NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT CO-OP CITY - RIVERBAY

October 9, 2013

Co-op City - Riverbay

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.

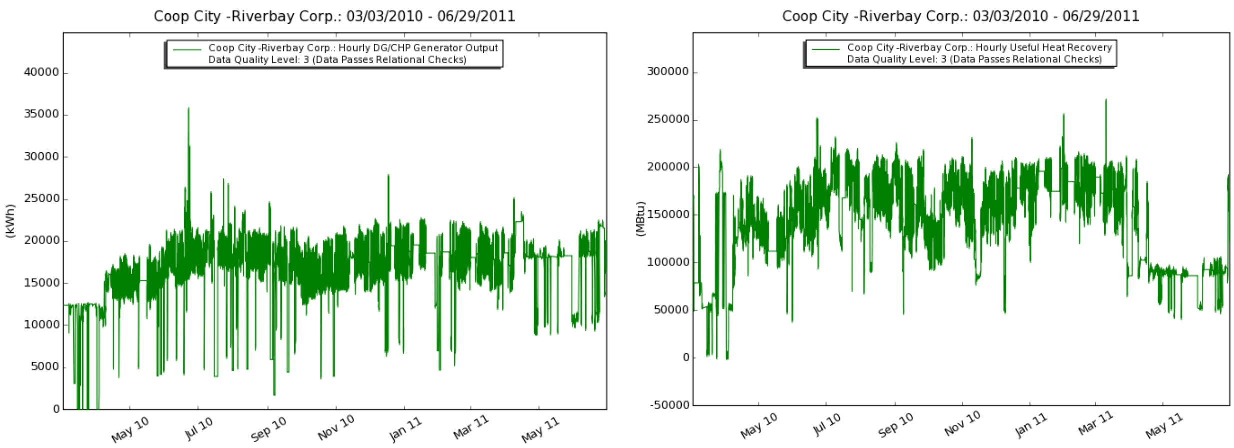

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

This report provides an 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 CO-OP CITY IS A NEW YORK CITY HOUSING CO-OPERATIVE

RiverBay Corporation is the company that manages Co-Op City. Co-op City is a New York City housing Co-operative located in the Northeast Bronx with 15,372 residential units in 35 high-rise buildings and 7 townhouse clusters. Co-op City has approximately 50,000 residents.

THE SYSTEM

The physical plant complex is located on the corner of Bartow Ave and Co-op City Blvd (Figure 3). Riverbay has submitted an application to the NYSERDA CIPP program to install a 38 MW Combined Cycle CHP system at their campus in the Bronx, New York. The Plant includes two 12.5 MW Siemens Combustion Turbines (CTs), two Once-Through Steam Generators (OTSGs) to generate 850 psig steam, and a 13 MW steam turbine generator. The steam exiting the turbine at 150 psig is used to meet campus heating loads in the winter and to drive steam-turbine centrifugal chillers in the summer. The combustion turbines can operate on natural gas or fuel oil. A Siemens T-3000 digital control system was installed to operate and monitor plant performance.

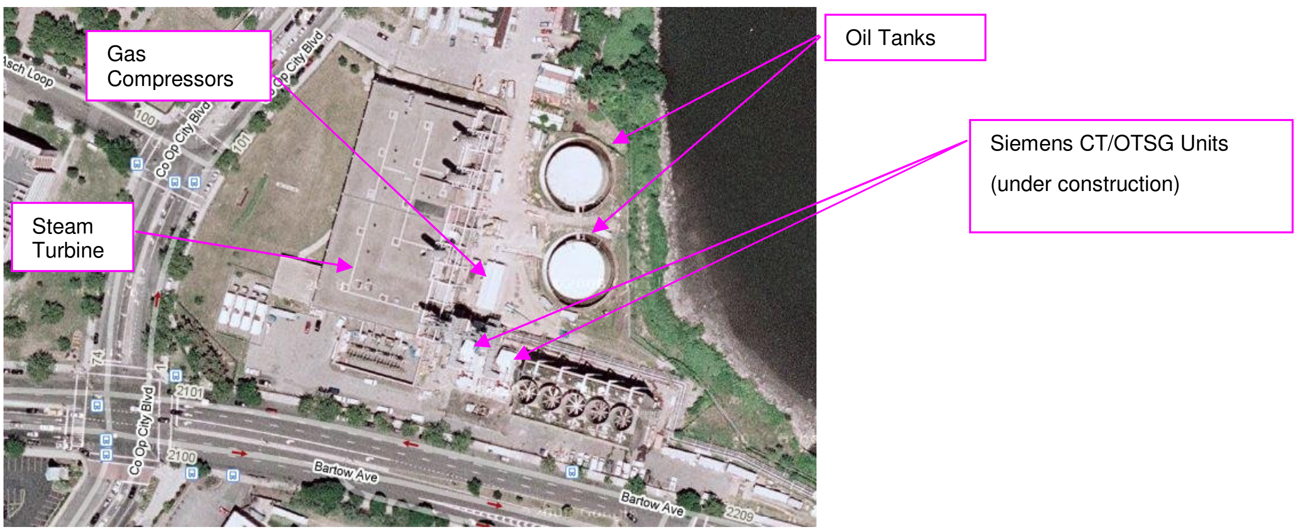

FIGURE 3. SATELLITE PHOTO OF PHYSICAL PLANT AT CO-OP CITY

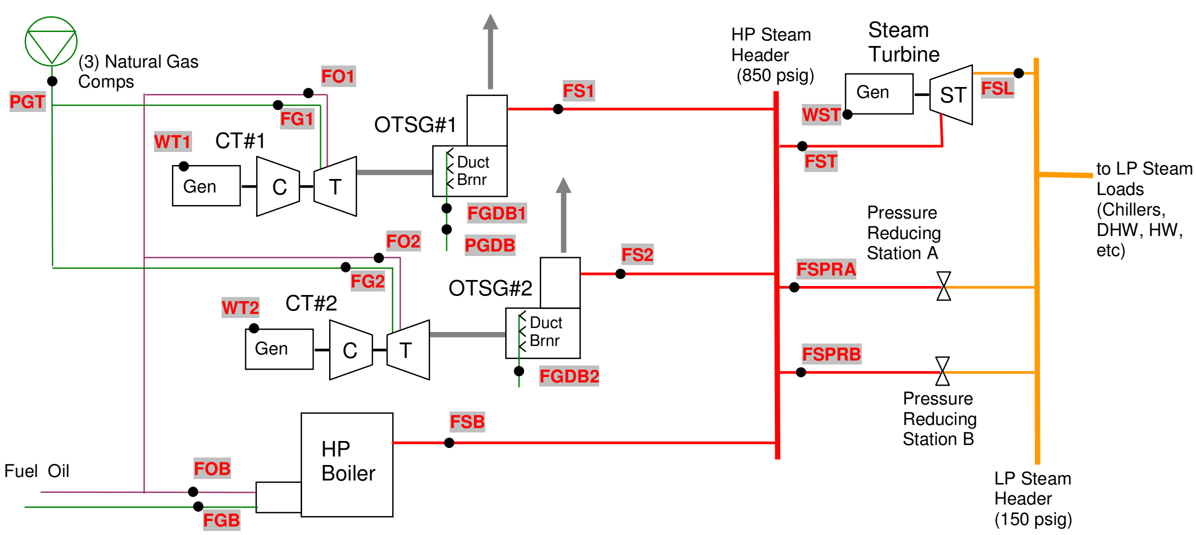

FIGURE 4. SCHEMATIC OF CHP SYSTEM WITH MONITORED DATA POINTS SHOWN

PERFORMANCE

The CHP system was commissioned in June 2010.

The system configuration is somewhat unique in that full power output of the steam turbine cannot be realized unless the high pressure boiler is used. Therefore data included in the NYSERDA DG/CHP database focuses on the entire system and three database values were setup as follows:

1. the combined electrical output is measured for all three turbines (2 combustion turbines and 1 steam turbine)
2. the single gas input includes the combustion turbines, the duct burners, and the high pressure boiler
3. the thermal output combines the steam output from the OTSGs and the high pressure steam boiler

This limitation met the needs of the NYSERDA incentive calculations but presents a particular problem in isolating the performance of the CHP system components from the duct burners and high pressure boiler.

