US EPA ARCHIVE DOCUMENT

Indeck Wharton Energy Center

GHG Permit Application Request for Additional Information

Submitted electronically to US EPA – January 8, 2014, via email to J. Huser

1. In the permit application, the proposed source has been defined as a 650 MW peaking power plant. Indeck has evaluated the emissions potential for two models of simple cycle combustion turbines: Siemens SGT6 5000F and GE Frame 7A. In order to complete the BACT analysis and compare Indeck's proposed limits against recently permitted similar sources, please indicate which GE Frame 7A model was utilized in the calculations provided in the application.

   Response: The GE turbine model is GE Frame 7FA.05.

2. In Figure 2-3 of the application, there is an indication for "evap coolers", but there is no further discussion of how these coolers will be used. Other similar sources have included the use of evaporative coolers on the inlet air for the turbines to increase efficiency. Please include a discussion of whether evaporative coolers will be used on the turbines and their projected impact to efficiency and emissions. If evaporative coolers will not be used, please discuss why they were ruled out for this facility.

   Response: Evaporative coolers are being proposed for the Indeck Wharton Energy Center. These coolers will be of the packing variety with trickling water re-circulated around multiple sections of the evaporative cooler that is located within the air inlet of each combustion turbine. The evaporation of the water effectively cools the incoming air, thus increasing gas turbine output as well as providing a slight improvement in efficiency. It is anticipated that the coolers will be effective at site conditions above 60 deg F. Relative humidity will play a factor, as higher humidity results in less evaporation, and thus less effective inlet air cooling.

   Table 1 shows the effect of the coolers at three ambient temperature points, 60, 80 and 100 degrees F, for both the GE and the Siemens turbines. For informational purposes, Indeck's site weather data shows annual hours above 60 degrees F historically average 5200 hours out of 8760 total.

   The data in Table 1 shows that the turbine gross output (kW) and heat input (MMBtu/hr) both increase with operation of the evaporative coolers. There is also a small increase in the turbine efficiency as shown by the improvement in gross heat rate (Btu/kWhr)

Table 1 – Turbine Performance Impact of Evaporative Cooling

Manufacturer		GE					
Temp	**°F**	60		80		100	
Rel. Humidity	**%**	75.5		76		40.4	
Evap Cooler Status		OFF	ON, 85%	OFF	ON, 85%	OFF	ON, 85%
Gross Output	**kW**	216,026	217,336	207,332	210,306	191,673	205,180
Gross Heat Rate	**Btu/kWh (HHV)**	9,827	9,821	9,982	9,964	10,130	10,014
Heat Input	**MMBtu/hr (HHV)**	2,123	2,134	2,070	2,096	1,941	2,054

Manufacturer		Siemens					
Temp	**°F**	60		80		100	
Rel. Humidity	**%**	75.5		76		40.4	
Evap Cooler Status		OFF	ON, 90%	OFF	ON, 90%	OFF	ON, 90%
Gross Output	**kW**	230,574	232,012	217,247	221,784	199,291	216,452
Gross Heat Rate	**Btu/kWh (HHV)**	10,353	10,233	10,391	10,370	10,526	10,404
Heat Input	**MMBtu/hr (HHV)**	2,387	2,374	2,257	2,300	2,098	2,252

A summary analysis by these temperature/humidity cases showing percent effectiveness is attached.

3. In Appendix B, Indeck relied upon GE and Siemens vendor data and performance spreadsheets to determine the maximum turbine heat rating (HHV), the heat rating for use in the annual calculations, and the gross output value in kW-hr. Please provide the vendor spreadsheets used to determine these values.

Response: Both the GE and Siemens datasheets are attached. Our calculations have assumed gross output. Both manufacturers consider this material to be proprietary and we would appreciate the agency viewing this data as confidential.

4. In order to evaluate Indeck's proposed emission limits, please provide the values (including units) used for each factor in Equation G-4 in Appendix G of 40 CFR Part 75.

Response: Equation G-4 from 40 CFR Part 75 is shown below, with the factors as specified in Section 2.3 of Appendix G:

$$W_{CO_2} = \left(\frac{F_C \times H \times U_f \times MW_{CO_2}}{2000} \right) \qquad (Eq.\ G\text{-}4)$$

Where:

WCO_2 = CO_2 emitted from combustion, tons/hr.

