Federal Coal Leasing Reform Options: Effects on CO_2 Emissions and Energy Markets

Summary of Modeling Results

FINAL REPORT

A Vulcan Philanthropy | Vulcan, Inc. Report with Analysis Supported by

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9300 Lee Highway
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January 26, 2016

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Chapter 1: Introduction

To understand the potential impacts of changes to the federal coal royalty system, Vulcan Inc. commissioned a forward-looking analysis using ICF International's (ICF) Integrated Planning Model (IPM®), relying on assumptions and scenarios as specified by Vulcan. ICF provided modeling guidance to Vulcan, helping to identify specific data needs, modeling inputs and run structures, and ran the IPM model. However, Vulcan had final responsibility for the selection of the model runs completed, as well as approval of all input assumptions and parameters of the modeling runs. IPM is a multi-region model that endogenously determines capacity expansion plans, unit dispatch and compliance decisions, fuel switching, as well as power and fuel price forecasts, all of which are based on power market fundamentals.

This report summarizes the results of multiple base and policy cases. The base case is the reference case against which the policy cases are compared to assess the incremental impact of the policy. The base cases differ in:

(a) Modeling assumptions. Two sets of modeling assumptions were used. Base Case A approximates the economic and generation assumptions from EPA's Base Case v.5.13 available at the time of the release of the Clean Power Plan Proposed Rule. Additional updates were made to this case including those for load growth, new unit construction costs, and gas resources assumptions from the updated EPA's Base Case v.5.15. Base Case B approximates the economic and generation assumptions from EPA's Base Case v.5.15, released with the Final Clean Power Plan in August 2015. Because economic assumptions carry inherent uncertainty, using these two sets of economic assumptions provides an opportunity to examine the sensitivity of the effect of changes in federal coal royalties to the underlying costs of different electricity sources. In selecting assumptions, Vulcan made every effort to use input assumptions from the Environmental Protection Agency (EPA) and the Energy Information Administration (EIA), including those used in EPA's v5.15 Base and Final Clean Power Plan (CPP) cases released in August 2015 and the EIA's Annual Energy Outlook (AEO) 2015.

(b) Coal prices. Base Case A adopts ICF's assumptions of coal prices as of October 2015. Base Case B modifies the coal prices assumed in Base Case A by reflecting higher growth rates by of coal prices over the forecast horizon. The higher growth rates are calculated based on EPA's analysis by coal supply basins. The resulting prices in Base Case B are higher than Base Case A.

(c) Assumptions about Clean Power Plan (CPP) implementation. The CPP has a number of compliance approaches available to states, and states have yet to decide which approach they will adopt. In addition, there are court challenges to the CPP and the court outcome is uncertain. For this reason, three CPP implementations were considered:

- No CPP.
- CPP with regional emission allowance trading under a mass-based rule. The mass-based scenario covers new and existing fossil fuel sources and includes the mass based caps and new source complements included in the final CPP.

- CPP with regional emission reduction credit (ERC) trading under a rate-based rule. The rate-based scenario covered existing fossil sources which were able to purchase ERCs from renewable units online after 2012, firm nuclear units, and energy efficiency to comply with the CPP rate requirement.

In both the mass-based and rate-based cases, the CPP state-level rate or mass targets are taken from the CPP final rule.

The two sets of economic assumptions, combined with the three sets of assumptions about CPP implantation, produce six base cases.

Base Cases

1. Base Case A, no CPP
2. Base Case A, CPP with mass-based regional trading
3. Base Case A, CPP with rate-based regional trading
4. Base Case B, no CPP
5. Base Case B, CPP with mass-based regional trading
6. Base Case B, CPP with rate-based regional trading

Each of these six cases assumes current law and regulations.

The report considers a number of policy cases related to possible reforms of the federal coal program, overlaid on these different base cases. Four of these cases consider changes in the royalty rate: increasing royalties by $2.50, and by 20%, 50%, and 100% of the Social Cost of Carbon (SCC). The remaining two policy cases consider ramping down coal production on federal lands by 50% or entirely. All of the policy cases are phased in to model their application to new, renewed, or modified leases, but not to existing leases, as is discussed in more detail below.

Policy Cases

1. Increase royalties by $2.50
2. Increase royalties by 20% of the SCC
3. Increase royalties by 50% of the SCC
4. Increase royalties by 100% of the SCC
5. Ramp down federal coal by 50%
6. Ramp down federal coal by 100%

The SCC percentage adders resulted in adders ($/short ton) which are outlined in Exhibit 1. The social cost of carbon adders are phased in incrementally over a period in 10 years, for example, in the 100% SCC case, the carbon adder is 10% of the SCC in 2016, 20% of the SCC in 2017, increasing to 100% of the SCC in 2025. As discussed in the next section, this phase-in approximates the application of royalty changes to new, modified, or renewed leases but not to existing leases.

Exhibit 1: Adders Based on Percentage of Social Cost of Carbon (2015$/Ton)[1]

Run Year	20%	50%	100%
2016	$1.5	$3.8	$7.7
2018	$4.8	$12.1	$24.2
2020	$8.7	$21.7	$43.4
2025	$19.0	$47.4	$94.8
2030	$21.0	$52.4	$104.9
2040	$24.6	$61.5	$123.1

The remainder of the report is organized as follows. Chapter 2 provides background and discusses the IPM model and modeling assumptions. Chapter 3 discusses Base Case A. Chapter 4 discusses the results of policy cases based on Base Case A. Chapter 5 discusses Base Case B and results for policy scenarios under Base Case B. Additional results are presented in the Appendix.

[1] [1] http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

Chapter 2: Background & Assumptions

Objective

Vulcan used the Integrated Planning Model (IPM®) to assess the direct impacts of possible reforms to the federal coal program. As discussed below, IPM has a detailed representation of coal markets and allows for endogenous decision making regarding coal production and consumption levels, sources, and prices depending on economics and other constraints.

IPM identified the full set of market impacts including fuel switching (from one coal to another, including from coal mined on federal lands to coal mined on non-federal lands in other regions, and from coal to gas); plant retrofits to allow burning of a different coal or fuel; coal plant retirements; replacement builds; dispatch changes; and all resulting changes in coal production and prices. In addition to these first-order impacts, IPM projects wholesale power price impacts, emissions changes (carbon and criteria pollutants), secondary fuel market impacts (e.g., natural gas), and changes in coal imports and exports.

Cases Analyzed

Vulcan had ICF analyze six Base Cases:

- **Base Case A.** A Base Case with current laws and regulations. This case was largely based on publicly available data and assumptions taken from EPA's Base Case v. 5.13 with key updates from EPA's Base Case v.5.15. Base Case A used ICF coal curves.
- **Base Case A, CPP with Mass-based Regional Trading.** Based on Base Case A, this CPP Mass Case was analyzed that includes the requirements of the Clean Power Plan (CPP), as included by EPA in August of 2015. The mass-based scenario covers existing and new fossil fuel fired sources and includes the mass based caps and new source complements included in the final CPP.
- **Base Case A, CPP with Rate-based Regional Trading.** Based on Base Case A, this CPP Rate Case was analyzed that also includes the requirements of the Clean Power Plan (CPP), as included by EPA in August of 2015. The rate-based scenario covered existing fossil sources which were able to purchase ERCs from renewable units online after 2012, firm nuclear units, and energy efficiency to comply with the CPP rate requirement.
- **Base Case B.** A Base Case with current laws and regulations. This case was largely based on publicly available data and assumptions taken from EPA's Base Case v.5.15 and included coal supply curves that approximated EPA's costs of production.
- **Base Case B, CPP with Mass-based Regional Trading.** Based on Base Case B, this CPP Mass Case includes the requirements of the Clean Power Plan (CPP), as included by EPA in August of 2015. The mass-based scenario covers existing and new fossil fuel fired sources and includes the mass based caps and new source complements included in the final CPP.
- **Base Case B, CPP with Rate-based Regional Trading.** Based on Base Case B, this CPP Rate Case was analyzed that also includes the requirements of the Clean Power Plan (CPP), as included by EPA in August of 2015. The rate-based scenario covered existing fossil sources which were able to purchase ERCs from renewable units online after 2012, firm nuclear units, and energy efficiency to comply with the CPP rate requirement.

Vulcan had ICF analyze 25 Policy Cases that build on the Base Cases:

Using Base Case A, the following cases where analyzed:

1. **Base Case with $2.50/ton Adder.** The assumption of a $2.50/ton adder to coals mined on federal lands was applied to Base Case A.
2. **CPP Mass Case with $2.50/ton Adder.** The assumption of a $2.50/ton adder to coals mined on federal lands was applied to Base Case A, CPP with mass-based regional trading.
3. **CPP Rate Case with $2.50/ton Adder.** The assumption of a $2.50/ton adder to coals mined on federal lands was applied to Base Case A, CPP with rate-based regional trading.
4. **Base Case 20%.** Applies 20% of the Social Cost of Carbon (SCC) to coal production on Federal Lands to Base Case A.
5. **Base Case 50%.** Applies 50% of the SCC to coal production on Federal Lands to Base Case A.
6. **Base Case 100%.** Applies 100% of the SCC to coal production on Federal Lands to Base Case A.
7. **CPP Mass 20%.** Applies 20% of the SCC to coal production on Federal Lands to Base Case A, CPP with mass-based regional trading.
8. **CPP Mass 50%.** Applies 50% of the SCC to coal production on Federal Lands to Base Case A, CPP with mass-based regional trading.
9. **CPP Mass 100%.** Applies 100% of the SCC to coal production on Federal Lands to Base Case A, CPP with mass-based regional trading.
10. **CPP Rate 20%.** Applies 20% of the SCC to coal production on Federal Lands to Base Case A, CPP with rate-based regional trading.
11. **CPP Rate 50%.** Applies 50% of the SCC to coal production on Federal Lands to Base Case A, CPP with rate-based regional trading.
12. **CPP Rate 100%.** Applies 100% of the SCC to coal production on Federal Lands to Base Case A, CPP with rate-based regional trading.
13. **Base No New Permits**. Mining on Federal Lands is assumed to cease by 2037, applied to Base Case A.
14. **Base Limited New Permits**. Mining on Federal Lands is reduced to 50% of 2013 levels by 2037, applied to Base Case A.
15. **CPP Mass No New Permits**. Mining on Federal Lands is assumed to cease by 2037, applied to Base Case A.
16. **CPP Mass Limited New Permits**. Mining on Federal Lands is reduced to 50% of 2013 levels by 2037, applied to Base Case A.

The following cases were analyzed using Base Case B:

1. **Base Case 20%.** Applies 20% of the Social Cost of Carbon (SCC) to coal production on Federal Lands to Base Case B.
2. **Base Case 50%.** Applies 50% of the SCC to coal production on Federal Lands to Base Case B.
3. **Base Case 100%.** Applies 100% of the SCC to coal production on Federal Lands to Base Case B.
4. **CPP Mass 20%.** Applies 20% of the SCC to coal production on Federal Lands to Base Case B, CPP with mass-based regional trading.
5. **CPP Mass 50%.** Applies 50% of the SCC to coal production on Federal Lands to Base Case B, CPP with mass-based regional trading.

6. **CPP Mass 100%.** Applies 100% of the SCC to coal production on Federal Lands to Base Case B, CPP with mass-based regional trading.
7. **CPP Rate 20%.** Applies 20% of the SCC to coal production on Federal Lands to Base Case B, CPP with rate-based regional trading.
8. **CPP Rate 50%.** Applies 50% of the SCC to coal production on Federal Lands to Base Case B, CPP with rate-based regional trading.
9. **CPP Rate 100%.** Applies 100% of the SCC to coal production on Federal Lands to Base Case B, CPP with rate-based regional trading.

Impacts of the policy cases discussed in this report focus on the incremental impacts of the policy cases to their relevant base case. This report provides both the absolute change between a Base Case and a Policy case and the percentage changes.

Key Assumptions

The following discusses some of the key assumptions of the analysis.

Load Growth and Energy Efficiency (EE)

As discussed further in the Base Case overview, three Base Cases were analyzed: Base Case, CPP Mass Case, and CPP Rate Case. The load growth for all cases is based on AEO 2015 and is an exogenous input into the model. The CPP Base Case incorporates EE in the amount analyzed by EPA in their CPP analysis[2]. The EE is an exogenous input to the model. Therefore, all of the Policy cases which use the CPP Base as the starting point will have the same amount of energy efficiency and therefore, the same load growth (AEO 2015 with EPA CPP EE). Furthermore, all Policy cases which use the Base Case as the starting point will have the same load growth (AEO 2015 without EE).

Treatment of Federal and Non-federal Coal Adders

The coal supply curves used in this analysis do not explicitly disaggregate coal available on federal and non-federal lands as the coal is assumed to be mined in logical mining units (LMU) and comingled such that it cannot be mined preferentially. The adders imposed are assumed only to apply to coal mined from federal land. Thus, when the adders are applied to the supply curves, they are added on a weighted basis for each step on the supply curve based on the amount of federal and non-federal coal at the mine represented in the supply curve step. For example, in the $2.50/ton adder case, if a mine has 100% of its coal on federal land, then the full $2.50/ton would be added to that step on the supply curve. However if a mine has only 80% of its coal on federal land, then that step on the supply curve would only get $2.00/ton added to it. Further, the focus of this analysis was mining on federal lands in CO, MT, UT and WY. While there are small amounts of coal mined on federal lands elsewhere, the adders and production limits discussed in this report are applied to these states only. Finally, for purposes of this analysis, the adders and production limits were applied regardless of whether the mine was surface or underground.

[2] Table 1, EPA v.5.15 Supplemental Documentation for the Clean Power Plan, August 2015. http://www.epa.gov/airmarkets/documents/ipm/EPA%20Base%20Case%20v515%20Documentation%20Supplement%20for%20Final%20CPP.pdf

Coal Export Terminal

Coal export terminals in the analysis reflect existing export capabilities. The largest coal export terminal capacity in the US is located in the mid-Atlantic region on the east coast. Terminals along the east coast primarily export coal from Appalachia. PRB coal has been exported through ports in Canada, while Colorado and Utah coal has been exported through ports in California. In both cases, the amount of exports has been small, on the order of 10 million tons per year collectively. The analysis assumes that PRB coal exports will be no greater than 8 million tons per year out of the existing Canadian ports, which is the average of recent PRB exports from these terminals.

Coal Supply Regions

IPM includes multiple coal supply basins, and each basin covers various coal supply regions representing geographic aggregations of coal mining areas. Each coal supply region may differ from others in the quality of coal produced, as measured primarily by the coal's heat content and sulfur content. Exhibit 2 illustrates the locations of coal supply regions. Exhibit 3 shows the mapping of coal supply basins, coal supply regions, and coal producing states. This report includes summary results for the coal supply basins, as defined in Exhibit 3.

Although there is some non-Western federal coal, over 90% of federal coal is from the four states of Montana, Wyoming, Colorado, and Utah. For purposes of modeling simplification, the policies under the alternative cases are only applied to these four states. For example, in the carbon adder cases, the carbon adder is only applied to federal coal from these four states.

Exhibit 2: Map of Coal Supply Regions and States

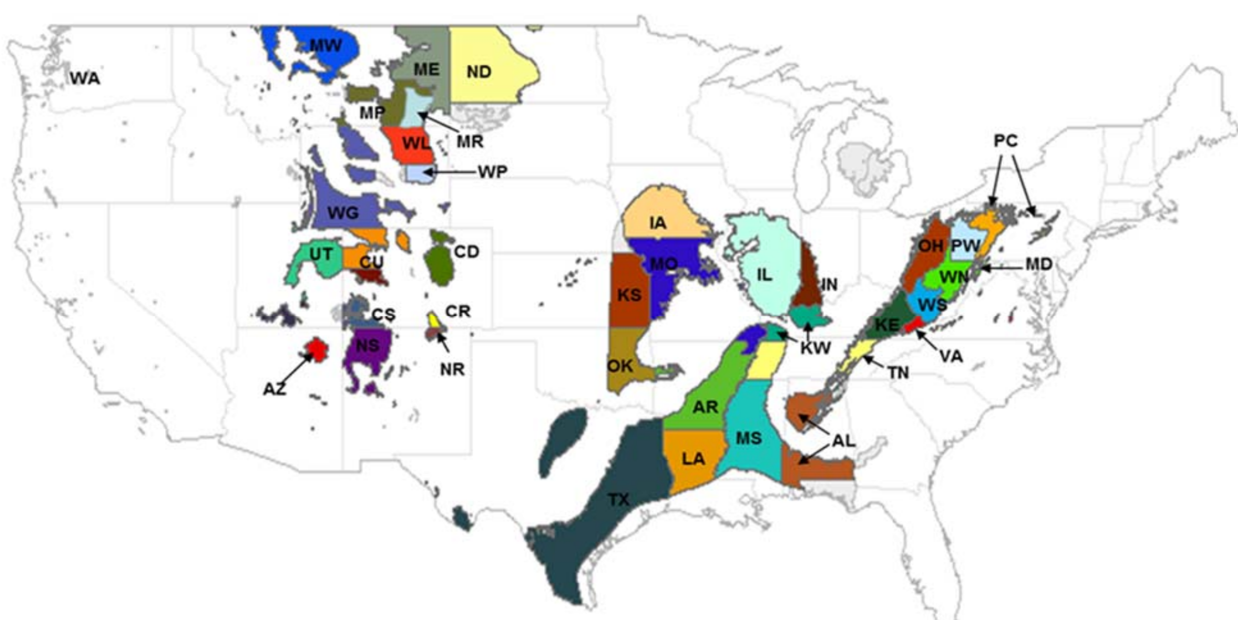


Exhibit 3: Mapping Coal Supply Basins, Coal Supply Regions, and States

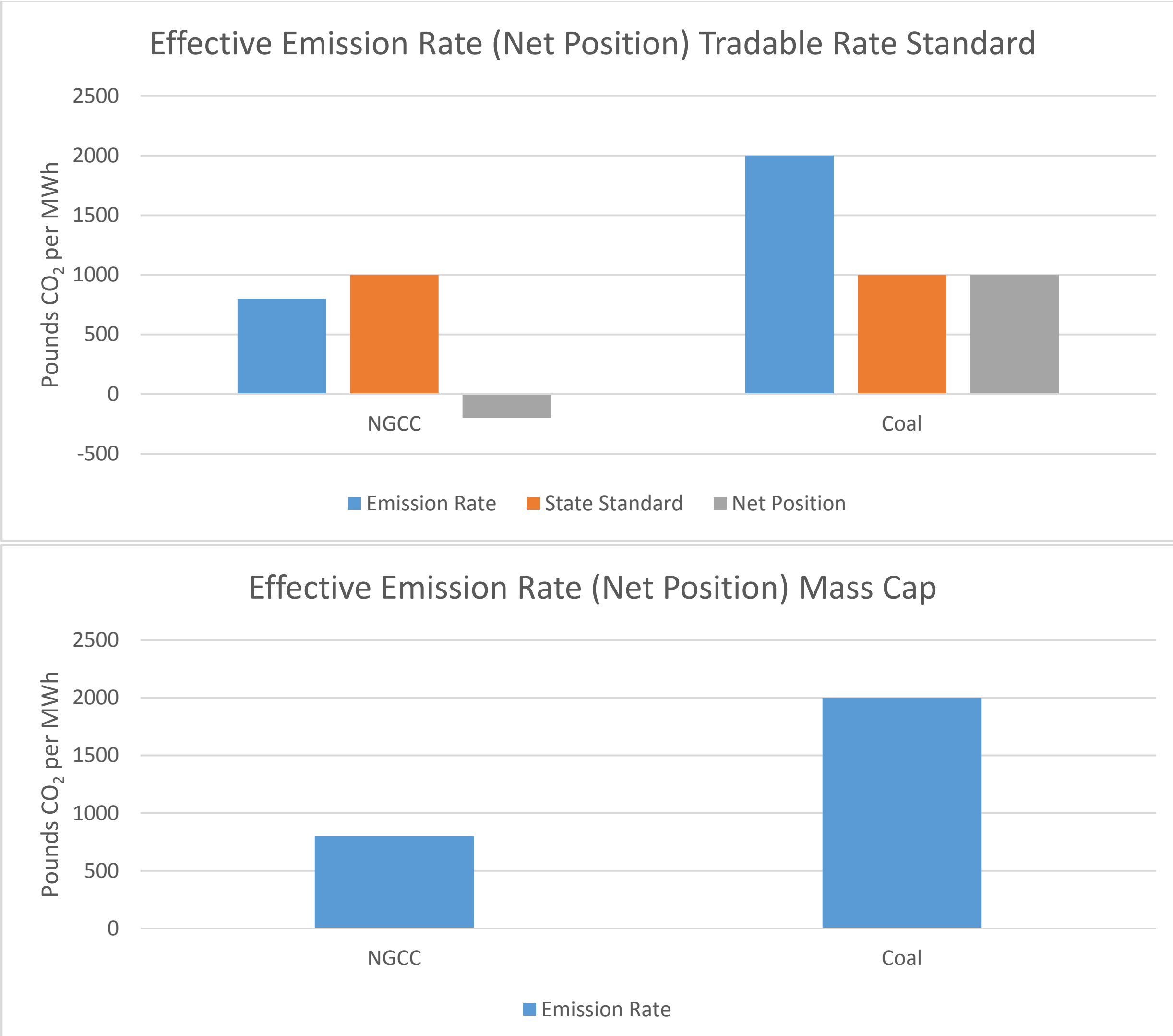
Coal Supply Basin	Coal Supply Region	State	Coal Supply Basin	Coal Supply Region	State
CAPP	KE, Kentucky East	KY	NAPP	MD, Maryland	MD
	TN, Tennessee	TN		OH, Ohio	OH
	VA, Virginia	VA		PC, Pennsylvania Central	PA
	WS, West Virginia, South	WV		PW, Pennsylvania West	PA
GP	ME, Montana, East	MT		WN, West Virginia, North	WV
	MW, Montana, West	MT	PRB	MP, Montana, Powder River	MT
	ND, North Dakota	ND		WL, Wyoming Low Btu (8400)	WY
GULF	LA, Louisiana	LA		WP, Wyoming, Powder River	WY
	MS, Mississippi	MS	ROCKIES	CD, Colorado, Denver	CO
	TX, Texas	TX		CR, Colorado, Raton	CO
ILB	IL, Illinois	IL		CS, Colorado, San Juan	CO
	IN, Indiana	IN		CU, Colorado, Uinta	CO
	KW, Kentucky West	KW		UT, Utah	UT
MIDW	AR, Arkansas	AR		WG, Wyoming, Green River	WY
	IA, Iowa	IA	SAPP	AL, Alabama	AL
	KS, Kansas	KS	SW	AZ, Arizona	AZ
	MO, Missouri	MO		NR, New Mexico, Raton	NM
	OK, Oklahoma	OK		NS, New Mexico, San Juan	NM

Mass vs Rate Structure

Under a traditional cap and trade regime (i.e., mass-based), every ton of CO_2 emitted from qualifying facilities is counted against the established emissions limit and effectively is valued at the market clearing allowance price. However, under a tradable rate-based standard the credit allowance price is valued based on the difference between the emission rate of each particular qualifying facility and the BSER target. This difference is also referred to as the effective emission rate or net position of the facility. These charges are the implicit costs that are added to a units cost of operations and for marginal units influence the price of power.

As shown in Exhibit 4, this means that under a tradable rate-based standard, units that emit below the BSER target, which in this example is 1,000 lb/MWh, effectively have a negative net position per MWh, while those that generate above the BSER target have a positive net position per MWh. In the case of a traditional mass cap, the net position per MWh of any qualifying facility is equal to the emission rate of the unit.

Exhibit 4: Effective Emission Rate under Rate Standard and Mass Cap



In order to calculate the $/MWh impact on costs to dispatch of a given credit allowance price for a particular unit, it is necessary to first calculate the net position of the unit and multiply this term by the credit or allowance price, as illustrated in Exhibit 5. For example, under a tradable rate-based approach with a BSER target of 1,000 lb/MWh and a CO_2 credit allowance price of $10/short ton, an NGCC unit with an emission rate of 800 lb/MWh would receive a $1/MWh credit. The same unit would incur a $4/MWh added costs to dispatch under a mass cap with a $10/short ton allowance price. Under the same rate based approach, a coal unit with an emission rate of 2,000 lb/MWh would incur a charge of $5/MWh. Under a mass cap, the unit would incur a $10/MWh adder. It is worth noting that the spread between the NGCC unit and the coal unit remains the same in either case assuming the credit price is the same in both cases.

Exhibit 5: Calculations of a Unit's Net Position under Rate Standard and Mass Cap

Program Type	CO_2 Price ($/Ton)	CO_2 Adder: NGCC ($/MWh)	CO_2 Adder: Coal ($/MWh)	Spread between NGCC and Coal ($/MWh)
		= Net Position ($\frac{lb}{MWh}$) * Credit Price ($\frac{\$}{Tonne}$) * ($\frac{Tonne}{lb}$)		
Mass Based	10	$(800) * (\frac{10}{2000})$ = 4	$(2000) * (\frac{10}{2000})$ = 10	10 - 4 = 6
Rate-Based	10	$(800 – 1000) * (\frac{10}{2000})$ = -1	$(2000 – 1000) * (\frac{10}{2000})$ = 5	5 – (-1) = 6

These differences are important to understanding the impact of the CPP on wholesale power prices. In a very simplified scenario where load remains the same, and assuming the wholesale power price is set by NGCC in all hours, wholesale power price would decline by $1/MWh under the rate based case, compared to increasing $4/MWh under the mass based case.

Chapter 3: Reference Case Results: Base Case A

Case Overview

This analysis included three Base Cases: Base Case A, no CPP (referred to as "Base Case A" in Chapter 3), Base Case A, CPP with mass-based regional trading (referred to as "CPP Mass Case" in Chapter 3), and Base Case A, CPP with rate based regional trading (referred to as "CPP Rate Case" in Chapter 3). The Base Case uses EPA's v5.13 Base Case assumptions as a starting point, with a few key updates based on EPA's v5.15 released with the final rule. These updates include the following:

- Energy and Peak demand based on AEO2015
- Revised capital costs for new capacity
- Revised natural gas resource and production assumptions

Base Case A only includes final environmental regulations such as the Cross State Air Pollution Rule (CSAPR) and the Mercury and Air Toxics Standards (MATS) rule and does not incorporate any other regulations such as the Clean Power Plan (CPP). The assumptions used in this case are generally consistent with those used in the EPA Base Case, except the use of new coal supply curves prepared for Base Case A analysis.

In addition to Base Case A, Vulcan also analyzed two CPP cases which incorporate the final CPP released in August 2015. The CPP is designed to reduce CO_2 emissions from existing fossil generation sources within the power sector. In Vulcan's analysis, the CPP Mass Case allows existing and new units to comply with the CPP constraints, and the CPP Rate Case only constrains existing fossil units. New units are included in the mass case to address leakage concerns raised by EPA in the final CPP. Both CPP cases assume regional credit trading under the regional trading structure below.

- West (WECC): CA, WA, OR, ID, MT, UT, NV, CO, WY, NM, AZ
- North Central (MISO): ND, SD, IA, MN, WI, MO, IL, IN, MI
- South Central (SPP + ERCOT): NE, KS, OK, AR, TX, LA
- Southeast (SERC + FL): KY, NC, SC, TN, MS, AL, GA, FL
- East Central (PJM): OH, PA, WV, MD, DE, NJ, VA
- Northeast (NPCC): NY, RI, MA, CT, NH, VT, ME

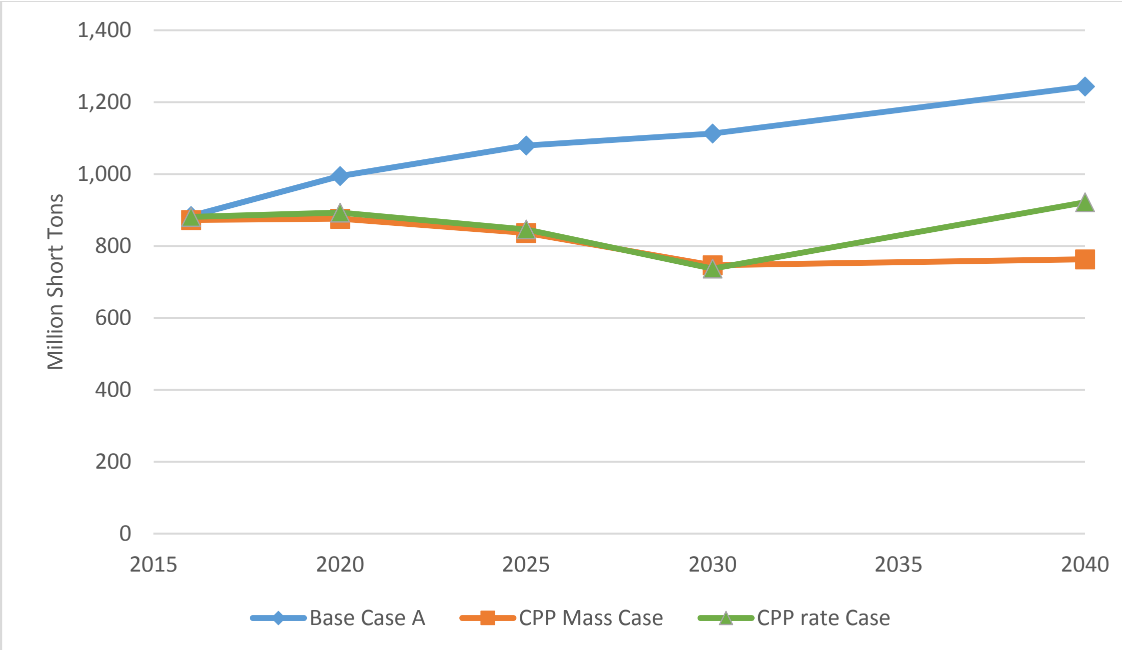
The incorporation of the CPP leads to differences between the Base Cases. The following sections provide an overview of the coal market results from the Base Case A and the CPP Base Cases.

Impacts on Coal Markets

Coal Production

The addition of the CPP program leads to a decrease in coal production in the CPP Mass Case compared to Base Case A due to the limitations on CO_2 emissions as well as overall lower load growth. Total US coal production declines by 243 million tons or 22% by 2025 and remains at or just over 33% lower in 2030 and 2040 in the CPP Mass Case. Of the 243 million ton decline in 2025, about 100 million tons of it is from coal produced in federal lands. The CPP Rate Case experiences a similar decrease in coal production as the CPP Mass Case. In the CPP Rate Case, total US coal production declines by 233 million tons or 22% by 2025, and coal production is 34% lower in 2030 compared to Base Case A. However, after 2030 coal production in the CPP Rate Case is higher than the CPP Mass Case, with only a 26% decrease in coal production compared to Base Case A in 2040. The increase beyond 2030 is driven by a difference in how the mass and rate based structures work. Under a mass based program emissions are capped at a finite amount. This limits the ability to generate from fossil sources, particularly coal. Under a rate based lb/MWh program, emissions at fossil sources can effectively be offset by emissions from cleaner sources. In the rate based program, as additional renewables and EE are added to the system, coal can continue to generate harder than under the mass based program. For example, if the state has an average rate of 1,000 lb/MWh, coal with a 2,000 lb/MWh rate can generate 1 MWh for every 1 MWh of non-emitting generation.

Exhibit 6: Coal Production – US



In Base Case A, total coal production increases steadily in the US. With the addition of the CPP, coal production decreases for all basins when the CPP is implemented in 2022. Northern Appalachia and Powder River Basin are the two coal supply regions that are affected most by the CPP. Around 40% of total US production reduction comes from Powder River Basin between 2020 and 2040 when the CPP is in place.

Exhibit 7: Coal Production by Basin, Deltas and % Change, CPP Mass Case Relative to Base Case A

Coal Supply Region	Delta (Million Short Tons)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	5	-9	-4	-7	-42	3%	-7%	-3%	-6%	-24%
Northern Appalachia (NAPP)	-9	-28	-42	-73	-82	-7%	-19%	-23%	-33%	-32%
Illinois Basin (ILB)	-3	-12	-33	-63	-96	-2%	-8%	-20%	-35%	-47%
Powder River Basin (PRB)	-3	-47	-107	-147	-173	-1%	-12%	-25%	-34%	-39%
Rocky Mountains	0	-7	-11	-16	-19	-1%	-20%	-29%	-42%	-41%
All other U.S. Regions	-1	-16	-45	-59	-68	-1%	-13%	-36%	-48%	-55%
Total	-11	-119	-243	-366	-481	-1%	-12%	-22%	-33%	-39%

Exhibit 8: Coal Production by Basin, Deltas and % Change, CPP Rate Case Relative to Base Case A

Coal Supply Region	Delta (Million Short Tons)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	5	-10	-5	-9	-30	3%	-8%	-3%	-8%	-17%
Northern Appalachia (NAPP)	-5	-25	-37	-69	-43	-4%	-17%	-21%	-31%	-17%
Illinois Basin (ILB)	-2	-13	-32	-64	-62	-1%	-8%	-19%	-36%	-30%
Powder River Basin (PRB)	-2	-40	-110	-163	-127	-1%	-10%	-26%	-38%	-29%
Rocky Mountains	1	-2	-5	-8	-10	4%	-5%	-15%	-21%	-22%
All other U.S. Regions	0	-12	-44	-63	-51	0%	-10%	-35%	-51%	-41%
Total	-3	-102	-233	-375	-322	0%	-10%	-22%	-34%	-26%

Exhibit 9: Coal Production on Western Federal Lands, Deltas and % Change, CPP Mass Case Relative to Base Case A

State	Delta (Million Short Tons)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0	1	-3	-5	-4	3%	10%	-28%	-49%	-33%
Utah	0	-3	-1	0	-3	-1%	-22%	-5%	-2%	-30%
Montana	3	-3	-3	-7	-10	11%	-8%	-10%	-26%	-42%
Wyoming	-7	-41	-93	-109	-113	-2%	-12%	-28%	-34%	-38%
Total	-3	-46	-100	-122	-130	-1%	-12%	-26%	-33%	-37%

Exhibit 10: Coal Production on Western Federal Lands, Deltas and % Change, CPP Rate Case Relative to Base Case A

State	Delta (Million Short Tons)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0	0	-3	-4	-2	0%	2%	-24%	-37%	-14%
Utah	0	-1	-1	0	-3	-2%	-11%	-5%	0%	-30%
Montana	3	-2	-3	-7	-9	10%	-6%	-11%	-27%	-35%
Wyoming	-4	-33	-91	-123	-72	-2%	-10%	-28%	-38%	-24%
Total	-2	-37	-98	-135	-85	0%	-9%	-25%	-36%	-25%

Coal Prices

With the addition of the CPP, coal prices in the Powder River Basin decrease in general.

Exhibit 11: Coal Prices from Western Coal Producing States, Deltas and % Change, CPP Mass Case Relative to Base Case A

State		Delta (2012$/Short Ton)					% Change				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	-0.6	-1.5	-1.8	-2.1	-3.1	-2%	-4%	-4%	-5%	-8%
Utah	0.9	-0.6	-1.0	-1.2	0.0	0.0	-1%	-2%	-3%	0%	0%
Montana	0.8	-1.3	-2.1	-1.9	-1.2	-0.5	-8%	-12%	-10%	-7%	-3%
Wyoming	0.8	-0.9	-1.0	-1.5	-1.7	-2.2	-7%	-7%	-11%	-12%	-14%

Exhibit 12: Coal Prices from Western Coal Producing States, Deltas and % Change, CPP Rate Case Relative to Base Case A

State		Delta (2012$/Short Ton)					% Change				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	-0.3	-1.0	-1.2	-1.3	-2.0	-1%	-2%	-3%	-3%	-5%
Utah	0.9	-0.3	-0.4	-1.1	0.0	0.0	-1%	-1%	-2%	0%	0%
Montana	0.8	-1.1	-1.8	-1.6	-1.6	-0.4	-7%	-10%	-9%	-9%	-2%
Wyoming	0.8	-0.7	-0.8	-1.2	-1.3	-1.7	-5%	-6%	-9%	-9%	-11%

Coal Exports

Among the Powder River Basin states, only Montana exports coal in the model, and total coal exports remain the same after the CPP is incorporated.

Chapter 4: Base Case A: Results for Policy Scenarios

Chapter 4A: Federal Coal Adder ($2.50/Ton) Policy Cases

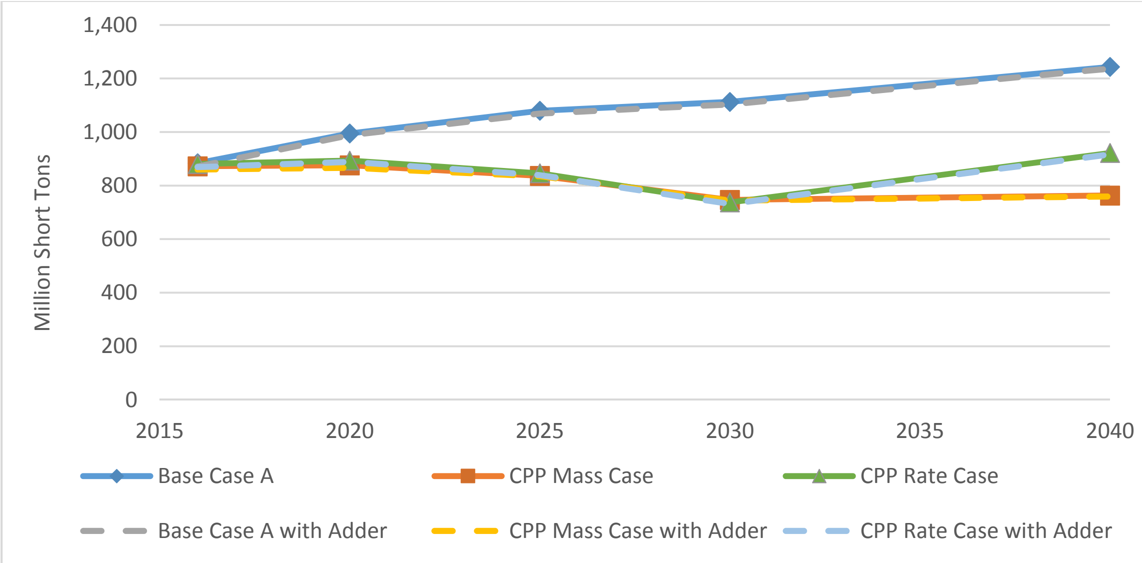
As discussed, Vulcan analyzed a Policy case with $2.50/ton added to coals mined on federal lands, as described in the Background and Assumptions section of this report. The $2.50/ton adder was applied to three Base Cases: Base Case A, no CPP (referred to as "Base Case A" in Chapter 4A), Base Case A, CPP with mass-based regional trading (referred to as "CPP Mass Case" in Chapter 4A, and Base Case A, CPP with rate-based regional trading (referred to as "CPP Rate Case" in Chapter 4A). The following sections compare the results of the Policy Cases to their corresponding Base Cases.

Impacts on Coal Markets

Coal Production

Total US coal production decreases by less than 1% when the Adder is applied on Base Case A. The average decrease in production levels of reporting years is 7.9 million short tons. Similarly, total US coal production decreases when the Adder is included in CPP Mass Case and CPP Rate Case. On average, CPP Mass Case leads to a drop of 6.0 million short tons on average, and the average decrease is 5.5 million short tons in CPP Rate Case with Adder. Exhibit 13 shows the coal production for Base Case A and CPP Cases and their corresponding cases with the $2.50/ton adder.

