MEMO: EMISSION REDUCTIONS, COSTS, BENEFITS AND ECONOMIC IMPACTS ASSOCIATED WITH BUILDING BLOCKS 1 AND 2

1 Introduction

This memo provides estimates of the costs, energy impacts, and the monetized climate benefits and air pollution health co-benefits associated with emission reductions for two illustrative compliance scenarios associated with building blocks 1 and 2 only. It also includes estimates of the labor impacts on the regulated sector. The methods applied to generate these estimates are described in detail in Chapter 3, 4, and 6 of the Regulatory Impact Analysis (RIA). For brevity, this memo just reports the results of these analyses.

EPA used the Integrated Planning Model (IPM), developed by ICF International, to conduct this analysis. It provides forecasts of least cost capacity expansion, electricity dispatch, and emission control strategies while meeting energy demand and environmental, transmission, dispatch, and reliability constraints.

This analysis also evaluates the climate benefits associated with emission reductions of CO_2 and the air pollution health co-benefits associated with reduced emissions of SO_2 and NOx, which would lead to lower ambient concentrations of $PM_{2.5}$ and ozone. Unlike the analysis of health co-benefits in Chapter 4 of the RIA, estimates of emissions reductions of directly emitted particles are not available for this analysis. Similar to Chapter 4 of the RIA, unquantified co-benefits include exposure to several HAPs (including mercury and hydrogen chloride), carbon monoxide, SO_2, and NO_2, as well as ecosystem effects and visibility impairment.

2 State Goals for Building Blocks 1 and 2

This analysis includes state-specific rate-based goals that reflect a two-building block approach. It is also based upon the same modeling framework, assumptions and calculations as presented in the RIA. The two-blocks incorporated in the following state goals include efficiency improvements at existing coal steam electric generating units (EGUs) and use of lower emitting power sources (increased utilization of existing NGCCs) and are identical to the proposed levels, included for purposes of establishing state-specific goals, associated with Option 1 (6% efficiency improvement and no more than 70% redispatch).

Table 1. State-specific Goals for Two-Block Approach for Existing Sources

State	Rate
Alabama	1,329
Alaska	1,252
Arizona	900
Arkansas	1,115
California	838
Colorado	1,521
Connecticut	809
Delaware	1,013
Florida	910
Georgia	1,296
Hawaii	1,751
Idaho	858
Illinois	1,865
Indiana	1,834
Iowa	1,846
Kansas	2,186
Kentucky	1,986
Louisiana	1,099
Maine	848
Maryland	1,868
Massachusetts	886
Michigan	1,511
Minnesota	1,369
Mississippi	843
Missouri	1,784
Montana	2,295
Nebraska	1,941
Nevada	882
New Hampshire	878
New Jersey	905
New Mexico	1,447
New York	927
North Carolina	1,329
North Dakota	2,226
Ohio	1,714
Oklahoma	1,186
Oregon	852
Pennsylvania	1,480
Rhode Island	918
South Carolina	1,514
South Dakota	1,456
Tennessee	1,798
Texas	1,083
Utah	1,559
Virginia	1,135
Washington	811
West Virginia	1,933
Wisconsin	1,619
Wyoming	2,151

3 Emissions and Power Sector Impacts

Tables 2 through 18 report the emissions and power sector impacts of the two-block approach.

Table 2. Projected CO_2 Emission Impacts

	CO_2 Emissions (MM Tonnes)			CO_2 Emissions Reductions from Base Case (MM Tonnes)			CO_2 Emissions Reductions: Percent Change from Base Case		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
Base Case	2,161	2,231	2,256						
Two-Block Regional	1,930	1,973	1,997	231	258	258	11%	12%	11%
Two-Block State	1,908	1,947	1,963	252	284	292	12%	13%	13%

Source: Integrated Planning Model run by EPA, 2014

Table 3. Projected Non-CO_2 Emissions Reductions

	Base Case	Two Block		Two Block	
		Regional	State	Regional	State
2020					
SO_2 (thousand tons)	1,476	1,243	1,199	-15.7%	-18.8%
NO_X (thousand tons)	1,559	1,319	1,286	-15.4%	-17.5%
Hg (tons)	8.3	7.2	7.1	-12.8%	-13.9%
HCl (thousand tons)	8	8	8	2.9%	-1.3%
2025					
SO_2 (thousand tons)	1,515	1,228	1,171	-19.0%	-22.7%
NO_X (thousand tons)	1,587	1,317	1,272	-17.0%	-19.9%
Hg (tons)	8.7	7.4	7.3	-14.9%	-16.2%
HCl (thousand tons)	8	9	9	0.8%	3.0%
2030					
SO_2 (thousand tons)	1,530	1,188	1,134	-22.3%	-25.9%
NO_X (thousand tons)	1,537	1,274	1,224	-17.1%	-20.4%
Hg (tons)	8.8	7.4	7.3	-15.2%	-16.8%
HCl (thousand tons)	9	9	9	0.0%	-5.1%

Source: Integrated Planning Model run by EPA, 2014

Table 4. Annualized Compliance Costs (billions of 2011$)

	2020	2025	2030
Two Block Regional	3.2	3.0	6.8
Two Block State	4.4	4.6	9.8

Source: Integrated Planning Model run by EPA, 2014

Table 5. Generation Mix (thousand GWh)

