NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT VASSAR COLLEGE

October 9, 2013

Vassar College

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.

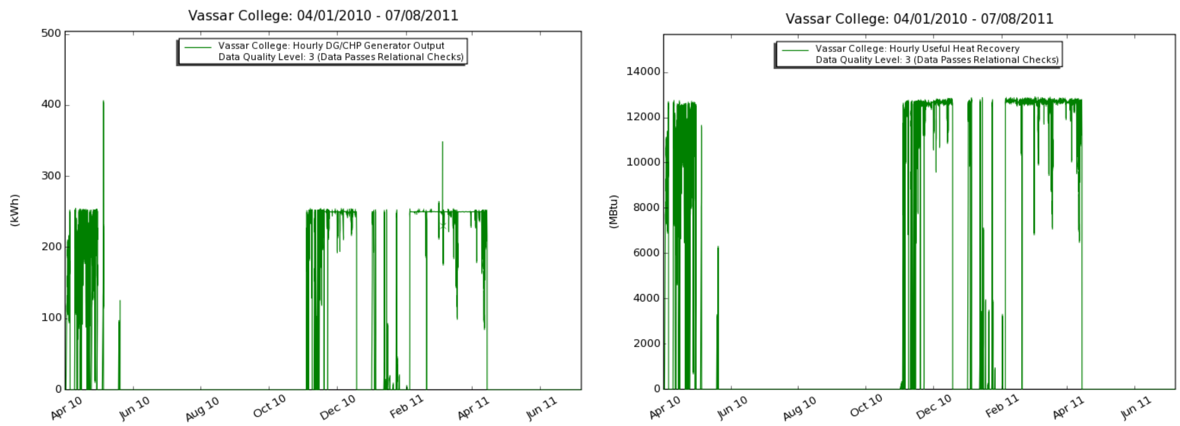

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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

Founded in 1861, Vassar College is located on a 1,000-acre landscaped campus, 70 miles north of New York City in the scenic Hudson River Valley near Poughkeepsie (area population about 100,000). Vassar is in a residential area three miles from the city center. Vassar has 2,450 students.

FIGURE 2 VASSAR COLLEGE MAIN BUILDING

THE SYSTEM

The system installed at Vassar College and monitored in this CHP waste heat recovery system is a 250 kW backpressure steam turbine generator.

Steam passes through pressure-reducing valves (PRVs), aka letdown valves, at various locations in the steam distribution system to let down or reduce its pressure. A noncondensing or backpressure steam turbine can perform the same pressure-reducing function as a PRV while converting steam energy into electrical energy.

In a backpressure steam turbogenerator, shaft power is produced when a nozzle directs jets of high-pressure steam against the blades of the turbine's rotor. The rotor is attached to a shaft that is coupled to an electrical generator. The steam turbine does not "consume" steam. It simply reduces the pressure of the steam that is subsequently exhausted into the process header. The enthalpy reduction of the steam is proportional to shaft power to the generator.

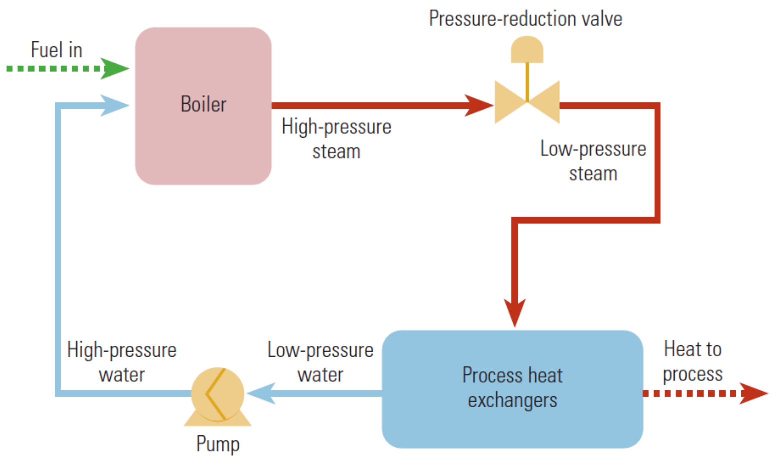

FIGURE 3 CONVENTIONAL BOILER STEAM PLANT[1]

Figure 3 shows a conventional boiler plant delivering process steam to the college campus steam heating header and/or domestic hot water loop.

Figure 4 shows installation of a backpressure steam turbine generator in parallel with the PRV.

Considering this system essentially produces electric power by absorbing heat energy from steam by reducing its pressure, there is no need to report on useful heat recovery, per se, since the heat recovered goes directly to power and the system was not instrumented to measure the heat energy used by the steam turbine in generating the power.