MW CO_2 = Molecular weight of carbon dioxide, 44.0 lb/lb-mole.

F_c = Carbon based F-factor, 1040 scf/mmBtu for natural gas; 1,420 scf/mmBtu for crude, residual, or distillate oil; and calculated according to the procedures in section 3.3.5 of appendix F to this part for other gaseous fuels.

H = Hourly heat input in mmBtu, as calculated using the procedures in section 5 of appendix F of this part.

Uf = 1/385 scf CO2/lb-mole at 14.7 psia and 68 °F.

By eliminating the denominator of 2000 lb/ton, using F_C for natural gas of 1040 scf/MMBtu, and also eliminating H from the equation, the result of the equation is in lb/MMBtu of CO_2, which we will designate as $E_{lb/MMBtu}$:

$E_{lb/MMBtu}$ = (1040 scf CO_2/MMBtu)(1/385 scf CO_2/lb-mole)(44.0 lb CO_2/lb-mole CO_2)

= 118.9 lb/MMBtu

5. Please provide the estimated CO_2 concentration in the flue gas with supporting documentation and the impact of this concentration on the carbon capture process considered in your BACT analysis.

Response: In the GE and Siemens datasheets that were attached for the response to question 3, the CO_2 concentrations in the flue gas are provided. These CO_2 concentration values at full load are up to 3.84% by volume for the GE turbine and up to 3.96% by volume for the Siemens turbine. The BACT analysis considered carbon capture processes based on the information provided in the *Report of the Interagency Task Force on Carbon Capture and Storage, US Department of Energy, 2010* ("*Task Force Report*"). The *Task Force Report* in turn cites the report *Cost and Performance Baseline for Fossil Energy Plants, Volume 1, Bituminous Coal and Natural Gas to Electricity, Revision 2, DOE/NETL 2010-1397, 2010 ("DOE/NETL Volume 1").* DOE/NETL Volume 1 also includes a September 2013 revision. Based on Exhibit 5-17 of *DOE/NETL Volume 1,* at page 478, the flue gas CO_2 concentration used for the natural gas combined cycle (NGCC) CO_2 capture analysis is 4.04% by volume. This value of 4.04% is sufficiently close to the upper end values for the project turbines. Thus, the *Task Force Report* BACT analysis NGCC results adequately reflects the flue gas CO_2 concentration range for both turbines under consideration for this project.

6. In the evaluation of Carbon Capture and Storage (CCS), please provide information for the carbon capture technology evaluated, and the costs associated with that carbon capture system (ie., was an amine- or ammonia-based CO2 capture system scaled for the proposed facility evaluated for efficacy and/or cost?). Please provide a break out of cost including: capture and compression process requirements (including solvent estimates), estimated pipeline/compression design used in the cost analysis, geologic storage costs, opportunities for revenue from the sale of CO2, the estimated number of injection wells, and associated disposal costs.

Response: As discussed in the response to Question 5 above, the BACT analysis is based on the *Task Force Report,* which is in turn cites *DOE/NETL Volume 1.* The *DOE/NETL Volume 1* NGCC cost analysis is based on an amine based CO_2 removal process, specifically the Econamine process. The *DOE/NETL Volume 1* cost analysis was done for a GE advanced F class turbine facility (2 x1) in combined cycle mode with an assumed capacity factor of 85%. While the turbine size is approximately the same as the project, with the combined cycle configuration, the *DOE/NETL Volume 1* NGCC plant will operate more hours and have greater economy of scale for CO_2 removal than the Indeck peaking turbines, which will only operate at maximum load for 2500 hours per year. (Note a 2 x1 combined cycle plant has two gas turbines with one steam turbine.) We have conservatively referenced the *Task Force Report* cost effectiveness value of $114/tonne of CO_2 value (for removal and compression) directly without scaling to the higher values that would be experienced for a peaking facility that will run less hours and produce less CO_2, but would require a similar equipment capital cost.

