NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT THE PEPSI BOTTLING COMPANY

October 9, 2013

Pepsi Bottling Company

NYSERDA New York State Energy Research and Development Authority

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BACKGROUND

The New York State Research and Development Authority (NYSERDA) web-based DG/CHP data system has been providing performance information on CHP systems for the past ten years. This system includes monitored performance data and operational statistics for NYSERDA's Distributed Generation (DG)/Combined Heat and Power (CHP) demonstration projects including:

- Monitored Hourly Performance Data
- Operational Reliability and Availability Data
- Characteristics of Each Facility and its Equipment

The Monitored Hourly Performance Data portion of the database allows users to view, plot, analyze, and compare performance data from one or several different DG/CHP sites in the NYSERDA portfolio. It allows DG/CHP operators at NYSERDA sites to enter and update information about their system. The database is intended to provide detailed, highly accurate performance data that can be used by potential users, developers, and other stakeholders to understand and gain confidence in this promising technology.

The Operational Reliability Data portion of the database is intended to allow individual facility managers to better understand reliability, availability, and performance of their particular units and also determine how their facilities compare with other units. Information on reliability and availability performance will enable potential onsite power users to make a more informed purchase decision, and will help policy makers quantify reliability benefits of customer-sited generation.

NYSERDA's web-based DG/CHP data system provides general equipment information and detailed performance data, however, data alone does not provide the complete picture with respect to CHP systems design or performance. This report seeks to explain the performance data presented in the two fundamental output graphs: kW/h versus time and Useful MBtu/h versus time.

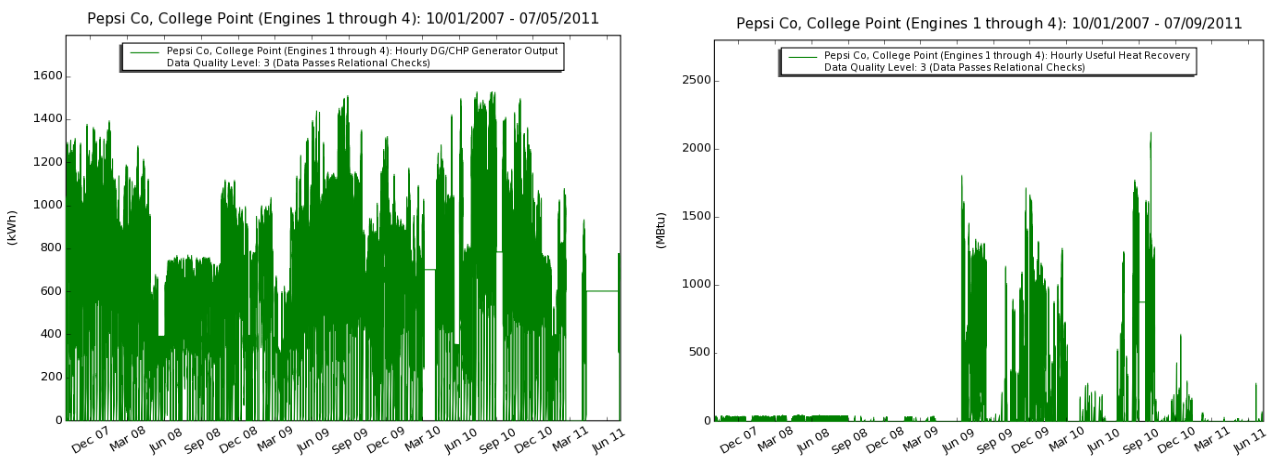

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

This report provides explanation for system performance trends and anomalies by further assessing the data supporting these two graphs and, where necessary, conducts interviews of the developers, owners and operators.

THE SITE

FIGURE 2 PEPSI-COLA BOTTLING COMPANY OF NEW YORK

The Pepsi-Cola Bottling Company of New York operates a production facility in College Point. The facility operates five to six days per week for up to 22 hours per day. The electric demand can approach 2 MW in summer when production peaks. Steam consumption follows a similar trend.

Beverage plants consume considerable energy processing raw materials and handling finished products. Electricity is consumed by various pumps, compressors, lights, conveyors and other devices. Hot water and steam is consumed cleaning and sterilizing production equipment and product containers. Bottles and cans are typically heated after being filled to prevent condensation from forming on the container surface; this is a necessity prior to labeling.

This simultaneous demand for heat and electricity make carbonated drink plants ideal candidates for CHP technology. Reciprocating engine-generators are a good match to these facilities for several reasons. Electrical loads are generally not excessive (< ~2 MW) and can be carried by a moderately sized generator(s). Thermal demands usually dominate site requirements though at a ratio favoring an engine's performance characteristics and the output of heat as hot water or low pressure steam.

THE SYSTEM

The CHP system at the Pepsi plant was configured on four natural gas fired engine-generator sets. Installation costs were minimized by pre-assembling the generators and electrical components in containers that were shipped to site where the remaining equipment was added. Automatic controls sequence the operation of each generator and modulate the electrical output to follow the site load. No power is exported to the grid. Waste heat from the engine exhaust is used to produce low pressure steam in a pair of heat recovery steam generators (HRSG). A limited amount of heat is also recovered from the engine coolant as hot water (though this is not measured). Any excess heat is rejected to the atmosphere through external radiators mounted on top of each container.

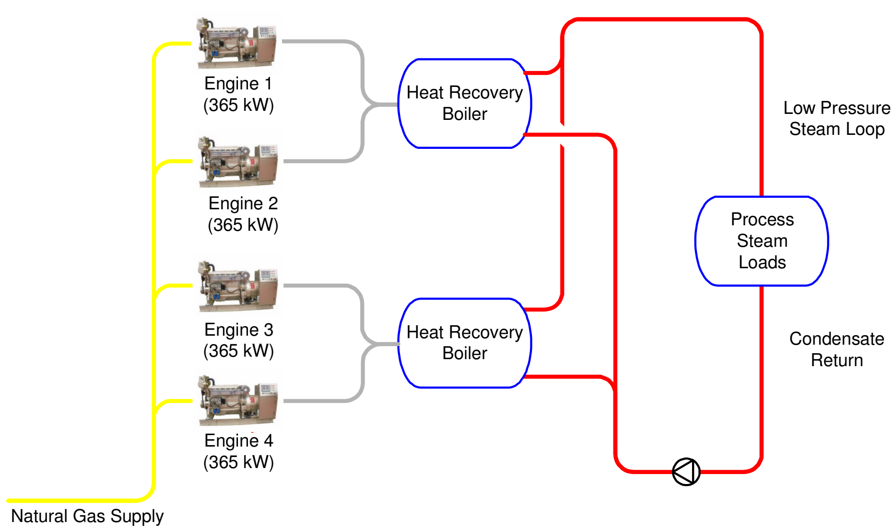

FIGURE 3 INSTALLED GENERATOR MODULES

FIGURE 4 DETAIL OF A TYPICAL RADIATOR AND SILENCER

PERFORMANCE

The New York State Energy Research and Development Authority (NYSERDA) offers certain incentives to promote the installation of clean, efficient, and commercially available CHP Systems that provide summer on-peak demand reduction.

Table 1 provides the data results taken since September 1, 2007.

TABLE 1 SYSTEM EFFICIENCY[1]

	Hours of Good (Pwr) Data	Net Electric Output (kWh)	Natural Gas Use (MCF)	Useful Heat Output (MMBtu)	Electrical Efficiency	Useful Thermal Efficiency	Fuel Conversion Efficiency
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[1] Efficiency data is collected using all data points flagged as high quality data. Generally there is good correlation between the data quality of net electric output, natural gas use and useful heat rejection. Anomalies do occur, particularly with respect to natural gas use which causes distortions in the results. If efficiency results are out of normal range, the most likely cause is poor quality concurrent data which can be corroborated by the Site Data Quality table located in the Lessons Learned section of this report.

