ERCOT Analysis of the Impacts of the Clean Power Plan

Final Rule Update

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In August 2015, the U.S. Environmental Protection Agency (EPA) released the Clean Power Plan (CPP) final rule, which sets limits on carbon dioxide (CO_2) emissions from existing fossil fuel-fired power plants. EPA had originally proposed the rule in June 2014, and the Electric Reliability Council of Texas (ERCOT) subsequently evaluated the potential implications for the resource mix and grid reliability in the ERCOT Region.[1] However, the final rule made adjustments to the emissions limits, as well as to the deadlines for compliance. Because the timing and magnitude of the required reductions for Texas have changed in the final rule, ERCOT updated its CPP analysis to reflect these changes.

Based on this analysis, ERCOT continues to see the potential for significant impacts on the planning and operation of the ERCOT grid resulting from compliance with the CPP. ERCOT estimates that the final CPP, by itself, will result in the retirement of at least 4,000 MW of coal generation capacity. This amount of unit retirements could pose challenges for maintaining grid reliability, and these impacts are likely to intensify and occur earlier when the effects of the CPP are combined with other environmental regulations, particularly EPA's proposed Regional Haze Federal Implementation Plan (FIP) for Texas. If ERCOT does not receive adequate notification of these retirements, and if multiple unit retirements occur within a short timeframe, there could be periods of reduced system-wide resource adequacy and localized transmission reliability issues.

A recent reliability analysis conducted by ERCOT of potential retirement scenarios resulting from compliance with the Regional Haze requirements showed that the retirement of 4,200 MW of coal-fired capacity, comparable to the amount expected to retire due to the CPP alone, would have a significant impact on the reliability of the transmission system. Model results indicated the exceedance of thermal capacities of 10 circuits (143 miles) of 345 kV transmission lines, 31 circuits (147 miles) of 138 kV transmission lines, 6 circuits (39 miles) of 69 kV transmission lines, and 11 transformers. As a general estimate, new 69 kV and 138 kV lines cost on the order of one million dollars per mile and new 345 kV lines cost on the order of three million dollars per mile. Additionally, in the ERCOT Region, it takes at least five years for a new major transmission project to be planned, routed, approved, and constructed.

As with ERCOT's analysis of the proposed rule, this study predicts a sizeable amount of renewable capacity additions, due both to the improving economics of these technologies as well as the impacts of regulating CO_2 emissions. The need to maintain operational reliability (i.e., sufficient committed and dispatchable capacity and ramping capability) could require the curtailment of renewable generation resources. Curtailment would reduce production from renewable resources, and could delay achievement of compliance with the CPP limits.

The CPP will also result in increased wholesale and retail energy costs in the ERCOT Region. Based on ERCOT's analysis, energy costs for customers may increase by up to 16% by 2030 due to the CPP alone, without accounting for the associated costs of transmission upgrades, higher natural gas prices caused by increased gas demand, procurement of additional ancillary services, and other costs associated with the retirement or decreased operation of coal-fired capacity in the ERCOT Region. Consideration of these factors would result in even higher energy costs for customers.

[1] Electric Reliability Council of Texas, Inc. *ERCOT Analysis of the Impacts of the Clean Power Plan*, November 2014. Available at http://www.ercot.com/content/news/presentations/2015/ERCOTAnalysis-ImpactsCleanPowerPlan.pdf.

1. Introduction

The EPA proposed the CPP in June 2014. Under the proposed rule, Texas would have been required to meet an interim CO_2 emissions limit of 853 lb CO_2/MWh on average during the period from 2020 to 2029, and a final limit of 791 lb CO_2/MWh on average from 2030 onward. Following the publication of the proposed rule, ERCOT evaluated the potential implications of compliance with the CPP proposal for the resource mix and grid reliability. ERCOT published a report on the results of the analysis in November 2014.[2] That analysis found that implementation of the CPP *as proposed* would have a significant impact on the planning and operation of the ERCOT grid. Specifically, ERCOT estimated that the proposed rule could result in the retirement or seasonal mothballing of up to 8,700 MW of coal generation capacity, result in potential transmission reliability issues due to the loss of generation resources in and around major urban centers, and strain ERCOT's ability to integrate additional renewable generation resources.

EPA released details of the CPP final rule on August 3, 2015. In the final rule, several changes were made to the proposal, including modifications to the emissions limit calculation and the compliance deadlines. Under the CPP final rule, Texas will be required to meet a final CO_2 emissions rate limit of 1,042 lb CO_2/MWh on average from 2030 onwards, or 190 million tons of CO_2. EPA calculated these limits based on assumptions about coal plant efficiency improvements, increased production from natural gas combined cycle units, and growth in generation from renewable resources. EPA also modified the compliance deadlines in the final rule, phasing in the reductions over three interim compliance periods between 2022 and 2029, referred to as the "glidepath."

Changes to the calculation methodology make it difficult to compare the emissions rates in the final rule directly to the rates in the proposed rule, but overall the final limits for Texas are less stringent than in the proposal. Though EPA made a number of modifications in the final rule, the most impactful for the stringency of the limits for Texas is EPA's shift to a uniform national approach for setting the standards in the final rule, rather than the state-by-state approach used in the proposal.

Because the timing and magnitude of the required reductions for Texas have changed in the final rule, ERCOT updated its analysis of the potential impacts for the ERCOT Region's resource mix and grid reliability. To do so, ERCOT conducted a modeling analysis using similar assumptions and methods as the 2014 study. This report describes the results of the modeling analysis and discusses the implications for grid reliability.