Exhibit 13: Coal Production – US, All Cases



With the addition of the $2.50/ton adder on coal mined on federal lands, the changes in total coal production between cases with and without the adder are small. The differences between the CPP Cases and the CPP Cases with Adder are further minimized, as the demand for coal decreases with the implementation of the CPP.

While total US coal production changes less than one percent between cases when the $2.50/ton adder is applied, there are shifts in coal produced in different coal supply regions. The exhibits below show the shift in coal production by supply region between cases with adder and their corresponding base cases.

Exhibit 14: Coal Production by Basin, Deltas and % Change, Base Case A with Adder Relative to Base Case A

Coal Supply Region	Delta (Million Short Tons)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	2	0	0	0	1	1%	0%	0%	0%	0%
Northern Appalachia (NAPP)	2	5	4	7	2	1%	3%	2%	3%	1%
Illinois Basin (ILB)	2	0	1	0	8	2%	0%	0%	0%	4%
Powder River Basin (PRB)	-16	-17	-21	-23	-16	-5%	-4%	-5%	-5%	-4%
Rocky Mountains	-2	-1	0	-1	-4	-8%	-2%	0%	-2%	-9%
All other U.S. Regions	1	7	6	7	2	1%	6%	5%	6%	2%
Total	-12	-6	-10	-9	-6	-1%	-1%	-1%	-1%	-1%

Exhibit 15: Coal Production by Basin, Deltas and % Change, CPP Mass Case with Adder Relative to CPP Mass Case

Coal Supply Region	Delta (Million Short Tons)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	0	0	1	1	0	0%	0%	0%	1%	0%
Northern Appalachia (NAPP)	3	2	2	1	4	2%	2%	1%	0%	2%
Illinois Basin (ILB)	0	1	0	3	3	0%	1%	0%	3%	3%
Powder River Basin (PRB)	-15	-12	-11	-11	-8	-4%	-3%	-3%	-4%	-3%
Rocky Mountains	-2	-2	-1	-1	-5	-6%	-7%	-5%	-4%	-17%
All other U.S. Regions	1	1	8	5	3	1%	1%	9%	7%	6%
Total	-12	-9	-2	-3	-3	-1%	-1%	0%	0%	0%

Exhibit 16: Coal Production by Basin, Deltas and % Change, CPP Rate Case with Adder Relative to CPP Rate Case

Coal Supply Region	Delta (Million Short Tons)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	2	2	-2	0	3	1%	2%	-2%	0%	2%
Northern Appalachia (NAPP)	2	2	1	1	3	1%	1%	1%	0%	2%
Illinois Basin (ILB)	1	1	0	2	3	0%	1%	0%	2%	2%
Powder River Basin (PRB)	-18	-16	-13	-13	-14	-5%	-4%	-4%	-5%	-5%
Rocky Mountains	-2	-1	0	0	-5	-8%	-3%	-1%	-1%	-15%
All other U.S. Regions	5	8	8	4	6	5%	8%	10%	7%	9%
Total	-12	-4	-7	-6	-5	-1%	0%	-1%	-1%	-1%

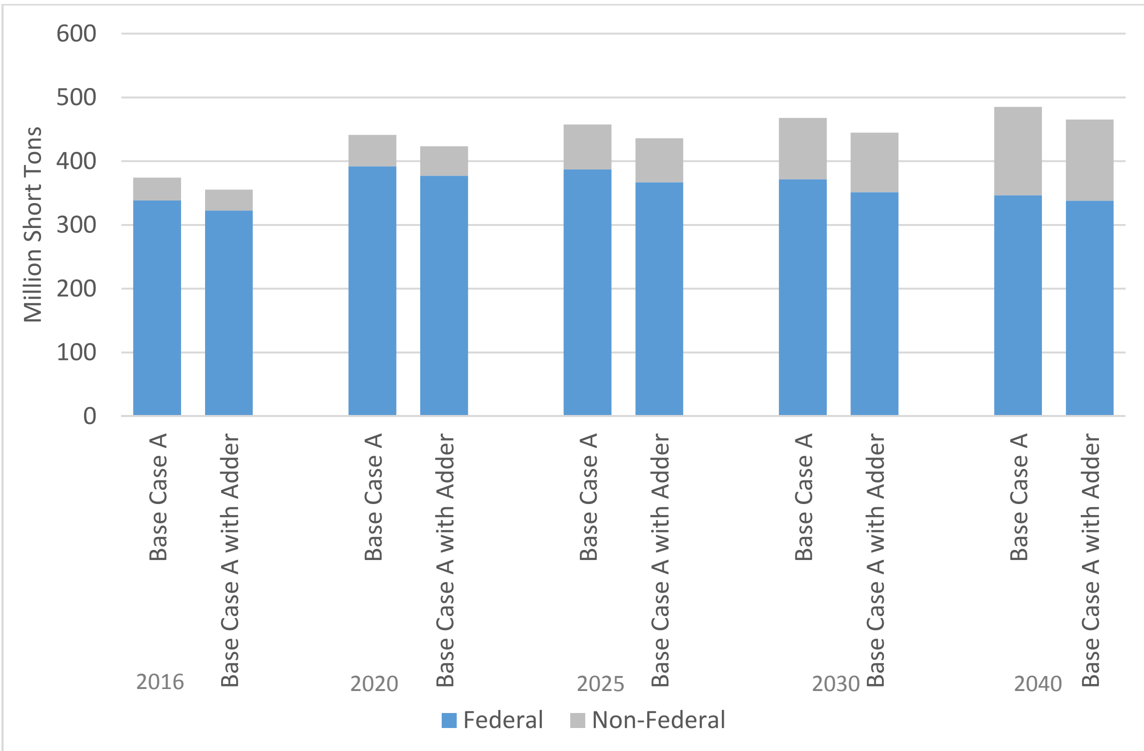
With the adder, all cases see a decrease in coal production in PRB and Rocky Mountains supply regions, where the majority of federal coal production takes place. The adder has a larger impact on Base Case A, as the demand for coal decreases with the implementation of the CPP. In the CPP Mass Case with the $2.50/ton adder, coal production from the Powder River Basin and Rocky Mountains decrease on average by 6.5 million short tons per year, while production levels increase in Central Appalachia, Northern Appalachia, Illinois Basin, and other regions by a collective average of 1.8 million short tons per year. In the CPP Rate Case with the $2.50/ton adder, coal production from the Powder River Basin and Rocky Mountains decrease on average by 8 million short tons per year, while production levels increase in Central Appalachia, Northern Appalachia, Illinois Basin, and other regions by a collective average of 2.6 million short tons per year.

In Base Case A, the $2.5/ton adder causes a decrease in coal production from the Powder River Basin. Total coal production in CO, UT, MT, and WY decrease by a collective average of 19.0 million short tons per year, but the share of federal and non-federal coal production remains the same, as seen in Exhibit 15. In the four states of interest, the adder leads to decreased coal production and increased coal production elsewhere in the US.

At existing mines in the four states of interest, there are non-federal reserves of close to 1,000 million tons, and federal coal reserves of about 8,300 million tons. Additional non-federal coal reserves in Wyoming are approximately 30,000 million tons, while reserves on federal lands are about 360,000 million tons. Not all of these reserves are likely to be economic at current coal prices; however, it provides an indication of the vast quantities of coal available.

Between Base Case A with and without the adder, the adder leads to a 5.5% decrease in coal production on federal lands in 2030 (Exhibit 17). Coal production on non-federal lands in Powder River Basin sees a similar trend. In 2030, the adder leads to a 5.4% decrease in federal coal production under CPP Mass Case and a 4.4% decrease in CPP Rate Case.

Exhibit 17: Coal Production on Federal & Non-Federal Lands – Base Case A & Base Case A with Adder



The cases with the CPP follow a similar trajectory, but the shift is smaller mainly due to the overall decrease in demand for coal (Exhibit 18).

Exhibit 18: Coal Production on Federal & Non-Federal Lands – CPP Mass Case and CPP Mass Case with Adder

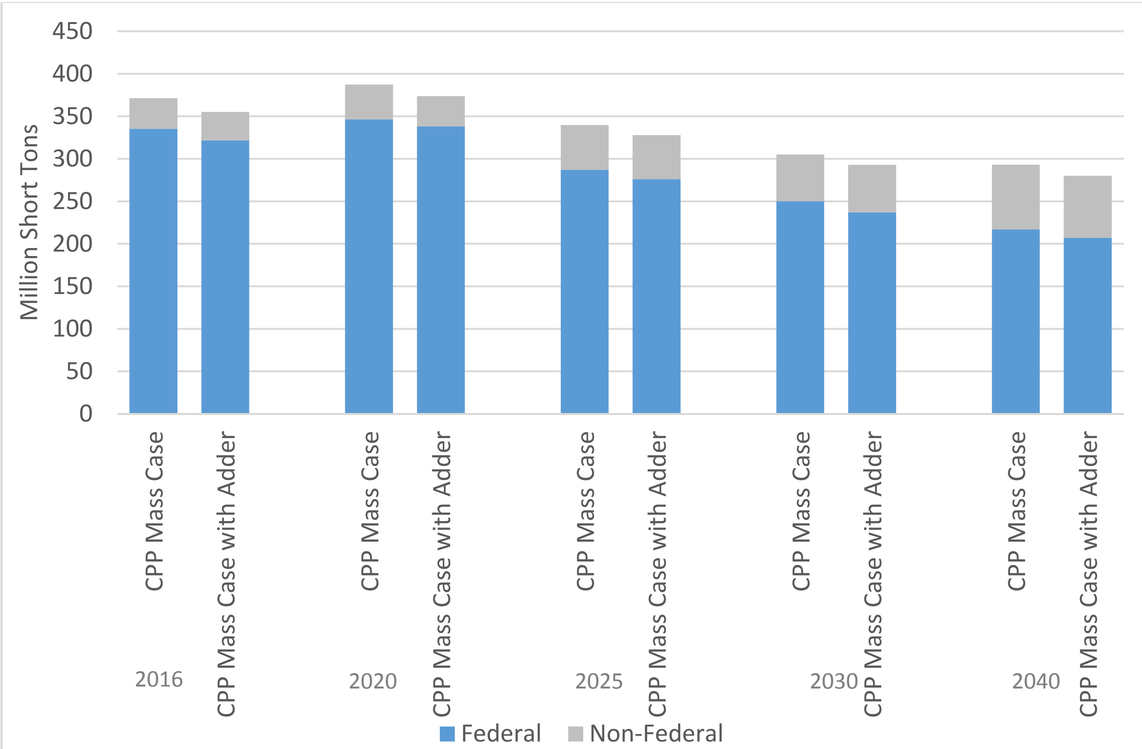
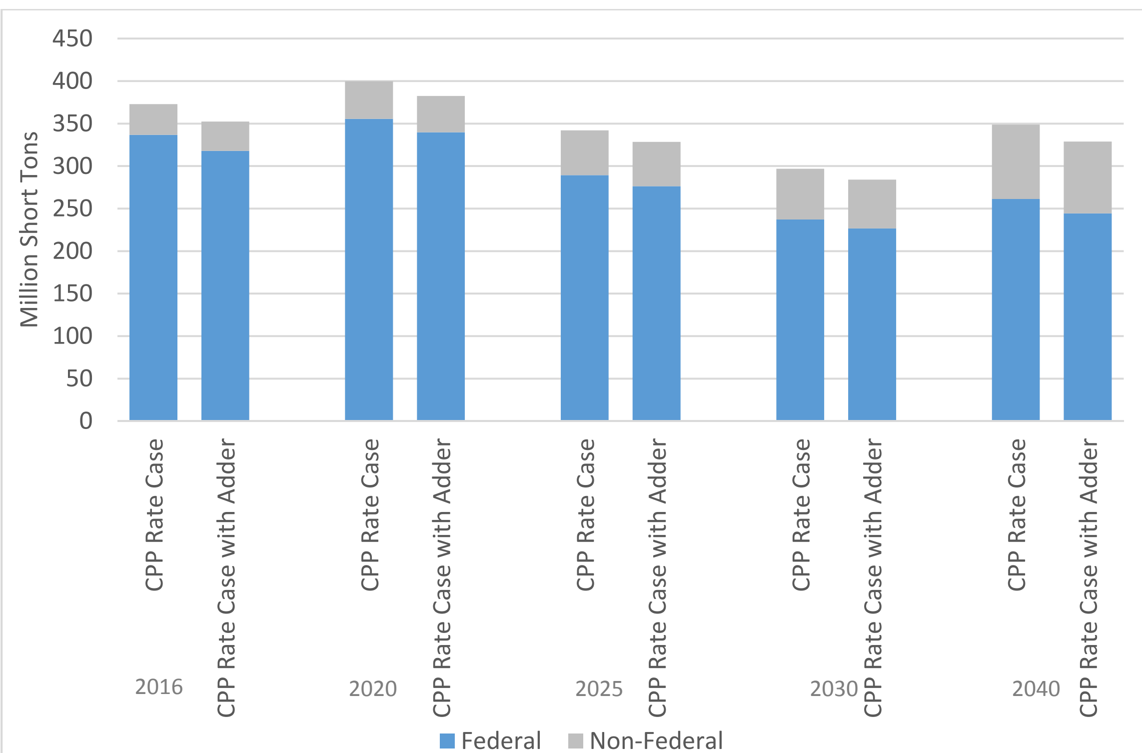


Exhibit 19: Coal Production on Federal & Non-Federal Lands – CPP Rate Case and CPP Rate Case with Adder



Coal Prices

After the $2.50/ton adder is included, coal prices increase by $0.6 to $1.9/ton in the four states of interest in Base Case A (Exhibit 20). In the CPP Mass Case, coal prices increase by $1.3 to $2.1/ton (Exhibit 21), and in the Rate Case they increase by $0.5 to $2.2/ton (Exhibit 22).

Exhibit 20: Coal Prices, Deltas and % Change, Base Case A with Adder Relative to Base Case A

State		Delta (2012$/Short Ton)					% Change				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	1.6	1.5	1.4	1.0	0.6	4.3%	3.8%	3.5%	2.3%	1.4%
Utah	0.9	1.8	1.6	1.7	1.5	1.4	4.0%	3.5%	3.7%	3.3%	3.3%
Montana	0.8	1.7	1.4	1.5	1.4	1.3	10.1%	7.9%	8.1%	7.3%	6.6%
Wyoming	0.8	1.9	1.9	1.7	1.6	1.5	14.9%	14.0%	12.5%	10.9%	9.8%

Exhibit 21: Coal Prices, Deltas and % Change, CPP Mass Case with Adder Relative to CPP Mass Case

State		Delta (2012$/Short Ton)					% Change				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	1.6	1.5	1.4	1.4	1.3	4.3%	4.0%	3.7%	3.4%	3.4%
Utah	0.9	1.8	1.7	1.7	1.5	1.4	3.9%	3.6%	3.9%	3.3%	3.3%
Montana	0.8	2.1	2.1	2.0	1.3	1.4	13.9%	13.0%	11.9%	7.4%	7.4%
Wyoming	0.8	2.1	2.0	1.9	1.8	1.6	17.0%	15.5%	15.5%	14.3%	11.8%

Exhibit 22: Coal Prices, Deltas and % Change, CPP Rate Case with Adder Relative to CPP Rate Case

State		Delta (2012$/Short Ton)					% Change				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	1.6	1.5	1.4	0.9	0.5	4.3%	3.9%	3.6%	2.3%	1.3%
Utah	0.9	1.8	1.7	1.6	1.5	1.4	3.9%	3.6%	3.6%	3.3%	3.3%
Montana	0.8	2.2	2.0	1.9	1.6	1.3	14.1%	12.2%	11.6%	9.5%	6.5%
Wyoming	0.8	2.1	1.9	1.9	1.6	1.6	16.8%	14.5%	15.3%	12.4%	11.4%

Coal Exports

With the $2.50/Ton adder, the total exports remain the same from Montana, which is the only state of interest that is exporting coal in the model. Montana is the only exporting state because its mines are closer to export terminals than other PRB coal and the coal in Montana has a higher heat content, which results in lower delivered costs per unit of heating value. For example, if the delivered cost of coal is $60/ton, then the cost for an 8,800 Btu/lb coal, which is a typical heat content in Wyoming, would be $3.41/MMBtu, while the cost of a 9,300 Btu/lb coal, which is representative of some coal in Montana, would be $3.22/MMBtu.

Impacts on Capacity and Generation Mix

EPA assumes that the addition of the CPP will lead to further development of energy efficiency programs, which leads to an overall decline in generation and a change in the overall generation mix relative to Base Case A (Exhibit 23). By 2025, the first reporting year after the initiation of the CPP in 2022, with only the addition of a moderate amount of EE, total generation is similar between the Base and the CPP Cases. The implementation of the CPP, however, does lead to a shift in the overall generation mix. In 2025, in Base Case A coal represents 41% of total generation, while in the CPP Mass Case and CPP Rate Case, coal drops to 34%. By 2030, the EE in the CPP Cases leads to an 8% decrease in demand and therefore total generation. The decrease in demand is all met through a decrease in coal generation, which falls from 41% of the mix in Base Case A to 29% in the CPP Mass Case and CPP Rate Case.

Similar to the total US coal production results, the generation mix between each Base Case and its corresponding Policy Case remains relatively unchanged. The increased production from non-federal coal offsets the reductions in the federal coal, leaving national coal-fired generation unchanged.

Exhibit 23: Generation Mix – US, Base Case A and CPP Mass Case

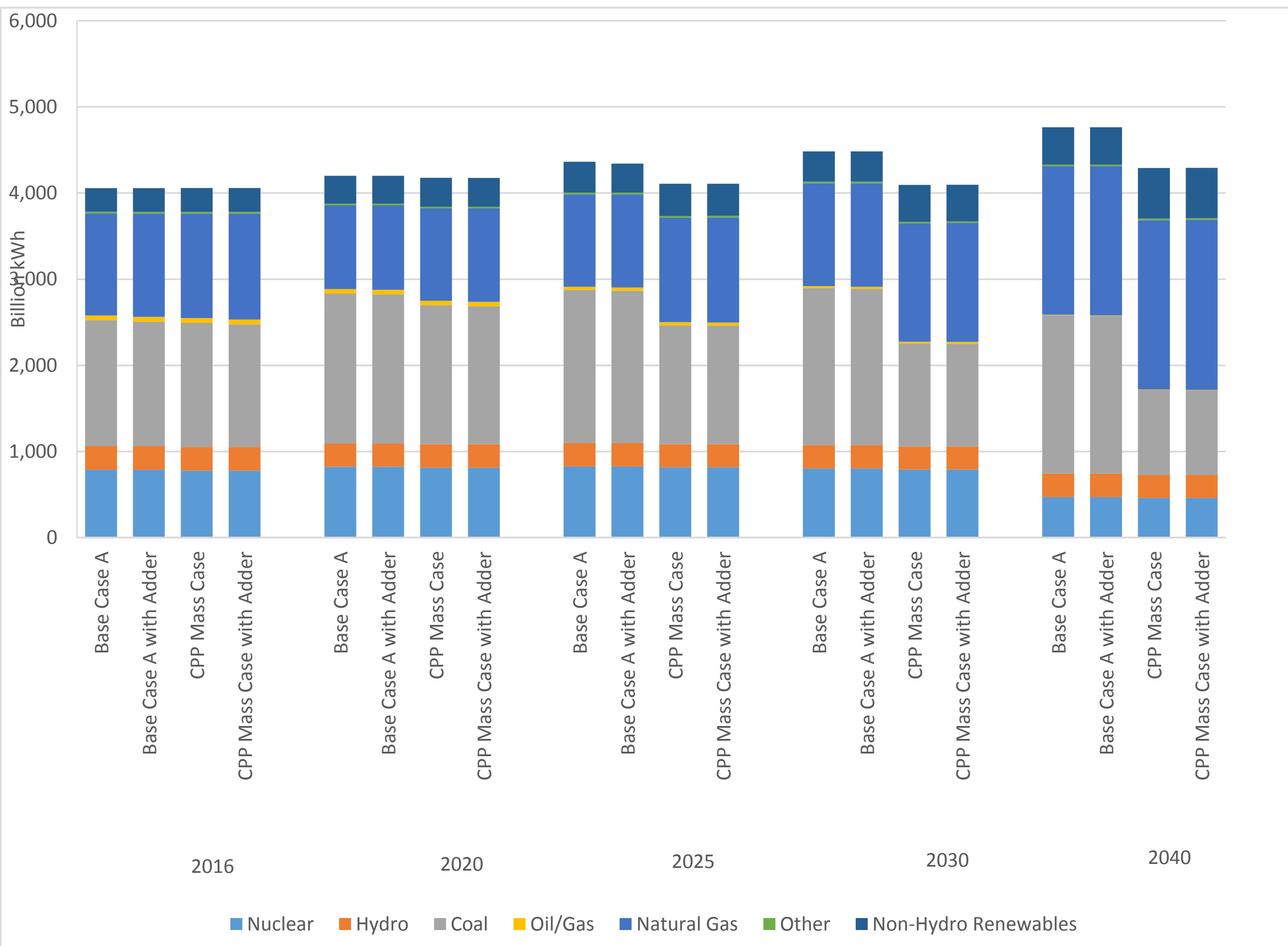
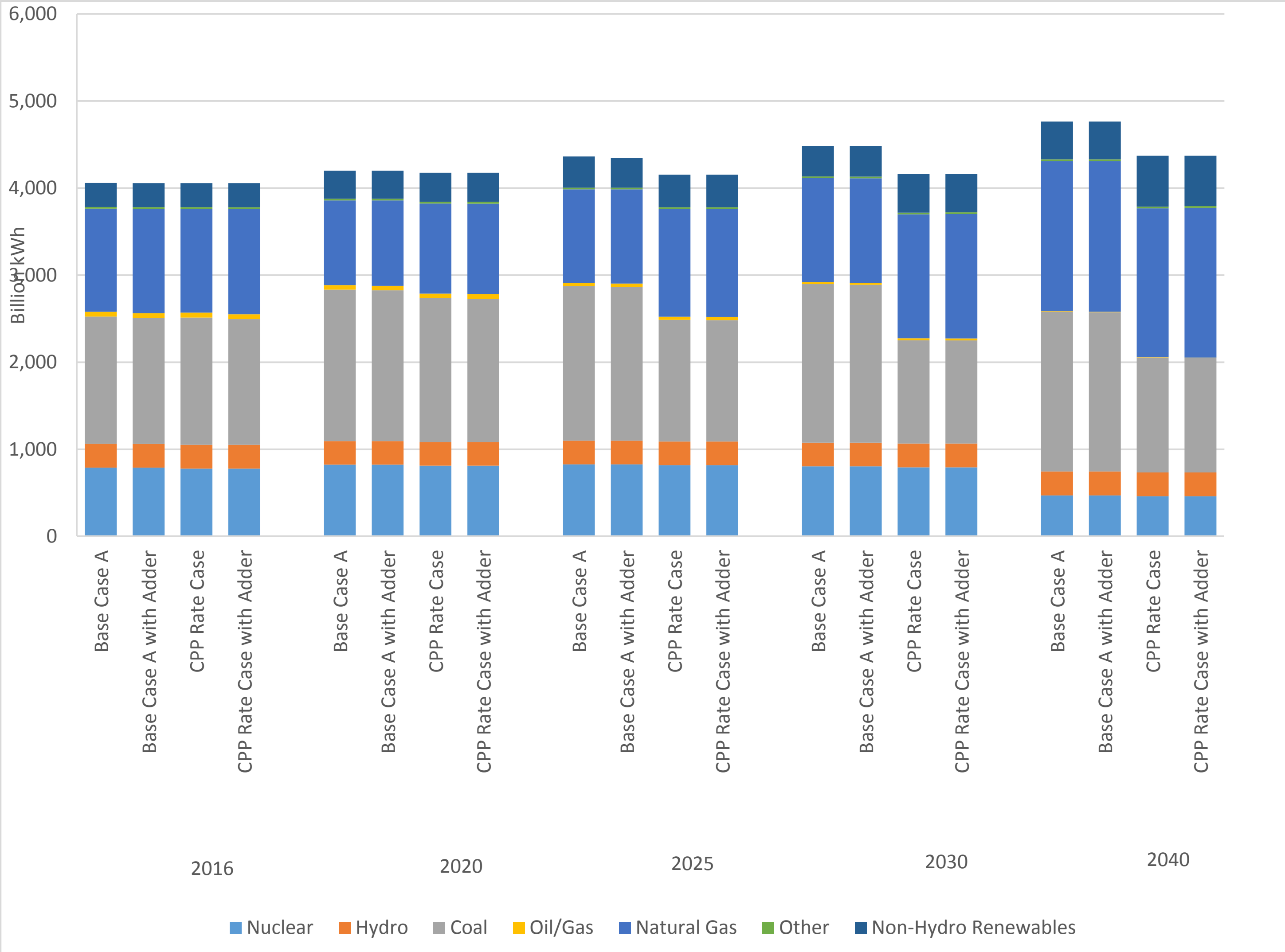


Exhibit 24: Generation Mix – US, Base Case A and CPP Rate Case

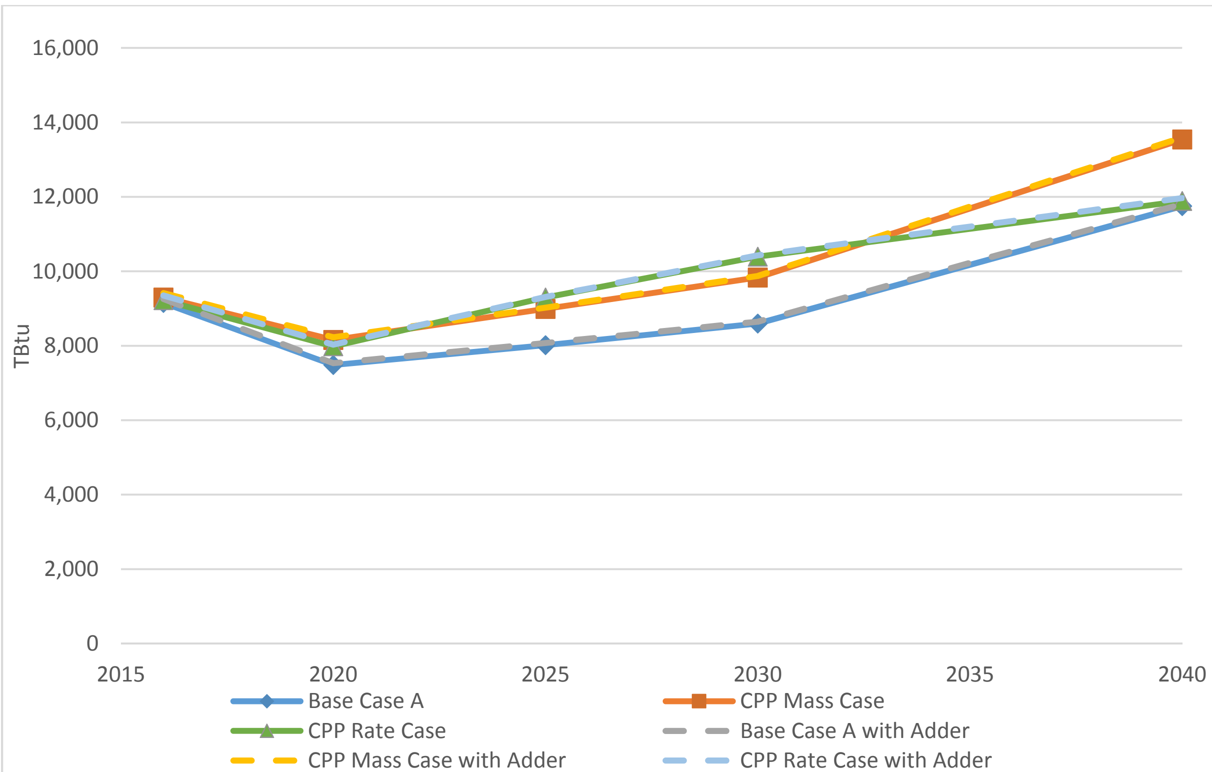


Impacts on Natural Gas Markets

In Base Case A, electric sector natural gas demand declines between 2016 and 2020 as coal consumption increases due to coal being the lower cost alternative (Exhibit 25). After 2020, electric sector natural gas demand increases as it is the fuel of choice for new power generation sources as overall electric demand increases.

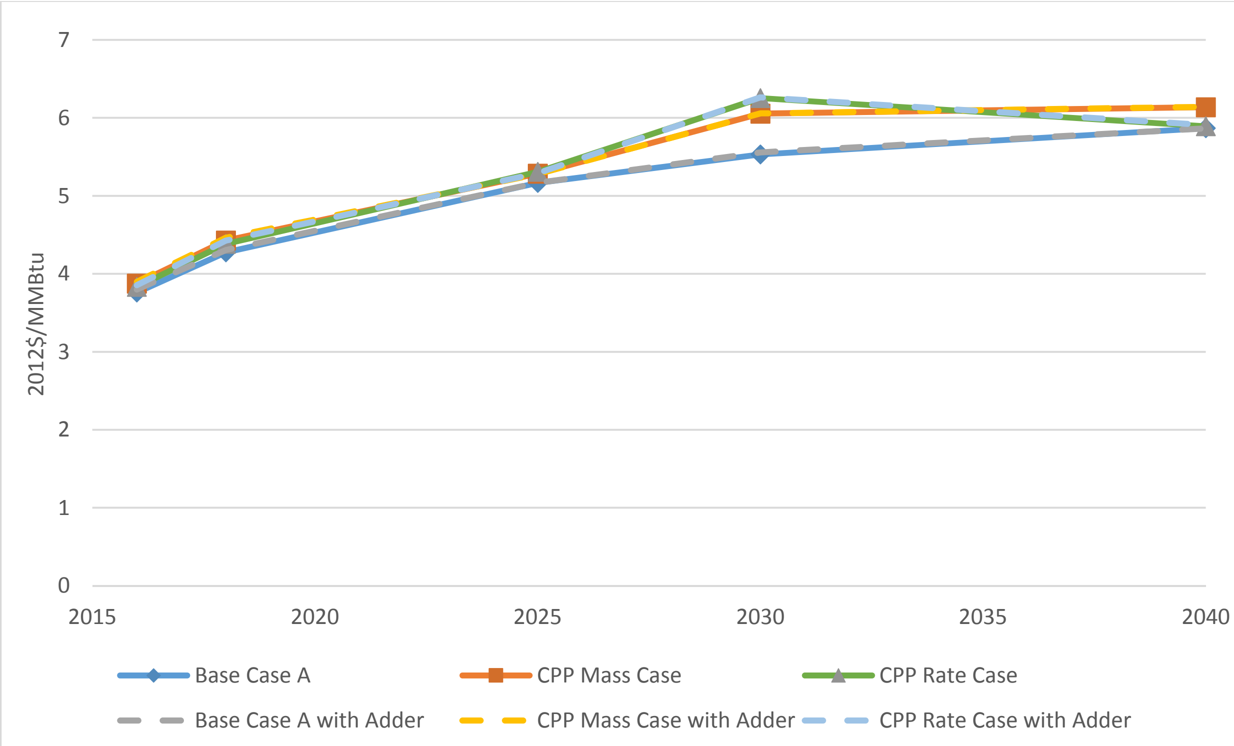
The shift from coal to natural gas leads to an increase in natural gas demand in the early years of the CPP prior to the full implementation of the EE programs. Between 2020 and 2030, gas demand is increasing in the CPP cases. Over the long-term, natural gas generation increases due to the retirement of nuclear units as they reach 60 years of age. In 2025, the gas demand is 16% higher in the CPP Mass Case than that in Base Case A, and 12% higher in the CPP Rate Case. By 2030, the trend flips, and the gas demand is 14% higher in the CPP Mass Case compared to Base Case A, and 21% higher in the CPP Rate Case. By 2040, the demand for gas from CPP Rate Case converges with Base Case A, while the gas demand continues to increase in the CPP Mass Case. The divergent trend of gas demand post 2030 in both CPP Cases is mainly due to the different impact mass and rate limits bring to fossil fuel generating sources. Mass caps more strongly incentivize shifting from coal-fired resources, while rate limits allow zero-emission sources such as renewable sources and energy efficiency to comply with the standards, hence allowing more coal-fired sources to remain as part of the generation portfolio. On the other hand, the demand for natural gas is more or less unchanged between each Base Case and its corresponding $2.50/ton adder Policy Case.

Exhibit 25: Power Sector Natural Gas Demand – US, All Cases



In addition to unchanged natural gas demand between cases with and without the $2.50/ton adder, Henry Hub price forecasts between each Base Case and its corresponding Policy Case remain unchanged. Similar to natural gas demand, the trajectory of Henry Hub prices also mirrors the gas demand trend. By 2040, Henry Hub prices converge between Base Case A and CPP Rate Case, while CPP Mass Case reaches a higher price than the two other cases.

Exhibit 26: Henry Hub Prices, All Cases



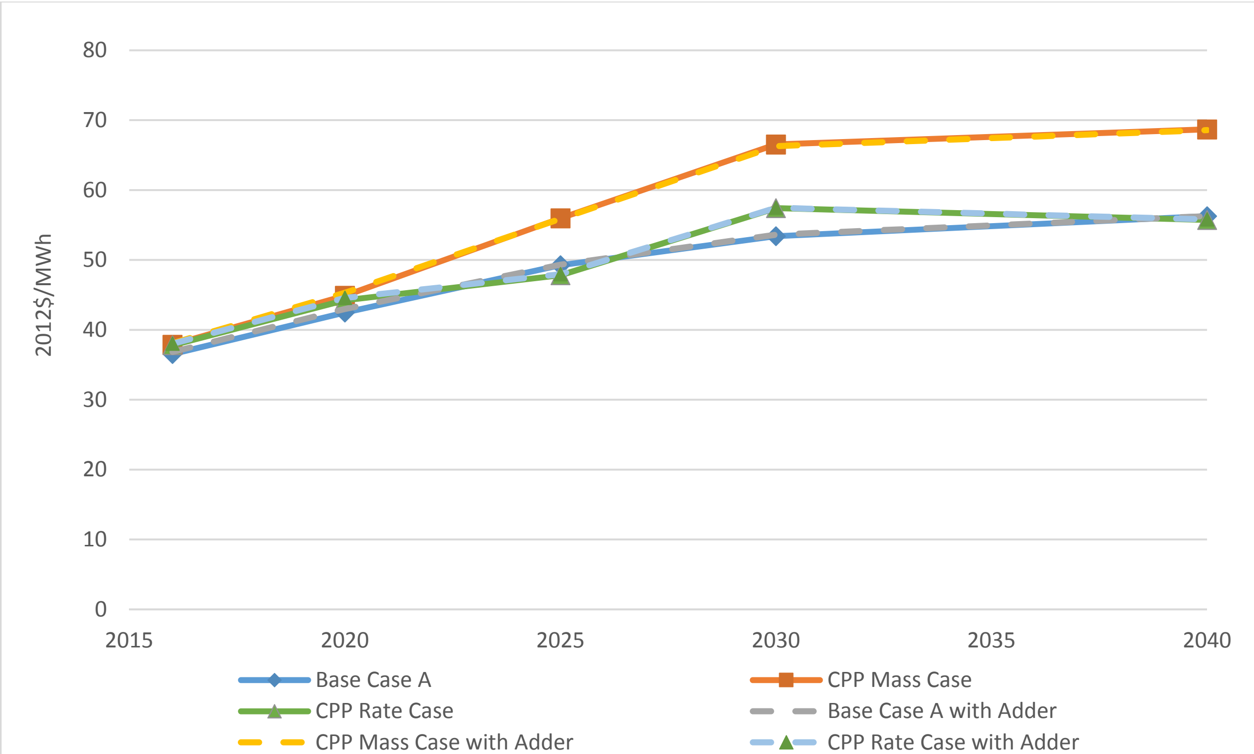
Impacts on Firm Wholesale Power Prices

The firm wholesale power prices represent both energy and capacity prices in organized markets such as PJM. For areas not in an organized market, the firm wholesale power price represents the cost for power including scarcity pricing.

In 2030, the addition of the CPP Mass program leads to a 25% increase in power prices due to primarily to the inclusion of the CO_2 program (Exhibit 27), while a rate based program leads to a 7% decrease in power prices in 2030. These differences are driven by the difference in the policy construct. When NGCC is on the margin and setting the wholesale power price it can lead to a reduction in the wholesale power price since it is receiving a credit. Under a mass based program it is charged for its emissions which results in higher wholesale power prices.

Power prices are unchanged between each Base Case and its corresponding Policy Case.

Exhibit 27: Firm Wholesale Power Prices – US, All Cases

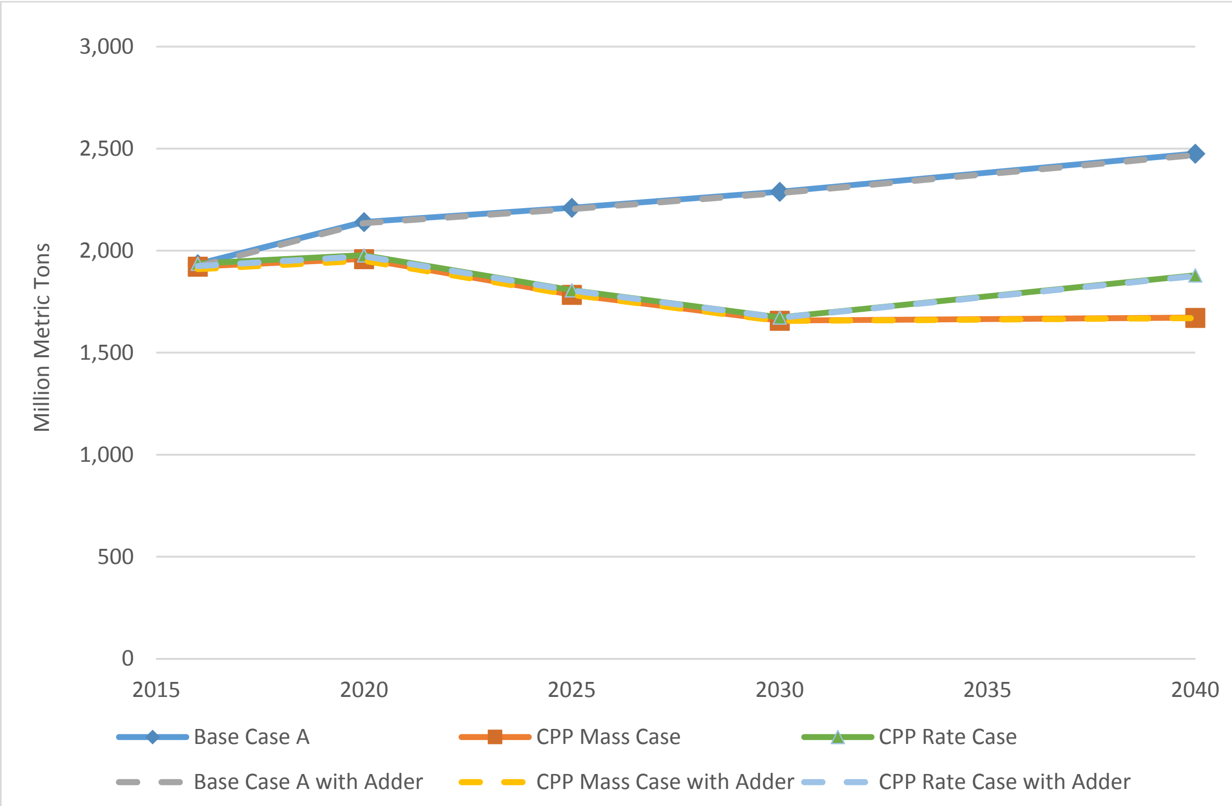


CO_2 Emissions

The CPP Mass and CPP Rate Cases have similar trajectories of CO_2 emissions from 2016 to 2030. The addition of the CPP in the CPP Mass Case leads to a 19% decline in total CO_2 emissions from generating sources fueled by coal, natural gas, oil, and biomass by 2025 relative to Base Case A (Exhibit 28). By 2030, total CO_2 emissions from these sources are 28% lower compared to Base Case A. In the CPP Rate Case there is an 18% and 27% decline in total CO_2 emissions compared to the 2025 and 2030 Base Case A, respectively. In the long run post 2030, CPP Rate Case forecasts higher CO_2 emissions, as Rate Case results in less coal to gas switching in the generation portfolio. Under a mass cap covering existing and new sources, CO_2 emissions remain flat after 2030. On the other hand, the rate limit case allows existing fossil fuel resources to generate more as energy efficiency and renewable sources are included to comply with standards.