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July-08	737	334,942	3,996.0	9.2	28.0%	0.2%	28.3%
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Total preceding 12 months	**4832**	**2,359,935**	**26,738.6**	**592.7**	**29.5%**	**2.2%**	**31.7%**

Note: All efficiencies based on higher heating value of the fuel (HHV)

OPERATING SUMMARY

The CHP system consists of four 365 kW reciprocating engines totaling an installed capacity of 1,450 kW with an approximate technical potential of generating about 2-3 MMBtu/hr of useful thermal energy (depending on temperature requirements).

Table 1 and Figure 5 show two distinct performance parameters:

1. Engine generator efficiency is skewed and likely not reliable prior to March of 2009 due to lack of quality fuel flow data. After that time, engine efficiency was consistently between 28.1% (September 2010) and 31.7% (February 2011).

2. Very little useful thermal energy has been recorded. The data appears to have been incorrect (i.e. the wrong order of magnitude) before July 2009. It is not clear whether there was no heat recovery, or if the values were improperly recorded.

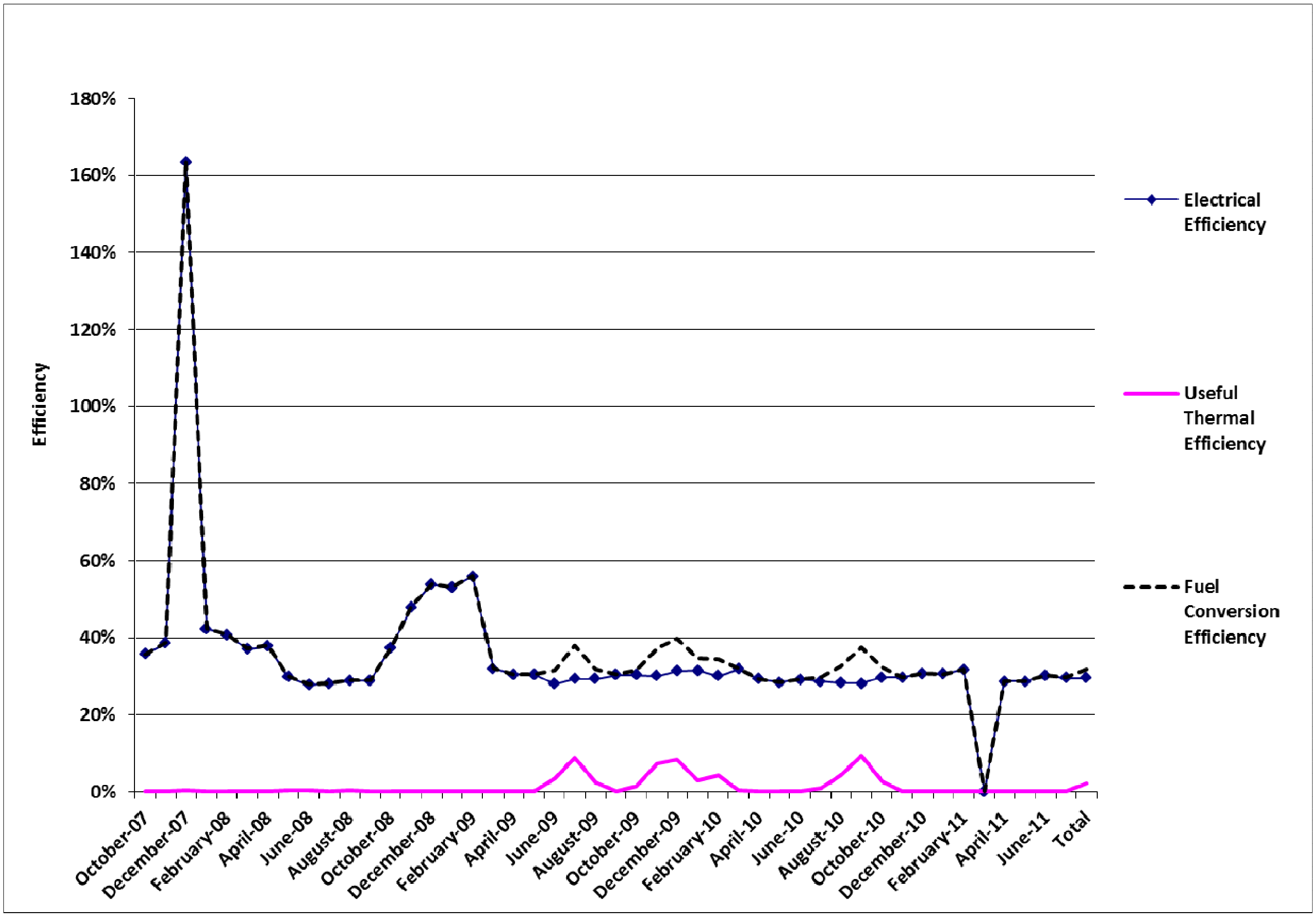

FIGURE 5 CHP SYSTEM EFFICIENCY BY MONTH

Figure 5 provides operating efficiency during 2010 showing a flat electric efficiency performance throughout the year and very little measured useful heat recovery.