[1] Courtesy of Platt's POWER, January/February, 2005

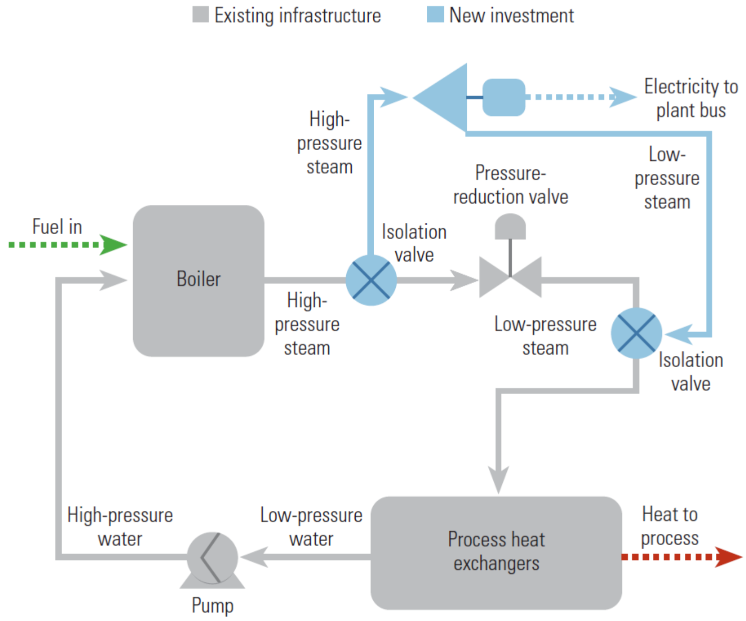

FIGURE 4 BACKPRESSURE STEAM TURBINE GENERATOR PRESSURE REDUCTION

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. 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 April of 2010. The useful thermal output is energy content of the steam leaving the turbine.

TABLE 1 SYSTEM EFFICIENCY[2]

	Hours of Good (Pwr) Data	Net Electric Output (kWh)	Useful Heat Output (MMBtu)	Electrical Efficiency
April-10	716	86,855	4,659.7	6.4%
May-10	743	2,087	94.2	7.6%
June-10	720	-	-	-
July-10	744	-	-	-
August-10	744	-	-	-
September-10	720	-	-	-
October-10	744	-	-	-
November-10	720	125,730	6,376.2	6.7%
December-10	744	104,599	5,306.6	6.7%
January-11	744	17,303	933.3	6.3%
February-11	672	148,185	7,555.0	6.7%
March-11	742	182,175	9,324.5	6.7%
April-11	720	76,279	3,940.5	6.6%
May-11	744	-	-	-
June-11	720	-	-	-
July-11	743	-	-	-
Total preceding 12 months	**8757**	**654,270**	**33,436.0**	**6.6%**

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

Table 1 presents annual data showing the 250 kW back pressure turbine operating the heating season from November through April. During that time it recovers about 250 kWh/h of power essentially taking the place of a pressure deducing valve.

OPERATING SUMMARY

[2] 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.

The Vassar College back pressure steam turbine operates in lieu of a pressure reducing station, recovering the potential flow energy normally lost in the pressure reduction, and producing power as a byproduct. The system operates at a relatively low "efficiency", extracting about 6% to 7% of the heat energy from the steam to produce shaft power (and electricity) however; the power is produced by converting heat energy to more valuable shaft power (or work) without the energy loss normally associated with a heat engine energy. The system operates only when the College boiler is producing steam for heating purposes.