	Base Case, Generation	Two Block, Generation		Two Block, Percent Change	
		Regional	State	Regional	State
2020					
Pulverized Coal	1,665	1,435	1,395	-14%	-16%
NG Combined Cycle (existing)	1,003	1,178	1,170	17%	17%
NG Combined Cycle (new)	85	153	199	81%	134%
Combustion Turbine	19	34	31	79%	63%
Oil/Gas Steam	52	25	26	-51%	-50%
Non-Hydro Renewables	299	300	300	0%	0%
Hydro	280	283	283	1%	1%
Nuclear	817	819	819	0%	0%
Other	8	8	9	11%	17%
Total	4,227	4,235	4,232	0%	0%
2025					
Pulverized Coal	1,702	1,420	1,377	-17%	-19%
NG Combined Cycle (existing)	919	1,176	1,144	28%	24%
NG Combined Cycle (new)	280	310	385	11%	37%
Combustion Turbine	27	42	38	57%	42%
Oil/Gas Steam	37	20	20	-47%	-46%
Non-Hydro Renewables	335	335	335	0%	0%
Hydro	280	282	282	1%	1%
Nuclear	817	819	819	0%	0%
Other	6	7	8	15%	22%
Total	4,404	4,411	4,408	0%	0%
2030					
Pulverized Coal	1,668	1,372	1,321	-18%	-21%
NG Combined Cycle (existing)	810	1,144	1,099	41%	36%
NG Combined Cycle (new)	599	551	644	-8%	7%
Combustion Turbine	23	43	40	92%	78%
Oil/Gas Steam	23	15	17	-34%	-29%
Non-Hydro Renewables	350	352	353	1%	1%
Hydro	280	282	282	1%	1%
Nuclear	797	797	797	0%	0%
Other	6	7	8	23%	31%
Total	4,557	4,565	4,560	0%	0%

Note: "Other" mostly includes MSW and fuel cells. Source: Integrated Planning Model run by EPA, 2014

In 2020, incremental coal retirements relative to the base case are 24 GW in the regional scenario, and 32 GW in the state scenario.

Table 6. Total Generation Capacity by 2020-2030 (GW)

	Base Case	Two Block Reg.	Two Block State	Two Block Reg.	Two Block State
2020					
Pulverized Coal	244	219	211	-10%	-13%
NG Combined Cycle (existing)	219	221	221	1%	1%
NG Combined Cycle (new)	12	23	30	93%	153%
Combustion Turbine	146	148	149	1%	2%
Oil/Gas Steam	83	80	79	-3%	-5%
Non-Hydro Renewables	93	93	93	0%	1%
Hydro	101	101	101	0%	0%
Nuclear	103	103	103	0%	0%
Other	5	5	5	2%	2%
Total	1,005	994	992	-1%	-1%
2025					
Pulverized Coal	243	219	211	-10%	-13%
NG Combined Cycle (existing)	219	221	221	1%	1%
NG Combined Cycle (new)	39	49	59	25%	52%
Combustion Turbine	149	160	160	8%	7%
Oil/Gas Steam	82	80	79	-2%	-4%
Non-Hydro Renewables	103	104	104	0%	1%
Hydro	101	101	101	0%	0%
Nuclear	103	103	103	0%	0%
Other	5	5	5	2%	2%
Total	1,044	1,042	1,043	0%	0%
2030					
Pulverized Coal	240	217	209	-10%	-13%
NG Combined Cycle (existing)	219	221	221	1%	1%
NG Combined Cycle (new)	84	88	101	6%	20%
Combustion Turbine	156	174	172	12%	10%
Oil/Gas Steam	82	80	79	-2%	-4%
Non-Hydro Renewables	107	108	109	1%	1%
Hydro	101	101	101	0%	0%
Nuclear	101	101	101	0%	0%
Other	5	5	5	2%	2%
Total	1,095	1,095	1,096	0%	0%

Source: Integrated Planning Model run by EPA, 2014

Table 7. Projected Capacity Factor of Existing Coal Steam and Natural Gas Combined Cycle Capacity

	Existing Coal Steam			Existing Natural Gas Combined Cycle		
	2020	2025	2030	2020	2025	2030
Base Case	78%	80%	79%	52%	48%	42%
Option 2 Regional	75%	74%	72%	61%	61%	59%
Option 2 State	75%	74%	72%	60%	59%	57%

Source: Integrated Planning Model run by EPA, 2014

Table 8. Projected Capacity Additions, Gas (GW)

	Cumulative Capacity Additions: Gas Combined Cycle			Incremental Cumulative Capacity Additions: Gas Combined Cycle		
	2020	2025	2030	2020	2025	2030
Base Case	11.9	38.9	83.8			
Two Block Regional	23.1	48.7	88.5	11.1	9.8	4.7
Two Block State	30.2	58.9	100.7	18.3	20.0	17.0

Source: Integrated Planning Model run by EPA, 2014

Table 9. Projected Capacity Additions, Non-hydro Renewable (GW)

	Cumulative Capacity Additions: Renewables			Incremental Cumulative Capacity Additions: Renewables		
	2020	2025	2030	2020	2025	2030
Base Case	17.8	28.4	32.7			
Two Block Regional	18.1	28.8	33.6	0.3	0.4	0.8
Two Block State	18.3	29.0	33.7	0.5	0.6	1.0