2. Modeling Analysis

As with ERCOT's previous modeling analysis of the CPP, this analysis uses stakeholder-vetted planning processes and methodologies consistent with ERCOT's regional Long-Term System Assessment (LTSA) studies. This analysis is focused on evaluating the potential impacts of the CPP, in combination with the Cross-State Air Pollution Rule (CSAPR) and the currently proposed Regional Haze FIP for Texas. It does not consider the impacts of other pending environmental regulations affecting generation resources, including the Mercury and Air Toxics Standards (MATS), which have more limited or unit-specific implications and are unlikely, by themselves, to impact overall trends on the ERCOT system. However, these other regulations, in combination with the CPP, CSAPR, and the Regional Haze FIP, could result in additional grid operational impacts and reliability challenges. For example, a number of coal-fired units in the ERCOT region have compliance extensions until April 2016 from the Texas Commission on Environmental Quality (TCEQ) for MATS compliance. There remains a risk that owners may choose to

[2] Ibid.

retire the affected units rather than comply with MATS next year, especially in light of the proposed Regional Haze FIP and eventual compliance with the Clean Power Plan. The implications of potential MATS-related retirements in 2016 are *not* considered in this analysis. Information about other environmental regulations affecting generation resources is available in ERCOT's December 2014 report, *Impacts of Environmental Regulations in the ERCOT Region.*[3]

2.1. Modeling Methodology

This analysis uses the same model (PLEXOS) and modeling approach as ERCOT's environmental regulatory impact study completed in 2014. A complete description of this methodology is provided in ERCOT's December 2014 report.[4] Certain assumptions have been updated for this analysis based on more recent information currently being developed for the 2016 LTSA[5] and the Future Ancillary Services Cost Benefit Analysis,[6] including natural gas prices and renewable capacity capital costs. Figure 1 shows the updated natural gas prices, in nominal dollars, used in this analysis.

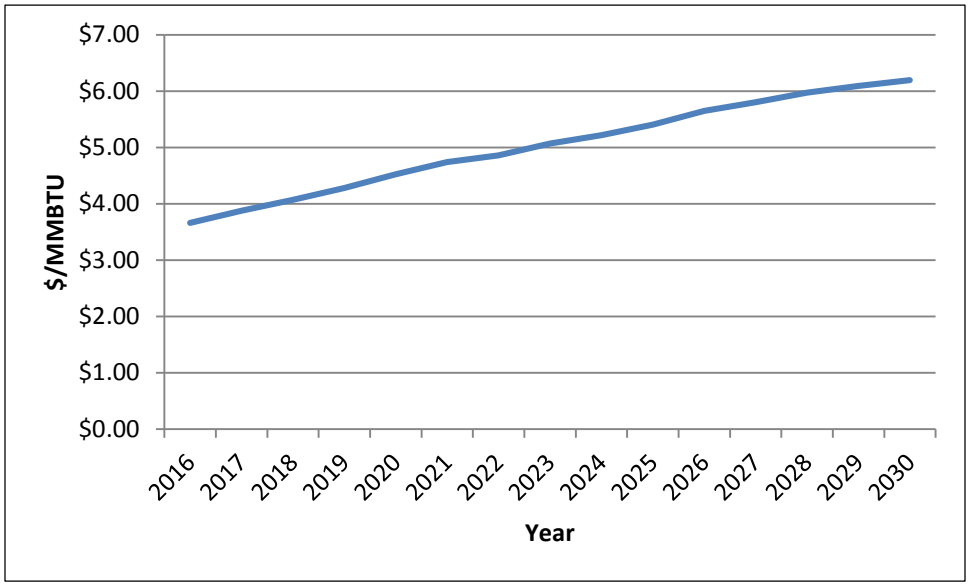

Figure 1: Natural Gas Price Assumptions

In this analysis, ERCOT models compliance with the mass-based CO_2 limits that EPA finalized for Texas. This is a departure from the 2014 study, where ERCOT modeled compliance with the rate-based standards proposed by EPA. In the final rule, EPA published both the rate- and mass-based forms of the CO_2 emissions standards, and states may choose to comply with either form of the standard. Compliance with a rate-based standard would allow overall emissions to increase as generation increases and new renewable energy and energy efficiency are added. Conversely, a mass-based standard would require emissions to remain under a set amount. Though the relative stringency of either form of the standard will depend on program design and availability of emissions reduction credits from renewable energy, energy efficiency, etc., in general modeling the mass-based form of the standard results in a slightly more stringent requirement, and thus provides a conservative estimate of

[3] Electric Reliability Council of Texas, Inc. *Impacts of Environmental Regulations in the ERCOT Region*, December 2014. Available at http://www.ercot.com/content/news/presentations/2015/Impacts%20of%20Environmental%20Regulations%20in%20the%20ERCOT%20Region.pdf.

[4] Ibid.

[5] These assumptions are available at http://www.ercot.com/content/wcm/key_documents_lists/75283/2016_LTSA_Scenario_Assumptions.pptx.

[6] Information on the proposal for a new framework for ancillary services in ERCOT and the cost benefit analysis is available at http://www.ercot.com/committees/other/fast/index.html.

the impacts of compliance. ERCOT scaled the mass limits for Texas based on the relative amount of load served in the ERCOT Region within Texas to derive ERCOT-specific limits. Figure 2 shows the mass-based emissions limits for Texas published in the CPP final rule and the ERCOT-specific limits modeled in this study.