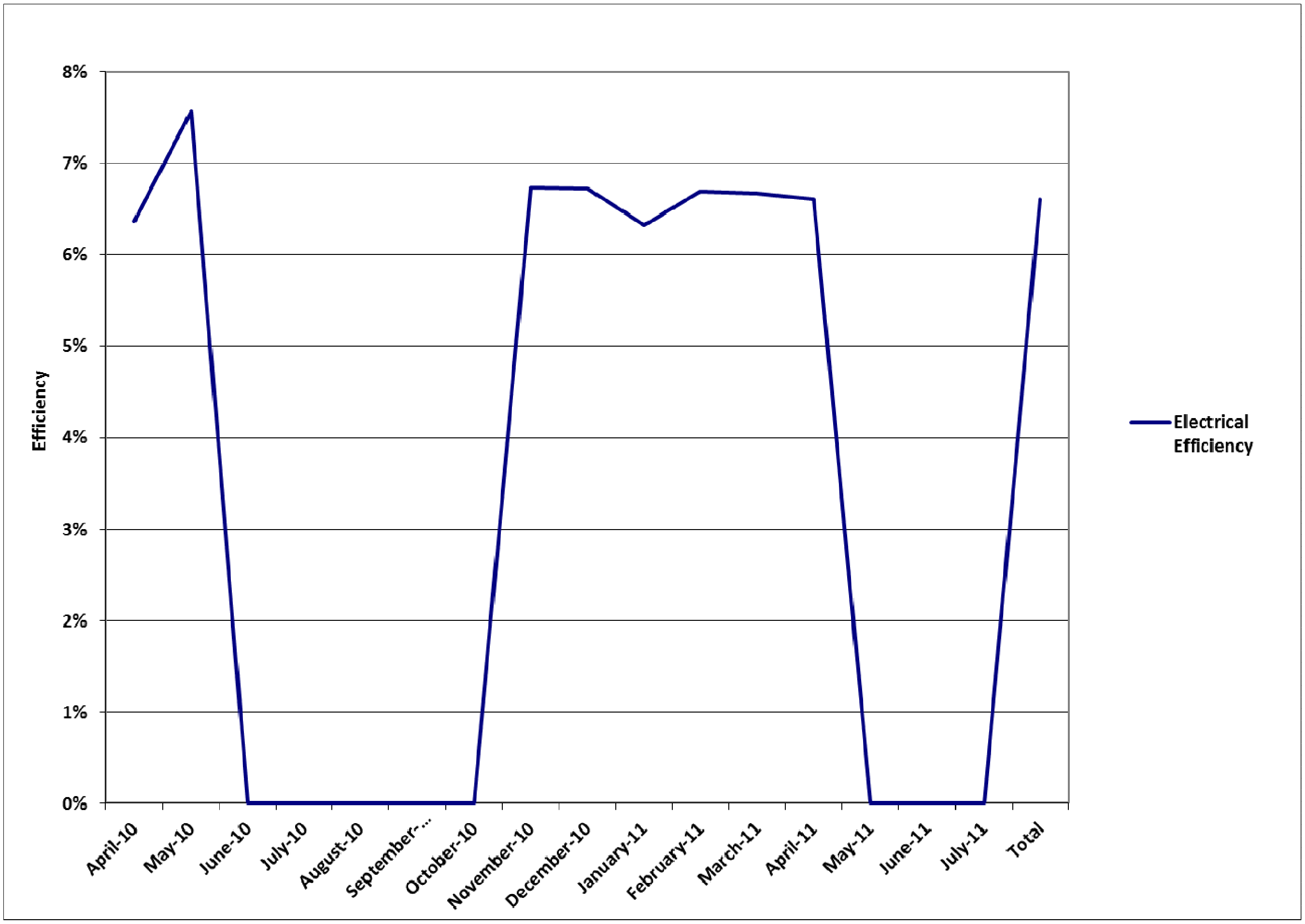

FIGURE 5 2010 CHP SYSTEM EFFICIENCY BY MONTH

Figure 5 shows operating efficiency of the back pressure turbine when operating.

POWER GENERATION AND USEFUL THERMAL ENERGY

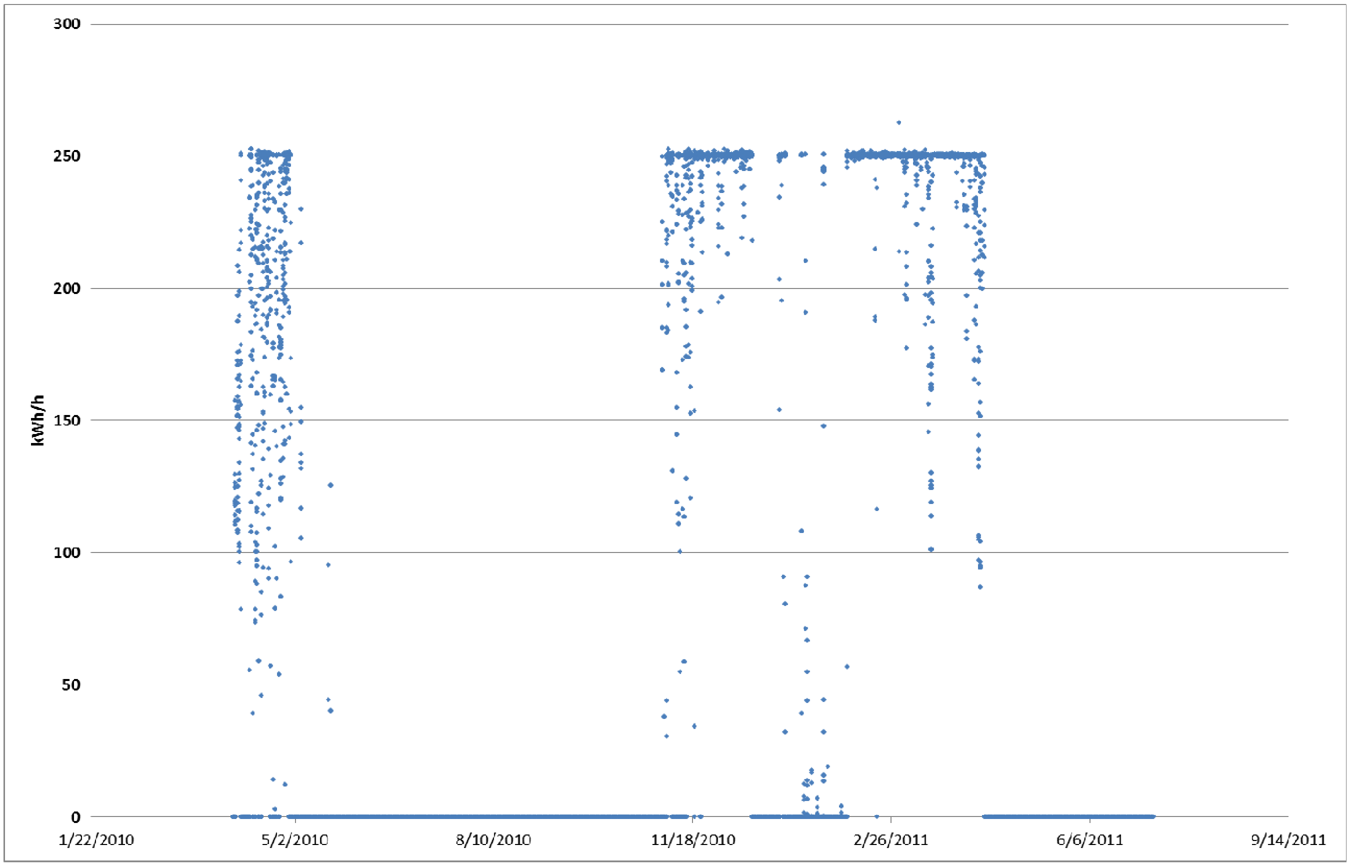

FIGURE 6 CHP POWER OUTPUT VERSUS TIME

Figure 6 show that the back pressure steam turbine operates when the steam plant at the college is in operation, which was November 2010 through mid April 2011.

