Anaergia Hilton CHP M&V Verification – November 26, 2013

The Anaergia CHP plant installed at the New York Hilton Midtown consists of seven 250-kW SDP Energy reciprocating engine generators. Each generator has a dedicated Cain HRSG to capture the energy from the exhaust gas and produce 15-psig low pressure steam. Steam is used to offset purchased steam from Con Ed. Engine jacket and lube oil heat are recovered from all seven engines to a common glycol loop, which is then used to heat service hot water (SHW) for the kitchen and laundry facilities.

The nominal rating of the CHP system, based on the SDPM250EV12MS4 specifications are displayed in Table 1. The combined system is rated to deliver up to 1,750 kW gross electrical output, with 5,971 MBtu/h of jacket water heat recovery and 2,771 MBtu/h of exhaust heat recovery. The system has an electrical FCE of 34.1% LHV and a CHP FCE of 83.9% LHV, using the NYSERDA value of 927 Btu/CF[1]. Using the HHV rating, the CHP FCE is 75.5%.

Table 1. SDP SDPM250EV12MS4 Ratings

		SDP Ratings	
		1 Unit	**7 Units**
Electric (Gross)	**kW**	250	1,750
Fuel	**CFH**	2,703	18,921
	MBtu/h LHV	2,506	17,540
	MBtu/h HHV	2,784	19,489
Electric FCE	**% LHV**	34.1%	34.1%
	% HHV	30.6%	30.6%
Jacket Water	**MBtu/h**	853.0	5,971
(used)	**MBtu/h**	n/a	n/a
(dumped)	**MBtu/h**	n/a	n/a
Exhaust/Steam	**MBtu/h**	395.8	2,771
Total Thermal	**MBtu/h**	1,248.8	8,741.5
CHP FCE	**% LHV**	83.9%	83.9%
	% HHV	75.5%	75.5%

CDH Energy was on-site on November 26, 2013 to field verify the M&V measurements used to quantify system performance. M&V measurements are being provided directly from the plant control system (PCS), installed as part of the system installation.

[1] By program definition, LHV = 0.9 × HHV = 0.9 × 1,030 Btu/CF HHV = 927 Btu/CF

Power Measurements

The system uses four power transducers to measure the gross output of the generators. The seven generators are disturbed across four separate electrical services to maximize the electrical generation potential.

Individual power measurements were made on each generator disconnect using a Fluke 39 handheld power meter. These readings were compared to the reading from the CHP system meters installed on the collector buss for each group of generators.

Generator #1 & #2 Disconnects

Generator #3, #4, & #5 Disconnects (Middle)
Generator #6 Disconnect (Right Top)
Generator #7 Disconnect (Right Middle)

Figure 1. CHP Generator Disconnects and Associated Power Transducers

Table 2. Manual Power Readings – CHP Units

Data Point	Measurement	Fluke 39 (kW)	Sum of Fluke 39 Measurements (kW)	SATEC Power Transducer (kW)	PCS Data File (Nov 26, 2013 1:00 PM) (kW)
WG12	Generator 1	OFF	202	199.1	199.4
	Generator 2	202			
WG345	Generator 3	251	751	650.2	650.8
	Generator 4	251			
	Generator 5	249			
WG6	Generator 6	252	252	250.2	249.8
WG7	Generator 7	252	252	250.1	249.8

The sum of the individual generator measurements was compared to the corresponding measurement by the M&V power transducers. The measurement for Generators 3, 4, & 5 (WG345) was found to be low by 100 kW or 13%. The cause for this low power measurement could not be determined, and a technician from SATEC has been scheduled to determine corrective measures.

Assuming the error in the WG345 power measurement is proportional to the actual produced power, then the system may be under-reporting the power generation by as much as 6%.

Other than this issue with WG345, the engine power transducers appear to be reporting correctly.

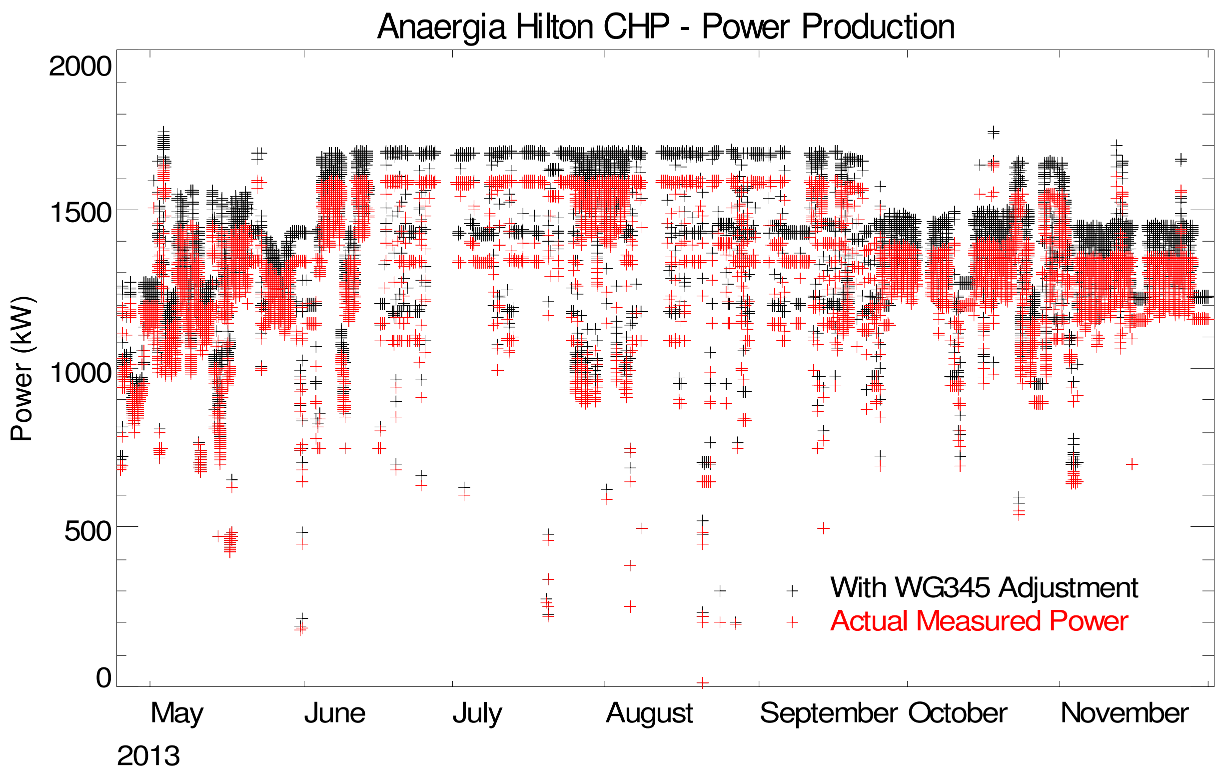


Figure 2. CHP Gross Generation Historic Data

Two additional power transducers are used to measure the parasitic consumption of the plant. The PPH panel power transducer (WPAR1) is located at the CHP skid on the fourth floor setback roof location, and an additional power transducer for the load side heat recovery circulation pumps (WPAR2) are located in the basement. The WPAR1 transducer was verified with the Fluke 39. Accessing the leads for the WPAR2 meter was not practical.

Table 3. Manual Power Readings – Parasitic Loads

Data Point	Measurement	Fluke 39 (kW)	ION 6200 Power Transducer (kW)	PCS Data File (Nov 26, 2013 1:00 PM) (kW)
WPAR1	PPH	62	63.5	16.0
WPAR2	MP-1	n/a	6.4	8.0

Parasitic Panel PPH Meter – WPAR1

Parasitic Panel MP-1 Meter – WPAR2

Figure 3. Parasitic Power Transducers

Examination of the one-time readings and historic data for the WPAR1 and WPAR2 meters indicate issues with the parasitic measurement. The manual power reading and the display on the ION 6200 indicate that WPAR1 is reading properly, but the data file indicates differently.

The data for both WPAR1 and WPAR2 are integer values for every data record. The WPAR1 readings range from 0 to 23, which imply the data may be in energy units (kWh/interval). The WPAR1 value of 16 at the coincident time of manual power readings would correspond to 64 kW if the reading is in kWh/interval[2].

Historic data for WPAR1 indicate that the data collected represents actual system operation, even if the magnitude of the data is questionable. The data for WPAR1 increases linearly with increasing heat rejection at the dumped radiator. The baseload power of 40 kW with zero heat rejection is reasonable given the installed pump horsepower on the skid (seven 10-HP pumps with VSDs, two 10-HP constant speed pumps). The dry-cooler dump radiator has a 10 fans with a total FLA of 35 amps at 460 VAC, resulting in an estimated 25 kW of variable fan power.