POWER GENERATION AND USEFUL THERMAL ENERGY

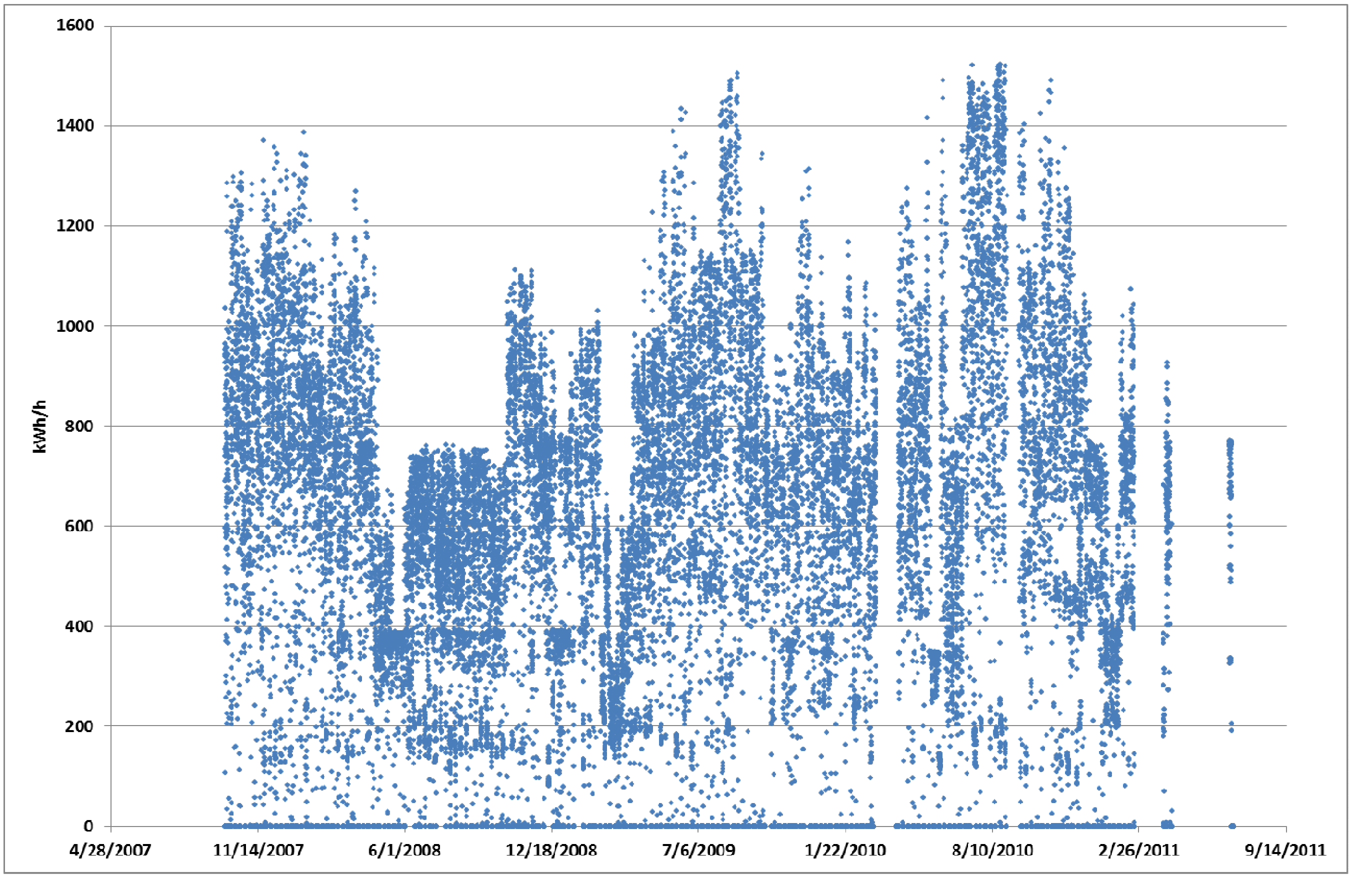

FIGURE 6 CHP POWER OUTPUT VERSUS TIME

Figure 6 shows operating patterns of a multi-shift beverage facility with a weekday morning ramp up in load, shift change and early morning ramp-down. Saturdays and Sundays there appears to be no production.

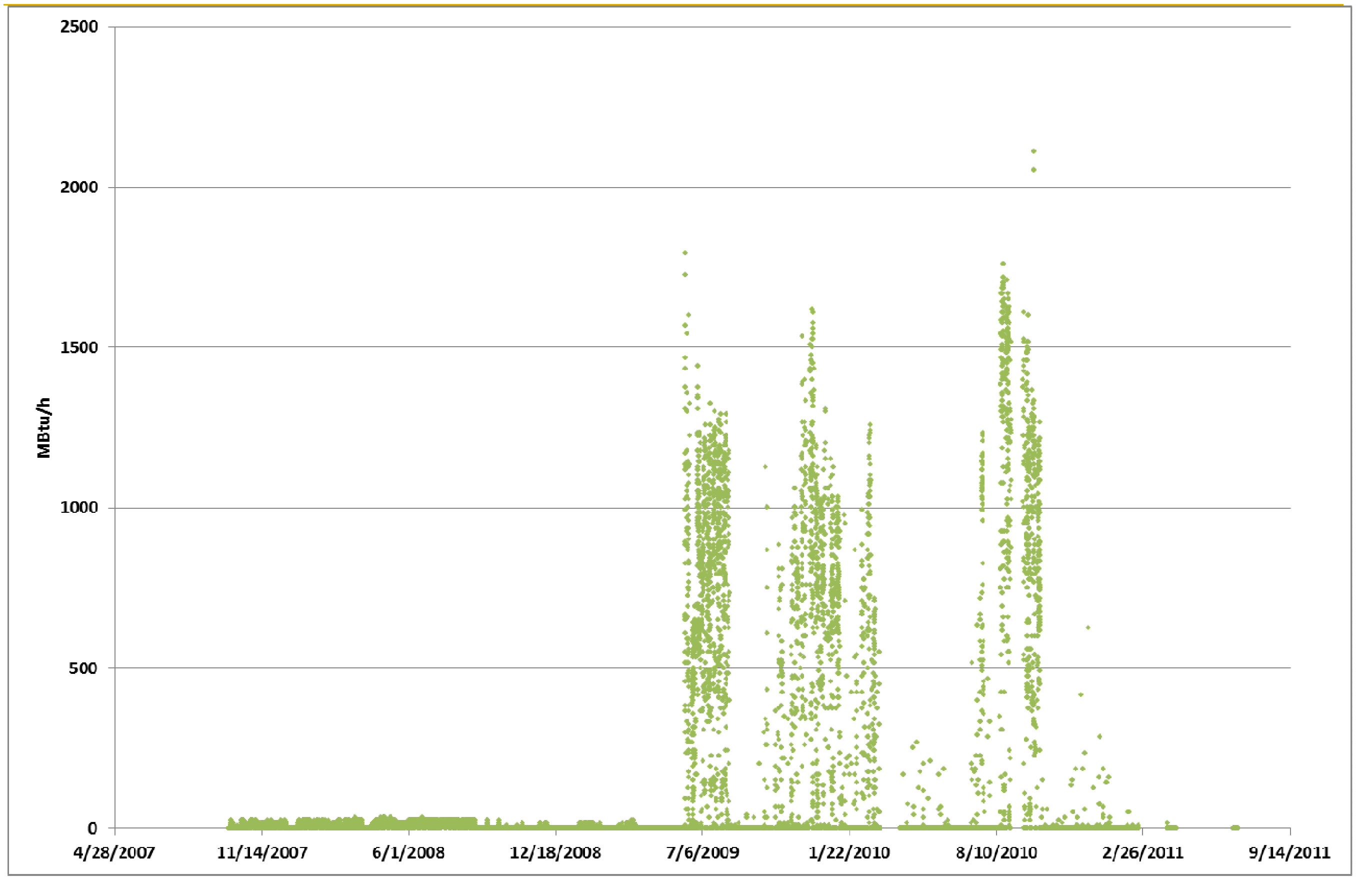

FIGURE 7 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 7 clearly shows that most of the time no useful heat recovery has been reported. The ensuing power and thermal graphs are all taken from weeks where there is useful heat recovered.

Note that on the following weekly graphs, weekend days are highlighted as dashed lines to quickly distinguish their operating characteristics.