CO_2 emissions are unchanged between each Base Case and its corresponding Policy Case.

Exhibit 28: CO_2 Emissions – US, All Cases



Chapter 4B: Social Cost of Carbon Policy Cases

ICF also analyzed a total of nine Social Cost of Carbon (SCC) Policy Cases – three based on each of the Base Cases: Base Case A, no CPP (referred to as "Base Case A" in Chapter 4B), Base Case A, CPP with mass-based regional trading (referred to as "CPP Mass Case" in Chapter 4B), and Base Case A, CPP with rate-based regional trading (referred to as "CPP Rate Case" in Chapter 4B). These policy cases were derived through adders based on 20%, 50%, and 100% of the social cost of carbon, respectively, to Base Case A, and the same series of carbon adders to the CPP Base Cases. Vulcan provided assumptions of the 20%, 50% and 100% of social cost of carbon adders in 2015$/short ton (Exhibit 29)[3]. The social cost of carbon adders are phased in incrementally over a period in 10 years, starting in 2016.

Exhibit 29: Adders Based on Percentage of Social Cost of Carbon (2015$/Ton)

Run Year	20%	50%	100%
2016	$1.5	$3.8	$7.7
2018	$4.8	$12.1	$24.2
2020	$8.7	$21.7	$43.4
2025	$19.0	$47.4	$94.8
2030	$21.0	$52.4	$104.9
2040	$24.6	$61.5	$123.1

The following sections compare the results of the SCC Policy Cases to their corresponding Base Cases.

Impacts on Coal Markets

Coal Production

With the implementation of the SCC adders, total coal production in the US decreases as the percentage of the SCC adder applied increases (Exhibit 30). With the 20% SCC adder, in 2040, the decrease in total US coal production is 5%. When the SCC adder increases to 50%, the decrease is 18% in 2040, and under the 100% SCC adder, the decrease is 29% in 2040.

Since the SCC adders are applied to coal mined on federal lands in CO, MT, UT and WY, coal production in the Powder River Basin and Rocky Mountains decrease, while other regions remain relatively stable or see an increase in production. For instance, with the 50% SCC adder, in 2030, total production in the Powder River Basin and Rocky Mountains decrease by 259 million short tons, while total US coal production decreases by 209 million short tons. In other words, production in other basins increases to offset some of the declines in PRB production; however, the increases are not enough to fully offset the decline in PRB production.

When the SCC adders are applied to Base Case A, overall coal production continues to increase in the long run. In CPP Mass Case with SCC adders, coal production steadily decreases as the CPP is implemented as a mass cap. On the other hand, when the SCC adders are applied to the CPP Rate Case, coal production

[3] http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

decreases until 2030, then the total coal production level begins to increase, as additional energy efficiency and renewable resources allow more existing coal-fired sources to remain online.

Similar trends exist in both Base Case A and CPP Mass and Rate Cases (Exhibits 30-32). However, the difference between cases is smaller for CPP Cases associated cases, since the total coal demand is lower in these cases. Exhibits 31 through 36 show the absolute and percent change in coal production for all of the SCC cases.

Exhibit 30: Coal Production – US, Base Case A with SCC Adders

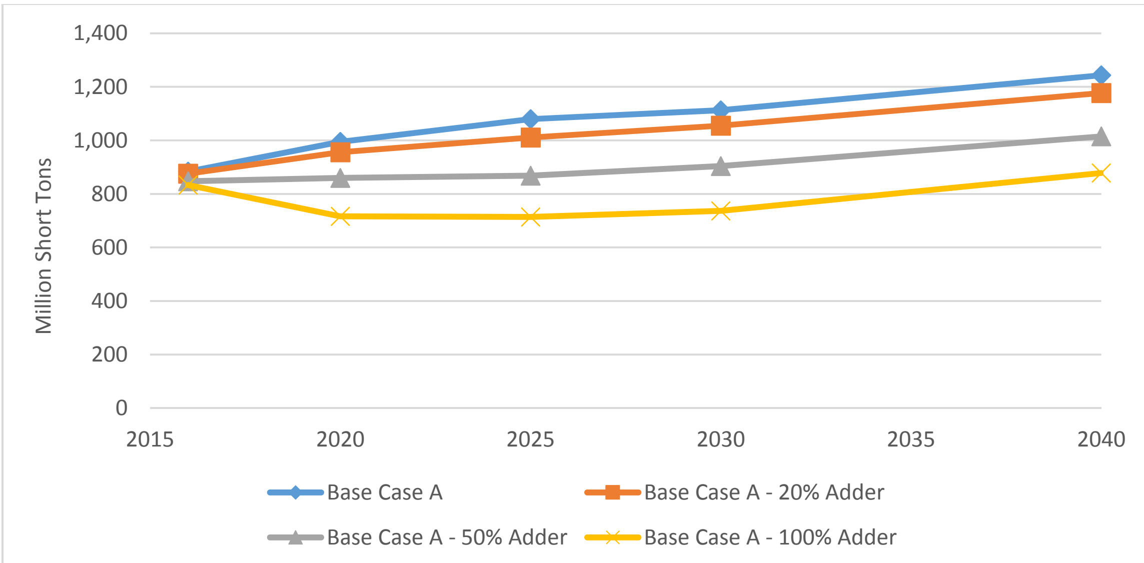


Exhibit 31: Coal Production – US, CPP Mass Cases with SCC Adders

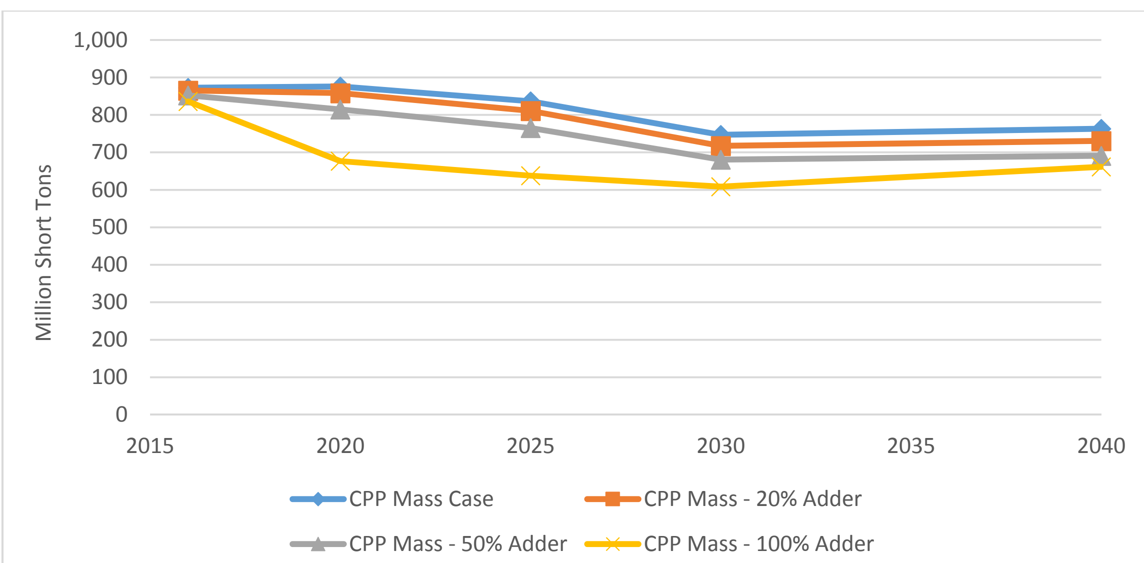


Exhibit 32: Coal Production – US, CPP Rate Cases with SCC Adders

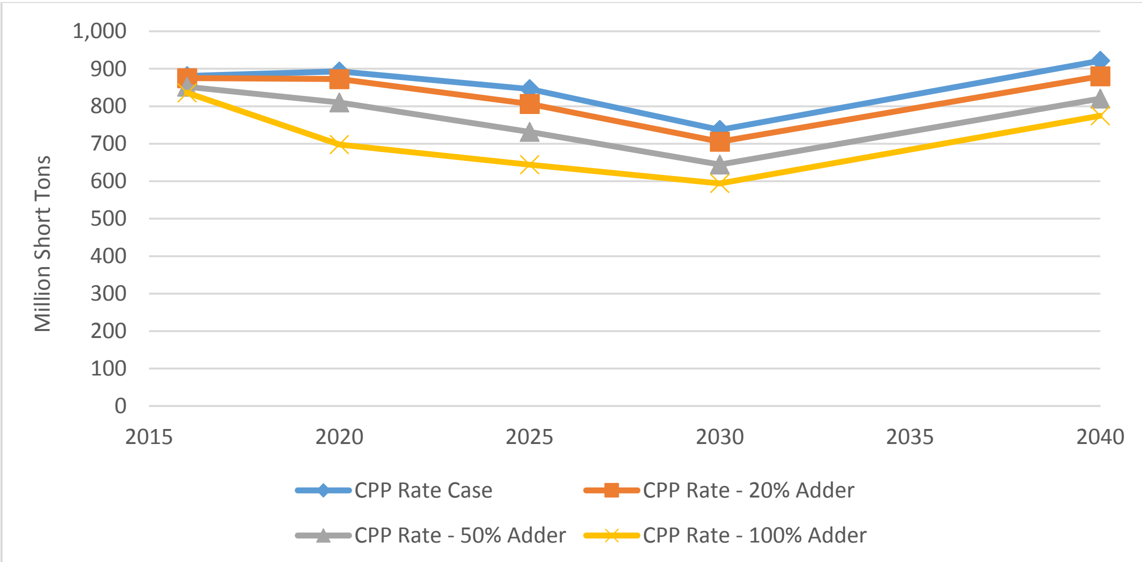


Exhibit 33: Coal Production by Basin Deltas, Base Case A with SCC Adders Relative to Base Case A (Million Short Tons)

Coal Supply Region	20%					50%					100%				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	3	2	-1	1	2	5	5	6	1	5	10	9	4	1	5
Northern Appalachia (NAPP)	4	8	24	22	7	12	16	30	25	18	18	22	37	30	23
Illinois Basin (ILB)	2	4	4	4	24	9	14	13	19	35	14	18	15	24	39
Powder River Basin (PRB)	-14	-57	-95	-86	-105	-60	-166	-256	-252	-292	-93	-316	-392	-406	-419
Rocky Mountains	3	-2	-5	-5	-6	1	-9	-9	-7	-4	-4	-14	-25	-19	-13
All other U.S. Regions	-4	7	5	6	10	-3	7	5	5	9	5	3	-5	-5	-1
Total	-7	-39	-68	-58	-66	-36	-135	-212	-209	-228	-50	-278	-365	-376	-366

Exhibit 34: Coal Production by Basin % Change, Base Case A with SCC Adders Relative to Base Case A

Coal Supply Region	20%					50%					100%				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	2%	1%	0%	1%	1%	3%	3%	4%	1%	3%	6%	7%	3%	1%	3%
Northern Appalachia (NAPP)	3%	5%	13%	10%	3%	9%	11%	16%	11%	7%	14%	15%	20%	13%	9%
Illinois Basin (ILB)	1%	3%	2%	2%	12%	7%	9%	7%	11%	17%	11%	12%	9%	13%	19%
Powder River Basin (PRB)	-4%	-14%	-23%	-20%	-24%	-17%	-41%	-61%	-59%	-66%	-27%	-78%	-93%	-95%	-95%
Rocky Mountains	10%	-4%	-13%	-14%	-13%	4%	-27%	-25%	-18%	-8%	-13%	-41%	-67%	-50%	-28%
All other U.S. Regions	-4%	5%	4%	5%	8%	-3%	6%	4%	4%	7%	5%	3%	-4%	-4%	-1%
Total	-1%	-4%	-6%	-5%	-5%	-4%	-14%	-20%	-19%	-18%	-6%	-28%	-34%	-34%	-29%

Exhibit 35: Coal Production by Basin Deltas, CPP Mass Case with SCC Adders Relative to CPP Mass Case (Million Short Tons)

Coal Supply Region	20%					50%					100%				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	1	1	0	2	-1	4	4	0	0	5	6	7	-2	-1	11
Northern Appalachia (NAPP)	7	5	7	4	12	14	17	28	22	27	23	28	34	33	31
Illinois Basin (ILB)	3	7	14	20	18	7	12	17	30	30	14	11	20	34	36
Powder River Basin (PRB)	-19	-35	-70	-78	-95	-51	-112	-160	-169	-200	-83	-254	-271	-250	-245
Rocky Mountains	0	-4	-4	-3	-2	1	-3	-1	1	8	-3	-6	-13	-4	5
All other U.S. Regions	1	9	27	26	34	4	20	46	50	57	7	15	33	48	61
Total	-7	-18	-26	-29	-32	-20	-61	-71	-66	-72	-36	-199	-199	-139	-102

Exhibit 36: Coal Production by Basin % Change, CPP Mass Case with SCC Adders Relative to CPP Mass Case

Coal Supply Region	20%					50%					100%				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	1%	1%	0%	1%	0%	2%	4%	0%	0%	4%	4%	5%	-1%	0%	8%
Northern Appalachia (NAPP)	6%	4%	5%	3%	7%	12%	15%	20%	15%	15%	19%	24%	24%	22%	17%
Illinois Basin (ILB)	3%	5%	11%	17%	17%	6%	8%	12%	26%	28%	11%	8%	15%	30%	34%
Powder River Basin (PRB)	-6%	-10%	-22%	-28%	-36%	-15%	-31%	-51%	-60%	-75%	-24%	-71%	-87%	-88%	-92%
Rocky Mountains	0%	-13%	-14%	-13%	-8%	5%	-11%	-5%	4%	31%	-10%	-23%	-50%	-17%	19%
All other U.S. Regions	1%	8%	33%	41%	62%	4%	19%	57%	77%	103 %	7%	15%	41%	75%	110%
Total	-1%	-2%	-3%	-4%	-4%	-2%	-7%	-9%	-9%	-9%	-4%	-23%	-24%	-19%	-13%

Exhibit 37: Coal Production by Basin Deltas, CPP Rate Case with SCC Adders Relative to CPP Rate Case (Million Short Tons)

Coal Supply Region	20%					50%					100%				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	3	6	-3	2	16	3	7	2	1	21	6	10	-1	0	21
Northern Appalachia (NAPP)	7	3	14	16	16	17	21	34	37	37	21	33	38	39	38
Illinois Basin (ILB)	2	9	16	19	23	4	14	32	32	48	12	14	31	36	57
Powder River Basin (PRB)	-19	-46	-82	-80	-113	-56	-130	-209	-190	-242	-83	-255	-282	-242	-292
Rocky Mountains	2	0	-1	-2	-4	2	-8	-4	-1	2	-4	-11	-20	-12	-4
All other U.S. Regions	-1	8	16	13	22	2	13	30	28	33	3	13	31	34	34
Total	-6	-20	-39	-32	-41	-29	-83	-115	-93	-101	-45	-195	-202	-143	-147

Exhibit 38: Coal Production by Basin % Change, CPP Rate Case with SCC Adders Relative to CPP Rate Case

Coal Supply Region	20%					50%					100%				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	2%	5%	-2%	2%	11%	2%	5%	1%	1%	15%	4%	8%	-1%	0%	15%
Northern Appalachia (NAPP)	6%	3%	10%	10%	7%	13%	18%	24%	24%	17%	17%	28%	26%	25%	18%
Illinois Basin (ILB)	1%	6%	11%	17%	16%	3%	10%	23%	28%	34%	9%	10%	23%	32%	40%
Powder River Basin (PRB)	-5%	-13%	-26%	-30%	-36%	-16%	-35%	-67%	-71%	-77%	-24%	-69%	-91%	-91%	-93%
Rocky Mountains	9%	-1%	-3%	-5%	-12%	6%	-23%	-14%	-3%	6%	-13%	-32%	-63%	-39%	-11%
All other U.S. Regions	-1%	7%	20%	22%	30%	2%	12%	36%	46%	46%	3%	12%	38%	57%	47%
Total	-1%	-2%	-5%	-4%	-4%	-3%	-9%	-14%	-13%	-11%	-5%	-22%	-24%	-19%	-16%

Coal mined on federal lands is affected by the SCC adders, particularly with the 50% and 100% SCC adders. In 2040, the 20% SCC adder leads to a 35% drop in coal mined on federal lands, while the 50% and 100% SCC adders have larger declines in federal coal production. The 50% adder leads to about a 78% decrease in federal coal production, while the 100% adder leads to a decline of almost 100% in 2040. Even with the 100% SCC adder, PRB coal production on federal lands is not completely eliminated. This is due in part to the ratios applied to mines that cover Federal and non-Federal land as well as some coal plants that remain online to meet generation needs and do not have the option to switch to an alternative coal.

Under the modeling assumptions regarding the comingling of federal and non-federal coal in logical mining units, coal cannot be preferentially mined on non-federal lands to substitute for declines in federal coal production. Therefore, when the SCC adders cause decreases in federal coal production, comingled non-federal coal witnesses a reduction as well. CPP Base Cases with the SCC adders also experience a drop in production levels in both federal and non-federal coal, but due to lower demand for coal, the impact is smaller in scale compared to Base Case A. Demand for coal is overall lower in the CPP cases due to the CO_2 rate limits and mass caps imposed and lower overall demand for electricity due to increased EE.

Exhibit 39: Coal Production on Federal & Non-Federal Lands – Base Case A & Base Case A with SCC Adders

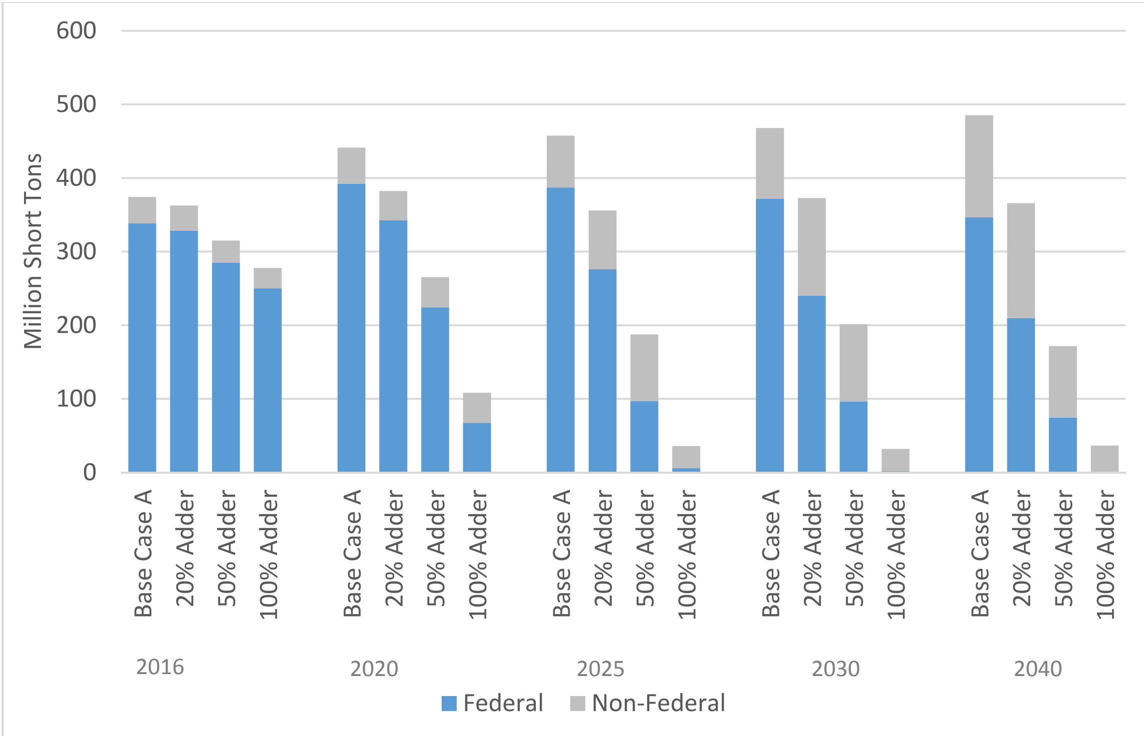


Exhibit 40: Coal Production on Federal & Non-Federal Lands – CPP Mass Case & CPP Mass Case with SCC Adders

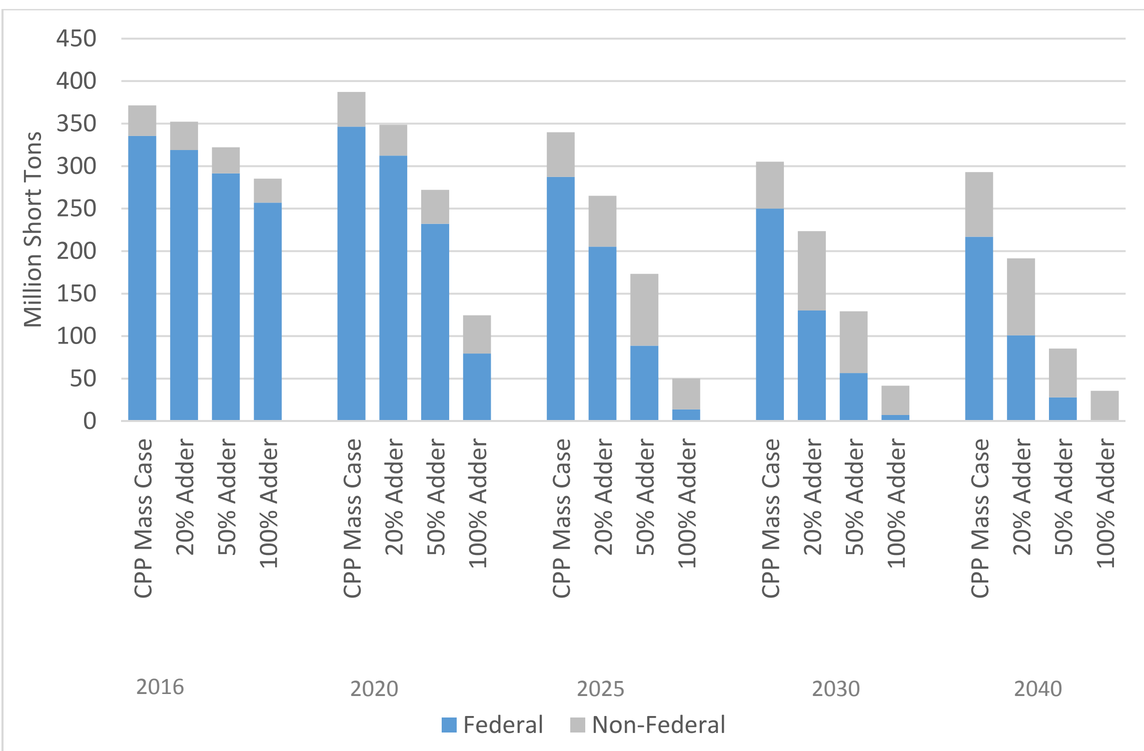
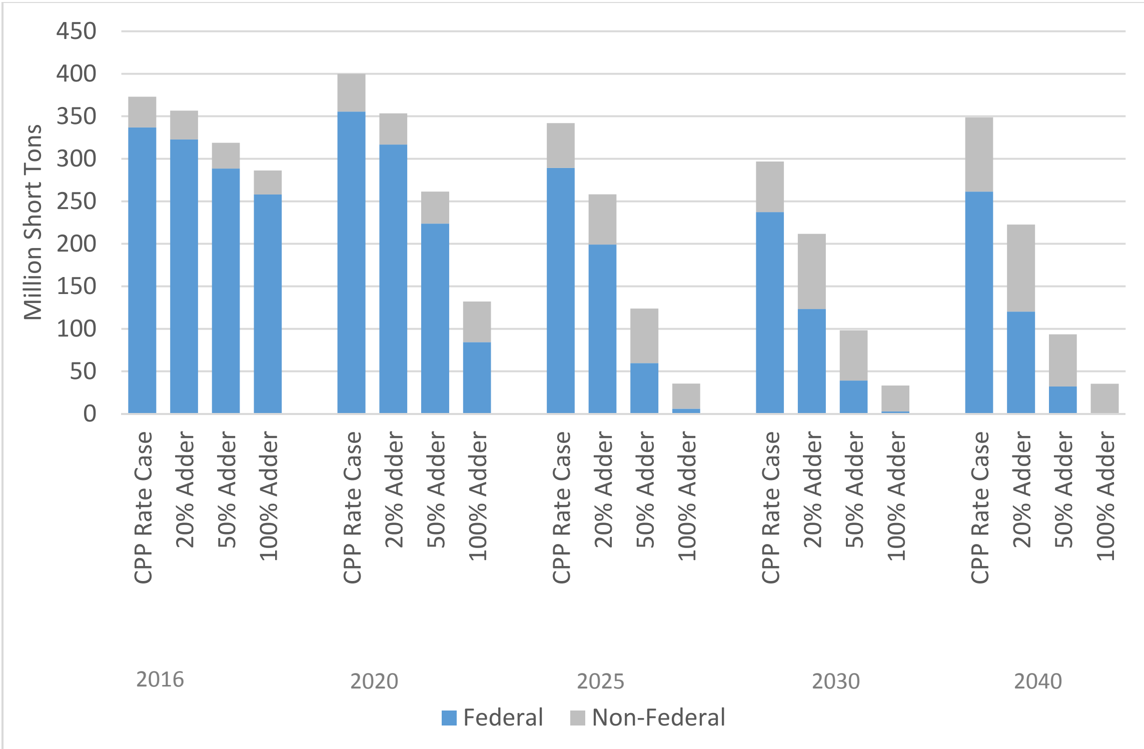


Exhibit 41: Coal Production on Federal & Non-Federal Lands – CPP Rate Case & CPP Rate Case with SCC Adders



Coal Prices

The increase in coal prices in CO, MT, UT, and WY reflect the incorporation of the SCC adders. Values of N/A in Exhibits 42 through 47 signify that no coal was produced and therefore, the model could not determine a price.

Exhibit 42: Coal Price Deltas, Base Case A with SCC Adders Relative to Base Case A (2012$/Short Ton)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	-1.6	2.9	9.2	8.3	11.6	0.8	12.3	25.6	23.7	30.6	4.5	23.7	N/A	N/A	N/A
Utah	0.9	-1.8	3.9	11.8	12.2	13.3	-0.5	14.2	30.0	30.2	33.1	2.1	26.8	N/A	N/A	N/A
Montana	0.8	-0.6	4.8	10.4	10.4	13.1	0.3	12.5	26.7	27.6	31.8	2.9	26.0	N/A	N/A	N/A
Wyoming	0.8	0.0	5.7	13.4	13.8	N/A	1.9	15.2	N/A	N/A	N/A	5.0	34.0	N/A	N/A	N/A

Exhibit 43: Coal Price % Change, Base Case A with SCC Adders Relative to Base Case A (% Change)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	-4%	7%	23%	19%	28%	2%	31%	64%	55%	75%	12%	60%	N/A	N/A	N/A
Utah	0.9	-4%	8%	26%	26%	31%	-1%	30%	65%	64%	77%	5%	57%	N/A	N/A	N/A
Montana	0.8	-4%	27%	56%	55%	67%	2%	70%	145%	145%	162%	18%	146%	N/A	N/A	N/A
Wyoming	0.8	0%	42%	97%	95%	N/A	14%	111%	N/A	N/A	N/A	39%	250%	N/A	N/A	N/A

Exhibit 44: Coal Price Deltas, CPP Mass Case with SCC Adders Relative to CPP Mass Case (2012$/Short Ton)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	-1.1	4.0	10.7	9.5	13.7	2.4	13.6	27.4	25.8	33.7	5.2	25.2	59.0	64.4	N/A
Utah	0.9	-1.2	4.4	12.9	12.2	13.3	0.1	15.0	31.2	30.2	33.1	2.8	27.7	N/A	N/A	N/A
Montana	0.8	0.8	5.9	12.3	11.7	13.6	1.4	14.6	28.6	28.8	32.3	4.5	28.1	N/A	N/A	N/A
Wyoming	0.8	0.7	6.5	14.0	15.4	N/A	2.7	16.2	N/A	N/A	N/A	5.9	35.0	N/A	N/A	N/A

Exhibit 45: Coal Price % Change, CPP Mass Case with SCC Adders Relative to CPP Mass Case (% Change)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	-3%	10%	28%	23%	37%	6%	36%	71%	63%	90%	14%	66%	154%	158%	N/A
Utah	0.9	-3%	10%	29%	26%	31%	0%	33%	69%	64%	77%	6%	60%	N/A	N/A	N/A
Montana	0.8	5%	37%	74%	66%	72%	9%	92%	173%	162%	170%	30%	178%	N/A	N/A	N/A
Wyoming	0.8	6%	51%	112%	121%	N/A	23%	128%	N/A	N/A	N/A	49%	277%	N/A	N/A	N/A

Exhibit 46: Coal Price Deltas, CPP Rate Case with SCC Adders Relative to CPP Rate Case (2012$/Short Ton)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	-1.4	3.7	10.2	9.5	13.1	1.1	13.2	26.8	25.0	N/A	4.7	24.7	N/A	N/A	N/A
Utah	0.9	-1.6	4.1	12.8	12.2	13.3	-0.2	14.5	31.1	30.2	33.1	3.1	27.2	N/A	N/A	N/A
Montana	0.8	0.5	5.7	12.0	12.0	13.5	0.9	14.3	28.3	29.2	32.1	4.0	27.8	N/A	N/A	N/A
Wyoming	0.8	0.6	6.2	13.7	15.1	N/A	2.6	16.0	N/A	N/A	N/A	5.7	34.8	N/A	N/A	N/A

Exhibit 47: Coal Price % Change, CPP Rate Case with SCC Adders Relative to CPP Rate Case (% Change)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	-4%	10%	26%	23%	34%	3%	34%	69%	60%	N/A	12%	64%	N/A	N/A	N/A
Utah	0.9	-3%	9%	28%	26%	31%	-1%	31%	69%	64%	77%	7%	58%	N/A	N/A	N/A
Montana	0.8	3%	36%	71%	69%	70%	6%	90%	169%	168%	167%	26%	174%	N/A	N/A	N/A
Wyoming	0.8	5%	49%	108%	115%	N/A	21%	125%	N/A	N/A	N/A	47%	271%	N/A	N/A	N/A

Coal Exports

With the 20% SCC adder, the total exports from western states remain the same as Base Case A. Montana is the only exporting state in the model because its mines are closer to export terminals than other PRB coal. Additionally, Montana coal also enjoys a higher heat content resulting in lower delivered costs per unit of heating value. However, under the 50% and 100% SCC adders, exports from Colorado, Utah, Montana, and Wyoming decrease to zero, while exports from states such as Alabama, Pennsylvania, and West Virginia increase to fill the gap. This trend is the same in both Base Cases and CPP Mass Cases.

Impacts on Capacity and Generation Mix

As the percentage of the SCC adder increases, there is a shift from coal to natural gas in the generation mix (Exhibits 48-50). For example, in the Base Case A with the 50% SCC adder scenario, in 2030, there is an increase of 68% in new combined cycle generation compared to Base Case A, while coal-fired generation experiences a decrease of 16%. The trend of increasing gas-fired and decreasing coal-fired generation is also evident in CPP Cases (Exhibit 49 and 50). In the long run, the coal to natural gas shift is most evident in the CPP Mass Cases with SCC adders, as the mass based emission caps lead to lower coal generation and coal production.

Exhibit 48: Generation Mix – US, Base Case A and Base Case A with SCC Adders

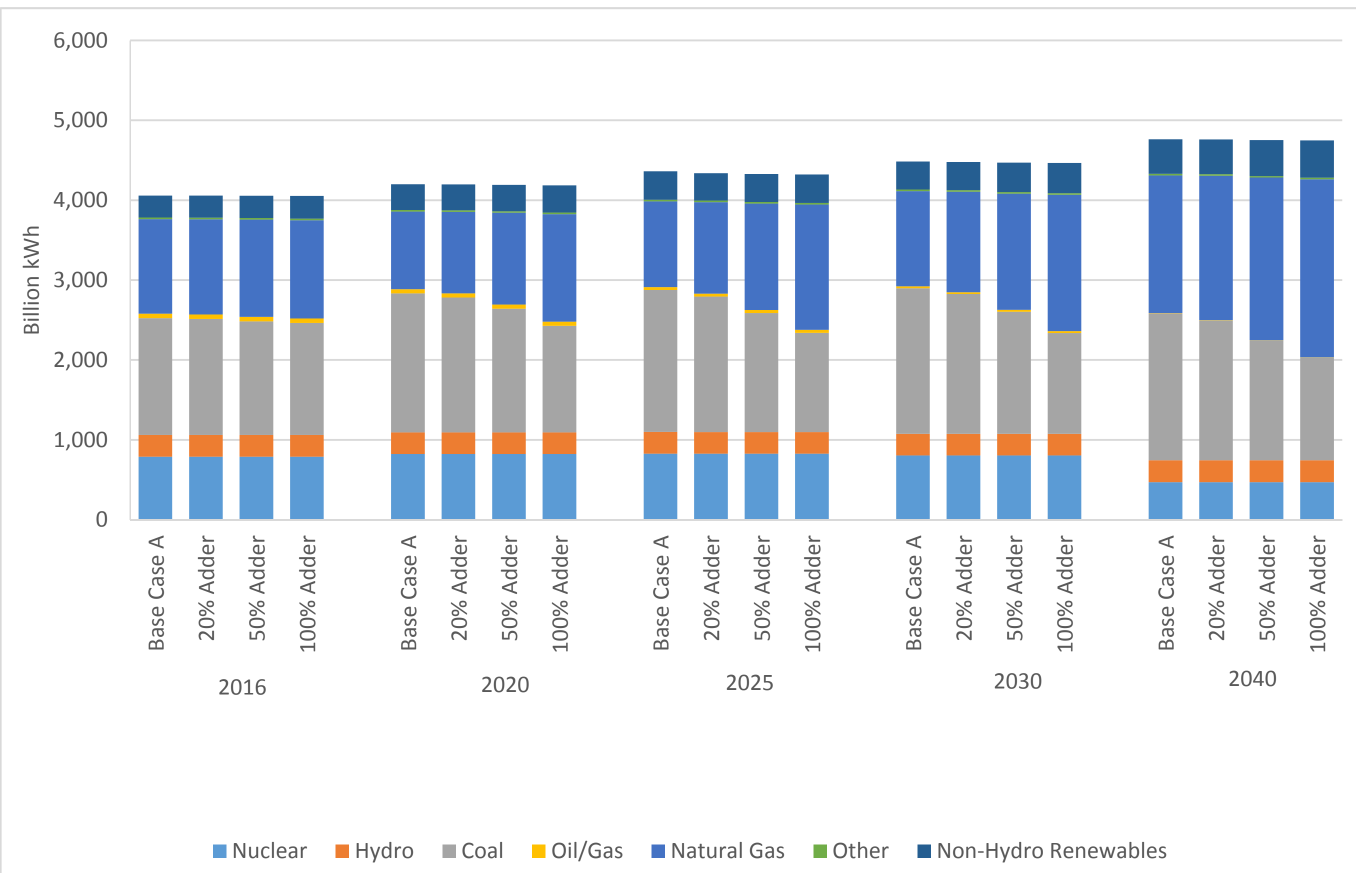


Exhibit 49: Generation Mix – US, CPP Mass Case and CPP Mass Case with SCC Adders

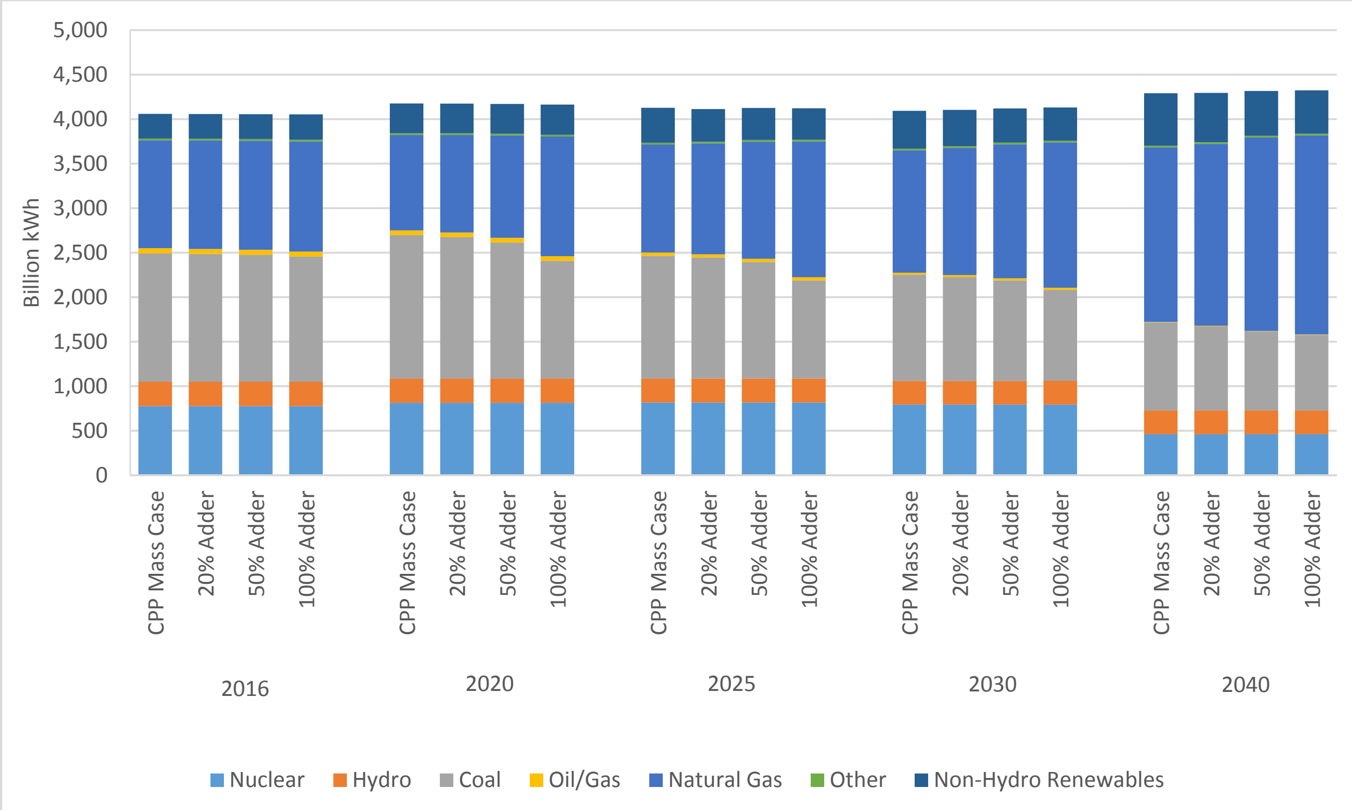
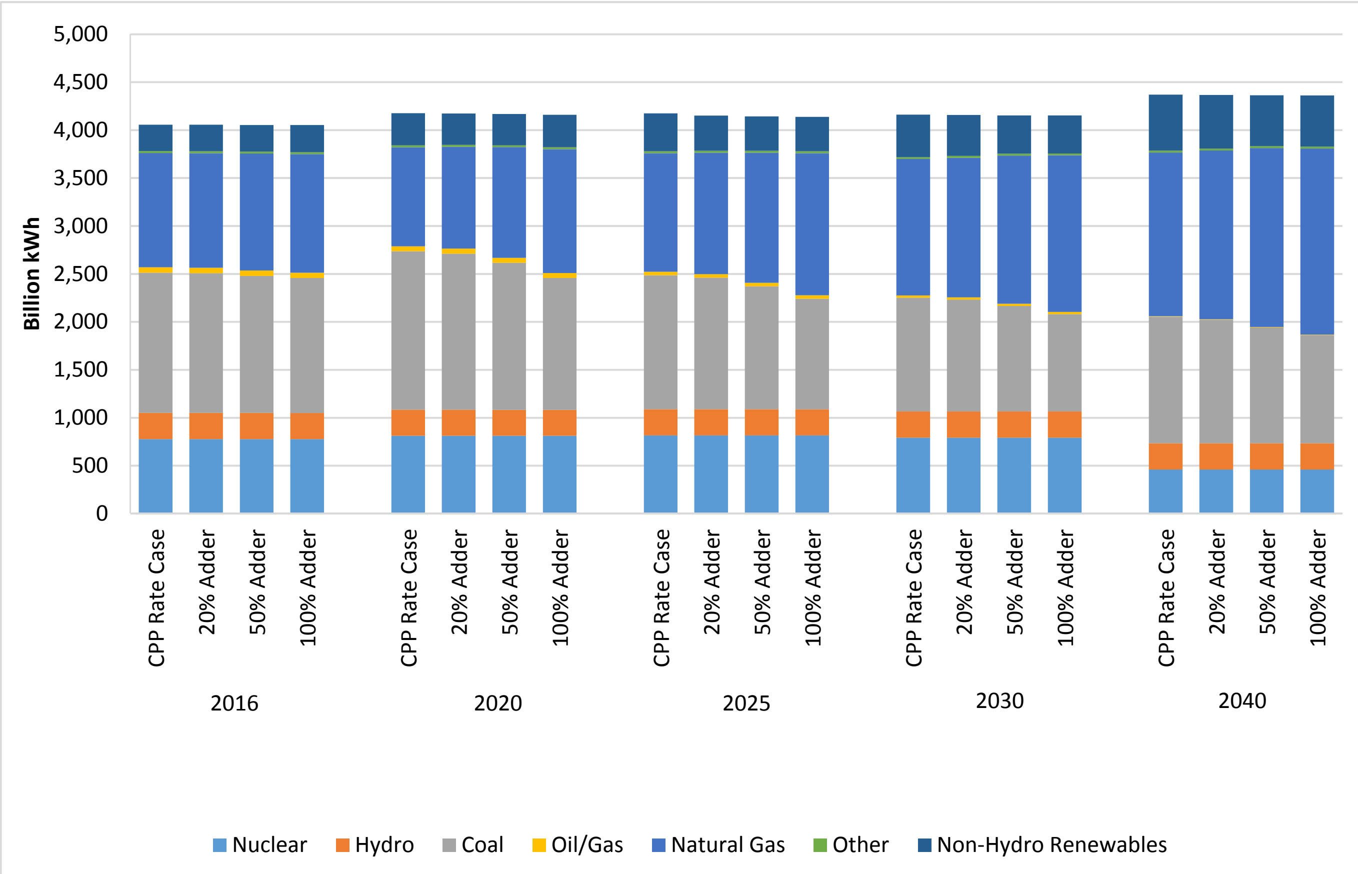


Exhibit 50: Generation Mix – US, CPP Rate Case and CPP Rate Case with SCC Adders



Impacts on Natural Gas Markets

As gas-fired generation increases with the implementation of different levels of the SCC adders, demand for natural gas consequently rises over the years in both Base Cases and CPP Cases (Exhibit 51, 52, and 53). For example, similar to other items, the 20% SCC adder has the least impact, resulting in an increase of 5% by 2040 in natural gas demand in Base Cases. In contrast, the 50% and 100% SCC adders lead to an increase of 17% and 28%, respectively in Base Cases. Percentage increases in CPP Cases with and without the SCC adders are smaller, as the CPP already leads to a rise in natural gas demand (Exhibits 52 and 53). Therefore the impact from the SCC adders alone is less pronounced.