[2] 16 kWh / 15 minutes × 60 minutes / hour = 16 × 60 ÷ 15 = 64 kWh/h

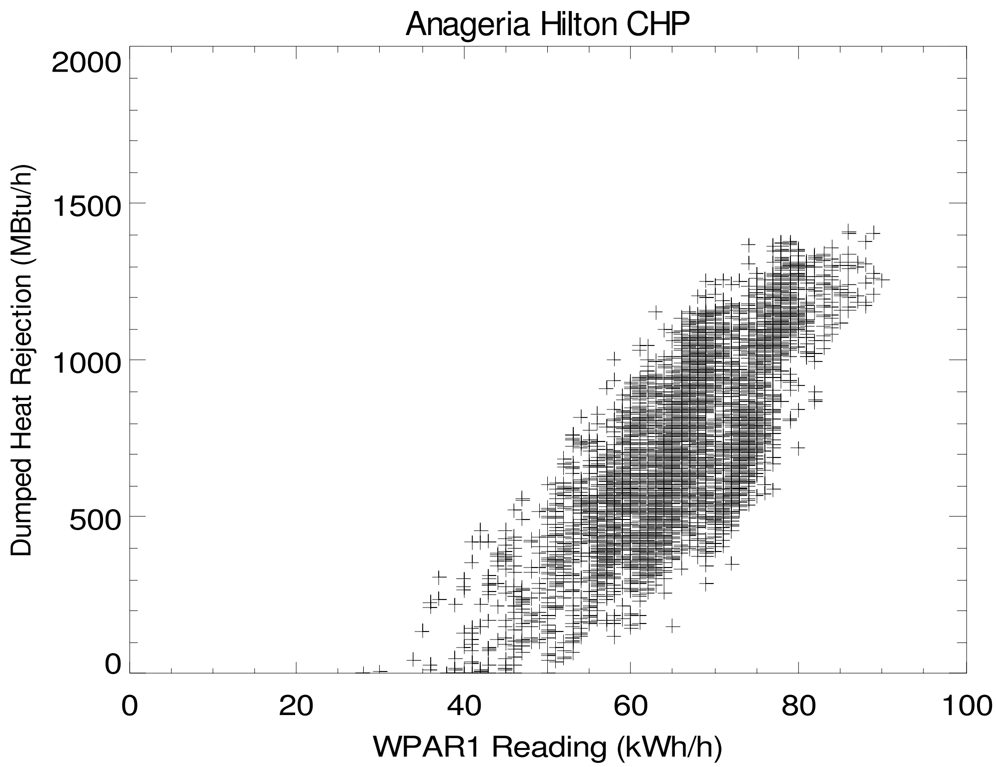


Figure 4. PPH (WPAR1) Parasitic Power Data Variation with Heat Rejection

Historic data from the WPAR2 meter does not agree with the size of connected loads on MP-1 or the observation of power displayed on the meter face, even if the data are expressed as energy units per interval. The data has indicated three distinct values of 8, 16, and 24, which if were expressed as kWh/interval values would correspond to 32, 64, and 96 kW. Based on the connected load schedule of 6-HP on MP-1 (two circulating pumps at 2-HP each, and two feedwater pumps at 1-HP each), the maximum power on this panel should be 4.4 kW.

Again, the pattern in the power data indicates that the measured data is indicative of an actual measured load, but the magnitude of the data is questionable. The pattern in the shade plot of the power data for WPAR2 indicates that operation increases around 8:00 AM, and remains consistent through 2:00 PM, then scattered operation of the pumps occurs. Pump operation increases during the early spring and late fall/early winter periods as more condensate pump occurs during these periods.

Overall the pattern in the data indicates a 33% duty cycle for the pumps on this panel.

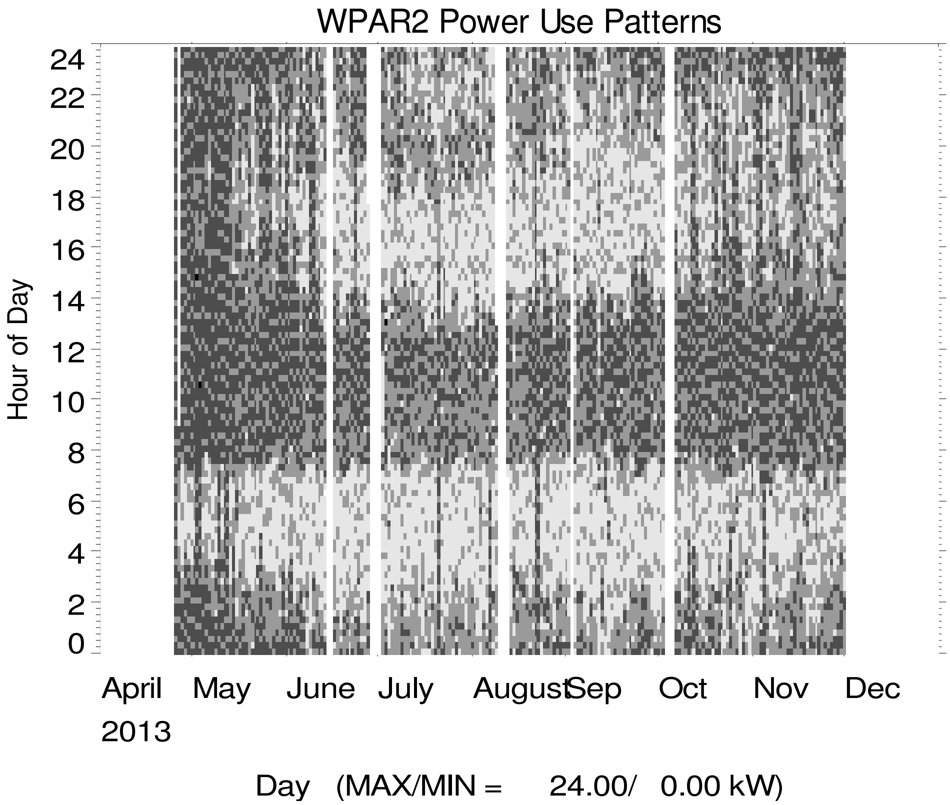


Figure 5. MP-1 (WPAR2) Parasitic Power Data

Temperature Measurements

Temperature measurements for the glycol loop are measured by three sensors, one supply sensor leaving the CHP skid (TLS), one returning from the useful HW loads (TLR1), and one downstream of the dump radiator (TLR2). The M&V plan had specified measuring all three temperatures on the CHP header, but final inspection of the system indicated that the TLS sensor was installed on a branch leg off the CHP secondary loop (Figure 6). While this location is sub-optimal, it does capture the same temperature as the location on the header, since there are no other heat sources or sinks between the two location.

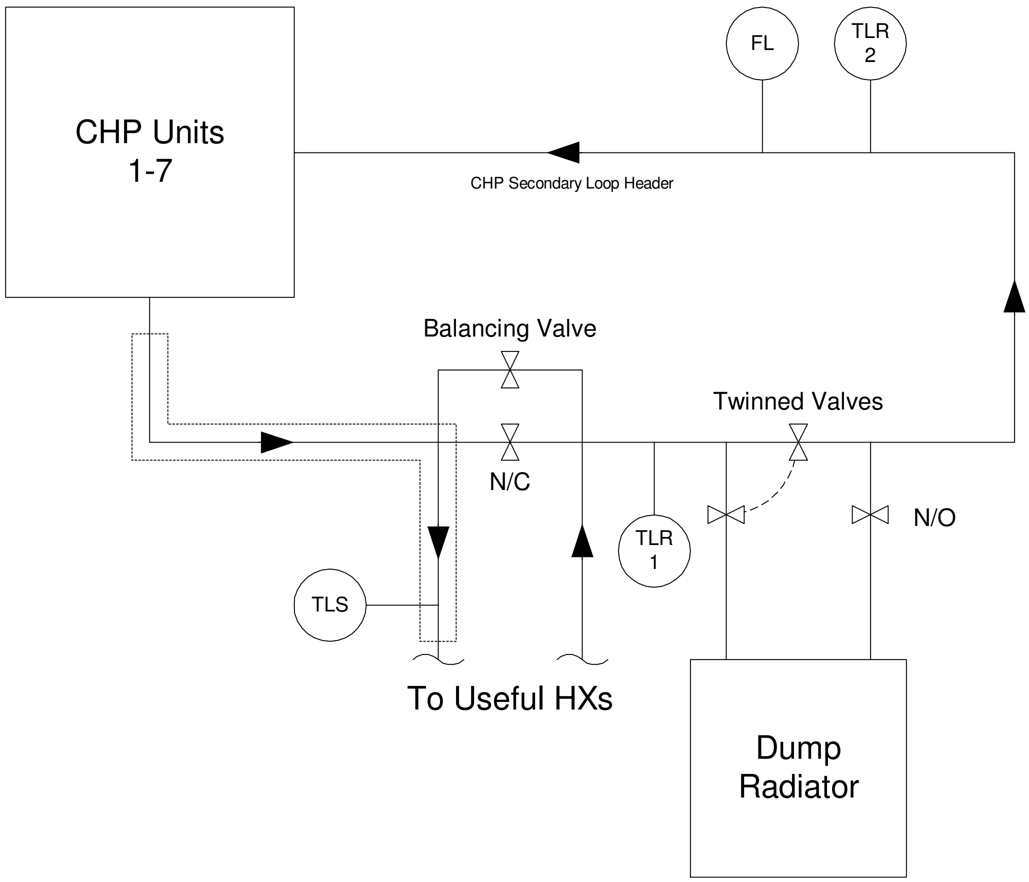


Figure 6. Simplified CHP Glycol Loop Diagram – TLS thermal node location shown as dashed line

Loop temperatures were verified using a Fluke 51-2 handheld thermometer, with a reading taken on the surface of the steel pipe, under the insulation. Where possible, a reference measurement was performed using the thermometer gauges installed entering and leaving each engine generator (supply and return temperatures only).

