions reductions than EPA's proposed emissions budgets, and the more stringent alternative results in slightly more NOX emissions reductions.

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

Ozone Season NOX (thousand tons)		Total Emissions				Change from Base Case		
		Base Case	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative
2021	12 States	124	106	122	106	-17	-2	-17
	Other States	236	236	236	236	0	0	0
	Total	359	342	358	342	-17	-2	-17
2022	12 States	123	100	121	100	-23	-2	-23
	Other States	235	235	235	235	0	0	0
	Total	358	335	356	335	-23	-2	-23
2023	12 States	117	96	116	96	-21	-2	-21
	Other States	227	227	227	227	0	0	0
	Total	345	324	343	324	-21	-2	-21
2024	12 States	114	93	113	79	-21	-2	-35
	Other States	225	225	225	225	0	0	0
	Total	340	319	338	304	-21	-2	-35
2025	12 States	114	93	113	79	-21	-2	-35
	Other States	225	225	225	225	0	0	0
	Total	340	319	338	304	-21	-2	-35

The results of EPA's analysis show that, with respect to compliance with the EGU NOX emission budgets in 2021, maximizing the use of existing operating SCRs provides the largest amount of ozone season NOX emission reductions (52 percent, affecting 60 units), and turning on idled SCRs produces an additional 34 percent (affecting 4 units) of the total ozone season NOX reductions. Generation shifting primarily from coal to gas generation (14 percent) makes up the remainder of the ozone season NOX reductions. Based on this analysis of how EGUs are expected to comply with the proposed Revised CSAPR Update, none of the Group 3 states are projected to hit their variability limits, nor bank significant allowances during the analysis period (2021-2025).[22]

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[22] As shown in Table 4-4, in 2021 and 2025 seasonal NOx emissions from affected EGUs in the Group 3 states are projected to emit at levels equal to the seasonal budget, and therefore (i) will not bank additional allowances, or (ii) on net, use any banked allowances available at the end of the previous year or, in the case of 2021, from the starting bank.

In addition to the ozone season NO_X reductions, there will also be reductions of other air emissions associated with EGUs burning fossil fuels (i.e., co-pollutants). These other emissions include the annual total changes in emissions of NOx and CO_2; there are no annual SO_2 and $PM_{2.5}$ emissions changes. The emissions reductions are presented in Table 4-5. Consistent with the limited impact of generation shifting, there were de minimis emissions changes of CO, mercury, and HCl.

Table 4-5. EGU Annual Emissions and Emissions Changes for NO_X, SO_2, $PM_{2.5}$, and CO_2 for the Regulatory Control Alternatives

Annual NO_X (thousand tons)		Total Emissions				Change from Base Case		
		Base Case	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative
2021	12 States	291	274	290	274	-17	-2	-17
	Other States	524	524	524	524	0	0	0
	Total	815	797	813	797	-17	-2	-17
2022	12 States	289	259	287	259	-30	-2	-30
	Other States	521	521	521	521	0	0	0
	Total	809	780	808	780	-30	-2	-30
2023	12 States	275	249	274	249	-27	-2	-27
	Other States	505	505	505	505	0	0	0
	Total	780	753	778	753	-27	-2	-27
2024	12 States	268	241	266	227	-27	-2	-41
	Other States	500	500	500	500	0	0	0
	Total	768	741	766	727	-27	-2	-41
2025	12 States	268	241	266	227	-27	-2	-41
	Other States	500	500	500	500	0	0	0
	Total	768	741	766	727	-27	-2	-41

Annual SO_2 (thousand tons)		Total Emissions				Change from Base Case		
		Base Case	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative
2021	12 States	376	376	376	376	0	0	0
	Other States	556	556	556	556	0	0	0
	Total	933	933	933	933	0	0	0
2022	12 States	332	332	332	332	0	0	0
	Other States	492	492	492	492	0	0	0
	Total	824	824	824	824	0	0	0

2023	12 States	302	302	302	302	0	0	0
	Other States	480	480	480	480	0	0	0
	Total	781	781	781	781	0	0	0
2024	12 States	338	338	338	338	0	0	0
	Other States	534	534	534	534	0	0	0
	Total	872	872	872	872	0	0	0
2025	12 States	338	338	338	338	0	0	0
	Other States	534	534	534	534	0	0	0
	Total	872	872	872	872	0	0	0

Annual $PM_{2.5}$ (thousand tons)		**Total Emissions**				**Change from Base Case**		
		Base Case	**Revised CSAPR Update Proposal**	**Less-Stringent Alternative**	**More-Stringent Alternative**	**Revised CSAPR Update Proposal**	**Less-Stringent Alternative**	**More-Stringent Alternative**
2021	12 States	50	50	50	50	0	0	0
	Other States	76	76	76	76	0	0	0
	Total	126	126	126	126	0	0	0
2022	12 States	50	50	50	50	0	0	0
	Other States	76	76	76	76	0	0	0
	Total	125	125	125	125	0	0	0
2023	12 States	48	48	48	48	0	0	0
	Other States	74	74	74	74	0	0	0
	Total	122	122	122	122	0	0	0
2024	12 States	47	47	47	47	0	0	0
	Other States	74	74	74	74	0	0	0
	Total	121	121	121	121	0	0	0
2025	12 States	47	47	47	47	0	0	0
	Other States	74	74	74	74	0	0	0
	Total	121	121	121	121	0	0	0

Annual CO_2 (thousand tons)		**Total Emissions**				**Change from Base Case**		
		Base Case	**Revised CSAPR Update Proposal**	**Less-Stringent Alternative**	**More-Stringent Alternative**	**Revised CSAPR Update Proposal**	**Less-Stringent Alternative**	**More-Stringent Alternative**
2021	12 States	478	478	478	478	0	0	0
	Other States	959	959	959	959	0	0	0
	Total	1,437	1,437	1,437	1,437	0	0	0
2022	12 States	507	505	506	504	-2	-1	-3
	Other States	985	985	985	985	0	0	0
	Total	1493	1490	1491	1489	-2	-1	-3
2023	12 States	537	532	534	530	-5	-3	-6

	Other States	1011	1012	1012	1011	0	0	0
	Total	1548	1544	1545	1542	-4	-3	-6
2024	12 States	532	527	528	523	-4	-3	-8
	Other States	1004	1004	1004	1004	0	0	0
	Total	1536	1531	1532	1527	-4	-3	-8
2025	12 States	526	522	523	516	-4	-3	-10
	Other States	996	996	996	997	0	0	0
	Total	1,523	1,518	1,519	1,513	-5	-4	-10

4.4.2 Impact of Emissions Reductions on Maintenance and Nonattainment Monitors

In 2021, there are two nonattainment receptors and two maintenance receptors (see section VI.C of the preamble for additional discussion). EPA evaluated the air quality improvements at the four receptors from projected compliance with the two regulatory alternatives at the highest EGU cost threshold levels (i.e., $1,600 per ton and $3,900 per ton). EPA found that the average air quality improvement at the four receptors relative to the engineering analytics baseline was 0.19 ppb at $1,600 per ton and 0.23 ppb at $3,900 per ton (see Table VII.D.1-1 in the preamble for additional discussion). EPA found that the one of the receptors (Westport, Connecticut receptor) remains nonattainment at all cost levels, another receptor the (Stratford, Connecticut receptor) switches from nonattainment to maintenance at $1,600 per ton (i.e., its average design value (DV)[23] falls below the standard but its maximum DV remains above the NAAQS), while a third receptor (Houston receptor) remains maintenance at all levels.[24]

EPA observes this $1,600 per ton level of stringency results in all downwind air quality problems for the 2008 ozone NAAQS being resolved after 2024 (one year earlier than the base case). There are also projected changes in receptor status (from projected nonattainment to maintenance-only) for the Stratford and Westport receptors (the first in 2021, the second in 2024). In addition, the Houston receptor changes from maintenance to attainment in 2023.

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[23] The DV is calculated as the 3-year average of the annual 4th highest daily maximum 8-hour ozone concentration in parts per billion, with decimals truncated. The DV is a metric compared to the standard level to determine whether a monitor is violating the NAAQS.

[24] The fourth receptor was clean in the engineering base case, which is the starting point for a Step 3 analysis.

4.4.3 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. Since the rule does not result in any additional recordkeeping, monitoring or reporting requirements, the costs associated with compliance, monitoring, recordkeeping, and reporting requirements are not included within the estimates in this table and can be found in preamble Section VIII.C.6.

Table 4-6. National Compliance Cost Estimates (millions of 2016$) for the Regulatory Control Alternatives

	Revised CSAPR Update Proposal	**More-Stringent Alternative**	**Less-Stringent Alternative**
2021-2025 (Annualized)	19.4	80.6	1.6
2021 (Annual)	20.9	37.2	3.8
2022 (Annual)	29.7	49.2	12.8
2023 (Annual)	27.8	47.3	12.8
2024 (Annual)	6.3	132.2	-12.0
2025 (Annual)	6.3	132.2	-12.0

"2021-2025 (Annualized)" reflects total estimated annual compliance costs levelized over the period 2021 through 2025, discounted using a 4.25 real discount rate.[25] This does not include compliance costs beyond 2025. "2021 (Annual)" through "2025 (Annual)" costs reflect annual 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 stringent alternative is negative (i.e., a cost reduction) in 2024 and 2025, although this regulatory control alternative reduces NO_X emissions by over 2,000 tons 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.[26] 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 or

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[25] This table reports compliance costs consistent with expected electricity sector economic conditions. An NPV of costs was calculated using a 4.25% real discount rate consistent with the rate used in IPM's objective function for cost-minimization. The NPV of costs was then used to calculate the levelized annual value over a 5-year period (2021-2025) using the 4.25% rate as well. Tables ES-9 and 7-3 report the NPV of the annual stream of costs from 2021-2025 using 3% and 7% consistent with OMB guidance.

[26] For more information, please see Chapter 2 of the IPM documentation.

retirement that 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. Since the less-stringent alternative is designed to include only generation shifting, it does not necessitate full operation of existing controls, nor installation of new controls, leading to a negative total cost point estimate in 2025, reflecting the decision to delay retirements until later in the forecast period. Under the Revised CSAPR Update proposed rule, fully operating existing SCR controls provide a large share of the total emissions reductions. These options are selected in 2021, while upgrading to state-of-the-art combustion controls is assumed to begin in 2022. Generation shifting costs are positive in 2021 and 2023, but negative in 2025. The result is that the costs in 2021-23 are higher than costs in 2025.

Under the more stringent alternative, while 2021 includes the same set of controls as under the Revised CSAPR Update proposed rule, a wider range of technologies is considered in subsequent years. This, combined with a more stringent cap driving generation shifting costs positive in every year, results in costs that grow over the 2021-25 period.

As part of the IPM model runs, the Group 2 regional trading program was updated to exclude the 12-state Group 3 regional trading program, and budgets for the remaining Group 2 states were left otherwise unchanged. The Group 2 states did not exhibit significant changes in projected allowance prices and level and location of Group 2 NO_X emissions between the baseline and regulatory alternatives as a result of this update.

In addition to evaluating annual compliance cost impacts, EPA believes that a full understanding of these three regulatory control alternatives benefits from an evaluation of annualized costs over the 2021-2025 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.[27] For this analysis we first calculated the NPV of the stream of costs from 2021 through 2025[28] using a 4.25 percent discount rate. EPA typically uses a 3 and a 7 percent discount rate to discount future

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[27] 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.

[28] Consistent with the relationship between IPM run years and calendar years, EPA assigned 2023 compliance cost estimates to both 2022 and 2023 in the calculation of NPV, and 2025 compliance cost to 2024 and 2025. For more information, see Chapter 7 of the IPM Documentation.

year social benefits and social costs in regulatory impact analyses (USEPA, 2010). In this cost annualization we use a 4.25 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. This discount rate is meant to capture the observed equilibrium market rate at which investors are willing to sacrifice present consumption for future consumption and is based on a Weighted Average Cost of Capital (WACC).[29] After calculating the NPV of the cost streams, the same 4.25 percent discount rate and 2021-2025 time period are used to calculate the levelized annual (i.e., annualized) cost estimates shown in Table 4-6.[30]

Additionally, note that the 2021-2025 equivalent annualized compliance cost estimates have the expected relationship to each other; the annualized costs are lowest for the less stringent alternative, and highest for the more stringent alternative.

4.4.4 Impacts on Fuel Use, Prices and Generation Mix

While the Revised CSAPR Update proposal 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.

Table 4-7 and Table 4-8 present the percentage changes in national coal and natural gas usage by EGUs in 2021. These fuel use estimates reflect a modest shift to natural gas from coal. The projected impacts in 2025 are similarly small.

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[29] The IPM Base Case documentation (Section 10.4.1 Introduction to Discount Rate Calculations) states "The real discount rate for all expenditures (capital, fuel, variable operations and maintenance, and fixed operations and maintenance costs) in the EPA Platform v6 is 4.25%."

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

Table 4-7. 2021 Projected U.S. Power Sector Coal Use for the Base Case and the Regulatory Control Alternatives

	Million Tons				Percent Change from Base Case		
	Base Case	Revised CSAPR Update Proposal	Less-Stringent Alt.	More-Stringent Alt.	Revised CSAPR Update Proposal	Less-Stringent Alt.	More-Stringent Alt.
Appalachia	85	85	85	85	0.16%	0.11%	0.36%
Interior	115	115	115	115	0.00%	0.01%	0.05%
Waste Coal	0	0	0	0	0.00%	0.00%	0.00%
West	287	286	286	286	-0.08%	-0.06%	-0.20%
Total	487	487	487	487	-0.02%	-0.01%	-0.04%

Table 4-8. 2021 Projected U.S. Power Sector Natural Gas Use for the Base Case and the Regulatory Control Alternatives

Trillion Cubic Feet				Percent Change from Base Case		
Base Case	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative
11	11	11	11	0.00%	0.00%	0.00%

Table 4-9 and Table 4-10 present the projected coal and natural gas prices in 2021, as well as the percent change from the base case projected as a result of the regulatory control alternatives. These minor impacts in 2021 are consistent with the small changes in fuel use summarized above. The projected impacts in 2025 are similarly very small.

Table 4-9. 2021 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	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative
Minemouth	1.21	1.21	1.21	1.21	0.08%	0.06%	0.22%
Delivered	1.87	1.87	1.87	1.87	0.03%	0.03%	0.09%

Table 4-10. 2021 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	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative
Henry Hub	3.19	3.19	3.19	3.19	0.00%	0.00%	0.02%
Delivered	3.24	3.24	3.24	3.24	0.00%	0.00%	0.02%

Table 4-11 presents the projected percentage changes in the amount of electricity generation in 2021 by fuel type. Consistent with the fuel use projections and emissions trends above, EPA projects a small overall shift from coal to gas. The projected impact in 2025 is similarly small.

Table 4-11. 2021 Projected U.S. Generation by Fuel Type for the Base Case and the Regulatory Control Alternatives

	Generation (TWh)				Percent Change from Base Case		
	Base Case	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative
Coal	797	797	797	797	-0.003%	-0.001%	0.001%
Natural Gas	1,582	1,582	1,582	1,582	0.001%	0.003%	0.002%
Nuclear	740	740	740	740	0.000%	0.000%	0.000%
Hydro	304	304	304	304	0.005%	-0.001%	-0.001%
Non-Hydro RE	536	536	536	536	0.000%	0.000%	0.000%
Oil\Gas Steam	58	58	58	58	-0.031%	-0.072%	-0.103%
Other	34	34	34	34	-0.043%	-0.042%	-0.020%
Total	4,051	4,051	4,051	4,051	-0.001%	0.000%	-0.001%

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 2021 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 2021, and the model was specified accordingly.

Table 4-12. 2021 Projected U.S. Capacity by Fuel Type for the Base Case and the Regulatory Control Alternatives

	Capacity (GW)				Percent Change from Base Case		
	Base Case	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative	Revised CSAPR Update Proposal	Less-Stringent Alternative	More-Stringent Alternative
Coal	216	216	216	216	0.0%	0.0%	0.0%
Natural Gas	421	421	421	421	0.0%	0.0%	0.0%
Nuclear	94	94	94	94	0.0%	0.0%	0.0%
Hydro	107	107	107	107	0.0%	0.0%	0.0%
Non-Hydro RE	184	184	184	184	0.0%	0.0%	0.0%
Oil\Gas Steam	74	74	74	74	0.0%	0.0%	0.0%
Other	8	8	8	8	0.0%	0.0%	0.0%
Total	1106	1106	1106	1106	0.0%	0.0%	0.0%

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

EPA estimated the change in the retail price of electricity (2016$) using the Retail Price Model (RPM).[31] The RPM was developed by ICF for 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 (shown in Figure 4-1) in the electricity market module of the National Energy Modeling System (NEMS).[32]

Table 4-13 and Table 4-14 present the projected percentage changes in the retail price of electricity for the three regulatory control alternatives in 2021 and 2025, 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 2025, EPA estimates that this rule will result in a 0.02 percent increase in national average retail electricity price, or by about 0.02 mills/kWh.