Exhibit 51: Power Sector Natural Gas Demand – US, Base Case A and Base Case A with SCC Adders

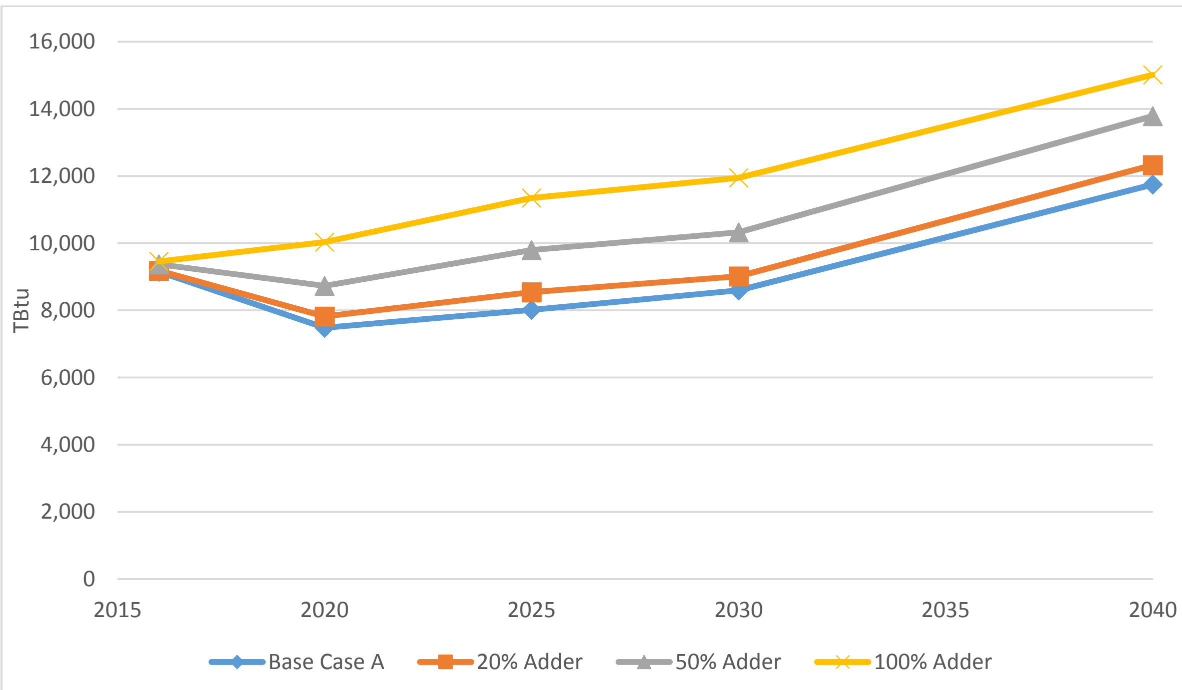


Exhibit 52: Power Sector Natural Gas Demand – US, CPP Mass Case and CPP Mass Case with SCC Adders

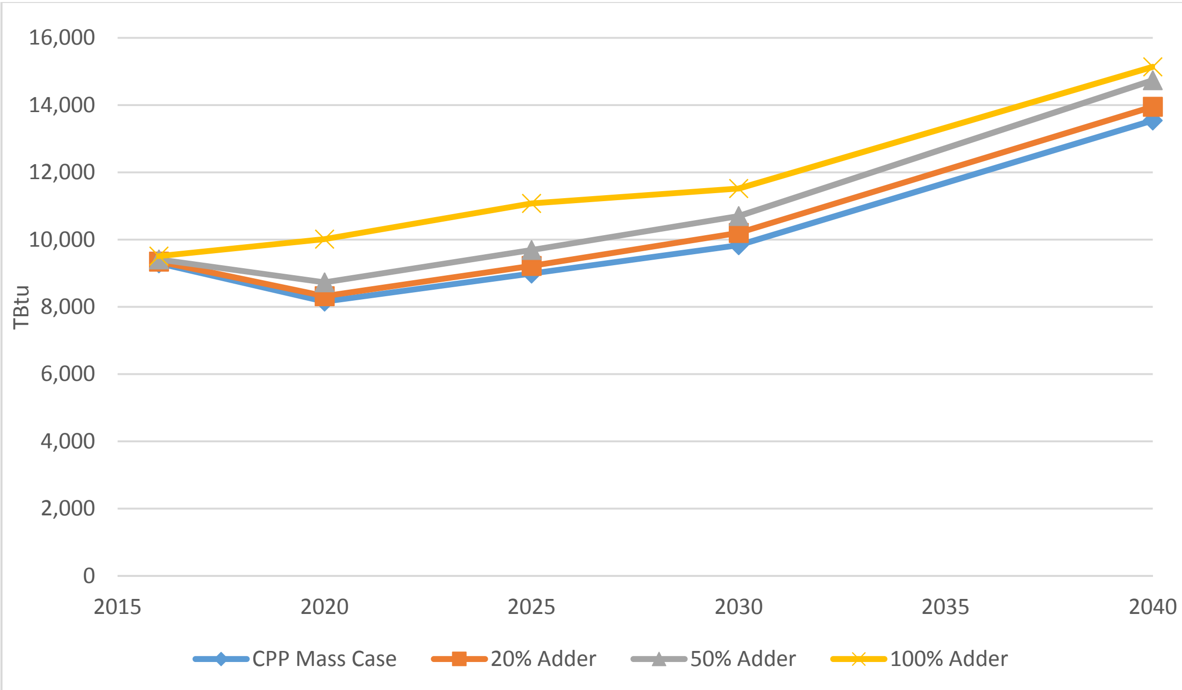
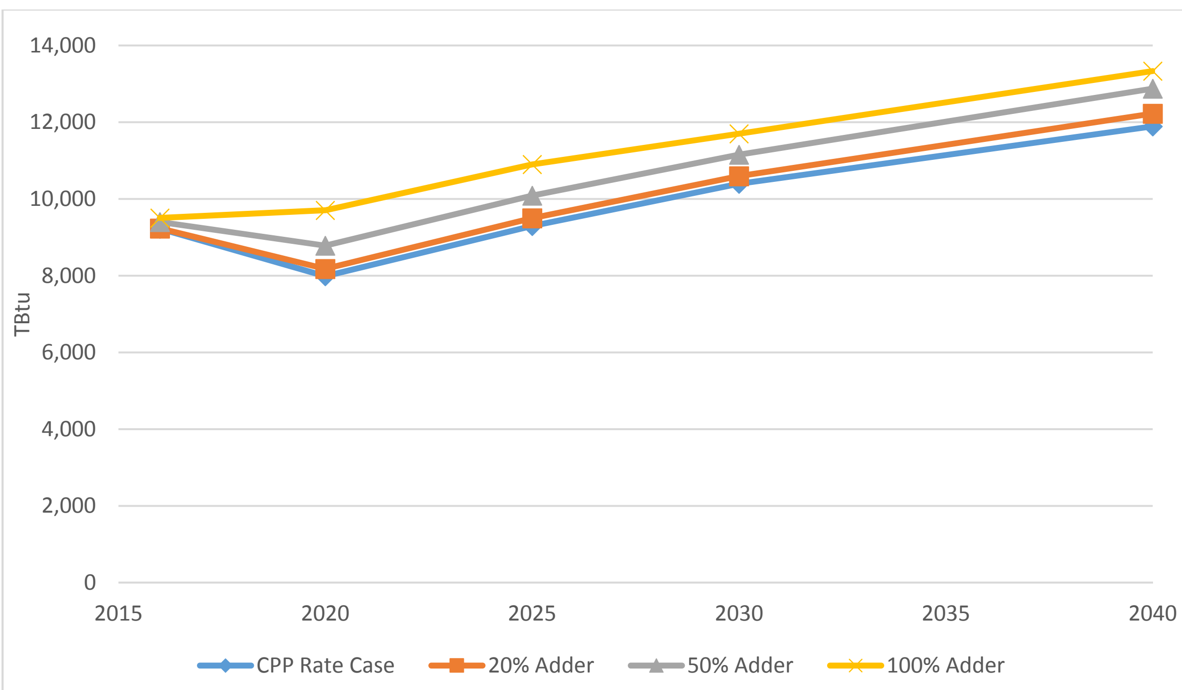


Exhibit 53: Power Sector Natural Gas Demand – US, CPP Rate Case and CPP Rate Case with SCC Adders



Relative to Base Case A, the addition of the SCC leads to early retirement of coal units, and an increase in natural gas prices early in the forecast horizon (Exhibits 54 and 55). As demand for natural gas continues to increase in all cases with SCC adders, Henry Hub Prices also witness a continuing increase over the forecast horizon. As the percentage of the SCC adder increases, the costs of mining federal coal increases. Therefore, higher percentage of the SCC tends to lead to higher demand for gas, hence higher Henry Hub prices. However, in CPP Rate Cases, long-term Henry Hub prices decrease slightly, as existing coal-fired capacity remains online as a result of the rate limits structure and allowing energy efficiency and renewable resources to comply with the CPP. The increase in coal generation in the long run offsets some gas consumption and leads to lower gas prices.

Exhibit 54: Henry Hub Gas Prices, Base Case A and Base Case A with SCC Adders

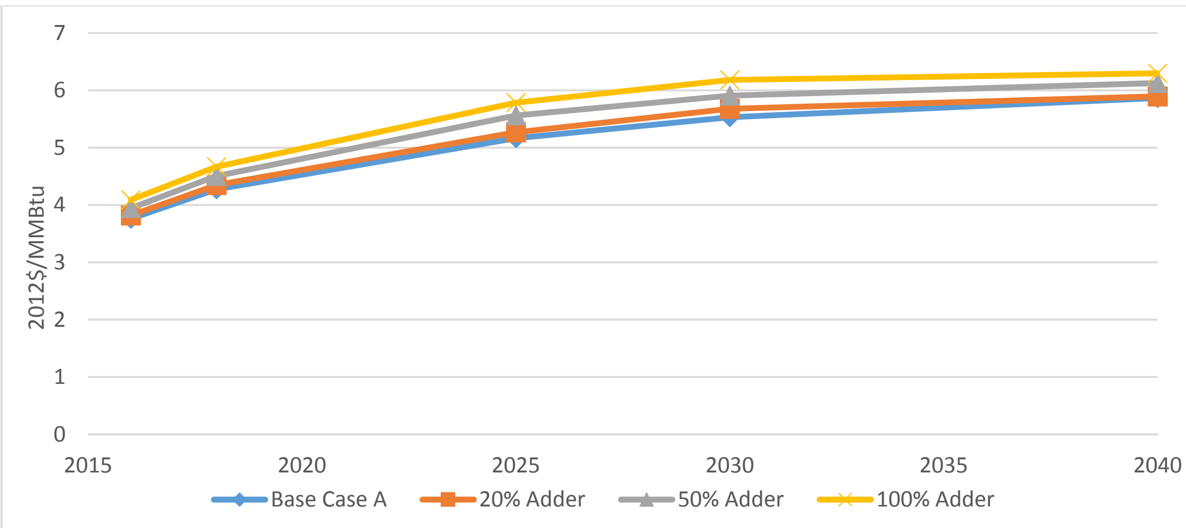


Exhibit 55: Henry Hub Gas Prices, CPP Mass Case and CPP Mass Case with SCC Adders

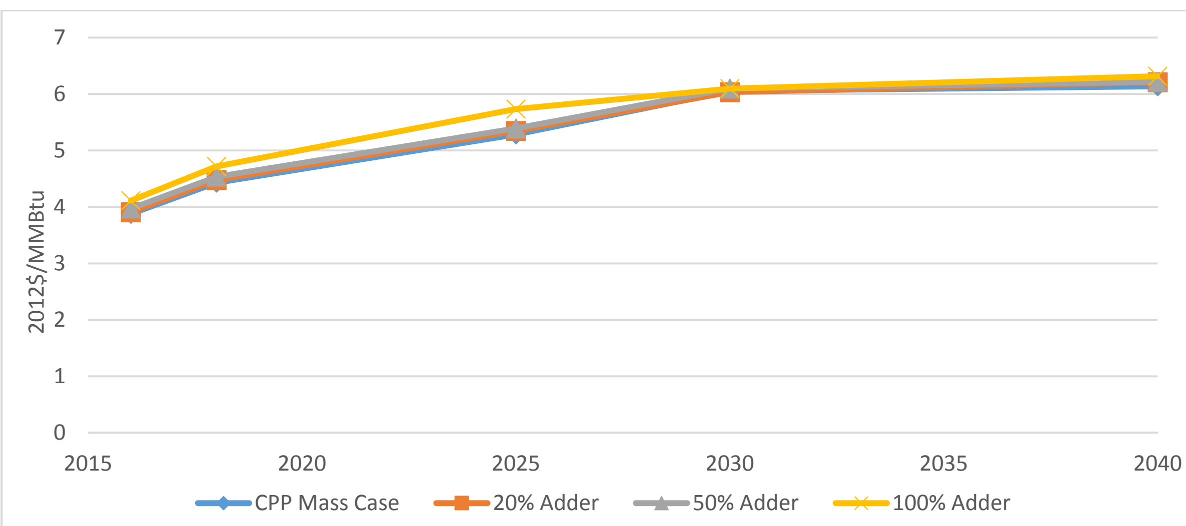
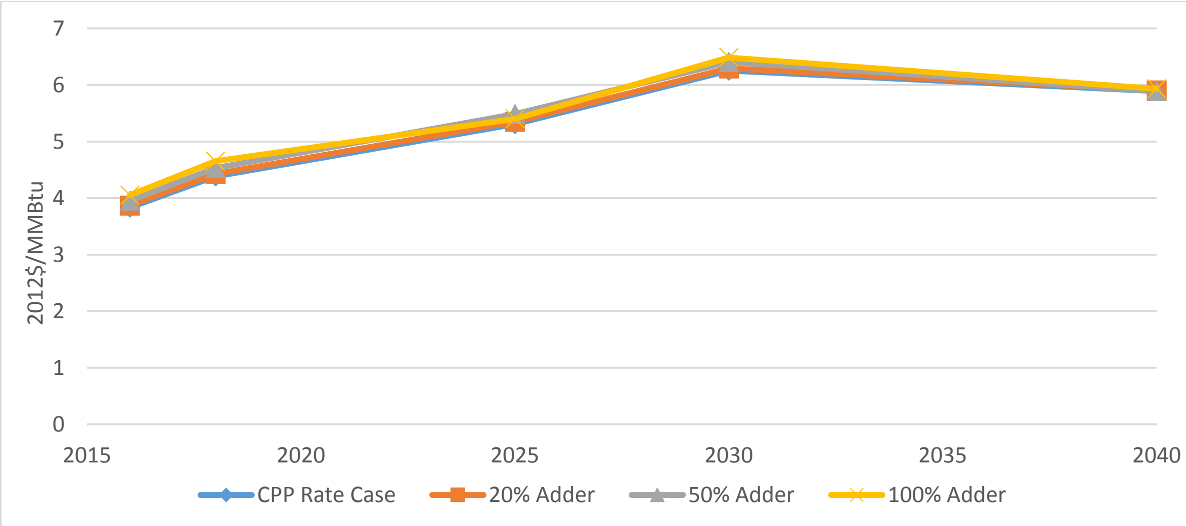


Exhibit 56: Henry Hub Gas Prices, CPP Rate Case and CPP Rate Case with SCC Adders



Impacts on Firm Wholesale Power Prices

The trajectory of average US natural gas prices and firm wholesale power prices is almost identical when the SCC adders are applied (Exhibits 57-59). In the short run, the system still relies on coal-fired generation, therefore the social cost of carbon is visible as part of the electricity prices. As the importance of coal-fired generation slowly diminishes in the long run and coal production decreases, the contribution of the SCC adders to power prices falls, hence the eventual convergence of power prices between cases in the long run.

While firm power prices from cases with SCC adders are higher than those from their corresponding base cases in the short run, the long-term trend is different between cases. When the SCC adders are applied to Base Case A and the CPP Rate Case, firm power prices from policy cases are consistently higher than the base cases, but the CPP Mass Cases display an opposite trajectory in the long run. It is worth-noting that firm power prices from CPP Mass Case are higher than Base Case A and the CPP Rate Case. Under a mass cap structure, the application of SCC adders results in higher delivered coal prices. Higher delivered coal prices lead to lower demand for coal, hence helping the system meet the CO_2 emission caps. Therefore, SCCs take away some burden and subsidizes the CPP program, resulting in lower CO_2 allowance prices. The lower CO_2 allowance prices lead to reduced costs of dispatch for NGCC units and coal units not burning federal coal thereby lowering the wholesale power price. Under the rate based program, when NGCC is receiving a credit, any decline in the CO_2 allowance price leads to less credit for an NGCC unit therefore, raising the NGCC unit's cost of dispatch and the overall wholesale power price. Note this explanation is a bit simplified since NGCC is not always on the margin, but given it is in a majority of hours in most markets it is the driven factor behind these trends.

Exhibit 57: Firm Wholesale Power Prices – US, Base Case A and Base Case A with SCC Adders

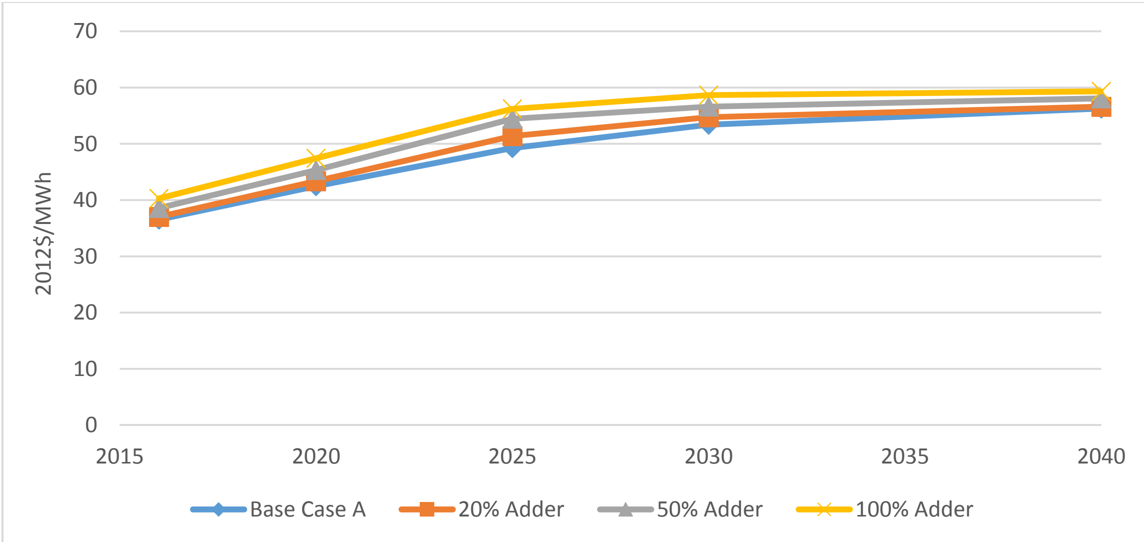


Exhibit 58: Firm Wholesale Power Prices – US, CPP Mass Case and CPP Mass Case with SCC Adders

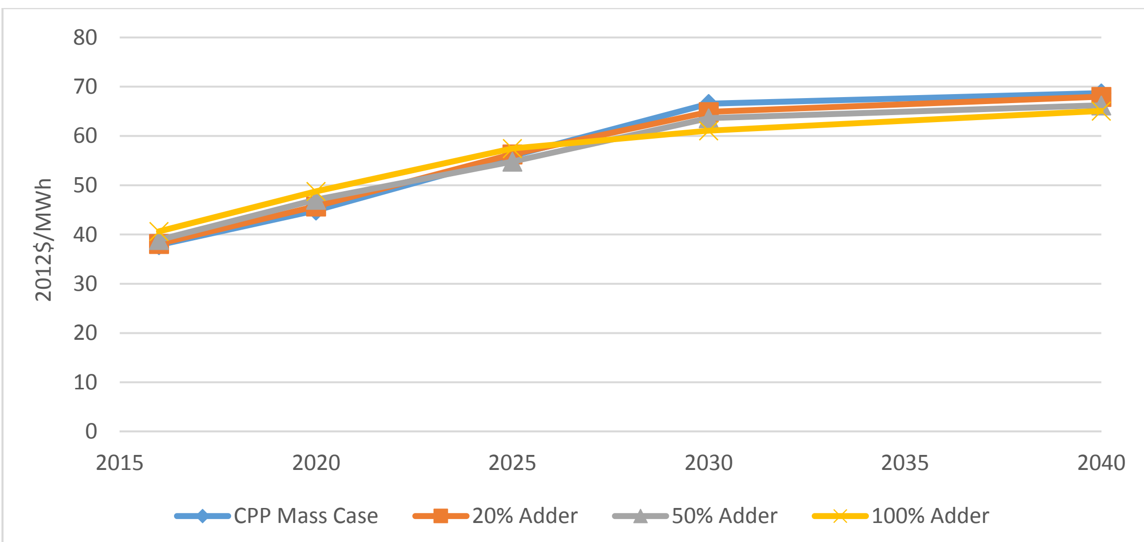
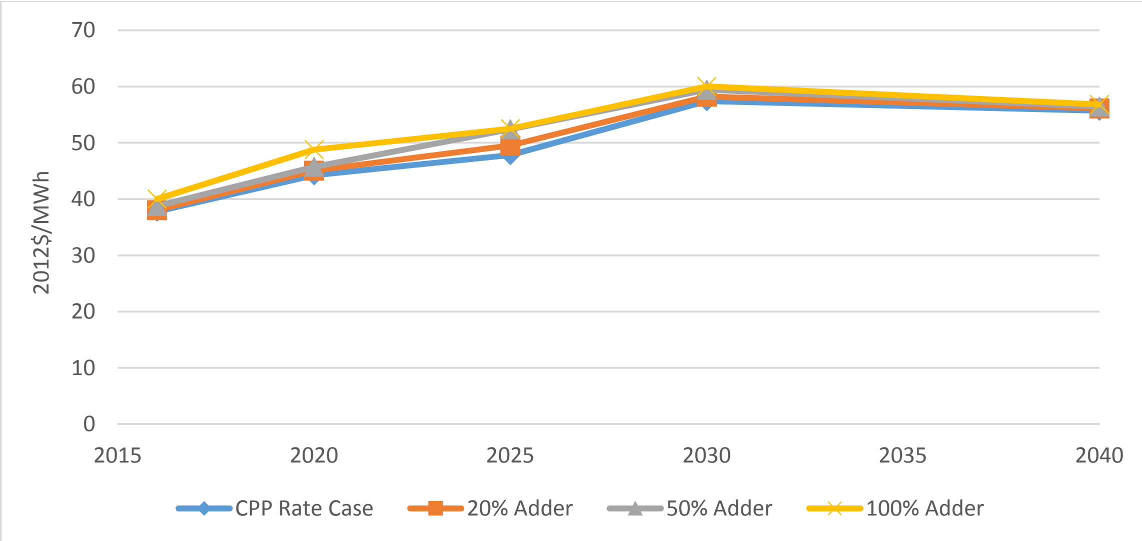


Exhibit 59: Firm Wholesale Power Prices – US, CPP Rate Case and CPP Rate Case with SCC Adders



CO_2 Emissions

As the shift between coal and gas-fired generation occurs when the SCC adders are applied, total CO_2 emissions decrease as the percentage of the SCC adders increases (Exhibits 60-62). By 2040, in Base Case A the 20% SCC adder leads to a 3% decrease in emissions, while the 50% and 100% adders lead to 10% and 16% reductions, respectively. The CPP Cases demonstrate similar trends.

Exhibit 60: CO_2 Emissions – US, All Cases

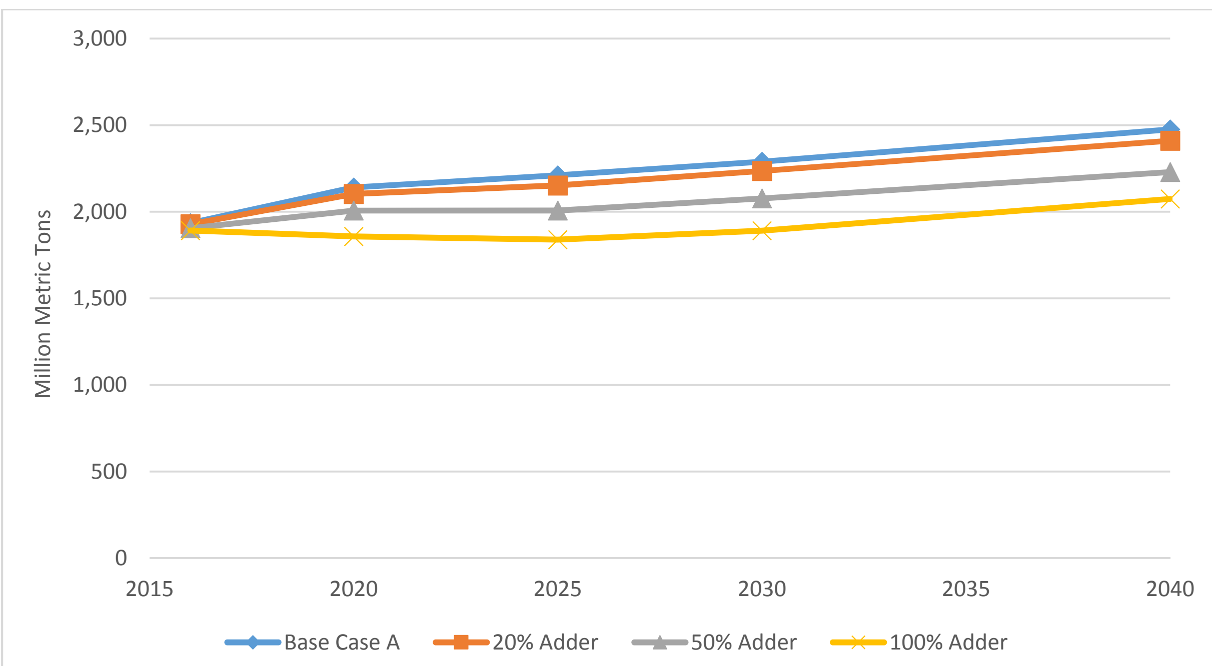


Exhibit 61: CO_2 Emissions – US, All Cases

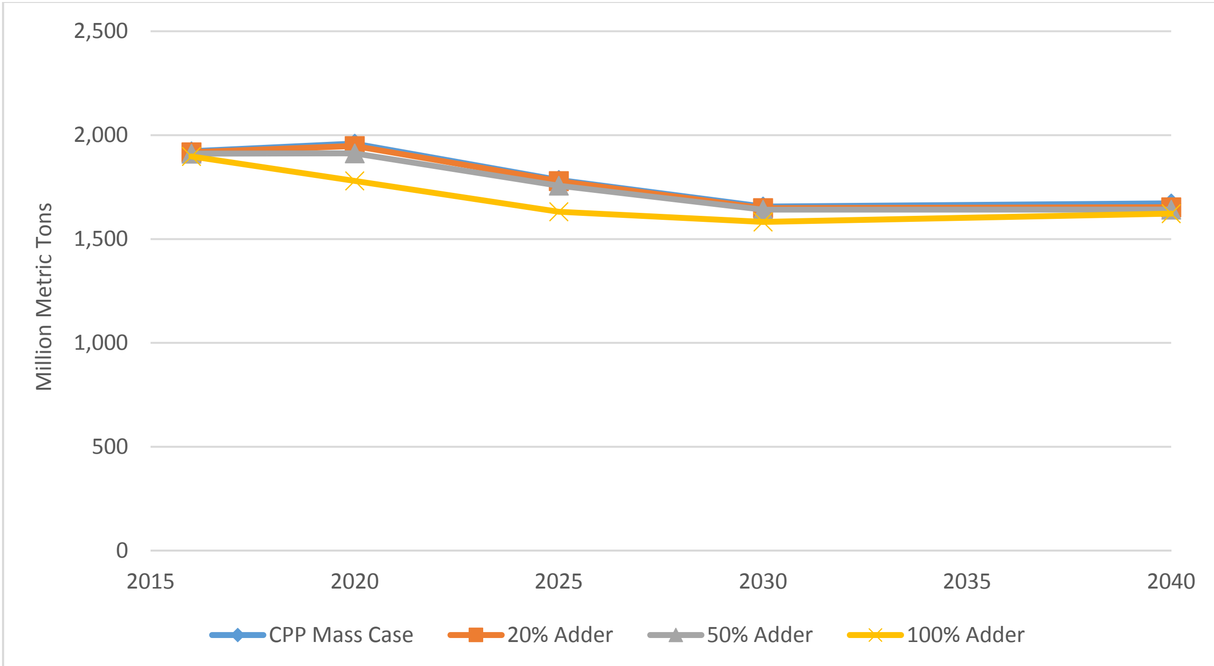


Exhibit 62: CO_2 Emissions – US, All Cases

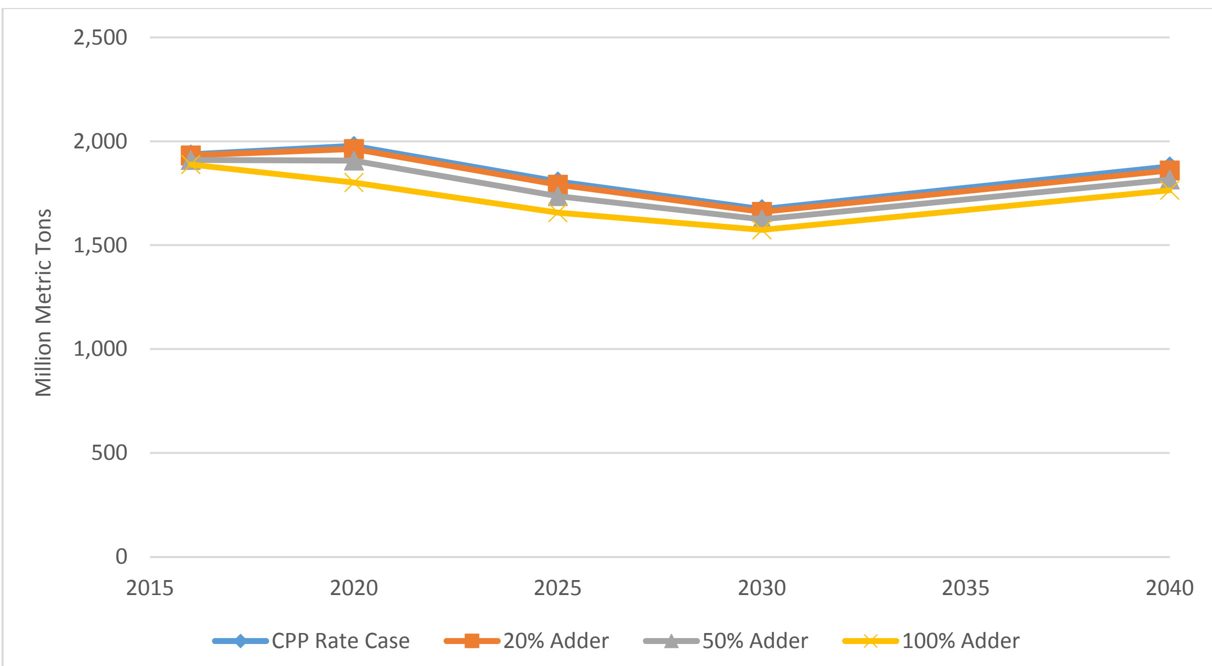


Exhibit 63: CO_2 Emissions (thousand metric tons CO_2) – US, All Cases

	2016	2018	2020	2025	2030	2040	2050
Base Case A	1,934,182	2,041,495	2,140,620	2,210,698	2,289,336	2,475,681	2,727,797
20% Adder	1,927,897	2,017,953	2,103,102	2,151,276	2,236,020	2,410,041	2,675,423
50% Adder	1,904,713	1,965,996	2,006,970	2,006,995	2,076,569	2,229,102	2,496,076
100% Adder	1,890,932	1,901,550	1,857,337	1,838,129	1,890,029	2,073,798	2,319,249

Exhibit 64: CO_2 Emissions (thousand metric tons CO_2) – US, All CPP Mass Cases

	2016	2018	2020	2025	2030	2040	2050
CPP Mass Case	1,922,342	1,998,792	1,959,142	1,784,678	1,657,056	1,671,542	1,757,785
20% Adder	1,917,480	1,984,591	1,947,271	1,779,082	1,649,278	1,652,733	1,735,523
50% Adder	1,910,577	1,955,550	1,912,073	1,756,878	1,641,136	1,640,979	1,725,882
100% Adder	1,897,693	1,888,350	1,779,893	1,631,342	1,581,933	1,622,023	1,723,993

Exhibit 65: CO_2 Emissions (thousand metric tons CO_2) – US, All CPP Rate Cases

	2016	2018	2020	2025	2030	2040	2050
CPP Rate Case	1,936,353	2,019,250	1,977,441	1,806,500	1,673,118	1,879,109	2,173,348
20% Adder	1,931,865	2,004,207	1,962,984	1,791,492	1,660,456	1,859,417	2,148,199
50% Adder	1,909,854	1,963,456	1,906,938	1,735,738	1,624,483	1,815,678	2,083,766
100% Adder	1,888,067	1,897,479	1,801,412	1,656,924	1,573,505	1,764,283	2,021,407

Exhibit 66: CO_2 Emissions Delta (thousand metric tons CO_2) – US, All Cases

	2016	2018	2020	2025	2030	2040	2050
Base Case A	-	-	-	-	-	-	-
20% Adder	-6,285	-23,542	-37,518	-59,422	-53,316	-65,640	-52,374
50% Adder	-29,469	-75,499	-133,650	-203,704	-212,767	-246,579	-231,721
100% Adder	-43,250	-139,945	-283,283	-372,569	-399,307	-401,883	-408,548

Exhibit 67: CO_2 Emissions Delta (thousand metric tons CO_2) – US, All CPP Mass Cases

	2016	2018	2020	2025	2030	2040	2050
CPP Mass Case	-	-	-	-	-	-	-
20% Adder	-4,862	-14,201	-11,871	-5,595	-7,778	-18,809	-22,262
50% Adder	-11,765	-43,242	-47,069	-27,800	-15,920	-30,563	-31,903
100% Adder	-24,648	-110,442	-179,249	-153,335	-75,123	-49,519	-33,792

Exhibit 68: CO_2 Emissions Delta (thousand metric tons CO_2) – US, All CPP Rate Cases

	2016	2018	2020	2025	2030	2040	2050
CPP Rate Case	-	-	-	-	-	-	-
20% Adder	-4,488	-15,043	-14,457	-15,008	-12,662	-19,692	-25,149
50% Adder	-26,499	-55,793	-70,504	-70,762	-48,635	-63,431	-89,582
100% Adder	-48,286	-121,771	-176,030	-149,576	-99,613	-114,826	-151,940

Chapter 4C: Production Limit Policy Cases

As discussed, Vulcan analyzed a total of four Production Limit Constraint Cases – two derived from placing constraints on Base Case A, no CPP (referred to as "Base Case A" in Chapter 4C), and two derived from placing those same constraints on Base Case A, CPP with mass-based regional trading (referred to as "CPP Mass Case" in Chapter 4C). The first type of production limit constraint, the No New Permits constraint, reflects the assumption that new and modified leases are not approved beginning in 2017, therefore coal production on federal lands would terminate by 2037. The second alternative, the Limited New Permits constraint, models the assumption that new and modified leases beginning in 2017 represent 50% of the production level in 2013 on federal lands. Both constraints on production levels are modeled as a linear decline over ten years. Further, it was assumed that co-mingled mines would cease production as it would not be economic or technically feasible to extract non-federal coal. The following sections compare the results of the alternative cases to their corresponding Base Cases.