Table 4. Temperature Verifications

Data Point	Fluke TC (deg F)	PCS (deg F)	Loop Thermometer (deg F)
TLS	171.1	173	168 - 172
TLR1	137.9	142	n/a
TLR2	126.9	133.8	128 - 130

No substantial deviation was observed in the PCS temperature measurements based on the manual readings. The surface measurements were typically a few degrees cooler than the PCS measurements, which are located in thermowells directly in the flow stream.

CHP Supply Temperature - TLS

CHP Supply Return from Dump HX Temperature and Loop Flow – TLR2 & FL

CHP Return Temperature From Useful HXs – TLR1

Figure 7. CHP Loop Temperature Sensors

Examination of the historic temperature data displays an unusual pattern in the temperature difference between TLS and TLR1. As thermal load decreases, the temperature difference between these two sensors should decrease to zero. After June 24, 2013 there is a constant 12°F increase in the temperature difference between the two sensors (Figure 8).

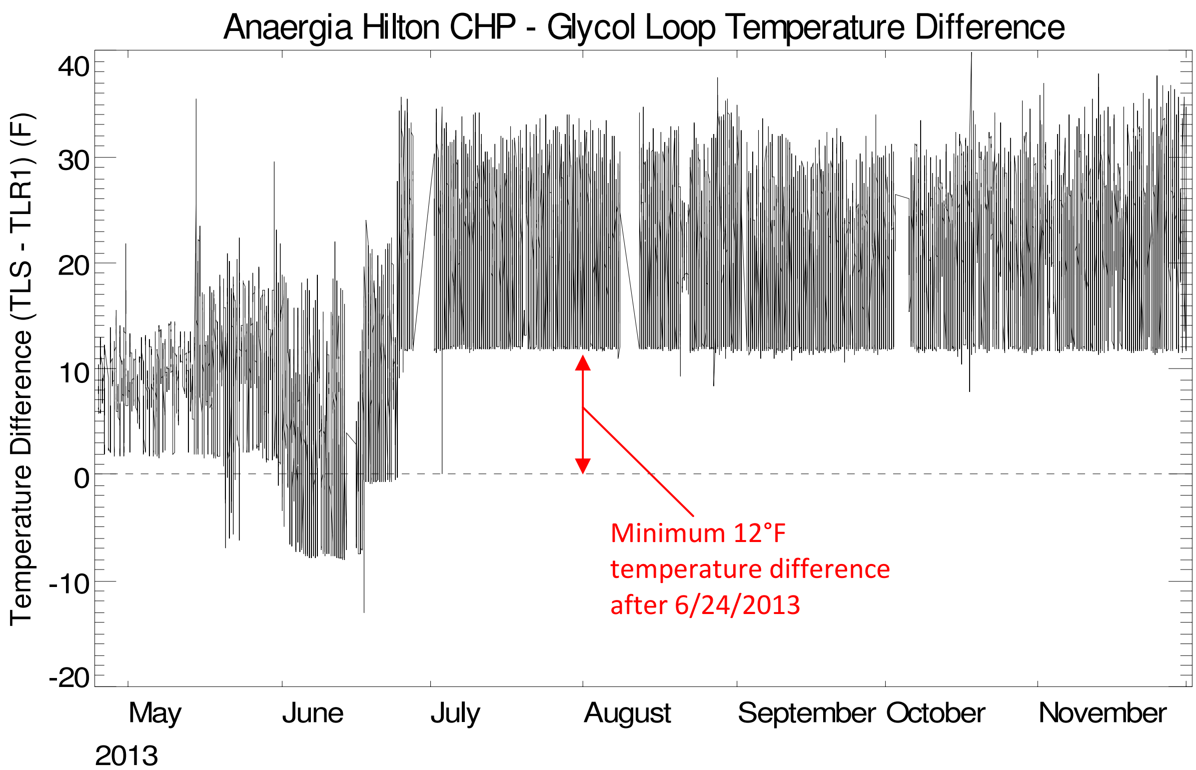


Figure 8. TLS – TLR1 Offset Observed After 6/24/2013

Plotting TLS and TLR1 against each other reveals that this deviation occurs at all temperatures, and during cool-down events, the two temperatures never converge (Figure 9). This implies that a constant offset is applied to either the TLS or TLR1 sensor.

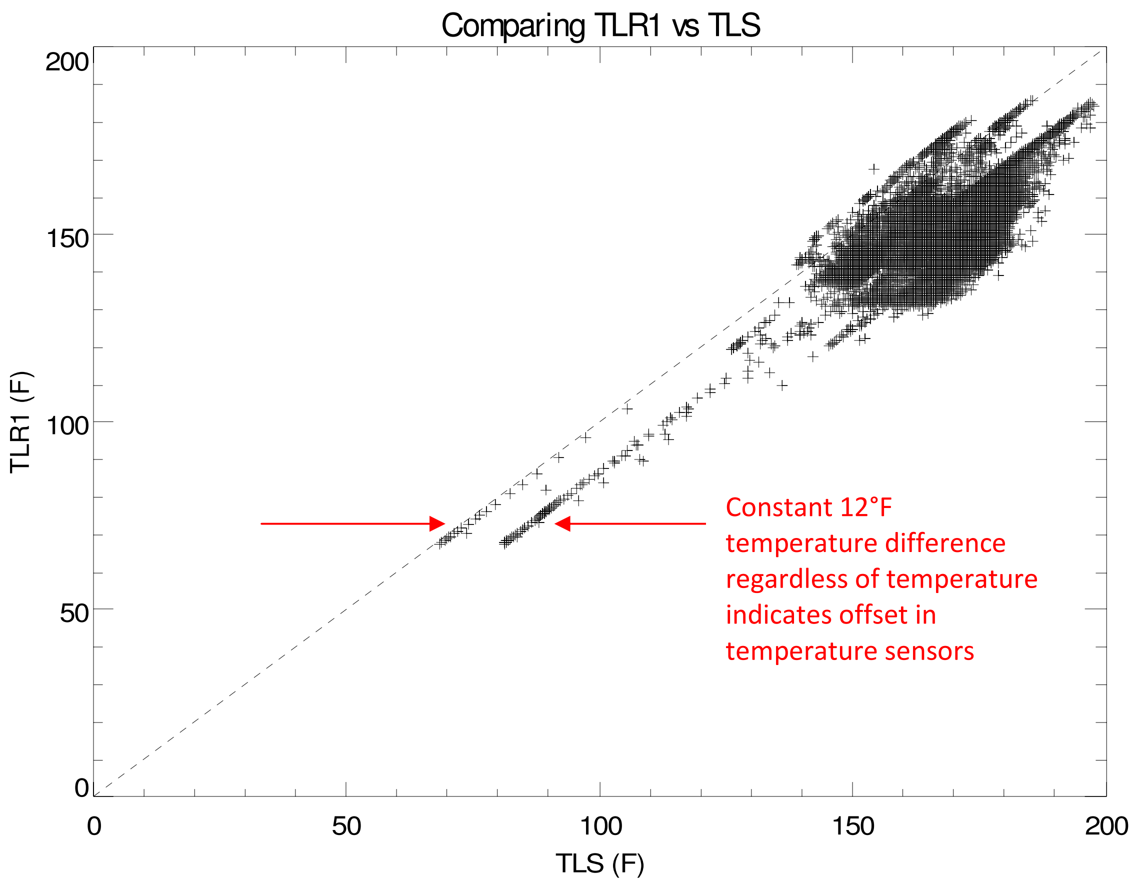


Figure 9. TLS – TLR1 Offset Observed After 6/24/2013

This issue is not observed when TLR1 and TLR2 are plotted against each other (Figure 10). These two temperature trend together during cool-down events, implying that the issue is with the TLS sensor, or the curve fit used in the PCS to convert the sensor output to engineering units.