Source: Integrated Planning Model run by EPA, 2014

Table 10. Coal Production for the Electric Power Sector, 2020

	Coal Production (MM Tons)			Percent Change from Base Case	
		Two Block		Two Block	
	Base Case	Regional	State	Regional	State
Appalachia	140	110	111	-22%	-21%
Interior	249	230	224	-8%	-10%
West	446	324	308	-27%	-31%
Waste Coal	9	11	11	20%	20%
Imports	0	0	0		
Total	844	675	654	-20%	-22%

Source: Integrated Planning Model run by EPA, 2014

Table 11. Power Sector Gas Use

	Power Sector Gas Use (TCF)			Percent Change in Power Sector Gas Use		
	2020	**2025**	**2030**	**2020**	**2025**	**2030**
Base Case	8.35	8.88	9.89			
Two Block Regional	9.90	10.90	12.14	18.7%	22.7%	22.6%
Two Block State	10.14	11.14	12.42	21.5%	25.5%	25.6%

Table 12. Projected Average Minemouth and Delivered Coal Prices (2011$/MMBtu)

	Minemouth			Delivered - Electric Power Sector		
	2020	**2025**	**2030**	**2020**	**2025**	**2030**
Base Case	1.73	1.88	2.06	2.62	2.80	2.98
Two Block Regional	1.55	1.69	1.81	2.32	2.47	2.59
Two Block State	1.55	1.69	1.83	2.31	2.47	2.62

Table 13. Projected Average Minemouth and Delivered Coal Prices: Percent Change from Base Case Projections

	Minemouth			Delivered - Electric Power Sector		
	2020	**2025**	**2030**	**2020**	**2025**	**2030**
Two Block Regional	-10.6%	-10.5%	-12.1%	-11.5%	-11.8%	-13.0%
Two Block State	-10.5%	-10.4%	-11.0%	-11.7%	-11.9%	-12.2%

Table 14. Projected Natural Gas Prices (2011$/MMBtu)

	Henry Hub			Delivered - Electric Power Sector		
	2020	2025	2030	2020	2025	2030
Base Case	4.98	5.68	6.00	5.36	6.11	6.39
Two Block Regional	5.53	6.06	6.62	5.90	6.42	6.94
Two Block State	5.56	6.10	6.73	5.93	6.45	7.05

Table 15. Projected Natural Gas Prices: Percent Change from Base Case Projections

	Henry Hub			Delivered - Electric Power Sector		
	2020	2025	2030	2020	2025	2030
Two Block Regional	10.9%	6.7%	10.3%	9.9%	5.0%	8.6%
Two Block State	11.5%	7.3%	12.2%	10.6%	5.5%	10.3%

Table 16. 2020 Projected Contiguous U.S. and Regional Retail Electricity Prices (cents/kWh)

	2020 Projected Retail Price (cents/kWh)			Percent Change from Base Case	
	Base Case	Two Block Regional	Two Block State	Two Block Regional	Two Block State
ERCT	9.9	10.3	10.4	4.8%	5.1%
FRCC	10.6	11.0	11.2	3.6%	5.1%
MROE	10.4	10.5	10.5	0.6%	0.5%
MROW	9.2	9.2	9.3	0.0%	1.8%
NEWE	13.8	14.2	14.5	2.5%	5.0%
NYCW	18.0	18.3	18.5	1.9%	2.6%
NYLI	14.7	15.1	15.2	2.5%	3.3%
NYUP	12.7	13.0	13.1	2.1%	2.8%
RFCE	12.2	12.6	12.7	3.2%	3.6%
RFCM	10.7	10.7	10.8	0.3%	1.1%
RFCW	10.1	10.3	10.4	1.7%	2.5%
SRDA	9.0	9.2	9.2	2.8%	2.6%
SRGW	9.3	9.5	9.6	1.9%	2.9%
SRSE	10.4	10.4	10.5	0.5%	0.7%
SRCE	8.2	8.2	8.2	-0.9%	-0.9%
SRVC	10.7	10.6	10.7	-0.3%	-0.1%
SPNO	10.6	10.5	10.5	-1.0%	-1.3%
SPSO	8.3	8.8	8.8	5.0%	5.3%
AZNM	10.5	10.7	10.8	1.7%	2.9%
CAMX	14.3	14.6	14.6	2.2%	2.4%
NWPP	7.3	7.4	7.4	1.3%	1.4%
RMPA	8.9	9.0	9.2	0.7%	2.9%
Contiguous U.S.	10.4	10.6	10.7	1.9%	2.5%

Table 17. 2025 Projected Contiguous U.S. and Regional Retail Electricity Prices (cents/kWh)

	2025 Projected Retail Price (cents/kWh)			Percent Change from Base Case	
	Base Case	Two Block Regional	Two Block State	Two Block Regional	Two Block State
ERCT	11.2	11.5	11.5	2.5%	3.0%
FRCC	10.9	11.2	11.3	2.6%	4.0%
MROE	10.5	10.5	10.4	0.3%	-0.8%
MROW	9.2	9.4	9.6	1.9%	4.2%
NEWE	14.2	14.6	14.9	2.2%	4.4%
NYCW	18.8	19.2	19.3	2.0%	2.3%
NYLI	15.6	16.0	16.1	2.9%	3.3%
NYUP	13.2	13.5	13.6	2.0%	2.3%
RFCE	12.6	12.8	12.9	1.6%	2.0%
RFCM	10.7	10.8	10.9	0.7%	1.8%
RFCW	10.9	11.0	11.1	0.7%	1.0%
SRDA	9.3	9.6	9.6	2.7%	3.0%
SRGW	10.1	10.3	10.3	1.3%	1.9%
SRSE	10.3	10.5	10.5	1.1%	1.1%
SRCE	8.2	8.1	8.1	-1.5%	-1.7%
SRVC	10.6	10.6	10.6	-0.1%	0.1%
SPNO	10.3	10.3	10.3	-0.2%	-0.3%
SPSO	8.8	9.3	9.2	4.9%	4.4%
AZNM	10.8	11.1	11.3	2.7%	4.7%
CAMX	13.9	14.1	14.1	1.0%	1.0%
NWPP	7.4	7.4	7.5	0.7%	1.7%
RMPA	9.4	9.5	9.7	0.9%	3.3%
Contiguous U.S.	10.8	10.9	11.0	1.4%	2.0%