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. Incentives are performance-based and correspond to the summer-peak demand reduction (kW), energy generation (kWh), and fuel conversion efficiency (FCE) achieved by the CHP system on an annual basis over a two-year measurement and verification (M&V) period.

Table 1 provides the data results taken since June, 2010. The system normally electric load follows up to about 20-22 MW. The electrical efficiency is calculated using natural gas supplied to the system including the combustion turbines, duct burners and high pressure boiler. Therefore, the reported electrical efficiency in Table 1 is less than would be expected from a more traditional combined cycle power generating system. In fact the system electrical efficiency drops when the high pressure boiler is used more (see August to December). The fuel conversion efficiency exceeds 100% in March 2010 and May-June 2011, likely due to an instrumentation error.

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
June-10	709	12,865,466	158,683	112,910	27.1%	69.8%	96.9%
July-10	604	11,363,795	159,460	113,557	23.8%	69.8%	93.7%
August-10	674	12,511,627	191,333	114,919	21.9%	58.9%	80.8%
September-10	615	10,624,956	162,503	106,453	21.9%	64.2%	86.1%
October-10	686	10,923,813	166,762	103,895	21.9%	61.1%	83.0%
November-10	684	11,854,840	165,442	99,288	24.0%	58.8%	82.8%
December-10	672	11,393,841	170,431	110,493	22.4%	63.6%	85.9%
January-11	408	6,943,064	102,725	68,899	22.6%	65.8%	88.4%
February-11	505	8,725,761	132,068	94,573	22.1%	70.2%	92.3%

[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.

March-11	575	9,829,174	148,080	90,261	22.2%	59.8%	82.0%
April-11	528	9,533,170	126,602	57,390	25.2%	44.4%	69.6%
May-11	456	7,677,823	26,519	35,026	96.9%	129.5%	226.4%
June-11	648	11,159,581	20,839	46,215	179.2%	217.4%	396.6%
July-11	479	9,903,605	47,722	60,929	69.4%	125.2%	194.6%
Total preceding 12 months	**6,930**	**121,081,255**	**1,461,027**	**988,342**	**27.7%**	**66.3%**	**94.1%**

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

At this particular site, the manual transfer of six different data files causes significant distortion of the results; therefore at certain times (e.g., starting in May 2011) we can receive part of the data set which skews the efficiency calculations for the month. This is a reporting problem and not an operating problem.

OPERATING SUMMARY

The CHP system consists of 38 MW of combined cycle power capacity with 150 psig steam for thermal uses. During the 9,998 hours that met the range and relational checks 96% of this time the CHP system delivered above 10 MW and 63% of the time between 15 and 20 MW. (Figure 14).

The performance from the CHP system at this site consisting of the combustion turbines, HRSGs and duct burners cannot be completely determined as the high pressure boiler fuel is also part of the calculation. Furthermore the supply of the data required is delayed and not reliable, so the accuracy of the overall efficiency data remains in question.

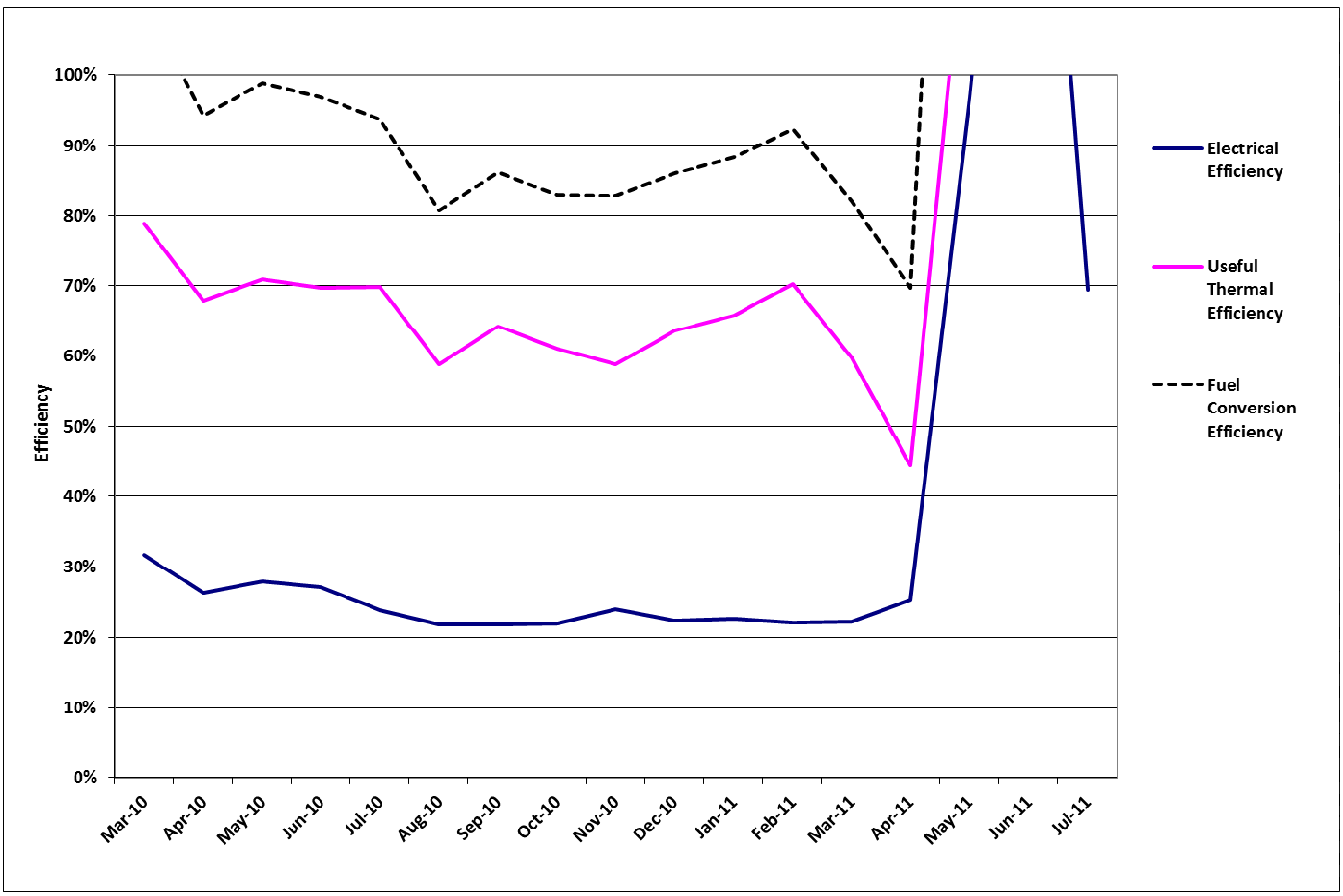

FIGURE 5 CHP SYSTEM EFFICIENCY BY MONTH

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Figure 5 provides operating efficiency during the period showing electric and useful thermal efficiency performance. Note: data for March 2010 and May-July 2011 shows data reporting error.

