DATE: July 31, 2015

SUBJECT: Achievability of the Standard for Newly Constructed Steam Generating EGUs

TO: Rulemaking Docket ID: EPA-HQ-OAR-2013-0495

This memorandum describes the achievability of the final standard of performance for greenhouse gas (GHG) emissions from newly constructed steam generating EGUs under CAA section 111(b).

The EPA finds the final standard of 1,400 lb CO_2/MWh-g to be achievable over a wide range of variable conditions that are reasonably likely to occur when the system is properly designed and operated.[1] As discussed elsewhere, the final standard reflects the degree of emission limitation achievable through the application of the best system of emission reduction (BSER) which we have determined to be a highly efficient supercritical pulverized coal (SCPC) unit implementing partial CCS at a level sufficient to achieve the final standard. A SCPC unit utilizing bituminous coal could achieve the BSER with partial capture of approximately 16 percent. In determining the predicted cost and performance of such a system, the EPA utilized information contained in updated DOE/NETL studies that assumed use of bituminous coal and an 85 percent capacity factor.[2] Here we examine the effects of deviating from those assumed operational parameters on the achievability of the final standard of performance.

Operational fluctuations, start-ups, shutdowns, and malfunctions

Importantly, compliance with the standard must be demonstrated over a 12-operating-month average. The total CO_2 emissions (pounds of CO_2) over 12 operational months are summed and divided by the total gross output (in megawatt-hours) over the same 12 operational months. Such a compliance averaging period is very forgiving of short-term excursions that can be associated with non-routine events such as start-ups, shutdowns, and malfunctions. A new fossil fuel-fired steam generating EGU – if constructed – would, most likely, be built to serve base load power demand and would not be expected to routinely start-up or shutdown or ramp its capacity factor in order to follow load demand. Thus, planned start-up and shutdown events would only be expected to occur a few times during the course of a 12-operating-month compliance period. Malfunctions are unplanned and unpredictable events

[1] "The DOE/NETL stated that … 'Actual average annual emissions from operating plants are likely to be higher than the design emissions rates shown due to start-up, shutdown, part-load operation, and performance degradation through maintenance cycles. Lower design emissions rates to ensure adequate margins may be required for compliance with future regulations; however, given that the slope of the variation of [L]COE with CO2 emission levels is not steep for either SC PC or IGCC plants (except at low capture rates), designing for this margin does not have major cost implications.'"

[2] See 'Cost and Performance Baselines for Fossil Energy Plants' reports available at http://www.netl.doe.gov/research/energy-analysis/energy-baseline-studies

and emission excursions can happen at or around the time of the equipment malfunction. But a malfunctioning EGU that cannot be operated properly should be shut down until it the malfunctioning equipment can be addressed and the EGU can be restarted to operate properly. Short-term and rare excursions would not be expected to affect a 12-operating-month rolling emission average.

The post-combustion capture systems that have been utilized have proven to be reliable. The Boundary Dam facility has been operating full CCS at commercial scale since October 2014. In evaluating results from the Mountaineer slip-stream demonstration, AEP and Alstom reported robust steady-state operation during all modes of power plant operation including load changes, and saw an availability of the CCS system of greater than 90 percent. [3,4]

Variations in coal type

The use of specific coal types can affect the amount of CO_2 that is emitted from a new coal-fired power plant. The EPA utilized studies by the DOE/NETL to predict the cost and performance of new steam generating units.

The EPA used emission values for SCPC firing bituminous coal from the updated DOE/NETL report.[5] The emission value for the SCPC firing low rank coal came from the DOE/NETL cost and performance for low rank coal – specifically from the case of an ultra-supercritical PC (USCPC) burning subbituminous coal.[6] The EPA then estimated the partial capture needed for the unit firing low rank coal (subbituminous coal and dried lignite[7]) to achieve the 1,400 lb CO_2/MWh-g standard by assuming that the performance curve for such a unit will follow the same slope as the bituminous coal. The DOE/NETL has not completed a similar partial capture study for units using low rank coal, but the equipment and configuration to do so would be the same as the cases evaluated for bituminous-fired units. Therefore, the EPA believes that this assumption is reasonable. The results are shown in Figure 1 and in Table 1 below.