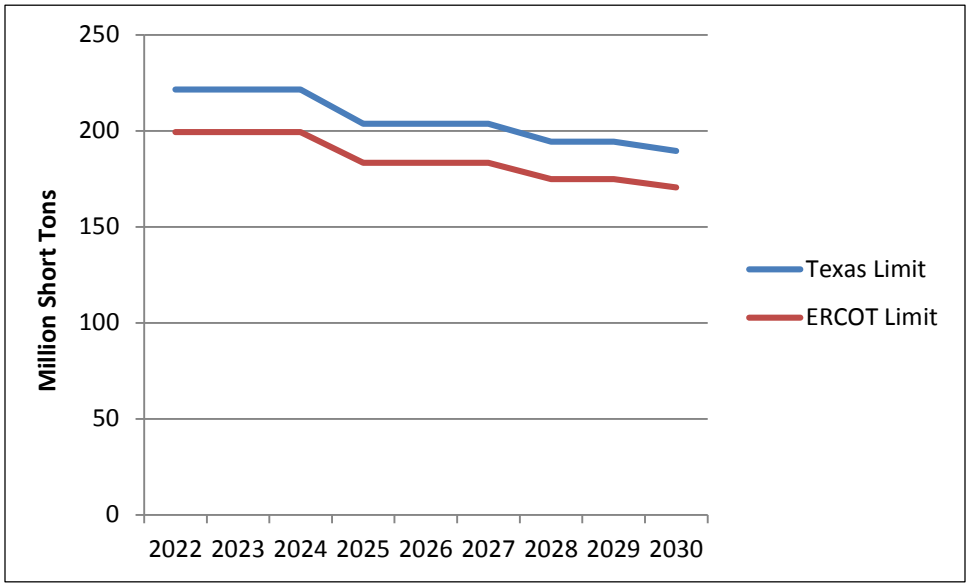

Figure 2: Carbon Dioxide Mass-Based Emissions Limits

As in the previous study, ERCOT modeled scenarios in which the CPP limits are achieved through a system CO_2 emissions constraint and a price per ton of CO_2. These scenarios were developed to evaluate the potential reliability implications of CPP compliance; they do not indicate any assessment of the policy merits or legal permissibility of either compliance approach. In addition to the CPP, the current requirements of CSAPR are included in all of the modeled scenarios, and the proposed Regional Haze FIP is included in one of the modeled scenarios.

The CSAPR program seeks to address cross-state air pollution through a cap and trade program for annual nitrogen oxide (NO_x) and sulfur dioxide (SO_2) emissions, and ozone season (summer) NO_x emissions. In the 2014 study, ERCOT modeled scenarios that included CSAPR as both an emissions limit and an emissions price, but did not include CSAPR in the baseline. Since the rule came into effect on January 1, 2015, this analysis includes CSAPR in both the baseline and CPP scenarios at current allowance prices to reflect the current status of the program.[7] CSAPR allowance prices have been relatively low since the rule came into effect, and therefore the inclusion of these prices in the modeled scenarios is likely to have minimal impacts on unit operations and retirements in the modeling results.

ERCOT modeled four scenarios over the timeframe 2016 to 2030 to evaluate the implications of the CPP on reliability in the ERCOT region:

1. **Baseline** – This scenario estimates a baseline of the ERCOT system under current market trends against which anticipated CPP changes are compared.
2. **CO_2 Limit** – This scenario applies the limits in the CPP to the ERCOT system to determine the least-cost way to comply with the limits. This scenario does not place a price on CO_2 emissions.
3. **CO_2 Price** – This scenario applies a CO_2 emissions price that causes the ERCOT system to achieve compliance with the limits.

[7] ERCOT did not consider any potential future changes to the CSAPR program that could result from recent legal proceedings.

4. **CO_2 Price & Regional Haze** – This scenario adds the impacts of compliance with the proposed Regional Haze FIP to the CO_2 price scenario.

It should be noted that the CO_2 limit scenario allows the simulation model to select the least-cost way to achieve CPP compliance from electric generating resources. While this approach minimizes the overall system costs, it may not be achievable within the current electricity market design in ERCOT. Electric supply is deregulated in the ERCOT region at the wholesale and retail level. As a result, electric generation and construction of new capacity is driven by market forces, and there is no mechanism to force the ERCOT system to achieve compliance with environmental regulations in a specific manner. Resource owners will make decisions about how to operate existing resources and whether to add new capacity based on market forces. In contrast, the CO_2 price scenarios rely on price signals to obtain emissions compliance rather than direct control of plant emissions, and thus may represent a potential approach to compliance.

To ensure that the price scenarios captured operational and economic constraints not considered by the model, ERCOT reviewed capacity factors and operating revenues from the modeling results in the two CO_2 price scenarios, and assumed that any coal unit operating below a 20% capacity factor annually would retire.[8] This retirement criterion was not applied to the CO_2 limit scenario in order to allow the model to select the least-cost way to achieve compliance for the ERCOT system.

In the two scenarios that implemented the CPP using an emissions price, ERCOT calculated a price for each year that would put carbon dioxide emissions from affected units below the mass-based emissions limit for that year. As shown in Figure 3, the prices in both scenarios follow a similar trend, increasing as the emissions limits tighten in each of the performance periods. The prices required for initial compliance in 2022 are relatively low, at \$1.00/ton CO_2 in the CO_2 Price scenario. In the CO_2 Price & Regional Haze scenario, unit retirements driven by the Regional Haze requirements put ERCOT-wide emissions below the emissions limit for the first interim performance period, resulting in a \$0.00/ton CO_2 price for the first three years of compliance. These prices then increase in the subsequent performance periods as the CO_2 emissions limits become more stringent. To meet the final emissions limit in 2030, a price of \$22.50/ton CO_2 is required, or \$21.00/ton CO_2 in the scenario that also includes Regional Haze.

[8] To account for this in the 2014 analysis, ERCOT reviewed capacity factors and operating revenues in the model output to determine additional units at risk of retirement, and reported a range of potential impacts in the 2014 report.