POWER GENERATION AND USEFUL THERMAL ENERGY

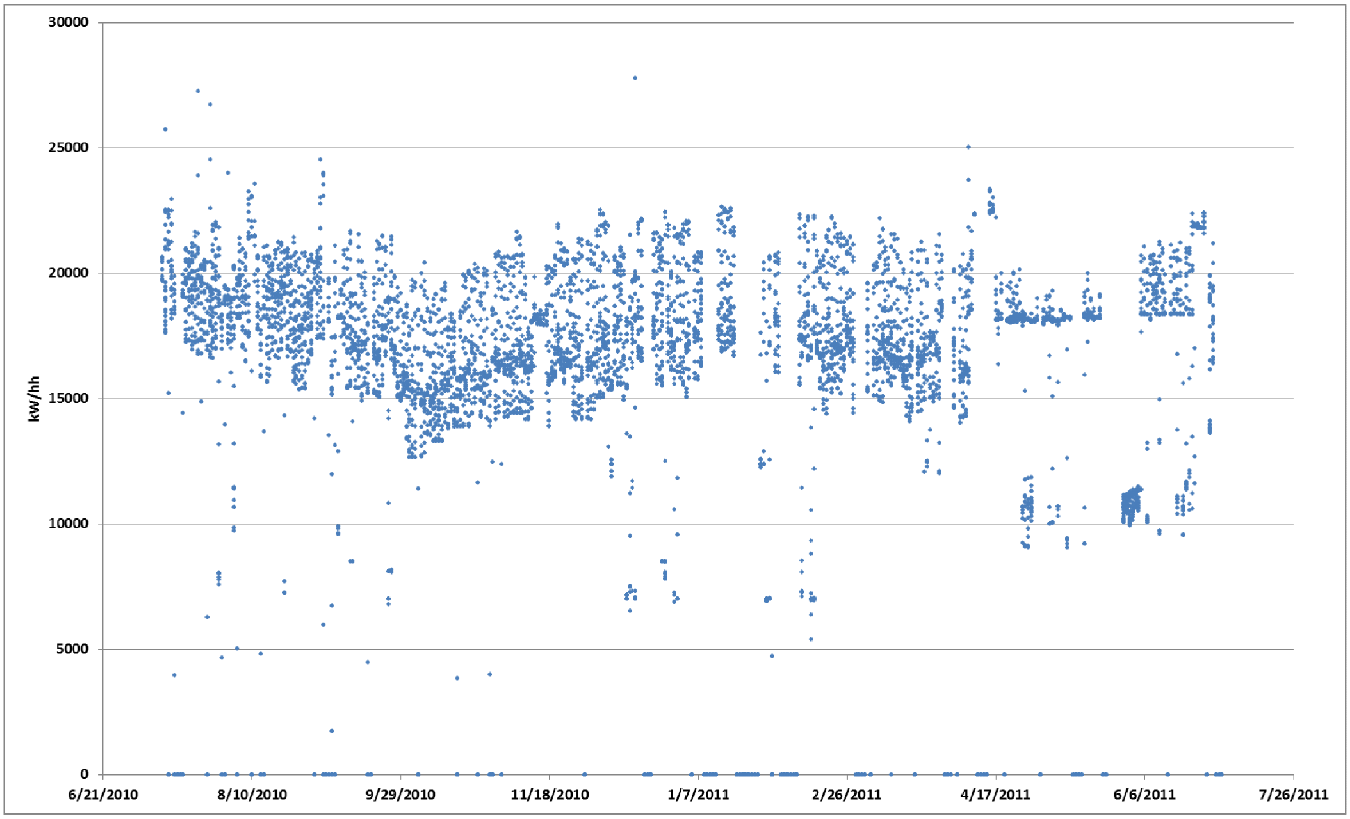

FIGURE 6 CHP POWER OUTPUT VERSUS TIME

Figure 6 presents two distinct power performance regions that require explanation. Prior to April 2011 the system operated in an electric load following mode with a power range between 15 to 22 MW depending on the time of day (Figure 8 and Figure 10) with weekends somewhat lower. After April 2011 the power range tightened to about 18 to 21 MW with one turbine offline occasionally creating a cluster around 10 MW (Figure 12).

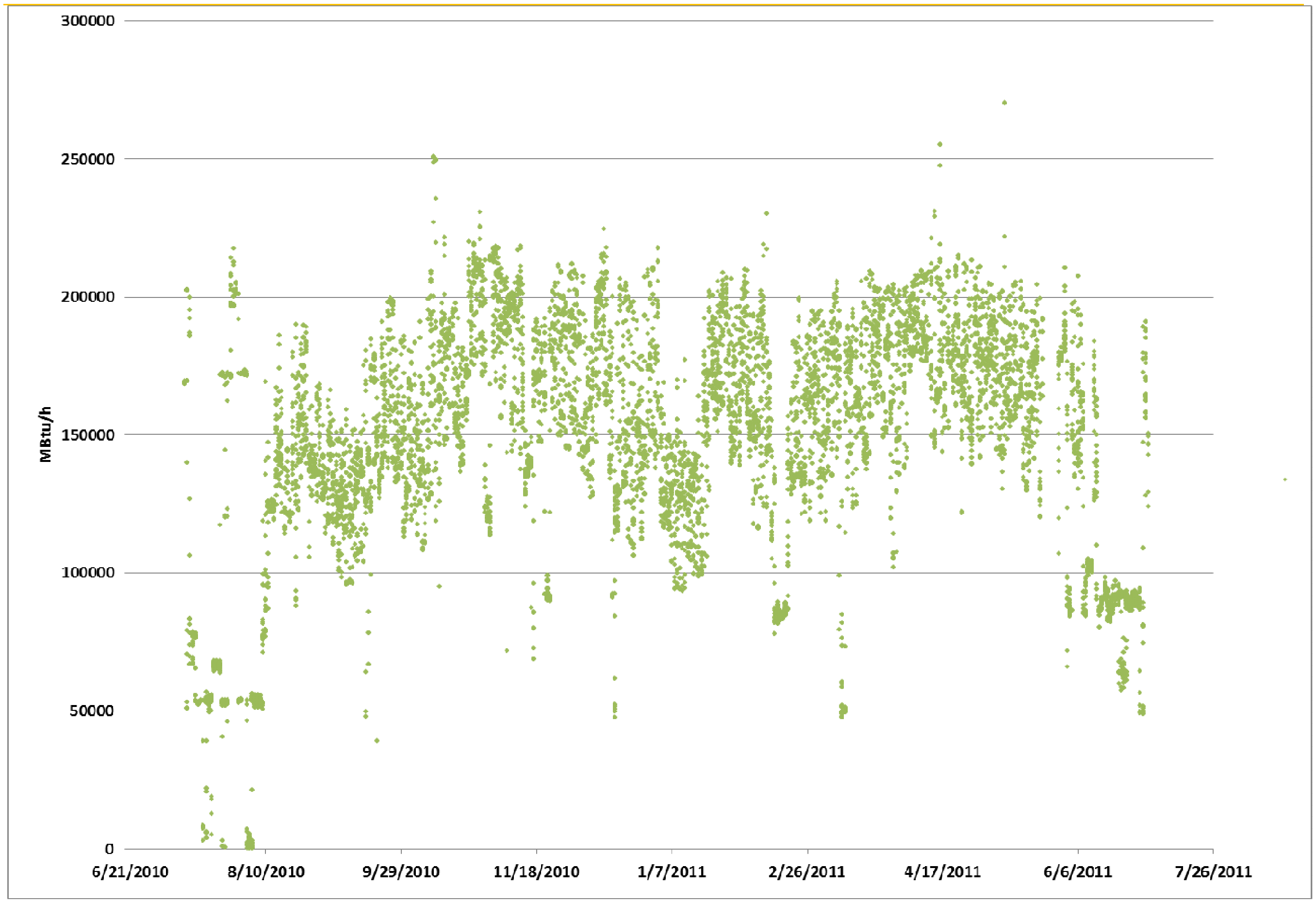

FIGURE 7 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Useful thermal energy varies from 100,000 MBtu to over 200,000 MBtu. Reported steam usage fell off in May and June of 2011. This may be because of the lack of good quality data which is being investigated.