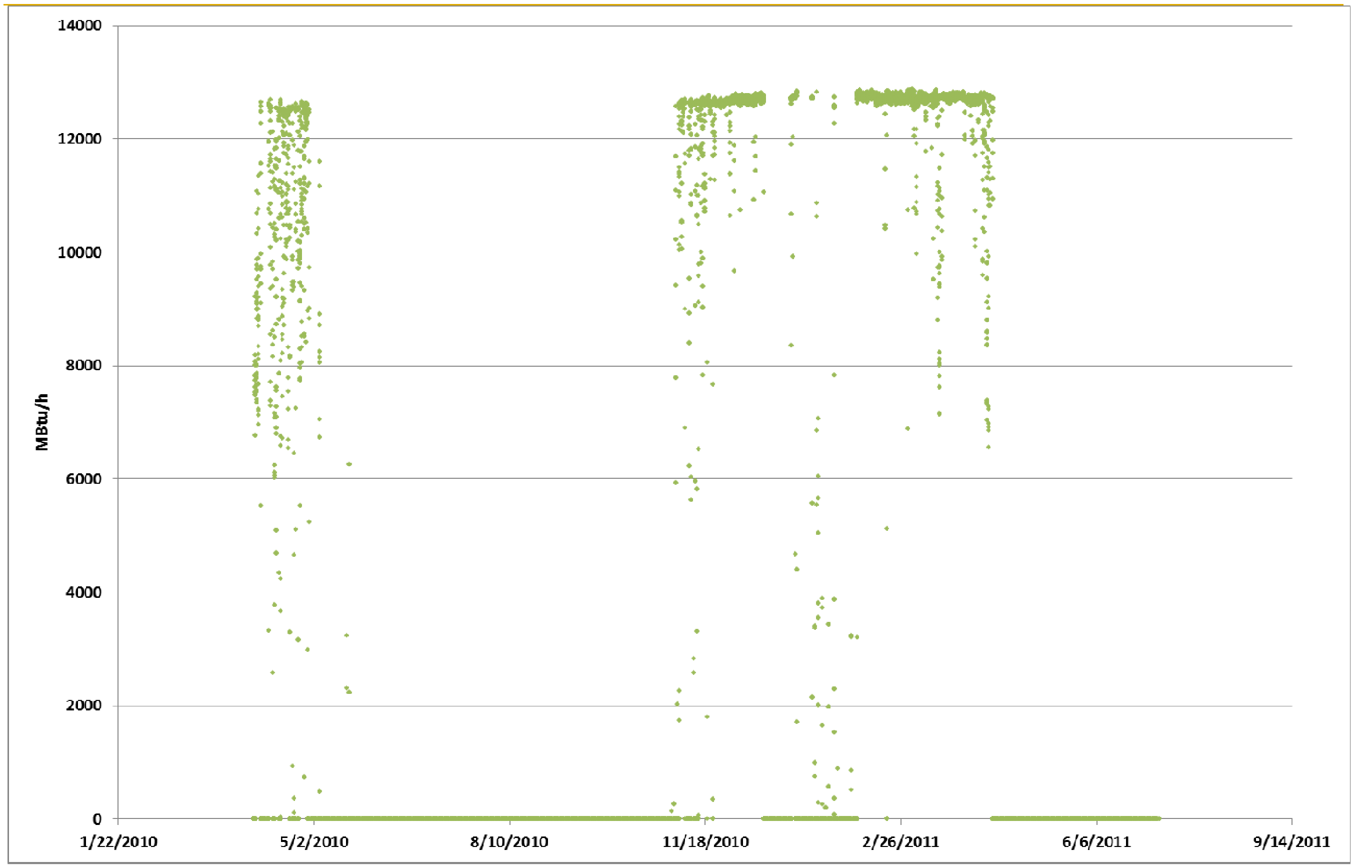

FIGURE 7 CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles (Figure 7) is calculated from the steam conditions leaving the steam turbine.