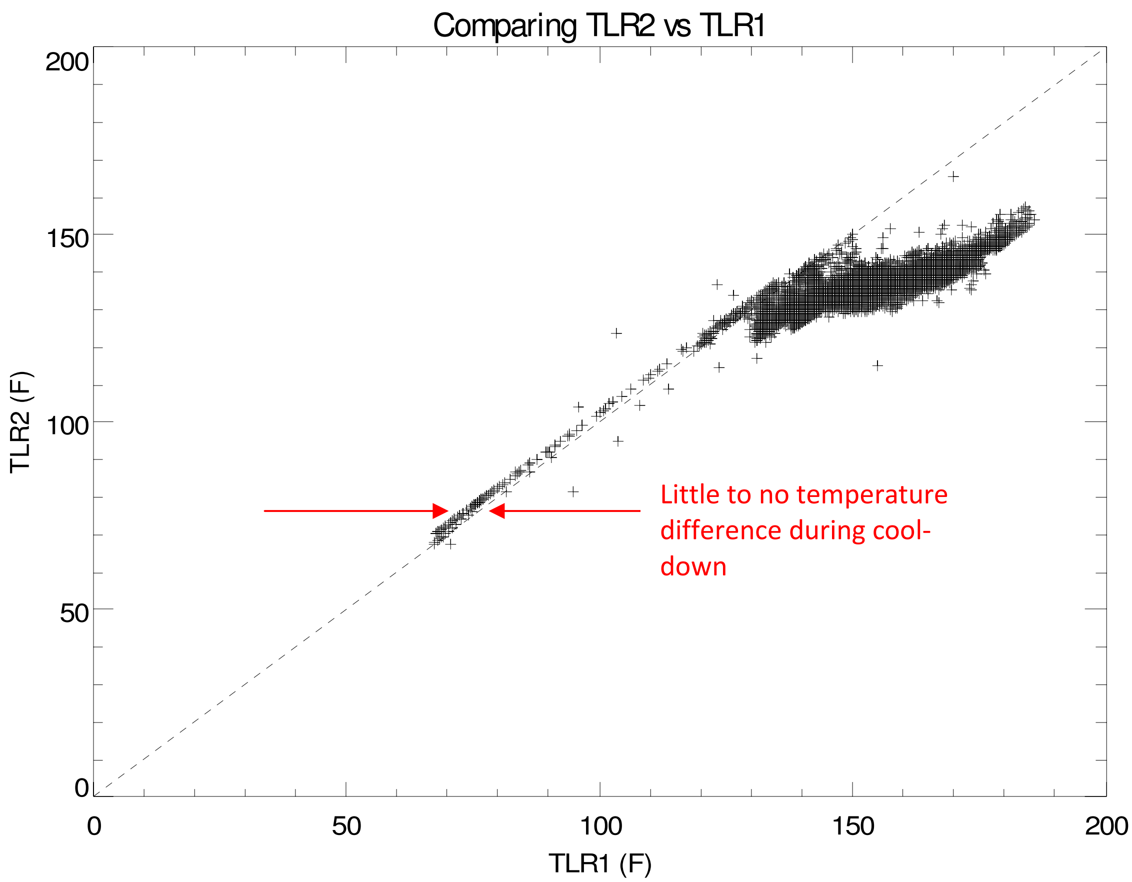


Figure 10. TLR1 – TLR2 Comparison

A 12°F offset in the temperatures used for useful heat recovery would result in overstating the hot water heat recovery by 2,000 MBtu/h.

Flow Measurements

CHP loop flow measurements are provided by a fixed paddlewheel meter installed in the vertical return leg of the CHP secondary header. An independent measurement of the flow for the CHP system was attempted using an ultrasonic flow meter, but the pipe size was too large for the transducer head. The flow output observed at the meter head of 359 GPM matched the reading at the PCS. CDH will return at a future date with a transducer that will work with the 10-inch pipe diameter, but until then, the flow is assumed to be accurate.

CHP Loop Flowmeter - FL *CHP Loop Flowmeter – Reading 359 GPM*

Figure 11. CHP Loop Flow Sensors

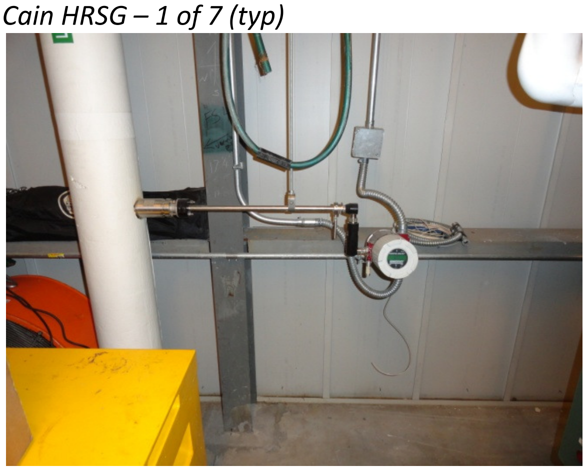
Table 5. Glycol Verifications

Data Point	Measurement	Meter Obs. (gpm)	PCS Data File (Nov 26, 2013 11:00 AM) (gpm)
FL	Glycol Flow	359	361.0

Steam flow is measured at the collection header for all seven HRSGs. Since the system uses a circulated deaerator, it is impossible to perform a single ultrasonic measurement to capture the entire feewater rate. At the historic observed steam production rates of 400 PPH – 1,500 PPH feedwater to all seven HRSGs combined would range from 0.8 GPM to 3.0 GPM. For an individual HRSG, that feedwater flow would range from 0.1 GPM to 0.4 GPM – typically too small to measure.

The HRSGs were observed to operate at 13.5 PSIG (1163.06 Btu/lb h_{fg}), and not 15 PSIG (1164.08 Btu/lb h_{fg}) , resulting in a slight change to the steam enthalpy used to calculate the heat content of the steam produced.

Cain HRSG – 1 of 7 (typ)



Steam Mass Flowmeter - FS

Cain HRSG Setpoint 13.5 PSIG (typ)

Steam Flow Reading – 369 PPH

Figure 12. CHP HRSG and Steam Meter

Table 6. Steam Verifications

Data Point	Measurement	Meter Obs. (PPH)	PCS Data File (Nov 26, 2013 10:15 AM) (PPH)
FS	Steam Flow	369	371.0

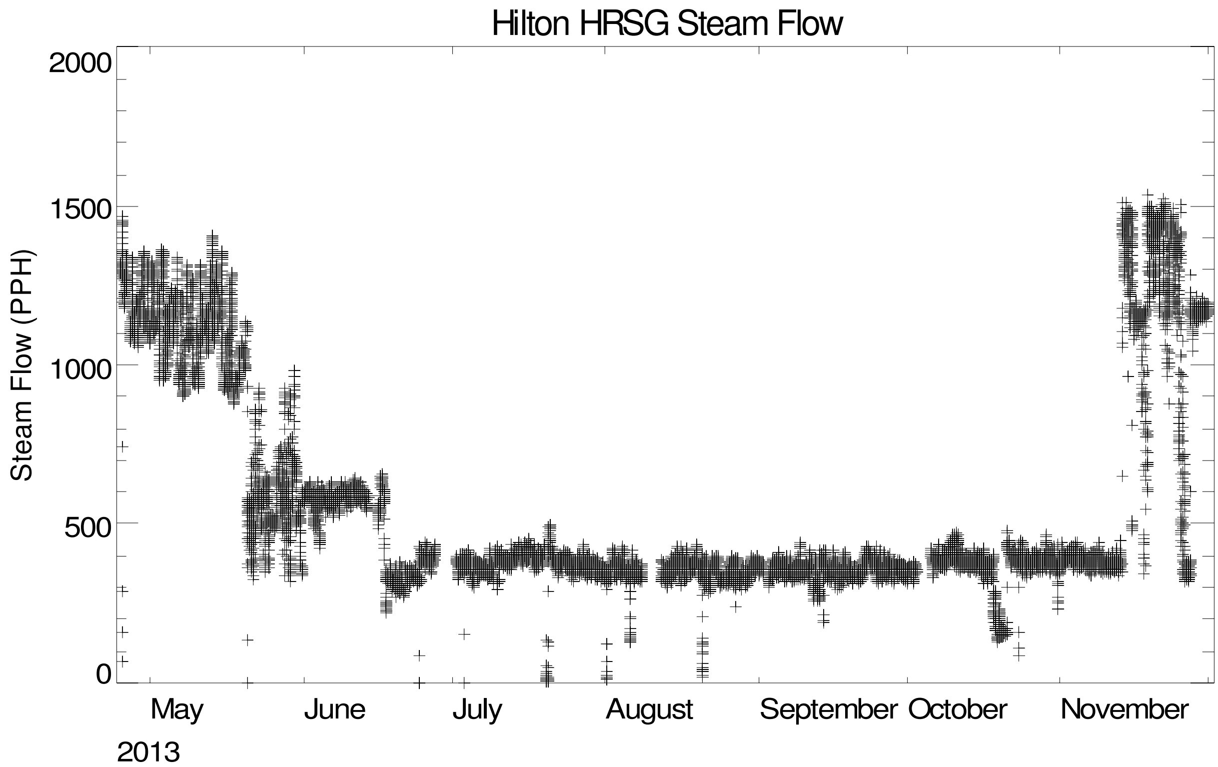


Figure 13. CHP HRSG Steam Production History

The overall system energy balance will be used to validate the steam volume.

