Carbon Dioxide Reduction in the U.S. Electric Power Sector without the Clean Power Plan: Is there a path to Paris Agreement Compliance?

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At the December 2009 United Nations Climate Change Conference in Copenhagen, the United States (U.S.) pledged to reduce overall domestic greenhouse gas (GHG) emissions in 2020 by approximately 17% from 2005 levels with the intent to further reduce levels by 2050 by 83% of 2005 levels [1]. An additional early target horizon was set for 2025 with the 2015 Paris Agreement, in which the U.S. nationally determined contribution (NDC) to GHG emission reduction was set at 26–28% below the 2005 levels [2]. To facilitate these reductions, President Obama implemented the Climate Action Plan (CAP) [3] to slow and manage the impacts of climate change. A central element in meeting the CAP's goal to reduce national carbon emissions is the U.S. Environmental Protection Agency's (EPA's) Clean Power Plan (CPP) that promulgates a reduction in carbon dioxide (CO_2) emissions from existing fossil-fuel power plants to 68% of the 2005 level by 2030 [4].[1] This CPP reduction represents the substantial contribution that the electric power sector makes to meeting the Paris Agreement targets: Intermediate targets in the CPP for 2020 and 2025 represent approximately 47% and 37–40% of the Paris Agreement reduction for the corresponding years [5].

The Trump administration is taking different actions concerning GHG emissions. On 28 March 2017, Executive Order 13783 revoked the Climate Action Plan and started a review of the CPP [6]—a review that is leading to the EPA's proposed repeal of the CPP [7]. The U.S. also notified the United Nations on 4 August 2017 of its intent to withdraw from the Paris Agreement, when it is eligible to do so in 2020 [8, 9]. Notwithstanding the repeal of the CPP and the impetus for the regulation, it may still be possible for the U.S. electric power sector to meet its contribution to the NDC pledge, depending on natural gas prices. To illustrate this point, this note summarizes work done to expand on the EPA's regulatory impact analysis of the CPP review [10] and work documented in Ramseur [5] with further analysis of data from the U.S. Energy Information Administration's (EIA's) 2017 Annual Energy Outlook (AEO) [11].[2] In particular, we examine projected electric power sector CO_2 emissions under different natural gas prices to determine if the 2020, 2025 and 2030 emission targets set in the CPP can still be met in its absence.[3]

In the AEO, projected commodity prices, capacities, generation mixes, and fleet emissions are determined by the National Energy Modeling System (NEMS) model, which incorporates, *inter alia*, the impact of economic growth, resource availability, and regulation [12]. Of the nine cases modeled for these three factors, two are shown with and without implementation of the CPP: one pair is the reference case, and the other is for the high resource availability case (which results in low natural gas prices).[4] When these pairs are compared to the CPP emission targets for the years in question, Table 1, one observes that the CPP cases continue on the decreasing glidepath to the 2030 target, while the emissions for the non-CPP cases remain stable. The 2020 emission target is achieved without the CPP in both natural gas price cases, and the case pairs are almost indistinguishable given the uncertainty in the CO_2 emission projection [17].[5] This is not true for the 2025 target. While the 2025 target is surpassed for the CPP cases,[6] the target in the other cases is not met in the absence of the CPP. However, the non-CPP case with the lower natural gas price is within 13 million tons of the target, which may be within the uncertainty of the projection. Though the NDC does not extend to 2030, the projections indicate that the 2030 CPP emission target will not be met without the associated emission cap and incentive mechanisms. This indicates the positive role that the CPP has on deeper emission reductions beyond 2025.

When the projected natural gas price[7,8] and the resulting fleet CO_2 emission reduction for the non-CPP cases are plotted with historical data (see the Figure),[9] one observes that the historical trend for CO_2 emissions decreasing with lower natural gas prices[10] is maintained in each case. Furthermore, the emissions for each case are greater than the estimated 2017 level, which may already meet the 2025 mass target.[11] The 2017 emission level, and the clustering of future emissions near the 2025 target, may be due in part to a fuel-switch from coal to renewable and natural gas sources[12] related to policy mechanisms for renewable energy[13] and/or a favorable natural gas price.[14] Therefore, one market-based mechanism to achieve the NDC emissions target for 2025 would be through an increase in fuel-switching to natural gas sources—to natural gas combined cycle (NGCC) plants[15]—that would occur if natural gas prices were below $3.40/MMBtu.[16] Reaching the 2030 target may require natural gas prices below the 2017 level.