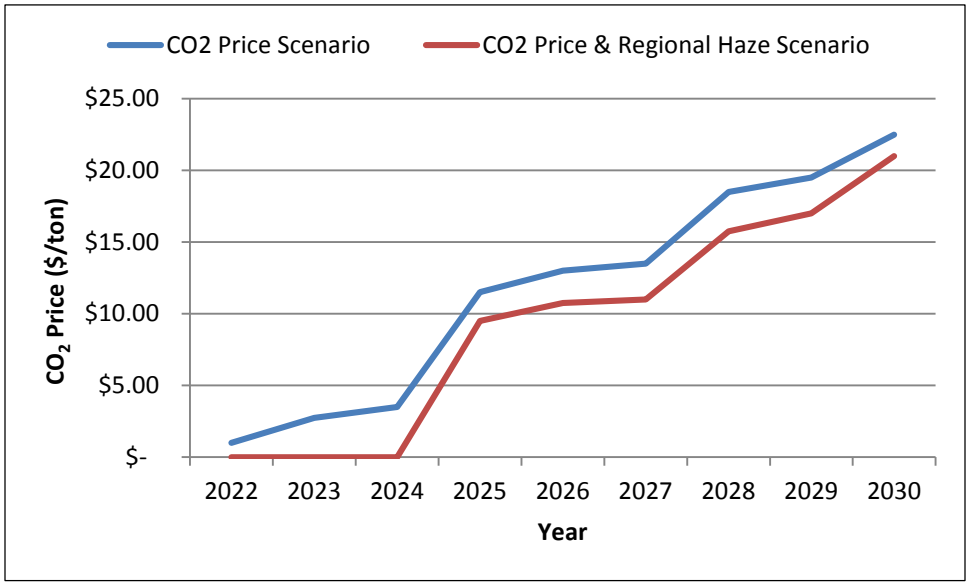

Figure 3: Carbon Dioxide Emissions Prices

In November 2014, EPA proposed a FIP disapproving portions of the Texas state implementation plan for Regional Haze, and setting SO_2 emissions limits for certain coal-fired units in Texas. EPA's proposed FIP would require seven coal-fired units in Texas to upgrade their existing scrubbers, and seven units (five of which are located in ERCOT) to install new scrubber retrofits. To model the proposed Regional Haze FIP requirements, ERCOT added the costs of scrubber upgrades and retrofits to units' fixed costs, as described in the December 2014 report.

In the 2014 study, ERCOT had modeled a 5% energy efficiency savings in scenarios that included the CPP. In this updated analysis, all four scenarios assume energy efficiency savings at 1% of load for all modeled years. At this time, it is unclear how the CPP will be implemented in Texas and how energy efficiency savings might be leveraged for compliance. If, for example, Texas becomes subject to a Federal Plan, it is unclear whether and how energy efficiency could be counted towards compliance. Therefore, the assumption that energy efficiency savings remain at current levels provides a conservative scenario for analysis, and is consistent with the current status of these programs in Texas. However, because energy efficiency remains a potentially cost-effective method for CPP compliance, ERCOT also modeled a scenario where energy efficiency may be used to help achieve compliance, discussed in Section 2.3.

2.2. Modeling Results

ERCOT's modeling of the CPP final rule suggests a different magnitude of impacts compared to the proposed rule. While these modeling results continue to indicate the potential for shifts in the generation mix away from coal and towards natural gas and renewables, the timing and magnitude of these trends differ. The modeling results indicate the potential retirement of at least 4,000 MW of coal-fired capacity due specifically to compliance with the CPP, occurring starting in 2025. However, when the impacts of the CPP are considered in combination with the requirements of EPA's proposed Regional Haze FIP, there are additional unit retirements, many of which occur before the start of CPP compliance in 2022. As with the proposed rule, the modeling predicts a sizeable amount of renewable capacity additions, due both to the improving economics of these technologies as well as impacts of regulating CO_2 emissions. Whereas the previous study saw customer costs increase as early as 2020, due to the stringency of the proposed interim compliance requirements, this analysis sees negligible increases in customer costs by 2022, but sizeable increases in 2030.

Table 1 shows the existing and planned capacity included in the model as the starting point for this analysis. The modeled scenarios resulted in different amounts of unit retirements and capacity additions relative to this baseline. Table 2 summarizes cumulative unit retirements in 2030 by scenario. The modeling results predict 2,300 MW of unit retirements in the baseline, including 800 MW of gas steam retirements and 1,500 MW of coal unit retirements.[9] The unit retirements estimated in the baseline are due to economics, and not compliance with environmental regulations. The next three scenarios consider the CPP, implemented either as a system emissions limit or an emissions fee. When the CPP is imposed as a limit, there are no additional unit retirements above the baseline scenario. When imposed as a price in the next scenario, however, compliance with the CPP results in 4,000 MW of additional coal unit retirements. These retirements occur starting in 2025, at the beginning of the second CPP interim performance period. Finally, the combined impacts of the CPP and Regional Haze result in 4,700 MW of additional coal retirements relative to the baseline. In this scenario, many of the units retire before 2022 due to the timing of the Regional Haze requirements. The number of gas steam unit retirements remains the same across all four scenarios.