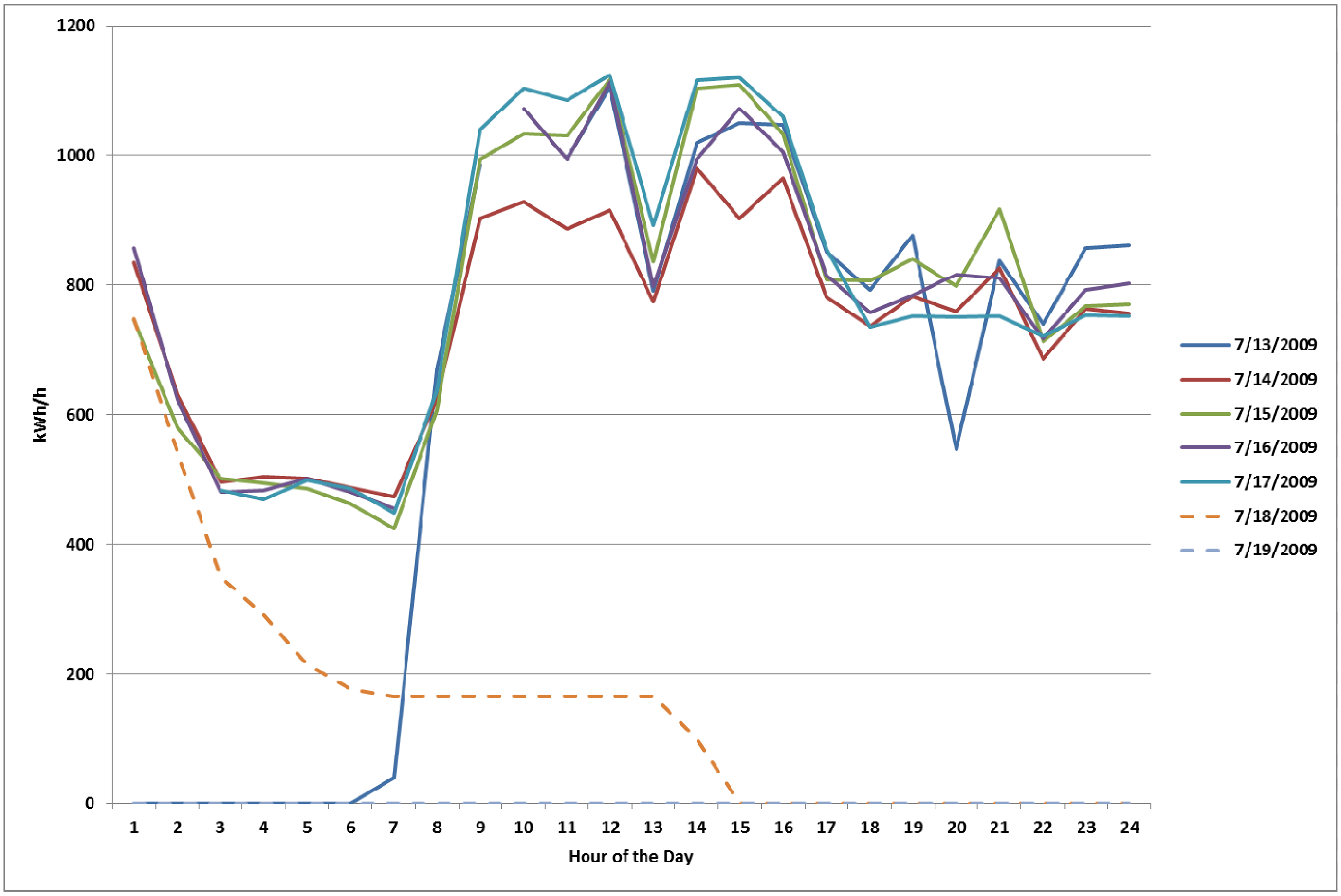

FIGURE 8 CHP POWER OUTPUT VERSUS TIME

Figure 8 covers the time period from July 13 – 19, 2009 providing CHP system power output by hour of the day pattern for the time period. July 18 is a Saturday. The power profile shows the process load starting at 7 AM on Monday morning, ramping to peak loading between 9 AM and 4 PM (900 to 1,00 kWh/h), dropping down to about 8200 kWh/h through midnight, then falling to 500 kWh/h from 3 AM to 7 AM to start the process over the next day. Saturday the load quickly falls off from ~ 800 kWh/h at midnight to under 200 kWh/h by 6 AM and then is shut down at around 2 AM for the remainder of the weekend. Examining Figure 9, one concludes this system is operating on an electric load following mode.

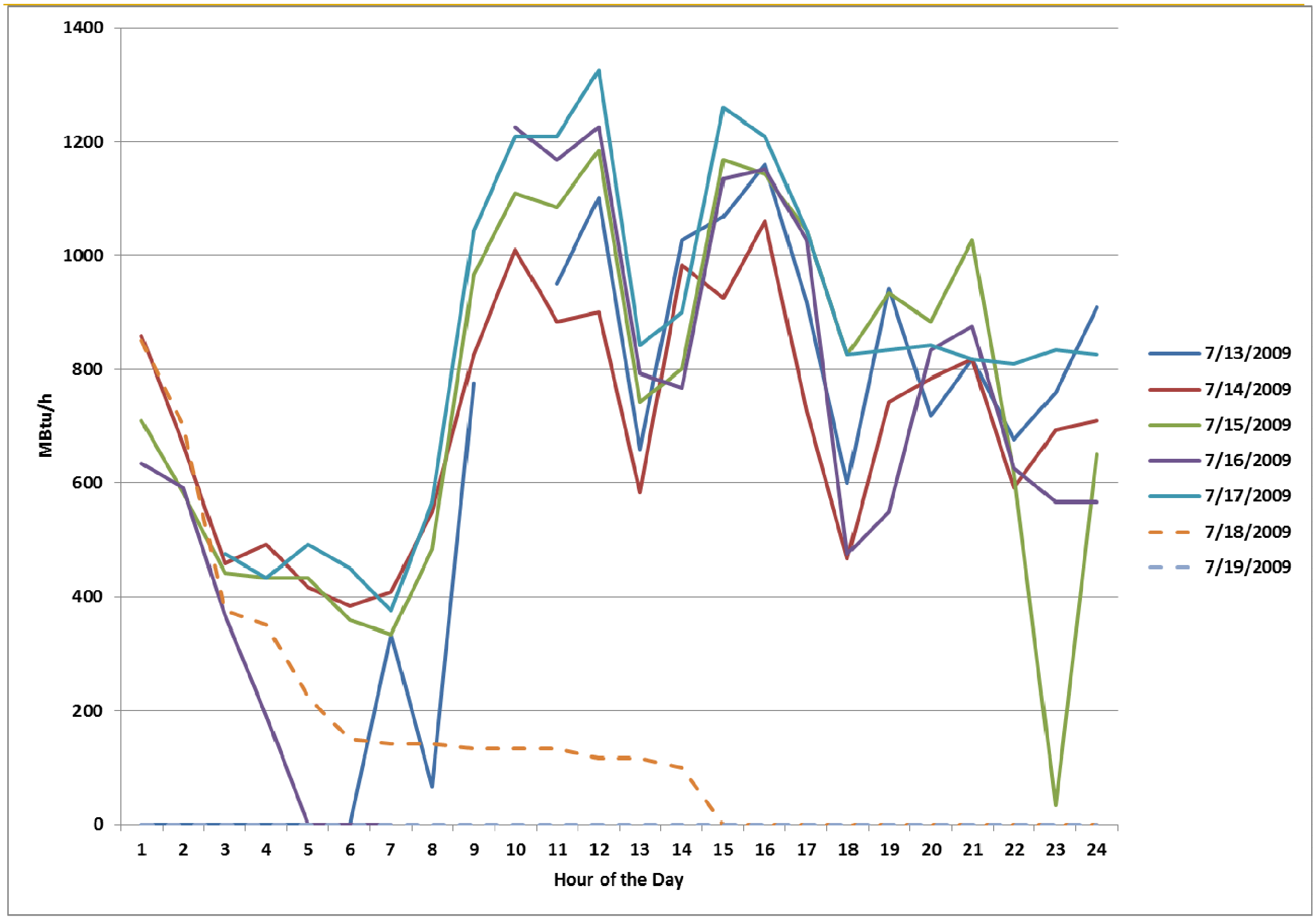

FIGURE 9 CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from July 13-19, 2009 (Figure 9) show a very consistent thermal load pattern. July 18 is a Saturday. The useful thermal heat recovered for this week based on the “rule-of-thumb” that 1/3 of the fuel in an engine based CHP plant goes to generate power and 1/3 is recoverable as useful heat, should result in a peak thermal recovery of about 3,750 MBtu/h. However, since heat is only being recovered as steam from the engine exhaust a rule of thumb closer to 1/6 should apply in this case (1,900 MBtu/h). Figure 9 shows a peak around 1,200 MBtu/h which is still less than the “rule-of-thumb” value for producing steam from engine exhaust.