Table 18. 2030 Projected Contiguous U.S. and Regional Retail Electricity Prices (cents/kWh)

	2030 Projected Retail Price (cents/kWh)			Percent Change from Base Case	
	Base Case	Two Block Regional	Two Block State	Two Block Regional	Two Block State
ERCT	11.6	12.1	12.1	4.0%	4.8%
FRCC	10.9	11.5	11.6	5.0%	6.3%
MROE	10.5	10.7	10.7	2.3%	1.6%
MROW	9.4	9.6	9.8	2.1%	4.9%
NEWE	15.1	15.4	15.4	2.0%	1.8%
NYCW	19.9	20.3	20.3	1.7%	1.6%
NYLI	16.9	17.2	17.1	1.8%	1.3%
NYUP	14.2	14.5	14.5	1.7%	1.6%
RFCE	12.4	12.8	12.8	2.8%	3.4%
RFCM	10.8	11.0	11.1	1.8%	2.9%
RFCW	11.2	11.4	11.4	1.3%	1.8%
SRDA	9.5	9.9	10.0	4.5%	5.0%
SRGW	10.4	10.5	10.6	0.9%	1.6%
SRSE	10.4	10.6	10.7	2.4%	2.6%
SRCE	8.1	8.1	8.1	-1.2%	-1.2%
SRVC	10.4	10.4	10.5	0.6%	1.1%
SPNO	10.2	10.2	10.2	-0.1%	0.2%
SPSO	9.1	9.7	9.6	6.3%	6.1%
AZNM	11.5	11.8	12.0	2.7%	4.4%
CAMX	14.1	14.4	14.5	1.9%	2.3%
NWPP	7.4	7.5	7.6	1.2%	2.6%
RMPA	9.9	10.1	10.4	2.1%	5.7%
Contiguous U.S.	10.9	11.2	11.3	2.3%	2.9%

4 Estimated Climate Benefits from CO_2 Emission Reductions

Tables 19 through 21 report the climate benefits estimated in three analysis years (2020, 2025, and 2030) for the two illustrative compliance scenarios (i.e., state and regional) evaluated.

Table 19. Estimated Global Climate Benefits of CO_2 Reductions for Building Blocks 1 and 2 in 2020 (billions of 2011$)*

Discount Rate and Statistic	State	Regional
Million metric tonnes of CO_2 reduced	252	231
5% (average)	$3.2	$3.0
3% (average)	$12	$11
2.5% (average)	$17	$16
3% (95th percentile)	$34	$31

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

Table 20. Estimated Global Climate Benefits of CO_2 Reductions for Building Blocks 1 and 2 in 2025 (billions of 2011$)*

Discount Rate and Statistic	State	Regional
Million metric tonnes of CO_2 reduced	284	258
5% (average)	$4.2	$3.9
3% (average)	$14	$13
2.5% (average)	$21	$19
3% (95th percentile)	$43	$39

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

Table 21. Estimated Global Climate Benefits of CO_2 Reductions for Building Blocks 1 and 2 in 2030 (billions of 2011$)*

Discount Rate and Statistic	State	Regional
Million metric tonnes of CO_2 reduced	292	258
5% (average)	$5.0	$4.4
3% (average)	$16	$14
2.5% (average)	$23	$21
3% (95th percentile)	$50	$44

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

5 Estimated Human Health Co-Benefits

Tables 22 through 24 provide the emission reductions estimated to occur in three analysis years (2020, 2025, and 2030) for two illustrative compliance scenarios (i.e., state and regional) by region (i.e., East, West, and California). Tables 25 through 27 report the health co-benefits estimated in three analysis years (2020, 2025, and 2030) for the two illustrative compliance scenarios (i.e., state and regional) evaluated.

Table 22. Emission Reductions of Criteria Pollutants in 2020 (thousands of short tons)

Region	SO_2	All-year NOx	Ozone-Season NOx
State			
East	253	233	96
West	23	40	17
California	0	0	0
Total	277	273	113
Regional	216	209	86
East	15	29	12
West	1	2	1
California	232	240	98
Total	216	209	86

Table 23. Emission Reductions of Criteria Pollutants in 2025 (thousands of short tons)

Region	SO_2	All-year NOx	Ozone-Season NOx
State			
East	318	265	111
West	26	41	17
California	0	9	1
Total	344	315	128
Regional			
East	265	237	97
West	22	26	11
California	1	8	1
Total	287	270	109

Table 24. Emission Reductions of Criteria Pollutants in 2030 (thousands of short tons)

Region	SO_2	All-year NOx	Ozone-Season NOx
State			
East	365	265	108
West	31	48	21
California	0	0	0
Total	396	313	128
Regional			
East	316	233	92
West	26	29	12
California	1	1	0
Total	342	263	105