Gas Measurements

Gas is measured using a pulse output from the utility meter, at a constant of 1000 CF/pulse. A spot check of the recorded data compared to the DP gas meter at the skid was performed. The instantaneous reading from the DP meter and the utility meter are in agreement.

Table 7. Gas Verifications

Data Point	Measurement	DP Meter Obs. (CFH)	PCS Data File - Utility Pulse Output (Nov 26, 2013 1:15 PM) (CFH)
FG	Gas flow	15886	16000.0

Figure 14. DP Gas Meter at CHP Skid (Not used for M&V)

Comparing CHP gross power production to fuel input indicates that the gas readings are reasonable, with a very linear relation between the two measurements.

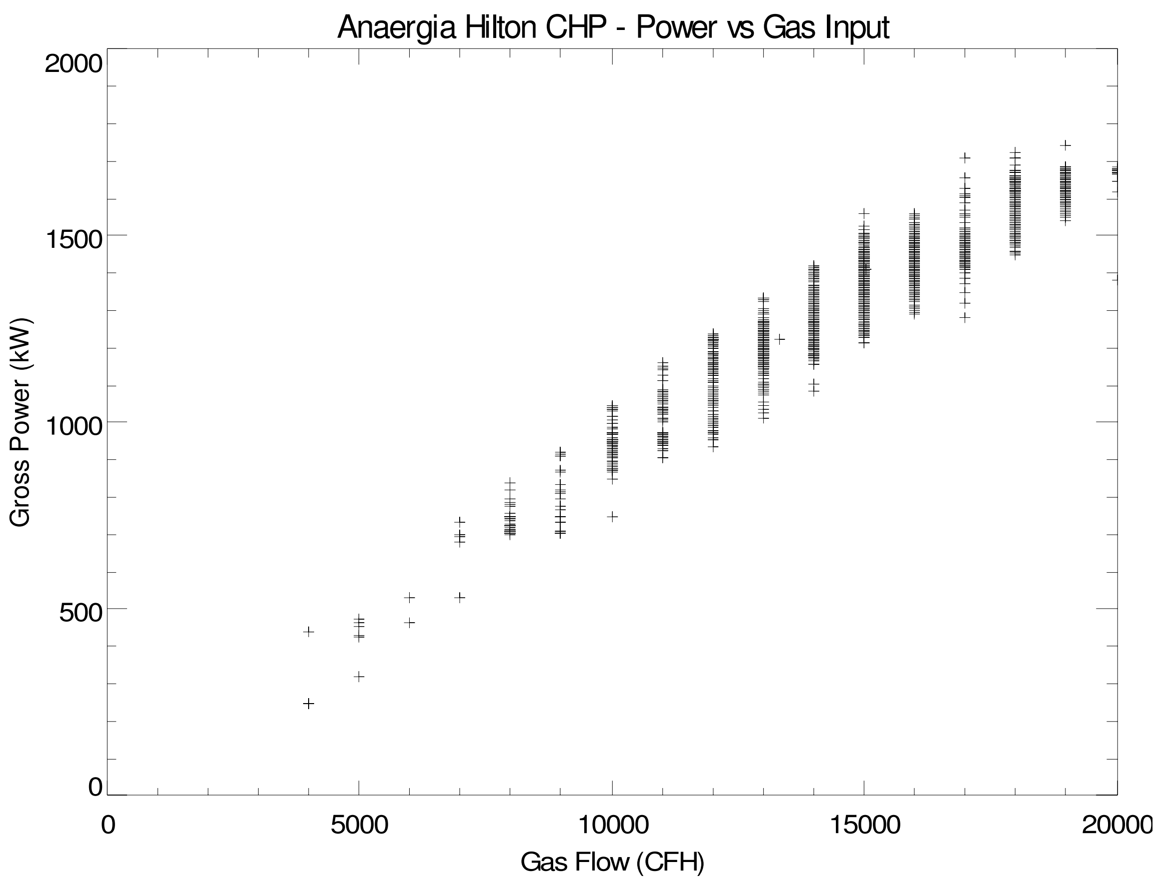


Figure 15. CHP Power Output Vs Gas Input

Gas data was disrupted between August 20 and September 18, 2013, as the gas meter was replaced. Data between these dates would be filled using a relation for power vs gas use if M&V were to be started before this date.

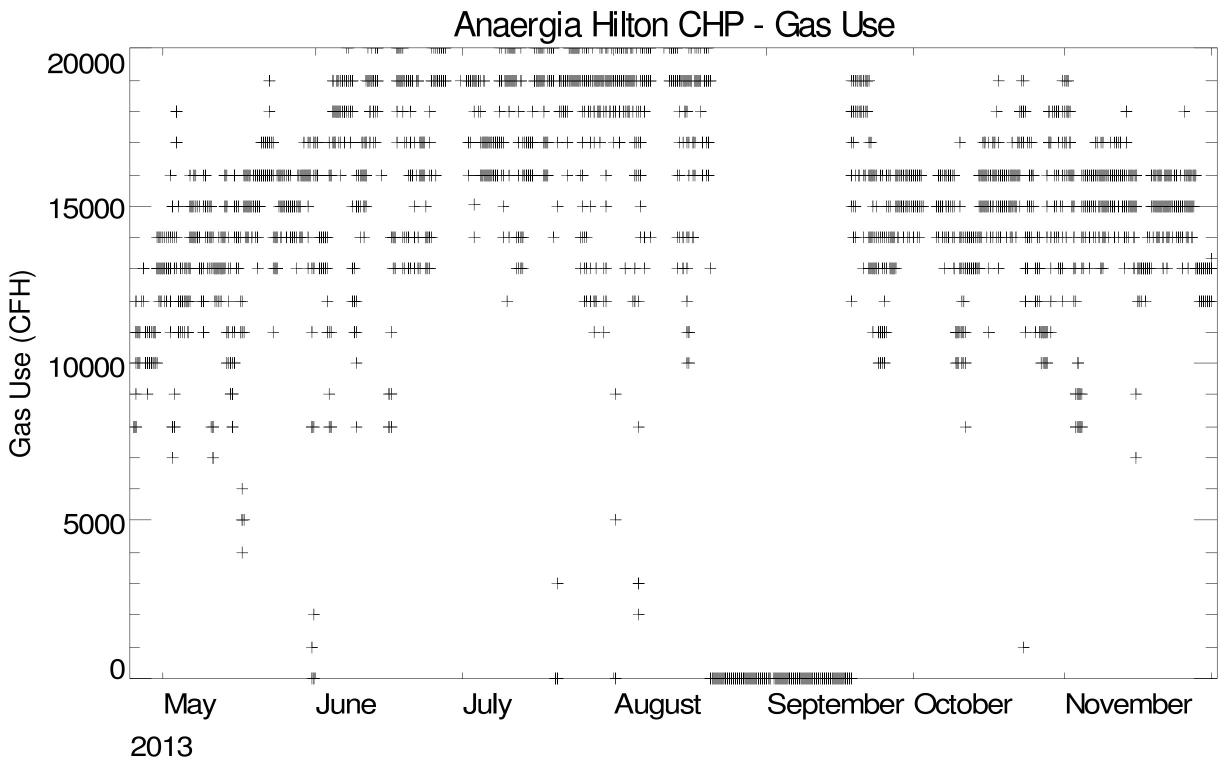


Figure 16. CHP Gas Use History

Summary of Performance

Figure 17 through Figure 23 display performance maps of the observed operation, with the WG345 meter adjusted by 6% to account for the observed measurement error. No parasitic energy consumptions are applied, for direct comparison to the SDP performance specifications.