It is noted that the September 2013 Revision 2a of *DOE/NETL Volume 1* updates certain factors and assumptions, which revises the cost effectiveness value for CO_2 control for the NGCC case (for removal and compression only) from

$114/tonne to $106/tonne. This is based on Exhibit 5-27 on page 499. The value of $106/tone is based on:

$$\frac{(\$108.9/MWh - \$74.7/MWh)}{(804\ lb/MWh - 94\ lb/MWh)} \times (2205\ lb/tonne) = \$106/tonne$$

However, this does not change the conclusion of the BACT analysis that just capture and compression of CO_2 is not cost effective.

Based on *DOE/NETL Volume 1 (page 495),* for a 475 MW 2x1 combined cycle plant, the total plant cost for CO_2 removal is $215,943,000 and for compression and drying is $24,390,000. The initial fill of MEA solvent is estimated at $775,561, and the annual cost of solvent is estimated at $337,908 (page 498). All these costs are included in the overall cost effectiveness of CO_2 control of $106/tonne.

The pipeline costs referenced in the BACT analysis are based on estimated costs for a supercritical fluid pipeline which is designed to meet the requirements of DOT regulations (40 CFR 195).

As noted in our BACT analysis, storage costs have not been specifically estimated. Therefore, details such as potential revenues from the sale of CO_2 or the number of injection wells were not specifically considered. Based on just the costs of capture, compression, and pipeline transport, the CO_2 capture and transport is not cost effective.

7. The evaluation for a CCS system only discussed putting the captured CO_2 into the Denbury pipeline. Has Indeck investigated geologic enhanced oil recovery options, or other possible geologic sequestration options? If so, please provide a detailed breakdown of costs associated with these options.

Response: Indeck has not investigated geological enhanced oil recovery options or other possible geologic sequestration options. Since the Indeck peaking turbines will only operate at maximum load for at most 2500 hours per year, it is very unlikely any third party would consider such an intermittent CO_2 source for enhanced oil recovery. A baseload facility would be a more logical candidate for enhanced oil recovery using captured CO_2, at a point in the future when flue gas CO_2 can be captured cost effectively.

8. In the evaluation of CCS, the application contains information for a 70% (or greater) efficient CCS system. Has Indeck considered or done a cost estimate for a partial capture scenario? Please provide a breakdown of costs, as discussed above in question #6.

Response: Indeck has not considered nor done a cost estimate for partial capture scenarios. As described in the response to question #7 above, application of a CCS system is not a practical option for an intermittent peaking power facility like the proposed Indeck Wharton project. Expanding the analysis to include partial capture scenarios does not improve the adverse economics and would provide less environmental benefit. Therefore, the partial capture scenario has not been evaluated.

9. Please provide an estimate of the overall project construction costs.

[redacted]

Indeck Wharton considers this project cost estimate to be confidential. We would appreciate agency concurrence.

10. Please explain whether the proposed BACT limits for CO_2 emissions from the combustion turbines are based on gross or net output generation. Please identify how much estimated energy output will be consumed by the plant.

As seen in the attached, the estimates prepared to date deal with gross output. That is the value presented by both GE and Siemens in their datasheets. The following summarizes the gross versus net total plant output assuming average annual values

Plant gross output in kw	=	643,322
Plant aux power in kw	=	2,908
Transformer losses in kw	=	3,202
Plant net output in kw	=	637,213

Indeck Wharton, LLC

Evaporative Cooler Analysis

from manufacturer's datasheets

Manufacturer		GE						Siemens					
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Evap Cooler Status		OFF	ON, 85%	OFF	ON, 85%	OFF	ON, 85%	OFF	ON, 90%	OFF	ON, 90%	OFF	ON, 90%
Gross Output	kW	216,026	217,336	207,332	210,306	191,673	205,180	230,574	232,012	217,247	221,784	199,291	216,452
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Cooler efffect per temperature/humidity case

								Average
Gross Output	%kW increase	0.6	1.4	7.0	0.6	2.1	8.6	4.0
Gross Heat Rate	%Btu/kWh decrease	-0.1	-0.2	-1.1	-1.2	-0.2	-1.2	-0.8
Heat Input	%MMBtu/hr increase	0.5	1.3	5.8	-0.5	1.9	7.3	3.2