Impacts on Coal Markets

Coal Production

Since the linear decline of production limits starts in 2028 and ends in 2037, the gap between coal production in Base Case A and alternative cases widens later in the forecast horizon (Exhibit 69). In 2030, not long after the production limits are implemented, the No New Permits Case's total coal production in the US is 7% less than Base Case A, and the Limited New Permits Case is 2% lower. By 2040, as federal coal production ceases by 2037 due to the No New Permits constraint, total US coal production in the No New Permits Case declines to 28% below Base Case A. On the other hand, as federal coal production continues under the 50% cap, total coal production under the Limited New Permits continues to be close to Base Case A, with a decrease of 5% in 2040. Similar trends exist in the CPP Mass Case and its alternative cases with production limits (Exhibit 70), but the scale of the declines is smaller. By 2040, in the CPP Mass Case's No New Permits Case total US coal production declines 11%, while the Limited New Permits Case's production level declines by 1%.

Exhibit 69: Coal Production – US, Base Case A and Base Case A with Constraints

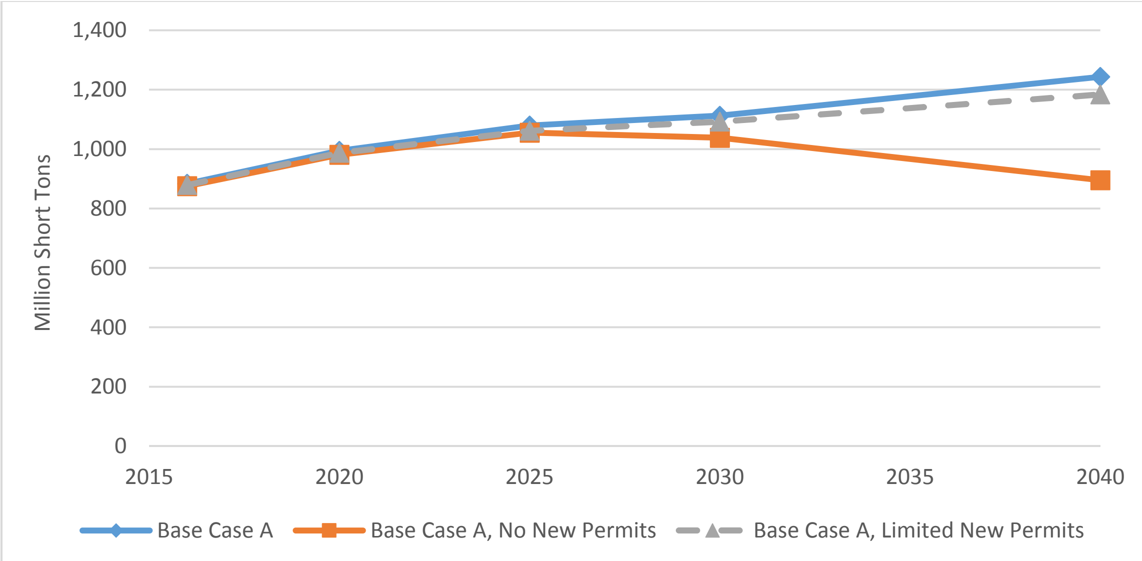
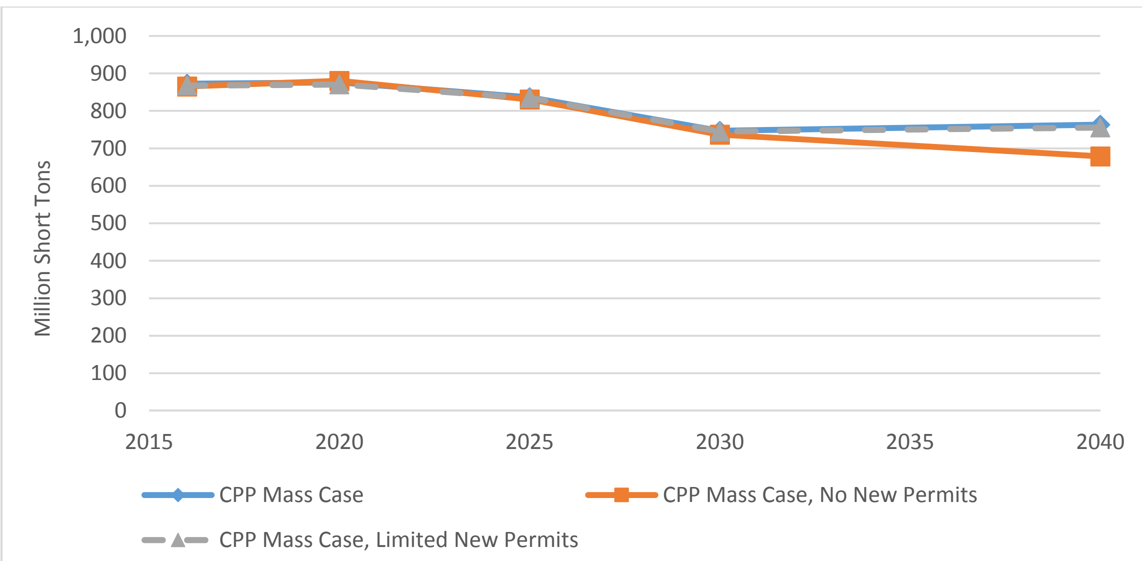


Exhibit 70: Coal Production – US, CPP Mass Case and CPP Mass Case with Constraints



Production limit constraints are only applied on coal production in CO, MT, UT and WY. Therefore, in addition to the decrease in coal production in these states, there is a considerable amount of shift in coal production among sources. In Base Case A No New Permits Case, while the total US coal production decreases by 348 million short tons in 2040, production from Powder River Basin drops by almost 400 million short tons (Exhibits 71 and 72). There is also a 9 million short tons decrease in coal production from the Rocky Mountains. Central Appalachia, Northern Appalachia, Illinois Basin, and other regions experience an increase in production levels. Under the Limited New Permits Case, the decrease in total US coal production is smaller than the No New Permits Case, as the increases in other areas are nearly enough to offset the declines in CO, MT, UT and WY. The CPP Mass Case has a smaller drop in PRB coal production as well as total coal production, due to lower overall coal demand due to the CPP (Exhibits 73 and 74).

Exhibit 71: Coal Production by Basin Delta, Constraint Relative to Base Case A (Million Short Tons)

Coal Supply Region	No New Permits					Limited New Permits				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	3	4	-2	0	6	1	1	0	0	2
Northern Appalachia (NAPP)	5	9	23	22	16	1	4	6	16	4
Illinois Basin (ILB)	2	6	3	8	31	1	1	2	2	20
Powder River Basin (PRB)	-17	-25	-32	-118	-397	-7	-11	-22	-63	-206
Rocky Mountains	2	0	-1	6	-9	-1	-1	-1	-5	1
All other U.S. Regions	-3	-7	-14	8	4	0	-1	-3	28	119
Total	-8	-14	-24	-75	-348	-4	-7	-18	-20	-60

Exhibit 72: Coal Production by Basin % Change, Constraint Relative to Base Case A

Coal Supply Region	No New Permits					Limited New Permits				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	2%	3%	-2%	0%	4%	1%	1%	0%	0%	1%
Northern Appalachia (NAPP)	4%	6%	13%	10%	6%	1%	3%	3%	7%	1%
Illinois Basin (ILB)	2%	4%	2%	5%	15%	1%	1%	1%	1%	10%
Powder River Basin (PRB)	-5%	-6%	-8%	-28%	-90%	-2%	-3%	-5%	-15%	-47%
Rocky Mountains	7%	0%	-3%	15%	-20%	-2%	-3%	-3%	-13%	3%
All other U.S. Regions	-3%	-6%	-11%	7%	3%	0%	-1%	-2%	23%	97%
Total	-1%	-1%	-2%	-7%	-28%	0%	-1%	-2%	-2%	-5%

Exhibit 73: Coal Production by Basin Deltas, Constraint Relative to CPP Mass Case (Million Short Tons)

Coal Supply Region	No New Permits					Limited New Permits				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	1	2	-1	-1	6	1	0	0	1	0
Northern Appalachia (NAPP)	5	3	4	1	27	1	1	1	0	5
Illinois Basin (ILB)	3	6	2	2	29	0	1	0	1	6
Powder River Basin (PRB)	-11	2	2	0	-223	-6	-3	-5	-4	-33
Rocky Mountains	-2	-2	-1	-2	8	0	-1	0	0	-1
All other U.S. Regions	-4	-6	-11	-10	69	0	-3	2	0	16
Total	-7	4	-6	-10	-85	-5	-5	-2	-1	-7

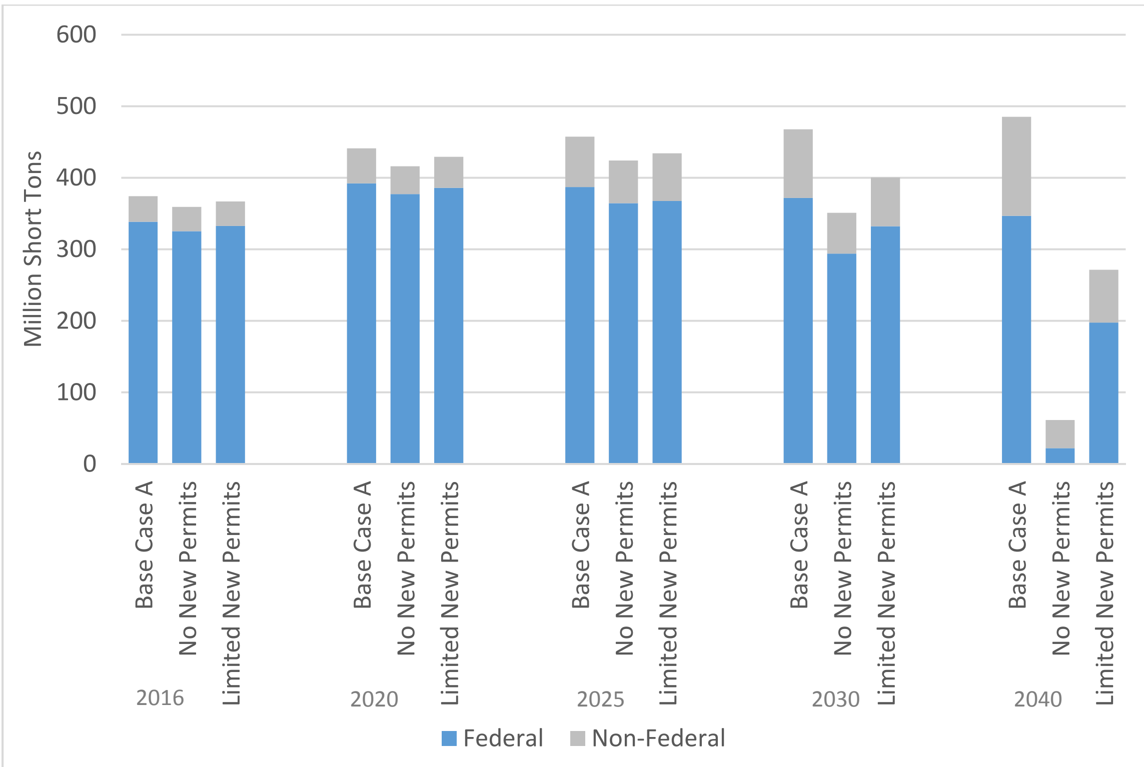
Exhibit 74: Coal Production by Basin % Change, Constraint Relative to CPP Mass Case

Coal Supply Region	No New Permits					Limited New Permits				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	1%	1%	-1%	-1%	4%	0%	0%	0%	1%	0%
Northern Appalachia (NAPP)	4%	3%	3%	1%	15%	1%	1%	1%	0%	3%
Illinois Basin (ILB)	3%	4%	2%	2%	27%	0%	1%	0%	1%	6%
Powder River Basin (PRB)	-3%	0%	1%	0%	-84%	-2%	-1%	-2%	-1%	-13%
Rocky Mountains	-8%	-6%	-6%	-10%	30%	0%	-3%	-1%	2%	-4%

All other U.S. Regions	-4%	-6%	-14%	-16%	124%	0%	-3%	3%	1%	29%
Total	-1%	0%	-1%	-1%	-11%	-1%	-1%	0%	0%	-1%

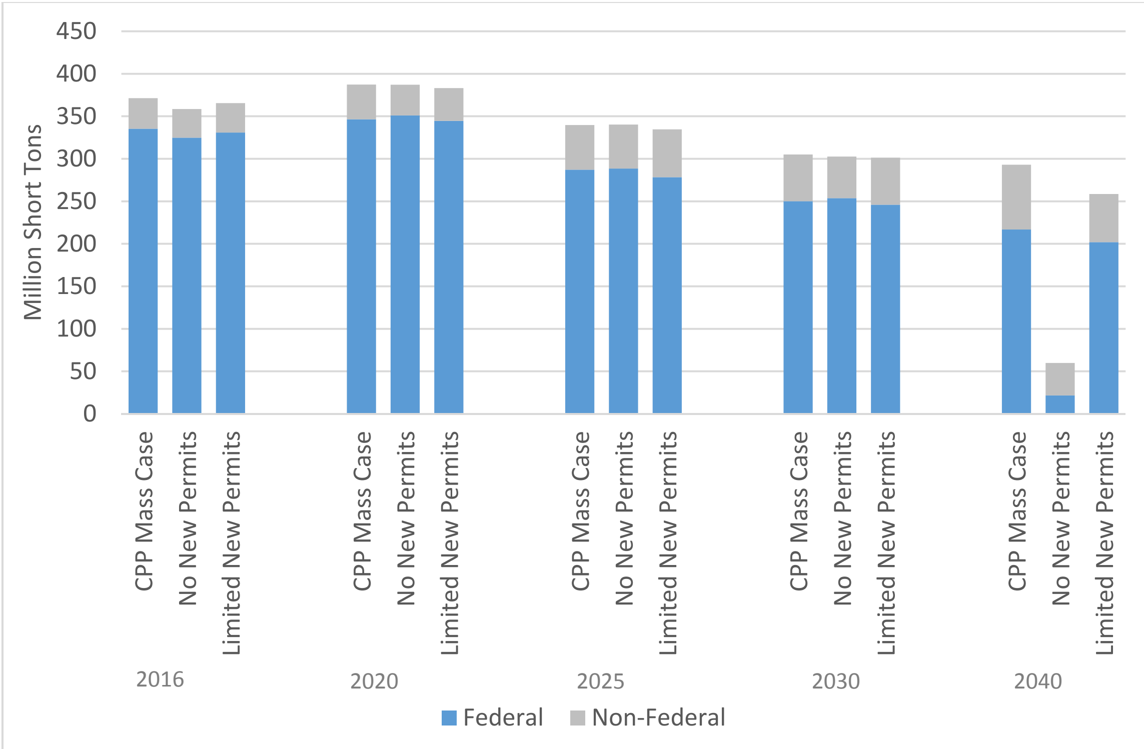
As the production limits are phased in, the difference in production between Base Case A and its alternative cases grows beginning in 2030. By 2040, a small amount of federal coal production remains, because in the IPM analysis, calendar years from 2034 to 2036 are also mapped under 2040, and under No New Permits Case, federal coal production becomes zero by 2037.[4] Additionally, the amount of non-federal coal production in 2040 mainly comes from the Youngs Creek mine and the Colorado, Raton area.

Exhibit 75: Coal Production on Federal & Non-Federal Lands – Base Case A & Base Case A with Constraints



[4] IPM uses model run years to represent the full planning horizon being modeled. Mapping each year in the planning horizon into a representative model run year enables IPM to perform multiple year analyses while keeping the model size manageable. Although IPM reports results only for model run years, it takes into account the costs in all years in the planning horizon.

Exhibit 76: Coal Production on Federal & Non-Federal Lands – CPP Mass Case & CPP Mass Case with Constraints



Coal Prices

Coal prices are higher under the production constraint limits because the model is placing a higher value on what is essentially a more limited resource in these cases. In 2040, coal prices decline in most regions in the No New Permits Case, compared to Base Case A, because the production limiting constraint is forcing the model to solve at a lower step on the coal supply curve.

Exhibit 77: Coal Price Deltas, Constraint Relative to Base Case A (2012$/Short Ton)

State		No New Permits					Limited New Permits				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	1.9	2.2	2.2	2.9	-3.6	-0.2	-0.3	-0.4	0.8	1.2
Utah	0.9	2.1	3.1	4.2	7.2	-7.0	-0.2	-0.2	0.0	0.0	0.0
Montana	0.8	-0.6	-1.3	-0.9	0.0	-5.9	0.0	-0.1	0.0	0.9	0.5
Wyoming	0.8	0.6	0.6	0.7	1.1	2.0	0.3	0.2	0.3	0.6	1.3

Exhibit 78: Coal Price % Change, Constraint Relative to Base Case A

State		No New Permits					Limited New Permits				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	5%	6%	5%	7%	-9%	-1%	-1%	-1%	2%	3%
Utah	0.9	5%	7%	9%	15%	-16%	0%	0%	0%	0%	0%
Montana	0.8	-4%	-7%	-5%	0%	-30%	0%	-1%	0%	5%	3%
Wyoming	0.8	5%	4%	5%	8%	13%	3%	1%	2%	4%	8%

Exhibit 79: Coal Price Deltas, Constraint Relative to CPP Mass Case (2012$/Short Ton)

State		No New Permits					Limited New Permits				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	0.6	1.0	1.2	-0.3	-0.5	0.2	0.3	0.4	1.6	3.4
Utah	0.9	0.6	1.1	1.1	1.4	-7.0	0.2	0.4	0.1	0.0	0.0
Montana	0.8	-1.1	-1.4	-1.7	-2.1	-5.4	0.4	0.2	0.2	0.3	1.1
Wyoming	0.8	-0.1	-0.1	-0.2	-0.2	-0.3	0.4	0.2	0.6	0.8	1.2

Exhibit 80: Coal Price % Change, Constraint Relative to CPP Mass Case

State		No New Permits					Limited New Permits				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	2%	3%	3%	-1%	-1%	0%	1%	1%	4%	9%
Utah	0.9	1%	2%	2%	3%	-16%	0%	1%	0%	0%	0%
Montana	0.8	-7%	-9%	-10%	-12%	-28%	2%	1%	1%	2%	6%
Wyoming	0.8	-1%	-1%	-1%	-2%	-2%	4%	2%	5%	6%	9%

Coal Exports

Similar to Base Case A and the CPP Mass Case, Montana continues to be the only state among the four western states that continues to export coal in the model. However, under the production limit constraints, Montana stops exporting in later years in some cases. For example, in Base Case A No New Permits Case, Montana does not export coal beginning in 2040, while when the production cap is 50% of 2013 level, Montana stops exporting coal in 2050.

Impacts on Capacity and Generation Mix

As production limits are fully implemented by 2037, there is a shift between coal and gas-fired generation in 2040. The effect is evident particularly under the No New Limits Case. In Base Case A, gas-fired generation contributes to 36% of total generation, while coal-fired generation contributes 39%. In the No New Limits Case, gas-fired generation increases to 47%, and coal-fired generation decreases to 28%. Similar changes exist in the CPP Base Case and its alternative cases.

Exhibit 81: Generation Mix – US, Base Case A and Base Case A with Constraints

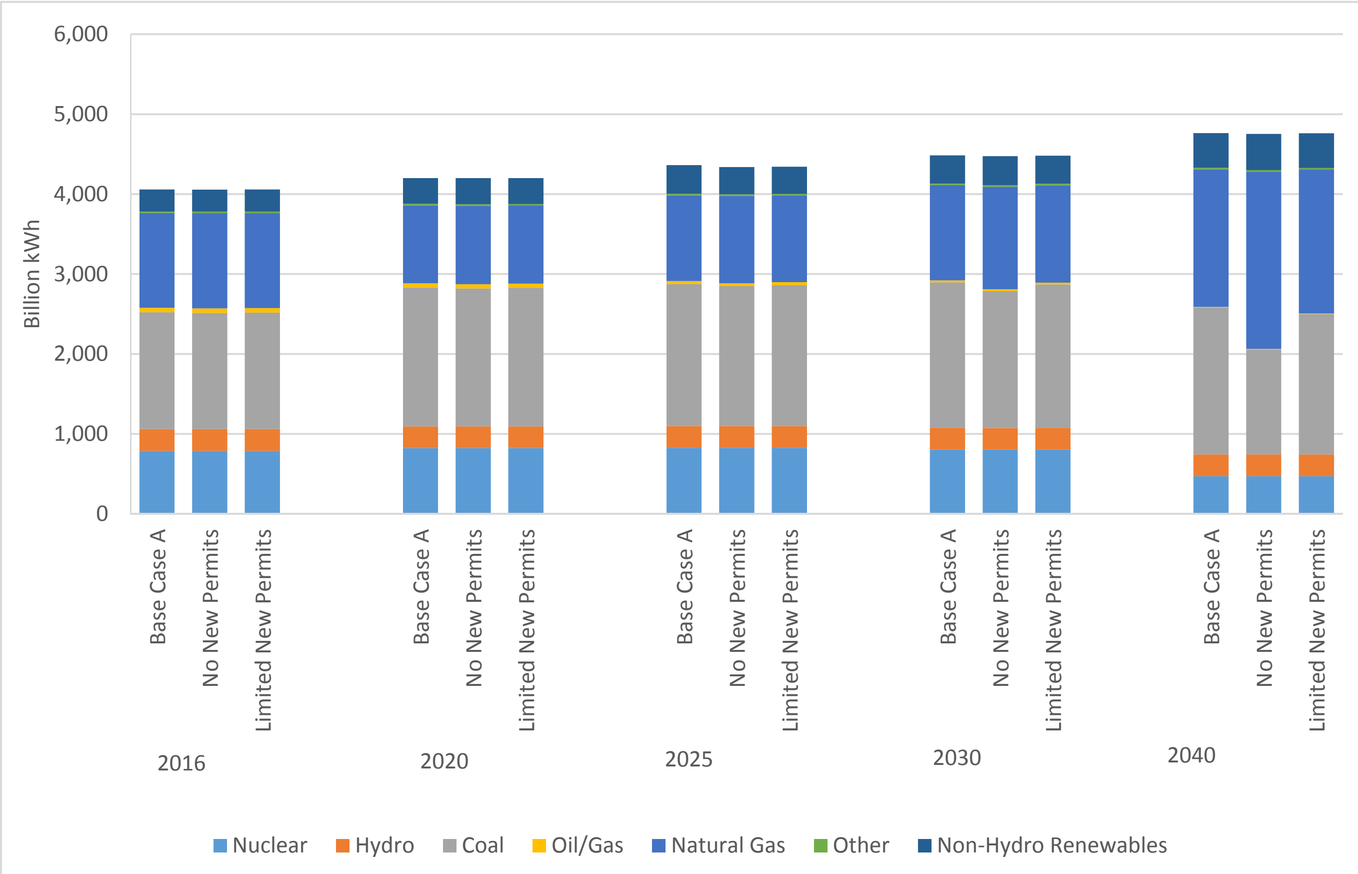
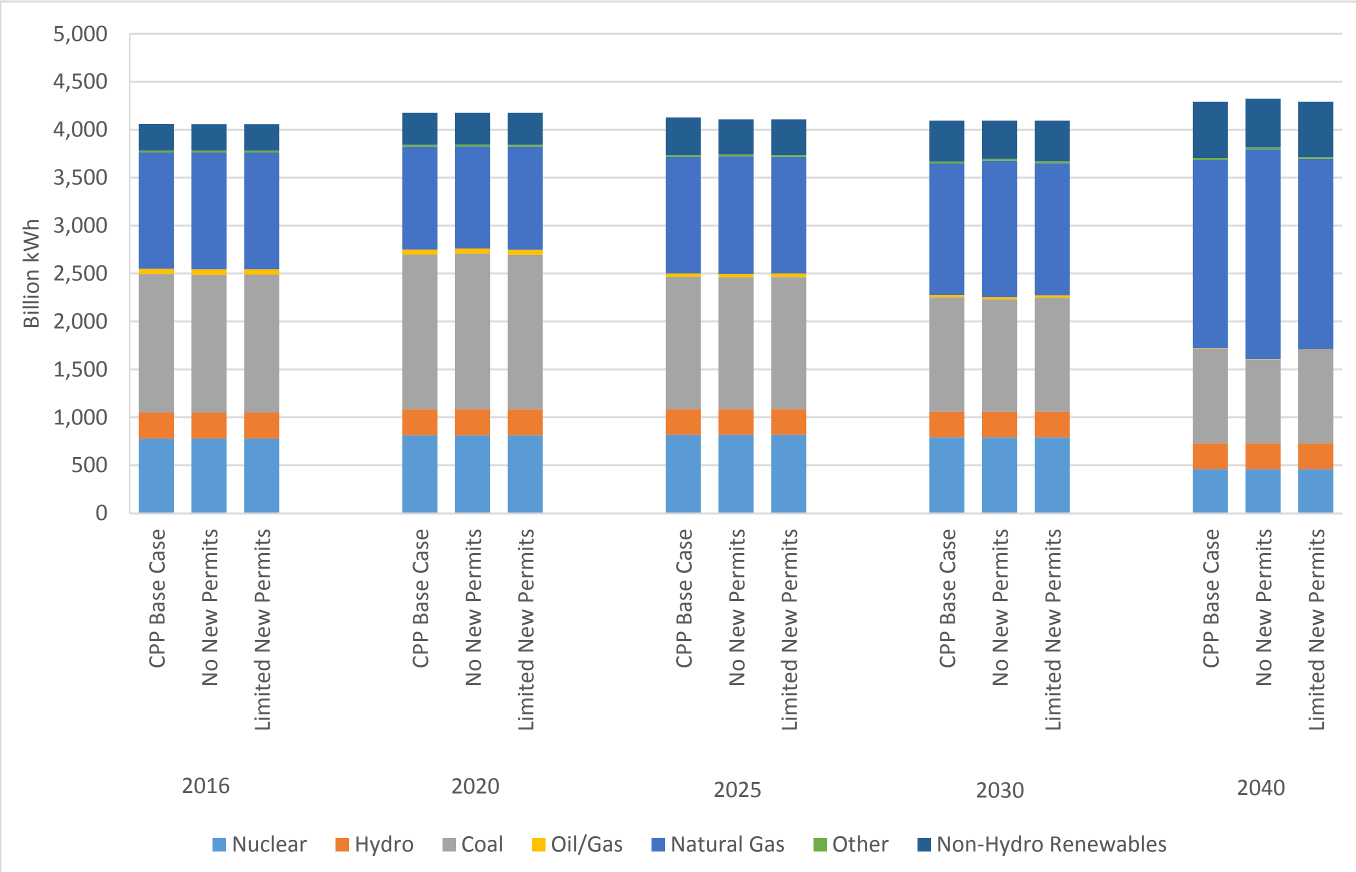


Exhibit 82: Generation Mix – US, CPP Base Case and CPP Base Case with Constraints



Impacts on Natural Gas Markets

After the production limits are applied, there is a shift from coal to gas fired generation between cases, and the shift is particularly evident in later years. Therefore, as illustrated below, under the No New Permits Case, gas consumption continues to increase after the production limits begin phasing in starting in 2028, and the gap widens due to the full implementation leading to zero federal coal production. In the CPP Cases, the trend is similar in later years. The slight increase in gas consumption in 2020 in the CPP Cases is due to the implementation of CPP, resulting in an increase in gas-fired generation. Henry Hub gas prices also reflect the same trajectory as gas consumption in all cases.

Exhibit 83: Power Sector Natural Gas Demand – US, Base Case A and Base Case A with Constraints

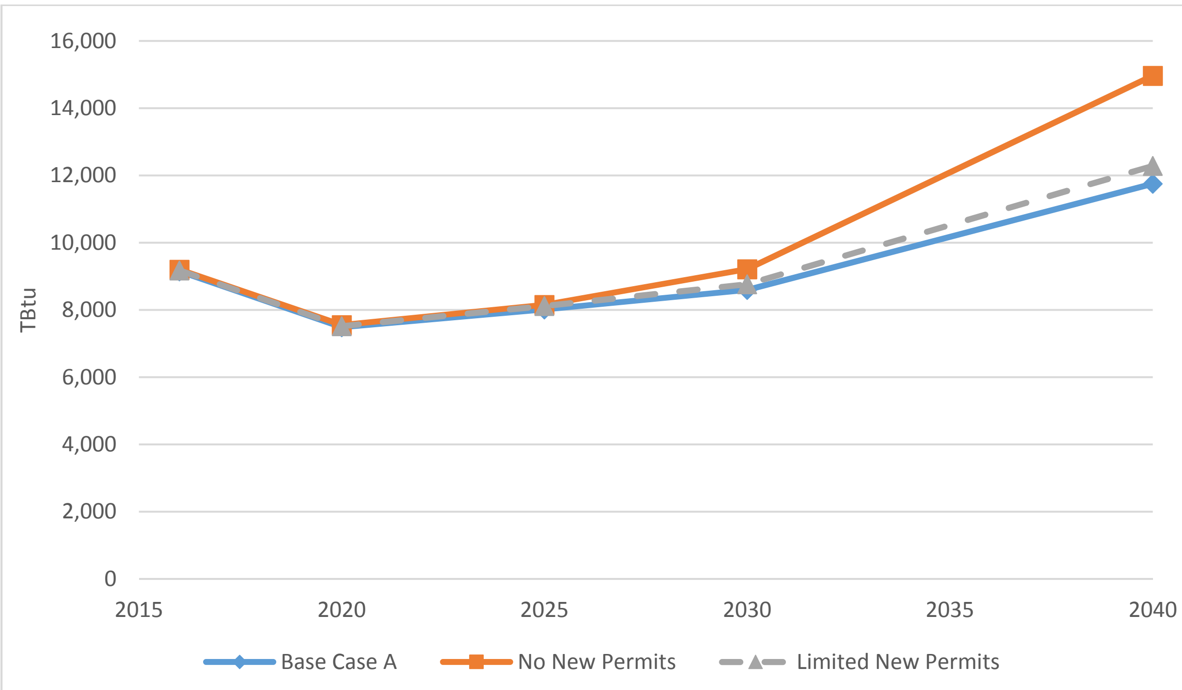


Exhibit 84: Power Sector Natural Gas Demand – US, CPP Mass Case and CPP Mass Case with Constraints

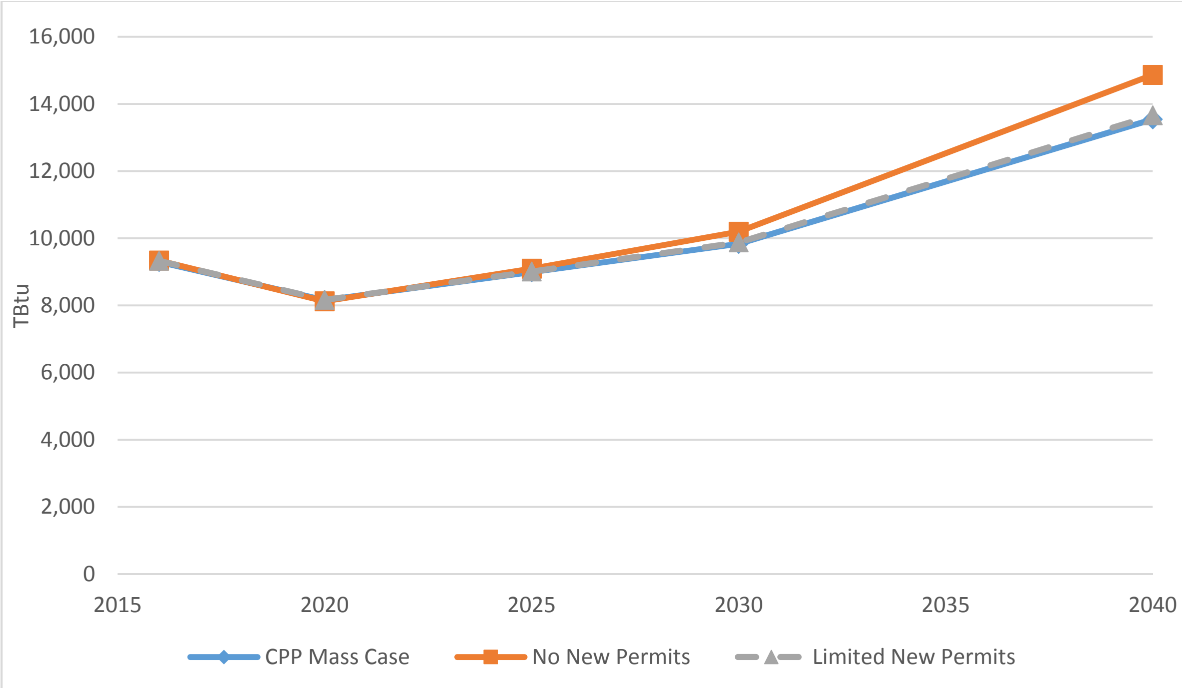


Exhibit 85: Henry Hub Prices, Base Case A and Base Case A with Constraints

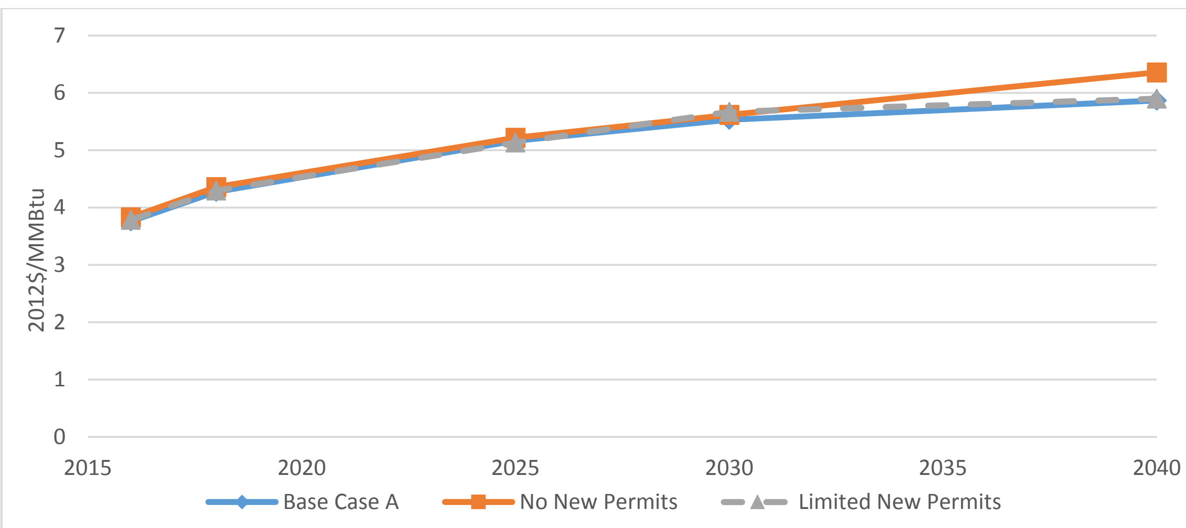
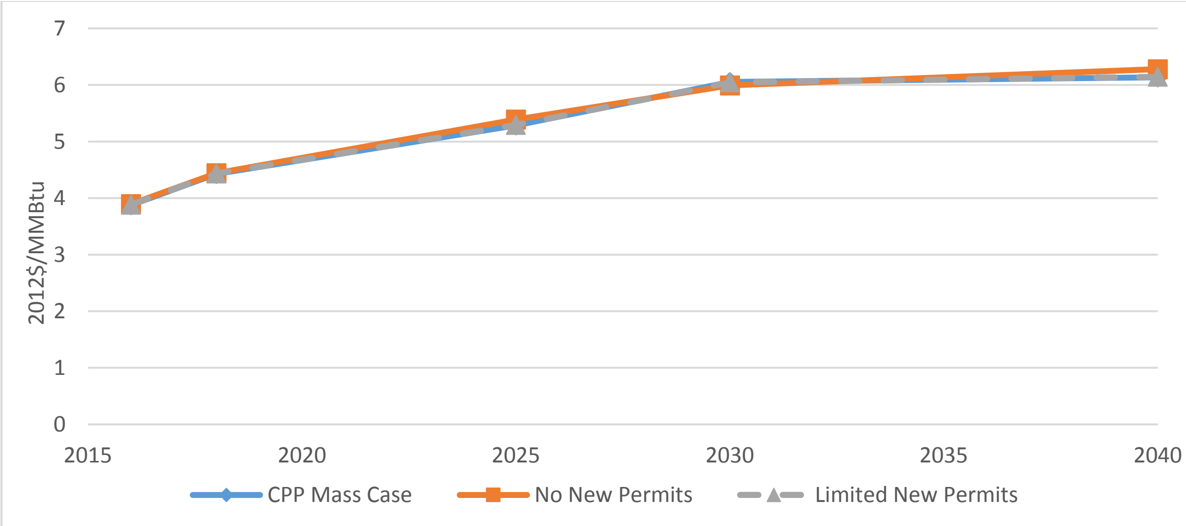


Exhibit 86: Henry Hub Prices, CPP Mass Case and CPP Mass Case with Constraints



Impacts on Firm Wholesale Power Prices

The No New Permits Cases have a larger impact on firm wholesale power prices compared to the Limited New Permits Case due to the larger shift between coal and gas-fired. By 2040, the national average firm wholesale power price in the Base Case A No New Permits Case is 6% higher than Base Case A, while the CPP Mass Cases experience a 6% decrease in the national average firm wholesale power prices. Under the Limited New Permits Cases, the differences between national average wholesale power prices remain within 2% throughout the forecast horizon.