Table 1: Baseline Capacity Assumptions

Fuel Type	Capacity (MW)
Nuclear	5,200
Coal	19,900
Natural Gas	59,300
Wind	19,400
Solar	250
Hydro	500
Other	1,000
Total	**105,500**

Table 2: Unit Retirements by 2030

Generation Technology Type	Baseline	CO_2 Limit	CO_2 Price	CO_2 Price & Regional Haze
Retired Gas Steam (MW)	800	800	800	800
Retired Coal (MW)	1,500	1,500	5,500	6,200
Total Retirements (MW)	**2,300**	**2,300**	**6,300**	**7,000**

Table 3: Capacity Additions by 2030

Generation Technology Type	Baseline	CO_2 Limit	CO_2 Price	CO_2 Price & Regional Haze
Wind (MW)	1,000	4,600	9,400	9,100
Solar (MW)	13,000	13,400	13,700	14,100
Combined Cycle (MW)	0	700	0	0
Combustion Turbine (MW)	1,100	700	2,600	2,900
Total Additions (MW)	**15,100**	**19,400**	**25,700**	**26,100**
Capital Costs of new capacity (billions of $2016)	**16**	**21**	**29**	**29**

The model added new capacity to replace retiring units and meet forecasted demand. Table 3 summarizes the cumulative capacity additions and associated capital costs (in real 2016 dollars) by 2030 for each scenario. In the baseline scenario, the model added 13,000 MW of solar capacity, 1,000 MW of wind capacity, and 1,100 MW of natural gas combustion turbines. It should be noted that this analysis assumes the expiration of the Production Tax Credit (PTC) and step-down of the Investment Tax Credit (ITC), as per current law. In the scenarios with the CPP, the model added an additional 4,000 to 9,200 MW of renewable capacity. There are also 1,500 to 1,800 MW of additional natural gas combustion turbines added in the CO_2 price scenarios.

Figure 4 summarizes the capacity additions and retirements in the modeled scenarios. The observed reserve margins resulting from these changes to the resource mix are comparable across all four scenarios.

[9] This includes the announced mothballing of CPS Energy's J.T. Deely units 1 and 2 in 2018.

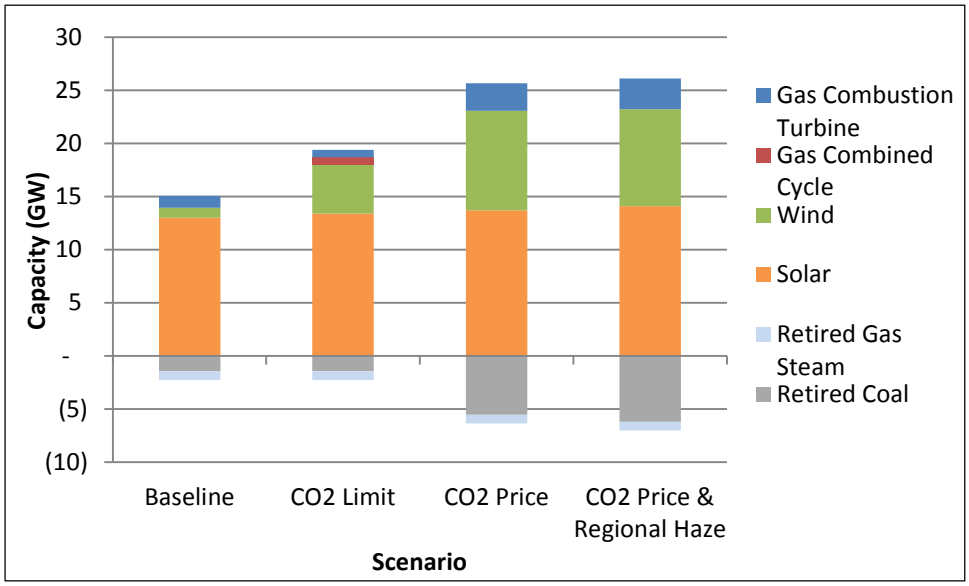

Figure 4: Capacity Additions and Retirements by 2030

Compliance with the CPP results in shifts in the generation mix away from coal and towards natural gas and renewables. Tables 4 and 5 show the annual generation by fuel in 2022 and 2030, respectively, in each of the scenarios. In 2022, the annual generation by fuel is very similar across the first three scenarios. In the fourth scenario, CO_2 Price & Regional Haze, a decrease in generation from coal is made up by increased generation from natural gas and solar resources. By 2030, the generation mix shifts more significantly as the CPP limits become more stringent. The share of generation provided by coal-fired capacity in the CPP scenarios is lower compared to the baseline, at 14 to 16%, versus 27% in the baseline. The difference is made up by increases in generation from natural gas and wind resources. As a result of increased generation from natural gas-fired capacity, in 2030 consumption of natural gas (in MMBTUs) is 14 to 18% higher compared to the baseline in the CPP scenarios.

Figure 5 shows the carbon dioxide emissions from units subject to the CPP in 2022 and 2030 for each scenario.[10] In 2022, CO_2 emissions in the baseline scenario are just above the CO_2 emissions limit for

Table 4: 2022 Annual Generation by Fuel

Fuel Type	Baseline	CO_2 Limit	CO_2 Price	CO_2 Price & Regional Haze
Natural Gas (%)	46	46	47	49
Coal (%)	27	27	26	24
Wind (%)	15	15	15	15
Solar (%)	2	2	2	3
Nuclear (%)	10	10	10	10
Other (%)	<1	<1	<1	<1

Table 5: 2030 Annual Generation by Fuel

Fuel Type	Baseline	CO_2 Limit	CO_2 Price	CO_2 Price & Regional Haze
Natural Gas (%)	43	51	50	50
Coal (%)	27	16	14	15
Wind (%)	14	16	20	20
Solar (%)	7	7	7	7
Nuclear (%)	9	9	9	9
Other (%)	<1	<1	<1	<1

[10] Figure 5 includes emissions only from those units that are subject to the CPP, it does *not* reflect total CO_2 emissions for the ERCOT generating fleet. Only existing fossil steam and combined cycle units subject to certain criteria are regulated under the CPP.

the first performance period. As noted previously, emissions in the CO_2 Price & Regional Haze scenario are below the limit in 2022 due to Regional Haze-related retirements. In 2030, the projected baseline CO_2 emissions are above the final CO_2 emissions limit, and the two price scenarios require a price of \$22.50/ton CO_2 and \$21.00/ton CO_2, respectively, to attain compliance with the limits.