The emission targets can also be met, *ceteris paribus*, through policy by building more NGCC and/or onshore wind sources. For the 2025 reference case with NGCC replacement, this will require eliminating 138 million tons of CO_2 by replacing approximately 31.5 gigawatts (GW) of coal-fired capacity with 26.5 GW of NGCC capacity, at a CO_2 avoidance cost of $34.8/ton and a total annual cost of $4.8 billion, Table 2. Reducing the same amount of CO_2 emissions through onshore wind generation will require an additional 56.3 gigawatts (GW) of wind capacity at a CO_2 avoidance cost of $11.2/ton[17] and a total annual cost of $1.5 billion. The required emission reduction to meet the target for the low natural gas price case is almost an order of magnitude less than the reference case; therefore, the associated capacity requirement and cost for each substitute source is also almost an order of magnitude lower.[18] Thus, it is possible to meet the 2025 NDC emission target at projected fuel prices by replacing coal-fired capacity with NGCC and/or wind sources. The required capacity of these sources and the total cost of meeting the target is dependent upon the natural gas price and a mechanism to promote this reduction.

The gap between the projected emissions and the target is greater for the 2030 cases, and requires more alternative source capacity at a greater cost to bridge, Table 3. In the 2030 reference case, almost twice as many excess CO_2 emissions must be replaced as in the 2025 case; therefore, the 2030 retired electric generating units (EGUs), alternative NGCC capacity, and cost requirements are almost twice as large. This scaling is also true for wind replacement; however, the wind avoidance cost is now twice as great as that for 2025 due to expiration of the production tax credit. Replacement in 2030 when the natural gas price is low results in the avoidance cost and overall cost for the NGCC replacement to be lower than that for the wind. This is due to the increased levelized cost of electricity for the wind source in the absence of the tax credit, and to the lower variable cost for the NGCC plant because of the low natural gas price.

While the Paris Agreement NDC is non-binding and the U.S. currently intends to withdraw prior to the target dates, the portion of the target that is represented by the reductions present in the CPP may still be met in 2020 and 2025, even if the CPP is repealed. Projections from the EIA indicate that the CO_2 emission reduction with or without the CPP may be substantially the same in 2020. Furthermore, the 2025 reduction may be met without the CPP, if natural gas prices are below $3.40/MMBtu. In lieu of lower natural gas prices, some coal-fired generation can be replaced with generation from NGCC and wind sources to meet the 2025 target and to achieve the 2030 CPP target. In the absence of the CPP's incentives and mechanisms to achieve these deeper reductions, the fuel choice for the replacement source and the cost for future reductions will depend upon the policy maker's decisions on renewable subsidies and mechanisms to incentivize the reductions, and on the actual natural gas price, however.

Tables

Table 1. Clean Power Plan CO_2 Emission Targets and AEO 2017 Projected CO_2 Emissions with and without the CPP for 2020, 2025, and 2030 [13, 15].[19] Values in boldface indicate that the case meets the target.

	Annual CO_2 Emissions (million short tons)		
Case/Year	2020	2025	2030
Target	2,073	1,901	1,814
Reference with CPP	**2,007**	**1,829**	**1,694**
Reference without CPP	**2,024**	2,039	2,078
Low Natural Gas Price with CPP	**1,922**	**1,782**	**1,689**
Low Natural Gas Price without CPP	**1,936**	1,914	1,922

Table 2. 2025 Cases without CPP for Replacement Sources to Decrease CO_2 Emissions to CPP Target

Parameter	**Units**	**Reference**		**Low NG Price**	
Excess CO_2	Million short tons	138		13	
Retired coal capacity[20]	Gigawatts	31.5		3.2	
Retired coal EGUs[21]	Number	82		8	
Natural gas price[22]	2010$/MMBtu	4.34		3.41	
New Generation Source Cases		NGCC[23]	Wind[24]	NGCC	Wind
New source capacity	Gigawatts	26.5	56.3	2.5	5.4
New sources	Number	38	18,755	8	1,795
CO_2 avoidance cost[25]	2010$/ton	34.8	11.2	26.4	11.2
Annual Cost[26]	Billion dollars	4.8	1.5	0.3	0.1