Table 25. Summary of Estimated Monetized Health Co-benefits in 2020 (millions of 2011$)*

Pollutant	3% Discount Rate			7% Discount Rate		
State						
SO_2	$10,000	to	$23,000	$9,300	to	$21,000
NOx (as $PM_{2.5}$)	$1,600	to	$3,600	$1,400	to	$3,200
NOx (as Ozone)	$450	to	$1,900	$450	to	$1,900
Total	**$12,000**	**to**	**$29,000**	**$11,000**	**to**	**$26,000**
Regional						
SO_2	$8,900	to	$20,000	$8,000	to	$18,000
NOx (as $PM_{2.5}$)	$1,500	to	$3,300	$1,300	to	$3,000
NOx (as Ozone)	$410	to	$1,700	$410	to	$1,700
Total	**$11,000**	**to**	**$25,000**	**$9,800**	**to**	**$23,000**

* All estimates are rounded to two significant figures so numbers may not sum down columns. The estimated monetized co-benefits do not include climate benefits or reduced health effects from direct exposure to NO_2, SO_2, ecosystem effects, or visibility impairment. All fine particles are assumed to have equivalent health effects, but the benefit-per-ton estimates vary depending on the location and magnitude of their impact on $PM_{2.5}$ levels, which drive population exposure. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles and ozone. Co-benefits for $PM_{2.5}$ precursors are based on regional benefit-per-ton estimates. Co-benefits for ozone are based on ozone season NOx emissions. Ozone co-benefits occur in analysis year, so they are the same for all discount rates. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology. In general, the 95^{th} percentile confidence interval for monetized $PM_{2.5}$ benefits ranges from approximately -90 percent to +180 percent of the central estimates based on Krewski et al. (2009) and Lepeule et al. (2012).

Table 26. Summary of Estimated Monetized Health Co-benefits in 2025 (millions of 2011$)*

Pollutant	3% Discount Rate			7% Discount Rate		
State						
SO_2	$14,000	to	$32,000	$13,000	to	$29,000
NOx (as $PM_{2.5}$)	$2,100	to	$4,800	$1,900	to	$4,300
NOx (as Ozone)	$680	to	$2,900	$680	to	$2,900
Total	**$17,000**	**to**	**$40,000**	**$15,000**	**to**	**$36,000**
Regional						
SO_2	$12,000	to	$27,000	$11,000	to	$24,000
NOx (as $PM_{2.5}$)	$1,900	to	$4,200	$1,700	to	$3,800
NOx (as Ozone)	$600	to	$2,600	$600	to	$2,600
Total	**$14,000**	**to**	**$34,000**	**$13,000**	**to**	**$30,000**

* All estimates are rounded to two significant figures so numbers may not sum down columns. The estimated monetized co-benefits do not include climate benefits or reduced health effects from direct exposure to NO_2, SO_2, ecosystem effects, or visibility impairment. All fine particles are assumed to have equivalent health effects, but the benefit-per-ton estimates vary depending on the location and magnitude of their impact on $PM_{2.5}$ levels, which drive population exposure. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles and ozone. Co-benefits for $PM_{2.5}$ precursors are based on regional benefit-per-ton estimates. Co-benefits for ozone are based on ozone season NOx emissions. Ozone co-benefits occur in analysis year, so they are the same for all discount rates. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology. In general, the 95^{th} percentile confidence interval for monetized $PM_{2.5}$ benefits ranges from approximately -90 percent to +180 percent of the central estimates based on Krewski et al. (2009) and Lepeule et al. (2012).

Table 27. Summary of Estimated Monetized Health Co-benefits in 2030 (millions of 2011$)*

Pollutant	3% Discount Rate			7% Discount Rate		
State						
SO_2	$17,000	to	$39,000	$16,000	to	$35,000
NOx (as $PM_{2.5}$)	$2,100	to	$4,700	$1,900	to	$4,200
NOx (as Ozone)	$700	to	$3,000	$700	to	$3,000
Total	$20,000	to	$47,000	$18,000	to	$43,000
Regional						
SO_2	$15,000	to	$34,000	$14,000	to	$31,000
NOx (as $PM_{2.5}$)	$1,800	to	$4,100	$1,700	to	$3,700
NOx (as Ozone)	$600	to	$2,600	$600	to	$2,600
Total	$18,000	to	$41,000	$16,000	to	$37,000

* All estimates are rounded to two significant figures so numbers may not sum down columns. The estimated monetized co-benefits do not include climate benefits or reduced health effects from direct exposure to NO_2, SO_2, ecosystem effects, or visibility impairment. All fine particles are assumed to have equivalent health effects, but the benefit-per-ton estimates vary depending on the location and magnitude of their impact on $PM_{2.5}$ levels, which drive population exposure. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles and ozone. Co-benefits for $PM_{2.5}$ precursors are based on regional benefit-per-ton estimates. Co-benefits for ozone are based on ozone season NOx emissions. Ozone co-benefits occur in analysis year, so they are the same for all discount rates. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology. In general, the 95th percentile confidence interval for monetized $PM_{2.5}$ benefits ranges from approximately -90 percent to +180 percent of the central estimates based on Krewski et al. (2009) and Lepeule et al. (2012).

6 Combined Climate Benefits and Health Co-benefits

Tables 28 through 30 provide the combined climate and health benefits for each compliance scenarios evaluated for 2020, 2025, and 2030.