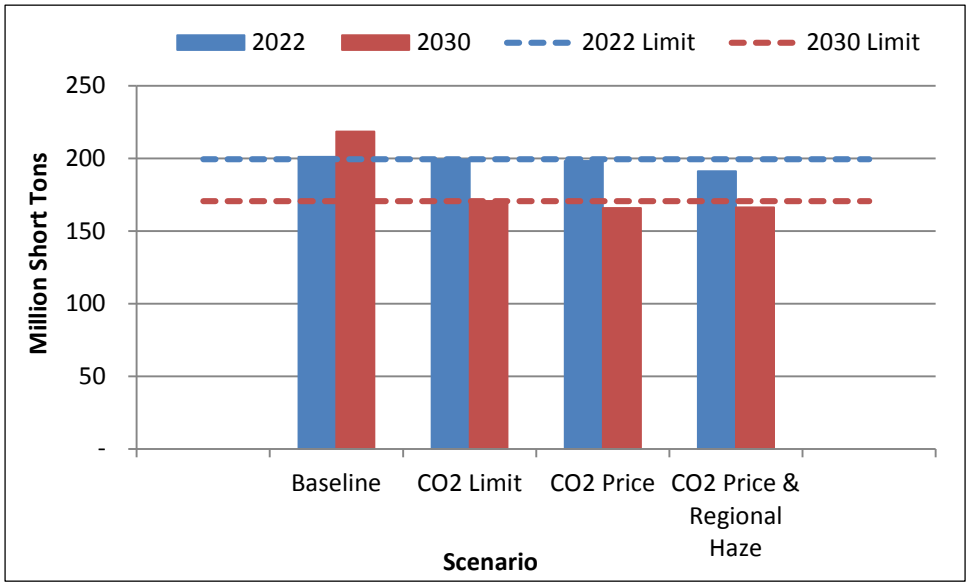

Figure 5: Carbon Dioxide Emissions from Clean Power Plan Affected Units

Compliance with the CPP will impact electricity prices in the ERCOT Region. Table 6 shows the impacts of CPP compliance on average locational marginal prices (LMPs) compared to the baseline scenario. In 2022 the average LMPs are similar across all four scenarios. By 2030 compliance with the CPP results in a 20 to 44% increase in LMPs relative to the baseline. As a general estimate, if wholesale power is 40% of the customer bill, these increases in average LMPs would result in a retail energy price increase of 8 to 18% in 2030. These results do not include the associated costs of building or upgrading transmission infrastructure, natural gas infrastructure upgrades, ancillary services procurement, or potential reliability-must-run contracts.

Table 6: Locational Marginal Prices

Locational Marginal Price	Baseline	CO_2 Limit	CO_2 Price	CO_2 Price & Regional Haze
2022 LMP (\$/MWh)	\$43.35	\$43.08	\$44.12	\$43.25
2030 LMP (\$/MWh)	\$57.20	\$68.53	\$79.78	\$82.59
2022 LMP % change from baseline	n/a	-1%	2%	<1%
2030 LMP % change from baseline	n/a	20%	39%	44%
2022 retail energy bill % change	n/a	<1%	<1%	<1%
2030 retail energy bill % change	n/a	8%	16%	18%

2.3. Energy Efficiency Scenario

As discussed in Section 2.1, energy efficiency is a potential tool that could be used to assist with CPP compliance, but at this time it remains uncertain what role energy efficiency could play in a state or Federal plan for Texas. For this reason, ERCOT did not assume any energy efficiency savings incremental to current levels in the four scenarios described in the previous section. However, because energy

efficiency is a potentially cost-effective method for CPP compliance, ERCOT modeled an additional scenario in which greater deployment of energy efficiency measures may be used to help achieve compliance.

In this scenario, a cumulative energy efficiency savings of 7% by 2030 is assumed, which is consistent with the amount EPA assumed for Texas in the Regulatory Impact Analysis (RIA) of the CPP final rule.[11] To construct the energy efficiency scenario, ERCOT customized the energy efficiency assumptions used by EPA to the ERCOT load forecast. The scenario with energy efficiency savings applies the CO_2 limits in the final CPP as a system constraint, comparable to the CO_2 limit scenario.

Tables 7 and 8 summarize the unit retirements and capacity additions, respectively, for this scenario. The number of unit retirements in the energy efficiency scenario is the same as the baseline and CO_2 limit scenarios. However, the number of capacity additions is lower, due to the energy efficiency measures offsetting increases in demand. The annual generation by fuel, shown in Table 9, is similar to that of the other scenarios in 2022. The differences in the generation mix compared to the other scenarios in 2030 are, again, attributable to the reduced demand resulting from energy efficiency measures, which leads to fewer wind and solar capacity additions, and thus slightly lower generation from those technologies.

The 2022 average LMP in the energy efficiency scenario is $43.48/MWh, which is similar to the results in the other scenarios. In 2030, the LMP is $63.75/MWh, representing an 11% increase above the baseline or a 5% increase in retail energy prices. However, these estimates do not account for the capital costs of investments in energy efficiency measures. Although ERCOT has not estimated these costs, EPA's estimates from the RIA can be illustrative of the potential costs. Based on inflating EPA's estimates to real 2016 dollars and scaling the costs to the level of estimated ERCOT savings, the capital costs to achieve the specified savings would be approximately $31 billion ($2016) by 2030.