[3] http://www.alstom.com/press-centre/2011/5/alstom-announces-sucessful-results-of-mountaineer-carbon-capture-and-sequestration-ccs-project/.

[4] "Cost and Performance Baseline for Fossil Energy Plants Volume 1a: Bituminous Coal (PC) and Natural Gas to Electricity, Revision 3", DOE/NETL-2015/1723 (July 2015) at p. 36 ("[t]he capture and CO_2 compression technologies have commercial operating experience with demonstrated ability for high reliability").

[5] "Cost and Performance Baseline for Fossil Energy Plants Supplement: Sensitivity to CO_2 Capture Rate in Coal-Fired Power Plants", DOE/NETL-2015/1720 (June 2015), Exhibit A-1, p. 16.

[6] "Cost and Performance Baseline for Fossil Energy Plants, Volume 3 Executive Summary: Low Rank Coal and Natural Gas to Electricity", DOE/NETL-2010/1399 (September 2011), Exhibit ES-3, p. 5.

[7] For a summary of lignite drying technologies see "Techno-economics of modern pre-drying technologies for lignite-fired power plants" available at www.iea-coal.org.uk/documents/83436/9095/Techno-economics-of-modern-pre-drying-technologies-for-lignite-fired-power-plants,-CCC/241; "Drying the lignite prior to combustion in the boiler is thus an effective way to increase the thermal efficiencies and reduce the CO_2 emissions from lignite-fired power plants."

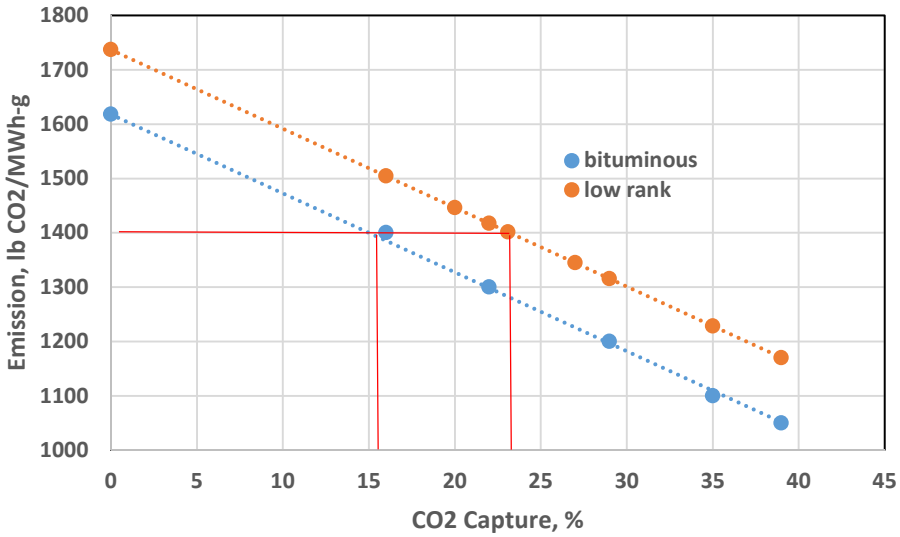

Figure 1. CO_2 emission with partial carbon capture for highly efficient SCPC firing bituminous coal and low rank coal

Table 1. CO_2 emissions for highly efficient SCPC with varying levels of partial capture – for units firing bituminous coal and low rank coal

Capture %	Bituminous LCOE ($2011/MWh)	Low Rank LCOE ($2011/MWh)	Bituminous Emission (lb CO_2/MWh-g)	Low Rank Emission (lb CO_2/MWh-g)
0	82.3	80.8	1,618	1,737
16	99.1	98.0	1,400	1,504
22	103.7	101.7	1,300	1,417
23	103.9	102.4	1,280	1,400
29	107.5	106.0	1,200	1,316
35	111.4	109.7	1,100	1,228
39	113.3	112.1	1,050	1,170

The EPA has evaluated those costs and finds them to remain reasonable. As shown in Table 2 below (Table 8 in the rule's final preamble), the predicted range of costs (accounting for uncertainty) remains within the estimated range of costs for the other principal base load, dispatchable non-NGCC generation technologies.