Table 28. Combined Climate Benefits and Health Co-Benefits in 2020 (billions of 2011$)*

SCC Discount Rate	Climate Benefits Only	Climate Benefits and Health Co-Benefits (Discount Rate Applied to Health Co-Benefits)					
		3%			7%		
State	252	million metric tonnes CO_2					
5%	$3.2	$16	to	$32	$14	to	$29
3%	$12	$24	to	$40	$23	to	$38
2.5%	$17	$30	to	$46	$28	to	$43
3% (95th percentile)	$34	$47	to	$63	$46	to	$61
Regional	231	million metric tonnes CO_2					
5%	$3.0	$14	to	$28	$13	to	$26
3%	$11	$21	to	$36	$20	to	$33
2.5%	$16	$27	to	$41	$26	to	$39
3% (95th percentile)	$31	$42	to	$57	$41	to	$54

*All estimates are rounded to two significant figures. Climate benefits are based on reductions in CO_2 emissions. Co-benefits are based on regional benefit-per-ton estimates. Co-benefits for ozone are based on ozone season NOx emissions. Ozone co-benefits occur in analysis year, so they are the same for all discount rates. The health co-benefits reflect the sum of the $PM_{2.5}$ and ozone co-benefits and reflect the range based on adult mortality functions (e.g., from Krewski et al. (2009) with Bell et al. (2004) to Lepeule et al. (2012) with Levy et al. (2005)). The monetized health co-benefits do not include reduced health effects from direct exposure to NO_2, SO_2, and HAP; ecosystem effects; or visibility impairment.

Table 29. Combined Climate Benefits and Health Co-Benefits in 2025 (billions of 2011$)*

SCC Discount Rate	Climate Benefits Only	Climate Benefits and Health Co-Benefits (Discount Rate Applied to Health Co-Benefits)					
		3%			7%		
State	284	million metric tonnes CO_2					
5%	$4.2	$21	to	$44	$20	to	$40
3%	$14	$31	to	$54	$30	to	$50
2.5%	$21	$38	to	$61	$36	to	$57
3% (95th percentile)	$43	$60	to	$83	$59	to	$79
Regional	258	million metric tonnes CO_2					
5%	$3.9	$18	to	$37	$17	to	$34
3%	$13	$27	to	$46	$26	to	$43
2.5%	$19	$33	to	$52	$32	to	$49
3% (95th percentile)	$39	$54	to	$73	$52	to	$70

*All estimates are rounded to two significant figures. Climate benefits are based on reductions in CO_2 emissions. Co-benefits are based on regional benefit-per-ton estimates. Co-benefits for ozone are based on ozone season NOx emissions. Ozone co-benefits occur in analysis year, so they are the same for all discount rates. The health co-benefits reflect the sum of the $PM_{2.5}$ and ozone co-benefits and reflect the range based on adult mortality functions (e.g., from Krewski et al. (2009) with Bell et al. (2004) to Lepeule et al. (2012) with Levy et al. (2005)). It is important to note that the monetized health co-benefits do not include reduced health effects from direct exposure to NO_2, SO_2, and HAP; ecosystem effects; or visibility impairment.

Table 30. Combined Climate Benefits and Health Co-Benefits in 2030 (billions of 2011$)*

SCC Discount Rate	Climate Benefits Only	Climate Benefits and Health Co-Benefits (Discount Rate Applied to Health Co-Benefits)					
		3%			7%		
State	292	million metric tonnes CO_2					
5%	$5.0	$25	to	$52	$23	to	$48
3%	$16	$36	to	$63	$35	to	$59
2.5%	$23	$44	to	$70	$42	to	$66
3% (95th percentile)	$50	$70	to	$97	$68	to	$92
Regional	258	million metric tonnes CO_2					
5%	$4.4	$22	to	$45	$20	to	$41
3%	$14	$32	to	$55	$30	to	$51
2.5%	$21	$38	to	$62	$37	to	$58
3% (95th percentile)	$44	$61	to	$85	$60	to	$81

*All estimates are rounded to two significant figures. Climate benefits are based on reductions in CO_2 emissions. Co-benefits are based on regional benefit-per-ton estimates. Co-benefits for ozone are based on ozone season NOx emissions. Ozone co-benefits occur in analysis year, so they are the same for all discount rates. The health co-benefits reflect the sum of the $PM_{2.5}$ and ozone co-benefits and reflect the range based on adult mortality functions (e.g., from Krewski et al. (2009) with Bell et al. (2004) to Lepeule et al. (2012) with Levy et al. (2005)). It is important to note that the monetized health co-benefits do not include reduced health effects from direct exposure to NO_2, SO_2, and HAP; ecosystem effects; or visibility impairment.

7 Net Benefits

Tables 31 through 33 summarize the benefits, costs, and net benefits for 2020, 2025, and 2030 for the two illustrative compliance scenarios evaluated for building blocks 1 and 2 only.