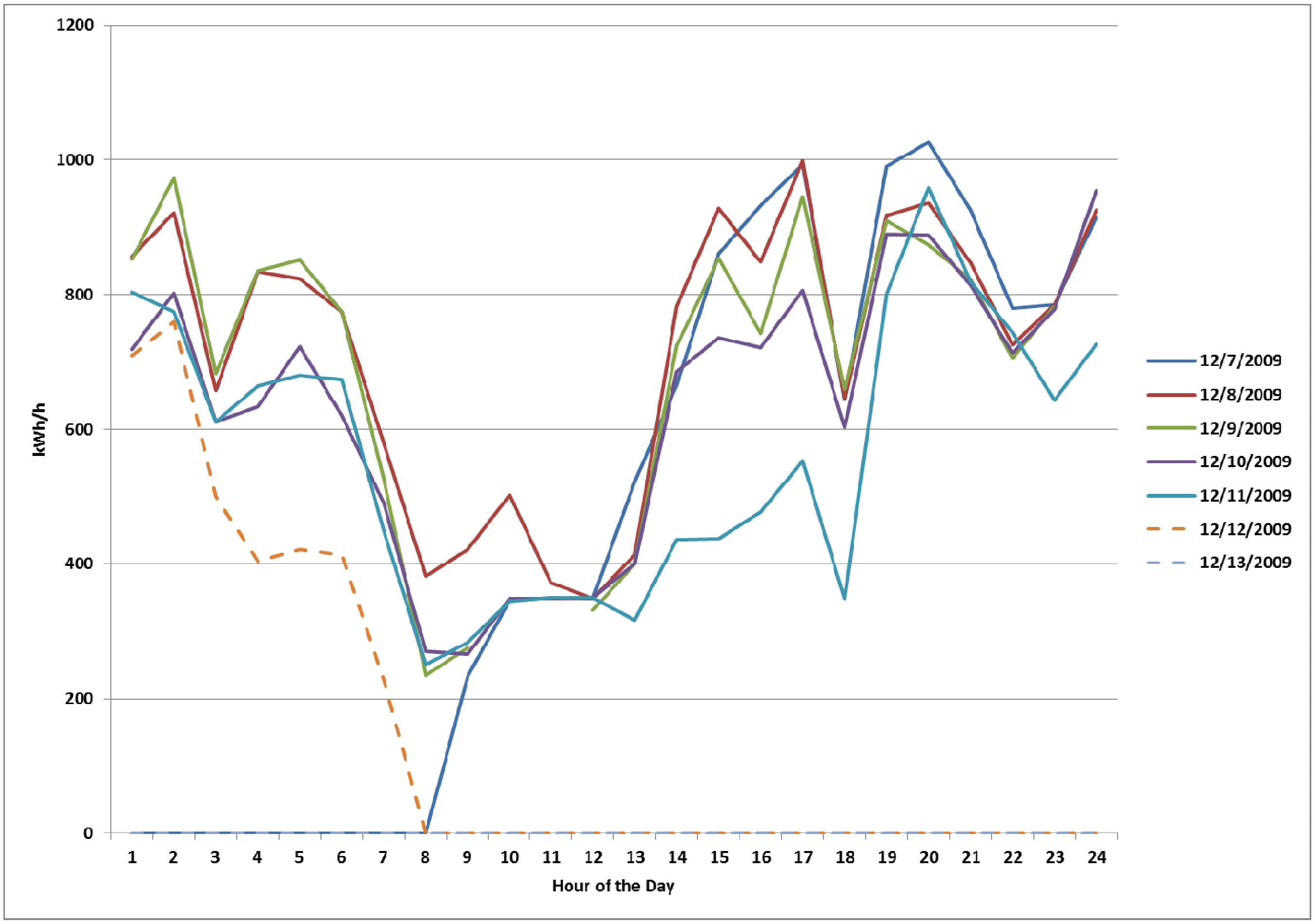

FIGURE 10 CHP POWER OUTPUT VERSUS TIME

Figure 10 covers the time period from December 7-13, 2009 providing CHP system power output by hour of the day pattern for the time period. December 12 is a Saturday. Figure 10 provides a similar load profile to Figure 8 with a slightly lower peak power requirement likely linked to the lower winter ambient temperatures.

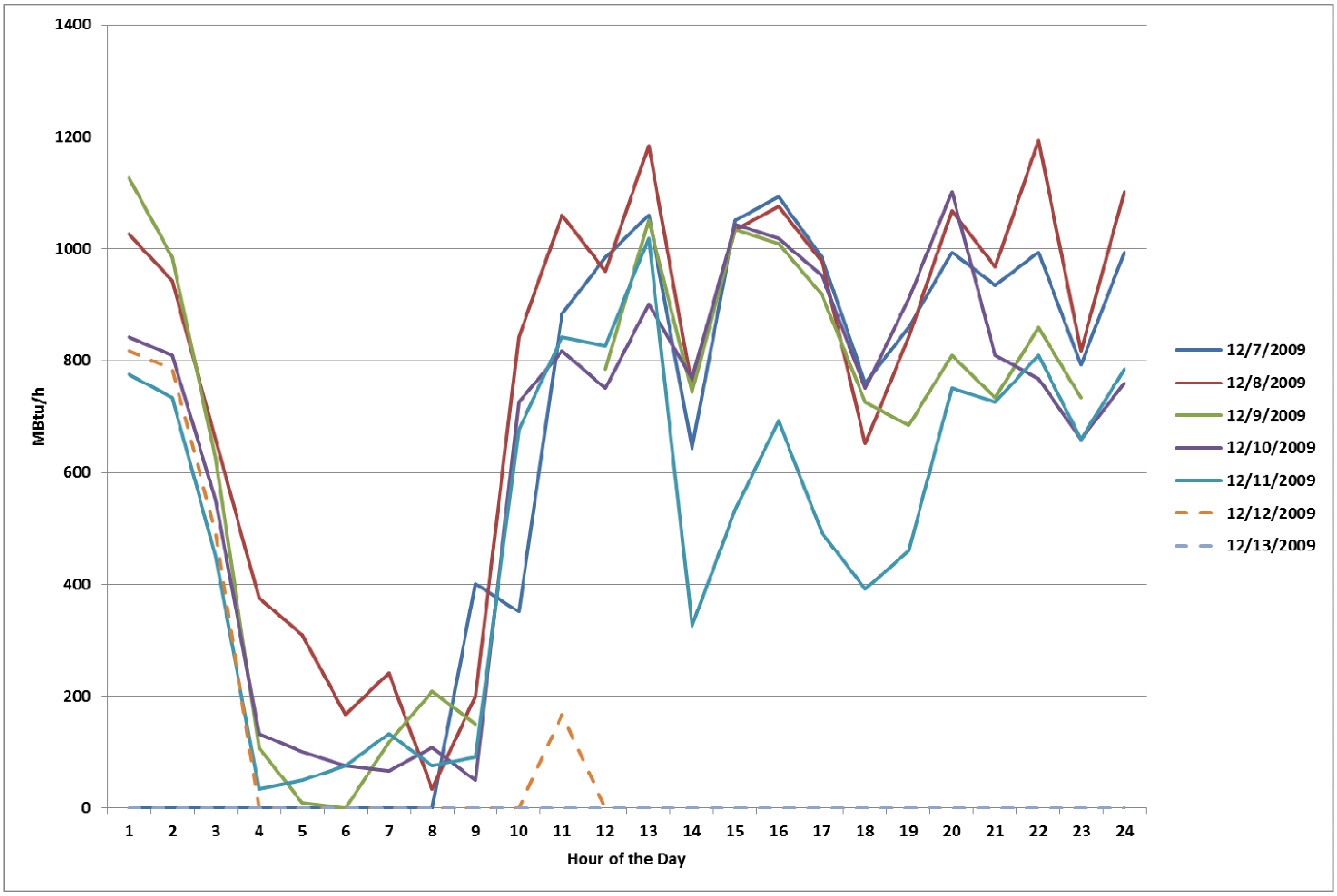

FIGURE 11 SELECTED DAY CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 11 covers the time period from December 7-13, 2009 providing CHP system power output by hour of the day pattern for the time period. December 12 is a Saturday. Figure 11 provides a similar thermal load profile to Figure 9.