Table 3. 2030 Cases without CPP for Replacement Sources to Decrease CO_2 Emissions to CPP Target

Parameter	**Units**	**Reference**		**Low NG Price**	
Excess CO_2	Million short tons	264		108	
Retired coal capacity	Gigawatts	58.9		25.9	
Retired coal EGUs	Number	153		67	
Natural gas price	2010$/MMBtu	4.60		3.62	
New Generation Source Cases		NGCC	Wind	NGCC	Wind
New source capacity	Gigawatts	50.6	107.4	28.6	44.1
New sources	Number	72	35,785	30	14,706
CO_2 avoidance cost	2010$/ton	37.2	29.2	28	29.4
Annual Cost	Billion dollars	9.8	7.7	3.0	3.2

Figure

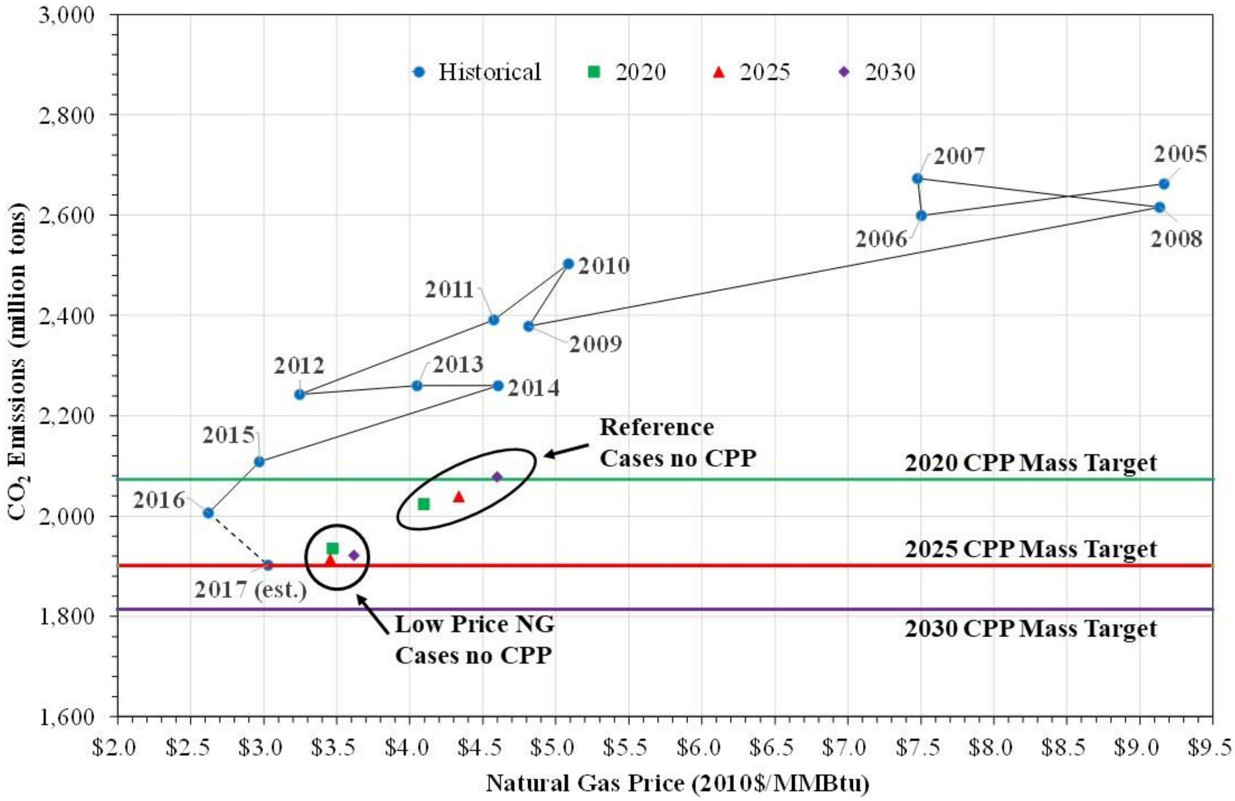

Figure. Historical[27] and projected 2020, 2025, and 2030 CO_2 emissions from the U.S. power sector in relation to natural gas price [15]. Projected emissions and gas prices are national averages based on scenarios in the Annual Energy Outlook (AEO) 2017 for the reference case, and the high oil and gas resource and technology case [11]. While complementary scenarios with and without the CPP from AEO 2017 are discussed, only the scenarios without the CPP are shown. Historical and projected natural gas prices from AEO 2017 are converted to 2010 dollars with the Consumer Price Index [14].