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

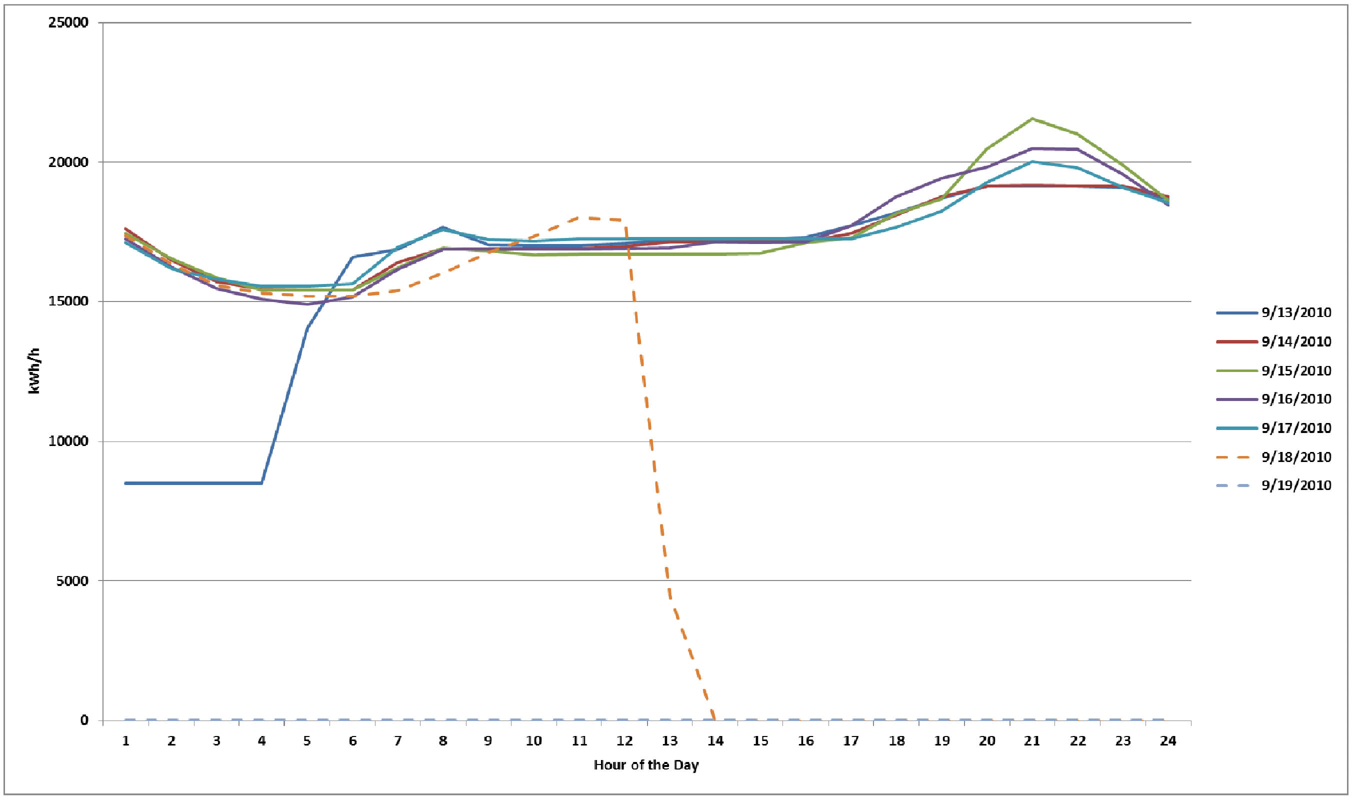

FIGURE 8 CHP POWER OUTPUT VERSUS TIME

Figure 8 covers the time period from September-13-19, 2010, providing CHP system power output by hour of the day pattern for the time period. September 13 is a Monday and September 18 and 19 are Saturday and Sunday respectively. Figure 6 shows that all days except Saturday and Sunday showing similar usage patterns operating in an electric load following mode. Saturday and Sunday usage patterns indicate that both of the two turbines were offline. Examining the delivered electric power pattern, the system is being controlled in electric load following mode during the week days and shut down at 2 pm on Saturday and remains off on Sunday.

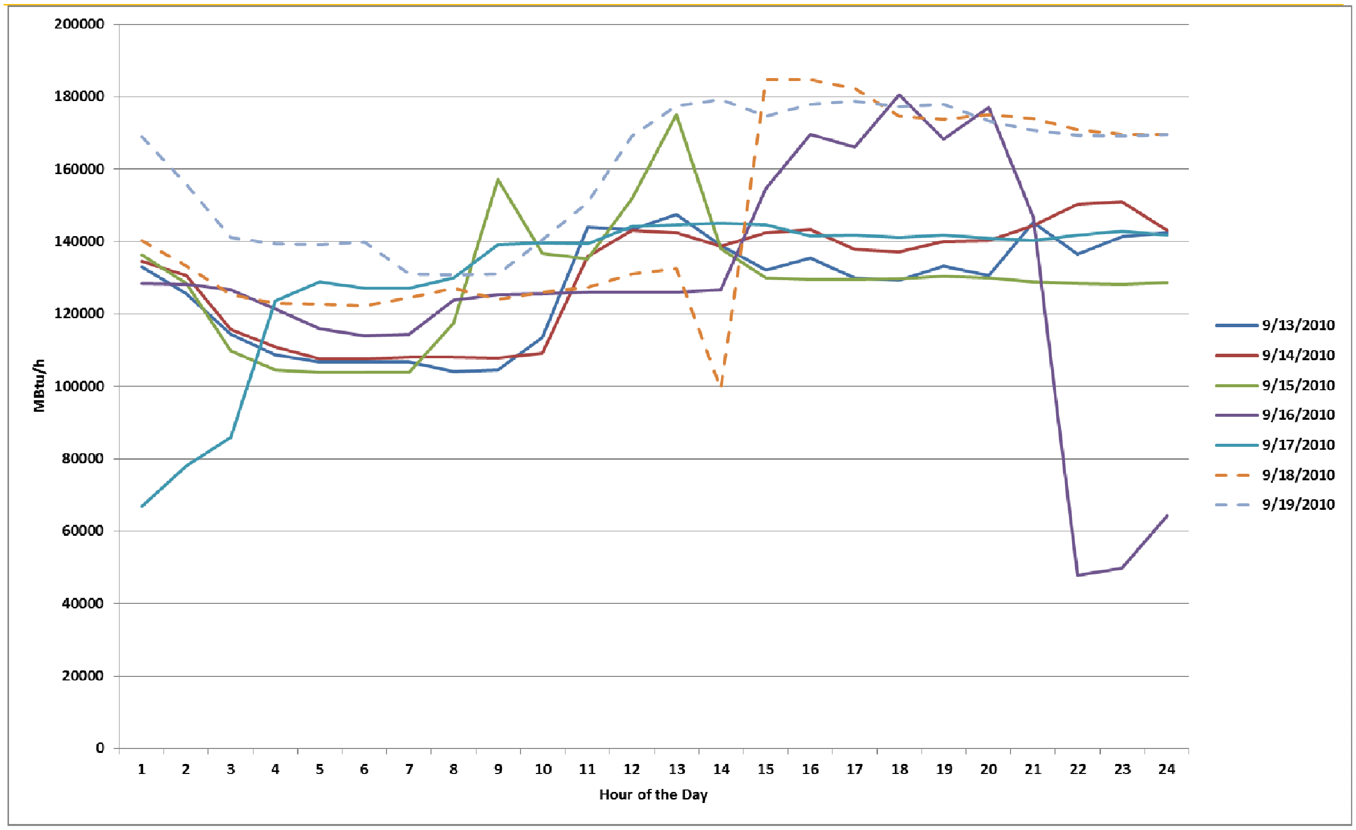

FIGURE 9 CHP USEFUL THERMAL OUTPUT VERSUS TIME (MBTU/HR)

Figure 9 covers the time period from September-13-19, 2010, providing CHP system power output by hour of the day pattern for the time period. September 13 is a Monday and September 18 and 19 are Saturday and Sunday respectively. Figure 9 shows a generally consistent load pattern through the week and during the weekend. It should be noted that the CHP plant was shut down over most of the weekend; however, steam was being produced by the high pressure boiler.