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

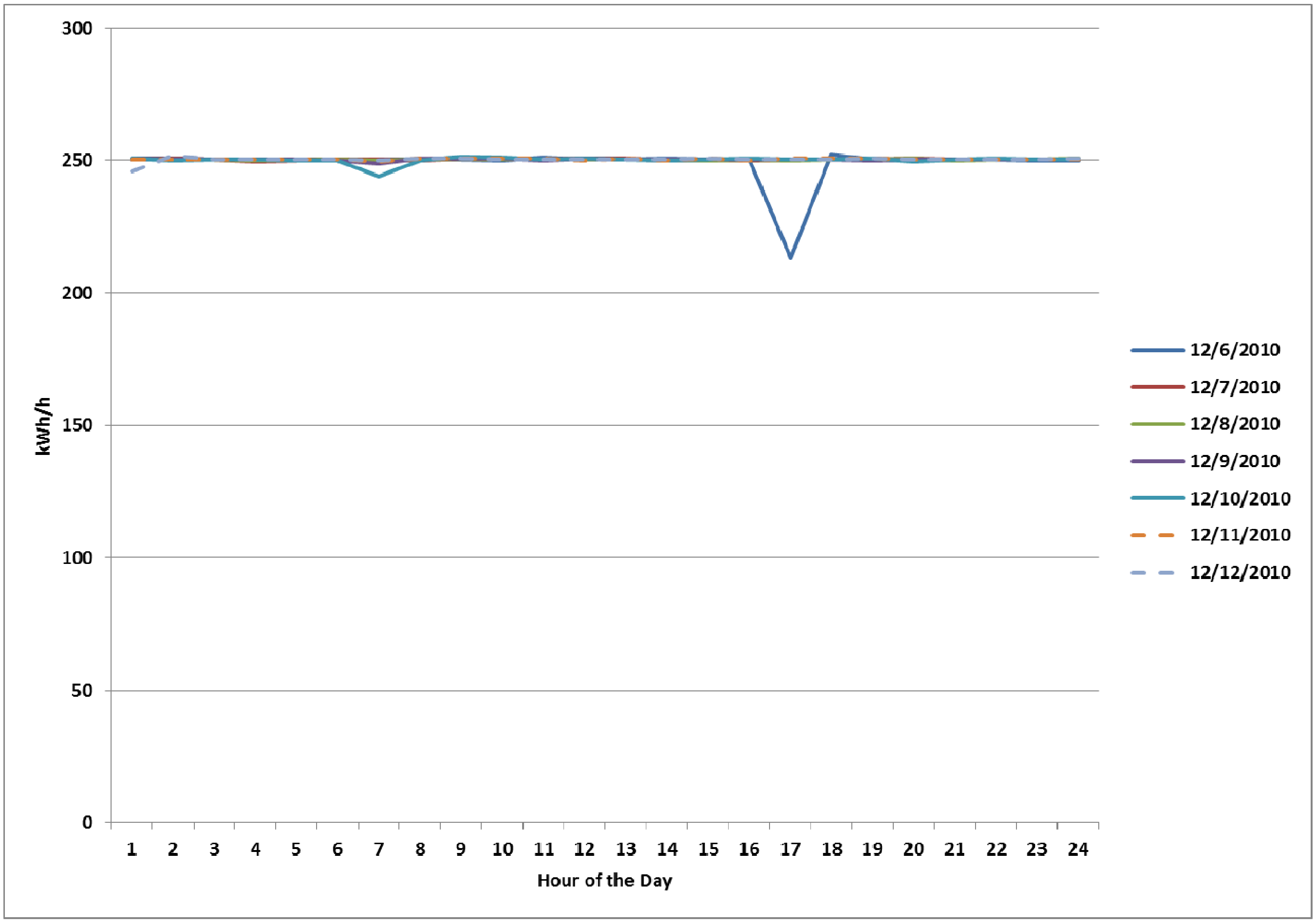

FIGURE 8 CHP POWER OUTPUT VERSUS TIME

Figure 8 covers the time period from December 6-12, 2010 providing CHP system power output by hour of the day pattern for the time period. December 11 is a Saturday. Figure 8 shows constant power recovery throughout the week.