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Endnotes

[1] The potential regulatory contribution of the CPP to the development of more stringent climate polices for the deeper carbon reduction pledge in the NDC for 2050 is beyond the discussion herein.

[2] The AEO projections assume that the mass-based approach is taken by all states.

[3] Many of the data used and the conclusions reached in this work are highly dependent upon the assumptions made in the referenced literature and made for the calculations. Changing these assumptions can lead to different conclusions. This work is a deterministic presentation that does not directly address the uncertainty in the data used.

[4] The low natural gas price cases used are specified in the AEO 2017 literature [11] as “high oil and gas resource and technology” and “high resource without Clean Power Plan.”

[5] The EIA data for the average, absolute, percent difference between the EIA emissions projection and the actual result for one to six-year projections since 2010 is 3.4% percent [17].

[6] In some cases, the AEO 2017 projections for emission reduction surpass the CPP targets. This over-reduction may be viewed as an overcorrection inefficiency, or as establishing a surplus reduction that may be used to offset other GHG reduction programs that do not meet associated targets for the NDC.

[7] Natural gas prices in dollars per million British thermal units ($/MMBtu) are converted to 2010 dollars with the Consumer Price Index (CPI) [14]. Natural gas prices from the EIA are based upon national averages.

[8] Unless specified otherwise, all dollar values are in 2010 dollars.

[9] Historical data are from EIA *Monthly Energy Review* [15] and are converted to 2010 dollars with the CPI [14]. The 2017 emission data are estimated from the nine months of 2017 historical data with a 23% adder for the emissions from the remaining three months. This adder is based upon the average increase in 2015 and 2016 nine-month emissions to achieve the annual total emissions. The natural gas price estimate for 2017 is based upon the average monthly price from the nine months of 2017 historical data.

[10] The correlation between price and reduction is not chronologically perfect, however. Coal prices, capacity planning, regulations and policy mechanisms (such as state-specific renewable portfolio standards and federal tax credits for solar and wind energy), unforeseen events, technology changes, and hedging related lags [16, 17, 18] may account for some of the imperfect responses between the natural gas price and the reduction, as occurs from 2006 to 2008 and from 2012 and 2014, when the natural gas prices increase but the emission intensities remain constant.

[11] While the emission level for 2017 may meet the 2025 target, the net generation produced is less than that projected for 2025. AEO 2017 projections for net generation are 3.9 billion megawatt-hours (MWh) in 2017 and 4.2 billion MWh in 2025. Therefore, the emission intensity of the fleet in 2025 will need to be lower than that for the fleet in 2017.

[12] Fugitive methane emissions for natural gas sources are not included.

[13] Such as state-specific renewable portfolio standards and federal tax credits for solar and wind energy.

[14] AEO 2017 projections indicate that the percent net generation from renewable sources increases for the case pairs in 2020, 2025, and 2030, relative to 2015 [11]. The percent-generation from coal decreases in the case pairs for these years, whereas the natural gas generation increase depends upon the gas price and emission target or cap for that year.

[15] The reduction in emissions comes from the difference in the CO_2 emission intensity for the two sources, based upon net generation. The 2015 average CO_2 emission intensity (lbs CO_2 per megawatt-hour) for the U.S. power sector coal-fired fleet was 2,200 lbs/MWh [15]. The CO_2 emission intensity for a new, conventional NGCC plant is 772 lbs/MWh. Therefore, replacing the net generation from the average coal-fired EGU with net generation from a new conventional NGCC plant reduces the total emissions by 65%.

[16] The projected natural gas price for 2030 may need to be lower than the 2015 price to achieve the CPP target, based upon the historical 2014-2015 relationship between natural gas price and CO_2 emission reduction.

[17] This assumes the 2025 wind sources enter service in 2022 and are eligible for the current production tax credit valued at $11.6/MWh (2016 dollars) [20].

[18] The avoidance cost for the NGCC source in the low natural gas price case is lower than that for the reference case because of the natural gas price.

[19] The AEO projections assume that the mass-based approach is taken by all states.

