From: Stephen O'Kane [stephen.okane@AES.com]
Sent: Wednesday, December 19, 2012 12:44 PM
To: 'Chris Perri'
Cc: 'Robert.Mason@CH2M.com'; 'Jerry.Salamy@CH2M.com'; 'McKinsey, John A.'; 'Foster, Melissa A.'; Miller, Felicia@Energy; 'John Yee'
Subject: RE: Heat Rate Tables
Attachments: AES_HBEP_SCAQMD_Revised_Tables_DR7-1_and_DR7-3_12-19-12.pdf

Chris,

As promised, here is the additional information on GHG calculations and heat rates including heat rates with duct burning at the 71o average temperature case. We have revised our December 7, 2012 response to Data Request DR7 to clarify how the heat rates and pounds of CO2 per megawatt-hour were calculated. Attached are revised Tables DR7-1R and DR7-3R.

Revised Table DR7-1R presents the same information included in the December 7th submittal, but includes clarifying notes to show where duct burners are being used during each state of power generation. As I already mentioned, duct burners are being used during turbine start ups to close the electrical production gap when the second and third turbine of each power block is started. AES would not operate all three turbines per power block with duct burners firing (nor is this thermally feasible due to the physical rating of the steam turbines). In addition to denoting duct burner usage, we have included a note on the 1 power block table that explains that the states represent the number of turbines in operation (State 1 is a 1 on 1 configuration, State 2 is a 2 on 1 configuration, etc.).

Revised Table DR7-3R includes additional notes explaining how the weighted annual average heat rate (with starts and stops but no degradation) and the CO2 efficiency were calculated. Briefly, we calculated the weighted annual average heat rate by multiplying the average heat rate (including duct burner operation) for each State by the number of hours for that State plus the start up and shutdown heat rates (again multiplied by the number of assumed operating hours for each). This product was divided by the total number of operating hours. The average heat rate of each State was used to represent a realistic heat rate for each State. It is unlikely that HBEP will be called on to operate a significant number of hours at a 70% turbine load rate. Likewise, since the duct burners are not intended to be used as peaking capacity, AES does not expect to operate in the duct fired mode for a significant number of hours. Therefore, the average heat rate for each State was used as a conservative assumption to approximate how HBEP is expected to operate. Below is the annual average heat rate calculation:

(State 1 - 250 hrs * 7564 btu/kWh + State 2 - 3200 hrs * 7353 btu/kWh + State 3 - 1460 hrs * 7350 btu/kWh + Start Up - 93.6 hrs * 18267 btu/kWh + Stop - 98.8 hrs * 16520 btu/kWh)/(4910 hrs + 93.6 hrs + 98.8 hrs) = 7740 btu/kWh Gross

The CO2 efficiency was calculated by assuming an 8% degradation on the plant gross heat rate (7740 btu/kWh gross / (1 – 0.08)) = 8413 btu/kWh gross) and using the natural gas CO2 emission factor of 53.02 kg CO2/MMBtu-HHV. Below is the calculation:

(8413 btu/kWh * 1000 kWh/MWh * 1.1 HHV/LHV * 1*10-6 MMBtu/Btu * 53.02 kg CO2/MMBtu-HHV * 2.205 lb/kg = 1082 lb CO2/MMWH)

Stephen

From: Stephen O'Kane
Sent: Wednesday, December 19, 2012 11:36 AM
To: Chris Perri
Cc: Robert.Mason@CH2M.com; 'Jerry.Salamy@CH2M.com'; McKinsey, John A.; Foster, Melissa A.; Miller, Felicia@Energy; John Yee
Subject: RE: Heat Rate Tables

Chris,

Here are some more heat rate data for various temperature and operating cases, including a summer temperature one-on-one duct firing case and a two-on-one duct firing case. We will also send over our assumptions and calculation method for calculating annual average CO2/MWh, which includes the contribution of duct firing under the assumed annual operating condition. As discussed, there are different assumptions that go into the different calculations for annual PM2.5 emissions; maximum month daily emissions; and predicted CO2/MWhr emissions. In each case we have made conservative assumptions to calculate the different regulatory requirements. One of the biggest differences our CCGT application will have compared to traditional supplemental fired CCGTs is how the duct burners are employed. The duct burners in our case are for ramp speed and not for power augmentation. It is not expected that the units would be parked at part load with duct firing and in the 3-on-1 case; we are physically constrained by the steam cycle and cannot duct fire with the three turbines at max load.

I hope this information helps. Additional information on our GHG calculations will follow shortly.