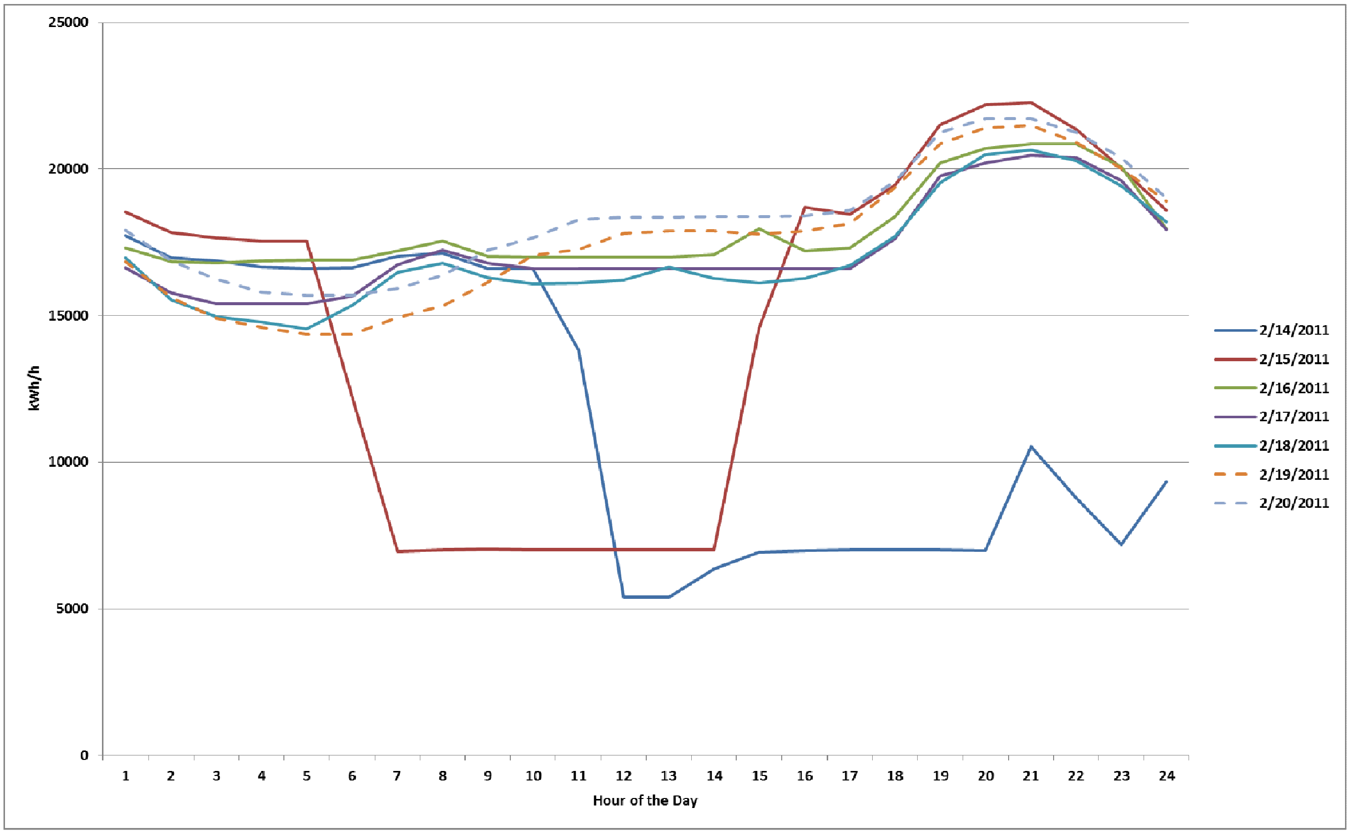

FIGURE 10 CHP POWER OUTPUT VERSUS TIME

Figure 10 covers the time period from February 14 – 20, 2011, providing CHP system power output by hour of the day pattern for the time period. February 14 is a Monday and February 19 and 20 are Saturday and Sunday respectively. Figure 10 shows that all days except Monday and Tuesday are showing similar usage patterns operating in an electric load following mode. Monday and Tuesday usage patterns indicate that one of the two turbines was periodically offline.

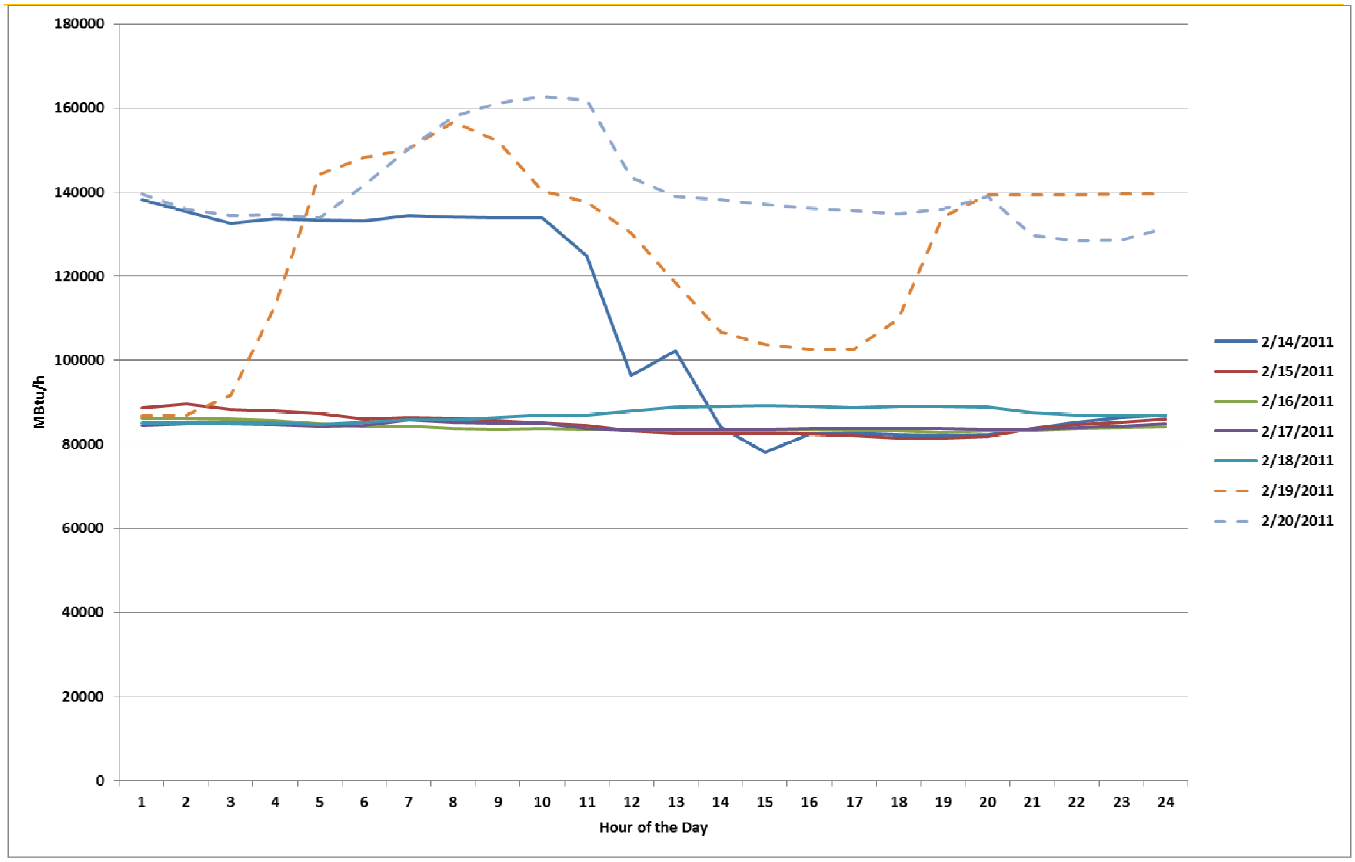

FIGURE 11 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 11 covers the time period from February 14 – 20, 2011, providing CHP system power output by hour of the day pattern for the time period. February 14 is a Monday and February 19 and 20 are Saturday and Sunday respectively. Figure 11 shows a generally consistent low load pattern Tuesday through Friday of the week.