Table 31. Summary of Monetized Benefits, Compliance Costs, and Net Benefits in 2020 (billions of 2011$) [a]

	State	
	3% Discount Rate	7% Discount Rate
Climate Benefits [b]		
5% discount rate	$3.2	
3% discount rate	$12	
2.5% discount rate	$17	
95th percentile at 3% discount rate	$34	
Air pollution health co-benefits [c]	$12 to $29	$11 to $26
Total Compliance Costs [d]	$4.4	
Net Benefits [e]	$20 to $36	$18 to $33
Non-Monetized Benefits	Direct exposure to SO_2 and NO_2 1.1 tons of Hg Ecosystem Effects Visibility impairment	
	Regional	
	3% Discount Rate	**7% Discount Rate**
Climate Benefits [b]		
5% discount rate	$3.0	
3% discount rate	$11	
2.5% discount rate	$16	
95th percentile at 3% discount rate	$31	
Air pollution health co-benefits [c]	$11 to $25	$9.8 to $23
Total Compliance Costs [d]	$3.2	
Net Benefits [e]	$18 to $32	$17 to $30
Non-Monetized Benefits	Direct exposure to SO_2 and NO_2 1.1 tons of Hg Ecosystem Effects Visibility impairment	

[a] All estimates are for 2020 and are rounded to two significant figures, so figures may not sum.
[b] The climate benefit estimates in this summary table reflect global impacts from CO_2 emission changes and do not account for changes in non-CO_2 GHG emissions. Also, different discount rates are applied to SCC than to the other estimates because CO_2 emissions are long-lived and subsequent damages occur over many years. The SCC estimates are year-specific and increase over time.
[c] The air pollution health co-benefits reflect reduced exposure to $PM_{2.5}$ and ozone associated with emission reductions of directly emitted $PM_{2.5}$, SO_2 and NO_X. The range reflects the use of concentration-response functions from different epidemiology studies. The reduction in premature fatalities each year accounts for over 90 percent of total monetized co-benefits from $PM_{2.5}$ and ozone. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type.
[d] Total costs are approximated by the illustrative compliance costs estimated using the Integrated Planning Model and a discount rate of approximately 5%. This estimate includes monitoring, recordkeeping, and reporting costs and demand side energy efficiency program and participant costs.
[e] The estimates of net benefits in this summary table are calculated using the global SCC at a 3 percent discount rate (model average). Tables 10-12 in this memo present combined climate and health estimates based on additional discount rates.

Table 32. Summary of Monetized Benefits, Compliance Costs, and Net Benefits in 2025 (billions of 2011$) [a]

	State	
	3% Discount Rate	**7% Discount Rate**
Climate Benefits [b]		
5% discount rate	$4.2	
3% discount rate	$14	
2.5% discount rate	$21	
95th percentile at 3% discount rate	$43	
Air pollution health co-benefits [c]	$17 to $40	$15 to $36
Total Compliance Costs [d]	$4.6	
Net Benefits [e]	$27 to $49	$25 to $46
Non-Monetized Benefits	Direct exposure to SO_2 and NO_2 1.4 tons of Hg Ecosystem Effects Visibility impairment	
	Regional	
	3% Discount Rate	**7% Discount Rate**
Climate Benefits [b]		
5% discount rate	$3.9	
3% discount rate	$13	
2.5% discount rate	$19	
95th percentile at 3% discount rate	$39	
Air pollution health co-benefits [c]	$14 to $34	$13 to $30
Total Compliance Costs [d]	$3.0	
Net Benefits [e]	$24 to $43	$23 to $40
Non-Monetized Benefits	Direct exposure to SO_2 and NO_2 1.3 tons of Hg Ecosystem Effects Visibility impairment	

[a] All estimates are for 2025 and are rounded to two significant figures, so figures may not sum.
[b] The climate benefit estimates in this summary table reflect global impacts from CO_2 emission changes and do not account for changes in non-CO_2 GHG emissions. Also, different discount rates are applied to SCC than to the other estimates because CO_2 emissions are long-lived and subsequent damages occur over many years. The SCC estimates are year-specific and increase over time.
[c] The air pollution health co-benefits reflect reduced exposure to $PM_{2.5}$ and ozone associated with emission reductions of directly emitted $PM_{2.5}$, SO_2 and NO_X. The range reflects the use of concentration-response functions from different epidemiology studies. The reduction in premature fatalities each year accounts for over 90 percent of total monetized co-benefits from $PM_{2.5}$ and ozone. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type.
[d] Total costs are approximated by the illustrative compliance costs estimated using the Integrated Planning Model and a discount rate of approximately 5%. This estimate includes monitoring, recordkeeping, and reporting costs and demand side energy efficiency program and participant costs.
[e] The estimates of net benefits in this summary table are calculated using the global SCC at a 3 percent discount rate (model average). Tables 10-12 in this memo present combined climate and health estimates based on additional discount rates.

Table 33. Summary of Monetized Benefits, Compliance Costs, and Net Benefits in 2030 (billions of 2011$) [a]

	State	
	3% Discount Rate	7% Discount Rate
Climate Benefits [b]		
5% discount rate	$5.0	
3% discount rate	$16	
2.5% discount rate	$23	
95th percentile at 3% discount rate	$50	
Air pollution health co-benefits [c]	$20 to $47	$18 to $43
Total Compliance Costs [d]	$9.8	
Net Benefits [e]	$27 to $53	$25 to $49
Non-Monetized Benefits	Direct exposure to SO_2 and NO_2 1.5 tons of Hg Ecosystem Effects Visibility impairment	
	Regional	
	3% Discount Rate	**7% Discount Rate**
Climate Benefits [b]		
5% discount rate	$4.4	
3% discount rate	$14	
2.5% discount rate	$21	
95th percentile at 3% discount rate	$44	
Air pollution health co-benefits [c]	$18 to $41	$16 to $37
Total Compliance Costs [d]	$6.8	
Net Benefits [e]	$25 to $48	$23 to $45
Non-Monetized Benefits	Direct exposure to SO_2 and NO_2 1.3 tons of Hg Ecosystem Effects Visibility impairment	