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[31] See documentation available at: https://www.epa.gov/airmarkets/retail-price-model

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

Table 4-13. Average Retail Electricity Price by Region for the Base Case and the Regulatory Control Alternatives, 2021

	2021 Average Retail Electricity Price (2016 mills/kWh)				Percent Change from Base Case		
Region	**Base Case**	**Revised CSAPR Update Proposal**	**Less-Stringent Alternative**	**More-Stringent Alternative**	**Revised CSAPR Update Proposal**	**Less-Stringent Alternative**	**More-Stringent Alternative**
MROE	118	118	118	118	0%	0%	0%
NYCW	166	166	166	166	0%	0%	0%
NYLI	134	134	134	134	0%	0%	0%
NYUP	109	109	109	109	0%	0%	0%
RFCE	115	115	115	115	0%	0%	0%
RFCM	91	91	91	91	0%	0%	0%
RFCW	93	93	93	93	0%	0%	0%
SRDA	83	83	83	83	0%	0%	0%
SRGW	87	87	87	87	0%	0%	0%
SRCE	85	85	85	85	0%	0%	0%
SRVC	100	100	100	100	0%	0%	0%
SPSO	88	88	88	88	0%	0%	0%
NATIONAL	100	100	100	100	0%	0%	0%

Table 4-14. Average Retail Electricity Price by Region for the Base Case and the Regulatory Control Alternatives, 2025

	2025 Average Retail Electricity Price (2016 mills/kWh)				Percent Change from Base Case		
Region	**Base Case**	**Revised CSAPR Update Proposal**	**Less-Stringent Alternative**	**More-Stringent Alternative**	**Revised CSAPR Update Proposal**	**Less-Stringent Alternative**	**More-Stringent Alternative**
MROE	116	116	116	116	0%	0%	0%
NYCW	198	198	198	198	0%	0%	0%
NYLI	159	159	159	159	0%	0%	0%
NYUP	135	135	134	134	0%	0%	0%
RFCE	132	132	132	132	0%	0%	0%
RFCM	105	105	105	105	0%	0%	1%
RFCW	104	104	104	104	0%	0%	0%
SRDA	83	83	83	83	0%	0%	0%
SRGW	98	97	97	97	0%	0%	0%
SRCE	83	83	83	83	0%	0%	0%
SRVC	101	101	101	101	0%	0%	0%
SPSO	93	93	93	93	0%	0%	0%
NATIONAL	107	107	107	107	0%	0%	0%

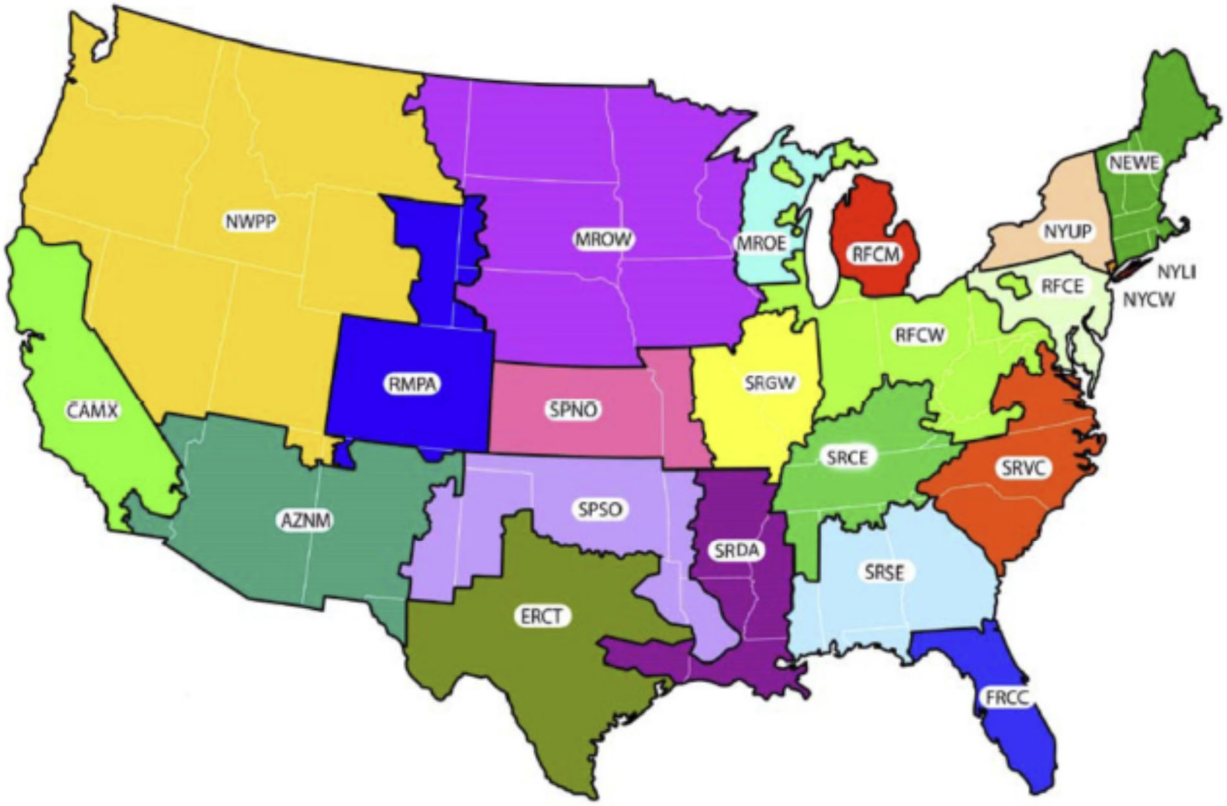

Figure 4-1. Electricity Market Module Regions

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

4.5 Social Costs

As discussed in EPA's *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 proposed and more or less stringent regulatory control 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 proposed 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 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 proposed 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 proposed rule.

As discussed in section 4.3.2, IPM v6 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 Ozone Transport Policy Analysis TSD. While the emissions 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). The effect of changes in facility and system-wide emissions from these changes in operating costs are also not accounted for in the spatial fields for the regulatory alternatives described in Chapter 3. These additional costs and their influence on projected changes in emissions and the level and location of ozone and $PM_{2.5}$ concentration patterns from the regulatory alternatives are relatively minor, and do not have a significant impact on the overall finding that the economic impacts of this proposed rule are minimal.

Additionally, the modeling includes two emission reduction strategies that are exogenously imposed where applicable: turning on idled SCRs (Revised CSAPR Update proposal and more-stringent alternative) and turning on idled SNCRs (mores stringent alternative only). While these strategies are exogenously imposed, the operation of controls is imposed in IPM and the costs and emissions reductions are estimated outside of IPM. 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 Revised CSAPR Update proposal.

4.7 References

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CHAPTER 5: BENEFITS

Overview

This action proposes to revise the Cross-State Air Pollution Rule (CSAPR) Update to reduce the emissions of nitrogen oxides (NO_X) transported from states that contribute significantly to nonattainment or interfere with maintenance of the 2008 ozone National Ambient Air Quality Standard (NAAQS) in downwind states. Implementing the Revised CSAPR Update proposed rule is expected to reduce emissions of NO_X and provide ozone reductions, as well as consequent reductions in fine particulate matter ($PM_{2.5}$) concentrations and carbon dioxide (CO_2) emissions. This chapter describes the methods used to estimate the domestic climate benefits from reductions of CO_2 emissions. Data, resource, and methodological limitations prevent EPA from monetizing health benefits from reducing concentrations of ozone and $PM_{2.5}$, as well as the benefits of reducing direct exposure to NO_2, ecosystem effects and visibility impairment as well as benefits from reductions in other pollutants, such as hazardous air pollutants (HAP). We qualitatively discuss these unquantified benefits in this chapter. However, to provide perspective regarding the scope of the estimated benefits, Appendix 5B illustrates the potential health effects associated with the change in $PM_{2.5}$ and ozone concentrations as calculated using methods developed prior to the 2019 PM ISA and 2020 Ozone ISA. The values of these estimated benefits are not reflected in the estimated net benefits reported in Tables 7-1 and 7-2.

This chapter reports the estimated monetized domestic climate benefits associated with emission reductions for the three regulatory control alternatives across several discount rates.

5.1 Estimated Climate Benefits from Reducing CO_2

We estimate the climate for this proposed rulemaking using a measure of the domestic social cost of carbon (SC-CO_2). The SC-CO_2 is a metric that estimates the monetary value of projected impacts associated with marginal changes in CO_2 emissions in a given year. The SC-CO_2 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, including reduced costs for heating and increased costs for air conditioning. The metric 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 presented in this RIA focus on the projected impacts of climate change that are anticipated to directly occur within U.S. borders.

The SC-CO_2 estimates used in this analysis are interim values developed under Executive Order (EO) 13783 for use in regulatory analyses until an improved estimate of the impacts of climate change to the U.S. can be developed based on the best available science and economics. EO 13783 directed agencies to ensure that estimates of the social cost of greenhouse gases used in regulatory analyses "are based on the best available science and economics" and are consistent with the guidance contained in OMB Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (EO 13783, Section 5(c)). In addition, EO 13783 withdrew the technical support documents (TSDs) used in the benefits analysis of the 2016 CSAPR Update rule (U.S. EPA, 2016b) for describing the global social cost of greenhouse gas estimates developed under the prior Administration as no longer representative of government policy.

Regarding the two analytical considerations highlighted in EO 13783 – how best to consider domestic versus international impacts and appropriate discount rates – current guidance in OMB Circular A-4 is as follows. Circular A-4 states that analysis of economically significant proposed and final regulations "should focus on benefits and costs that accrue to citizens and residents of the United States." (OMB, 2003)[1] EPA follows this guidance by adopting a domestic perspective in our central analysis. Regarding discount rates, Circular A-4 states that regulatory analyses "should provide estimates of net benefits using both 3 percent and 7 percent." (OMB, 2003) The 7 percent rate is intended to represent the average before-tax rate of return to private capital in the U.S. economy. The 3 percent rate is intended to reflect the rate at which society discounts future consumption, which is particularly relevant if a regulation is expected to affect private consumption directly. EPA follows this guidance below by presenting estimates based on both 3 and 7 percent discount rates in the main analysis. See Appendix 5A for a discussion of the modeling steps involved in estimating the domestic SC-CO_2 estimates based on these discount rates. These SC-CO_2 estimates developed under EO 13783 and presented below will be used in

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[1] Office of Management and Budget (OMB), 2003, Circular A-4, http://www.whitehouse.gov/omb/circulars_a004_a-4 and OMB, 2011. Regulatory Impact Analysis: A Primer. http://www.whitehouse.gov/sites/default/files/omb/inforeg/regpol/circular-a-4_regulatory-impact-analysis-aprimer.pdf

regulatory analysis until more comprehensive domestic estimates can be developed, which would take into consideration recent recommendations from the National Academies of Sciences et al. (2017) to further update the current methodology to ensure that the SC-CO_2 estimates reflect the best available science.

Table 5-1 presents the average domestic SC-CO_2 estimate across all of the integrated assessment model runs used to estimate the SC-CO_2 for each discount rate for the years 2015 to 2050.[2] As with the global SC-CO_2 estimates, the domestic SC-CO_2 increases over time because future emissions are expected to produce larger incremental damages as economies grow and physical and economic systems become more stressed in response to greater climate change.

EPA estimated the dollar value of the CO_2-related effects for each analysis year between 2021 and 2025 by applying the SC-CO_2 estimates, shown in Table 5-1, to the estimated changes in CO_2 emissions in the corresponding year under the regulatory options. EPA then calculated the present value and annualized benefits from the perspective of 2020 by discounting each year-specific value to the year 2020 using the same 3 percent and 7 percent discount rates.

Table 5-1. Interim Domestic Social Cost of Carbon Values (2016$/Metric Tonne CO_2)

Year	3% Discount Rate, Average	7% Discount Rate, Average
2020	$7	$1
2025	$7	$1
2030	$8	$1
2035	$9	$2
2040	$9	$2
2045	$10	$2
2050	$11	$2

Note: These SC-CO_2 values are stated in $/metric tonne CO_2 and rounded to the nearest dollar (1 metric tonne equals 1.102 short tons). 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. EPA interpolated annual values for intermediate years.

Source: U.S. EPA Analysis, 2020 based on U.S. EPA, 2019b

The limitations and uncertainties associated with the SC-CO_2 analysis, which were discussed in the 2016 CSAPR Update RIA (U.S. EPA, 2016b), likewise apply to the domestic

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[2] The SC-CO_2 estimates rely on an ensemble of three integrated assessment models (IAMs): Dynamic Integrated Climate and Economy (DICE) 2010; Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) 3.8; and Policy Analysis of the Greenhouse Gas Effect (PAGE) 2009.

SC-CO_2 estimates presented in this chapter. Some uncertainties are captured within the analysis, as discussed in Appendix 5A, while other areas of uncertainty have not yet been quantified in a way that can be modeled. For example, limitations include the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation of the relationship between the discount rate and uncertainty in economic growth over long time horizons. The science incorporated into these models understandably lags behind the most recent research, and the limited amount of research linking climate impacts to economic damages makes this comprehensive global modeling exercise even more difficult. These individual limitations and uncertainties do not all work in the same direction in terms of their influence on the SC-CO_2 estimates. In accordance with guidance in OMB Circular A-4 on the treatment of uncertainty, Appendix 5A provides a detailed discussion of the ways in which the modeling underlying the development of the SC-CO_2 estimates used in this RIA addressed quantified sources of uncertainty and presents a sensitivity analysis to show consideration of the uncertainty surrounding discount rates over long time horizons.

Recognizing the limitations and uncertainties associated with estimating the SC-CO_2, the research community has continued to explore opportunities to improve SC-CO_2 estimates. Notably, the National Academies of Sciences, Engineering, and Medicine conducted a multidiscipline, multi-year assessment to examine potential approaches, along with their relative merits and challenges, for a comprehensive update to the current methodology. The task was to ensure that the SC-CO_2 estimates that are used in Federal analyses reflect the best available science, focusing on issues related to the choice of models and damage functions, climate science modeling assumptions, socioeconomic and emissions scenarios, presentation of uncertainty, and discounting. In January 2017, the Academies released their final report, "Assessing Approaches to Updating the Social Cost of Carbon," and recommended specific criteria for future updates to the SC-CO_2 estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process (National Academies of Sciences et al., 2017).

The Academies' 2017 report also discussed the challenges in developing domestic SC-CO_2 estimates, noting that current integrated assessment models do not model all relevant regional interactions – *i.e.*, how climate change impacts in other regions of the world could affect the United States, through pathways such as global migration, economic destabilization, and political destabilization. The Academies concluded that it "is important to consider what constitutes a domestic impact in the case of a global pollutant that could have international implications that impact the United States. More thoroughly estimating a domestic SC-CO_2 would therefore need to consider the potential implications of climate impacts on, and actions by, other countries, which also have impacts on the United States." (National Academies of Sciences et al., 2017, pg. 12-13). In addition to requiring reporting of impacts at a domestic level, Circular A-4 states that when an agency "evaluate[s] a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately" (OMB, 2003; page 15). This guidance is relevant to the valuation of damages from CO2 and other greenhouse gases (GHGs), given that GHGs contribute to damages around the world independent of the country in which they are emitted. Therefore, in accordance with this guidance in OMB Circular A-4, Appendix 5A presents the global climate benefits from this proposed rule using global SC-CO2 estimates based on both 3 and 7 percent discount rates. EPA did not quantitatively project the full impact of the proposed rule on international trade and the location of production, so it is not possible to present analogous estimates of international costs resulting from the regulatory options. However, to the extent that the electricity market analysis endogenously models international electricity and natural gas trade (see Chapter 4), and to the extent that affected firms have some foreign ownership, some of the costs accruing to entities outside U.S. borders is captured in the technology implementation costs presented in the RIA (U.S. EPA, 2020c).

Table 5-2 shows the estimated monetary value of the estimated changes in CO_2 emissions in 2021 and 2025 for the Revised CSAPR Update, the more-stringent alternative, and the less-stringent alternative.

Table 5-2. Estimated Domestic Climate Benefits from Changes in CO_2 Emissions 2021 - 2025 (Millions of 2016$)

Regulatory Option	Year	3% Discount Rate	7% Discount Rate
Proposal	2021	0.3	0.0

Table 5-2. Estimated Domestic Climate Benefits from Changes in CO_2 Emissions 2021 - 2025 (Millions of 2016$)

	2022	14.9	2.3
	2023	30.0	4.8
	2024	31.4	5.1
	2025	32.9	5.4
More-Stringent Alternative	2021	0.8	0.1
	2022	21.6	3.4
	2023	43.1	6.8
	2024	57.1	9.2
	2025	71.5	11.7
Less-Stringent Alternative	2021	0.2	0.0
	2022	9.4	1.5
	2023	18.9	3.0
	2024	22.1	3.6
	2025	25.5	4.2

Table 5-3 shows the total annualized monetary values associated with changes in CO_2 emissions for the three regulatory options. EPA annualized monetary value estimates to enable consistent reporting across benefit categories (*e.g.*, benefits from reduction in NOx emissions). The annualized values for the Revised CSAPR update rule are $22.1 million and $3.6 million, using discount rates of 3 and 7 percent, respectively.

Table 5-3. Estimated Total Annualized Domestic Climate Benefits (2021-25) from Changes in CO_2 Emissions (Millions of 2016$)

Regulatory Option	3% Discount Rate	7% Discount Rate
Proposal	22.1	3.6
More-Stringent Alternative	38.9	6.3
Less-Stringent Alternative	15.3	2.5

5.2 Unquantified Benefits

The monetized benefits estimated in this RIA reflect a subset of benefits attributable to the climate benefits from reductions associated with CO_2. The proposal is also expected to reduce emissions of ozone season NO_X. In the presence of sunlight, NO_X and volatile organic compounds (VOCs) can undergo a chemical reaction in the atmosphere to form ozone. Reducing

NO_X emissions generally reduces human exposure to ozone and the incidence of ozone-related health effects, though the degree to which ozone is reduced will depend in part on local levels of VOCs as discussed in Chapter 3. The proposal would 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 reduce human exposure to ambient $PM_{2.5}$ throughout the year and would thus reduce the incidence of $PM_{2.5}$-attributable health effects.[3] Reducing emissions of NO_X would also reduce ambient exposure to NO_2 and its associated health effects.

Data, time, and resource limitations prevented EPA from quantifying the estimated impacts or monetizing estimated benefits associated with exposure to ozone, $PM_{2.5}$, and NO_2 (independent of the role NO_2 plays as precursors to $PM_{2.5}$), as well as ecosystem effects, and visibility impairment due to the absence of air quality modeling data for these pollutants in this analysis. Lack of quantification does not imply that there are no benefits associated with reductions in exposures to ozone, $PM_{2.5}$, or NO_2. In this section, we provide a qualitative description of these benefits, which are listed in Table 5-4. However, to provide perspective regarding the scope of the estimated benefits, Appendix 5B illustrates the potential health effects associated with the change in $PM_{2.5}$ and ozone concentrations as calculated using methods developed prior to the 2019 PM ISA and 2020 Ozone ISA.

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[3] This RIA does not quantify $PM_{2.5}$-related benefits associated with SO_2 emission reductions. As discussed in Chapter 4, EPA does not estimate significant SO_2 emission reductions as a result of this proposal. Additionally, this RIA does not estimate changes in emissions of directly emitted particles.