Exhibit 87: Firm Wholesale Power Prices – US, Base Case A and Base Case A with Constraints

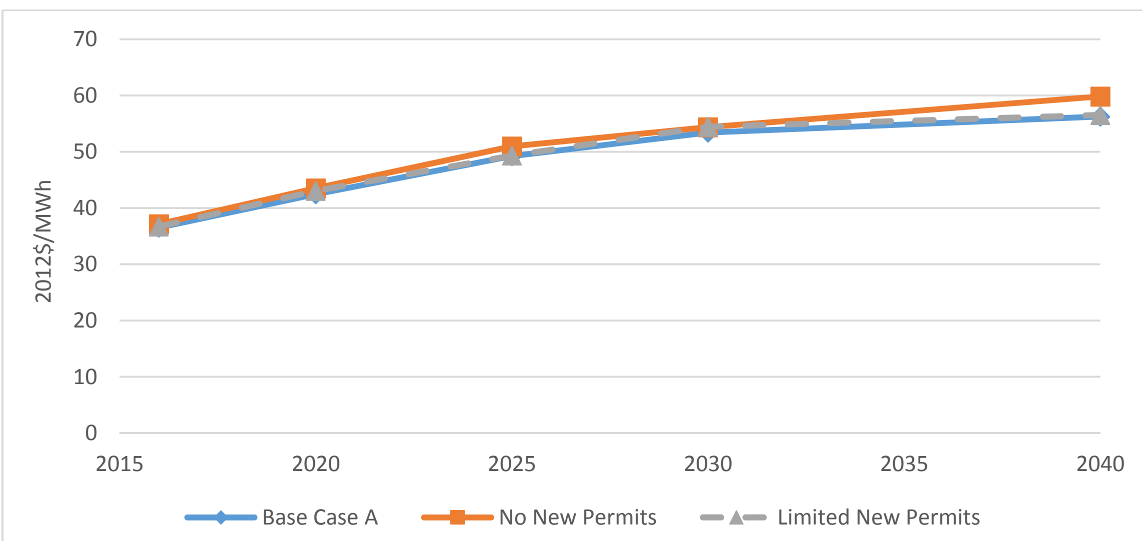
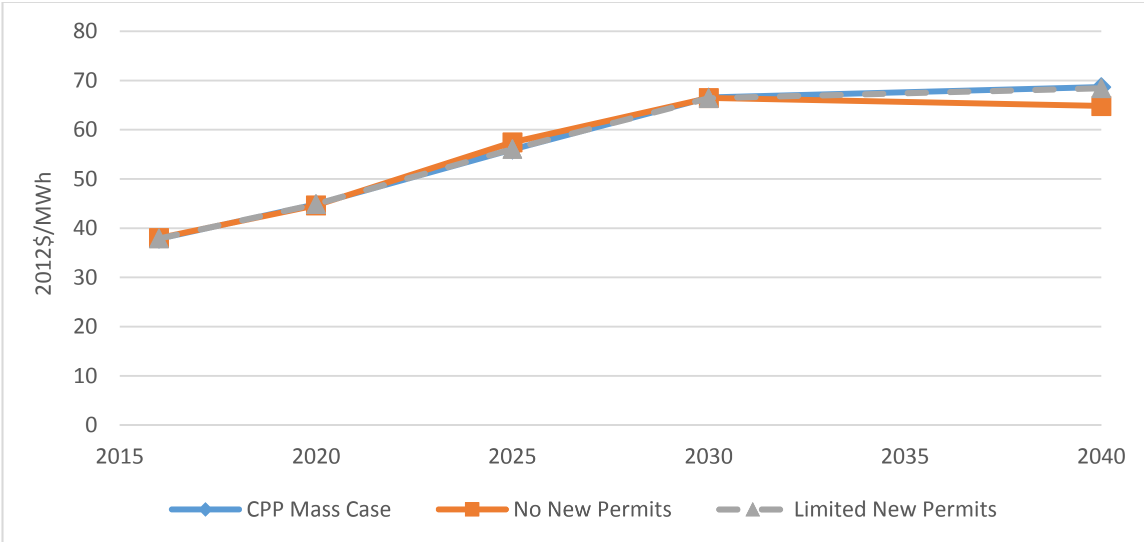


Exhibit 88: Firm Wholesale Power Prices – US, CPP Mass Case and CPP Mass Case with Constraints



CO_2 Emissions

The shift from coal to gas-fired generation after production limits are applied leads to lower CO_2 emissions. The decrease is larger under the No New Permits Cases, due to greater changes in generation mix.

Exhibit 89: CO_2 Emissions – US, Base Case A and Base Case A with Constraints

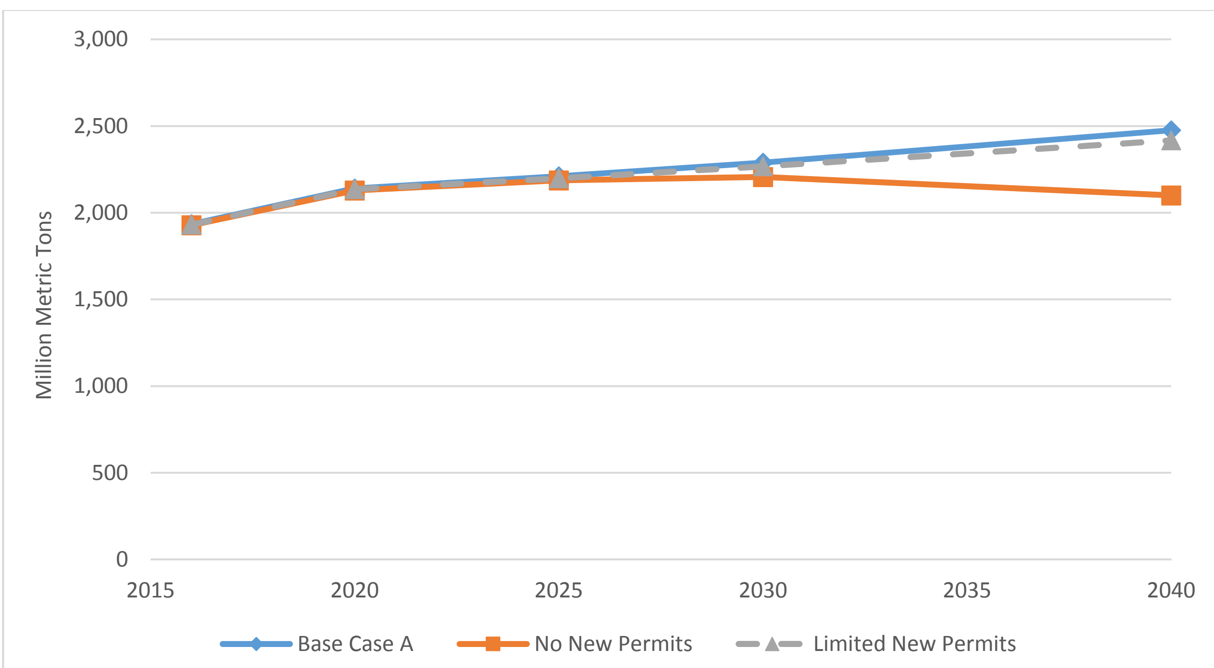
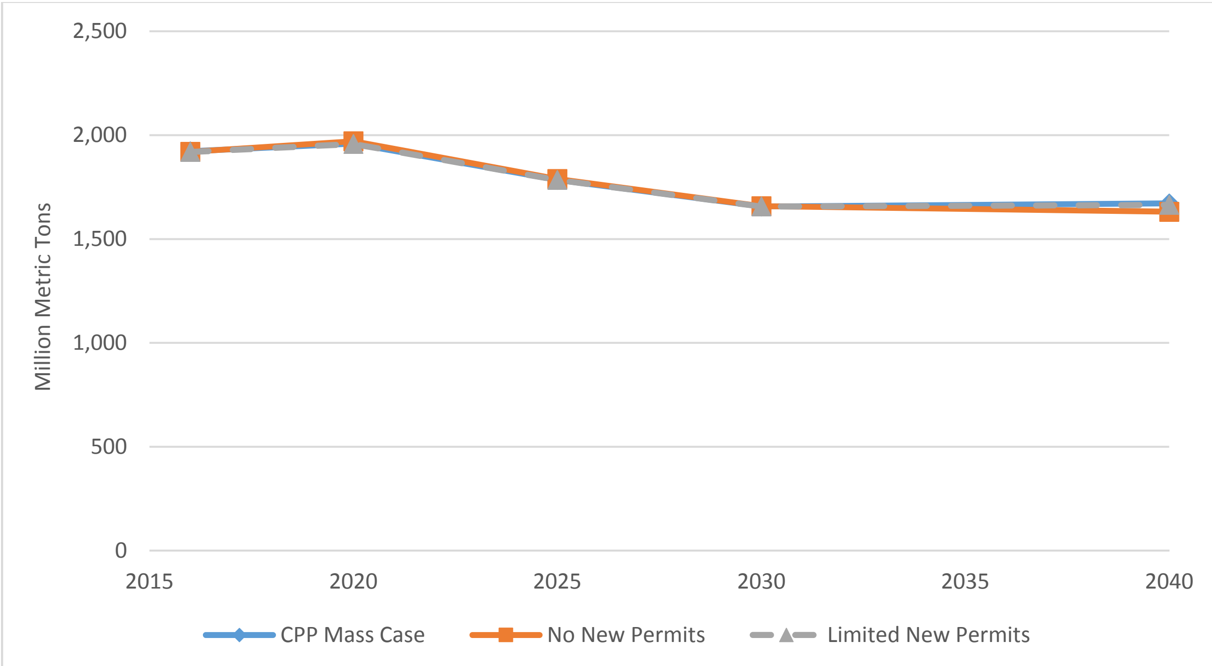


Exhibit 90: CO_2 Emissions – US, CPP Mass Case and CPP Mass Case with Constraints



Chapter 5: Reference Case Results: Base Case B

Chapter 5A: Comparison of Base Cases A and B

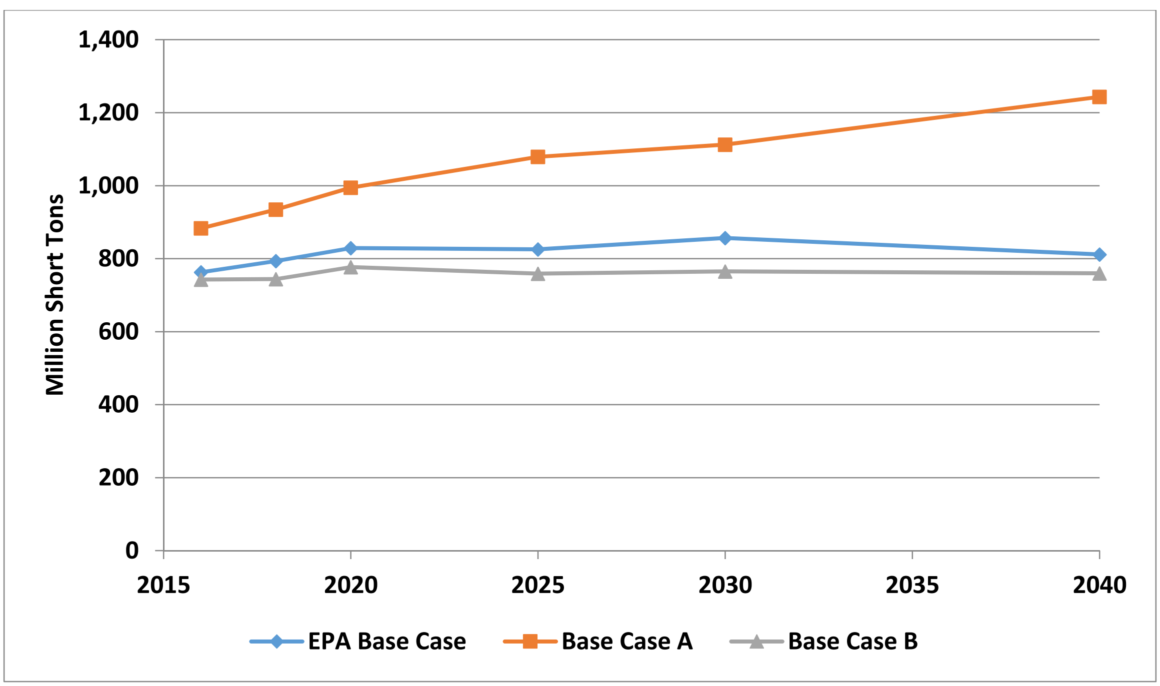
The Base Case A uses key assumptions largely consistent with those used in the EPA Base Case v.5.13 with load growth, build costs, and natural gas production assumptions from EPA Base Case v.5.15, except the coal supply curves. The coal supply curves included in Base Case A were, in general, at lower costs compared to the coal supply curves included in EPA's analysis. In Base Case B, the coal supply curves were revised to reflect the higher growth rates of coal prices and higher starting points of coal supply curves in EPA's analysis.

Additionally, Base Case B adopts publicly available assumptions from EPA more fully than the previously delivered Base Case A. Base Case A was based on EPA's Power Sector Modeling Platform v.5.13, the version used for the draft CPP RIA in June 2014. Base Case B is constructed based on EPA's Power Sector Modeling Platform v.5.15, released with the CPP Final Rule.

With adjusted coal supply curves and assumptions from EPA's Base Case for Clean Power Plan, results for Base Case B are close to EPA's final Clean Power Plan analysis. The remaining part of this section compares the results of the following three cases: EPA's Base Case for Clean Power Plan, Base Case A, and Base Case B.

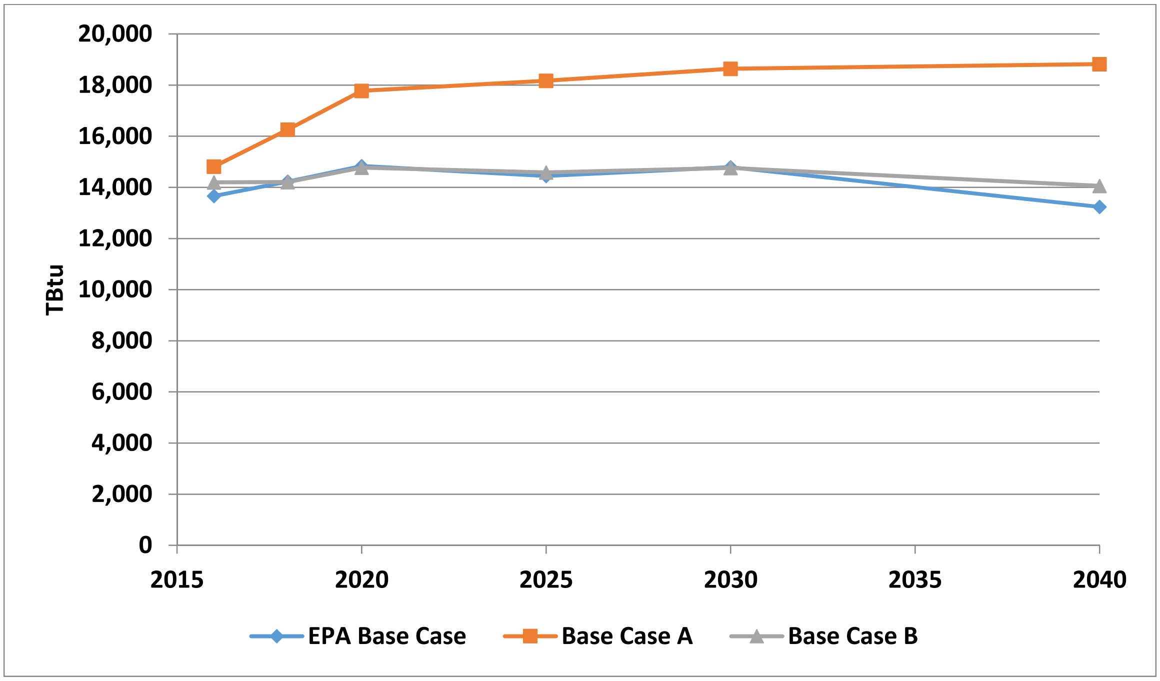
Since the EPA Base Case has coal supply curves with higher costs than in Base Case A, Base Case A forecasts higher coal production than the EPA Base Case and the Base Case B. By 2040, total coal production in the US is 53% higher in the Base Case A, while under Base Case B is 6% lower than the EPA Base Case.

Exhibit 91: Total US Coal Production



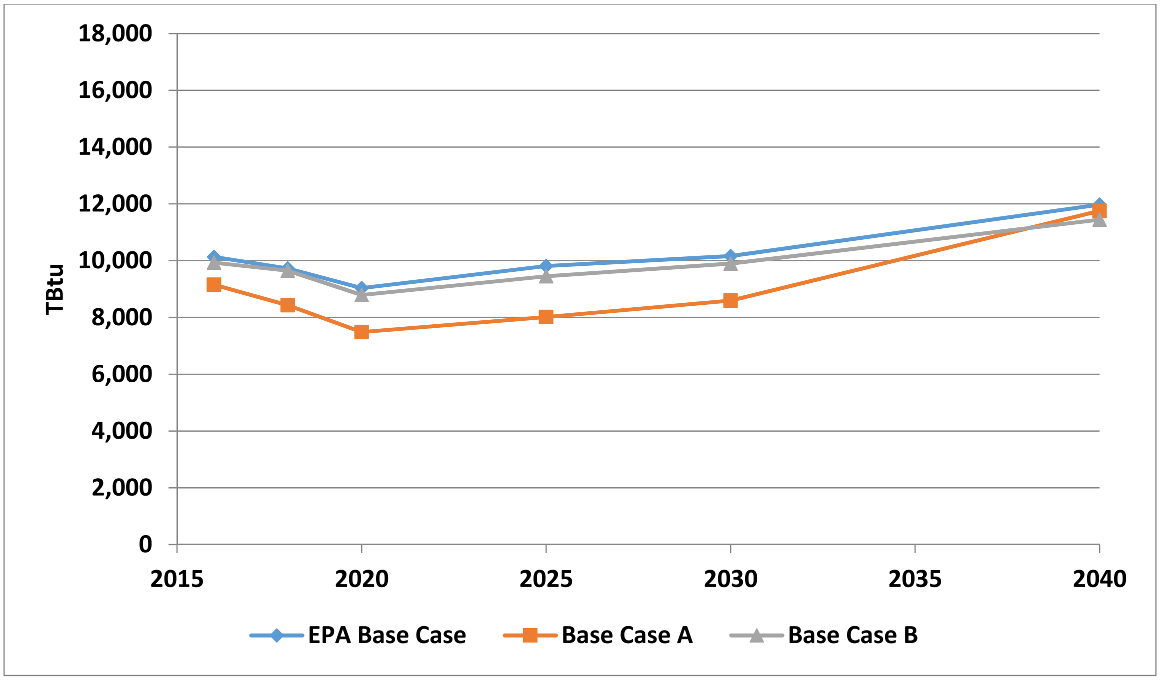
Similar to coal production, coal consumption levels show the same trend. In 2030, coal consumption in Base Case A is 26% higher than EPA's analysis and Base Case B. Throughout the majority of the forecast horizon, coal consumption from EPA's Base Case and Base Case B remains almost identical, while coal consumption from Base Case A is persistently higher.

Exhibit 92: Total US Coal Consumption



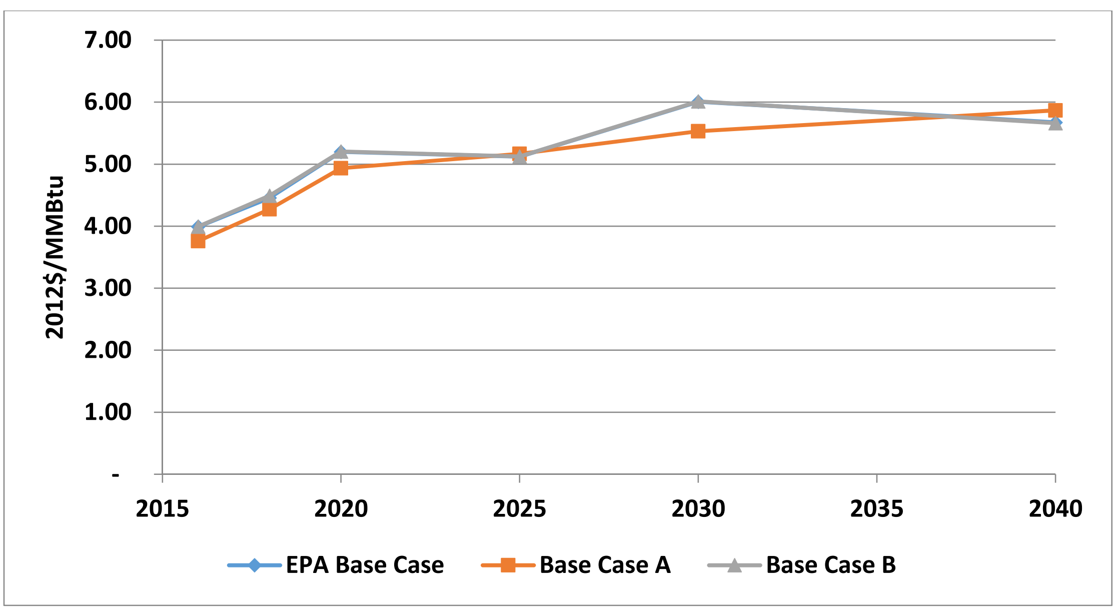
While coal production is lower in EPA's analysis and Base Case B, the higher coal supply curves in these cases lead to higher gas consumption. Natural gas consumption from Base Case A is 15% lower than EPA's analysis, while Base Case B is 3% lower. Gas consumption from Base Case A exceeds the other two cases post 2035, mainly because EPA's Base Case and Base Case B see a large increase in solar capacity after 2030, hence the demand for gas is lower. Total generation from solar capacity increases from 34 TWh to 59 TWh between the original and Base Case B in 2030, and from 105 TWh to 450 TWh in 2040.

Exhibit 93: Total US Gas Consumption



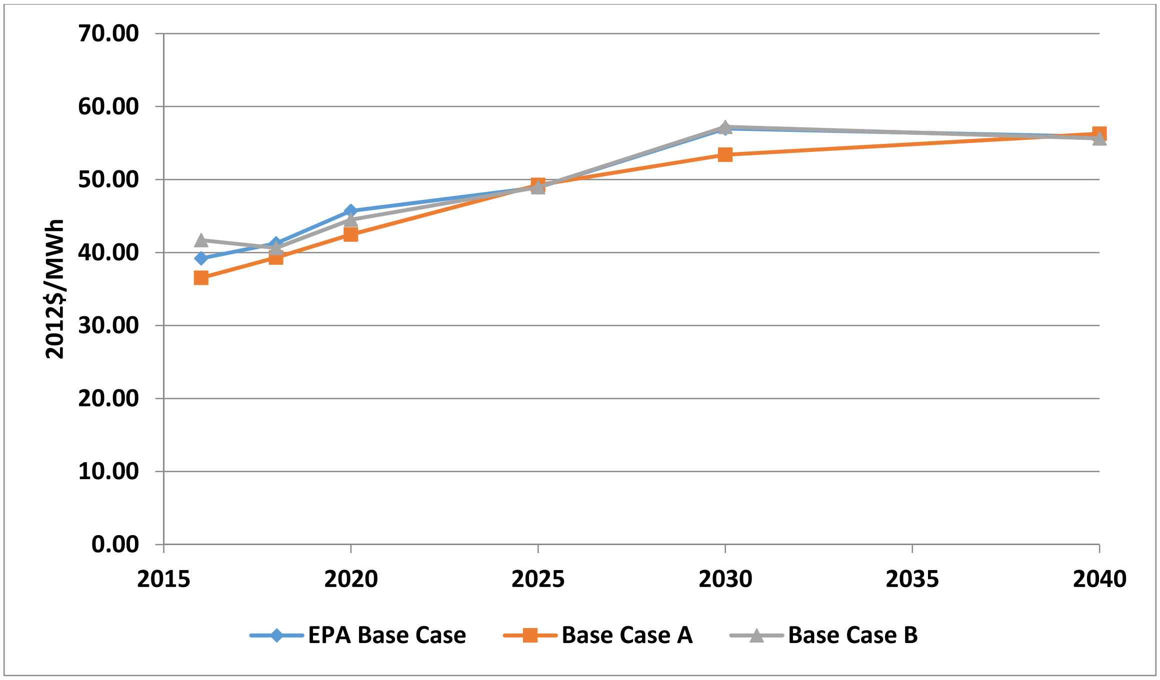
Higher gas consumption also leads to higher gas prices in Base Case B. As shown in the exhibit below, gas prices from the EPA's analysis and Base Case B remain almost identical. Similar to the trend of gas consumption, as gas demand in the Base Case A begins to exceed the other two cases, Henry Hub prices become higher.

Exhibit 94: Henry Hub Prices



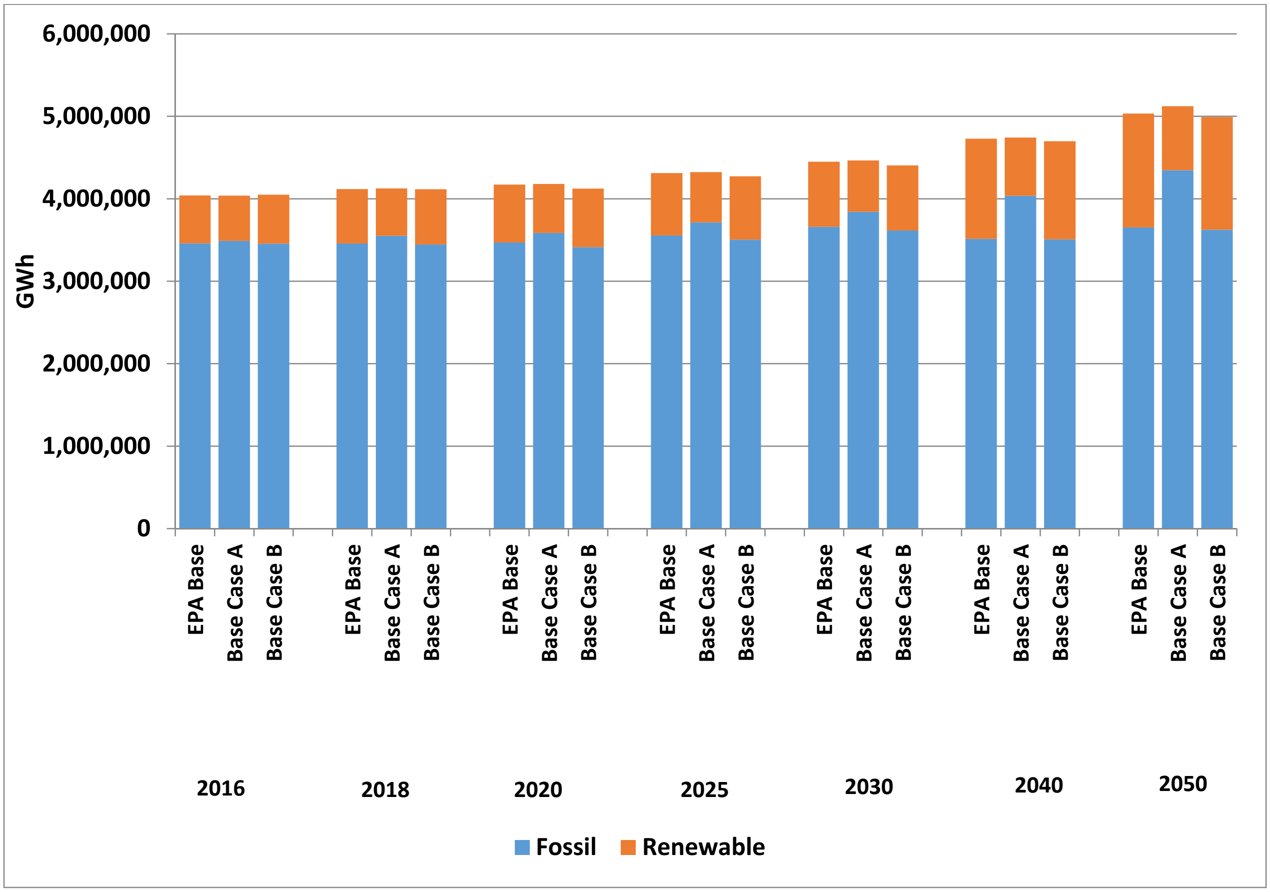
Firm wholesale power prices from three cases also exhibit a trend similar to gas consumption and Henry Hub prices. Power prices in Base Case B are higher than in Base Case A, and the prices converge towards the end of the forecast horizon.

Exhibit 95: Firm Wholesale Power Prices



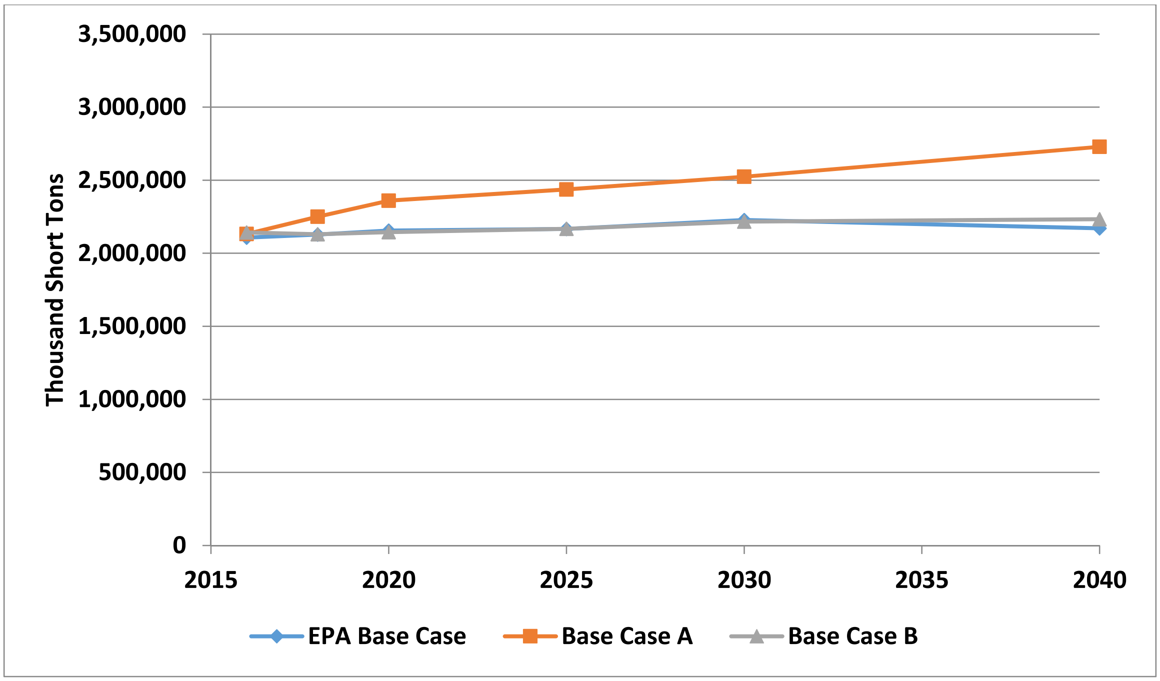
With more costly coal supply curves and low costs for renewable potential builds, Base Case B forecasts more renewable generation and less fossil fuel-fired generation in the generation mix. Similar to other metrics mentioned above, Base Case B aligns closely with EPA's Base Case for Clean Power Plan.

Exhibit 96: US Generation Mix – Fossil Fuels and Renewable



Since there is a shift from fossil fuel-fired generation to renewable generation, particularly solar, in Base Case B, CO_2 emissions are lower than in Base Case A. Compared to EPA's Base Case, in 2040, CO_2 emissions from the Base Case A are 26% higher. In Base Case B, CO_2 emissions are 3% higher than EPA's analysis. Throughout the entire forecast horizon, CO_2 emissions from the Base Case B are within 3% of EPA's Base Case for the Clean Power Plan.

Exhibit 97: Total US CO_2 Emissions



Chapter 5B: Social Cost of Carbon Policy Cases

ICF also analyzed a total of nine Social Cost of Carbon (SCC) Policy Cases – three based on each of the Base Cases: Base Case B, no CPP (referred to as "Base Case B" in Chapter 5B), Base Case B, CPP with mass-based regional trading (referred to as "CPP Mass Case" in Chapter 5B), and Base Case B, CPP with rate-based regional trading (referred to as "CPP Rate Case" in Chapter 5B). These policy cases were derived through adders based on 20%, 50%, and 100% of the social cost of carbon, respectively, to Base Case B, and the same series of carbon adders to the CPP Base Cases. The SCC values were added to the coal supply curves of coal on federal lands, thus increasing the cost of coal. Vulcan provided assumptions of the 20%, 50% and 100% of social cost of carbon adders in 2015$/short ton (Exhibit 98)[5]. The social cost of carbon adders are phased in incrementally over a period in 10 years, starting in 2016.

Exhibit 98: Adders Based on Percentage of Social Cost of Carbon (2015$/Ton)

Run Year	20%	50%	100%	% Phased-in
2016	$1.5	$3.8	$7.7	10%
2018	$4.8	$12.1	$24.2	30%
2020	$8.7	$21.7	$43.4	50%
2025	$19.0	$47.4	$94.8	100%
2030	$21.0	$52.4	$104.9	100%
2040	$24.6	$61.5	$123.1	100%

The following sections compare the results of the SCC Policy Cases to their corresponding Base Cases.

Impacts on Coal Markets

Coal Production

With the implementation of the SCC adders, total coal production in the US decreases as the percentage of the SCC adder applied increases (Exhibit 99). With the 20% SCC adder, in 2040, the decrease in total US coal production is 11%. When the SCC adder increases to 50%, the decrease is 34% in 2040, and under the 100% SCC adder, the decrease is 36% in 2040.

Since the SCC adders are applied to coal mined on federal lands in CO, MT, UT and WY, coal production in the Powder River Basin and Rocky Mountains decrease, while other regions remain relatively stable or see an increase in production. For instance, with the 50% SCC adder, in 2030, total production in the Powder River Basin and Rocky Mountains decrease by 228 million short tons (61%), while total US coal production decreases by 157 million short tons (20%). In other words, production in other basins increases to offset some of the declines in PRB production; however, the increases are not enough to fully offset the decline in PRB production.

[5] http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

In Base Case B with SCC adders, coal production decreases after 2030, with the 50% and 100% cases experiencing sharper declines in production before 2030. In CPP Mass Case with SCC adders, coal production steadily decreases as the CPP is implemented as a mass cap. On the other hand, when the SCC adders are applied to the CPP Rate Case, coal production decreases until 2030, then the total coal production level begins to increase, as additional energy efficiency and renewable resources allow more existing coal-fired sources to remain online without exceeding the emission rates.

Similar trends exist in both Base Cases and CPP Mass and Rate Cases (Exhibit 99 to

Exhibit 101). However, the difference between cases is smaller for the CPP Cases, since the total coal demand is lower in these cases.

Exhibit 102 to Exhibit 107 show the absolute and percent changes in coal production for all of the SCC cases.