Table 7: Unit Retirements by 2030

Generation Technology Type	CO_2 Limit & Energy Efficiency
Retired Gas Steam (MW)	800
Retired Coal (MW)	1,500
Total Retirements (MW)	**2,300**

Table 8: Capacity Additions by 2030

Generation Technology Type	CO_2 Limit & Energy Efficiency
Wind (MW)	2,200
Solar (MW)	10,200
Combined Cycle (MW)	0
Combustion Turbine (MW)	900
Total Additions (MW)	**13,300**
Capital Costs of new capacity (billions of $2016)	**14**

Table 9: Annual Generation by Fuel

Fuel Type	2022	2030
Natural Gas (%)	46	51
Coal (%)	27	18
Wind (%)	15	16
Solar (%)	2	6
Nuclear (%)	10	9
Other (%)	<1	<1

3. Discussion

As with ERCOT's 2014 analysis of the CPP proposed rule, this modeling analysis indicates that compliance with the CPP is likely to result in the retirement of existing generation capacity and require significant amounts of generation from renewable sources. Though the specific amounts of unit retirements and capacity additions differ from ERCOT's previous study of the CPP proposal – due both to changes to the emissions limits and timing in the CPP final rule as well as changing market economics – ERCOT continues to see potential challenges to grid reliability resulting from these resource mix changes, as well as associated impacts to the transmission system.

[11] U.S. Environmental Protection Agency. *Demand-Side Energy Efficiency Technical Support Document*, August 2015. Available at http://www3.epa.gov/airquality/cpp/tsd-cpp-demand-side-ee.pdf.

3.1. Impact of Unit Retirements

The modeling results suggest that compliance with the CPP could result in the retirement of at least 4,000 MW of coal-fired capacity in the ERCOT region. In addition to these retirements, several units in the modeling results operate at low capacity factors during off-peak months, and would be potential candidates for suspended operations during those months (seasonal mothball). Though overall fewer coal units are at risk compared to the number of units under the CPP proposal, due to the differing level of stringency in the final rule, there continues to be a risk that the ERCOT Region could see multiple unit retirements within a short timeframe, which could result in implications for reliability.

The potential impacts to coal-fired generation increase when other environmental compliance requirements are considered. There are several environmental regulations for which owners of coal units will need to take actions to comply between now and 2022. With the implementation of the CPP to consider, resource owners may choose to retire units rather than install the required control technology retrofits to comply with these other rules. For more information about other environmental regulations affecting generation resources, see ERCOT's December 2014 report.

In this analysis, ERCOT included the CO_2 Price & Regional Haze scenario to assess the combined impacts of the two rules. The results of that scenario suggest that compliance with the CPP and the Regional Haze FIP could result in the retirement of at least 4,700 MW of coal-fired capacity. Model results indicate that many of the retirements will occur before the start of CPP compliance in 2022, due to the timing of the proposed Regional Haze FIP requirements. However, these results likely represent a lower bound on the number of potential coal unit retirements, in large part because the model is not requiring a competitive market rate of return for unit upgrades like investors would. Note that in the 2014 study, ERCOT considered 8,500 MW of coal-fired capacity to have some risk of retirement due to the proposed Regional Haze requirements.

If ERCOT does not receive adequate notification of these retirements, and if multiple unit retirements occur within a short timeframe, there could be implications for reliability. Coal resources provide essential reliability services necessary to maintain the reliability of the grid. The retirement of coal resources will require studies to determine if there are any resulting reliability issues, including whether there are localized voltage/reactive power control issues and the necessity of potential transmission upgrades, which is discussed in the following section.

3.2. Impact on Transmission

The modeling results indicate that the compliance requirements in the CPP could result in the retirement of at least 4,000 MW of coal-fired capacity. The retirement of legacy coal-fired generation could result in localized reliability issues and require transmission system upgrades. As part of ongoing work studying the potential impacts of environmental regulations, ERCOT recently conducted a reliability analysis that evaluated potential retirement scenarios resulting from compliance with the proposed Regional Haze FIP.[12] Though this study was focused specifically on scenarios associated with the Regional Haze requirements, the results are illustrative of the likely transmission reliability implications and associated costs of losing a substantial amount of legacy coal-fired generation over a relatively short period of time.

In the study, ERCOT retired affected units in phases – first assuming the retirement of units with scrubber retrofit requirements, and then adding to that the potential retirement of units with scrubber upgrade requirements. ERCOT evaluated the potential impacts separately for each region with affected

[12] Additional information on this study is available on ERCOT's Regional Planning Group (RPG) website at http://www.ercot.com/content/wcm/key_documents_lists/76860/Transmission_Impact_of_the_Regional_Haze_Environmental_Regulation_Oct_RPG.pdf.

capacity (East/Coast, South/South Central, and North/North Central), using the 2015 Regional Transmission Plan (RTP) cases for the year 2020. New conventional and solar generation resources outside of the study region with a signed generator interconnection agreement (SGIA) were added to each scenario to balance the load, supply, and reserves.

The study showed that the retirement of coal-fired generation affected by the proposed Regional Haze FIP would have a significant impact on the reliability of the transmission system and would require substantial upgrades to transmission infrastructure. The study identified local transmission issues in all of the studied regions, as well as zonal transfer issues in the North/North Central region. In one scenario that assumed the retirement of 4,200 MW of coal-fired capacity, comparable to the amount expected to retire due to the CPP alone, model results indicated that the thermal capacities of 10 circuits (143 miles) of 345 kV transmission lines, 31 circuits (147 miles) of 138 kV transmission lines, 6 circuits (39 miles) of 69 kV transmission lines, and 11 transformers would be exceeded. Note that the transmission impacts of unit retirements are highly location specific. As a general estimate, new 69 kV and 138 kV lines cost on the order of one million dollars per mile and new 345 kV lines cost on the order of three million dollars per mile. Additionally, in the ERCOT Region, it takes at least five years for a new major transmission project to be planned, routed, approved, and constructed.