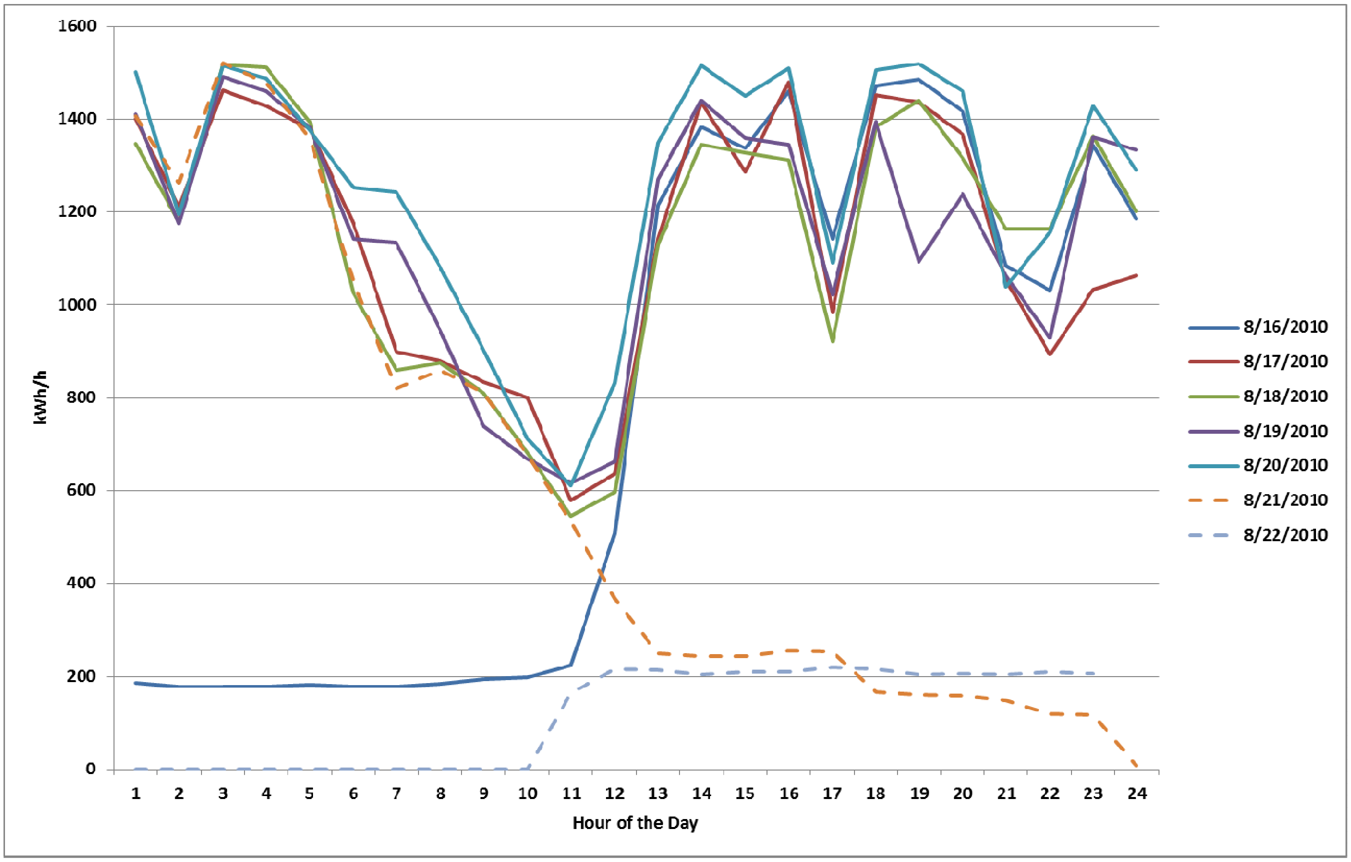

FIGURE 12 CHP POWER OUTPUT VERSUS TIME

Figure 12 covers the time period from August 16–22, 2010 providing CHP system power output by hour of the day pattern for the time period. August 21 is a Saturday. Figure 12 has a similar load shape to the two predecessor power curves (Figure 8 and Figure 10), but Figure 12 exhibits tighter control and increased load.