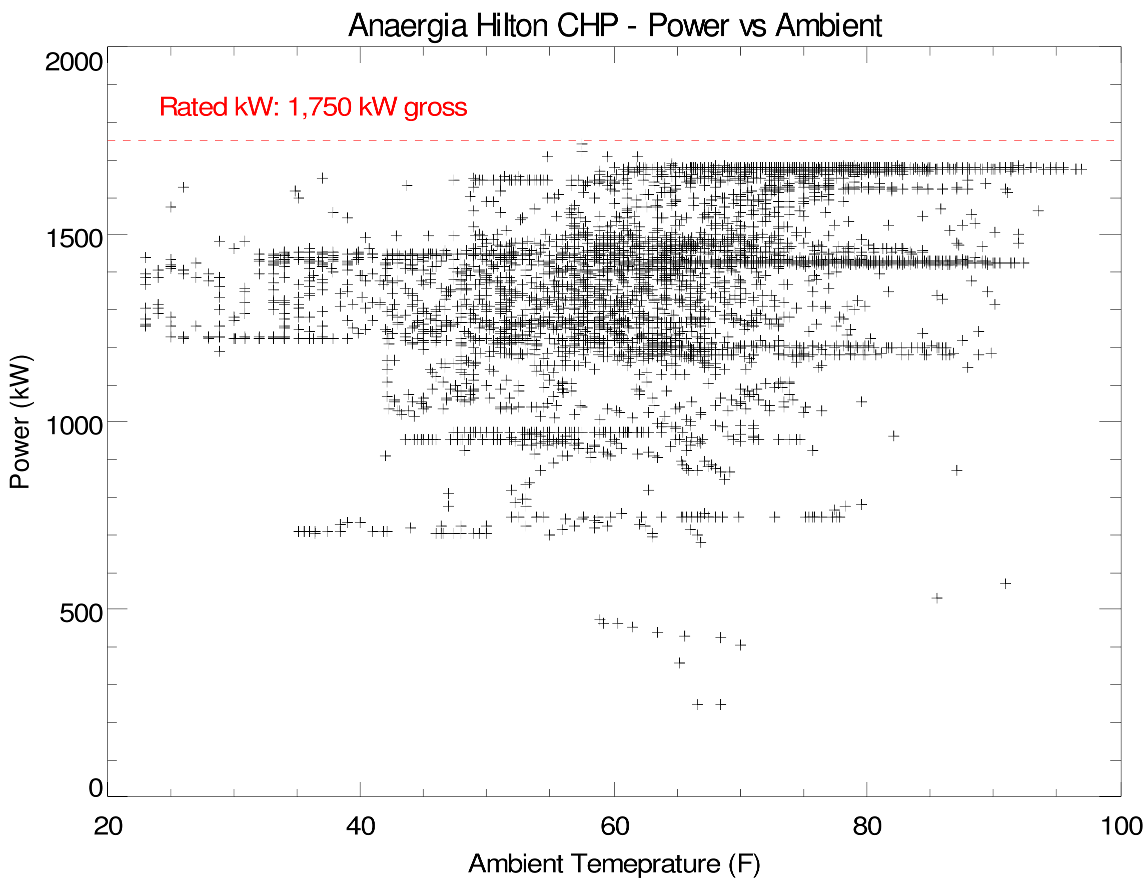


Figure 17. CHP Gross Power Production (with WG345 adjustment applied)

CHP gross power production is approaching the nameplate 1,750 kW at full load.

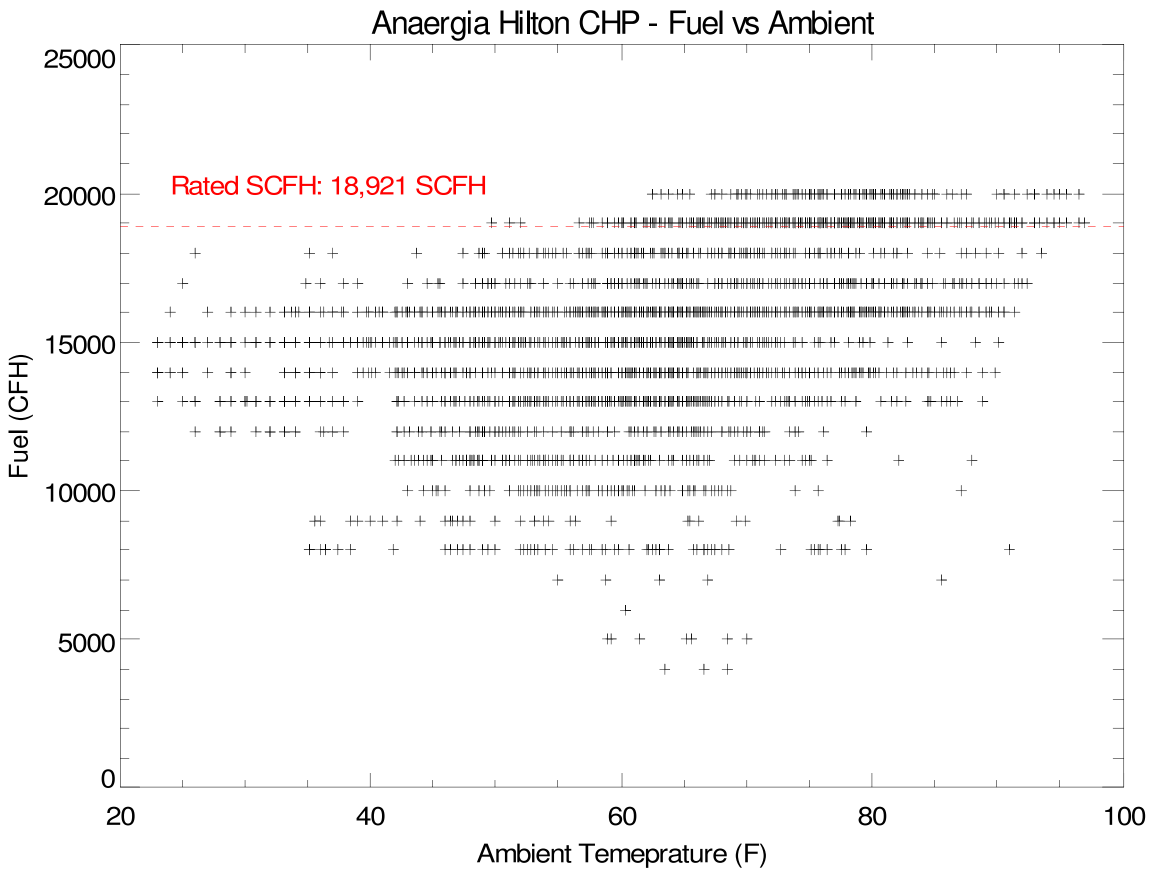


Figure 18. CHP Fuel Consumption

Observed CHP fuel consumption is at or near the 18,921 SCFH at full load.

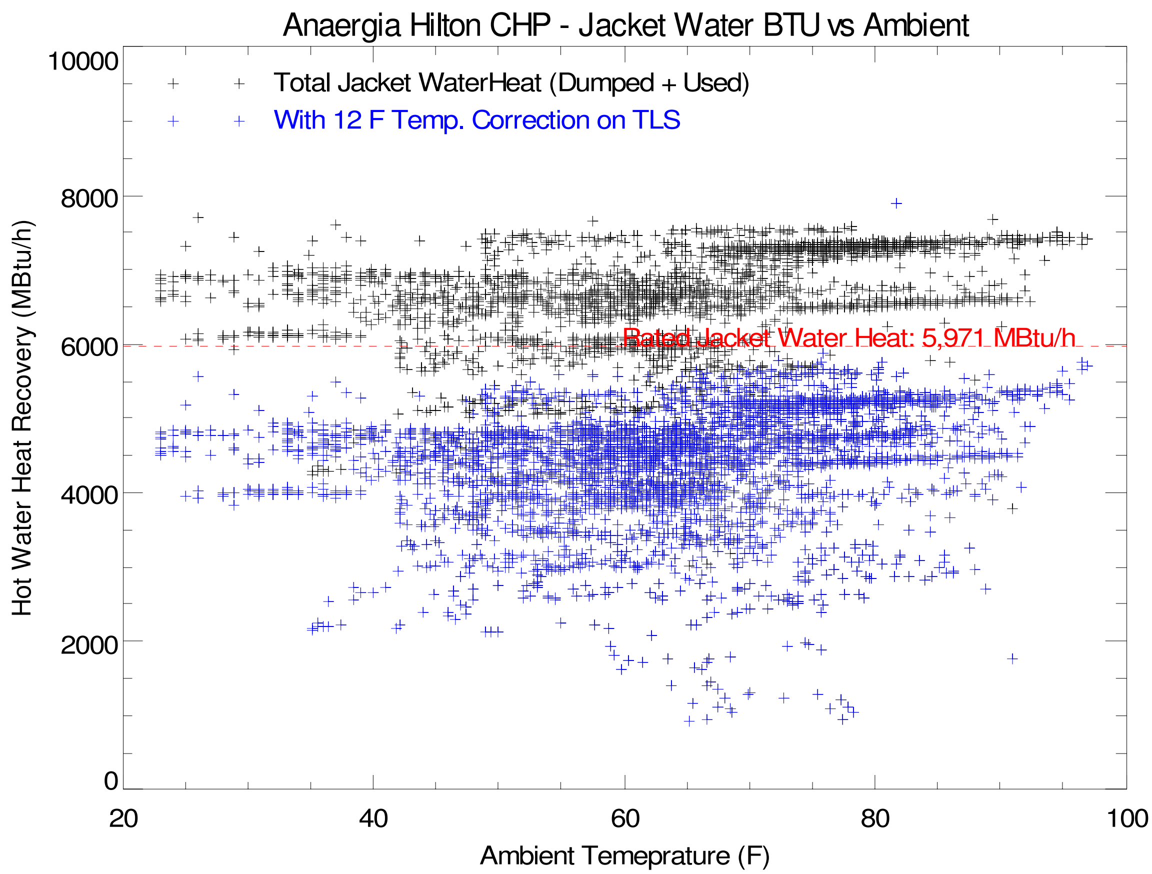


Figure 19. CHP Jacket Water Heat Production

The peak CHP jacket water heat (consisting of the useful heat transfer plus the dumped heat rejection) is well above the 5,971 MBtu/h rating for the seven engines combined. If the 12°F temperature correction identified in the review of the temperature data is applied, then the total jacket water heat transfer becomes in line with the rated heat available.