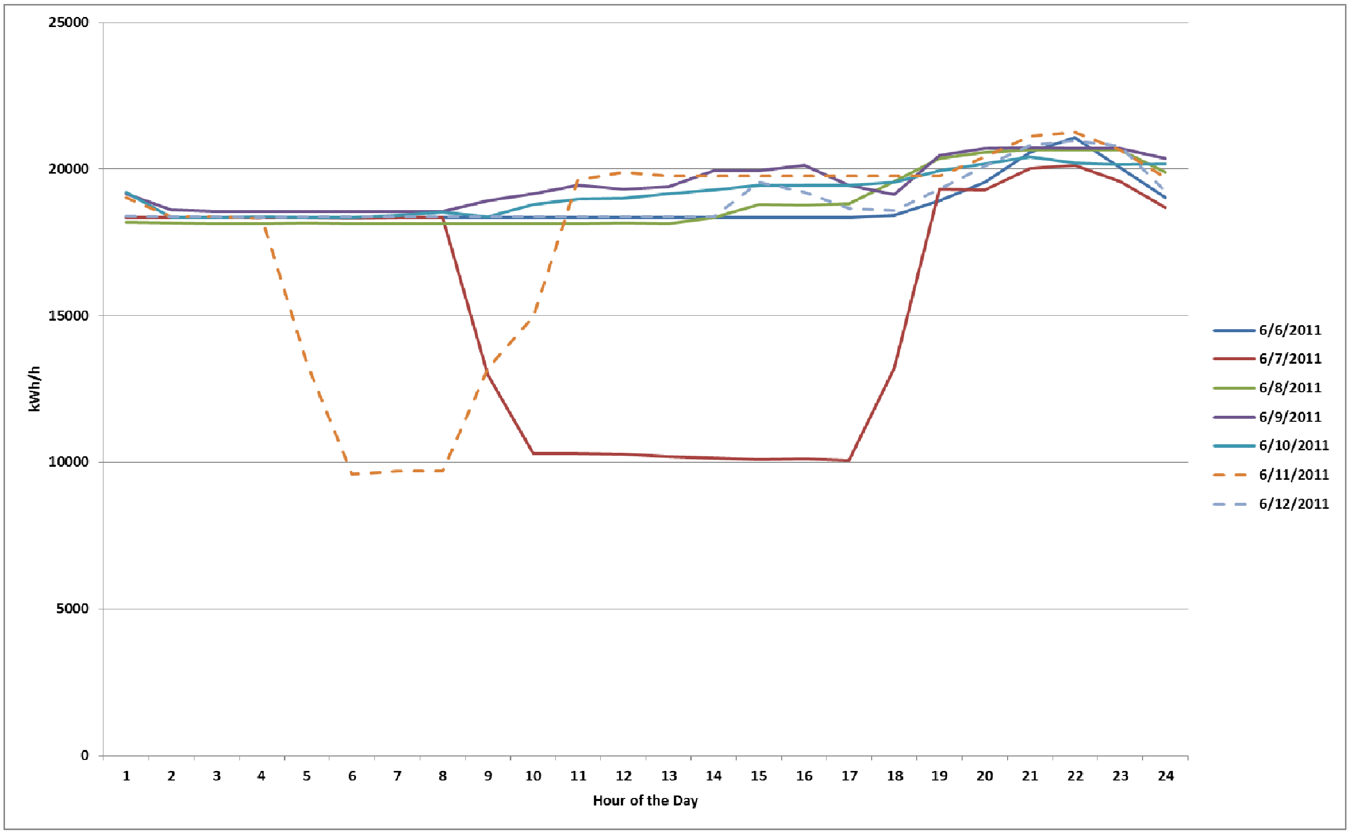

FIGURE 12 CHP POWER OUTPUT VERSUS TIME

Figure 12 covers the time period from June 6 - 12, 2011, providing CHP system power output by hour of the day pattern for the time period. June 6 is a Monday and June 11 and 12 are Saturday and Sunday respectively. Figure 12 shows that all days except Tuesday and Saturday are showing similar usage patterns operating in a tighter electric load following range than operation before April 2011. Tuesday and Saturday operation indicates that one of the two turbines was periodically offline.

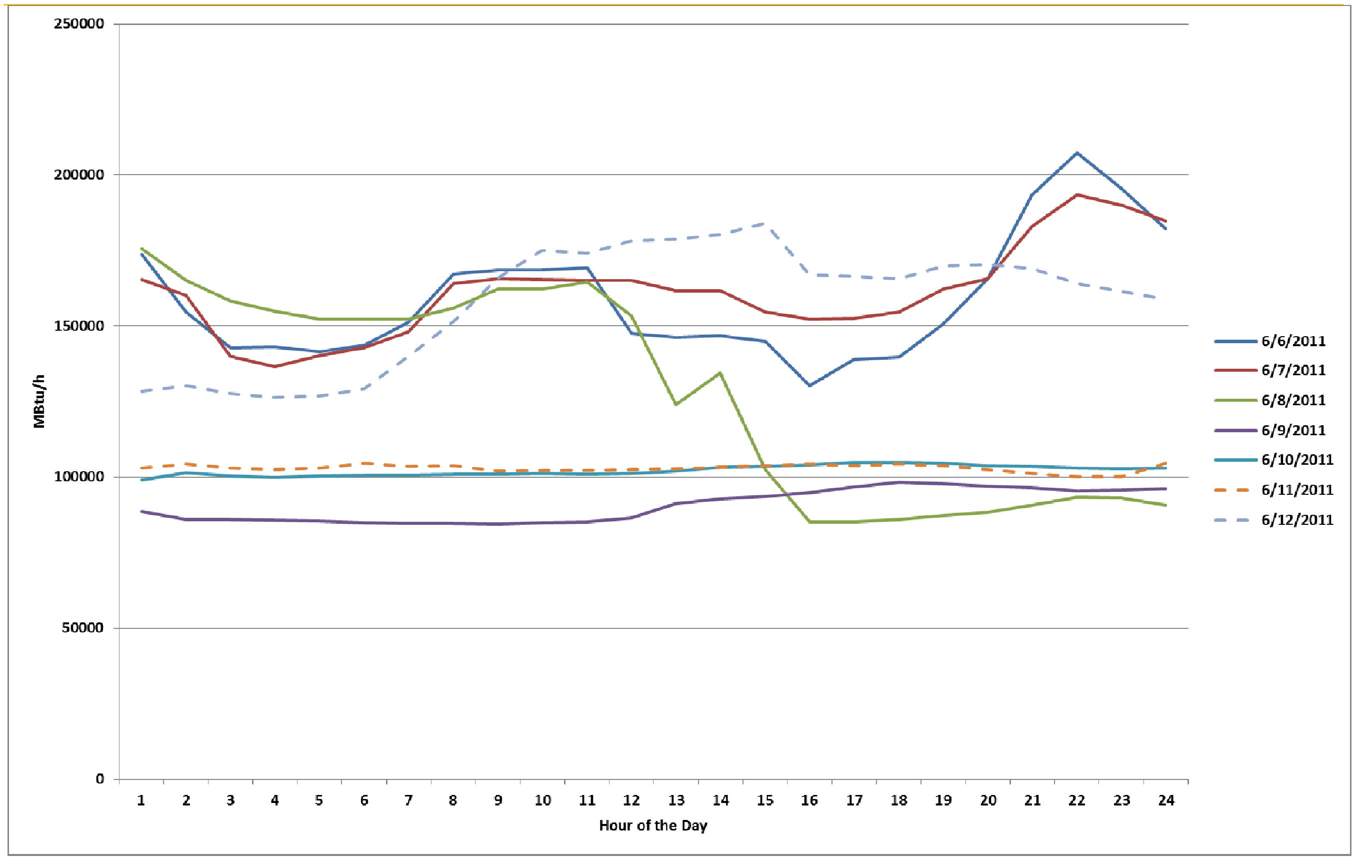

FIGURE 13 CHP USEFUL THERMAL OUTPUT VERSUS

Figure 13 covers the time period from June 6 - 12, 2011, providing CHP system power output by hour of the day pattern for the time period. June 6 is a Monday and June 11 and 12 are Saturday and Sunday respectively. Figure 13 shows two consistent load patterns, Thursday through Saturday at around 100,000 MBtu/hr and the remainder of the week operating between 130,000 and 200,000 MBtu/hr.