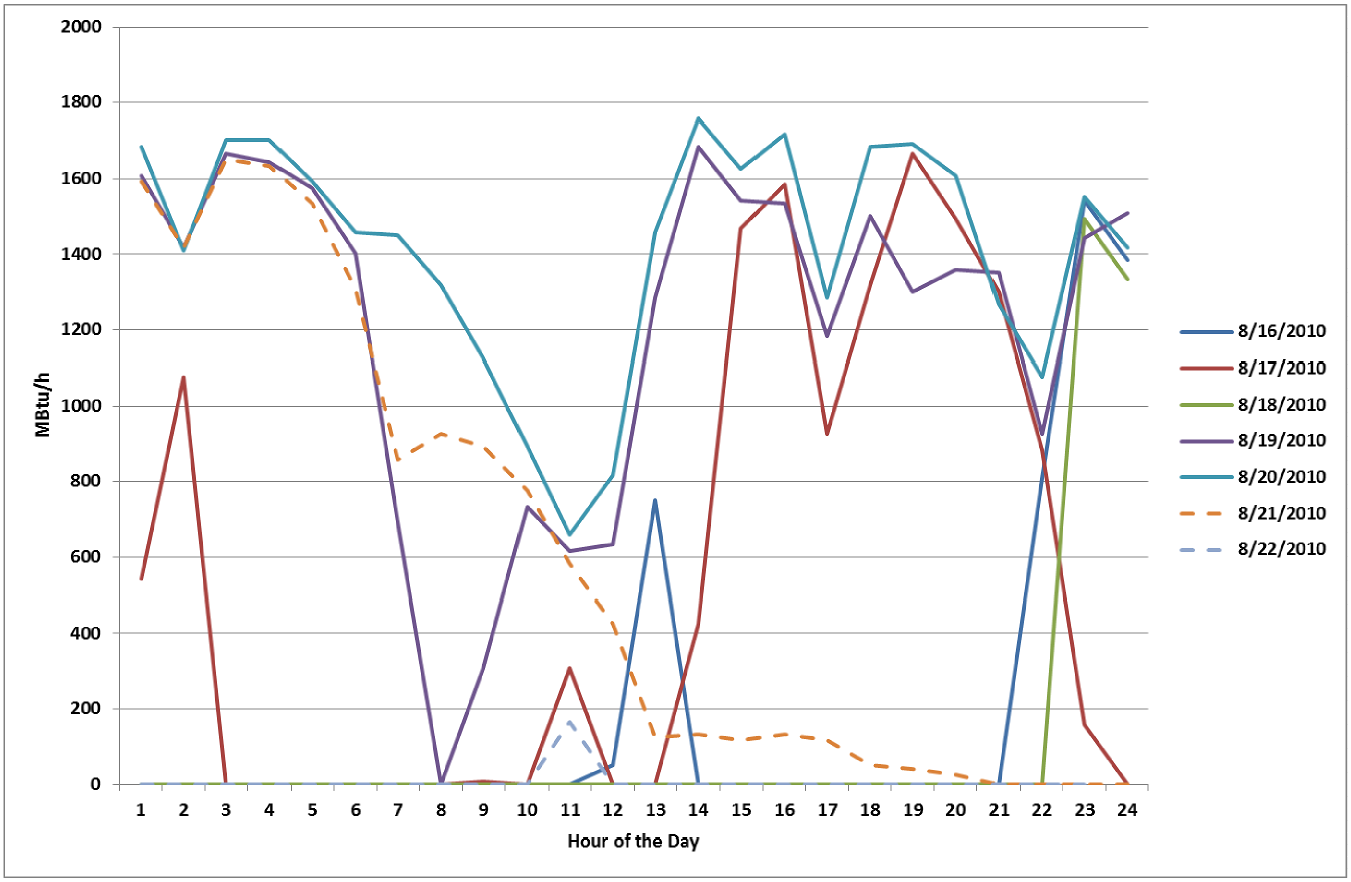

FIGURE 13 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 13 covers the time period from August 16-22, 2010 providing CHP system power output by hour of the day pattern for the time period. August 21 is a Saturday. The useful thermal recovered heat in Figure 13 is higher than the two preceding graphs showing useful recovered heat, but the data is more erratic.

PERFORMANCE SUMMARY

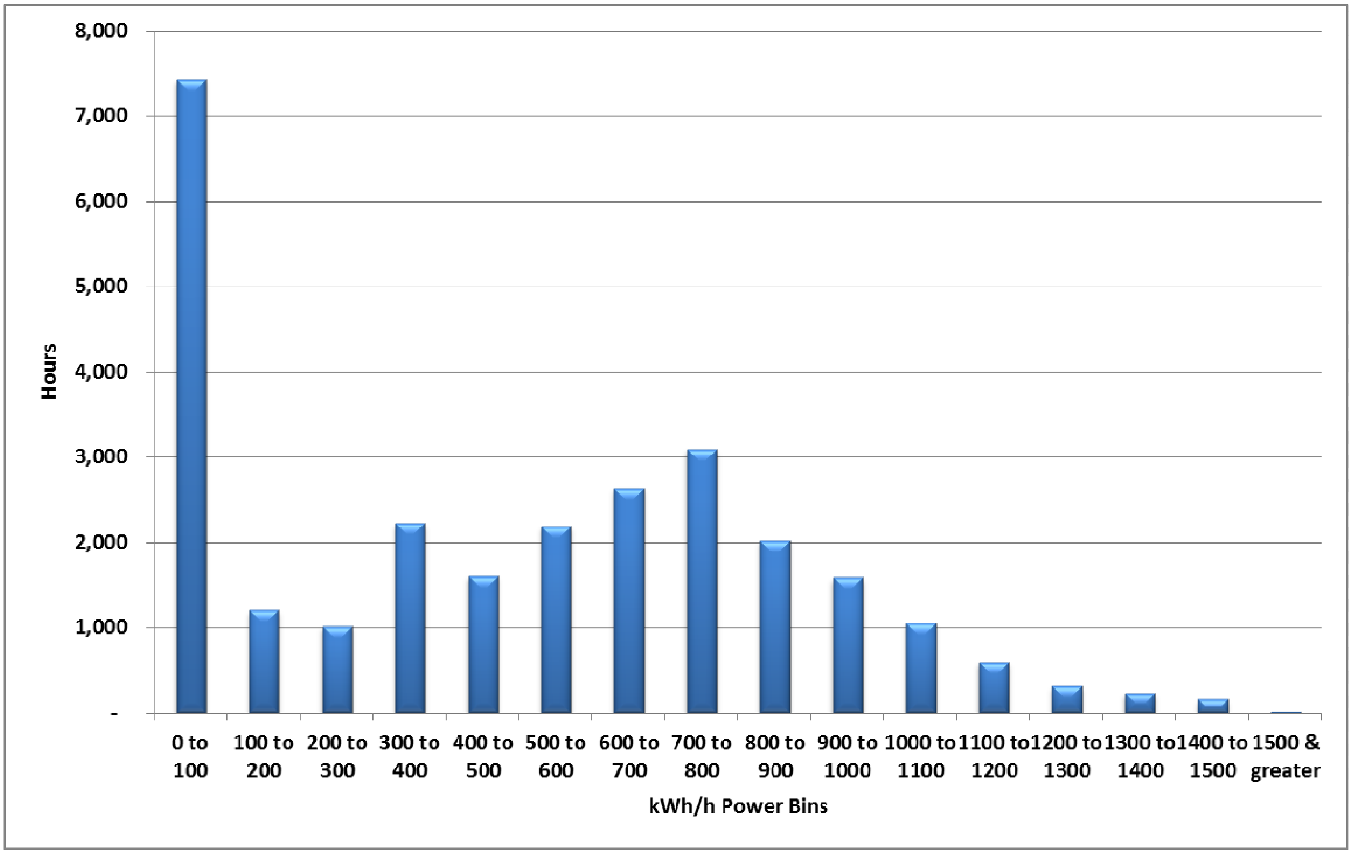

FIGURE 14 PERFORMANCE BY POWER BINS

During the 27,341 hours that met the range and relational checks 67% of the time, the CHP system was operating at a power output of less than 700 kWh/h.

LESSONS LEARNED

TABLE 2 SYSTEM EFFICIENCY[2]

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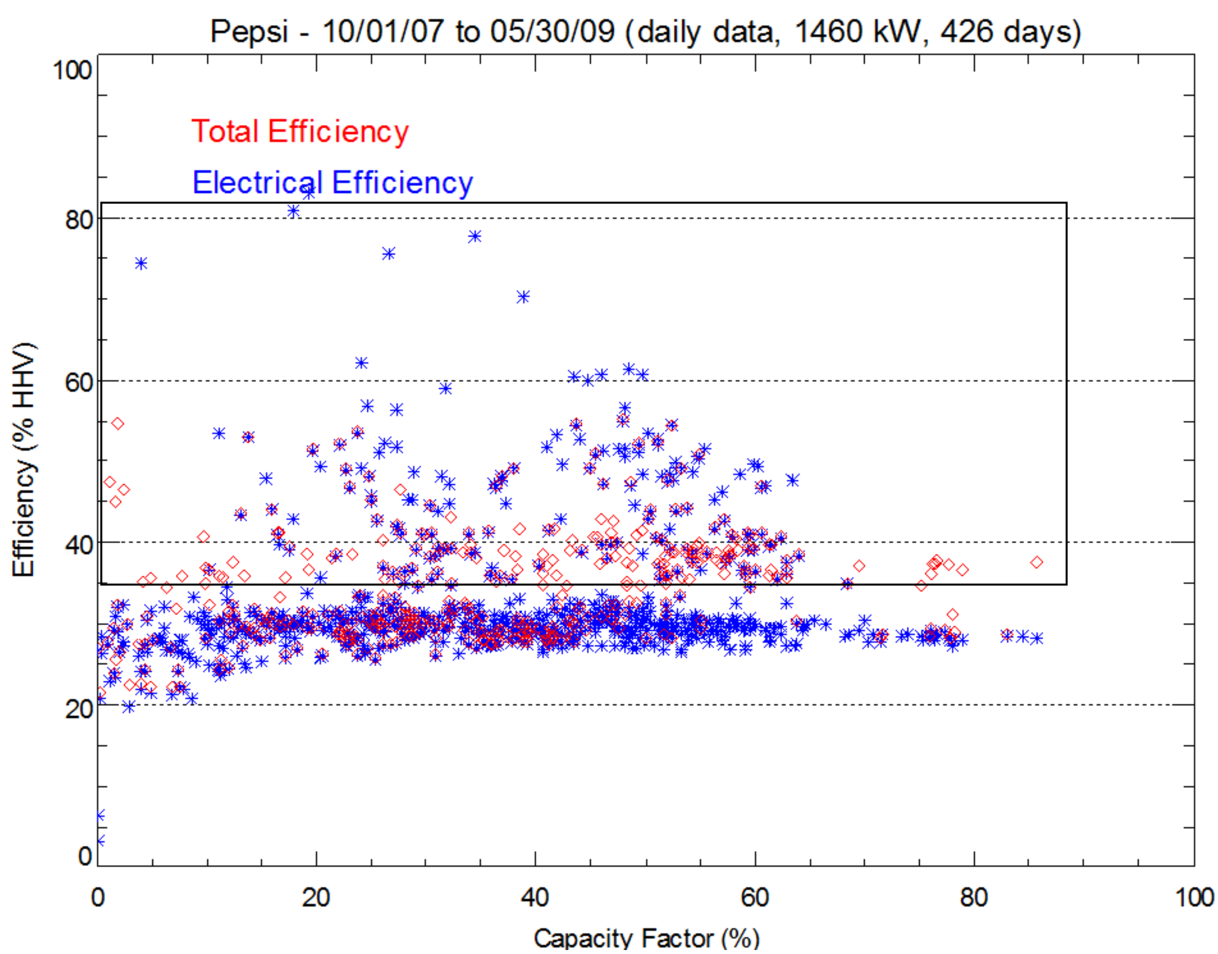