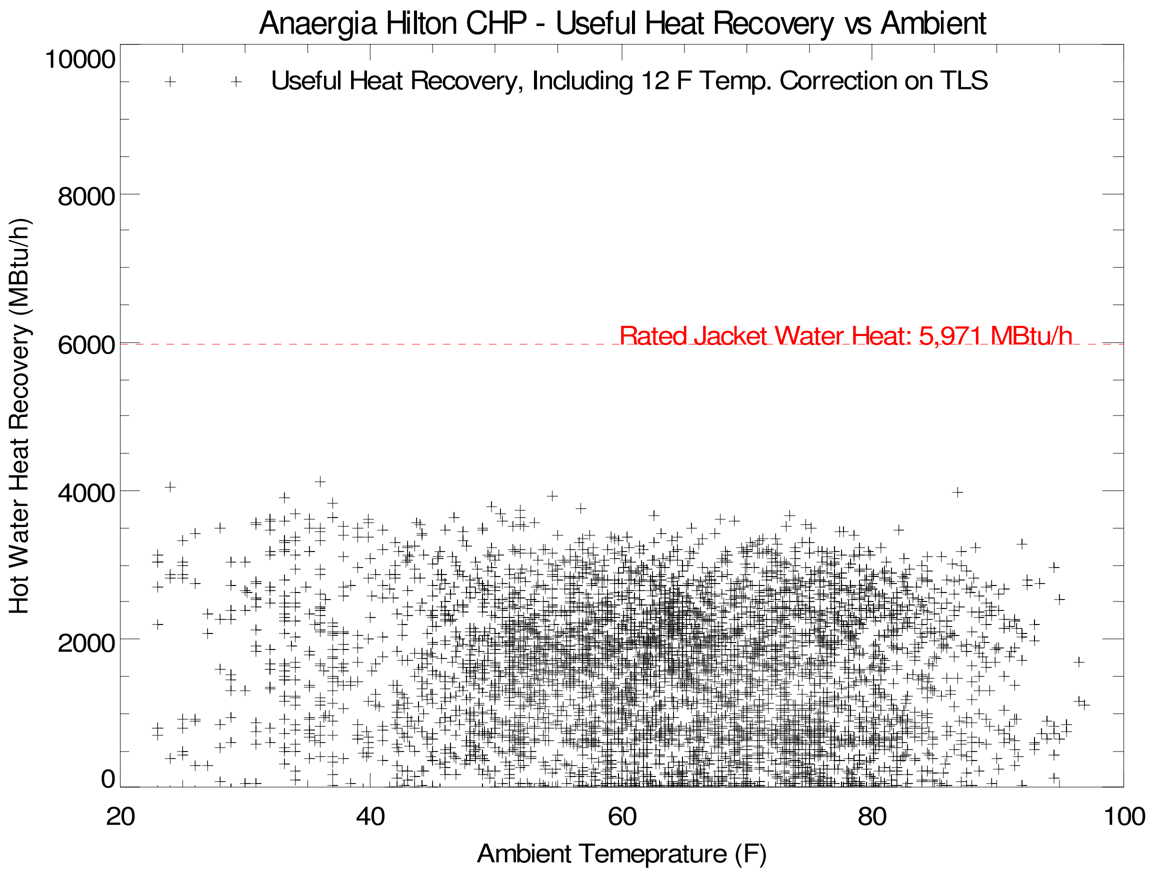


Figure 20. CHP Jacket Water Useful Heat Recovery

Useful heat recovery on the glycol loop has little temperature dependence, because the heat is used for service hot water heating. The peak heat recovery observed is approximately 4 MMBtu/h across all temperatures.

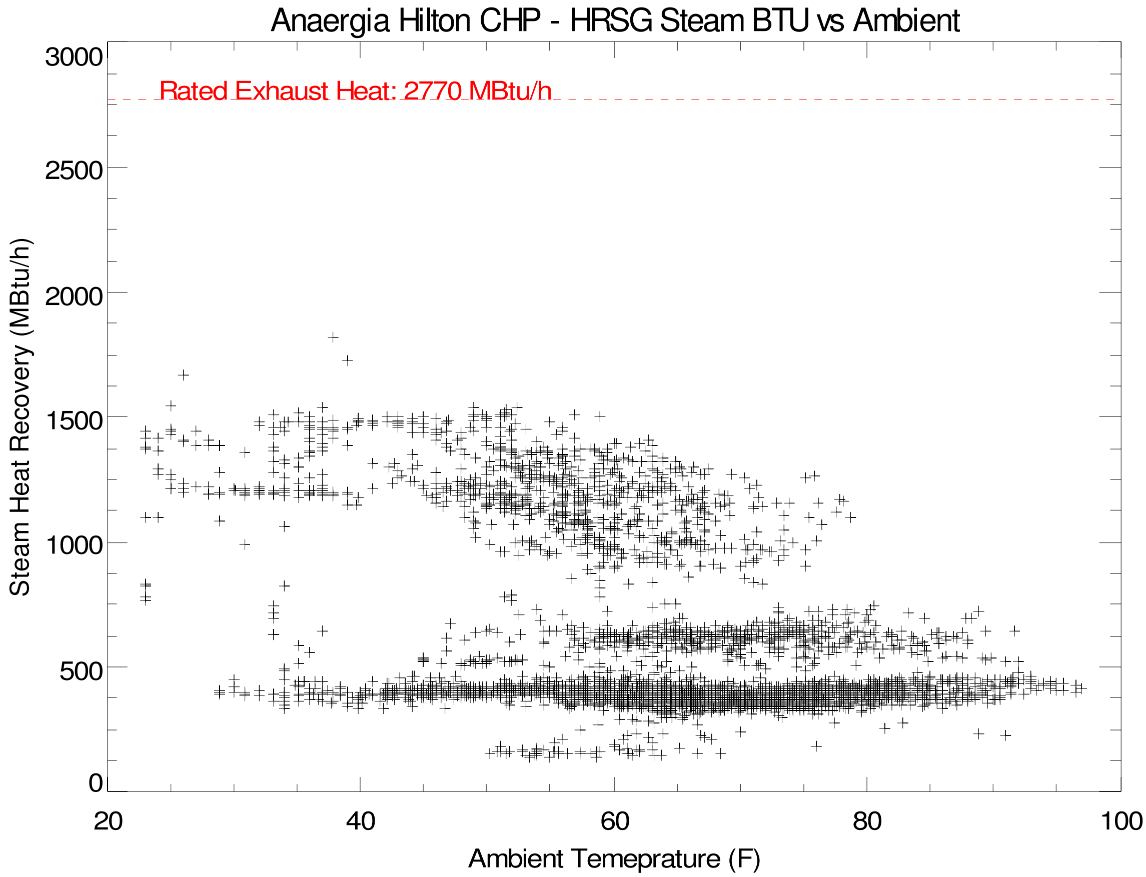


Figure 21. CHP HRSG Steam Production Heat Recovery

Steam production data has two trends, the first trend is a flat baseload of 400 – 600 MBtu/h when the building is accepting steam only for re-heat and domestic water heating loads. The second trend is a temperature dependent trend that increases to 1,500 MBtu/h for space heating. This level is well below the rated level of heat available in the exhaust.