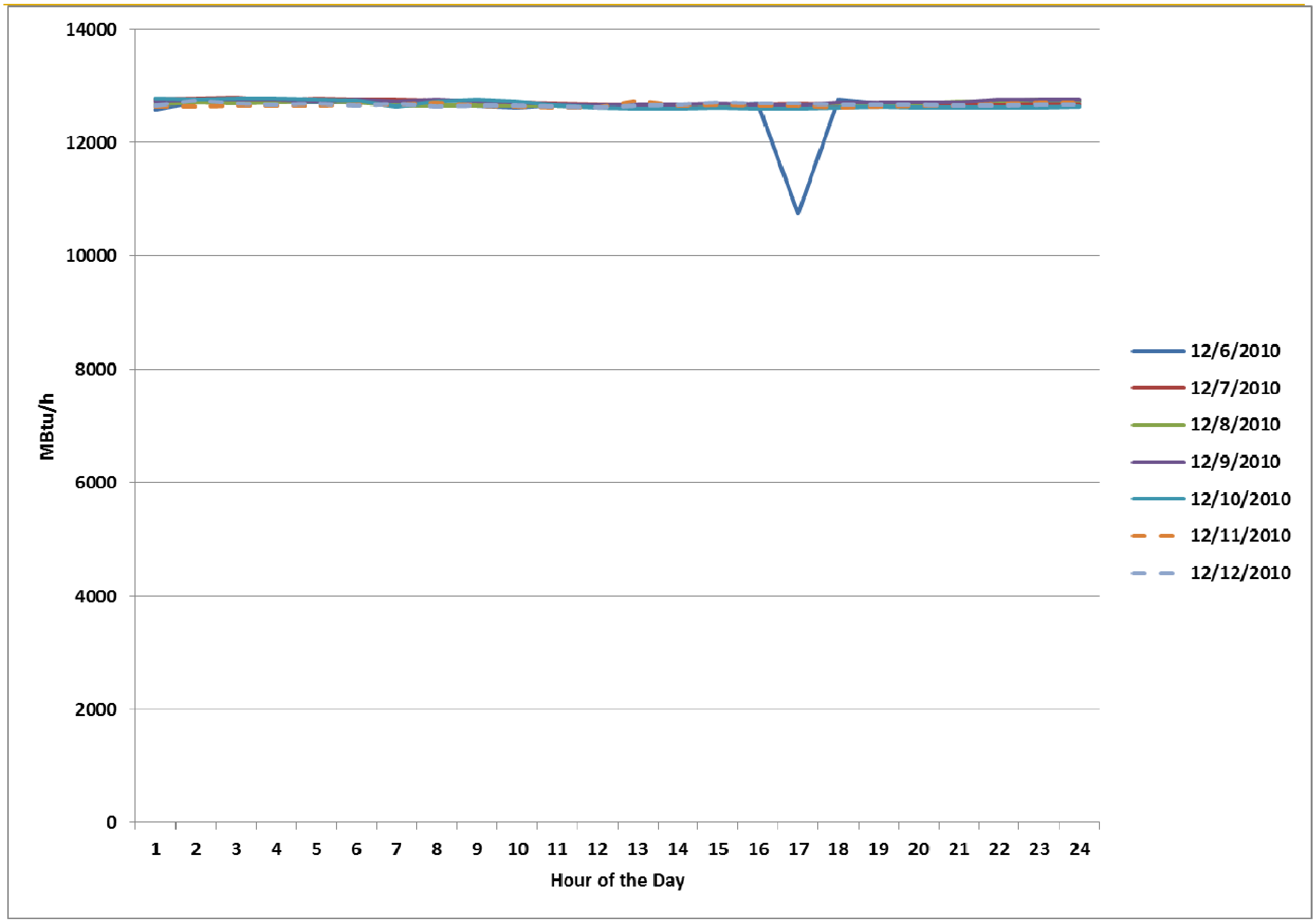

FIGURE 9 CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from December 6-12, 2010 (Figure 9) are calculated from the steam conditions before and after the steam turbine. December 11 is a Saturday.