FIGURE 15 CAPACITY FACTOR[3]

Capacity Factor (Figure 15) presents the CHP generated power efficiency over the time period (426 days). This Figure provides a very good overview of the CHP power capacity versus site power requirements and a good understanding of the useful thermal energy recovered. Note the electrical efficiencies located within the black rectangle are invalid and are caused by fuel gas meter problems. The Figure shows the system operating in electric load following mode between 1% and 85% of capacity performing at 32.4% power efficiency (HHV) during the period of the Figure (excluding all months > 40% due to continuous measurement errors) and 25.9% power efficiency (HHV) for the final 12 months in Table 2. A typical lean burn engine of this size range would have an expected electrical efficiency of ~ 33.5% (HHV). The Table 2 performance data indicates a falloff in performance. The useful thermal energy to produce steam is taken from engine exhaust which limits the potential heat recovery. There have been several problems with the steam metering which may account for the very low 2.28% thermal efficiency (HHV). During the Figure measurement period during two months of the year ~8.8% thermal efficiency (HHV) was achieved.

When the only form of heat recovery is to make steam, it is difficult to have fuel conversion efficiency greater than 40-45% (in this case highest measured value was 40% in December 2009). Even with this low efficiency, the economics of the system can still make sense because heat provided as steam is more valuable than the low grade heat available as hot water from the engine jacket.

3 The data shown in the Capacity Factor graph passes all data quality checks and therefore, in some cases where data quality is poor, leaves out a significant amount of data points.

APPENDIX A: KEY DATA MEASURES AND QUALITY

The three key parameters contributing to system energy efficiency were DG/CHP Generator Output, DG/CHP Generator Gas Use and Useful Heat Recovery (total MBtu). These parameters were measured at this site as follows:

1. **DG/CHP Generator Output (total kWh)** The data for Generator Output comes from two 15-minute accumulators for the energy produced by the engines. The rows of origin for these data points are labeled “Eng1Net-kWh”, “Eng2Net-kWh”, “Eng3Net-kWh”, and “Eng4Net-kWh” in the data files received from Coned Solutions. The sum of the four generators is assigned as the energy produced for that interval. This 15-minute energy data is then summed into hourly data.
2. **DG/CHP Generator Gas Use (total cubic feet)** The data for Generator Gas Input comes from two 15-minute accumulators for gas flow. The rows of origin for these data points are labeled “Engine1Gas”, “Engine2Gas”, “Engine3Gas”, and “Engine4Gas” in the data files received from Coned Solutions. The sum of the four generators is assigned as the gas used for that interval. This 15-minute gas data is then summed into hourly data.
3. **Useful Heat Recovery (total MBtu)** The Useful Heat Recovery comes from a 15-minute accumulator for the steam produced from the engines. The row of origin for this data point is labeled “BFd-Wtr-Tot” in the data files received from Coned Solutions. This value was provided for engines 1&2 and engines 3&4. The value for engine 1 & 2 was only ever greater than zero. This 15-minute heat recovery data is then summed into hourly data.

Data Collection and quality for this site for much of the period is in the range for the three critical parameters (power, fuel and useful thermal energy) from a low of 15.5% to a high of 100%. Data for most months is in the high (Table 3). For this site two files are received for the ESCO which compose most of the data. The second file has not been sent consistently for a few months. The useful heat recovery is on the first file.

Data collection plans should form the backbone of demonstrating sites and these plans need mechanisms to require and automate all critical data collection.

TABLE 3 PERCENTAGE OF GOOD DATA

	Percentage of Good Data		
	Power	**Gas Use**	**Useful Heat**
October-07	97.7%	96.9%	98.4%
November-07	100.0%	100.0%	100.0%
December-07	99.7%	48.1%	100.0%
January-08	98.7%	95.4%	99.6%
February-08	99.6%	99.6%	99.6%
March-08	96.1%	96.1%	96.9%
April-08	99.7%	97.5%	100.0%
May-08	97.3%	97.3%	97.3%
June-08	97.2%	97.1%	98.8%
July-08	99.1%	99.1%	99.1%
August-08	99.3%	99.3%	99.3%
September-08	97.9%	97.9%	97.9%
October-08	97.6%	97.4%	99.3%
November-08	96.8%	96.8%	97.5%
December-08	97.2%	97.2%	97.3%
January-09	78.2%	78.2%	85.2%
February-09	85.0%	84.8%	91.4%
March-09	95.0%	92.5%	98.1%
April-09	92.2%	91.9%	18.2%

May-09	92.2%	91.9%	18.2%
June-09	95.7%	95.7%	60.6%
July-09	95.5%	95.5%	97.6%
August-09	94.9%	94.9%	96.2%
September-09	97.6%	97.6%	98.3%
October-09	69.4%	69.4%	77.5%
November-09	76.9%	76.9%	87.5%
December-09	94.8%	94.8%	94.8%
January-10	91.4%	91.4%	96.9%
February-10	88.5%	88.5%	93.9%
March-10	15.5%	15.5%	15.5%
April-10	87.8%	87.8%	89.0%
May-10	91.1%	91.1%	91.7%
June-10	99.3%	99.3%	99.4%
July-10	95.2%	95.2%	95.7%
August-10	95.0%	95.0%	95.0%
September-10	46.0%	46.0%	47.0%
October-10	86.6%	86.6%	93.6%
November-10	98.7%	98.7%	98.9%
December-10	98.6%	98.2%	98.8%
January-11	94.4%	94.4%	96.9%
February-11	66.4%	66.4%	66.4%
March-11			
April-11	31.7%	31.7%	96.5%
May-11	31.7%	31.7%	96.5%
June-11	4.6%	4.6%	99.7%
July-11	12.9%	12.9%	98.9%