Exhibit 99: Coal Production – US, Base Case B with SCC Adders

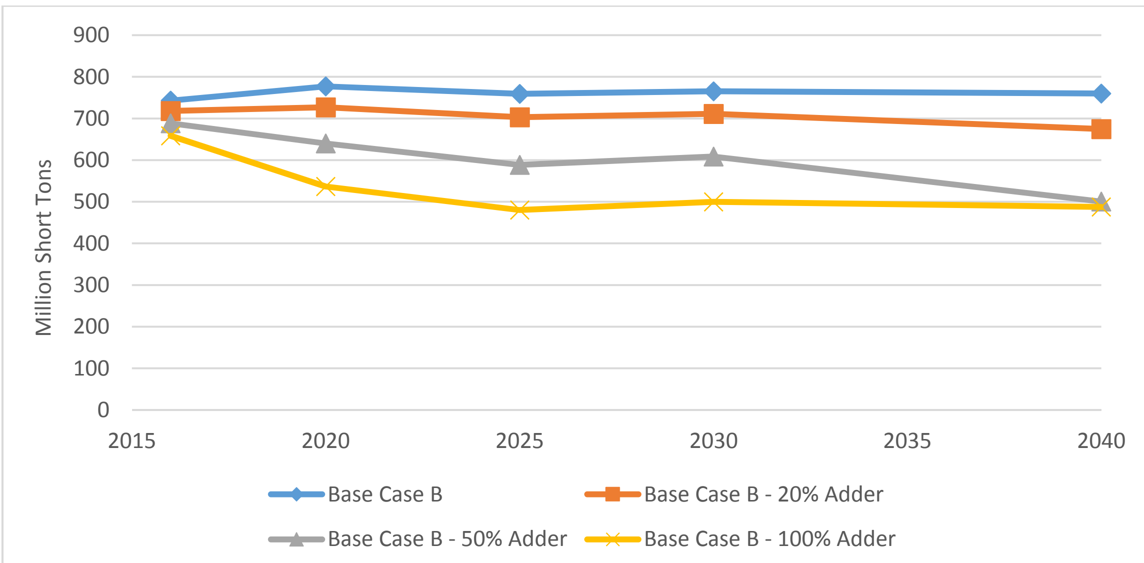


Exhibit 100: Coal Production – US, CPP Mass Cases with SCC Adders

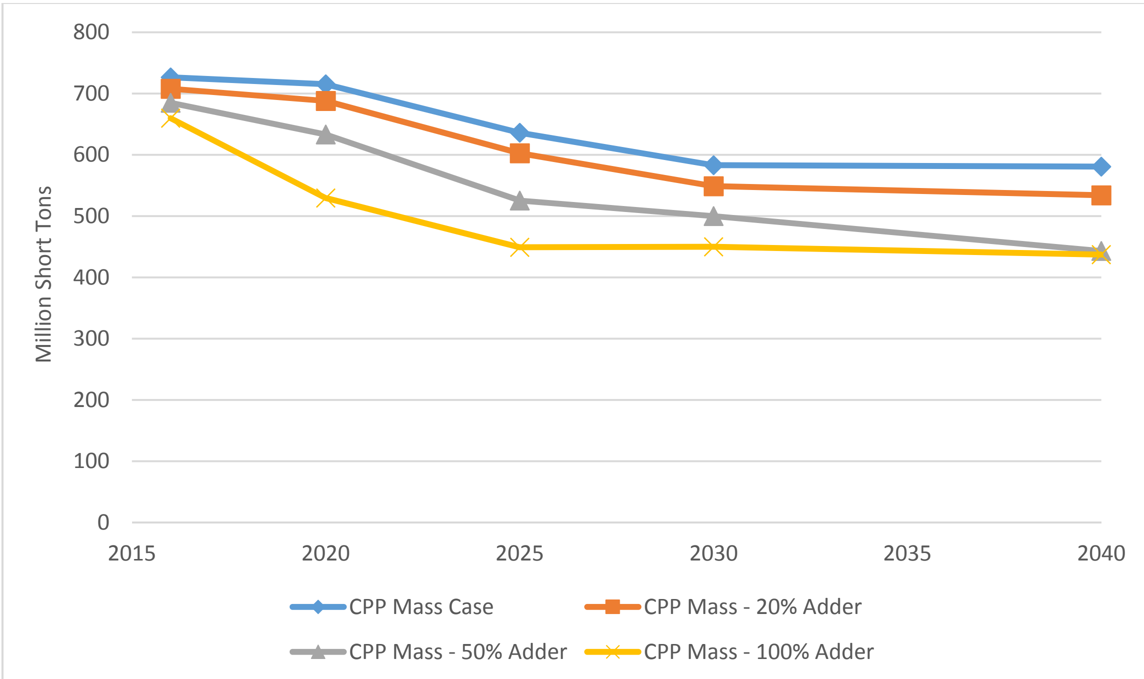


Exhibit 101: Coal Production – US, CPP Rate Cases with SCC Adders

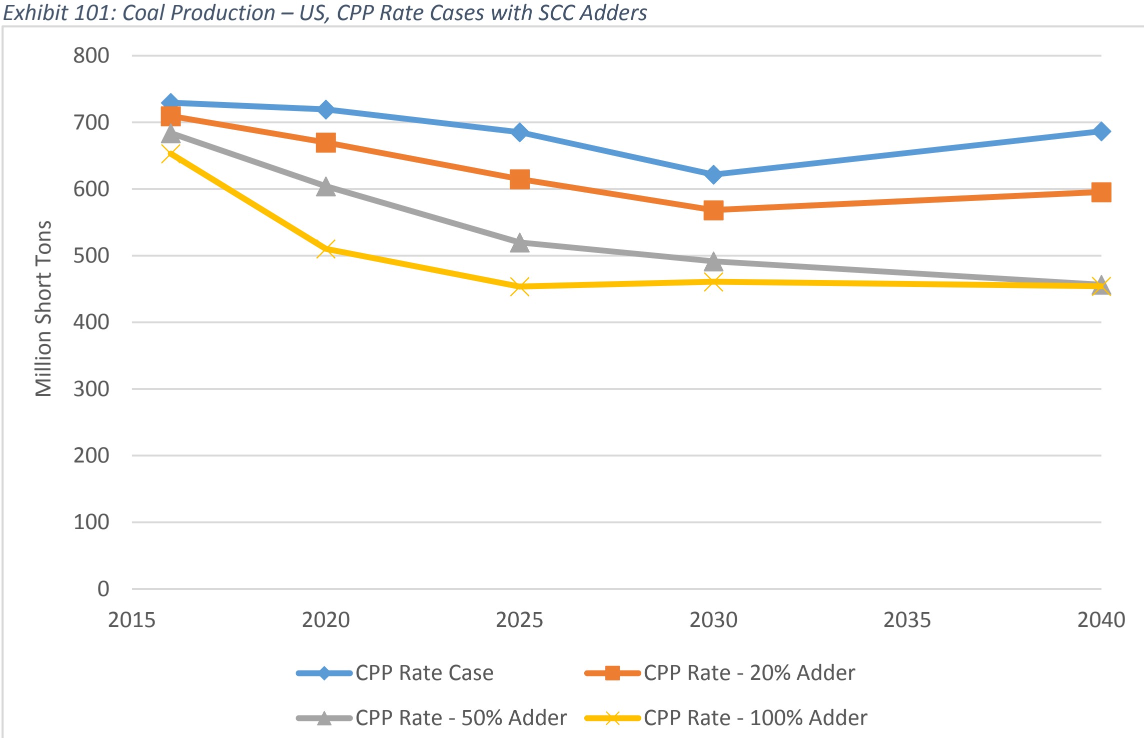


Exhibit 102: Coal Production by Basin Deltas, Base Case B with SCC Adders Relative to Base Case B (Million Short Tons)

Coal Supply Region	20%					50%					100%				
	2016	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**
Central Appalachia (CAPP)	2	7	5	1	0	7	15	11	3	0	6	25	14	5	1
Northern Appalachia (NAPP)	6	8	8	12	7	8	15	26	20	13	12	22	40	31	13
Illinois Basin (ILB)	2	3	16	15	17	3	4	19	35	35	2	11	26	50	54
Powder River Basin (PRB)	-28	-56	-86	-76	-110	-64	-156	-233	-208	-294	-99	-277	-328	-308	-305
Rocky Mountains	-3	-10	-14	-15	-14	-6	-14	-20	-20	-14	-5	-25	-38	-36	-26
All other U.S. Regions	-3	-3	15	10	14	-3	0	26	13	1	-1	3	6	-8	-10
Total	-25	-50	-56	-54	-85	-54	-137	-171	-157	-260	-84	-240	-279	-265	-273

Exhibit 103: Coal Production by Basin % Change, Base Case B with SCC Adders Relative to Base Case B

Coal Supply Region	20%					50%					100%				
	2016	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**
Central Appalachia (CAPP)	2%	12%	13%	3%	-1%	10%	24%	27%	10%	2%	9%	42%	36%	16%	9%
Northern Appalachia (NAPP)	8%	12%	11%	15%	8%	12%	21%	34%	26%	16%	17%	31%	52%	39%	16%
Illinois Basin (ILB)	3%	3%	18%	16%	17%	4%	4%	22%	39%	34%	3%	12%	30%	55%	53%
Powder River Basin (PRB)	-8%	-16%	-25%	-24%	-35%	-18%	-44%	-69%	-65%	-94%	-27%	-77%	-97%	-97%	-97%
Rocky Mountains	-5%	-18%	-26%	-26%	-25%	-11%	-26%	-37%	-36%	-26%	-9%	-45%	-71%	-65%	-46%
All other U.S. Regions	-3%	-2%	9%	5%	7%	-2%	0%	16%	7%	0%	-1%	2%	4%	-4%	-5%
Total	-3%	-6%	-7%	-7%	-11%	-7%	-18%	-22%	-20%	-34%	-11%	-31%	-37%	-35%	-36%

Exhibit 104: Coal Production by Basin Deltas, CPP Mass Case with SCC Adders Relative to CPP Mass Case (Million Short Tons)

Coal Supply Region	20%					50%					100%				
	2016	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**
Central Appalachia (CAPP)	0	8	4	1	1	2	13	12	7	2	4	24	15	11	2
Northern Appalachia (NAPP)	4	5	8	7	9	7	11	19	21	22	9	19	33	32	29
Illinois Basin (ILB)	4	10	18	23	23	6	13	31	36	47	7	17	37	45	55
Powder River Basin (PRB)	-25	-56	-82	-92	-114	-52	-125	-201	-193	-248	-84	-247	-278	-255	-256
Rocky Mountains	-1	-6	0	1	8	-5	-7	-7	1	6	-4	-16	-22	-12	-2
All other U.S. Regions	-1	12	18	26	25	0	14	35	45	34	1	17	29	46	29
Total	-19	-27	-33	-34	-47	-41	-82	-111	-83	-137	-66	-185	-187	-133	-143

Exhibit 105: Coal Production by Basin % Change, CPP Mass Case with SCC Adders Relative to CPP Mass Case

Coal Supply Region	20%					50%					100%				
	2016	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**
Central Appalachia (CAPP)	0%	13%	14%	5%	12%	3%	22%	38%	40%	21%	6%	41%	47%	61%	21%
Northern Appalachia (NAPP)	6%	7%	13%	11%	15%	10%	16%	30%	34%	36%	14%	28%	51%	51%	47%
Illinois Basin (ILB)	5%	13%	25%	31%	32%	8%	17%	43%	48%	66%	9%	23%	50%	61%	78%
Powder River Basin (PRB)	-7%	-17%	-29%	-35%	-43%	-15%	-37%	-70%	-73%	-94%	-24%	-74%	-97%	-97%	-97%
Rocky Mountains	-2%	-12%	1%	3%	27%	-9%	-14%	-18%	4%	20%	-8%	-33%	-58%	-39%	-7%
All other U.S. Regions	-1%	9%	12%	20%	18%	0%	11%	25%	33%	23%	1%	13%	20%	34%	20%
Total	-3%	-4%	-5%	-6%	-8%	-6%	-11%	-17%	-14%	-24%	-9%	-26%	-29%	-23%	-25%

Exhibit 106: Coal Production by Basin Deltas, CPP Rate Case with SCC Adders Relative to CPP Rate Case (Million Short Tons)

Coal Supply Region	20%					50%					100%				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	2	6	2	2	0	1	13	11	8	-2	1	24	17	12	-2
Northern Appalachia (NAPP)	5	7	9	11	9	8	14	20	28	20	11	18	35	38	19
Illinois Basin (ILB)	4	10	20	22	18	6	13	30	34	34	7	18	34	49	50
Powder River Basin (PRB)	-29	-73	-107	-107	-135	-54	-151	-232	-218	-284	-88	-262	-305	-272	-292
Rocky Mountains	-2	-10	-4	-1	-2	-7	-15	-10	-4	-6	-6	-20	-23	-14	-11
All other U.S. Regions	0	10	9	19	18	0	11	16	22	7	1	14	11	26	3
Total	-20	-50	-70	-53	-91	-46	-115	-165	-130	-230	-76	-209	-232	-161	-233

Exhibit 107: Coal Production by Basin % Change, CPP Rate Case with SCC Adders Relative to CPP Rate Case

Coal Supply Region	20%					50%					100%				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Central Appalachia (CAPP)	2%	10%	6%	11%	-1%	1%	23%	31%	39%	-13%	1%	43%	49%	65%	-13%
Northern Appalachia (NAPP)	7%	11%	14%	19%	12%	12%	20%	31%	46%	27%	15%	27%	53%	61%	26%
Illinois Basin (ILB)	6%	13%	27%	29%	21%	8%	17%	40%	44%	38%	9%	23%	45%	64%	56%
Powder River Basin (PRB)	-8%	-22%	-34%	-38%	-45%	-15%	-44%	-74%	-78%	-94%	-25%	-77%	-97%	-97%	-97%
Rocky Mountains	-4%	-20%	-11%	-2%	-4%	-14%	-31%	-26%	-11%	-14%	-12%	-42%	-61%	-43%	-28%
All other U.S. Regions	0%	8%	5%	13%	11%	0%	9%	10%	15%	4%	1%	10%	7%	17%	2%
Total	-3%	-7%	-10%	-9%	-13%	-6%	-16%	-24%	-21%	-34%	-10%	-29%	-34%	-26%	-34%

Coal mined on federal lands is affected by the SCC adders, particularly with the 50% and 100% SCC adders. As illustrated in Exhibit 108, in 2040, the 20% SCC adder leads to a 48.1% drop in coal mined on federal lands, while the 50% and 100% SCC adders have 95.8% and 99.7% declines in federal coal production, respectively. Even with the 100% SCC adder, PRB coal production on federal lands is not completely eliminated. This is due in part to the ratios applied to mines that cover Federal and non-Federal land as well as some coal plants that remain online to meet generation needs and do not have the option to switch to an alternative coal.

Under the modeling assumptions regarding the comingling of federal and non-federal coal in logical mining units, coal cannot be preferentially mined on non-federal lands to substitute for declines in federal coal production. Therefore, when the SCC adders cause decreases in federal coal production, comingled non-federal coal witnesses a reduction as well. CPP Base Cases with the SCC adders also experience a drop in production levels in both federal and non-federal coal, but due to lower demand for coal in the CPP Base Case, the impact is smaller in scale compared to Base Case B. Demand for coal is overall lower in the CPP cases due to the CO_2 rate limits and mass caps imposed, and electric demand is also lower due to increased energy efficiency (EE).

Exhibit 108: Coal Production on Federal & Non-Federal Lands – Base Case B & Base Case B with SCC Adders

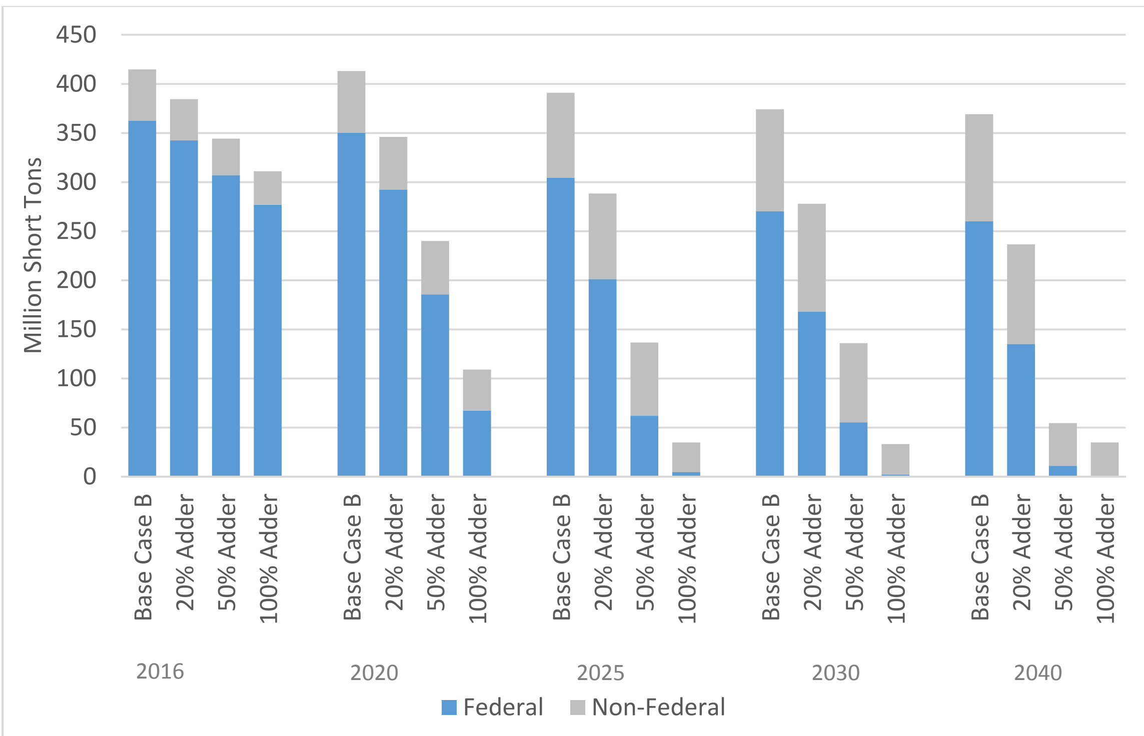


Exhibit 109: Coal Production on Federal & Non-Federal Lands – CPP Mass Case & CPP Mass Case with SCC Adders

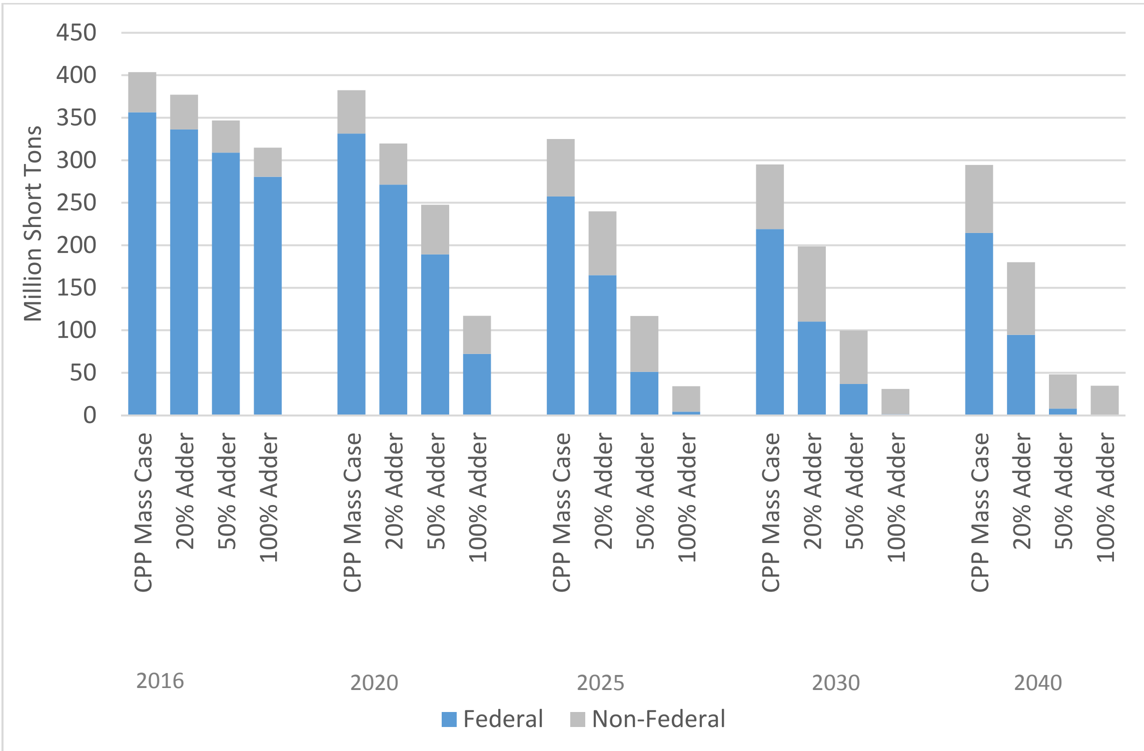
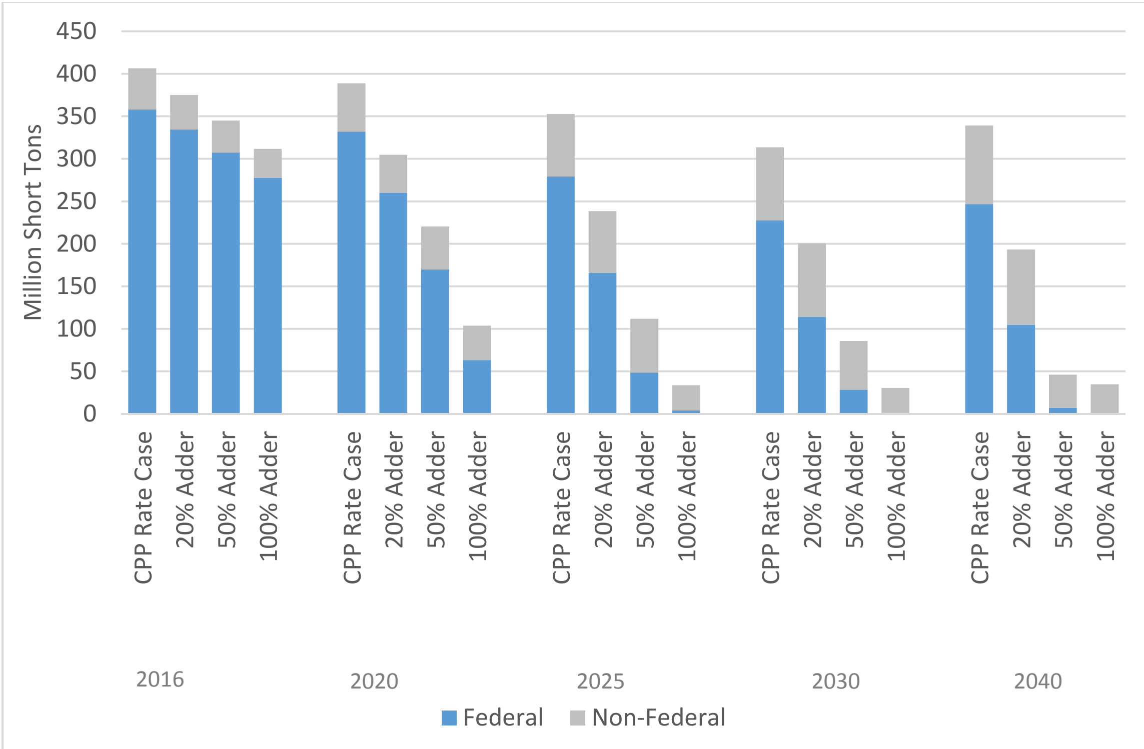


Exhibit 110: Coal Production on Federal & Non-Federal Lands – CPP Rate Case & CPP Rate Case with SCC Adders



Coal Prices

The increase in coal prices in CO, MT, UT, and WY reflect the incorporation of the SCC adders. Values of "NA" in Exhibit 111 through Exhibit 116 signify that no coal was produced and therefore, the model could not determine a price.

Exhibit 111: Coal Prices Deltas, Base Case B with SCC Adders Relative to Base Case B (2012$/Short Ton)

State				20%					50%					100%		
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	0	3	10	11	13	2	12	25	28	NA	5	23	NA	NA	NA
Utah	0.9	2	6	12	12	13	2	14	30	31	32	6	30	NA	NA	NA
Montana	0.8	0	4	10	11	13	1	11	NA	NA	NA	3	NA	NA	NA	NA
Wyoming	0.8	0	4	12	13	NA	1	14	NA	NA	NA	3	NA	NA	NA	NA

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Exhibit 112: Coal Prices % Change, Base Case B with SCC Adders Relative to Base Case B (% Change)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	0%	7%	25%	25%	26%	4%	29%	60%	63%	NA	12%	58%	NA	NA	NA
Utah	0.9	4%	14%	29%	28%	25%	6%	37%	74%	69%	61%	14%	78%	NA	NA	NA
Montana	0.8	0%	22%	49%	44%	41%	6%	58%	NA	NA	NA	16%	NA	NA	NA	NA
Wyoming	0.8	0%	28%	71%	65%	NA	7%	94%	NA	NA	NA	23%	NA	NA	NA	NA

Exhibit 113: Coal Prices Deltas, CPP Mass Case with SCC Adders Relative to CPP Mass Case (2012$/Short Ton)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	1	5	9	10	NA	3	13	23	NA	NA	5	25	NA	NA	NA
Utah	0.9	1	6	12	12	13	2	15	31	31	32	5	31	NA	NA	NA
Montana	0.8	1	5	11	11	43	2	12	NA	NA	0	4	NA	NA	NA	NA
Wyoming	0.8	0	5	13	14	NA	2	15	NA	NA	NA	4	NA	NA	NA	NA

Exhibit 114: Coal Prices % Change, CPP Mass Case with SCC Adders Relative to CPP Mass Case (% Change)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	2%	13%	23%	24%	NA	7%	34%	57%	NA	NA	13%	64%	NA	NA	NA
Utah	0.9	2%	16%	30%	28%	25%	5%	39%	75%	69%	61%	13%	81%	NA	NA	NA
Montana	0.8	3%	26%	56%	47%	N/A	10%	63%	NA	NA	NA	22%	NA	NA	NA	NA
Wyoming	0.8	3%	36%	84%	77%	NA	13%	107%	NA	NA	NA	30%	NA	NA	NA	NA

Exhibit 115: Coal Prices Deltas, CPP Rate Case with SCC Adders Relative to CPP Rate Case (2012$/Short Ton)

State		20%					50%					100%				
	SO_2	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado	0.9	1	5	9	10	NA	2	13	23	NA	NA	5	24	NA	NA	NA
Utah	0.9	1	6	12	12	13	1	14	31	30	32	5	30	NA	NA	NA
Montana	0.8	0	5	11	11	12	1	12	NA	NA	NA	4	NA	NA	NA	NA
Wyoming	0.8	0	5	12	13	NA	1	15	NA	NA	NA	4	NA	NA	NA	NA

Exhibit 116: Coal Prices % Change, CPP Rate Case with SCC Adders Relative to CPP Rate Case (% Change)

State		20%					50%					100%				
	SO_2	**2016**	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**	**2016**	**2020**	**2025**	**2030**	**2040**
Colorado	0.9	2%	12%	21%	22%	NA	6%	33%	55%	NA	NA	12%	62%	NA	NA	NA
Utah	0.9	2%	16%	30%	28%	25%	4%	37%	75%	68%	61%	12%	78%	NA	NA	NA
Montana	0.8	1%	26%	51%	45%	39%	7%	63%	NA	NA	NA	21%	NA	NA	NA	NA
Wyoming	0.8	-1%	32%	75%	68%	NA	9%	99%	NA	NA	NA	25%	NA	NA	NA	NA

Coal Exports

With the 20% SCC adder, the total exports from western states are similar to Base Case B. Montana is the main exporting state in the model because its mines are closer to export terminals than other PRB coal. Additionally, Montana coal also enjoys a higher heat content resulting in lower delivered costs per unit of heating value. However, under the 50% and 100% SCC adders, exports from Colorado, Utah, and Wyoming decrease to zero. This trend is the same in both Base Cases and CPP Mass Cases.

Impacts on Capacity and Generation Mix

As the percentage of the SCC adder increases, there is a shift from coal to natural gas in the generation mix (Exhibit 117). For example, in Base Case B with the 50% SCC adder scenario, in 2030, there is an increase of 48% in new combined cycle generation compared to Base Case B, while coal-fired generation experiences a decrease of 15%. The trend of increasing gas-fired and decreasing coal-fired generation is also evident in CPP Cases (Exhibit 118 and Exhibit 119). In the long run, the coal to natural gas shift is most evident in the CPP Mass Cases with SCC adders, as the mass based emission caps lead to lower coal generation and coal production.

Exhibit 117: Generation Mix – US, Base Case B and Base Case B with SCC Adders

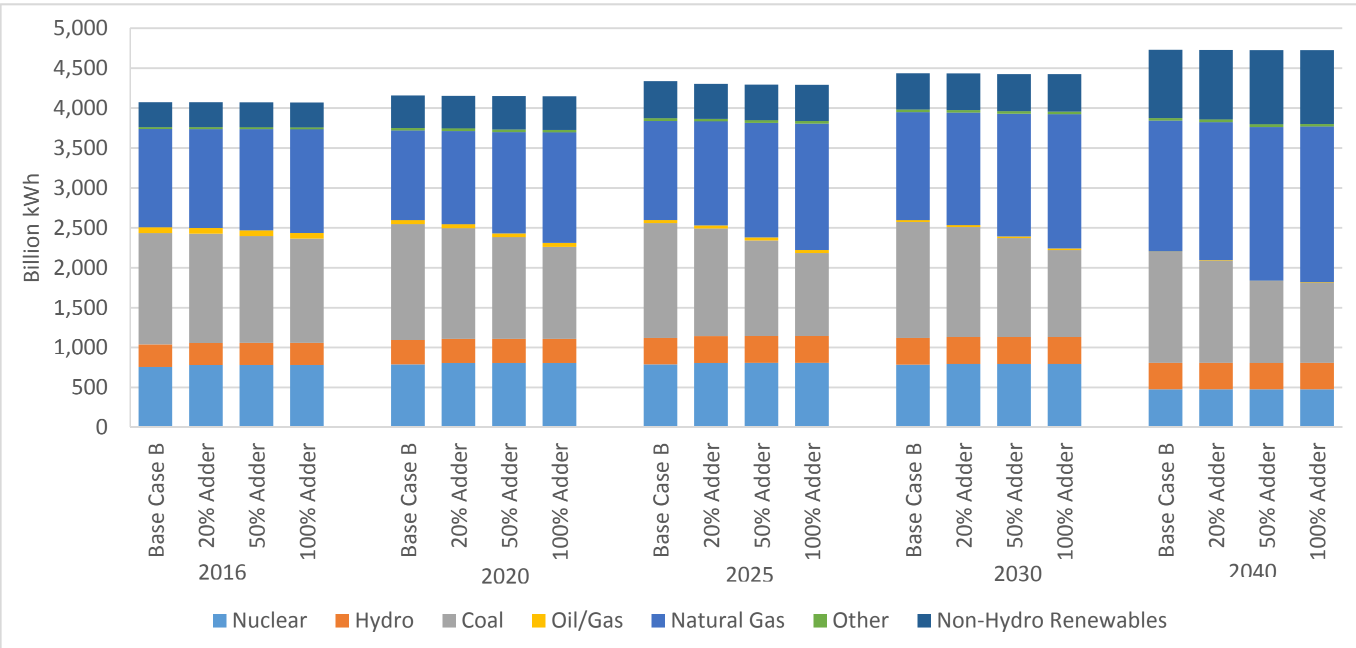


Exhibit 118: Generation Mix – US, CPP Mass Case and CPP Mass Case with SCC Adders

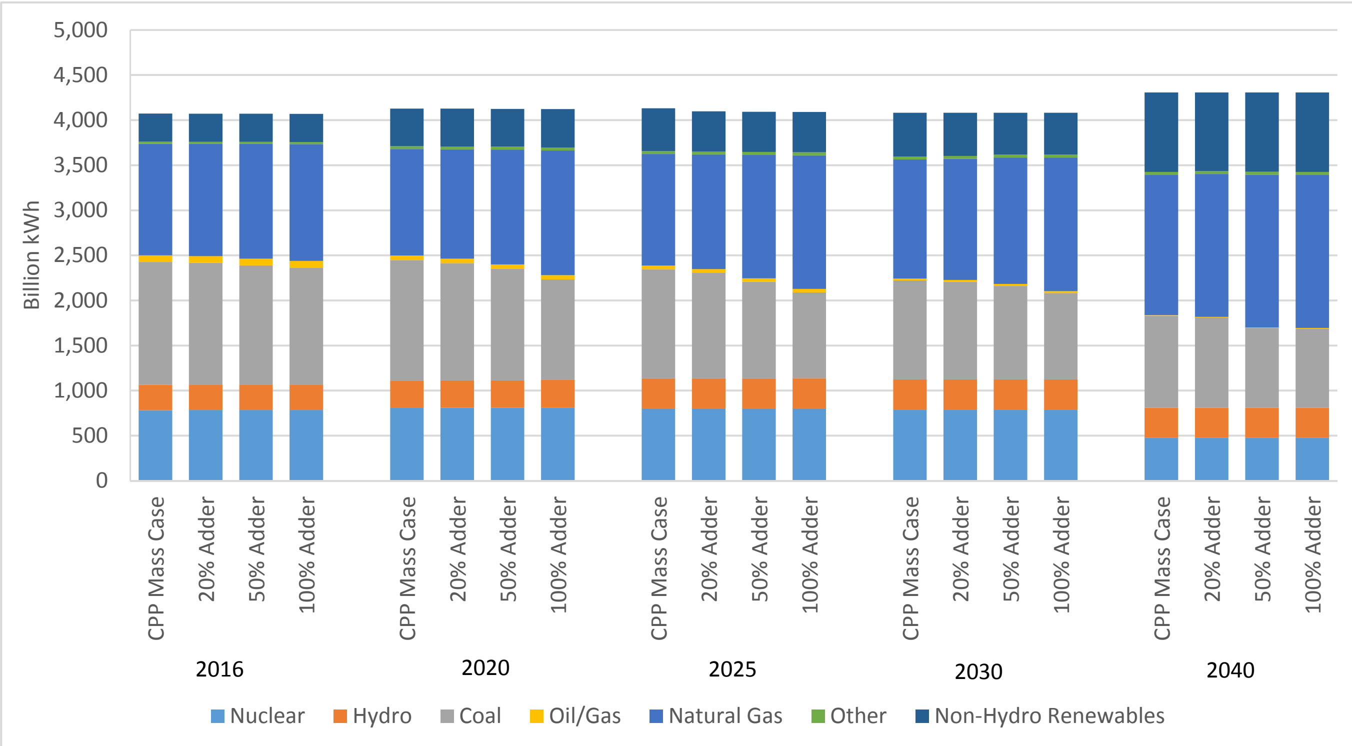
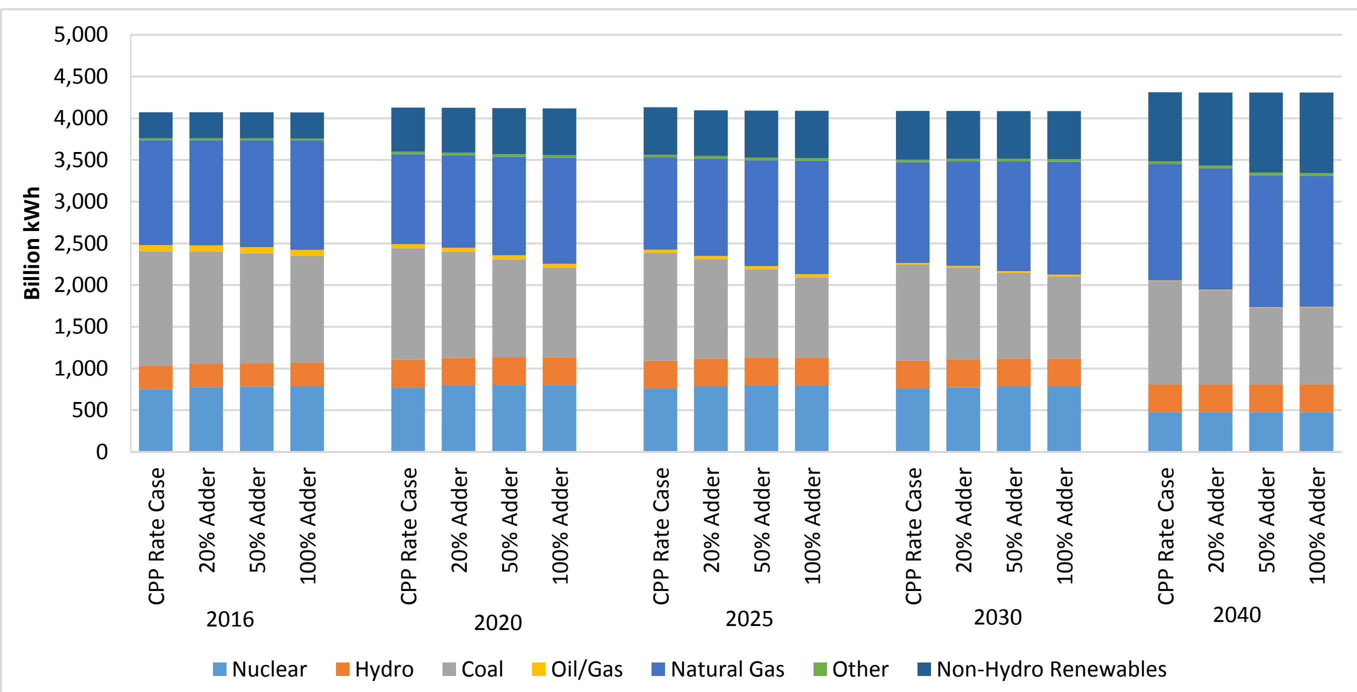


Exhibit 119: Generation Mix – US, CPP Rate Case and CPP Rate Case with SCC Adders



Impacts on Natural Gas Markets

As gas-fired generation increases with the implementation of different levels of the SCC adders, demand for natural gas consequently rises over the years in both Base Cases and CPP Cases (Exhibit 120 to Exhibit 122). For example, similar to other metrics, the 20% SCC adder has the least impact, resulting in an increase of 5% by 2040 in natural gas demand in Base Case B. In contrast, the 50% and 100% SCC adders lead to an increase of 16% and 18%, respectively in Base Case B. Percentage increases in CPP Cases with and without the SCC adders are smaller, as the CPP already leads to a rise in natural gas demand. Therefore the impact from the SCC adders alone is less pronounced.

Exhibit 120: Power Sector Natural Gas Demand – US, Base Case B and Base Case B with SCC Adders

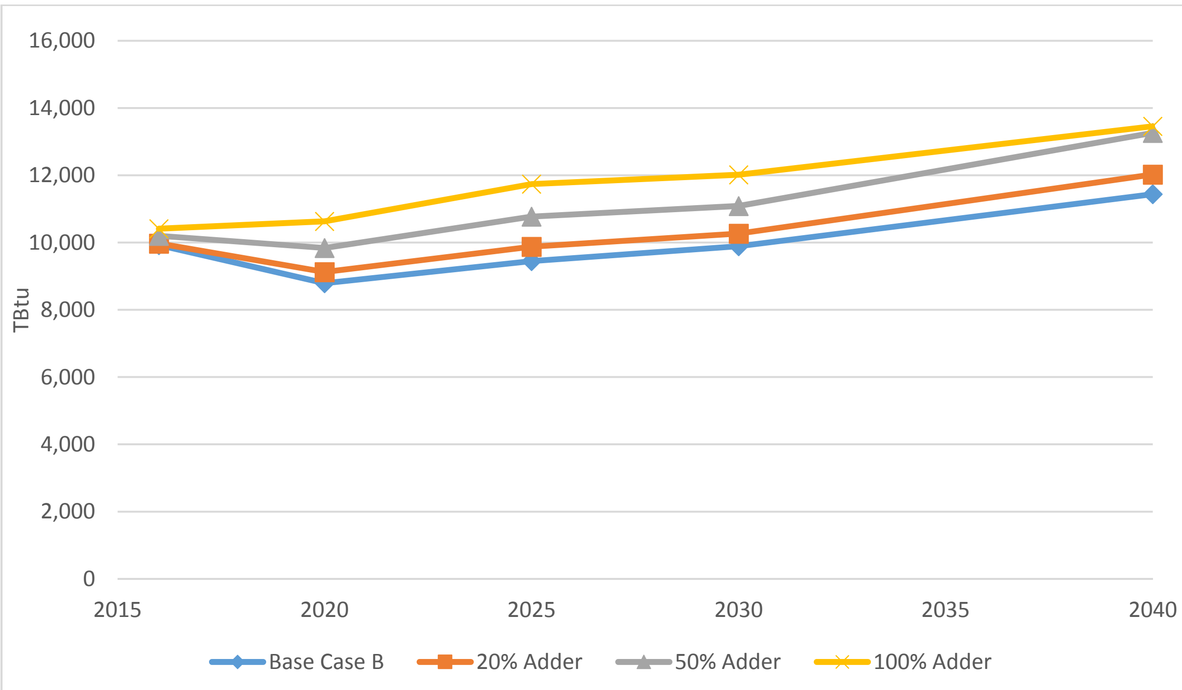


Exhibit 121: Power Sector Natural Gas Demand – US, CPP Mass Case and CPP Mass Case with SCC Adders

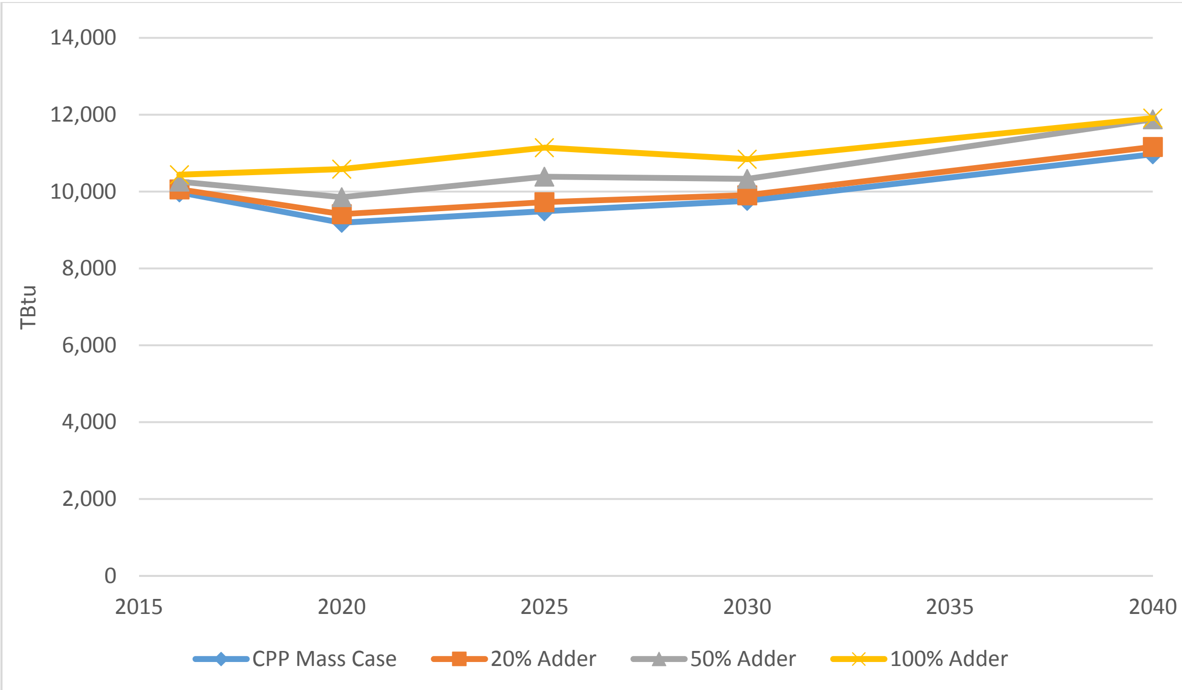
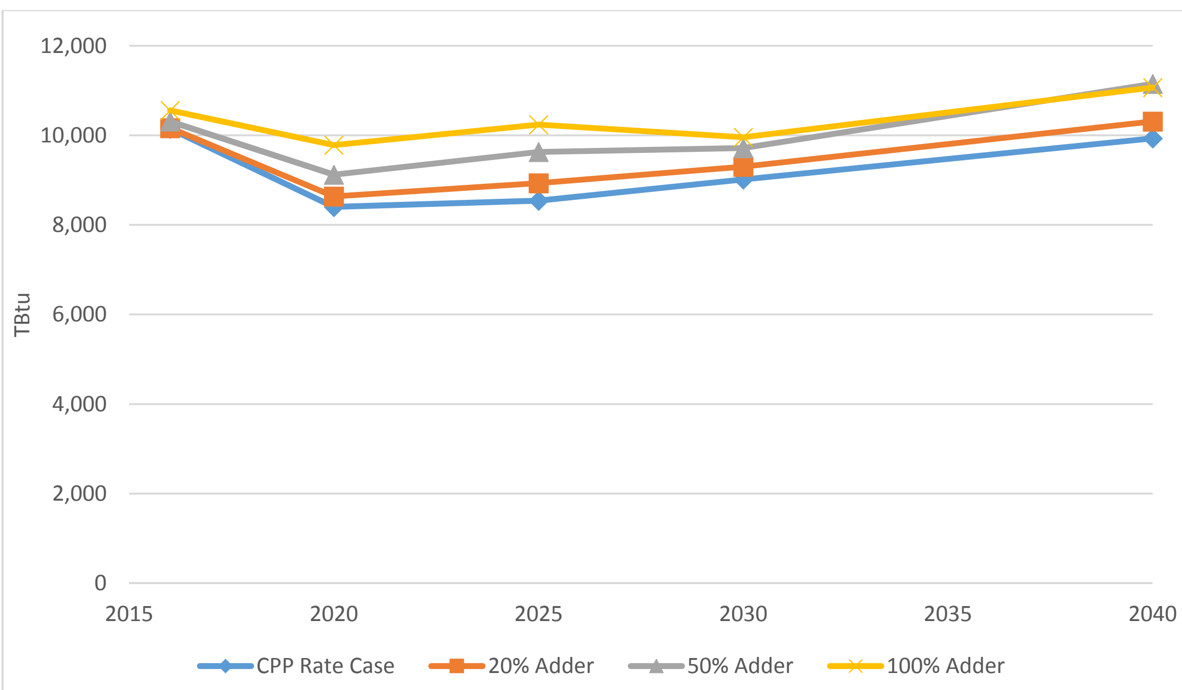


Exhibit 122: Power Sector Natural Gas Demand – US, CPP Rate Case and CPP Rate Case with SCC Adders



Relative to Base Case B, the addition of the SCC leads to early retirement of coal units, and an increase in natural gas prices early in the forecast horizon (Exhibit 123 to Exhibit 125). As demand for natural gas continues to increase in all cases with SCC adders, Henry Hub Prices also witness an increasing trend over the forecast horizon. As the percentage of the SCC adder increases, the costs of mining federal coal increases. Therefore, higher percentage of the SCC tends to lead to higher demand for gas, hence higher Henry Hub prices. In the Base, CPP Mass, and CPP Rate Cases, Henry Hub prices decrease in 2040, with the largest decrease in the CPP Rate Case. In the CPP Rate Case, long-term Henry Hub prices decrease slightly, as existing coal-fired capacity remains online as a result of the rate limits structure and allowing energy efficiency and renewable resources to comply with the CPP. The increase in coal generation in the long run offsets some gas consumption and leads to lower gas prices.