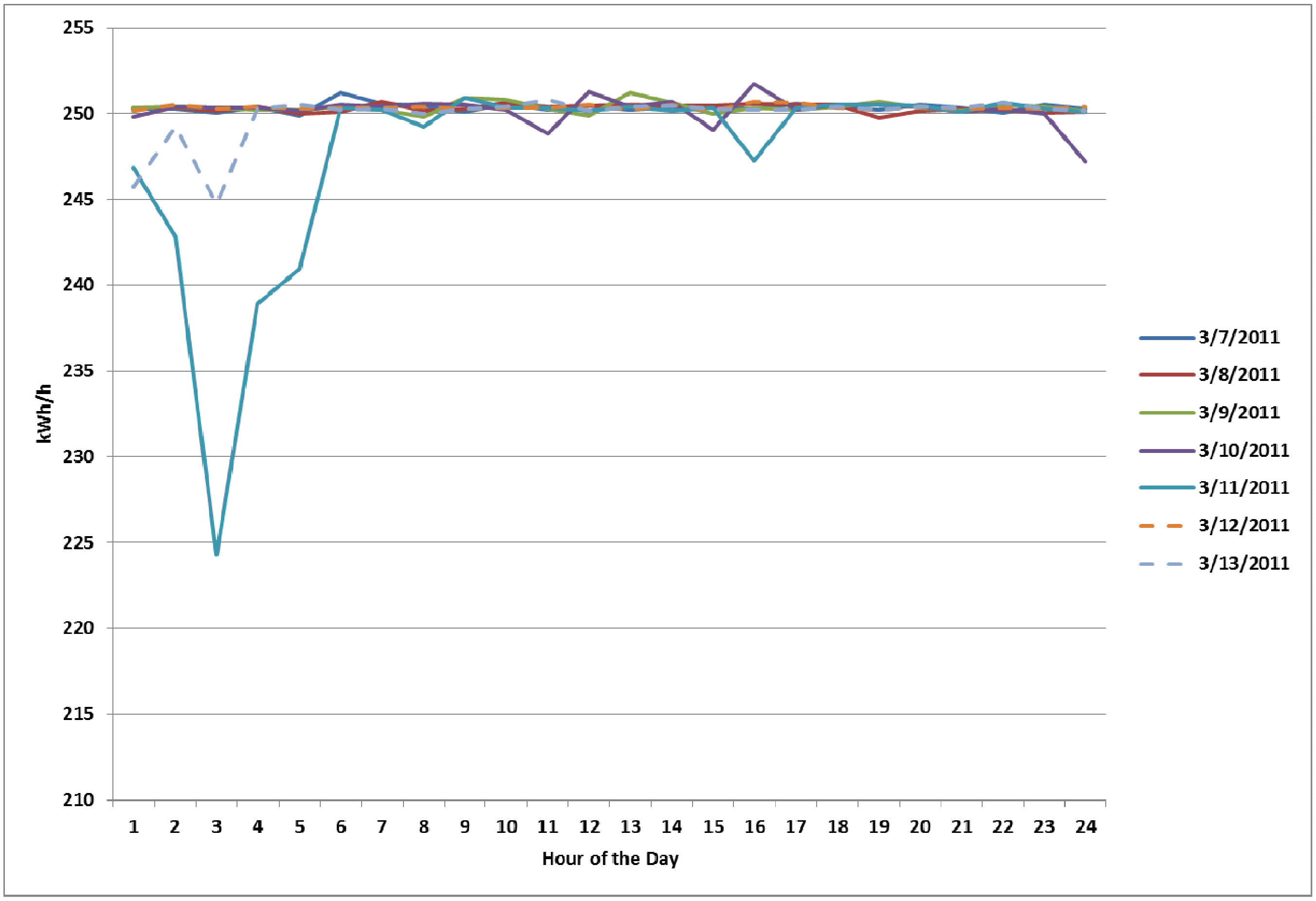

FIGURE 10 CHP POWER OUTPUT VERSUS TIME

Figure 10 covers the time period from March 7-13, 2011 providing CHP system power output by hour of the day pattern for the time period. March 12 is a Saturday. Figure 6 shows constant power recovery throughout the week with minor power fluctuations on March 11 and 13 in the early morning hours.

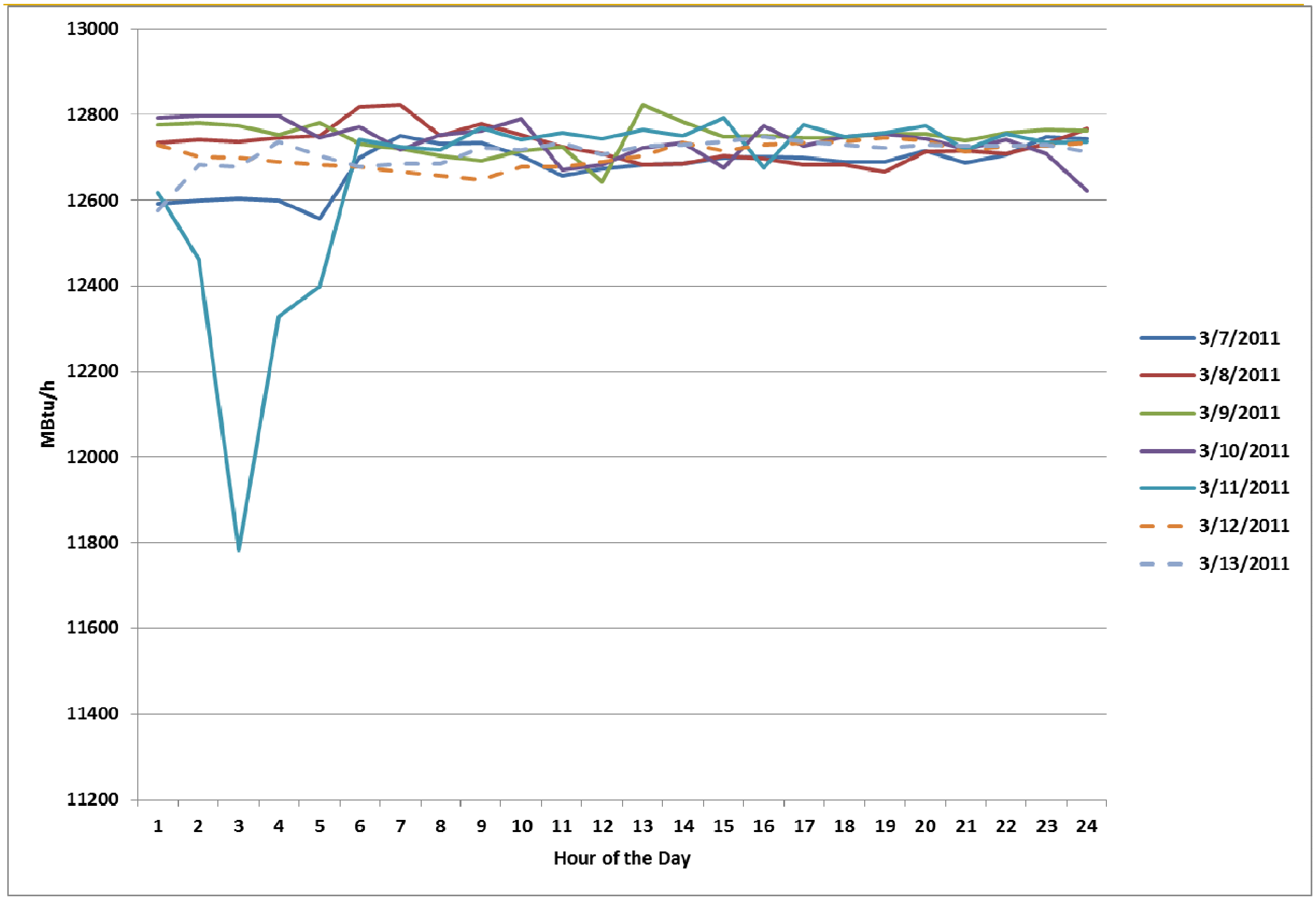

FIGURE 11 CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from March 7-13, 2011 (Figure 11) are calculated from the steam conditions before and after the steam turbine. March 12 is a Saturday.