Growth in renewable generation would also likely have a significant impact on transmission requirements. In early 2014, the transmission upgrades needed to integrate the Texas Competitive Renewable Energy Zones (CREZ) were completed. These upgrades were intended to facilitate the integration of wind resources onto the ERCOT system and included more than 3,600 miles of new transmission lines, constructed at a cost of $6.9 billion dollars. The project took nearly a decade to complete. To date, more than 14 gigawatts of wind capacity have been successfully integrated onto the ERCOT grid. While the CREZ transmission upgrades provide some transmission capacity beyond current generation development, the modeling results indicate as much or more growth in renewable capacity over the next 15 years. Integrating these resources would likely require significant investments in new transmission and a substantial acquisition of new transmission line right of way, incremental to those that have already been completed as part of CREZ.

3.3. Impact of Renewables Integration

Integrating new wind and solar resources will increase the challenges of reliably operating the ERCOT grid. In 2014, 10.6% of the ERCOT region's annual generation came from wind resources. At its highest levels of instantaneous penetration, wind has provided enough energy to serve 40.58% of system load.[13] The modeling results predict further growth in both wind and solar resources, which together would constitute 27% of total generation by 2030 in the CO_2 Price and CO_2 Price & Regional Haze scenarios. However, in hourly operations, this level of renewables would result in intermittent generation serving more than 50% of load in over 400 hours of the year, and a peak instantaneous penetration of 67%. This is an increase in renewable generation compared to the results of ERCOT's 2014 study, due to the improving economics of these technologies, as reflected in the updated capital cost assumptions included in this analysis.

Further, these scenarios show significant growth in both wind and solar resources, compared to the 2014 study which predicted mostly solar capacity additions. Wind production in West Texas results in high renewable penetration during off-peak hours, when customer demand for electricity is lowest. The modeling results indicate lower net loads (defined as total customer demand minus generation from intermittent energy resources) compared to the 2014 study (14,611 MW in this analysis as compared to 17,611 MW in the 2014 study).[14] As a result, the anticipated challenges to grid reliability indicated by

[13] The current record in the ERCOT Region for wind penetration occurred on March 29, 2015 at 2:00 a.m.

[14] The current record in the ERCOT Region for net load is 14,809 MW, which occurred on March 24, 2014 at 2:25 a.m.

these modeling results may be more severe. In addition, if a significant portion of future solar generation capacity is located on the distribution grid (e.g., rooftop solar and small scale utility solar connected at lower voltage levels), as opposed to the utility-scale, it could result in additional operational impacts.

The increased penetration of intermittent renewable generation, as projected by these results, will pose challenges to the reliable operation of all generation resources. In the periods when the output of renewable generation provides a large percentage of total energy, significant ramping capability and operational reserves will be required to maintain grid reliability. If there is not sufficient ramping capability and operational reserves during these periods, the need to maintain operational reliability could require the curtailment of renewable generation resources. The ability to curtail intermittent generation resources in real-time operations is a key backstop for maintaining the reliability of the system. Curtailment would reduce production from renewable resources, and could delay achievement of compliance with the CPP limits.

4. Conclusion

ERCOT's modeling of the CPP final rule suggests impacts of a different magnitude compared to the proposed rule. Though overall fewer coal units are at risk compared to the number of units under the CPP proposal, there continues to be a risk that the ERCOT Region could see multiple unit retirements within a short timeframe. When the impacts of the CPP are considered in combination with the requirements of EPA's proposed Regional Haze FIP, there are additional unit retirements, many of which occur even before the start of CPP compliance in 2022. If ERCOT does not receive adequate notification of these retirements, there could be periods of reduced system-wide reserve margins and localized transmission reliability issues due to the loss of generation resources in and around major urban centers. A recent reliability analysis of potential retirement scenarios resulting from compliance with the proposed Regional Haze FIP indicated that the retirement of 4,200 MW of coal-fired capacity would have a significant impact on the reliability of the transmission system.

As with ERCOT's analysis of the proposed rule, this study predicts a sizeable amount of renewable capacity additions, due both to the improving economics of these technologies as well as impacts of regulating CO_2 emissions. If there is not sufficient ramping capability and operational reserves during periods of high renewable penetration, the need to maintain operational reliability could require the curtailment of renewable generation resources. The ability to curtail intermittent generation resources in real-time operations is a key backstop for maintaining the reliability of the system. Curtailment would reduce production from renewable resources, and could delay achievement of compliance with the CPP limits.

The CPP will also result in increased energy costs for customers in the ERCOT region. Based on ERCOT's modeling analysis, energy costs for customers may increase by up to 16% by 2030 due to the CPP alone, without accounting for the associated costs of transmission upgrades, higher natural gas prices caused by increased gas demand, procurement of additional ancillary services, and other costs associated with the retirement or decreased operation of coal-fired capacity in ERCOT. Consideration of these factors would result in even higher energy costs for customers.

At this time, there is uncertainty regarding the implementation of the CPP in Texas. In the coming years, resource owners will need to make decisions about their generation units – taking into account the CPP as well as other environmental regulations – that could result in localized reliability issues and transmission constraints associated with a changing resource mix. As new information becomes available, ERCOT will continue to analyze the impacts of regulatory developments that may affect the ability to provide reliable electricity to customers in Texas.