Table 5-4. Unquantified Health and Welfare Benefits Categories

Category	Effect	Effect Quantified	Effect Monetized	More Information
Premature mortality from exposure to $PM_{2.5}$	Adult premature mortality	—	—	PM ISA[1,2]
	Infant mortality	—	—	PM ISA[1,2]
Morbidity from exposure to $PM_{2.5}$	Non-fatal heart attacks	—	—	PM ISA[1,2]
	Hospital admissions—respiratory	—	—	PM ISA[1,2]
	Hospital admissions—cardiovascular	—	—	PM ISA[1,2]
	Emergency room visits for asthma	—	—	PM ISA[1,2]
	Acute bronchitis	—	—	PM ISA[1,2]
	Lower respiratory symptoms	—	—	PM ISA[1,2]
	Upper respiratory symptoms	—	—	PM ISA[1,2]
	Exacerbated asthma	—	—	PM ISA[1,2]
	Lost work days	—	—	PM ISA[1,2]
	Minor restricted-activity days	—	—	PM ISA[1,2]
	Chronic Bronchitis	—	—	PM ISA[2]
	Emergency room visits for cardiovascular effects	—	—	PM ISA[2]
	Strokes and cerebrovascular disease	—	—	PM ISA[2]
	Other cardiovascular effects	—	—	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]
Mortality from exposure to ozone	Premature mortality based on short-term study estimates	—	—	Ozone ISA[1,2]
	Premature mortality based on long-term study estimate	—	—	Ozone ISA[1,2]
Morbidity from exposure to ozone	Hospital admissions—respiratory causes	—	—	Ozone ISA[1,2]
	Emergency department visits for asthma	—	—	Ozone ISA[1,2]
	Exacerbated asthma	—	—	Ozone ISA[1,2]
	Minor restricted-activity days	—	—	Ozone ISA[1,2]
	School absence days	—	—	Ozone ISA[1,2]
	Decreased outdoor worker productivity	—	—	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]
Improved Human Health				
Reduced incidence of morbidity from exposure to NO_2	Asthma hospital admissions	—	—	NO_2 ISA[2]
	Chronic lung disease hospital admissions	—	—	NO_2 ISA[2]
	Respiratory emergency department visits	—	—	NO_2 ISA[2]
	Asthma exacerbation	—	—	NO_2 ISA[2]
	Acute respiratory symptoms	—	—	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]
Improved Environment				
	Visibility in Class 1 areas	—	—	PM ISA[2]

Reduced visibility impairment	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 effects from 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]
Reduced effects from nutrient enrichment	Species composition and biodiversity in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[3]
	Coastal eutrophication	—	—	NO_x SO_x ISA[3]
	Recreational demand in terrestrial and estuarine ecosystems	—	—	NO_x SO_x ISA[3]
	Other non-use effects			NO_x SO_x ISA[3]
	Ecosystem functions (e.g., biogeochemical cycles, fire regulation)	—	—	NO_x SO_x ISA[3]
Reduced vegetation effects from ambient exposure to SO_2 and NO_x	Injury to vegetation from SO_2 exposure	—	—	NO_x SO_x ISA[3]
	Injury to vegetation from NO_x exposure	—	—	NO_x SO_x ISA[3]

Improved Human Health				
Reduced incidence of morbidity from exposure to NO$_2$	Asthma hospital admissions	—	—	NO$_2$ ISA[2]
	Chronic lung disease hospital admissions	—	—	NO$_2$ ISA[2]
	Respiratory emergency department visits	—	—	NO$_2$ ISA[2]
	Asthma exacerbation	—	—	NO$_2$ ISA[2]
	Acute respiratory symptoms	—	—	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]
Improved Environment				
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 effects from 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]
Reduced effects from nutrient enrichment	Species composition and biodiversity in terrestrial and estuarine ecosystems	—	—	NO$_x$ SO$_x$ ISA[3]
	Coastal eutrophication	—	—	NO$_x$ SO$_x$ ISA[3]
	Recreational demand in terrestrial and estuarine ecosystems	—	—	NO$_x$ SO$_x$ ISA[3]
	Other non-use effects			NO$_x$ SO$_x$ ISA[3]
	Ecosystem functions (e.g., biogeochemical cycles, fire regulation)	—	—	NO$_x$ SO$_x$ ISA[3]
Reduced vegetation effects from ambient exposure to SO$_2$ and NO$_x$	Injury to vegetation from SO$_2$ exposure	—	—	NO$_x$ SO$_x$ ISA[3]
	Injury to vegetation from NO$_x$ exposure	—	—	NO$_x$ SO$_x$ ISA[3]

[1] These endpoints are generally quantified and monetized when EPA quantitatively characterizes the benefits of changes in PM$_{2.5}$ and Ozone.

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

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

[4] 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.

The proposed Revised CSAPR Update is expected to reduce concentrations of both ground-level ozone and fine particles ($PM_{2.5}$) (see Chapter 3). EPA historically has used conclusions of the most recent Integrated Science Assessment (ISA) to inform its approach for quantifying air pollution-attributable health, welfare and environmental impacts associated with that pollutant. There is a separate ISA for each of the criteria pollutants. The ISA synthesizes the epidemiologic, controlled human exposure and experimental evidence "…useful in indicating the kind and extent of identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in ambient air."[4]

The ISA uses a weight of evidence approach to assess the extent to the evidence supports conclusions about the likelihood that a given criteria pollutant causes a given health outcome. EPA generally estimates the number and economic value of the effects for which the ISA identifies the pollutant as having "causal" or "likely to be causal" relationship. The endpoints for which the 2020 final Ozone ISA (U.S. EPA, 2020b) and the 2019 final PM ISA (U.S. EPA, 2019a) identified as being causal or likely causal differed in some cases the endpoints for which those pollutants were identified as being causal or likely causal in the Ozone and PM ISAs completed for the previous NAAQS reviews (Tables 5-5 and 5-6). EPA traditionally uses the ISAs' characterizations of the health and ecological literature to identify individual studies that may be of sufficient quality for use in supporting PM or ozone benefits analysis.

When updating its approach for quantifying the benefits of changes in $PM_{2.5}$ and Ozone, the Agency will incorporate evidence reported in these two recently completed ISAs and account for forthcoming recommendations from the Science Advisory Board on this issue (U.S. EPA-SAB 2020). When updating the evidence for a given endpoint, EPA will consider the extent to which there is a causal relationship, whether suitable epidemiologic studies exist to allow quantification of concentration response function, and whether there are robust economic approaches for estimating the value of the impact of reducing human exposure to the pollutant. Carefully and systematically reviewing the full breadth of this information requires significant time and resources. This process is still underway and will not be completed in time for this

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[4] Section 108 of the Clean Air Act. 42 U.S.C. 7408

proposal. For this reason, this RIA characterizes the potential benefits of reducing these two pollutants in qualitative terms only.[5] EPA intends to update its quantitative methods for estimating the number and economic value of Ozone and $PM_{2.5}$ health effects in time for publication as part of the final Revised CSAPR Update RIA.[6]

EPA is reviewing this evidence and is following a five-step approach as it updates its methods for quantifying and monetizing ozone and $PM_{2.5}$ attributable health endpoints:

1. Identify Ozone- and $PM_{2.5}$-attributable health effects for which the ISA reports the strongest evidence. EPA will consider the ISA-reported evidence for each endpoint, including the extent to which the ISA identifies that endpoint as either causally, or likely-to-be-causally, related to each pollutant.
2. Identify health outcomes that may be quantified in a benefits assessment. We would select among clinically significant outcomes (e.g. premature mortality and hospital admissions) for which endpoint-specific baseline incidence data are available.
3. Choose concentration-response parameters characteristic of the literature reviewed in the ISA. We would weigh criteria including study design, location, population characteristics, and other attributes.[7] In some cases we will need to identify and select new rates of baseline disease to quantify these effects.

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[5] The RIA for the Effluent Limit Guidelines rule separately noted that "…the 2020 Integrated Science Assessment for Ozone concludes the currently available evidence for cardiovascular effects and total mortality is suggestive of, but not sufficient to infer, a causal relationship with short-term (as well as long-term) O3 exposures (ISA, sections IS.4.3.4 and IS.4.3.5)....Until a replacement method that only estimates the benefits associated with respiratory causes of premature mortality has been developed, EPA will be removing the estimate of the impact of reduced ozone exposure on premature mortality from its benefits estimates from subsequent rulemakings." (U.S. EPA, 2020a) Rather than selectively updating the evidence for individual endpoints, the Agency is instead systematically updating its approach for quantifying all ozone and $PM_{2.5}$ effects using evidence reported in the Final Ozone ISA (2020) and the Final PM ISA (2019).

[6] In particular, the 2020 Ozone ISA concludes that the currently available evidence for cardiovascular effects and total mortality is suggestive of, but not sufficient to infer, a causal relationship with short-term (as well as long-term) ozone exposures (U.S. EPA, 2020b, sections IS.4.3.4 and IS.4.3.5). As such, EPA is in the process of recalibrating its benefits estimates to quantify only premature mortality from respiratory causes (i.e., non-respiratory causes of premature mortality associated with ozone exposure would no longer be estimated). Similarly, the 2019 PM ISA concludes that the currently available evidence for nervous system effects and cancer is likely to be a causal relationship with long term $PM_{2.5}$ exposure. EPA is in the process of evaluating nervous system effects from long term $PM_{2.5}$ exposure and evaluating the relationship between long term $PM_{2.5}$ exposure and cancer. Furthermore, the ISA references a variety of additional studies for consideration in quantifying the health implications of changes in $PM_{2.5}$ and ozone exposure. EPA is updating the estimates for several other health endpoints to account for this new scientific literature.

[7] In some cases, the ISA will identify whether there are more recent epidemiologic studies that are better suited than the prior studies used for endpoints whose causality did not change between the prior ISA and the current ISA (e.g. respiratory hospital admissions). In these cases, we may substitute this new epidemiologic evidence.

4. Choose economic unit values. For each health endpoint we would identify a corresponding willingness-to-pay or cost-of-illness measure to express the economic value of the adverse effect.
5. Develop methods for characterizing uncertainty associated with quantified benefits estimates. Building on EPA's current methods for characterizing uncertainty, these approaches will include, among others, reporting confidence intervals calculated from concentration-response parameter estimates and separate quantification using multiple studies and concentration response parameters for particularly influential endpoints (e.g., mortality risk), and potentially approaches for aggregating and representing the results of multiple studies evaluating a particular health endpoint.[8]

At each of the four stages above, the Agency would report a Preferred Reporting Items for System Reviews (PRISMA) diagram, detailing for each endpoint, study and concentration-response (effect coefficients), which are included and excluded and the rationale for applying or excluding this information.[9]

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[8] Study quality, inter-study heterogeneity, and redundancy issues will be taken into consideration if epidemiologic risk estimates are aggregated.

[9] Additional information regarding the PRISMA can be found here: https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1000097

Table 5-5. Estimated Summary of Causality Determination for each Ozone-Related Endpoint

(endpoints for which EPA's causality determination has changed reported in ***bold italic***)

	Health outcome	**Conclusion from the:**	
		2013 Ozone ISA	*2020 Ozone ISA*
Short-term exposure	Respiratory effects	Causal relationship	Causal relationship
	Cardiovascular effects	Likely to be causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
	Metabolic effects	Not determined	Likely to be causal relationship
	Total mortality	Likely to be causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
	Central nervous system effects	Suggestive of a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
Long-term exposure	Respiratory effects	Likely to be causal relationship	Likely to be causal relationship
	Cardiovascular effects	Suggestive of a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
	Metabolic effects	Not determined	Suggestive of, but not sufficient to infer, a causal relationship
	Total mortality	Suggestive of a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
	Reproductive effects	Suggestive of a causal relationship	Effects on fertility and reproduction: suggestive of, but not sufficient to infer, a causal relationship
			Effects on pregnancy and birth outcomes: suggestive of, but not sufficient to infer, a causal relationship
	Central nervous system effects	Suggestive of a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
	Cancer	Inadequate to infer a causal relationship	Inadequate to infer the presence or absence of a causal relationship

Table 5-6. Summary of Causality Determination for each $PM_{2.5}$-Related Endpoint
(endpoints for which EPA's causality determination has changed reported in ***bold italic***)

	Health outcome	**Conclusion from the:** *2009 PM ISA*	 *2019 PM ISA*
Short-term exposure	Respiratory effects	Likely to be causal relationship	Likely to be causal relationship
	Cardiovascular effects	Causal	Causal
	Metabolic effects	Not determined	Suggestive of, but inadequate to infer
	Nervous system effects	Inadequate to infer	Suggestive of, but inadequate to infer
	Mortality	Causal	Causal
Long-term exposure	Respiratory effects	Likely to be causal relationship	Likely to be causal relationship
	Cardiovascular effects	Causal	Causal
	Metabolic effects	Not determined	Suggestive of, but inadequate to infer
	Nervous system effects	Not determined	Likely to be causal relationship
	Reproductive effects	Effects on fertility and reproduction: suggestive of, but not sufficient to infer, a causal relationship	Effects on fertility and reproduction: suggestive of, but not sufficient to infer, a causal relationship
		Effects on pregnancy and birth outcomes: suggestive of, but not sufficient to infer, a causal relationship	Effects on pregnancy and birth outcomes: suggestive of, but not sufficient to infer, a causal relationship
	Cancer	Suggestive of, but not sufficient to infer	Likely to be causal
	Pre-mature Mortality	Causal	Causal

5.2.1 Ozone Health Benefits

Following a comprehensive review of health evidence, the Integrated Science Assessment for Ozone and Related Photochemical Oxidants (2020 ozone ISA) (U.S. EPA, 2020b) also made several determinations of causal or likely causal impacts for long- and short-term ozone exposures. Regarding long-term exposures, the ozone ISA found that evidence supports a likely to be causal relationship with respiratory effects; and is suggestive, but inadequate to infer, a causal relationship with cardiovascular effects, metabolic effects, total mortality, reproductive effects, and central nervous system effects. The 2020 ozone ISA found that short-term exposure evidence supports a causal relationship with respiratory effects; a likely to be causal relationship with metabolic effects; and is suggestive, but inadequate to infer, a causal relationship with cardiovascular effects, total mortality, reproductive effects, and central nervous system effects. While metabolic effects were not included in the 2013 ozone ISA, the determination for short-term cardiovascular effects was increased and the determination for short-term total mortality was decreased in the 2020 ozone ISA relative to the 2013 ozone ISA.

5.2.2 $PM_{2.5}$ Health Benefits

Following a similar comprehensive review of health evidence from epidemiologic and laboratory studies, the Integrated Science Assessment for Particulate Matter (2019 PM ISA) (U.S. EPA, 2019a) made several determinations for long- and short-term $PM_{2.5}$ exposures. Regarding long-term exposures, the PM ISA found that evidence supports a causal relationship with cardiovascular effects and total mortality; a likely to be causal relationship with respiratory effects, nervous system effects, and cancer; and is suggestive, but inadequate to infer, a causal relationship with metabolic effects and reproductive effects. The 2019 PM ISA found that short-term exposure evidence supports a causal relationship with cardiovascular effects and total mortality; a likely to be causal relationship with respiratory effects; and is suggestive, but inadequate to infer, a causal relationship with metabolic effects and nervous system effects. Metabolic effects and long-term nervous system effects were not included in the 2009 PM ISA, and the determinations of causal or likely causal impacts for all health outcomes evaluated in that ISA, other than cancer, which was increased, remained the same.

5.2.3 NO_2 Health Benefits

In addition to being a precursor to $PM_{2.5}$ and ozone, NOx emissions are also linked to a variety of adverse health effects associated with direct exposure. We were unable to estimate the health benefits associated with reduced NO_2 exposure in this analysis. 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, 2016c) concluded that there is a likely 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.

5.2.4 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, 2013a). 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.

5.2.5 NO_2 Welfare Benefits

As described in the Integrated Science Assessment for Oxides of Nitrogen and Sulfur — Ecological Criteria (NOx/SOx ISA) (U.S. EPA, 2008b), 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. Terrestrial acidification affects several important ecological services, including declines in habitat for threatened and endangered species (cultural), declines in forest aesthetics (cultural), declines in forest productivity (provisioning), and increases in forest soil erosion and reductions in water retention (cultural and regulating). (U.S. EPA, 2008b)

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, 2008b)

5.2.6 Visibility Impairment 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, 2009). 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, 2009). Previous analyses (U.S. EPA, 2011a) show that visibility 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 emission guidelines would be likely to have a significant impact on visibility in urban areas or Class I areas.

Reductions in emissions of NO_2 will improve the level of visibility throughout the United States because these gases (and the particles of nitrate and sulfate formed from these gases) 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).

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APPENDIX 5A: UNCERTAINTY ASSOCIATED WITH ESTIMATING THE SOCIAL COST OF CARBON

Overview

This appendix provides additional information on the climate benefits associated with CO_2 emissions reductions. It first provides a brief overview of the 2009 Endangerment Finding and climate science assessments released since 2009 and then provides greater detail about the methodology used to estimate climate benefits due to changes in CO2 emissions. The methodology used to develop interim domestic SC-CO_2 estimates and uncertainty associated with the interim SC-CO_2 values are the same as described in the RIA for the Affordable Clean Energy (ACE) final rule (U.S. EPA, 2019). This appendix applies the methodology to the analysis of the climate benefits of changes in CO_2 emissions under the regulatory options described in Chapter 4.

5A.1 Overview of 2009 Endangerment Finding and Climate Science Assessments

A 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 2009.

Through the implementation of Clean Air Act (CAA) regulations, 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 greenhouse gas (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. Table 5A-1 summarizes the quantified and unquantified climate benefits in this analysis.

Table 5A-1. Climate Effects

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]	✓[2]	SCC TSD
	Climate impacts from ozone and black carbon (directly emitted PM)	—	—	Ozone ISA, PM ISA[3]
	Other climate impacts (e.g., other GHGs such as methane, aerosols, other impacts)	—	—	IPCC[3]

[1] The global climate and related impacts of CO_2 emissions changes, such as sea level rise, are estimated within each integrated assessment model as part of the calculation of the SC-CO_2.

[2] The monetized damages, which are relevant for conducting the benefit-cost analysis, are used in this RIA to estimate the welfare effects of quantified changes in CO_2 emissions. The SC-CO_2 estimates used in the main benefits analysis in this RIA focus on the projected impacts of climate change that are anticipated to directly occur within U.S. borders. Monetized damages from global impacts are provided in Section 5A.4 of this appendix.

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

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). 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, as noted earlier, we do not estimate the climate benefits associated with reductions in PM and O_3 precursors.

5A.2 Overview of Methodology Used to Develop Interim Domestic SC-CO2 Estimates

The methodology used to develop interim domestic SC-CO_2 estimates and uncertainty associated with the interim SC-CO_2 values are the same as described in the RIA for the ACE final rule (U.S. EPA, 2019). This section applies the methodology to the analysis of the climate benefits of changes in CO_2 emissions under the regulatory alternatives described in Chapter 4.

The domestic SC-CO_2 estimates rely on the same ensemble of three integrated assessment models (IAMs) that were used to develop the global SC-CO_2 estimates (DICE 2010, FUND 3.8, and PAGE 2009)[1] used in the benefits analysis of the 2016 rule (U.S. EPA, 2016). The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socioeconomic (GDP and population) pathways. These emissions are translated into atmospheric concentrations, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter, equilibrium climate sensitivity. The effect of the changes is estimated in terms of consumption-equivalent economic damages. As in the estimation of SC-CO_2 estimates used in the 2016 benefits analysis (U.S. EPA, 2016), three key inputs were harmonized across the three models: a probability distribution for equilibrium climate sensitivity; five scenarios for economic, population, and emissions growth; and discount rates.[2] All other model features were left unchanged. Future damages are discounted using constant discount rates of both 3 and 7 percent, as recommended by OMB Circular A-4. The domestic share of the global SC-CO_2 – *i.e.*, an approximation of the climate change impacts that

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[1] The full model names are as follows: Dynamic Integrated Climate and Economy (DICE); Climate Framework for Uncertainty, Negotiation, and Distribution (FUND); and Policy Analysis of the Greenhouse Gas Effect (PAGE).