PERFORMANCE SUMMARY

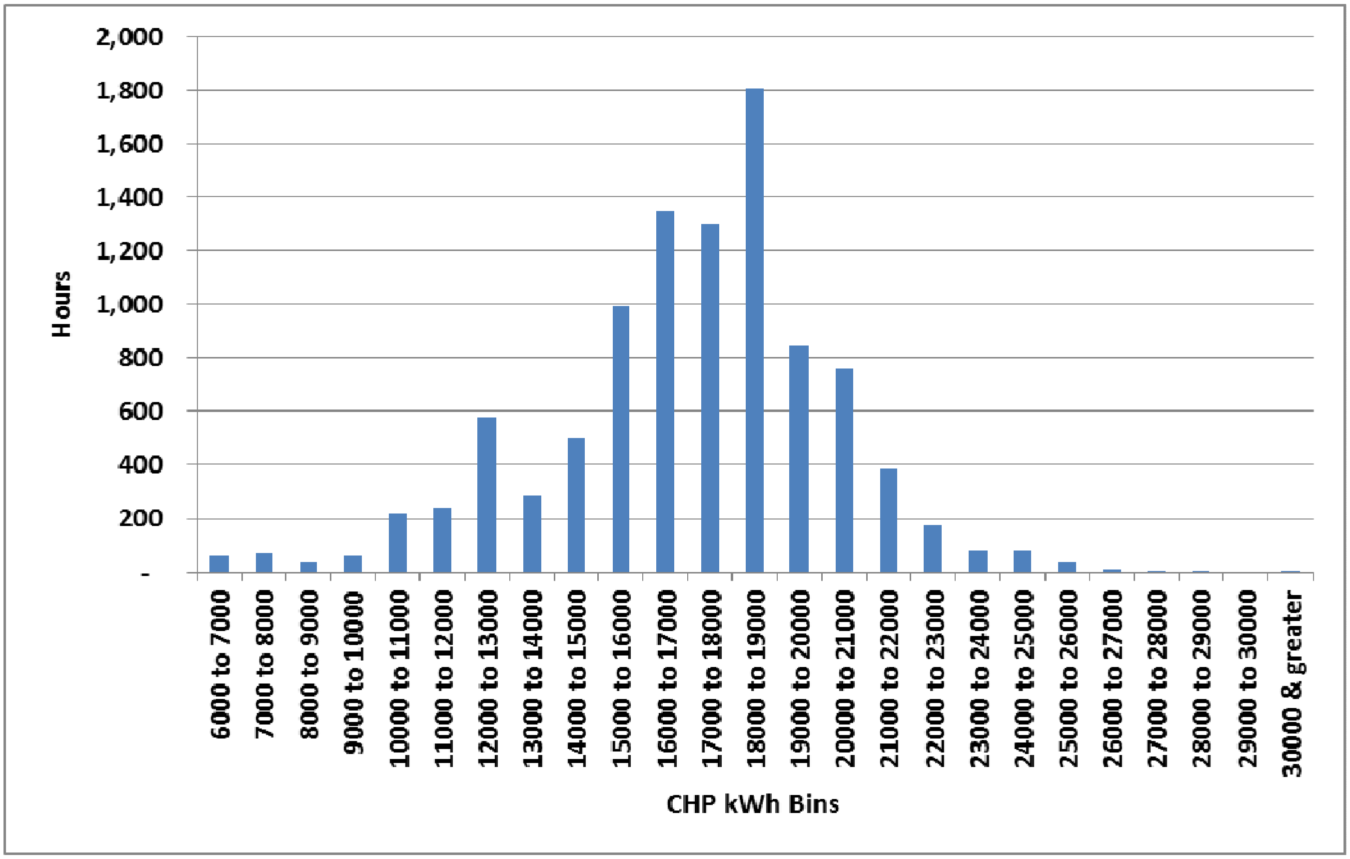

FIGURE 14 CHP SYSTEM POWER DELIVERED PER HOUR BINS

During the 9,998 hours that met the range and relational checks 96% of this time, the CHP system delivered above 10 MW and 63% of the time between 15 and 20 MW.

LESSONS LEARNED

TABLE 2 SYSTEM EFFICIENCY[2]

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

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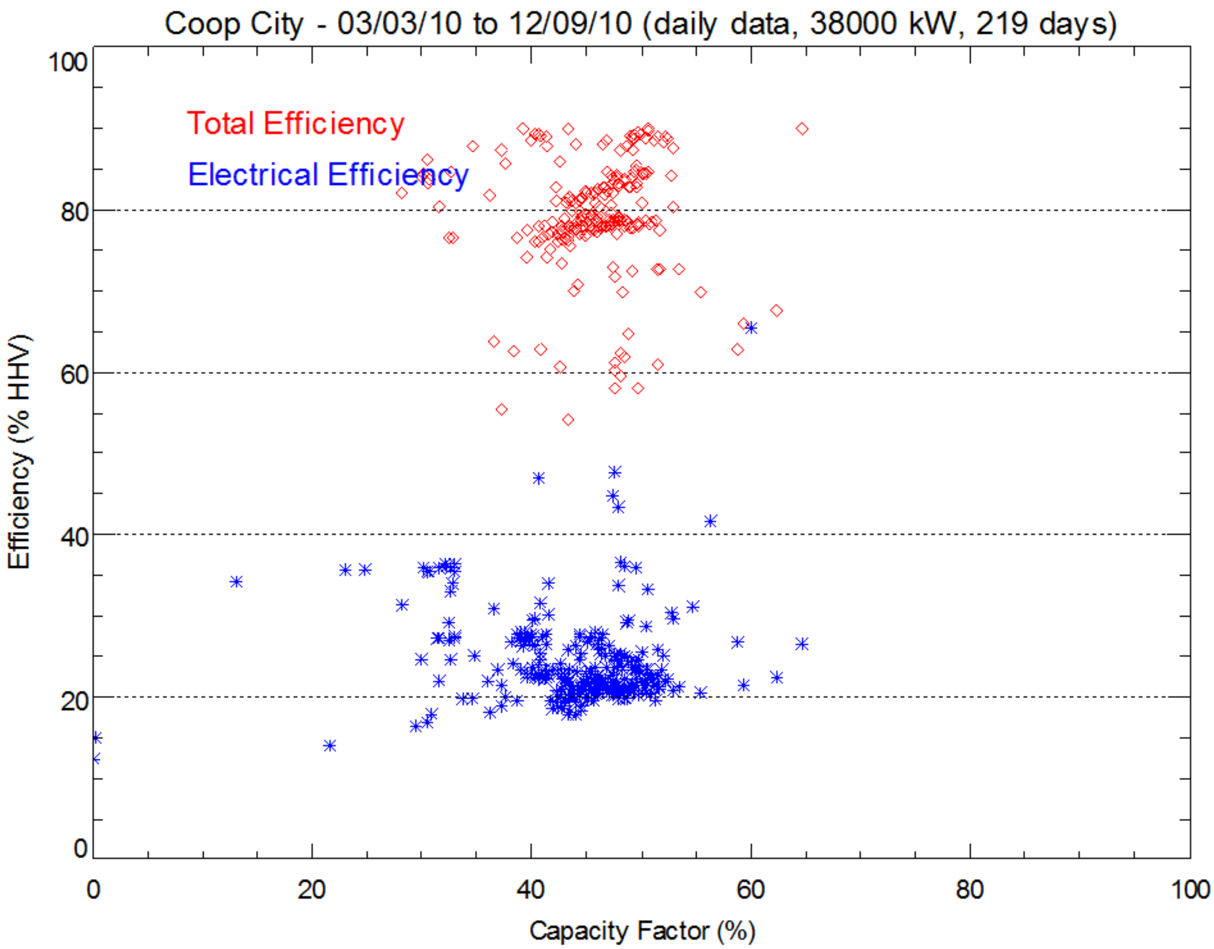

FIGURE 15 CAPACITY FACTOR[3]

Capacity Factor (Figure 15) presents the CHP generated power efficiency over the time period (219 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. The Figure shows the system operated between 22% and 62% of the generating capacity at about 27.7% power efficiency (HHV). The bulk of operation during 2010 occurred between 40% and 50% of plant capacity. The data reporting on this site is difficult as much of the data is manually uploaded and some data is simply not available. Examining the most recent data from the site shows little change from this reporting period containing reliable data. The useful thermal energy also contains a boiler output which is not accounted for in the fuel meter data leading to a high average of 66.31% thermal efficiency (HHV).