[20] The calculation for the required retirement capacity for the coal-fired fleet is based upon four parameters: (1) the projected profile of the coal-fired fleet in 2020, 2025, and 2030 (the fleet capacity, average emission intensity), and net generation), (2) the required reduction in coal-fired generation, (3) the CO_2 emissions emitted from the

replacement source to match the reduced coal-fired generation, and (4) the required reduction in CO_2 emissions to meet the target. The projected coal-fired emission intensities are calculated from AEO 2017 coal-fired emission and net generation data [11]. The resulting values for 2020, 2025, and 2030 are 2131, 2143, and 2132 lbs/MWh, respectively. The replaced coal-fired net generation is found by setting the coal-fired emission intensity multiplied by replaced net generation plus the emissions from the replacement source equal to the required reduction in CO_2 emissions to meet the target, and solving for the net generation. The retirement capacity is then determined from the calculated coal-fired fleet capacity factor, based upon the projected capacity and net generation [11], and the coal-fired net generation that needs to be replaced.

[21] The required number of coal plants to be retired to reach the emissions goal serves as a reference only, and is based upon the capacity of a proxy coal EGU emitting CO_2 at the emission intensities described in the previous endnote. This capacity of this proxy plant is the average net summer capacity of the 669, operational coal plants with capacity greater than 25 MW that use bituminous, subbituminous, lignite and waste coal, as listed in the August 2017 EIA form 860M [19]. The calculated average capacity is 386 MW. The number of actual plants that might be retired in this scenario will depend upon many factors and is beyond the scope of this work.

[22] The EIA data for the average absolute percent difference between the EIA emissions projection and the actual result for one to six-year projections since 2010 is 21% percent [17].

[23] The replacement NGCC plant is a conventional NGCC plant that is constructed in 2022 for the 2025 scenario and in 2030 for the 2030 scenario. The capacity is taken as 702 MW net summertime capacity [21]. This plant operates at an 87% capacity factor [20], has a heat rate of 6,600 Btu/kWh and the fuel CO_2 emission intensity is 117 lbs/MMBtu [21].

[24] The replacement onshore wind turbine enters into service in 2022 for the 2025 scenario and in 2030 for the 2030 scenario. The capacity is taken as 1.79 MW [20] and operates at a 41% capacity factor [20].

[25] The CO_2 avoidance cost is based upon the difference in the generation levelized cost of electricity (LCOE) between the base case and the case to obtain the reduced emissions divided by the associated change in CO_2 emission intensity. The projected baseline generation LCOE for the projected fleet is given in the AEO 2017 [11]. This is adjusted for the replaced coal-fired generation with an assumed generation LCOE for the coal-fired fleet taken from Jean et al [22] as $33/MWh (assumed in 2016 dollars). The coal-fired LCOE is held constant for all years, given a projected maximum 0.6% annual increase in delivered coal price between 2016 and 2050 for the cases [11]. The 2025 and 2030 generation LCOE for the conventional NGCC plant is taken as $57.5/MWh, and is adjusted with the plant heat rate for variation in natural gas price from the 2022 reference case with CPP level [20]. The 2025 generation LCOE for the wind turbines is taken as $41.4/MWh, which is the LCOE for service entry in 2022 inclusive of a $11.6/MWh tax credit [20]. The 2030 LCOE is taken $55.0/MWh, which includes a linear approximation of the LCOE increase between 2022 and 2040 and excludes the tax credit [20]. Dollar values in this endnote are given in 2016 dollars. The replacement LCOEs exclude any additional transmission investments.

[26] These costs are the annual costs, based upon the avoidance costs and the necessary emission reduction.

[27] The slight increase in emissions from 2012 through 2014, during a period of increasing natural gas prices, was due to a 1.3% increase in fleet net generation contribution from coal-fired sources, as that from NGCC sources decreased by 2.9%. This migration from lower CO_2 emitting NGCC sources was partially offset by increases in net generation from nuclear (0.5%) and renewable sources (0.9%) [15]. The estimated emissions for 2017 are lower than those from 2015 due to a projected decrease in contribution to fleet net generation from coal-fired sources and an increase in that from renewable sources [15]. While coal-fired generation is projected to decrease from 34% to 31% of the fleet net generation from 2015 to 2017, net generation from renewable energy is projected to increase from 13% to 17%. Over this same period, generation from natural gas is projected to decrease from 32% to 31%.