[2] See the summary of the methodology in the 2015 Clean Power Plan docket, document ID number EPA-HQ-OAR-2013-0602-37033, "Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon United States Government, 2015. See also National Academies of Sciences et al., 2017 for a detailed discussion of each of these modeling assumptions.

occur within U.S. borders – are calculated directly in both FUND and PAGE. However, DICE 2010 generates only global SC-CO_2 estimates. Therefore, EPA approximated U.S. damages as 10 percent of the global values from the DICE model runs, based on the results from a regionalized version of the model (RICE 2010) reported in Table 2 of Nordhaus (2017).

The steps involved in estimating the social cost of CO_2 are as follows. The three integrated assessment models (FUND, DICE, and PAGE) are run using the harmonized equilibrium climate sensitivity distribution, five socioeconomic and emissions scenarios, and constant discount rates described above. Because the climate sensitivity parameter is modeled probabilistically, and because PAGE and FUND incorporate uncertainty in other model parameters, the final output from each model run is a distribution over the SC-CO_2 in year *t* based on a Monte Carlo simulation of 10,000 runs. For each of the IAMs, the basic computational steps for calculating the social cost estimate in a particular year *t* are:

1. Calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions;
2. Adjust the model to reflect an additional unit of emissions in year *t*;
3. Recalculate the temperature effects and damages expected in all years beyond *t* resulting from this adjusted path of emissions, as in step 1; and
4. Subtract the damages computed in step 1 from those in step 3 in each model period and discount the resulting path of marginal damages back to the year of emissions. In PAGE and FUND step 4 focuses on the damages attributed to the US region in the models. As noted above, DICE does not explicitly include a separate US region in the model and therefore, EPA approximates U.S. damages in step 4 as 10 percent of the global values based on the results of Nordhaus (2017).

This exercise produces 30 separate distributions of the SC-CO_2 for a given year, the product of 3 models, 2 discount rates, and 5 socioeconomic scenarios. Following the approach used by the IWG, the estimates are equally weighted across models and socioeconomic scenarios in order to reduce the dimensionality of the results down to two separate distributions, one for each discount rate.

5A.3 Treatment of Uncertainty in Interim Domestic SC-CO_2 Estimates

There are various sources of uncertainty in the SC-CO_2 estimates used in this BCA. Some uncertainties pertain to aspects of the natural world, such as quantifying the physical effects of greenhouse gas emissions on Earth systems. Other sources of uncertainty are associated with current and future human behavior and well-being, such as population and economic growth, GHG emissions, the translation of Earth system changes to economic damages, and the role of adaptation. It is important to note that even in the presence of uncertainty, scientific and economic analysis can provide valuable information to the public and decision makers, though the uncertainty should be acknowledged and when possible taken into account in the analysis (Institute of Medicine, 2013). OMB Circular A-4 also requires a thorough discussion of key sources of uncertainty in the calculation of benefits and costs, including more rigorous quantitative approaches for higher consequence rules. This section summarizes the sources of uncertainty considered in a quantitative manner in the domestic SC-CO_2 estimates.

The domestic SC-CO_2 estimates consider various sources of uncertainty through a combination of a multi-model ensemble, probabilistic analysis, and scenario analysis. EPA provides a summary of this analysis here; more detailed discussion of each model and the harmonized input assumptions can be found in the 2017 National Academies report. For example, the three IAMs used collectively span a wide range of Earth system and economic outcomes to help reflect the uncertainty in the literature and in the underlying dynamics being modeled. The use of an ensemble of three different models at least partially addresses the fact that no single model includes all of the quantified economic damages. It also helps to reflect structural uncertainty across the models, which is uncertainty in the underlying relationships between GHG emissions, Earth systems, and economic damages that are included in the models. Bearing in mind the different limitations of each model and lacking an objective basis upon which to differentially weight the models, the three integrated assessment models are given equal weight in the analysis.

Monte Carlo techniques were used to run the IAMs a large number of times. In each simulation the uncertain parameters are represented by random draws from their defined probability distributions. In all three models the equilibrium climate sensitivity is treated probabilistically based on the probability distribution from Roe and Baker (2007) calibrated to the IPCC AR4 consensus statement about this key parameter.[3] The equilibrium climate

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[3] Specifically, the Roe and Baker distribution for the climate sensitivity parameter was bounded between 0 and 10 with a median of 3 °C and a cumulative probability between 2 and 4.5 °C of two-thirds.

sensitivity is a key parameter in this analysis because it helps define the strength of the climate response to increasing GHG concentrations in the atmosphere. In addition, the FUND and PAGE models define many of their parameters with probability distributions instead of point estimates. For these two models, the model developers' default probability distributions are maintained for all parameters other than those superseded by the harmonized inputs (*i.e.*, equilibrium climate sensitivity, socioeconomic and emissions scenarios, and discount rates). More information on the uncertain parameters in PAGE and FUND is available upon request.

For the socioeconomic and emissions scenarios, uncertainty is included in the analysis by considering a range of scenarios selected from the Stanford Energy Modeling Forum exercise, EMF-22. Given the dearth of information on the likelihood of a full range of future socioeconomic pathways at the time the original modeling was conducted, and without a basis for assigning differential weights to scenarios, the range of uncertainty was reflected by simply weighting each of the five scenarios equally for the consolidated estimates. To better understand how the results vary across scenarios, results of each model run are available in the docket for the ACE final rule (Docket ID EPA-HQ-OAR-2017-0355).

The outcome of accounting for various sources of uncertainty using the approaches described above is a frequency distribution of the SC-CO_2 estimates for emissions occurring in a given year for each discount rate. Unlike the approach taken for consolidating results across models and socioeconomic and emissions scenarios, the SC-CO_2 estimates are not pooled across different discount rates because the range of discount rates reflects both uncertainty and, at least in part, different policy or value judgements; uncertainty regarding this key assumption is discussed in more detail below. The frequency distributions reflect the uncertainty around the input parameters for which probability distributions were defined, as well as from the multi-model ensemble and socioeconomic and emissions scenarios where probabilities were implied by the equal weighting assumption. It is important to note that the set of SC-CO_2 estimates obtained from this analysis does not yield a probability distribution that fully characterizes uncertainty about the SC-CO_2 due to impact categories omitted from the models and sources of uncertainty that have not been fully characterized due to data limitations.

Figure 5A-1 presents the frequency distribution of the domestic SC-CO_2 estimates for emissions in 2030 for each discount rate. Each distribution represents 150,000 estimates based on 10,000 simulations for each combination of the three models and five socioeconomic and emissions scenarios. In general, the distributions are skewed to the right and have long right tails, which tend to be longer for lower discount rates. To highlight the difference between the impact of the discount rate on the SC-CO_2 and other quantified sources of uncertainty, the bars below the frequency distributions provide a symmetric representation of quantified variability in the SC-CO_2 estimates conditioned on each discount rate. The full set of SC-CO_2 results through 2050 is available in the docket for the ACE final rule (Docket ID EPA-HQ-OAR-2017-0355).

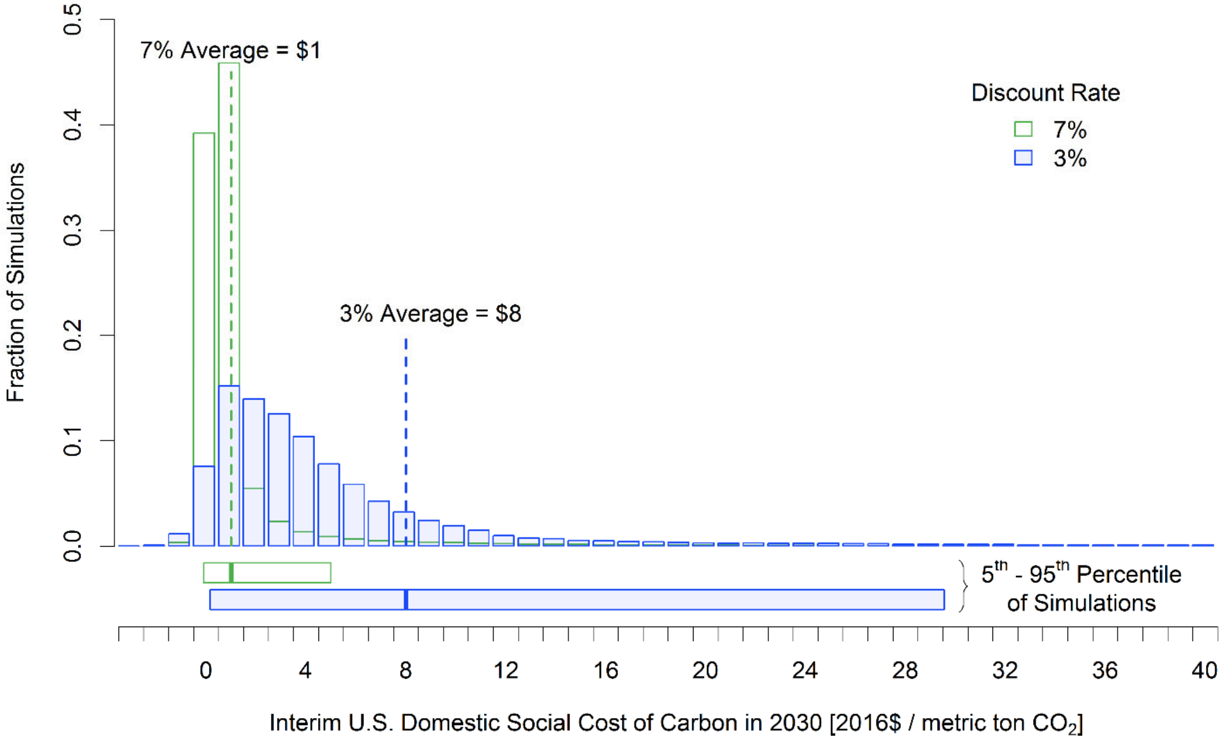

Figure 5A-1. Frequency Distribution of Interim Domestic SC-CO_2 Estimates for 2030 (in 2016$ per Metric Ton CO_2)

As illustrated by the frequency distributions in Figure 5A-1, the assumed discount rate plays a critical role in the ultimate estimate of the social cost of carbon. This is because CO_2 emissions today continue to impact society far out into the future, so with a higher discount rate, costs that accrue to future generations are weighted less, resulting in a lower estimate. Circular

A-4 recommends that costs and benefits be discounted using the rates of 3 percent and 7 percent to reflect the opportunity cost of consumption and capital, respectively. Circular A-4 also recommends quantitative sensitivity analysis of key assumptions[4], and offers guidance on what sensitivity analysis can be conducted in cases where a rule will have important intergenerational benefits or costs. To account for ethical considerations of future generations and potential uncertainty in the discount rate over long time horizons, Circular A-4 suggests "further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefit using discount rates of 3 and 7 percent" (page 36) and notes that research from the 1990s suggests intergenerational rates "from 1 to 3 percent per annum" (OMB, 2003). EPA considers the uncertainty in this key assumption by calculating the domestic SC-CO_2 based on a 2.5 percent discount rate, in addition to the 3 and 7 percent used in the main analysis. Using a 2.5 percent discount rate, the average domestic SC-CO_2 estimate across all the model runs for emissions occurring over 2021-2025 $10 per metric ton of CO_2 (in 2016$). In this case the domestic climate benefits under the proposed alternative at a 2.5 percent discount rate in 2021 are $0.4 million (2016$) and in 2025 are $47 million.

In addition to the approach to accounting for the quantifiable uncertainty described above, the scientific and economics literature has further explored known sources of uncertainty related to estimates of the SC-CO_2. For example, researchers have published papers that explore the sensitivity of IAMs and the resulting SC-CO_2 estimates to different assumptions embedded in the models (*e.g.*, Hope, 2013, Anthoff et al., 2013, and Nordhaus, 2014). However, there remain additional sources of uncertainty that have not been fully characterized and explored due to remaining data limitations. Additional research is needed in order to expand the quantification of various sources of uncertainty in estimates of the SC-CO_2 (*e.g.*, developing explicit probability distributions for more inputs pertaining to climate impacts and their valuation). On the issue of intergenerational discounting, some experts have argued that a declining discount rate would be appropriate to analyze impacts that occur far into the future (Arrow et al., 2013). However, additional research and analysis is still needed to develop a methodology for implementing a declining discount rate and to understand the implications of applying these theoretical lessons in practice. The 2017 National Academies report also provides recommendations pertaining to

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[4] "If benefit or cost estimates depend heavily on certain assumptions, you should make those assumptions explicit and carry out sensitivity analyses using plausible alternative assumptions." (OMB, 2003, page 42).

discounting, emphasizing the need to more explicitly model the uncertainty surrounding discount rates over long time horizons, its connection to uncertainty in economic growth, and, in turn, to climate damages using a Ramsey-like formula (National Academies of Sciences et al., 2017). These and other research needs are discussed in detail in the 2017 National Academies' recommendations for a comprehensive update to the current methodology, including a more robust incorporation of uncertainty.

5A.4 Global Climate Benefits

In addition to requiring reporting of impacts at a domestic level, OMB Circular A-4 states that when an agency "evaluate[s] a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately" (OMB, 2003; page 15).[5] This guidance is relevant to the valuation of damages from CO_2 and other GHGs, given that GHGs contribute to damages around the world independent of the country in which they are emitted. Therefore, this section presents the global climate benefits in 2021 and 2025 from this proposed rule using the global SC-CO_2 estimates corresponding to the model runs that generated the domestic SC-CO_2 estimates used in the main analysis. The average global SC-CO_2 estimate across all the model runs for emissions occurring over 2021-2025 range from $5 to $6 per metric ton of CO_2 emissions (in 2016$) using a 7 percent discount rate, and $49 to $53 per metric ton of CO_2 emissions (in 2016$) using a 3 percent discount rate. In the 2021-2025 timeframe, the domestic SC-CO_2 estimates presented above are approximately 19 percent and 14 percent of the global SC-CO_2 estimates for the 7 percent and 3 percent discount rates, respectively. Applying these estimates to the CO_2 emission reductions results in estimated global climate benefits in 2021 of $0.2 million using a 7 percent discount rate and $2.0 million using a 3 percent discount rate. By 2025, the estimated global climate benefits are $24.5 million using a 7 percent discount rate and $222.6 million using a 3 percent discount rate. Under the sensitivity analysis considered

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[5] While Circular A-4 does not elaborate on this guidance, the basic argument for adopting a domestic only perspective for the central benefit-cost analysis of domestic policies is based on the fact that the authority to regulate only extends to a nation's own residents who have consented to adhere to the same set of rules and values for collective decision-making, as well as the assumption that most domestic policies will have negligible effects on the welfare of other countries' residents (U.S. EPA, 2010b; Kopp et al., 1997; Whittington et al., 1986). In the context of policies that are expected to result in substantial effects outside of U.S. borders, an active literature has emerged discussing how to appropriately treat these impacts for purposes of domestic policymaking (*e.g.*, Gayer et al., 2016, 2017; Anthoff et al., 2010; Fraas et al., 2016; Revesz et al., 2017). This discourse has been primarily focused on the regulation of GHGs, for which domestic policies may result in impacts outside of U.S. borders due to the global nature of the pollutants.

above using a 2.5 percent discount rate, the average global SC-CO_2 estimate across all the model runs for emissions occurring over 2021-2025 ranges from $72 to $77 per metric ton of CO_2 (2016 dollars); in this case the global climate benefits in 2021 are $3.1 million; by 2025, the global benefits in this sensitivity case increase to $331.8 million.

5A.5 References

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APPENDIX 5B: AIR POLLUTION-RELATED HUMAN HEALTH BENEFITS ESTIMATED USING PREVIOUS METHODS

Overview

This appendix reports the estimated number and economic value of reducing $PM_{2.5}$ and Ozone associated with the three regulatory control alternatives across several discount rates. We estimate the incidence of air pollution-attributable premature deaths and illnesses using methods first developed in 2009 for $PM_{2.5}$ (U.S. EPA, 2009) and 2013 for Ozone (U.S. EPA, 2013a). These methods have not yet been updated to reflect the new evidence reported in the most recent PM and Ozone Integrated Science Assessments (U.S. EPA 2019a, 2020b). These limitations notwithstanding, this appendix provides useful context for readers and sheds some light on the potential magnitude of the benefits associated with the type of emissions reductions estimated in this proposal.

As noted in the Executive Summary and Chapter 5, EPA intends to update its methodology in time to quantify the number and economic value of Ozone and $PM_{2.5}$ health effects resulting from this rulemaking in the final Revised CSAPR Update RIA. When updating its approach for quantifying the benefits of changes in $PM_{2.5}$ and Ozone, the Agency will incorporate evidence reported in these two recently published ISAs and account for forthcoming recommendations from the EPA Science Advisory Board. When updating the evidence for each endpoint, EPA will consider the extent to which there is a causal relationship, whether suitable epidemiologic evidence exists to quantify the effect and whether the economic value of the effect may be estimated. Carefully and systematically reviewing the full breadth of this information requires significant time and resources that were unavailable to the Agency at the time of this proposal.

5B.1 Estimated Human Health Benefits

The proposal is expected to reduce emissions of ozone season NO_X. In the presence of sunlight, NO_X and volatile organic compounds (VOCs) can undergo a chemical reaction in the atmosphere to form ozone. Reducing NO_X emissions generally reduces human exposure to ozone and the incidence of ozone-related health effects, though the degree to which ozone is reduced will depend in part on local levels of VOCs. The proposal would 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 reduce human exposure to ambient $PM_{2.5}$ throughout the year and would reduce the incidence of $PM_{2.5}$-attributable health effects.[1] Reducing emissions of NO_X would also reduce ambient exposure to NO_2 and its associated health effects, though we do not quantify these effects due to lack of data.

The Regulatory Impact Analysis (RIA) for the Particulate Matter (PM) National Ambient Air Quality Standards (NAAQS) (U.S. EPA 2012), the RIA for the Ozone NAAQS (U.S. EPA 2015e) and the user manual for the Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE) program (U.S. EPA 2018) each provide a full discussion of the Agency's approach for quantifying the number and value of estimated air pollution-related impacts.[2] In these documents the reader can find the rationale for selecting health endpoints to quantify; the demographic, health and economic data we apply within BenMAP-CE; modeling assumptions; and our techniques for quantifying uncertainty. Additional information regarding our approach for characterizing uncertainty in PM-attributable risk of premature mortality may be found in the RIA for the Affordable Clean Energy Rule (U.S. EPA 2019b).

These estimated health benefits do not account for the influence of future changes in the climate on ambient concentrations of pollutants (USGCRP 2016). For example, recent research suggests that future changes to climate may create conditions more conducive to forming ozone; the influence of changes in the climate on $PM_{2.5}$ concentrations are less clear (Fann et al. 2015). The estimated health benefits also do not consider the potential for climate-induced changes in temperature to modify the relationship between ozone and the risk of premature death (Jhun et al. 2014; Ren et al. 2008a, 2008b).