Table 2. Predicted Cost and CO_2 Emission Levels for a Range of Potential New Generation Technologies[8] (This is Table 8 in the rule preamble)

New Generation Technology	Emission lb CO_2/MWh-g	LCOE* $/MWh
SCPC - no CCS (bit)	1,620	76 - 95
SCPC – no CCS (low rank)	1,740	75 - 94
SCPC + ~16% partial CCS (bit)	1,400	92 - 117
SCPC + ~23% partial CCS (low rank)	1,400	95 - 121
Nuclear (EIA)	0	87 - 115
Nuclear (Lazard)	0	92 - 132
Biomass (EIA)[9]	-	94 – 113
Biomass (Lazard)	-	87 - 116
IGCC	1,430	94 - 120
NGCC	1,000	52 – 86**

The EPA also estimated the increase in capital cost to implement partial CCS to the degree sufficient to meet the final standard of performance. Again, the EPA used information from the updated partial capture report for the bituminous cases and adapted information from the report on use of low rank coal for those cases and assumed that the increases in capital needed for varying levels of partial would follow the same slope for the low rank case as for the bituminous case (see Figure 2 below)[10]. Again, as mentioned earlier, the DOE/NETL has not completed a similar partial capture study for units using low rank coal, but the equipment

[8] LCOE cost estimates for SCPC and IGCC cases come from "Cost and Performance Baseline for Fossil Energy Plants Supplement: Sensitivity to CO_2 Capture Rate in Coal-Fired Power Plants" DOE/NETL-2015/1720 (June 22, 2015). Cost and performance for low rank SCPC is adapted from "Cost and Performance Baseline for Fossil Energy Plants Volume 3 Executive Summary: Low Rank Coal and Natural Gas to Electricity", DOE/NETL-2010/1399 (September 2011). LCOE cost estimates for nuclear and biomass are derived from "Levelized Cost and Levelized Avoid Cost of New Generation Resources in the Annual Energy Outlook 2015", June 2015, www.eia.gov/forecasts/aeo/pdf/electricity_generation.pdf. LCOE cost estimates for NGCC technology are EPA estimates based on a range of potential natural gas prices.

[9] Table 8 includes LCOE figures for biomass-fired generation, a potential sources of dispatchable base load power that is not fueled by natural gas. The EPA includes this information for completeness, while noting that biomass-fired units in operation in the U.S. are smaller scale and thus are not as robust analogues as nuclear power. CO_2 emissions are not provided for biomass units because different biomass feedstocks have different net CO_2 emissions; therefore a single emission rate is not appropriate to show in Table 8.

[10] The cost of the lignite drying equipment is assumed to be low compared to the cost of the carbon capture equipment. Further, pre-drying of the lignite reduces fuel, auxiliary power consumption and other O&M costs. www.iea-coal.org.uk/documents/83436/9095/Techno-economics-of-modern-pre-drying-technologies-for-lignite-fired-power-plants,-CCC/241

and configuration to do so would be the same as the cases evaluated for bituminous-fired units. Energy and water use would be expected to be similar as well since energy and water use are related to taking steam from the process and using it to regenerate the solvent and a similar amount of steam will be utilized regardless of coal type. Therefore, the EPA believes that this assumption is reasonable.

The EPA determined that the increase of capital expense needed to implement partial capture (21% for the bituminous coal case and 23% for the low rank coal case) is reasonable because, as discussed in the final preamble for the rule, these costs are reasonably consistent with capital cost increases in previous NSPS – including those in the power sector.