[a] All estimates are for 2030, and are rounded to two significant figures, so figures may not sum.
[b] The climate benefit estimates in this summary table reflect global impacts from CO_2 emission changes and do not account for changes in non-CO_2 GHG emissions. Also, different discount rates are applied to SCC than to the other estimates because CO_2 emissions are long-lived and subsequent damages occur over many years. The SCC estimates are year-specific and increase over time.
[c] The air pollution health co-benefits reflect reduced exposure to $PM_{2.5}$ and ozone associated with emission reductions of directly emitted $PM_{2.5}$, SO_2 and NO_X. The range reflects the use of concentration-response functions from different epidemiology studies. The reduction in premature fatalities each year accounts for over 90 percent of total monetized co-benefits from $PM_{2.5}$ and ozone. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type.
[d] Total costs are approximated by the illustrative compliance costs estimated using the Integrated Planning and a discount rate of approximately 5%. This estimate includes monitoring, recordkeeping, and reporting costs and demand side energy efficiency program and participant costs.
[e] The estimates of net benefits in this summary table are calculated using the global SCC at a 3 percent discount rate (model average). Tables 10-12 in this memo present combined climate and health estimates based on additional discount rates.

8 Labor

Table 34 presents the labor changes estimated in job-years associated with the illustrative building blocks 1 and 2 analysis.

Table 34. Engineering-Based[a] Changes in Labor Utilization, Building Blocks 1 & 2 (Number of Job-Years of Employment in Year)

Category	Regional Compliance			State Compliance		
	2017-2020	**2021-2025**	**2026-2030**	**2017-2020**	**2021-2025**	**2026-2030**
Construction-related (One-time) Changes*						
Heat Rate Improvement: Total	**37,400**	**0**	**0**	**35,300**	**0**	**0**
Boilermakers and General Construction	26,000	0	0	24,500	0	0
Engineering and Management	6,900	0	0	6,500	0	0
Equipment-related	3,300	0	0	3,200	0	0
Material-related	1,200	0	0	1,100	0	0
New Capacity Construction: Total	**7,700**	**7,300**	**1,600**	**11,000**	**9,400**	**1,000**
Renewables	0	500	1,600	-700	500	1,600
Natural Gas	7,700	6,800	0	11,700	8,900	-600
Recurring Changes**						
	2020	**2025**	**2030**	**2020**	**2025**	**2030**
Operation and Maintenance: Total	**-10,970**	**-9,500**	**-8,300**	**-14,100**	**-12,200**	**-10,600**
Changes in Gas	1,330	1,500	1,100	2,200	2,400	2,100
Retired Coal	-11,800	-10,700	-9,200	-15,600	-14,100	-12,300
Retired Oil and Gas	-500	-300	-200	-700	-500	-400
Fuel Extraction: Total	**-1,900**	**-1,000**	**-700**	**-1,500**	**-1,000**	**-800**
Coal	-9,700	-11,100	-12,000	-10,500	-12,400	-13,500
Natural Gas	7,800	10,100	11,300	9,000	11,400	12,700
Supply Side Employment Impacts – Quantified	**32,230**	**-3,200**	**-7,400**	**30,700**	**-3,800**	**-10,400**

[a] Job-year estimates are derived from IPM investment and O&M cost estimates, as well as IPM fuel use estimates (tons coals or MMBtu gas)

[b]All job-year estimates on this are Full Time Equivalent (FTE) jobs. Job estimates in the Demand-Side energy efficiency section (below) include both full time and part time jobs

*Construction-related job-year changes are one-time impacts, occurring during each year of the 2 to 4 year period during which construction and HRI installation activities occur. Figures in table are average job-years during each of the years in each range. Negative job-year estimates when additional generating capacity must be built in the base case, but is avoided in the Guideline implementation scenarios due to HRI or Demand-side energy efficiency programs.

**Recurring Changes are job-years associated with annual recurring jobs including operating and maintenance activities and fuel extraction jobs. Newly built generating capacity creates a recurring stream of positive job-years, while retiring generating capacity, as well as avoided new built capacity, create a stream of negative job-years. In addition, there are recurring jobs prior to 2020 to fuel and operate new generating capacity brought online before 2020; the recurring jobs prior to 2020 are not estimated.

9 References

Bell, M.L., et al. 2004. "Ozone and Short-Term Mortality in 95 U.S. Urban Communities, 1987-2000." Journal of the American Medical Association, 292(19): pp. 2372-8.

Krewski D; M. Jerrett; R.T. Burnett; R. Ma; E. Hughes and Y. Shi, et al. 2009. Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality. HEI Research Report, 140, Health Effects Institute, Boston, MA.

Lepeule, J.; F. Laden; D. Dockery and J. Schwartz. 2012. "Chronic Exposure to Fine Particles and Mortality: An Extended Follow-Up of the Harvard Six Cities Study from 1974 to 2009." Environmental Health Perspectives, July, 120(7): pp. 965-70.

Levy, J.I.; S.M. Chemerynski and J.A. Sarnat. 2005. "Ozone Exposure and Mortality: An Empiric Bayes Meta-regression Analysis." Epidemiology, 16(4): pp. 458-68.