PERFORMANCE SUMMARY

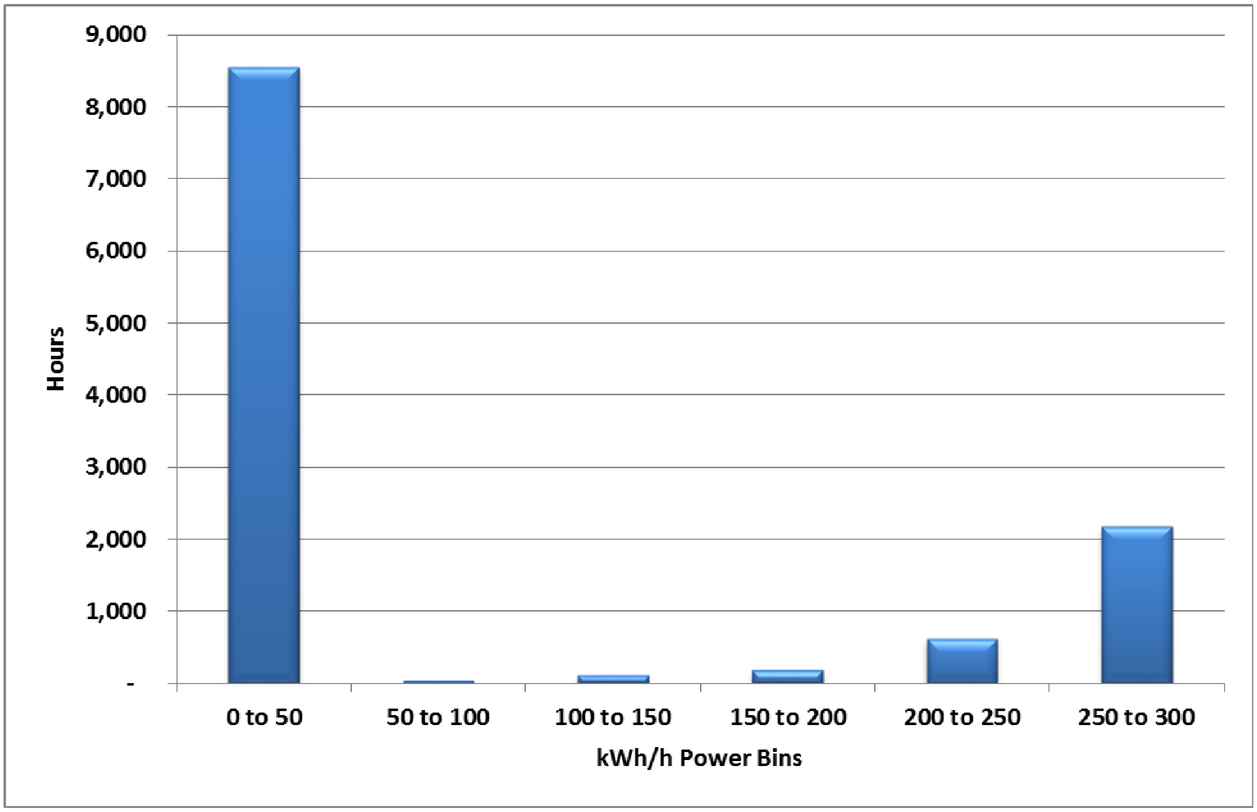

FIGURE 12 PERFORMANCE BY POWER BINS

During the 11,678 hours that met the range and relational checks, the CHP system delivered above 200 kWh/h about 23.9% of the time (Figure 12).

LESSONS LEARNED

Note: since this site uses a back pressure turbine to generate electricity, a capacity factor graph could not be created.

The operators only use the backpressure turbine when the steam flow is sufficient to generate full power. In the summer, when steam flow is too low, turbine operation is discontinued.

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 Turbine Output comes from the channel in the raw data file labeled, "WT1". Only the power for the new turbine is included in the data displayed on the website. The 15-minute kW reading is converted to kWh and summed into hourly data.
2. **DG/CHP Generator Gas Use (total cubic feet)** Not applicable to this site
3. **Useful Heat Recovery (total MBtu)** The Useful heat Recovery is calculated from the channels in the raw data file labeled, "TG1StmFlow" and "PLPS1". The pressure reading is used to determine the enthalpy of the steam. The enthalpy is then used to calculate the energy content of the steam leaving the turbine for each 15-minute interval. This 15-minute data is averaged into hourly data.

This heat recovery steam turbine generator operates as intended.

Data collection and quality for this site for much of the period is in the high 90th percentile or at 100%. (Table 2)

TABLE 2 SITE DATA QUALITY

	Percentage of Good Data		
	Power	**Gas Use**	**Useful Heat**
April-10	99.4%	0.0%	100.0%
May-10	99.9%	0.0%	100.0%
June-10	100.0%	0.0%	100.0%
July-10	100.0%	0.0%	100.0%
August-10	100.0%	0.0%	100.0%
September-10	100.0%	0.0%	100.0%
October-10	100.0%	0.0%	100.0%
November-10	100.0%	0.0%	100.0%
December-10	100.0%	0.0%	100.0%
January-11	100.0%	0.0%	100.0%
February-11	100.0%	0.0%	100.0%
March-11	99.7%	0.0%	100.0%
April-11	100.0%	0.0%	100.0%
May-11	100.0%	0.0%	100.0%
June-11	100.0%	0.0%	100.0%
July-11	100.0%	0.0%	100.0%