Implementing the proposal will affect the distribution of ozone and $PM_{2.5}$ concentrations in much of the U.S.; this includes locations both meeting and exceeding the NAAQS for ozone

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[1] This RIA does not quantify $PM_{2.5}$-related benefits associated with SO_2 emission reductions. As discussed in Chapter 4, EPA does not estimate significant SO_2 emission reductions as a result of this proposal. Additionally, this RIA does not estimate changes in emissions of directly emitted particles. As a result, quantified $PM_{2.5}$-related benefits are subject to uncertainty.

[2] The Agency is evaluating the adequacy of the Ozone and PM NAAQS, see 85 FR 49830 and 85 FR 24094. Once EPA promulgates final PM and Ozone NAAQS, the Agency will revisit its approach for estimating benefits for each pollutant. Until that point, EPA will continue to apply methods for estimating benefits that are consistent with the evidence supporting the 2012 PM and 2015 Ozone NAAQS.

and PM. This RIA estimates avoided ozone- and $PM_{2.5}$-related health impacts that are distinct from those reported in the RIAs for both NAAQS (U.S. EPA 2012, 2015e). The ozone and $PM_{2.5}$ NAAQS RIAs hypothesize, but do not predict, the benefits and costs of strategies that States may choose to enact when implementing a revised NAAQS; these costs and benefits are illustrative and cannot be added to the costs and benefits of policies that prescribe specific emission control measures. This RIA estimates the benefits (and costs) of specific emissions control measures.

We project levels of ozone and $PM_{2.5}$ to increase and decrease over the U.S. compared to the baseline. Some portion of the air quality and health benefits from the regulatory control alternatives would occur in areas not attaining the Ozone or $PM_{2.5}$ NAAQS. However, we do not simulate how states would account for this rule when complying with the NAAQS; this affects the estimated benefits (and costs) of the proposal and more and less stringent alternatives, which introduces uncertainty in the estimated benefits (and costs).

5B.1.1 Health Impact Assessment for Ozone and $PM_{2.5}$

We estimate the quantity and economic value of air pollution-related effects using a "damage-function" approach. This approach quantifies counts of air pollution-attributable cases of adverse health outcomes and assigns dollar values to those counts, while assuming that each outcome is independent of one another. We construct this damage function by adapting primary research— specifically, air pollution epidemiology studies and economic value studies—from similar contexts. This approach is sometimes referred to as "benefits transfer." Below we describe the procedure we follow for: (1) selecting air pollution health endpoints to quantify; (2) calculating counts of air pollution effects using a health impact function; (3) specifying the health impact function with concentration-response parameters drawn from the epidemiological literature.

5B.1.1.1 Selecting Air Pollution Health Endpoints to Quantify

As a first step in quantifying ozone and $PM_{2.5}$-related human health impacts, the Agency consults the Integrated Science Assessment for Ozone and Related Photochemical Oxidants (Ozone ISA) (U.S. EPA 2013a) and the Integrated Science Assessment for Particulate Matter (PM ISA) (U.S. EPA 2009). These two documents synthesize the toxicological, clinical and epidemiological evidence to determine whether each pollutant is causally related to an array of adverse human health outcomes associated with either acute (i.e., hours or days-long) or chronic (i.e. years-long) exposure; for each outcome, the ISA reports this relationship to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship or not likely to be a causal relationship. In brief, the ISA for ozone found acute exposure to ozone to be causally related to respiratory effects, a likely-to-be-causal relationship with cardiovascular effects and total mortality and a suggestive relationship for central nervous system effects. Among chronic effects, the ISA reported a likely-to-be-causal relationship for respiratory outcomes and respiratory mortality, and a suggestive relationship for cardiovascular effects, reproductive and developmental effects, central nervous system effects, and total mortality. The Agency estimates the incidence of air pollution effects for those health endpoints above where the ISA classified as either causal or likely-to-be-causal. The PM ISA found acute exposure to $PM_{2.5}$ to be causally related to cardiovascular effects and mortality (i.e., premature death), and respiratory effects as likely-to-be-causally related. The ISA identified cardiovascular effects and total mortality as being causally related to long-term exposure to $PM_{2.5}$ and respiratory effects as likely-to-be-causal; and the evidence was suggestive of a causal relationship for reproductive and developmental effects as well as cancer, mutagenicity and genotoxicity. Table ES-2 reports the effects we quantified and those we did not quantify in this RIA.[3] The list of benefit categories not quantified is not exhaustive. And, among the effects quantified, it might not have been possible to quantify completely either the full range of human health impacts or economic values. The table below omits health effects associated with direct $PM_{2.5}$, and NO_2, and any welfare effects such as acidification and nutrient enrichment; these effects are described in the Ozone and PM NAAQS RIA (U.S. EPA 2015e, 2012) and summarized later in this appendix.

Consistent with economic theory, the willingness to pay (WTP) for reductions in exposure to environmental hazard will depend on the expected impact of those reductions on human health and welfare. All else equal, the WTP will be higher when there is strong evidence of a causal relationship between exposure to the contaminant and changes in the endpoint of interest. When there is some evidence of a relationship, but that evidence is insufficient to definitively determine a causal relationship, individuals are still expected to have a positive WTP

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[3] Note that, as discussed in Chapter 5, EPA has not updated the endpoints in this table to reflect the evidence reported in the most recent PM or Ozone ISAs (U.S. EPA 2019a, 2020b).

for a reduction in exposure to that environmental hazard. However, the WTP for reductions in exposure would be less than the case where the relationship can be determined to be causal. Conversely, valuing expected changes in the risk of an endpoint as if the relationship was known to be causal would overestimate the benefits of pollution reductions if there is uncertainty about whether the relationship is indeed causal. EPA currently lacks a robust methodology to adjust WTP estimates when the evidence is insufficient to conclude a causal relationship and therefore, endpoints for which the association cannot be determined to be causal or likely causal are not currently quantified or monetized.

Table 5B-2. Health Effects of Ambient Ozone and $PM_{2.5}$

Category	Effect	Effect Quantified	Effect Monetized	More Information
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
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
	Exacerbated asthma (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]
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]
Morbidity from exposure to ozone	Hospital admissions—respiratory causes (age > 65)	✓	✓	Ozone ISA
	Emergency department visits for asthma (all ages)	✓	✓	Ozone ISA
	Exacerbated asthma (asthmatics age 6-18)	✓	✓	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]

[1] Not quantified due to data and resource limitations for this analysis.

[2] Not quantified because we do not have sufficient confidence in available data or methods.

[3] Not quantified because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

5B.1.1.2 Calculating Counts of Air Pollution Effects Using the Health Impact Function

We use BenMAP-CE to quantify counts of premature deaths and illnesses attributable to photochemical modeled changes in summer season average ozone concentrations for the year

2021, and summer season average ozone concentrations and annual mean $PM_{2.5}$ for the year 2025 using a health impact function. A health impact function combines information regarding the: concentration-response relationship between air quality changes and the risk of a given adverse outcome; population exposed to the air quality change; baseline rate of death or disease in that population; and, air pollution concentration to which the population is exposed.

The following provides an example of a health impact function, in this case for $PM_{2.5}$ mortality risk. We estimate counts of $PM_{2.5}$-related total deaths (y_{ij}) during each year i (i=2025) among adults aged 30 and older (a) in each county in the contiguous U.S. j (j=1,…,J where J is the total number of counties) as

$$y_{ij} = \Sigma_a \, y_{ija}$$
$$y_{ija} = mo_{ija} \times (e^{\beta \cdot \Delta C_{ij}} - 1) \times P_{ija}, \quad \text{Eq[1]}$$

where mo_{ija} is the baseline all-cause mortality rate for adults aged a=30-99 in county j in year i stratified in 10-year age groups, β is the risk coefficient for all-cause mortality for adults associated with annual average $PM_{2.5}$ exposure, C_{ij} is the annual mean $PM_{2.5}$ concentration in county j in year i, and P_{ija} is the number of county adult residents aged a=30-99 in county j in year i stratified into 5-year age groups.[4]

The BenMAP-CE tool is pre-loaded with projected population from the Woods & Poole company; cause-specific and age-stratified death rates from the Centers for Disease Control and Prevention, projected to future years; recent-year baseline rates of hospital admissions, emergency department visits and other morbidity outcomes from the Healthcare Cost and Utilization Program and other sources; concentration-response parameters from the published epidemiologic literature cited in the Integrated Science Assessments for fine particles and ground-level ozone; and, cost of illness and willingness to pay economic unit values for each endpoint. Ozone and $PM_{2.5}$ concentrations are taken from the air pollution spatial surfaces described in Chapter 3.

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[4] In this illustrative example, the air quality is resolved at the county level. For this RIA, we simulate air quality concentrations at 12km by 12km grids. The BenMAP-CE tool assigns the rates of baseline death and disease stored at the county level to the 12km by 12km grid cells using an area-weighted algorithm. This approach is described in greater detail in the appendices to the BenMAP-CE user manual.

This health impact assessment quantifies outcomes using a suite of concentration-response parameters described in the PM NAAQS RIA (U.S. EPA 2012), Ozone NAAQS RIA (U.S. EPA 2015) and the user manual for the BenMAP-CE program (U.S. EPA 2018). These documents describe in detail our rationale for selecting air pollution-related health endpoints, the source of the epidemiological evidence, the specific concentration-response parameters applied, and our approach for pooling evidence across epidemiological studies. Given both the severity of air pollution-related mortality and its large economic value, below we describe the source of the concentration-response parameters for this endpoint.

5B.1.1.3 Quantifying Cases of Ozone-Attributable Premature Death

In 2008, the National Academies of Science (NRC 2008) issued a series of recommendations to EPA regarding the procedure for quantifying and valuing ozone-related mortality due to short-term exposures. Chief among these was that "…short-term exposure to ambient ozone is likely to contribute to premature deaths" and the committee recommended that "ozone-related mortality be included in future estimates of the health benefits of reducing ozone exposures…" The NAS also recommended that "…the greatest emphasis be placed on the multicity and [National Mortality and Morbidity Air Pollution Studies (NMMAPS)] …studies without exclusion of the meta-analyses" (NRC 2008). Prior to the 2015 Ozone NAAQS RIA, the Agency estimated ozone-attributable premature deaths using an NMMAPS-based analysis of total mortality (Bell et al. 2004), two multi-city studies of cardiopulmonary and total mortality (Huang et al. 2004; Schwartz 2005) and effect estimates from three meta-analyses of non-accidental mortality (Bell et al. 2005; Ito et al. 2005; Levy et al. 2005). Beginning with the 2015 Ozone NAAQS RIA, the Agency began quantifying ozone-attributable premature deaths using two newer multi-city studies of non-accidental mortality (Smith et al. 2009; Zanobetti and Schwartz 2008) and one long-term cohort study of respiratory mortality (Jerrett et al. 2009). We report the ozone-attributable deaths in this RIA as a range reflecting the concentration-response parameters from Smith et al. (2009) on the low end to Jerrett et al. (2009) on the high end.[5]

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[5] See section 6.6 of the RIA for the Ozone NAAQS (U.S. EPA 2015e) for further details.

5B.1.1.4 Quantifying Cases of PM$_{2.5}$-Attributable Premature Death

For adult PM-related mortality, we use the effect coefficients from two epidemiology studies examining two large population cohorts: the American Cancer Society cohort (Krewski et al. 2009) and the Harvard Six Cities cohort (Lepeule et al. 2012). The Integrated Science Assessment for Particulate Matter (PM ISA) (U.S. EPA 2009) concluded that the analyses of the ACS and Six Cities cohorts provide the strongest evidence of an association between long-term PM$_{2.5}$ exposure and premature mortality with support from additional cohort studies. The SAB's Health Effects Subcommittee (SAB-HES) also supported using effect estimates from these two analyses to estimate the benefits of PM reductions (U.S. EPA-SAB 2010). There are distinct attributes of both the ACS and Six Cities cohort studies that make them well-suited to being used in a PM benefits assessment and so here we present PM$_{2.5}$ related effects derived using relative risk estimates from both cohorts.

The PM ISA, which was twice reviewed by the Clean Air Scientific Advisory Committee of EPA's Science Advisory Board (SAB-CASAC) (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. The PM ISA also concluded that the scientific literature supports the use of a no-threshold log-linear model to portray the PM-mortality concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response function. The PM ISA, which informed the setting of the 2012 PM NAAQS, reviewed available studies that examined the potential for a population-level threshold to exist in the concentration-response relationship. Based on such studies, the ISA concluded that the evidence supports the use of a "no-threshold" model and that "little evidence was observed to suggest that a threshold exists" (U.S. EPA 2009) (pp. 2-25 to 2-26). Consistent with this evidence, the Agency historically has estimated health impacts above and below the prevailing NAAQS (U.S. EPA 2010c, 2010d, 2011c, 2011d, 2012, 2013b, 2014a, 2014b, 2014c, 2015a, 2015b, 2015c, 2015d, 2015e, 2016b).

Following this approach, we report the estimated PM$_{2.5}$-related benefits (in terms of both health impacts and monetized values) calculated using a log-linear concentration-response function that quantifies risk from the full range of simulated PM$_{2.5}$ exposures (NRC 2002; U.S. EPA 2009). When setting the 2012 PM NAAQS, the Administrator also acknowledged greater uncertainty in specifying the "magnitude and significance" of PM-related health risks at PM concentrations below the NAAQS. As noted in the preamble to the 2012 PM NAAQS final rule, "EPA conclude[d] that it [was] not appropriate to place as much confidence in the magnitude and significance of the associations over the lower percentiles of the distribution in each study as at and around the long-term mean concentration." (78 FR 3154, 15 January 2013). The preamble separately noted that "[a]s both the EPA and CASAC recognize, in the absence of a discernible threshold, health effects may occur over the full range of concentrations observed in the epidemiological studies." (78 FR 3149, 15 January 2013). In general, we are more confident in the size 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 data in these studies. To give insight to the level of uncertainty in the estimated $PM_{2.5}$ mortality benefits at lower ambient concentrations, we report the PM benefits according to alternative concentration cut points. Below we further describe our rationale for selecting these cut points. In addition to adult mortality discussed above, we use effect coefficients from a multi-city study to estimate PM-related infant mortality (Woodruff et al. 1997).

5B.1.2 Economic Valuation Methodology for Health Benefits

We next quantify the economic value of the ozone and $PM_{2.5}$-related deaths and illnesses estimated above. Changes in ambient concentrations of air pollution generally yield small changes in the risk of future adverse health effects for a large number of people. Therefore, the appropriate economic measure is WTP for changes in risk of a health effect. For some health effects, such as hospital admissions, WTP estimates are not generally 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 2012).

The value of avoided premature deaths account for over 95 percent of monetized ozone-related benefits and over 98 percent of monetized $PM_{2.5}$-related benefits. The economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still developing. The value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economics and public policy analysis community. Following the advice of the SAB's Environmental Economics Advisory Committee (SAB-EEAC), EPA currently uses the value of statistical life (VSL) approach in calculating estimates of mortality benefits, because we believe this calculation provides the most reasonable single estimate of an individual's willingness to trade off money for changes in the risk of death (U.S. EPA-SAB 2000). The VSL approach is a summary measure for the value of small changes in the risk of death experienced by a large number of people.

EPA continues work to update its guidance on valuing mortality risk reductions, and the Agency consulted several times with the SAB-EEAC on this issue. Until updated guidance is available, the Agency determined that a single, peer-reviewed estimate applied consistently, best reflects the SAB-EEAC advice it has received. Therefore, EPA applies the VSL that was vetted and endorsed by the SAB in the Guidelines for Preparing Economic Analyses (U.S. EPA 2016a) while the Agency continues its efforts to update its guidance on this issue. This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $6.3 million (2000$). 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 VSLs applied in this analysis in 2016$ after adjusting for income growth is $10.5 million for 2021 and $10.7 million for 2025.

The Agency is committed to using scientifically sound, appropriately reviewed evidence in valuing changes in the risk of premature death and continues to engage with the SAB to identify scientifically sound approaches to update its mortality risk valuation estimates. Most recently, the Agency proposed new meta-analytic approaches for updating its estimates (U.S. EPA 2010d), which were subsequently reviewed by the SAB-EEAC. EPA is taking the SAB's formal recommendations under advisement (U.S. EPA 2017).

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 (U.S. Office of Management and Budget 2003). We assume that there is a multi-year "cessation" lag between changes in PM exposures and the total realization of changes in health effects. Although the structure of the lag is uncertain, EPA follows the advice of the SAB-HES to use a segmented lag structure that assumes 30 percent of premature deaths are reduced 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 2004). 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. When valuing changes in ozone-attributable deaths using the Jerrett et al. (2009) study, we follow advice provided by the Health Effects Subcommittee of the SAB, which found that "…there is no evidence in the literature to support a different cessation lag between ozone and particulate matter. The HES therefore recommends using the same cessation lag structure and assumptions as for particulate matter when utilizing cohort mortality evidence for ozone" (U.S. EPA-SAB 2010).

5B.1.3 Characterizing Uncertainty in the Estimated Benefits

This analysis includes many data sources as inputs that are each subject to uncertainty. Input parameters include projected emission inventories, projected emissions from the electricity planning model, air quality data from models (with their associated parameters and inputs), population data, population estimates, health effect estimates from epidemiology studies, economic data, and assumptions regarding the future state of the world (i.e., regulations, technology, and human behavior). When compounded, even small uncertainties can greatly influence the size of the total quantified benefits.

Our estimate of the total monetized $PM_{2.5}$ and ozone-attributable benefits is based on 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). Below are key assumptions underlying the estimates for $PM_{2.5}$-related premature mortality, followed by key uncertainties associated with estimating the number and value of ozone-related premature deaths.

We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, 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 2009).

As noted above, we assume that the health impact function for fine particles is log-linear without a threshold. Thus, the estimates include health benefits from reducing fine particles in areas with different concentrations of $PM_{2.5}$, including both areas that do not meet the fine particle standard and those areas that are in attainment and reflect the full distribution of $PM_{2.5}$ air quality simulated above.

Also, as noted above, 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 2004), which affects the valuation of mortality benefits at different discount rates. The above assumptions are subject to uncertainty.

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 data in these studies. There are uncertainties inherent in identifying any particular point at which our confidence in reported associations decreases appreciably, and the scientific evidence provides no clear dividing line. This relationship between the air quality data and our confidence in the estimated risk is represented below in Figure 5B-2.