Stephen O'Kane

From: Chris Perri [mailto:CPerri@aqmd.gov]
Sent: Tuesday, December 18, 2012 2:29 PM
To: Stephen O'Kane
Cc: Robert.Mason@CH2M.com; 'Jerry.Salamy@CH2M.com'; McKinsey, John A.; Foster, Melissa A.; Miller, Felicia@Energy; John Yee
Subject: Heat Rate Tables

Stephen,

I'm just now trying to complete my heat rate tables for the 2 on 1 and 1 on 1 cases. I'm using the information you provided in a previous email, however, I'm not coming up with the same heat rates. For the 2 on 1 case, I've tried to break it down on a per turbine basis (I also assumed that the net output is 96.6% of the gross output). For both cases, I assumed that HHV/LHV = 1.13. Could you look at these tables and tell me if I've misinterpreted the data you provided? Thanks.

2-on-1 Operation

	85 F – 46% RH (Evaporative Cooling On)	66 F – 58% RH (Evaporative Cooling On)
Gas Turbine Heat Input, mmbtu/h HHV	1,354	1,403
Total Heat Input, mmbtu/h HHV (w/duct fire)	1,861	1,910
Gas Turbine Gross Output, kW	115,962	121,840
Steam Turbine Gross Output, kW	49,751	51,320
Total Gross Power Output, kW	165,713	173,160
Net Power Output, Kw	160,078	167,273
Net Plant Heat Rate, btu/kWh, LHV	10,288	10,104
Net Plant Heat Rate, btu/kWh, HHV	11,626	11,418

1-on-1 Operation

	85 F – 46% RH (Evaporative Cooling On)	66 F – 58% RH (Evaporative Cooling On)
Gas Turbine Heat Input, mmbtu/h HHV	1,354	1,403
Total Heat Input, mmbtu/h HHV (w/duct fire)	1,861	1,910

Gas Turbine Gross Output, kW	115,962	121,840
Steam Turbine Gross Output, kW	49,382	47,192
Total Gross Power Output, kW	171,222	163,152
Net Power Output, Kw	163,611	155,661
Net Plant Heat Rate, btu/kWh, LHV	10,066	10,858
Net Plant Heat Rate, btu/kWh, HHV	11,375	12,270

From: Stephen O'Kane [mailto:stephen.okane@AES.com]
Sent: Thursday, October 25, 2012 4:40 PM
To: Chris Perri
Cc: Robert.Mason@CH2M.com; 'Jerry.Salamy@CH2M.com'; McKinsey, John A.; Foster, Melissa A.; Miller, Felicia@Energy
Subject: RE: HBEP emission rates and modeling results

Chris,

Here's the data I can provide. If you really need the additional performance data at the other temperatures I will have to get our consultants to run some additional heat balance models. Please let me know as this is an extra expenditure and additional time to execute.

With these two temperature cases you can see the performance of the CCGT in both 1-on-1 and 2-on-1 modes. Additional data would merely show the same relative difference compared to the 3-on-1 case for different operating temperatures and humidities. Note the highlighted numbers. Our CCGT design actually provides the best performance on a heat rate basis (and consequently CO2e per MW) in the 2-on-1 case. Which is a big part of the design objective. Instead of the normal heat rate curve of a CCGT that deteriorates as output or load is decreased, this design will maintain a very constant heat rate across a wide range of output, and be able to ramp up and down output very quickly. Thus we achieve approximately 800-1,000 BTU/kwh better heat rate than a simple cycle LMS 100 and still provide the fast ramp and quick start support.

	32 F – 87% RH (Evaporative Cooling Off, Case 2)	ISO 59 F-60% RH (Evaporative Cooling Off)	66 F – 58% RH (Evaporative Cooling On, Case 7)	85 F - 45.75% RH (Evaporative Cooling On)	110 F-8% RH (Evaporative Cooling On, Case 12)
Gas Turbine Heat Input, mmbtu/h HHV[1]	1,498	1,388	1,403	1,354	1,350
Total Heat Input, mmbtu/h HHV (w/duct fire)[2]	2,005	1,895	1,910	1,861	1,857
Gas Turbine Gross Output, kW[3]	132,256	121,435	121,840	115,962	115,264
Steam Turbine Gross Output, kW[3]	49,579	51,865	50,192	48,523	43,632
Total Gross Power Output, kW[3]	181,835	173,300	172,032	164,485	158,896
Total Net Power Output, Kw[3]	175,925	167,583	166,328	158,901	153,352
Net Plant Heat Rate, btu/kWh, LHV	7,558	7,354	7,487	7,508	7,814
Net Plant Heat Rate, btu/kWh, HHV	8,516	8,285	8,435	8,459	8,803
Steam Turbine Gross Output, kW (2-on-1)			102,640	99,501	
Total Gross Power Output, kW (2-on-1)			346,320	331,425	
Total Net Power Output, Kw (2-on-1)			334,035	319,363	
Net Plant Heat Rate, btu/kWh, LHV (2-on-1)			7,337	7,408	
Net Plant Heat Rate, btu/kWh, HHV (2-on-1)			8,400	8,483	
Steam Turbine Gross Output, kW (1-on-1)			49,382	47,192	