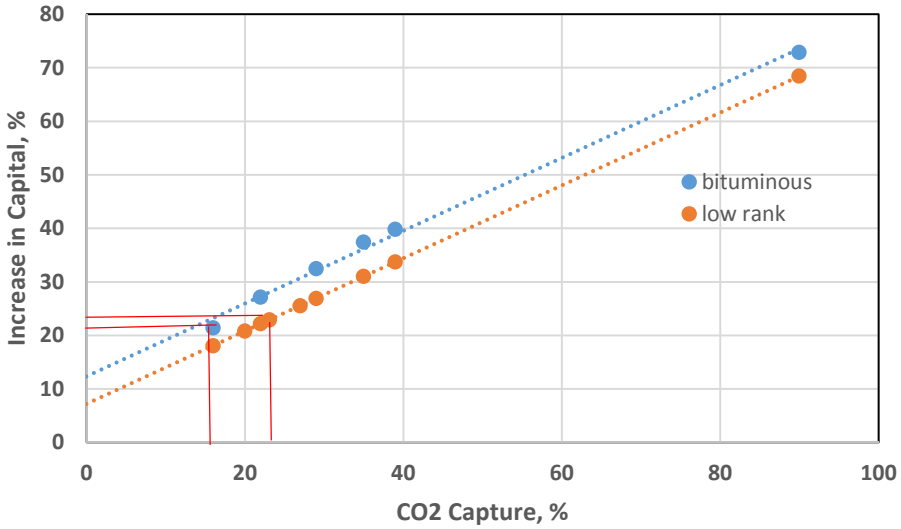

Figure 2. Predicted increase in capital expense with varying levels of CO_2 capture (%) a highly efficient SCPC firing bituminous and low rank coal

Comparison to Emission Rates from Existing EGUs

The DOE/NETL stated that … "Actual average annual emissions from operating plants are likely to be higher than the design emissions rates shown due to start-up, shutdown, part-load operation, and performance degradation through maintenance cycles. Lower design emissions rates to ensure adequate margins may be required for compliance with future regulations; however, given that the slope of the variation of [L]COE with CO_2 emission levels is not steep for either SC PC or IGCC plants (except at low capture rates), designing for this margin does not have major cost implications."[11]

Because the DOE/NETL reports assume design emission rates for highly efficient SCPC units, the EPA compared those rates against the performance of recently built units as a means of assessing the reasonableness of the reports' assumption. The EPA used emissions and output

[11] "Cost and Performance Baseline for Fossil Energy Plants Supplement: Sensitivity to CO_2 Capture Rate in Coal-Fired Power Plants", DOE/NETL-2015/1720 (June 2015) at p. 4.

data from the Clean Air Markets Division (CAMD) Acid Rain Program database and identified Longview Power's Plant (a 700 MW SCPC unit in West Virginia that began operations in 2011) and AEP's John W. Turk Jr. Plant (a 609 MW USCPC unit in Arkansas that began operations in 2012) as the best performing units using bituminous and low rank coal respectively. The results are given in Table 3 below. The best monthly emission rates (i.e., all CO_2 emissions for the month divided by all gross power output for the month) for both facilities are below the design rates used by NETL. The best 12-operating-month averages for both facilities are slightly higher than the NETL design rates (1.9 % higher for Longview Power and 0.9 % higher for AEP Turk) which would result in only slightly higher compliance costs than those provided in Tables 1 and 2 above and would still be within the range of dispatchable, base load generating technologies. The highest 12-operating-month averages for the Longview Power plant is about 11% higher than the NETL design – but the Longview Power plant utilizes different steam conditions than NETL assumes in the cost and performance report. Newly constructed, properly operated and well maintained bituminous-fired plants that do incorporate ultra-supercritical technology would expect to achieve better performance than the Longview Power plant.

In contrast, the AEP Turk's highest 12-operating-month average emission is only 4.6% higher than the NETL design – and AEP Turk does incorporate the ultra-supercritical steam conditions assumed in the NETL reports. Therefore, even over the range of operating conditions for these best performing actual plants, the EPA finds the final standard of performance of 1,400 lb/MWh-g is achievable – and achievable at a reasonable cost.

Table 3. Best performing recently constructed SCPC EGUs

Unit	Coal-type	Best Monthly Rate*	Best 12-Month Avg Rate*	Highest 12-Month Avg Rate*
Longview Power	bituminous	1,578	1,648 (1.9%)	1,801 (11.3%)
John W. Turk Jr.	subbituminous	1,725	1,753 (0.9%)	1,817 (4.6%)

* The rates are given in lb CO2/MWh-g. The range of 12-operating-month average rates are provide – from best (lowest) to the highest rate during the facilities' operation. A comparison to the DOE/NETL design rate is provide in parenthesis.