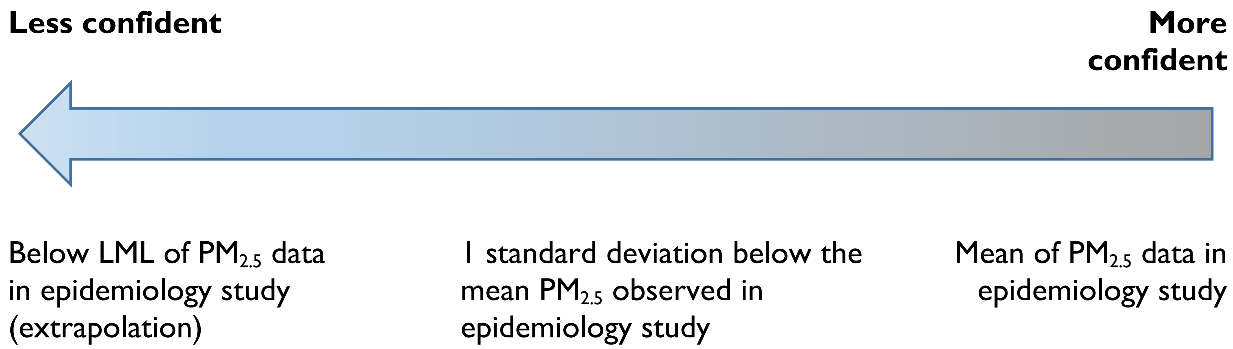

Figure 5B-2. Stylized Relationship between the $PM_{2.5}$ Concentrations Considered in Epidemiology Studies and our Confidence in the Estimated PM-related Premature Deaths

In this analysis, we build upon the concentration benchmark approach (also referred to as the Lowest Measured Level (LML) analysis) that has been featured in recent RIAs and EPA's *Policy Assessment for Particulate Matter* (U.S. EPA 2011) by reporting the estimated PM-related deaths according to alternative concentration cut points.

Concentration benchmark analyses 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. EPA does not view these concentration benchmarks as concentration thresholds below which we would not quantify health benefits of air quality improvements.[6] Rather, the $PM_{2.5}$-attributable benefits estimates reported in this RIA are the most appropriate estimates because they reflect the full range of air quality concentrations associated with the emission reduction strategies being evaluated in this proposal. The PM ISA concluded that the scientific evidence collectively is sufficient to conclude that there is a causal relationship between long-term $PM_{2.5}$ exposures and mortality and that overall the studies support the use of a no-threshold log-linear model to estimate mortality attributed to long-term $PM_{2.5}$ exposure (U.S. EPA 2009). Furthermore, while the tables below show the benefits above the LML only, it is the benefits below those cut-points that are more

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[6] 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).

uncertain, and may be greater or smaller in magnitude when estimating $PM_{2.5}$ benefits across the full range of projected exposures.

Figure 5B-3 reports the percentage of the population, and number of PM-related deaths, both above and below concentration benchmarks in the proposed policy modeling for the year 2025. The figure identifies the LML for each of the major cohort studies and the annual mean $PM_{2.5}$ NAAQS of 12 $\mu g/m^3$. For Krewski, the LML is 5.8 $\mu g/m^3$ and for Lepeule et al., the LML is 8 $\mu g/m^3$. These results are sensitive to the annual mean $PM_{2.5}$ concentration the air quality model predicted in each 12km by 12km grid cell. The air quality modeling predicts $PM_{2.5}$ concentrations to be at or below the $PM_{2.5}$ NAAQS (12 $\mu g/m^3$) in nearly all locations. The photochemical modeling we employ accounts for the suite of local, state and federal policies expected to reduce $PM_{2.5}$ and $PM_{2.5}$ precursor emissions in future years, such that we project a very small number of locations exceeding the annual standard. After presenting the full suite of results below we stratify these estimated $PM_{2.5}$ mortality deaths according to the concentration at which they occurred: below the LML, between the LML and the NAAQS, and above the NAAQS in future years across different policy scenarios. The results above should be viewed in the context of the air quality modeling technique we used to estimate $PM_{2.5}$ concentrations. We are more confident in our ability to use the air quality modeling technique described above to estimate *changes* in annual mean $PM_{2.5}$ concentrations than we are in our ability to estimate *absolute* $PM_{2.5}$ concentrations.

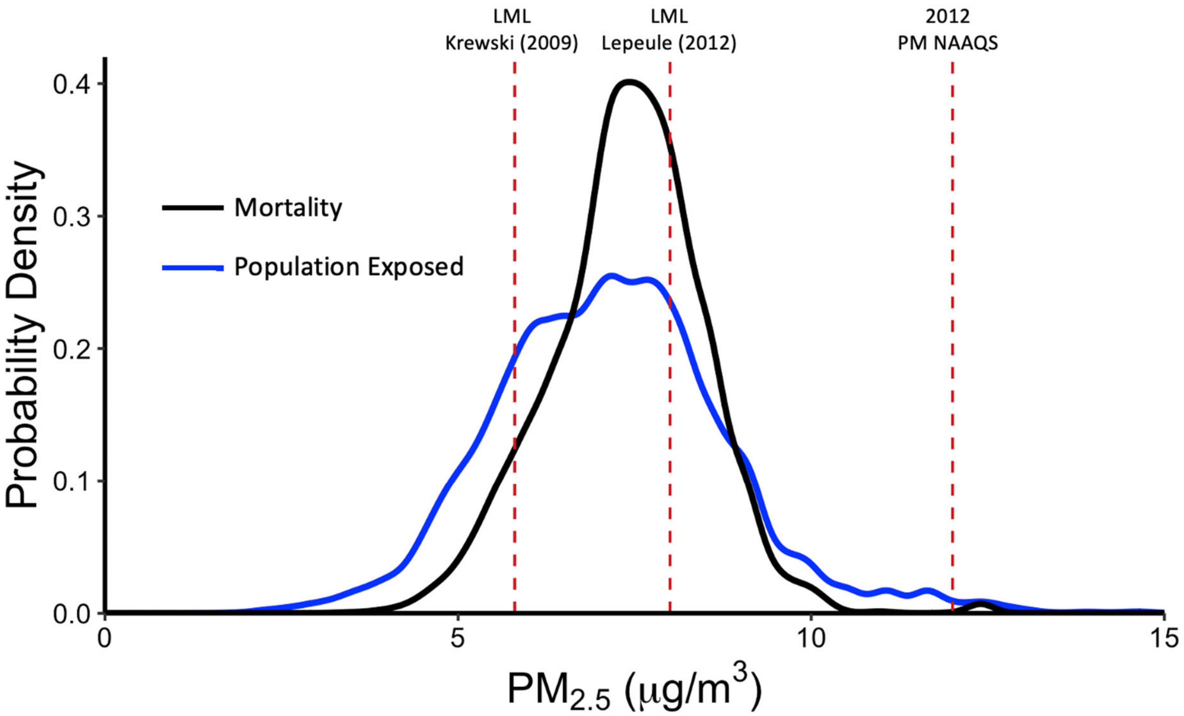

Figure 5B-3. Estimated Percentage of $PM_{2.5}$-Related Deaths and Number of Individuals Exposed by Annual Mean $PM_{2.5}$ Level in 2025

The estimated number and value of avoided ozone-attributable deaths are also subject to uncertainty. When estimating the economic value of avoided premature mortality from long-term exposure to ozone, we use a 20-year segment lag (as used for $PM_{2.5}$) as there is no alternative empirical estimate of the cessation lag for long-term exposure to ozone. The 20-year segmented lag accounts for the onset of cardiovascular related mortality, an outcome which is not relevant to the long-term respiratory mortality estimated here. 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, the estimates include health benefits from reducing ozone in areas with varied concentrations of ozone down to the lowest modeled concentrations.

5B.1.4 Estimated Number and Economic Value of Health Benefits

Below we report the estimated number of reduced premature deaths and illnesses in each year relative to the baseline along with the 95% confidence interval (Table 5B-3and Table 5B-4). The number of reduced estimated deaths and illnesses from the proposal and more and less stringent alternatives are calculated from the sum of individual reduced mortality and illness risk across the population. Table 5B-5 and Table 5B-6 report the estimated economic value of avoided premature deaths and illness in each year relative to the baseline along with the 95% confidence interval. The tables below are followed by the estimated number of avoided $PM_{2.5}$-related premature deaths calculated using different approaches to help the reader determine the fraction of $PM_{2.5}$ attributable deaths occuring at lower ambient concentrations. We summarize the dollar value of these impacts for the proposal and more and less stringent alternatives across all $PM_{2.5}$ and ozone-related premature deaths and illnesses, using alternative approaches to representing and quantifying PM mortality risk effects (and Table 5B-9). The alternative approaches to quantifying and presenting mortality risk effects include both different means for quantifying expected impacts using concentration-response functions over the entire domain of exposure (i.e., the no-threshold model) along with different means of presenting impacts by limiting consideration to only those impacts at exposures above the LML or above the NAAQS (Table 5B-10).[7]

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[7] EPA continues to refine its approach for estimating and reporting PM-related effects at lower concentrations, particularly at levels below those considered by the long-term exposure epidemiology studies used here to quantify PM-related premature deaths. The Agency acknowledges the additional uncertainty associated with effects estimated at these lower levels (particularly below the LML of the long-term exposure mortality studies) and seeks to develop quantitative approaches for reflecting this uncertainty in the estimated PM benefits.

Table 5B-3. Estimated Avoided Ozone-Related Premature Deaths and Illnesses for the Proposal and More and Less Stringent Alternatives for 2021 (95% Confidence Interval) [a,b]

	Proposal	More Stringent Alternative	Less Stringent Alternative
Avoided premature death among adults			
Smith *et al.* (2009)	30 (-2.8 to 57)	30 (-2.8 to 57)	2.7 (-0.25 to 5)
Jerrett et al. (2009)	110 (36 to 180)	110 (36 to 180)	9.1 (3.1 to 15)
All other morbidity effects			
Hospital admissions—respiratory	47 (-11 to 100)	47 (-11 to 100)	4.1 (-0.95 to 9)
ED visits for asthma	200 (19 to 490)	200 (19 to 490)	17 (1.7 to 42)
Exacerbated asthma	69,000 (-59,000 to 170,000)	69,000 (-59,000 to 170,000)	6,100 (-5,200 to 15,000)
Minor restricted-activity days	140,000 (59,000 to 230,000)	140,000 (59,000 to 230,000)	13,000 (5,200 to 20,000)
School absence days	43,000 (15,000 to 97,000)	43,000 (15,000 to 97,000)	3,800 (1,400 to 8,600)

[a] Values rounded to two significant figures.

[b] We estimated changes in annual mean $PM_{2.5}$ and $PM_{2.5}$ -related benefits in 2025, but not 2021. As discussed in Chapter 4, in 2021, the only control measure expected to be adopted for compliance in the regulatory control alternatives is optimization of existing SCRs beginning in May of 2021, and this measure will operate only during the ozone season. As discussed in Chapter 3, NOx reductions in the ozone season provide minimal $PM_{2.5}$ benefits since $PM_{2.5}$ nitrate concentrations, which result from conversion of NOx emissions to nitrate, are minimal during the warmer temperatures during the ozone season. Conversely, the conversion of nitrates to $PM_{2.5}$ is much greater in cooler (non-ozone season) months, and thus it becomes worthwhile to estimate $PM_{2.5}$ benefits from NOx reductions in those months. In 2025, the presence of additional control measures that operate year round and other changes in market conditions as a result of the rule lead to notable NOx reductions in the winter months.

Table 5B-4. Estimated Avoided PM$_{2.5}$ and Ozone-Related Premature Deaths and Illnesses for the Proposal and More and Less Stringent Alternatives for 2025 (95% Confidence Interval) [a]

		Proposal	More Stringent Alternative	Less Stringent Alternative
Avoided premature death among adults				
PM$_{2.5}$	Krewski *et al.* (2009)	7 (4.8 to 9.3)	7 (4.8 to 9.3)	0 (0 to 0)
	Lepeule *et al.* (2012)	16 (7.9 to 24)	16 (7.9 to 24)	0 (0 to 0)
Ozone	Smith *et al.* (2009)	38 (-3.5 to 70)	61 (-5.7 to 110)	2.6 (-0.25 to 4.9)
	Jerrett et al. (2009)	130 (45 to 220)	220 (73 to 360)	9.1 (3.1 to 15)
PM$_{2.5}$- related non-fatal heart attacks among adults				
	Peters et al. (2001)	7.2 (1.8 to 13)	7.2 (1.8 to 13)	0 (0 to 0)
	Pooled estimate	0.77 (0.29 to 2.1)	0.77 (0.29 to 2.1)	0 (0 to 0)
All other morbidity effects				
	Hospital admissions—cardiovascular (PM$_{2.5}$)	1.8 (0.78 to 3.3)	1.8 (0.78 to 3.3)	0 (0 to 0)
	Hospital admissions—respiratory (PM$_{2.5}$ & O$_3$)	65 (-16 to 150)	110 (-25 to 240)	4.4 (-1 to 9.7)
	ED visits for asthma (PM$_{2.5}$ & O$_3$)	250 (22 to 600)	400 (37 to 960)	17 (1.6 to 41)
	Exacerbated asthma (PM$_{2.5}$ & O$_3$)	85,000 (-73,000 to 210,000)	140,000 (-120,000 to 340,000)	6,000 (-5,100 to 14,000)
	Minor restricted-activity days (PM$_{2.5}$ & O$_3$)	170,000 (74,000 to 270,000)	280,000 (120,000 to 440,000)	12,000 (4,900 to 19,000)
	Acute bronchitis (PM$_{2.5}$)	8.4 (-2 to 19)	8.4 (-2 to 19)	0 (0 to 0)
	Upper resp. symptoms (PM$_{2.5}$)	150 (27 to 270)	150 (27 to 270)	0 (0 to 0)
	Lower resp. symptoms (PM$_{2.5}$)	110 (40 to 170)	110 (40 to 170)	0 (0 to 0)
	Lost work days (PM$_{2.5}$)	740 (630 to 850)	740 (630 to 850)	0 (0 to 0)
	School absence days (O$_3$)	54,000 (19,000 to 120,000)	89,000 (31,000 to 200,000)	3,800 (1,300 to 8,400)

[a] Values rounded to two significant figures.

Table 5B-5. Estimated Value of Avoided Ozone-Related Premature Deaths and Illnesses for the Proposal and More and Less Stringent Alternatives for 2021 (95% Confidence Interval; millions of 2016$)[a,b]

	Proposal	More Stringent Alternative	Less Stringent Alternative
Avoided premature death among adults			
Smith *et al.* (2009)	$310 ($-7.5 to $1,000)	$310 ($-7.5 to $1,000)	$28 ($-0.66 to $89)
Jerrett et al. (2009)[c]	$1,000 ($81 to $3,000)	$1,000 ($81 to $3,000)	$86 ($6.9 to $260)
All other morbidity effects			
Hospital admissions—respiratory	$1 ($-0.24 to $2.3)	$1 ($-0.24 to $2.3)	$0.09 ($-0.02 to $0.2)
ED visits for asthma	$0.06 ($0.01 to $0.15)	$0.06 ($0.01 to $0.15)	$0.01 ($0.0 to $0.01)
Exacerbated asthma	$3.2 ($-2.7 to $9.5)	$3.2 ($-2.7 to $9.5)	$0.28 ($-0.24 to $0.84)
Minor restricted-activity days	$7.7 ($2.9 to $14)	$7.7 ($2.9 to $14)	$0.68 ($0.25 to $1.3)
School absence days	$3.3 ($1.2 to $7.4)	$3.3 ($1.2 to $7.4)	$0.29 ($0.1 to $0.66)

[a] Values rounded to two significant figures.

[b] We estimated changes in annual mean $PM_{2.5}$ and $PM_{2.5}$ -related benefits in 2025, but not 2021. As discussed in Chapter 4, in 2021, the only control measure expected to be adopted for compliance in the regulatory control alternatives is optimization of existing SCRs beginning in May of 2021, and this measure will operate only during the ozone season. As discussed in Chapter 3, NOx reductions in the ozone season provide minimal $PM_{2.5}$ benefits since $PM_{2.5}$ nitrate concentrations, which result from conversion of NOx emissions to nitrate, are minimal during the warmer temperatures during the ozone season. Conversely, the conversion of nitrates to $PM_{2.5}$ is much greater in cooler (non-ozone season) months, and thus it becomes worthwhile to estimate $PM_{2.5}$ benefits from NOx reductions in those months. In 2025, the presence of additional control measures that operate year round and other changes in market conditions as a result of the rule lead to notable NOx reductions in the winter months.

[c] Discounted at 3%. Summary tables below report mortality benefits discounted at 7%.

Table 5B-6. Estimated Value of Avoided PM2.5 and Ozone-Related Premature Deaths and Illnesses for the Proposal and More and Less Stringent Alternatives for 2025 (95% Confidence Interval; millions of 2016$)[a]

		Proposal	More Stringent Alternative	Less Stringent Alternative
Avoided premature death among adults				
$PM_{2.5}$	Krewski *et al.* (2009)[b]	$67 ($6.3 to $180)	$67 ($6.3 to $180)	$0 ($0 to $0)
	Lepeule *et al.* (2012)[b]	$150 ($14 to $430)	$150 ($14 to $430)	$0 ($0 to 0)
Ozone	Smith *et al.* (2009)	$400 ($-9.5 to $1,300)	$640 ($-15 to $2,100)	$28 ($-0.67 to $89)
	Jerrett et al. (2009)[b]	$1,300 ($100 to $3,800)	$2,100 ($170 to $6,200)	$88 ($7.1 to $260)
$PM_{2.5}$- related non-fatal heart attacks among adults				
	Peters et al. (2001)[b]	$1 ($0.16 to $2.6)	$1 ($0.16 to $2.6)	$0 ($0 to $0)
	Pooled estimate[b]	$0.11 ($0.023 to $0.39)	$0.11 ($0.023 to $0.39)	$0 ($0 to $0)
All other morbidity effects				
	Hospital admissions—cardiovascular ($PM_{2.5}$)	$0.082 ($0.036 to $0.15)	$0.082 ($0.036 to $0.15)	$0 ($0 to $0)
	Hospital admissions—respiratory ($PM_{2.5}$ & O_3)	$1.5 ($-0.36 to $3.3)	$2.4 ($-0.57 to $5.3)	$0.097 ($-0.023 to $0.22)
	ED visits for asthma ($PM_{2.5}$ & O_3)	$0.074 ($0.0059 to $0.19)	$0.12 ($0.01 to $0.31)	$0.005 ($0.0005 to $0.013)
	Exacerbated asthma ($PM_{2.5}$ & O_3)	$4 ($-3.4 to $12)	$6.5 ($-5.6 to $19)	$0.28 ($-0.24 to $0.83)
	Minor restricted-activity days ($PM_{2.5}$ & O_3)	$9.6 ($3.6 to $18)	$15 ($5.8 to $28)	$0.65 ($0.24 to $1.2)
	Acute bronchitis ($PM_{2.5}$)	$0.0044 ($-0.001 to $0.013)	$0.0044 ($-0.001 to $0.013)	$0 ($0 to $0)
	Upper resp. symptoms ($PM_{2.5}$)	$0.0055 ($0.001 to $0.014)	$0.0055 ($0.001 to $0.014)	$0 ($0 to $0)
	Lower resp. symptoms ($PM_{2.5}$)	$0.0025 ($0.0008 to $0.005)	$0.0025 ($0.0008 to $0.005)	$0 ($0 to $0)
	Lost work days ($PM_{2.5}$)	$0.13 ($0.11 to $0.15)	$0.13 ($0.11 to $0.15)	$0 ($0 to $0)
	School absence days (O_3)	$4.1 ($1.5 to $9.2)	$6.8 ($2.4 to $15)	$0.29 ($0.1 to $0.64)

[a] Values rounded to two significant figures.