Total Gross Power Output, kW (1-on-1)			171,222	163,154	
Total Net Power Output, Kw (1-on-1)			163,611	155,661	
Net Plant Heat Rate, btu/kWh, LHV (1-on-1)			7,489	7,600	
Net Plant Heat Rate, btu/kWh, HHV (1-on-1)			8,575	8,702	

Notes:
1. Cases 110F, 32F and 66F heat input taken directly from M501DA Gas Turbine Expected Performance and Emissions Provided by MPSA a included in Table 5.1B.2 of *HBEP_Appendix 5.1B_Ops Emissions Calcs.pdf.* ISO 59F Case Heat input taken from GT PRO model.

2. Total Heat Input per gas turbine with duct firing can only be achieved while operating in a 1-on-1 or 2-on-1 mode. The steam cycle is sized the maximum heat input into the steam cycle is reached in a 3-on-1 mode without duct firing.

3. All output is provided on a per turbine basis assuming a 3-on-1 operating mode. To calculate total output for the entire power block these va must be multiplied by 3

Stephen

Table DR7-3R HBEP Calculate Annual Average CO2 (lb/MWh)

Annual Average - Assume all hours for each State are at the average heat rate for that State

Start Up and Stop Heat Rate Calculations

624	startups / yr	
9	min / startup	
93.6	hours startup / year	
18267	Btu/ gross kWh	Effective Heat Rate during Turbine Start
624	stops / yr	
9.5	min / stop	
98.8	hours stops / year	
16520	Btu/kWh Gross	Effective Heat Rate during Turbine Stops

Plant CO2 Efficiency Calculation

7740	Btu LHV / kWh Gross	Weighted Annual Average Heat Rate with SU/SD and no Degradation. (250 hrs * 7564 Btu/kWh + 3200 hrs * 7353 btu/kWh + 1460 hrs * 7350 btu/kWh + 18267 btu/kWh * 93.6 hrs + 16520 btu/kWh * 98.8 hrs)/(4910 hrs + 93.6 hrs + 98.8 hrs)
8%	Assumed Plant Degradation	
8413	Btu LHV / kWh Gross	Annual Average CO2 Efficiency with SU/SD and Degradation (7740 btu/kWh / (1 - 0.08))
1082	lb CO2 /MWh Gross	Annual Average CO2 Efficiency with SU/SD and Degradation (8413 btu/kWh * 1000 kWh/MWh * 1.1 HHV/LHV * 1*10^{-6} MMBtu/Btu * 53.02 kg CO2/MMBtu-HHV * 2.205 lb/kg)

Table DR7-1R HBEP Heat Rate Estimate

HBEP Expected Annual Average Operating Profile at an Ambient Air Temperature of 71 F[1]																	Expected Annual Hours
Blocks 1 and 2	**Hours/year**		250			DB[3]		3200			DB			1460			4910
Net Plant Power	**kW**	233954	261500	288570	322300	407140	482162	537404	591440	658918	735826	726498	735836	807312	886132	984530	
Estimated Gross Heat Rate, LHV[2]	**Btu/kW-hr**	7730	7562	7439	7351	7740	7501	7359	7259	7191	7453	7467	7451	7348	7267	7217	
		State 1					State 2					State 3					
		Average Kw 302693			Average State 1	7564	Average Kw 601150			Average State 2	7353	Average Kw	828062		Average State 3		7350

HBEP Performance for 1 Power Block[4]						DB					DB					
Net Plant Power	**kW**	116977	130750	144285	161150	203570	241081	268702	295720	329459	367913	363249	367918	403656	443066	492265
Net Heat Rate, LHV[2]	**Btu/kW-hr**	7969	7796	7669	7578	7979	7733	7587	7484	7413	7683	7698	7681	7575	7492	7440
Estimated Gross Heat Rate, LHV	**Btu/kW-hr**	7730	7562	7439	7351	7740	7501	7359	7259	7191	7453	7467	7451	7348	7267	7217

1. Operating data from TFLINX 71F Part Load Curve.xls.
2. Station loads ranging from 3.3 to 5.7% and selecting a conservatively low load results in a conservatively high gross heat rate, for estimating annual average CO_2. Therefore, a 3% station load was selected to convert the gross heat rates to net heat rates.
3. DB = Duct firing.
4. State 1 represents a 1 on 1 configuration, State 2 represents a 2 on 1 configuration, and State 3 represents a 3 on 1 configuration.

Conservative average station load 3%