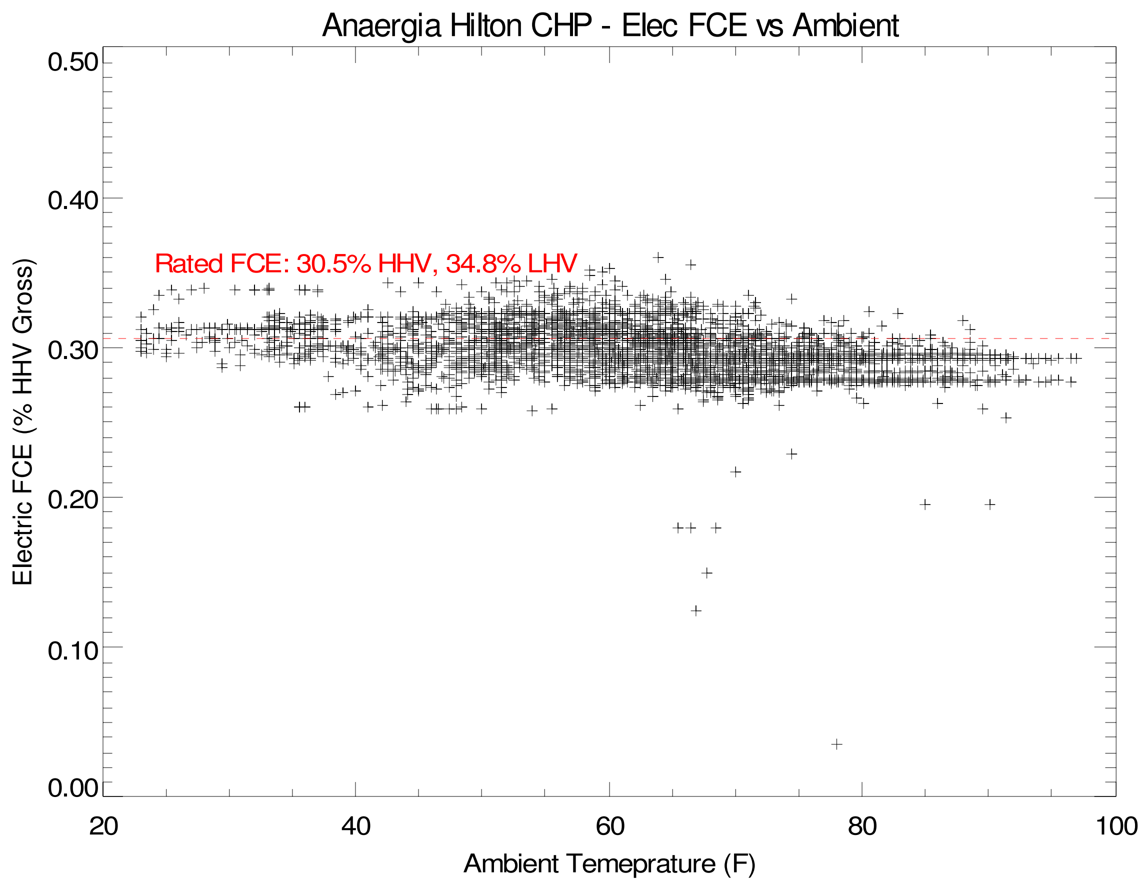


Figure 22. CHP Electrical Fuel Conversion Efficiency

The electrical FCE for the CHP system is near the rated value of 30.5% HHV.

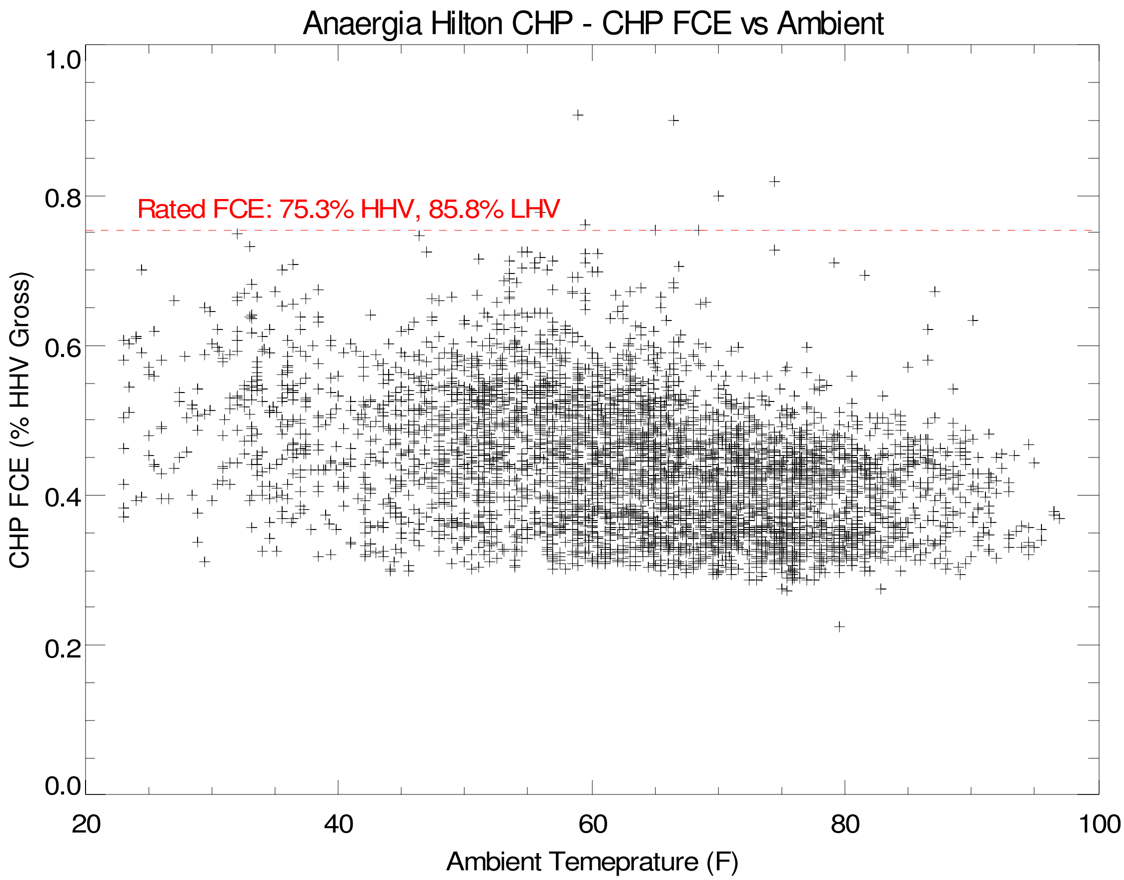


Figure 23. CHP Fuel Conversion Efficiency

The CHP FCE for the plant has ranged from 35 – 75% HHV, with the majority of the data between 40-60% HHV. The plant is operating lower than the rated efficiency of 75% HHV for a majority of hours.

Table 8 displays the summary of the performance observed to date, and compares the performance to the specification performance in Table 1. The performance in this table includes the adjustment to WG345, as well as the adjustment to the glycol loop heat transfer.

Table 8. Observed Operation – Comparison to Rated Performance

	Observed Operation - Adjusted					
	Total Energy			Full Load Normalized		Comparison to Spec.
Electric (Gross)	kWh	5,860,565		kW	1,750	
Fuel	CF	65,587,244		CFH	19,585	Higher
	MBtu LHV	59,356,456		MBtu/h LHV	17,724	Higher
	MBtu HHV	67,554,861		MBtu/h HHV	20,172	Higher
Electric FCE	% LHV	33.70%		% LHV	33.70%	Lower
	% HHV	29.61%		% HHV	29.61%	Lower
Jacket Water	MBtu	18,710,648		MBtu/h	5,587	Lower
(used)	MBtu	6,494,661		MBtu/h	1,939	
(dumped)	MBtu	12,215,987		MBtu/h	3,648	
Exhaust/Steam	MBtu	2,571,335		MBtu/h	768	Lower
Total Thermal	MBtu	21,281,983		MBtu/h	6,355	Lower
CHP FCE	% LHV	48.97%		% LHV	48.97%	
	% HHV	43.03%		% HHV	43.03%	

Table 9 displays the performance using the NYSERDA FCE calculation, which includes net generation (less parasitic energy), and is performed on an LHV basis only. The system is operating at 43% LHV, which would be insufficient for any performance incentive.

Table 9. NYSERDA FCE Calculation

	Observed Operation - Adjusted with NYSERDA FCE Calculation	
	Total Energy	
Electric (Net)	kWh	5,576,485
Fuel	CF	65,587,244
	MBtu LHV	59,356,456
Electric FCE	% LHV	32.06%
Useful	MBtu	6,494,661
CHP FCE	% LHV	43.0%

M&V Recommendations

Several field point measurements have issues that require addressing for M&V to be fully accurate.

Field point measurement issues to be resolved:

- Correct power reading on WG345. Determine if meter is configured and operating properly.
- Provide clarification on the units for data provided from WPAR1 (PPH Panel). CDH is assuming the data are in kWh/interval, and will update the database accordingly.
- Check configuration on WPAR2 (MP-1 Panel). Data from this meter is unusable. CDH will apply a 4.4 kW × 0.33 load factor parasitic consumption to back data.
- Provide documentation for the configuration and calibration of the TLS sensor, and offset that is present in the data starting June 26, 2013. Re-calibrate or replace sensors as necessary.