Exhibit 123: Henry Hub Gas Prices, Base Case B and Base Case B with SCC Adders

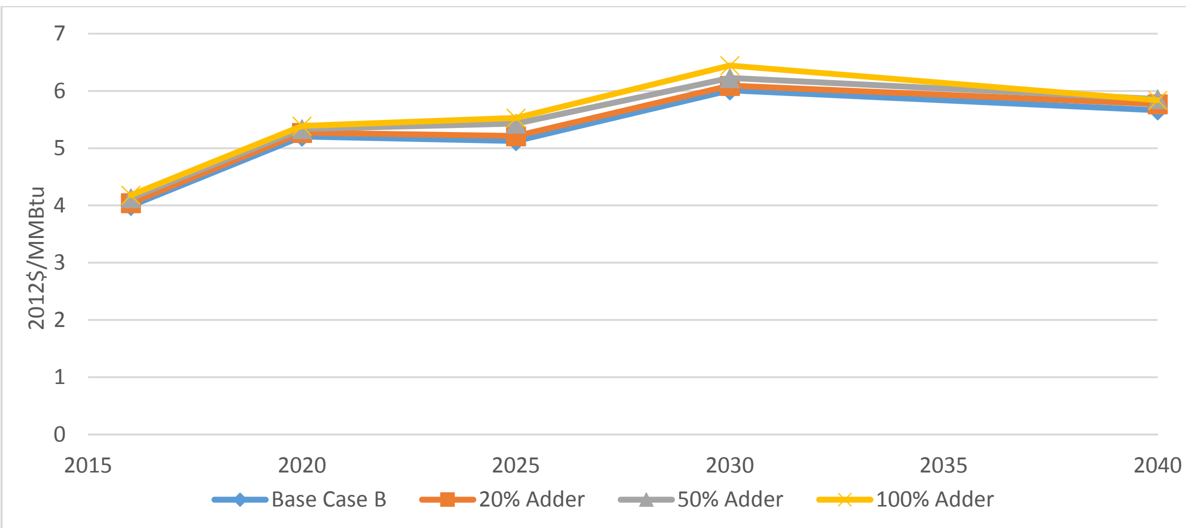


Exhibit 124: Henry Hub Gas Prices, CPP Mass Case and CPP Mass Case with SCC Adders

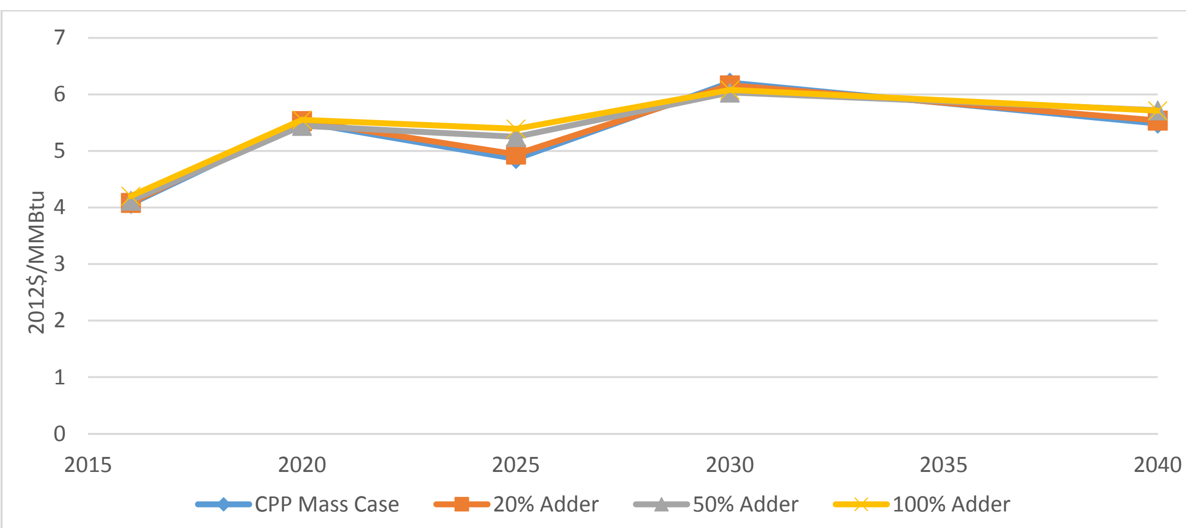
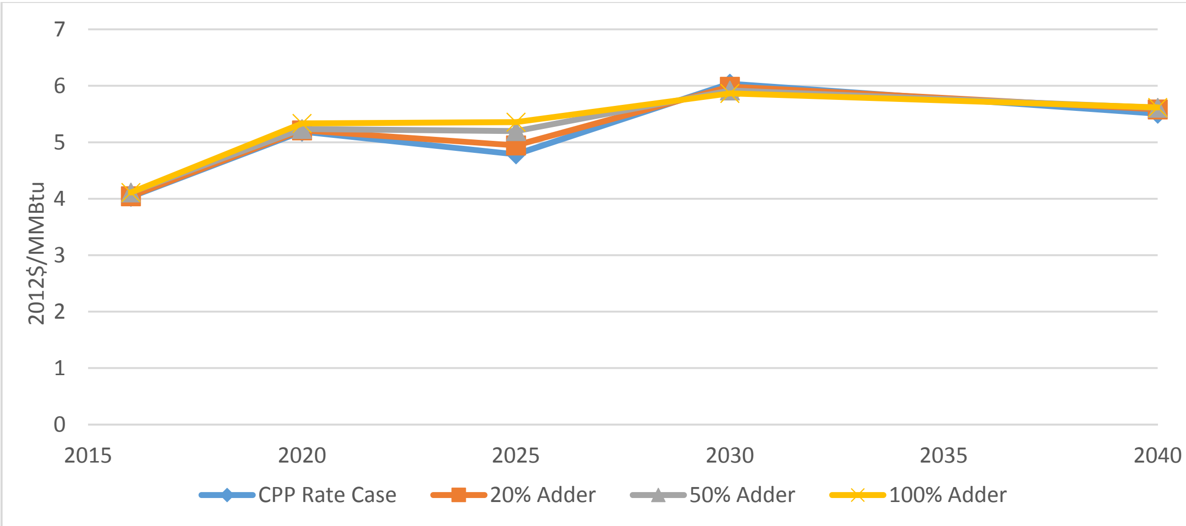


Exhibit 125: Henry Hub Gas Prices, CPP Rate Case and CPP Rate Case with SCC Adders



Impacts on Firm Wholesale Power Prices

The trajectory of average US natural gas prices and firm wholesale power prices is almost identical when the SCC adders are applied (Exhibit 126 to Exhibit 128). In the short run, the system still relies on coal-fired generation, therefore the social cost of carbon is visible as part of the electricity prices. As the importance of coal-fired generation slowly diminishes in the long run and coal production decreases, the contribution of the SCC adders to power prices falls, hence the eventual convergence of power prices between cases in the long run.

While firm power prices from cases with SCC adders are higher than those from their corresponding base cases in the short run, the long-term trend is different between cases. When the SCC adders are applied to Base Case B and the CPP Rate Case, firm power prices from policy cases are consistently higher than the base cases, but the CPP Mass Cases display an opposite trajectory in the long run. It is worth-noting that firm power prices from CPP Mass Case are higher than Base Case B and the CPP Rate Case. Under a mass cap structure, the application of SCC adders result in higher delivered coal prices. Higher delivered coal prices lead to lower demand for coal, hence helping the system meet the CO_2 emission caps. Therefore, the SCC adder in effect bears some of the compliance costs of the CPP, resulting in lower CO_2 allowance prices. The lower CO_2 allowance prices lead to reduced costs of dispatch for NGCC units and coal units not burning federal coal thereby lowering the wholesale power price when those are the marginal units. Under the rate based program, when NGCC is receiving a credit, any decline in the CO_2 allowance price leads to less credit for an NGCC unit therefore, raising the NGCC unit's cost of dispatch and the overall wholesale power price. Note this explanation is a bit simplified since NGCC is not always on the margin, but given it is in a majority of hours in most markets it is the driving factor behind these trends.

Exhibit 126: Firm Wholesale Power Prices – US, Base Case B and Base Case B with SCC Adders

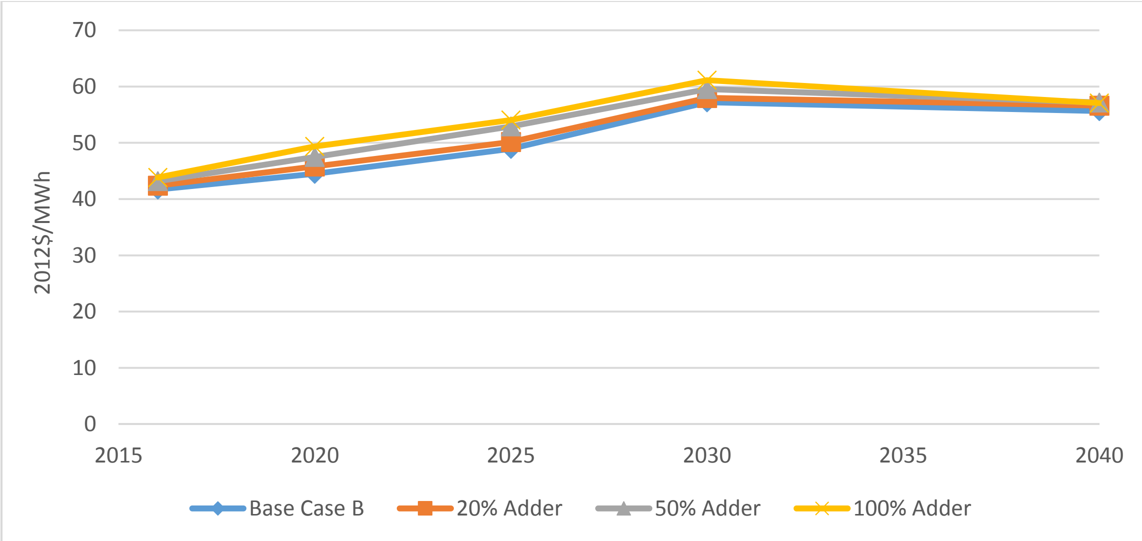


Exhibit 127: Firm Wholesale Power Prices – US, CPP Mass Case and CPP Mass Case with SCC Adders

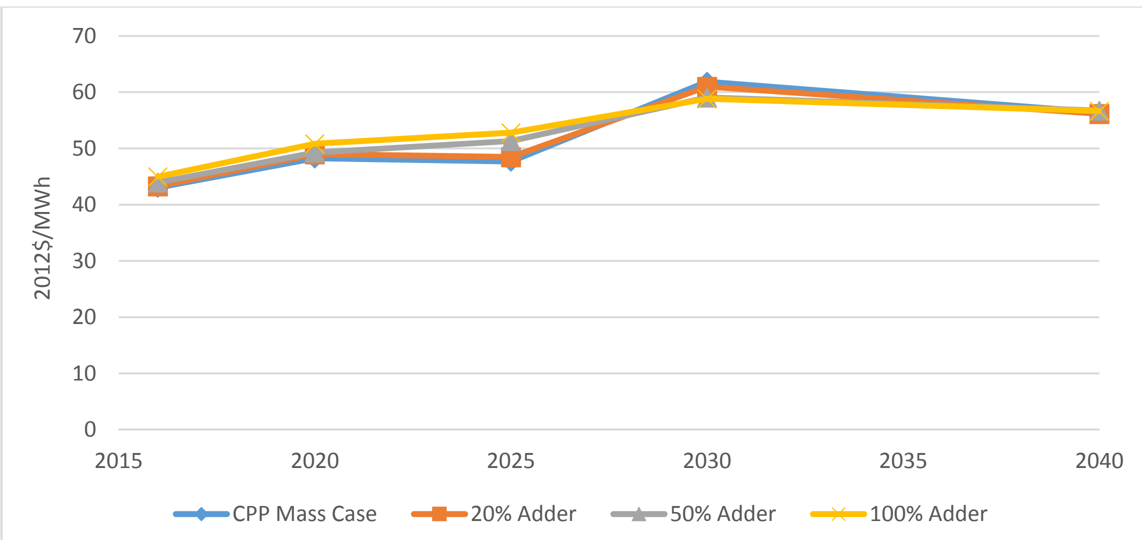
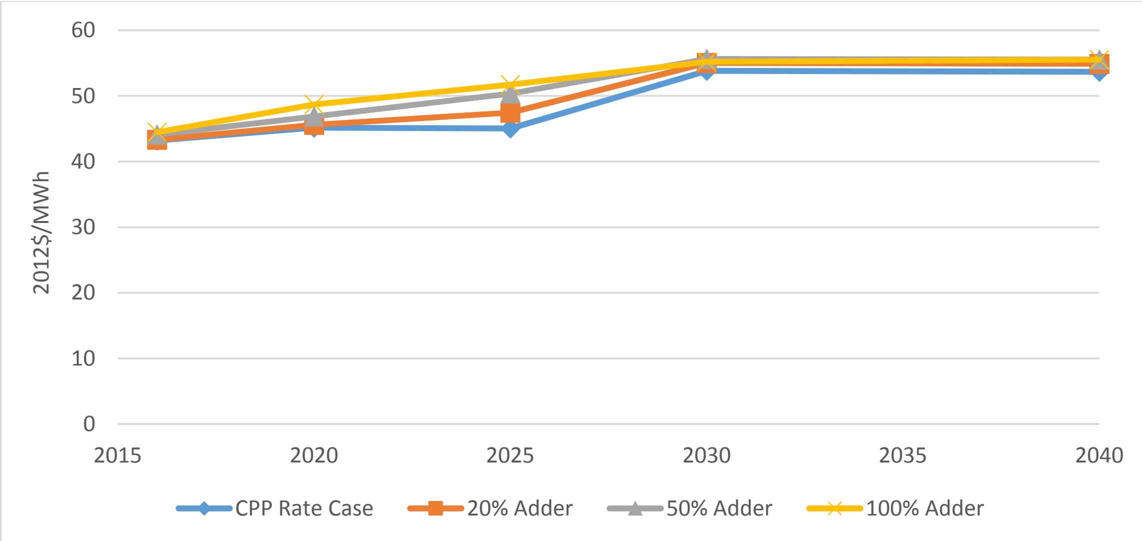


Exhibit 128: Firm Wholesale Power Prices – US, CPP Rate Case and CPP Rate Case with SCC Adders



CO_2 Emissions

As the shift between coal and gas-fired generation occurs when the SCC adders are applied, total CO_2 emissions decrease as the percentage of the SCC adders increases (Exhibit 129 to Exhibit 131). By 2040, in Base Case B the 20% SCC adder leads to a 4% decrease in emissions, while the 50% and 100% adders lead to 14% of reductions, respectively. The CPP Cases demonstrate similar trends.

Exhibit 129: CO_2 Emissions – US, Base Case B and Base Case B with SCC Adders

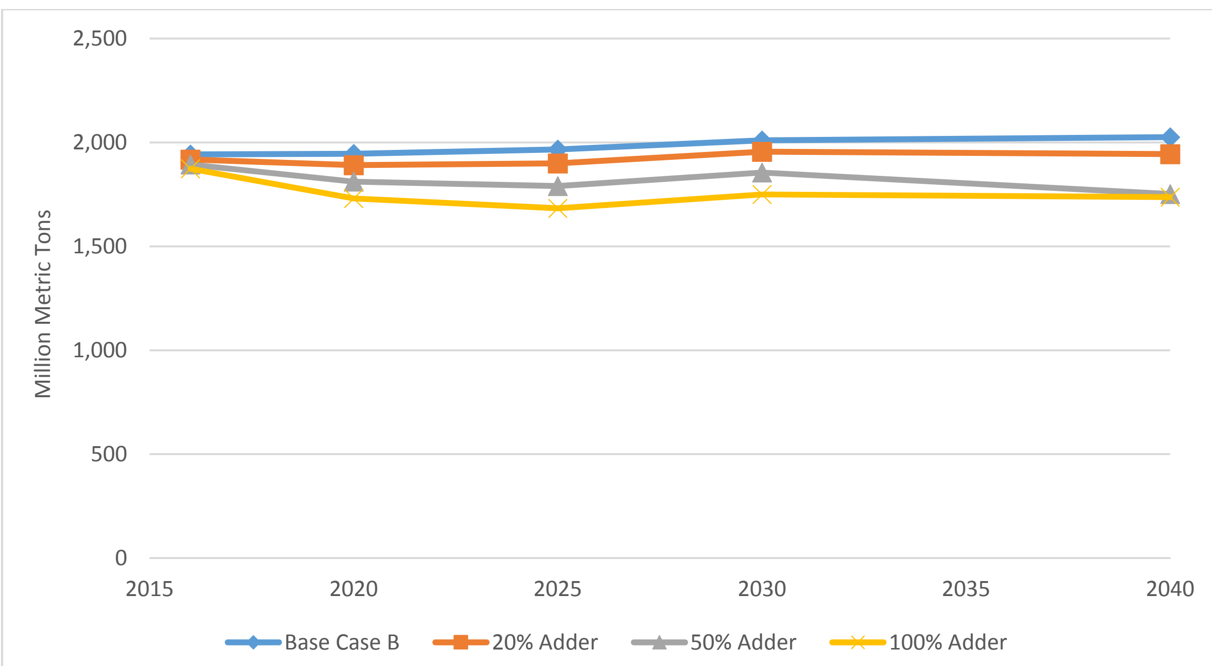


Exhibit 130: CO_2 Emissions – US, CPP Mass Cases with SCC Adders

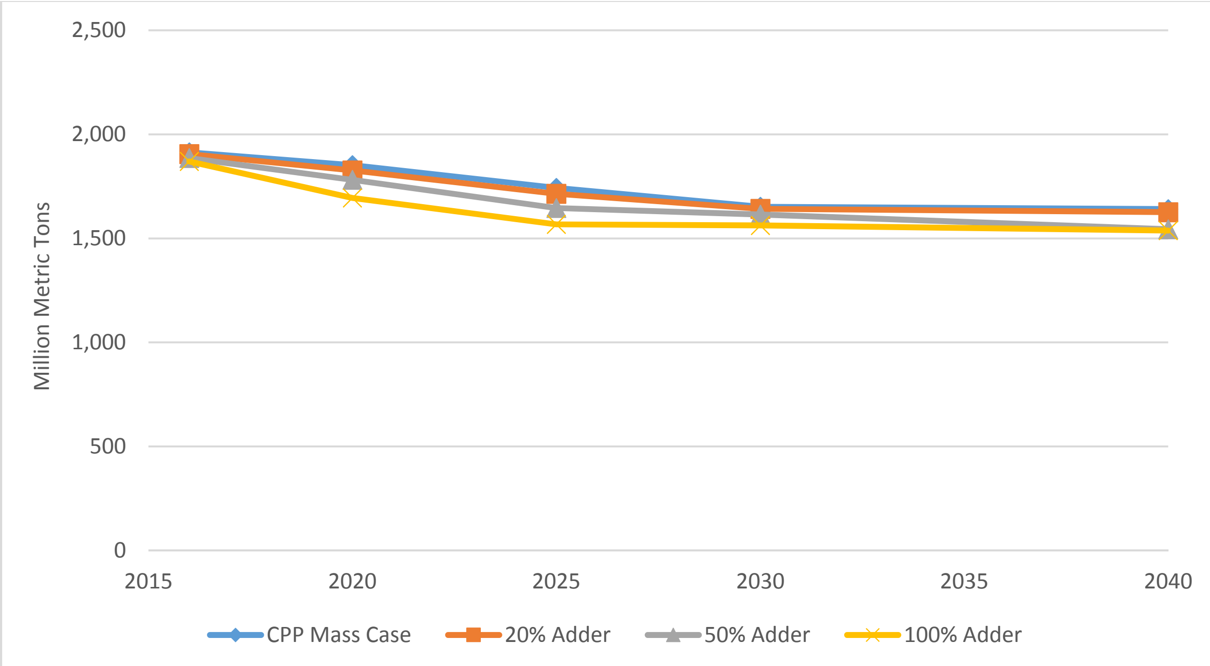


Exhibit 131: CO_2 Emissions – US, CPP Rate Cases with SCC Adders

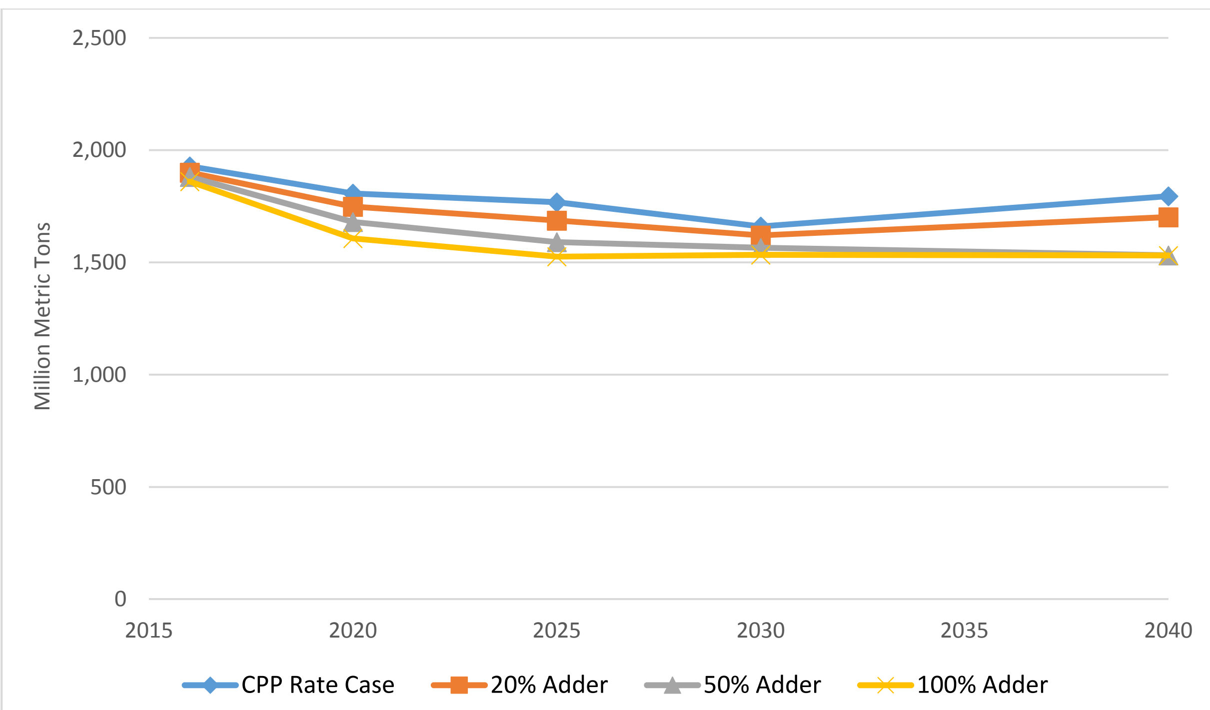


Exhibit 132: CO_2 Emissions (thousand metric tons CO_2) – US, Base Case B and Base Case B with SCC Adders

	2016	2018	2020	2025	2030	2040	2050
Base Case B	1,942,661	1,932,506	1,945,042	1,966,008	2,010,046	2,025,394	2,188,376
20% Adder	1,917,836	1,883,185	1,890,652	1,899,543	1,955,753	1,944,040	2,085,036
50% Adder	1,894,149	1,821,896	1,811,626	1,789,732	1,855,302	1,751,148	1,920,931
100% Adder	1,873,735	1,765,114	1,730,611	1,682,825	1,749,688	1,736,445	1,917,633

Exhibit 133: CO_2 Emissions (thousand metric tons CO_2) – US, CPP Mass Cases with SCC Adders

	2016	2018	2020	2025	2030	2040	2050
CPP Mass Case	1,913,344	1,858,804	1,852,165	1,742,587	1,651,870	1,640,193	1,654,042
20% Adder	1,905,463	1,834,643	1,826,678	1,714,240	1,641,874	1,626,025	1,648,020
50% Adder	1,886,248	1,798,770	1,781,045	1,645,951	1,614,669	1,543,278	1,613,394
100% Adder	1,869,735	1,733,489	1,694,051	1,567,156	1,561,730	1,537,186	1,610,590

Exhibit 134: CO_2 Emissions (thousand metric tons CO_2) – US, CPP Rate Cases with SCC Adders

	2016	2018	2020	2025	2030	2040	2050
CPP Rate Case	1,928,421	1,858,776	1,806,933	1,767,831	1,660,015	1,794,666	1,920,146
20% Adder	1,900,632	1,811,948	1,748,346	1,686,995	1,620,646	1,701,641	1,805,323
50% Adder	1,881,401	1,767,974	1,680,107	1,590,850	1,564,992	1,531,554	1,678,037
100% Adder	1,860,511	1,711,565	1,606,648	1,525,720	1,533,656	1,530,490	1,683,325

Exhibit 135: CO_2 Emissions Delta (thousand metric tons CO_2) – US, Base Case B and Base Case B with SCC Adders

	2016	2018	2020	2025	2030	2040	2050
Base Case B	-	-	-	-	-	-	-
20% Adder	-24,824	-49,321	-54,390	-66,465	-54,293	-81,354	-103,340
50% Adder	-48,512	-110,610	-133,416	-176,276	-154,743	-274,246	-267,445
100% Adder	-68,926	-167,392	-214,431	-283,183	-260,358	-288,948	-270,743

Exhibit 136: CO_2 Emissions Delta (thousand metric tons CO_2) – US, All CPP Mass Cases

	2016	2018	2020	2025	2030	2040	2050
CPP Mass Case	-	-	-	-	-	-	-
20% Adder	-7,881	-24,161	-25,486	-28,347	-9,996	-14,168	-6,021
50% Adder	-27,096	-60,034	-71,120	-96,636	-37,202	-96,915	-40,648
100% Adder	-43,609	-125,315	-158,114	-175,431	-90,140	-103,007	-43,451

Exhibit 137: CO_2 Emissions Delta (thousand metric tons CO_2) – US, All CPP Rate Cases

	2016	2018	2020	2025	2030	2040	2050
CPP Rate Case	-	-	-	-	-	-	-
20% Adder	-27,788	-46,827	-58,586	-80,836	-39,369	-93,025	-114,823
50% Adder	-47,020	-90,801	-126,826	-176,981	-95,023	-263,111	-242,109
100% Adder	-67,909	-147,211	-200,284	-242,110	-126,359	-264,176	-236,821

Chapter 6: Appendix

Coal Royalty Payments

ICF calculated coal royalty payments for the following cases: Base Case A, no CPP (referred to as "Base Case A" in Chapter 6), Base Case A with Adder (referred to as "Base Case with Adder" in Chapter 6), Base Case A with SCC Adders (referred to as "Base Case with SCC Adders" in Chapter 6), Base Case A, CPP with mass-based regional trading (referred to as "CPP Mass Case" in Chapter 6), Base Case A, CPP with mass-based regional trading with adder (referred to as "CPP Mass Case with Adder" in Chapter 6), and Base Case A, CPP with mass-based regional trading with SCC adders(referred to as "CPP Mass Cases with SCC Adders" in Chapter 6). Coal royalty payments consist of two parts: royalty payments based on minemouth prices and royalty payments from adders. The first part of coal royalty payments calculations is based on minemouth prices and federal coal production levels. Based on the share of underground and surface mining for each coal production basin, ICF assumes an 8% royalty rate for underground mining and a 12.5% royalty rate for surface mining. The second part of coal royalty payments are based on adders and federal coal production levels.

As SCC adders increase, federal coal production decreases as a result. Therefore, cases with 20% SCC adders tend to have higher total coal royalty payments than the corresponding Base Cases, but with 50% SCC and 100% SCC, total coal royalty payments decrease due to low federal coal production. Additionally, after the CPP is incorporated, coal production decreases, and coal royalty payments consequently decrease due to a lower level of production activity. Exhibits below show the changes between coal royalty payments from Base Cases and corresponding Policy Cases by coal production basin.

Exhibit 138: Coal Royalty Payments, Deltas and % Change, Base Case A and CPP Mass Case

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	0	-1	-4	-8	-13	N/A	-28%	-64%	-63%	-66%
Colorado, Uinta	0	3	-8	-11	-1	1%	8%	-26%	-45%	-4%
UT	-1	-11	-3	-2	-11	-3%	-29%	-9%	-6%	-30%
Montana, Powder River	3	-11	-10	-19	-24	7%	-21%	-21%	-45%	-56%
Wyoming, Green River	0	0	0	0	0	-2%	-6%	-7%	-10%	-13%
Wyoming, Low Btu (8400)	-6	-14	-42	-37	-34	-9%	-15%	-43%	-41%	-36%
Wyoming, Powder River	-21	-66	-121	-165	-185	-6%	-18%	-32%	-42%	-48%
Total	-25	-100	-187	-241	-267	-5%	-17%	-31%	-41%	-45%

Exhibit 139: Coal Royalty Payments, Deltas and % Change, Base Case A and Base Case with Adder

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	0	0	4	9	14	N/A	23%	71%	70%	73%
Colorado, Uinta	27	20	21	14	4	80%	68%	68%	59%	28%
UT	23	32	32	25	16	94%	85%	89%	84%	45%
Montana, Powder River	72	79	83	64	49	190%	154%	179%	152%	117%
Wyoming, Green River	4	19	19	19	18	379%	1484%	1471%	1377%	2507%
Wyoming, Low Btu (8400)	133	170	157	119	200	191%	178%	161%	133%	208%
Wyoming, Powder River	516	589	563	589	509	160%	159%	149%	149%	133%
Total	775	910	878	838	811	158%	154%	148%	141%	137%

Exhibit 140: Coal Royalty Payments, Deltas and % Change, Base Case A and Base Case with 20% SCC

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	0	2	23	34	13	N/A	82%	385%	281%	65%
Colorado, Uinta	14	97	83	19	-8	42%	322%	273%	80%	-48%
UT	18	69	214	179	183	72%	184%	600%	597%	514%
Montana, Powder River	51	288	840	826	976	136%	563%	1817%	1971%	2331%
Wyoming, Green River	7	58	97	83	145	559%	4584%	7535%	6103%	19680%
Wyoming, Low Btu (8400)	63	364	308	364	892	90%	379%	316%	409%	930%
Wyoming, Powder River	279	1,811	3,219	3,087	2,482	87%	488%	853%	783%	649%
Total	432	2,688	4,785	4,592	4,683	88%	456%	805%	775%	791%

Exhibit 141: Coal Royalty Payments, Deltas and % Change, Base Case A and Base Case with 50% SCC

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	0	7	87	141	44	N/A	395%	1480%	1148%	226%
Colorado, Uinta	47	228	197	47	-8	138%	761%	646%	197%	-47%
UT	57	156	242	238	218	230%	417%	678%	796%	614%
Montana, Powder River	124	844	1,764	1,501	1,533	329%	1650%	3815%	3582%	3660%
Wyoming, Green River	1	6	-1	-1	-1	97%	474%	-100%	-100%	-100%
Wyoming, Low Btu (8400)	127	247	1,418	2,090	2,022	182%	257%	1454%	2344%	2107%
Wyoming, Powder River	574	2,830	274	385	104	178%	762%	73%	98%	27%
Total	930	4,318	3,981	4,400	3,913	190%	733%	670%	742%	661%

Exhibit 142: Coal Royalty Payments, Deltas and % Change, Base Case A and Base Case with 100% SCC

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	4	48	100	-3	-8	N/A	2634%	1689%	-21%	-44%
Colorado, Uinta	92	227	-31	-24	-16	272%	756%	-100%	-100%	-100%
UT	51	212	-36	-30	-36	208%	566%	-100%	-100%	-100%
Montana, Powder River	248	863	351	27	34	658%	1687%	760%	64%	82%
Wyoming, Green River	2	-1	-1	-1	-1	191%	-100%	-100%	-100%	-100%
Wyoming, Low Btu (8400)	246	872	-67	15	-96	352%	908%	-68%	17%	-100%
Wyoming, Powder River	1,014	66	-377	-394	-383	314%	18%	-100%	-100%	-100%
Total	1,657	2,288	-60	-410	-505	338%	388%	-10%	-69%	-85%

Exhibit 143: Coal Royalty Payments, Deltas and % Change, CPP Mass Case and CPP Mass Case with Adder

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	0	1	1	4	5	N/A	70%	69%	79%	81%
Colorado, Uinta	26	25	18	10	-1	76%	78%	77%	74%	-9%
UT	24	23	29	24	19	99%	87%	88%	86%	76%
Montana, Powder River	85	85	70	52	35	210%	210%	192%	223%	191%
Wyoming, Green River	5	6	5	5	5	428%	474%	438%	382%	783%
Wyoming, Low Btu (8400)	137	153	122	103	139	215%	187%	218%	198%	226%
Wyoming, Powder River	503	538	426	378	295	167%	176%	166%	165%	149%
Total	779	831	671	575	497	168%	170%	165%	163%	153%

Exhibit 144: Coal Royalty Payments, Deltas and % Change, CPP Mass Case and CPP Mass Case with 20% SCC

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	0	3	17	23	4	N/A	233%	791%	515%	67%
Colorado, Uinta	15	92	95	33	-11	45%	284%	416%	254%	-74%
UT	26	70	187	132	168	107%	263%	572%	467%	679%
Montana, Powder River	49	282	620	547	450	122%	697%	1699%	2365%	2456%
Wyoming, Green River	0	2	5	6	4	32%	204%	445%	473%	598%
Wyoming, Low Btu (8400)	72	318	224	279	316	113%	389%	400%	535%	514%
Wyoming, Powder River	279	1,734	2,430	1,445	1,285	92%	568%	948%	629%	650%
Total	441	2,502	3,578	2,466	2,217	95%	512%	878%	700%	682%

Exhibit 145: Coal Royalty Payments, Deltas and % Change, CPP Mass Case and CPP Mass Case with 50% SCC

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	0	8	91	67	6	N/A	591%	4260%	1474%	88%
Colorado, Uinta	47	224	208	78	-12	137%	688%	913%	599%	-76%
UT	58	166	184	89	154	241%	621%	563%	314%	626%
Montana, Powder River	120	795	1,548	941	587	297%	1965%	4240%	4069%	3203%
Wyoming, Green River	1	6	-1	-1	-1	104%	513%	-100%	-100%	-100%
Wyoming, Low Btu (8400)	134	292	1,457	1,309	714	211%	358%	2605%	2505%	1159%
Wyoming, Powder River	631	3,100	286	85	-96	209%	1016%	111%	37%	-49%
Total	991	4,591	3,772	2,567	1,353	213%	939%	926%	729%	416%

Exhibit 146: Coal Royalty Payments, Deltas and % Change, CPP Mass Case and CPP Mass Case with 100% SCC

Coal Production Basin	Delta (Million 2012$)					% Change				
	2016	2020	2025	2030	2040	2016	2020	2025	2030	2040
Colorado, Raton	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Colorado, San Juan	4	49	186	5	4	N/A	3723%	8712%	113%	65%
Colorado, Uinta	91	273	-17	-8	-15	267%	840%	-75%	-61%	-100%
UT	57	223	-33	-28	-25	238%	833%	-100%	-100%	-100%
Montana, Powder River	246	970	912	355	58	611%	2399%	2499%	1534%	315%
Wyoming, Green River	2	6	-1	-1	-1	198%	518%	-100%	-100%	-100%
Wyoming, Low Btu (8400)	252	886	73	280	-62	398%	1084%	130%	536%	-100%
Wyoming, Powder River	1,090	499	-256	-230	-198	361%	164%	-100%	-100%	-100%
Total	1,744	2,907	863	373	-238	375%	594%	212%	106%	-73%