[b] Discounted at 3%. Summary tables below report mortality benefits discounted at 7%.

Table 5B-7. Estimated Avoided PM-Related Premature Deaths Using Alternative Approaches Using Two Approaches to Quantifying Avoided PM-Attributable Deaths (95% Confidence Interval) in 2025[a]

	Proposal	More Stringent Alternative	Less Stringent Alternative
Log-Linear no-threshold model			
Krewski *et al.* (2009)	7 (4.8 to 9.3)	7 (4.8 to 9.3)	0 (0 to 0)
Lepeule *et al.* (2012)	16 (7.9 to 24)	16 (7.9 to 24)	0 (0 to 0)
Quantifying effect of PM2.5 above the LML in each study and below the NAAQS			
Krewski *et al.* (2009) (LML= 5.8 μg/m^3)	6.5 (4.4 to 8.6)	6.5 (4.4 to 8.6)	0 (0 to 0)
Lepeule *et al.* (2012) (LML=8μg/m^3)	4.4 (2.2 to 6.6)	4.4 (2.2 to 6.6)	0 (0 to 0)
Quantifying effect of PM2.5 above the NAAQS			
Krewski *et al.* (2009)	0.021 (0.014 to 0.028)	0.021 (0.014 to 0.028)	0 (0 to 0)
Lepeule *et al.* (2012)	0.048 (0.024 to 0.072)	0.048 (0.024 to 0.072)	0 (0 to 0)

[a] Values rounded to two significant figures.

Table 5B-8. Estimated Economic Value of Ozone-Attributable Deaths and Illnesses for the Proposed Policy Scenarios in 2021 (95% Confidence Interval; millions of 2016$)[a,b]

	Proposal			**More Stringent Alternative**			**Less Stringent Alternative**		
3% Discount Rate	$330 ($-6.5 to $1,000)	*to*	$1,000 ($82 to $3,000)	$330 ($-6.5 to $1,000)	*to*	$1,000 ($82 to $3,000)	$29 ($-0.57 to $92)	*to*	$87 ($7 to $260)
7% Discount Rate	$330 ($-6.5 to $1,000)	*to*	$930 ($75 to $2,800)	$330 ($-6.5 to $1,000)	*to*	$930 ($75 to $2,800)	$29 ($-0.57 to $92)	*to*	$79 ($6.4 to $240)

[a] Values rounded to two significant figures.

[b] We estimated changes in annual mean $PM_{2.5}$ and $PM_{2.5}$ -related benefits in 2025, but not 2021. As discussed in Chapter 4, in 2021, the only control measure expected to be adopted for compliance in the regulatory control alternatives is optimization of existing SCRs beginning in May of 2021, and this measure will operate only during the ozone season. As discussed in Chapter 3, NOx reductions in the ozone season provide minimal $PM_{2.5}$ benefits since $PM_{2.5}$ nitrate concentrations, which result from conversion of NOx emissions to nitrate, are minimal during the warmer temperatures during the ozone season. Conversely, the conversion of nitrates to $PM_{2.5}$ is much greater in cooler (non-ozone season) months, and thus it becomes worthwhile to estimate $PM_{2.5}$ benefits from NOx reductions in those months. In 2025, the presence of additional control measures that operate year round and other changes in market conditions as a result of the rule lead to notable NOx reductions in the winter months.

Table 5B-9. Estimated Economic Value of Avoided Ozone and $PM_{2.5}$-Attributable Deaths and Illnesses for the Proposed Policy Scenario Using Alternative Approaches to Represent $PM_{2.5}$ Mortality Risk Effects in 2025 (95% Confidence Interval; millions of 2016$)[a]

		Proposal			More Stringent Alternative			Less Stringent Alternative		
Ozone										
3% Discount Rate		$410 ($-8.3 to $1,300)	*to*	$1,300 ($110 to $3,900)	$670 ($-14 to $2,100)	*to*	$2,100 ($170 to $ 6,300)	$29 ($-0.59 to $92)	*to*	$89 ($7.2 to $260)
7% Discount Rate		$410 ($-8.3 to $1,300)	*to*	$1,200 ($96 to $3,500)	$670 ($-14 to $2,100)	*to*	$1,900 ($160 to $ 5,700)	$29 ($-0.59 to $92)	*to*	$81 ($6.6 to $240)
$PM_{2.5}$										
3% Discount Rate	No-threshold model	$69 ($6.6 to $190)	*to*	$150 ($14 to $440)	$69 ($6.6 to $190)	*to*	$150 ($14 to $440)	$0 ($0 to $0)	*to*	$0 ($0 to 0)
	Limited to above LML	$44 ($4.2 to $120)	*to*	$63 ($6.1 to $170)	$44 ($4.2 to $120)	*to*	$63 ($6.1 to $170)	$0 ($0 to $0)	*to*	$0 ($0 to 0)
	Effects above NAAQS	$1.3 ($0.37 to $3)	*to*	$2.5 ($0.53 to $6)	$1.3 ($0.37 to $3)	*to*	$2.5 ($0.53 to $6)	$0 ($0 to $0)	*to*	$0 ($0 to 0)
7% Discount Rate	No-threshold model	$63 ($6.1 to $170)	*to*	$140 ($13 to $400)	$63 ($6.1 to $170)	*to*	$140 ($13 to $400)	$0 ($0 to $0)	*to*	$0 ($0 to 0)
	Limited to above LML	$41 ($3.9 to $110)	*to*	$58 ($5.6 to $160)	$41 ($3.9 to $110)	*to*	$58 ($5.6 to $160)	$0 ($0 to $0)	*to*	$0 ($0 to 0)
	Effects above NAAQS	$1.3 ($0.36 to $3)	*to*	$2.4 ($0.51 to $5.9)	$1.3 ($0.36 to $3)	*to*	$2.4 ($0.51 to $5.9)	$0 ($0 to $0)	*to*	$0 ($0 to 0)

[a] Values rounded to two significant figures.

Table 5B-10. Estimated Percent of Avoided $PM_{2.5}$-related Premature Deaths Above and Below $PM_{2.5}$ Concentration Cut Points in 2025

	Epidemiological study	Total mortality	Avoided $PM_{2.5}$-related premature deaths reported by air quality cut point		
			Above NAAQS	*Below NAAQS and Above LML* [a]	*Below LML* [a]
Proposal	Krewski	7	0.021 *(0%)*	6.5 *(92%)*	0.55 *(8%)*
	Lepeule	16	0.048 *(0%)*	4.4 *(27%)*	12 *(72%)*
More Stringent Alternative	Krewski	7	0.021 *(0%)*	6.5 *(92%)*	0.55 *(8%)*
	Lepeule	16	0.048 *(0%)*	4.4 *(27%)*	12 *(72%)*
Less Stringent Alternative	Krewski	0	0	0	0
	Lepeule	0	0	0	0

[a] The LML of the Krewski study is 5.8 µg/m^3 and 8 µg/m^3 for Lepeule et al study.

The estimated number of deaths above and below the LML varies considerably according to the epidemiology study used to estimate risk. Thus, for any year analyzed, we estimate a substantially larger fraction of PM-related deaths above the LML of the Krewski et al. (2009) study than we do the Lepeule et al. (2012) study as shown in Table 5B-10. Likewise, we estimate a greater percentage of $PM_{2.5}$-related deaths below the LML of the Lepeule et al. (2012) study than we do the Krewski et al. (2009) study. Table 5B-10 also shows we estimate a very small percentage of PM-related premature deaths occurring above the NAAQS in 2025 using either of these two studies.

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CHAPTER 6: STATUTORY AND EXECUTIVE ORDER REVIEWS

Overview

This chapter presents the statutory and executive orders applicable to EPA rules, and discusses EPA's actions taken pursuant to these orders.

6.1 Executive Order 12866: Regulatory Planning and Review

This action is an economically significant regulatory action that was submitted to the Office of Management and Budget (OMB) for review. EPA believes if the ozone and $PM_{2.5}$-related health benefits were quantified and monetized that the benefits of the proposed rule would exceed $100 million in one of the analytic years. Any changes made in response to OMB recommendations have been documented in the docket. EPA prepared an analysis of the potential costs and benefits associated with this proposed action. This analysis is available in the docket and is briefly summarized in Section IX of the preamble.

6.2 Executive Order 13771

This action is expected to be an Executive Order 13771 regulatory action.

6.3 Paperwork Reduction Act

This action does not impose any new information collection burden under the PRA. This action would relocate certain existing information collection requirements for certain sources from subpart EEEEE of 40 CFR part 97 to a new subpart GGGGG of 40 CFR part 97 but would make no changes to any existing information collection requirements for any source. OMB has previously approved the information collection activities contained in the existing regulations and has assigned OMB control number 2060-0667.

6.4 Regulatory Flexibility Act

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. EPA has determined that no small entities potentially affected by the proposal will have compliance costs greater than 1 percent of annual revenues in 2021. 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 proposed rulemaking, it must prepare and make available an initial regulatory flexibility analysis, unless it certifies that the proposed rule, if promulgated, will not have a significant economic impact on a substantial number of small entities (5 U.S.C. 605[b]). Small entities include small businesses, small organizations, and small governmental jurisdictions.

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.6, used in this RIA.1 This analysis draws on the "parsed" unit-level estimates using IPM results for 2021, as well as ownership, employment, and financial information for the potentially affected small entities drawn from other resources described in more detail below. This analysis is focused on estimating impacts in 2021 because implementation of the proposed EGU controls occurs in the 2021 ozone season.

EPA identified the size of ultimate parent entities by using the Small Business Administration (SBA) size standard guidelines.[2] 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

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[1] Detailed documentation for IPM v.6 is available at: http://www.epa.gov/airmarkets/powersectormodeling.html.
[2] U.S. Small Business Administration (SBA). 2019. Small Business Size Standards, effective as of August 19, 2019 and available at the following link: https://www.sba.gov/sites/default/files/2019-08/SBA%20Table%20of%20Size%20Standards_Effective%20Aug%2019%2C%202019.pdf.

    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.[3]

- Publicly-owned entities
  - Publicly-owned entities include federal, state, municipal, and other political subdivision entities.
  - The federal and state governments are considered to be large. Municipalities and other political units with populations fewer than 50,000 ae 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.

6.4.1 Identification of Small Entities

In this analysis, EPA considered EGUs that meet the following five criteria: 1) EGU is represented in NEEDS v6; 2) EGU is fossil fuel-fired; 3) EGU is located in a state covered by this proposed rule; 4) EGU is neither a cogeneration unit nor solid waste incineration unit; and 5) EGU capacity is 25 MW or larger. EPA next refined this list of EGUs, narrowing it to those that exhibit at least one of the following changes under the proposal, in comparison to the baseline.

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

Based on these criteria, EPA identified a total of 97 potentially affected EGUs warranting examination in this RFA analysis. Next, we determined power plant ownership information,

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

including the name of associated owning entities, ownership shares, and each entity's type of ownership. We primarily used data from Ventyx, supplemented by limited research using publicly available data.[4] Majority owners of power plants with affected EGUs were categorized as one of the seven ownership types.[5] 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.
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, EPA used both the D&B Hoover's online database and the Ventyx database to identify the ultimate owners of power plant owners identified in the Ventyx database. This was necessary, as many majority owners of power plants (listed in Ventyx) are themselves owned by other ultimate parent entities (listed in D&B Hoover's).[6] In these cases, the ultimate parent entity was identified via D&B Hoover's, whether domestically or internationally owned.

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[4] 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.

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

[6] The D&B Hoover's online platform includes company records that can contain NAICS codes, number of employees, revenues, and assets. For more information, see: https://www.dnb.com/products/marketing-sales/dnb-hoovers.html.

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 D&B 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 EPA's IPM base case.

Table 6-1. SBA Size Standards by NAICS Code

NAICS Codes	NAICS U.S. Industry Title	Size Standards (millions of dollars)	Size Standards (number of employees)
221111	Hydroelectric Power Generation		500
221112	Fossil Fuel Electric Power Generation		750
221113	Nuclear Electric Power Generation		750
221114	Solar Electric Power Generation		250
221115	Wind Electric Power Generation		250
221116	Geothermal Electric Power Generation		250
221117	Biomass Electric Power Generation		250
221118	Other Electric Power Generation		250
221121	Electric Bulk Power Transmission and Control		500
221122	Electric Power Distribution		1000
221210	Natural Gas Distribution		1000
221310	Water Supply and Irrigation Systems	$30	
221320	Sewage Treatment Facilities	$22	
221330	Steam and Air-Conditioning Supply	$16	

Note: Based on size standards effective at the time EPA conducted this analysis (SBA size standards, effective August 19, 2019. Available at the following link: https://www.sba.gov/document/support--table-size-standards).
Source: SBA, 2019

EPA compared the relevant entity size criterion for each ultimate parent entity to the SBA size standard 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**: EPA used the D&B Hoover's database as the primary source for information on ultimate parent entity employee numbers, revenue, and assets.[7] In parallel, EPA also considered estimated revenues from affected EGUs based on analysis of parsed-file estimates for the proposal. EPA assumed that the ultimate parent entity revenue was the larger of the two revenue estimates. In limited instances, supplemental research was also conducted to estimate an ultimate parent entity's number of employees, revenue, or assets.

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

2. **Population**: Municipal entities are defined as small if they serve populations of less than 50,000. EPA primarily relied on data from the Ventyx database and the U.S. Census Bureau to inform this determination.

Ultimate parent entities for which the relevant measure is less than the SBA size standard were identified as small entities and carried forward in this analysis. In total EPA identified 97 potentially affected EGUs, owned by 16 entities. Of these, EPA identified 7 potentially affected EGUs owned by 2 small entities[8] included in EPA's Base Case.

6.4.2 Overview of Analysis and Results

This section presents the methodology and results for estimating the impact of the Revised CSAPR Update proposal on small entities in 2021 based on the following endpoints:

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

6.4.2.1 Methodology for Estimating Impacts of the Revised CSAPR Update proposal on Small Entities

An entity can comply with the Revised CSAPR Update proposal through some combination of the following: optimizing existing SCRs, turning on idled SCR controls, using allocated allowances, purchasing allowances, or reducing emissions through a reduction in generation. Additionally, units with more allowances than needed can sell these allowances in the market. The chosen compliance strategy will be primarily a function of the unit's marginal control costs and its position relative to the marginal control costs of other units.

To attempt to account for each potential control strategy, EPA estimates compliance costs as follows:

$$C_{Compliance} = \Delta\ C_{Operating+Retrofit} + \Delta\ C_{Fuel} + \Delta\ C_{Allowances} + \Delta\ C_{Transaction} + \Delta\ R$$

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[8] Both of these small entities are in NAICS 221118, which is defined as establishments primarily engaged in operating electric power generation facilities (except hydroelectric, fossil fuel, nuclear, solar, wind, geothermal, biomass). These facilities convert other forms of energy, such as tidal power, into electric energy.

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 Revised CSAPR Update proposal in 2021.

Realistically, 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 Revised CSAPR Update proposed rule, some units will forgo some level of electricity generation (and thus revenues) to comply and this impact will be lessened on these entities by the projected increase in electricity prices under the Revised CSAPR Update proposed rule. 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 proposal on small entities.

For this analysis, 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 Revised CSAPR Update proposal relative to the base case. These individual components of compliance cost were estimated as follows:

(1) **Operating and retrofit costs:** Using engineering analytics, EPA identified which compliance option was selected by each EGU in 2021 (i.e., SCR optimization or turning on existing SCR controls) and applied the appropriate cost to this choice. EPA assumes that state of the art combustion controls may be installed in 2022 and are not part of the controls available in 2021.

(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 $1,600 (2016$) per ton, which is the marginal cost of NO_X

reductions used to set the proposed budgets in the Revised CSAPR Update proposal. 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 Revised CSAPR Update proposal.

(3) **Fuel costs:** The change in fuel expenditures under the Revised CSAPR Update proposal was estimated by taking the difference in projected fuel expenditures between the IPM estimates for the Revised CSAPR Update proposed rule 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, EPA used the wholesale electricity price instead of the 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. 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, EPA considered the primary administrative cost to be transaction costs related to purchasing or selling allowances. EPA assumed that transaction costs were equal to 1.5 percent of the total absolute value of the difference between a unit's allocation and projected NO_X emissions. This assumption is based on market research by ICF.

6.4.2.2 Results

The potential impacts of the Revised CSAPR Update proposal on small entities are summarized in Table 6-2. All costs are presented in 2016$. EPA estimated the annual net compliance cost to small entities to be approximately $0.04 million in 2021.

Table 6-2. Projected Impact of the Revised CSAPR Update Proposal on Small Entities in 2021

EGU Ownership Type	Number of Potentially Affected Entities	Total Net Compliance Cost ($2016 millions)	Number of Small Entities with Compliance Costs >1% of Generation Revenues	Number of Small Entities with Compliance Costs >3% of Generation Revenues
Cooperative	1	0.04	0	0
Private	1	0.00	0	0
Total	2	0.04	0	0

Source: IPM analysis

EPA assessed the economic and financial impacts of the proposed rule using the ratio of compliance costs to the value of revenues from electricity generation, focusing in particular on entities for which this measure is greater than 1 percent. Although this metric is commonly used in EPA impact analyses, it makes the most sense when as a general matter an analysis is looking at small businesses that operate in competitive environments.[9] However, small businesses in the electric power industry often operate in a price-regulated environment where they are able to recover expenses through rate increases. Given this, EPA considers the 1 percent measure in this case a crude measure of the price increases these small entities will be asking of rate commissions or making at publicly owned companies. Of the 2 small entities considered in this analysis, neither is projected to experience compliance costs greater than 1 percent of generation revenues in 2021. EPA has concluded that there is no significant economic impact on a substantial number of small entities (no SISNOSE) for this rule.

The separate components of annual costs to small entities under the Revised CSAPR Update proposal are summarized in Table 6-3. The most significant components of incremental cost to the cooperative category under the Revised CSAPR Update proposal are due to higher operating costs (reflecting the cost of controls). Among the private category, however, reduced generation is the key driver. Total impacts to the private category are well below $10,000.

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[9] U.S. EPA. EPA's Action Development Process. Final Guidance for EPA Rulewriters: Regulatory Flexibility Act as Amended by the Small Business Regulatory Enforcement Fairness Act. September 2006. Available at https://www.epa.gov/sites/production/files/2015-06/documents/guidance-regflexact.pdf.