[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.

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The manual transfer of data (by the night time operator via email) was intermittent and inconsistent. This problem was further exacerbated starting in April 2011 when only part of the data set was provided for any given day. This confounded the monthly calculations of efficiency.

The hybrid combined cycle system –with a high pressure boiler – does fit into the normal definition of a CCHP plant, since boiler operation is required to get the full system power output. Therefore this system did not fit well into the framework of the DG/CHP database system.

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)** This value comes from 3 columns in the first file (columns 2, 4, and 5), which represents the power output for all three turbines. The data is given in kW for the combustion turbines and MW for the steam turbine. These 3 values are summed and converted into kWh using the interval length. This 15-minute interval energy data is summed into hourly data.
2. **DG/CHP Generator Gas Use (total cubic feet)** The data for Turbine Gas Input comes from files 3 and 4 (columns 1, 4 and 3, 5, 7 respectively). These 5 channels include the gas consumption for the two combustion turbines, the two duct burners, and the high pressure boiler. This data is provided as 1000 cubic feet per hour or as lbs per hour for each 15-minute interval. It is converted into standard cubic feet of natural gas and summed into hourly data.
3. **Useful Heat Recovery (total MBtu)** Useful heat recovery comes from file 4 (columns 1, 2, 4) and represents the high pressure steam output of the Once Through Steam Generators (OTSGs) and the High Pressure Boiler. The data is provided in 1000 lbs per hour for each 15 minute interval and represents the steam which leaves the high pressure side of this system. This data is converted into MBtus (using a factor of 1159.5 Btu/lb) and summed into hourly data.

Clearly, the results reported on this site do not reflect the performance of the CHP system, as fuel, power and steam data is from combined sources:

1. Measured fuel combined combustion turbine, duct burners and high pressure boiler fuel. The combustion turbines, duct burners and high pressure boiler should all be sub-metered.
2. Thermal output from the unfired Heat Recovery Steam Generators needs to be reported separately from the duct burner and boiler contribution.
3. Electric power output from the combustion turbines should be separated from the steam turbine generator.

The above instrumentation changes would provide a clear and more accurate picture of the system performance.

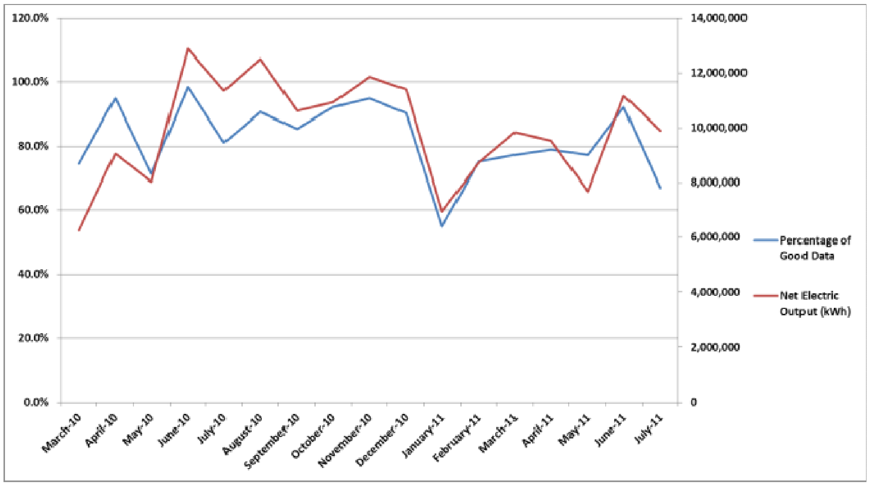
This particular site uses manual data collection resulting in significant data gap. Table 1 provides insight into the data quality. The default value for poor or missing data is zero; therefore, monthly summary data with low percentage of useful data causes distortions in reported results.

TABLE 3 DATA QUALITY

	Percentage of Good Data		
	Power	Gas Use	Useful Heat
March-10	74.5%	77.3%	77.3%
April-10	95.0%	94.9%	94.9%
May-10	71.2%	69.6%	71.0%
June-10	98.5%	98.5%	98.5%
July-10	81.2%	84.3%	84.3%

August-10	90.6%	93.5%	93.5%
September-10	85.4%	88.8%	95.1%
October-10	92.2%	88.8%	92.1%
November-10	95.0%	93.3%	95.0%
December-10	90.3%	87.1%	90.3%
January-11	54.8%	51.6%	51.6%
February-11	75.1%	71.4%	78.6%
March-11	77.3%	74.1%	74.1%
April-11	78.9%	75.3%	78.9%
May-11	77.3%	18.5%	69.2%
June-11	92.2%	10.4%	71.7%
July-11	67.1%	20.0%	53.6%

At this particular site, the manual reporting of energy flow data from multiple meters causes significant distortion of the results. Using manual data collection is problematic and should not be used as standard practice. There appears to be some correlation, particularly after the June 2010 commissioning, between data availability and reported fuel use and system energy outputs. (See Figure 16 and Table 3). In fact, the percentage of good data for fuel consumption for May – June 2011 ranges from 10.4% to a high of 20%, where the good data for power generation ranges from 67.1% to 92.2% and good data for useful thermal energy ranges from 53.6% to 71.7%. The low fuel usage numbers currently reported on the site cause large distortions in efficiencies accounting for FCEs ranging from 194.6% to 396.6%.



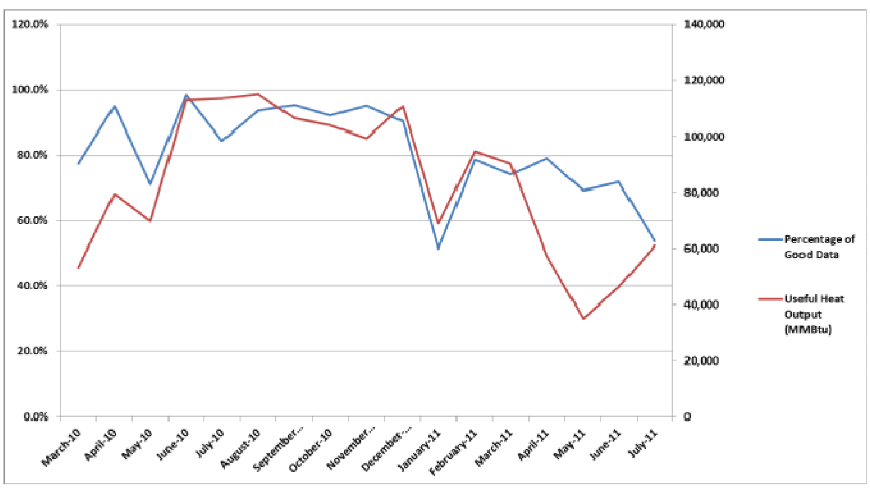


FIGURE 16 CORRELATION BETWEEN DATA QUALITY, KWH, FUEL AND USEFUL HEAT