Table 6-3. Incremental Annual Costs under the Revised CSAPR Update Proposal Summarized by Ownership Group and Cost Category in 2021 (2016$ millions)

EGU Ownership Type	Operating Cost	Net Purchase of Allowances	Fuel Cost	Lost Electricity Revenue	Administrative Cost
Cooperative	0.06	0.00	-0.02	0.00	0.00
Private	0.00	0.00	0.00	0.00	0.00

Source: IPM analysis

6.4.3 Summary of Small Entity Impacts

EPA examined the potential economic impacts to small entities associated with this proposal based on assumptions of how the affected states will implement control measures to meet their emissions. To summarize, of the 2 small entities potentially affected, none are projected to experience compliance costs in excess of 1 percent of revenues in 2021, based on assumptions of how the affected states implement control measures to meet their emissions budgets as set forth in this proposal.

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 12 states for which EPA is proposing FIPs.

6.5 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, 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).

As outlined in Section 4.4.2, EPA projects the total cost of compliance with the Revised CSAPR Update proposal to be well below $100 million in every year. Furthermore, as EPA stated in the proposal, EPA is not directly establishing any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments. Thus, under the Revised CSAPR Update proposal, EPA is not obligated to develop under Section 203 of the UMRA a small government agency plan.

6.6 Executive Order 13132: Federalism

This proposed action does not have federalism implications. If finalized, this proposed action will not have substantial direct effects on the states, on the relationship between the national government and the states, or on the distribution of power and responsibilities among the various levels of government.

6.7 Executive Order 13175: Consultation and Coordination with Indian Tribal Governments

This proposed action has tribal implications. However, it would neither impose substantial direct compliance costs on federally recognized tribal governments, nor preempt tribal law.

This action proposes to implement EGU NO_X ozone season emissions reductions in 12 eastern states (Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Virginia, and West Virginia). However, at this time, none of the existing or planned EGUs affected by this rule are owned by tribes or located in Indian country. This proposed action may have tribal implications if a new affected EGU is built in Indian country. Additionally, tribes have a vested interest in how this proposed rule would affect air quality.

In developing the CSAPR, which was promulgated on July 6, 2011, to address interstate transport of ozone pollution under the 1997 ozone NAAQS, EPA consulted with tribal officials under EPA Policy on Consultation and Coordination with Indian Tribes early in the process of developing that regulation to allow for meaningful and timely tribal input into its development. A summary of that consultation is provided at 76 FR 48346.

EPA received comments from several tribal commenters regarding the availability of the CSAPR allowance allocations to new units in Indian country. EPA responded to these comments by instituting Indian country new unit set-asides in the final CSAPR. In order to protect tribal sovereignty, these set-asides are managed and distributed by the federal government regardless of whether the CSAPR in the adjoining or surrounding state is implemented through a FIP or SIP. While there are no existing affected EGUs in Indian country covered by this proposal, the Indian country set-asides will ensure that any future new units built in Indian country will be able to obtain the necessary allowances. This proposal maintains the Indian country new unit set-aside and adjusts the amounts of allowances in each set-aside according to the same methodology of the CSAPR rule.

EPA informed tribes of our development of this proposal through a National Tribal Air Association – EPA air policy conference call on June 25, 2020. EPA plans to further consult with tribal officials under EPA Policy on Consultation and Coordination with Indian Tribes early in the process of developing this proposed regulation to solicit meaningful and timely input into its development. EPA will facilitate this consultation before finalizing this proposed rule.

6.8 Executive Order 13045: Protection of Children from Environmental Health & Safety Risks

This proposed action is not subject to EO 13045 because EPA does not believe the environmental health risks or safety risks addressed by this action present a disproportionate risk to children. This action's health and risk assessments are discussed in Chapter 5.

6.9 Executive Order 13211: Actions that Significantly Affect Energy Supply, Distribution, or Use

This action, which is a significant regulatory action under EO 12866, is likely to have a significant effect on the supply, distribution, or use of energy. EPA has prepared a Statement of

Energy Effects for the proposed regulatory control alternative as follows. We estimate a less than 1 percent change in retail electricity prices on average across the contiguous U.S. in 2021, and a less than 1 percent change in coal-fired electricity generation in 2021 as a result of this proposed rule. EPA projects that utility power sector delivered natural gas prices will change by less than 1 percent in 2021. For more information on the estimated energy effects, please see Chapter 4 of this RIA.

6.10 National Technology Transfer and Advancement Act

The proposed rulemaking does not involve technical standards.

6.11 Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations

EPA believes the human health or environmental risk addressed by this action will not have potential disproportionately high and adverse human health or environmental effects on minority, low-income, or indigenous populations.

EPA notes that this action proposes to revise the CSAPR Update to reduce interstate ozone transport with respect to the 2008 ozone NAAQS. This rule uses EPA's authority in CAA section 110(a)(2)(d) (42 U.S.C. 7410(a)(2)(d)) to reduce NOX pollution that significantly contributes to downwind ozone nonattainment or maintenance areas. As a result, the rule will reduce exposures to ozone in the most-contaminated areas (i.e., areas that are not meeting the 2008 ozone NAAQS). In addition, the proposed rule separately identifies both nonattainment areas and maintenance areas. This requirement reduces the likelihood that areas close to the level of the standard will exceed the current health-based standards in the future. EPA proposes to implement these emission reductions using the CSAPR NOX Ozone Season Group 3 program with assurance provisions.

EPA recognizes that many environmental justice communities have voiced concerns in the past about emission trading and the potential for any emission increases in any location. The CSAPR NOX Ozone Season Group 3 trading program in the proposed action is the result of EPA's application of the 4-step framework to reduce interstate ozone pollution and implement those reductions, similar to the emissions trading programs developed in the CSAPR (CSAPR NOX Ozone Season Group 1 trading program) and modified in the CSAPR Update (CSAPR

NO_X Ozone Season Group 2 trading program), both of which also resulted from the application of the 4-step framework. EPA believes that this approach used in the CSAPR and in the CSAPR Update mitigated community concerns about emissions trading, and that this proposal, which applies the same 4-step framework and proposes an emissions trading program similar to those used in the CSAPR and the CSAPR Update, will also minimize community concerns. EPA seeks comment from communities on this proposal.

Ozone pollution from power plants has both local and regional components: part of the pollution in a given location—even in locations near emission sources—is due to emissions from nearby sources and part is due to emissions that travel hundreds of miles and mix with emissions from other sources. It is important to note that the section of the Clean Air Act providing authority for this proposed rule, section 110(a)(2)(D) (42 U.S.C. 7410(a)(2)(D)), unlike some other provisions, does not dictate levels of control for particular facilities. In this proposed action, as in the CSAPR and the CSAPR Update, sources in the emissions trading program may trade allowances with other sources in the same or different states, but any emissions shifting that may occur is constrained by an effective ceiling on emissions in each state (the assurance level). As in the CSAPR and the CSAPR Update, assurance provisions in the proposed rule outline the allowance surrender penalties for failing to meet the assurance level (see section VIII.C.2.); there are additional allowance for failing to hold an adequate number of allowances to cover emissions.

This approach will reduce EGU emissions in each state that significantly contributes to downwind nonattainment or maintenance areas with respect to the 2008 ozone NAAQS, while allowing power companies to adjust generation as needed and ensure that the country's electricity needs will continue to be met. As in the CSAPR and the CSAPR Update, EPA believes that the existence of these assurance provisions in the emissions trading program, including the penalties imposed when triggered, will ensure that emissions from states covered by this proposal will stay below the level of the budget plus variability limit.

In addition, under this proposed rule all sources participating in the CSAPR NO_X Ozone Season Group 3 trading program must hold enough allowances to cover their emissions. Therefore, if a source emits more than its allocation in a given year, either another source must have used less than its allocation and be willing to sell some of its excess allowances, or the source itself had emitted less than its allocation in one or more previous years (i.e., banked allowances for future use).

In summary, like the CSAPR and the CSAPR Update, this proposed rule minimizes community concerns about localized hot spots and reduces ambient concentrations of pollution where they are most needed by sensitive and vulnerable populations by: considering the science of ozone transport to set strict state emissions budgets to reduce significant contributions to ozone nonattainment and maintenance (i.e., the most polluted) areas; implementing air quality-assured trading; requiring any emissions above the level of the allocations to be offset by emission decreases; and imposing strict penalties for sources that contribute to a state's exceedance of its budget plus variability limit. In addition, it is important to note that nothing in this proposed rule allows sources to violate their title V permit or any other federal, state, or local emissions or air quality requirements.

In addition, it is important to note that CAA section 110(a)(2)(D), which addresses transport of criteria pollutants between states, is only one of many provisions of the CAA that provide EPA, states, and local governments with authorities to reduce exposure to ozone in communities. These legal authorities work together to reduce exposure to these pollutants in communities, including for minority, low-income, and tribal populations, and provide substantial health benefits to both the general public and sensitive sub-populations.

EPA has already taken steps to begin informing communities of our development of this proposal through a National Tribal Air Association – EPA air policy conference call on June 25, 2020. EPA plans to further consult with communities early in the process of developing this regulation to permit them to have meaningful and timely input into its development. EPA will facilitate this engagement before finalizing this proposed rule.

CHAPTER 7: COMPARISON OF BENEFITS AND COSTS

Overview

EPA performed an analysis to estimate the costs and climate benefits of compliance with the proposed Revised CSAPR Update and more and less stringent alternatives. EPA is proposing electric generating unit (EGU) oxides of nitrogen (NOx) ozone season emissions budgets for 12 states.[1] This action proposes to find that for these states, their projected 2021 ozone season NOx emissions significantly contribute to downwind states' nonattainment and/or maintenance problems for the 2008 ozone national ambient air quality standards (NAAQS). For these 12 states, EPA proposes to amend their federal implementation plans (FIPs) to revise the existing Cross-State Air Pollution Rule (CSAPR) NOx Ozone Season Group 2 emissions budgets for EGUs and implement the revised budgets beginning in the 2021 ozone season (May 1, 2021 - September 30, 2021) via a new CSAPR NOx Ozone Season Group 3 Trading Program.

The proposed Revised CSAPR Update state budgets reflect the optimization of existing selective catalytic reduction (SCR) controls and installation of state-of-the-art NOx combustion controls, with an estimated marginal cost of $1,600 per ton (2016$). For the RIA, in order to implement the OMB Circular A-4 requirement for fulfilling Executive Order 12866 to assess one less stringent and one more stringent alternative to the proposal, EPA is also analyzing EGU NOx ozone season emissions budgets reflecting NOx reduction strategies that are widely available at a uniform cost of $9,600 per ton (2016$) and strategies that are widely available at a uniform cost of $500 per ton (2016$). These alternatives are used illustrate the monetized cost and climate benefit impacts of varying program stringency. 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 proposed NOx emissions budgets. We show the results for 2021 to reflect the year in which implementation of this proposal begins, and for 2025 to reflect full implementation of the proposal. This RIA evaluates how the EGUs covered by the proposed rule are expected to reduce their emissions in response to the requirements and flexibilities provided

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[1] The 12 states include Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Virginia, and West Virginia.

by the remedy implemented by the proposed Revised CSAPR Update and the benefit, cost and impacts of their expected compliance behavior. This chapter summarizes these results.

7.1 Results

The proposal and regulatory control alternatives' compliance costs are estimated using the IPM model and an evaluation of control technologies evaluated outside of IPM. As shown in Chapter 4, the estimated annual compliance costs to implement the proposal, as described in this document, are approximately \$21 million in 2021 and \$6 million in 2025 (2016\$). As described in Section 4.5, this RIA uses compliance costs as a proxy for social costs. As shown in Chapter 5, the estimated monetized climate benefits from implementation of the proposal are approximately \$0.31 million and \$0.05 million in 2021 (2016\$, based on a real discount rate of 3 percent and 7 percent, respectively). For 2025, the estimated monetized climate benefits from implementation of the proposal are approximately \$33 million and \$5.4 million (2016\$, based on a real discount rate of 3 percent and 7 percent, respectively). As discussed in Chapter 5, the monetized benefits presented in this proposal RIA are those for climate (from CO_2 emissions reductions). The non-monetized benefits for ozone and $PM_{2.5}$ are discussed qualitatively in Chapter 5.

EPA calculates the net benefits of the proposal by subtracting the estimated compliance costs from the estimated climate benefits in both 2021 and 2025. The annual net benefits of the proposal in 2021 (in 2016\$) are approximately -\$21 million using both a 3 percent and 7 percent real discount rate for the climate benefits. The annual net benefits of the proposal in 2025 are approximately \$27 using a 3 percent real discount rate and -\$0.9 million using a 7 percent real discount rate. Table 7-1 presents a summary of the climate benefits, costs, and net benefits of the proposal and the more and less stringent alternatives for 2021. Table 7-2 presents a summary of these impacts for the proposal and the more and less stringent alternatives for 2025. The tables represent the present annual value of non-monetized benefits from ozone, $PM_{2.5}$ and NO_2 reductions as a B. The annual value of B will differ across discount rates, year of analysis, and the regulatory alternatives analyzed. At a 3 and 7 percent real discount rate the least stringent alternative has the greatest annual monetized net-benefits in the two analytic years. The monetized net-benefit estimates exclude important benefits from reductions in ozone and $PM_{2.5}$ concentrations.

Table 7-1. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2021 for the U.S. (millions of 2016$) [a,b,c,d]

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	0.31 + B	21	-21 + B
7%	0.05 + B		-21 + B
More Stringent Alternative			
3%	0.80 + B	37	-36 + B
7%	0.12 + B		-37 + B
Less Stringent Alternative			
3%	0.17 + B	4	-4 + B
7%	0.03 + B		-4 + B

[a] We focus results to provide a snapshot of costs and benefits in 2021, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates.
[b] Benefits ranges represent discounting of climate benefits at a real discount rate of 3 percent and 7 percent. Climate benefits are based on changes (reductions) in CO_2 emissions. The costs presented in this table are 2021 annual estimates for each alternative analyzed.
[c] All costs and benefits are rounded to two significant figures; rows may not appear to add correctly.
[d] B is the sum of all unquantified ozone, $PM_{2.5}$, and NO_2 benefits. The annual value of B will differ across discount rates, year of analysis, and the regulatory alternatives analyzed. While EPA did not estimate these benefits in this RIA, Appendix 5B presents $PM_{2.5}$ and ozone estimates quantified using methods consistent with the previously published ISAs to provide information regarding the potential magnitude of the benefits of this proposed rule.

Table 7-2. Benefits, Costs, and Net Benefits of the Proposal and More and Less Stringent Alternatives for 2025 for the U.S. (millions of 2016$) [a,b,c,d]

Discount Rate	Benefits	Costs	Net Benefits
Proposal			
3%	33 + B	6	27 + B
7%	5.4 + B		-0.9 + B
More Stringent Alternative			
3%	71.5 + B	132	-61 + B
7%	11.7 + B		-120 + B
Less Stringent Alternative			
3%	25 + B	-12	37 + B
7%	4.2 + B		16 + B

[a] We focus results to provide a snapshot of costs and benefits in 2025, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates.
[b] Benefits ranges represent discounting of climate benefits at a real discount rate of 3 percent and 7 percent. Climate benefits are based on changes (reductions) in CO_2 emissions. The costs presented in this table are 2025annual estimates for each alternative analyzed.
[c] All costs and benefits are rounded to two significant figures; rows may not appear to add correctly.
[d] B is the sum of all unquantified ozone, $PM_{2.5}$, and NO_2 benefits. The annual value of B will differ across discount rates, year of analysis, and the regulatory alternatives analyzed. While EPA did not estimate these benefits in this RIA, Appendix 5B presents $PM_{2.5}$ and ozone estimates quantified using methods consistent with the previously published ISAs to provide information regarding the potential magnitude of the benefits of this proposed rule.

As part of fulfilling analytical guidance with respect to E.O. 12866, EPA presents estimates of the present value of the benefits and costs over the five-year period of 2021 to 2025, which is the analytical period for this proposal. To calculate the present value of the social net-benefits of the proposed Revised CSAPR Update, annual benefits and costs are discounted to 2021 at 3 percent and 7 discount rates as directed by OMB's circular A-4. The present value (PV) of the net benefits, in 2016$ and discounted to 2021, is -$68 million when using a 7 percent discount rate and $14 million when using a 3 percent discount rate.[2] The equivalent annualized value (EAV), an estimate of the annualized value of the net benefits consistent with the present value, is -$17 million per year when using a 7 percent discount rate and $3 million when using a 3 percent discount rate. The EAV represents a flow of constant annual values that, had they occurred in each year from 2021 to 2025, would yield a sum equivalent to the PV. The EAV represents the value of a typical cost or benefit for each year of the analysis, in contrast to the year-specific estimates mentioned earlier in the RIA for the analysis years 2021 and 2025. The comparison of benefits and costs in PV and EAV terms for the proposal can be found in Table 7-3. Estimates in the table are presented as rounded values. The table represents the present value of non-monetized benefits from ozone, $PM_{2.5}$ and NO_2 reductions as a β, while b represents the equivalent annualized value of these non-monetized benefits. These values will differ across the discount rates and depend on the value of the B's in the previous tables.

Table 7-3. Summary of Present Values and Equivalent Annualized Values for the 2021-2025 Timeframe for Estimated Compliance Costs, Climate Benefits, and Net Benefits for the Proposed Rule (millions of 2016$, discounted to 2021)[a,b]

		3% Discount Rate	7% Discount Rate
Present Value	Benefits[c,d]	101+β	15+β
	Climate Benefits[c]	101	15
	Compliance Costs[e]	87	83
	Net Benefits	**14+β**	**-68+β**
Equivalent Annualized Value			
	Benefits	22+b	4+b
	Climate Benefits	22	4
	Compliance Costs	19	20

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[2] In annualizing compliance costs using social discount rates, this analysis treats the annual compliance costs as reflecting the use of real resources in a particular year. In practice, annual costs from IPM and costs of NOx controls estimated outside of IPM (e.g., capital costs of combustion controls) reflect annual payments for financed capital and not solely the change in the use of real resources in a particular year (i.e., the opportunity cost of those resources).

Net Benefits	**3+b**	**-17+b**

[a] All estimates in this table are rounded to two significant figures, so numbers may not sum due to independent rounding.

[b] The annualized present value of costs and benefits are calculated over a 5 year period from 2021 to 2025.

[c] Benefits ranges represent discounting of climate benefits at a real discount rate of 3 percent and 7 percent. Climate benefits are based on changes (reductions) in CO_2 emissions.

[d] β and b is the sum of all unquantified ozone, $PM_{2.5}$, and NO_2 benefits. The annual values of β and b will differ across discount rates. While EPA did not estimate these benefits in this RIA, Appendix 5B presents $PM_{2.5}$ and ozone estimates quantified using methods consistent with the previously published ISAs to provide information regarding the potential magnitude of the benefits of this proposed rule.

[e] The costs presented in this table reflect annualized present value compliance costs calculated over a 5 year period from 2021 to 2025.

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