NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT CLARKSON UNIVERSITY

October 9, 2013

Clarkson University

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.

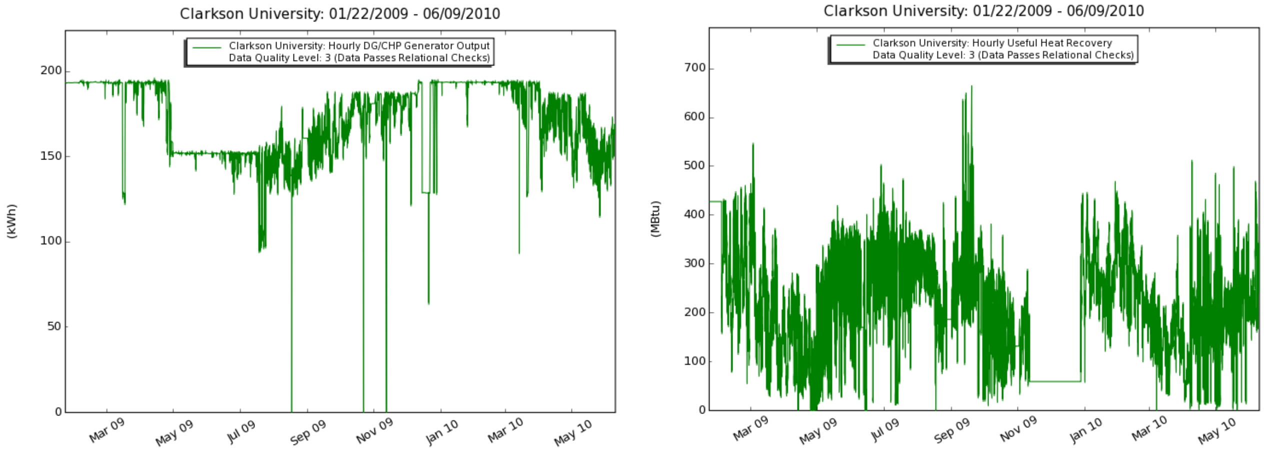


FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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

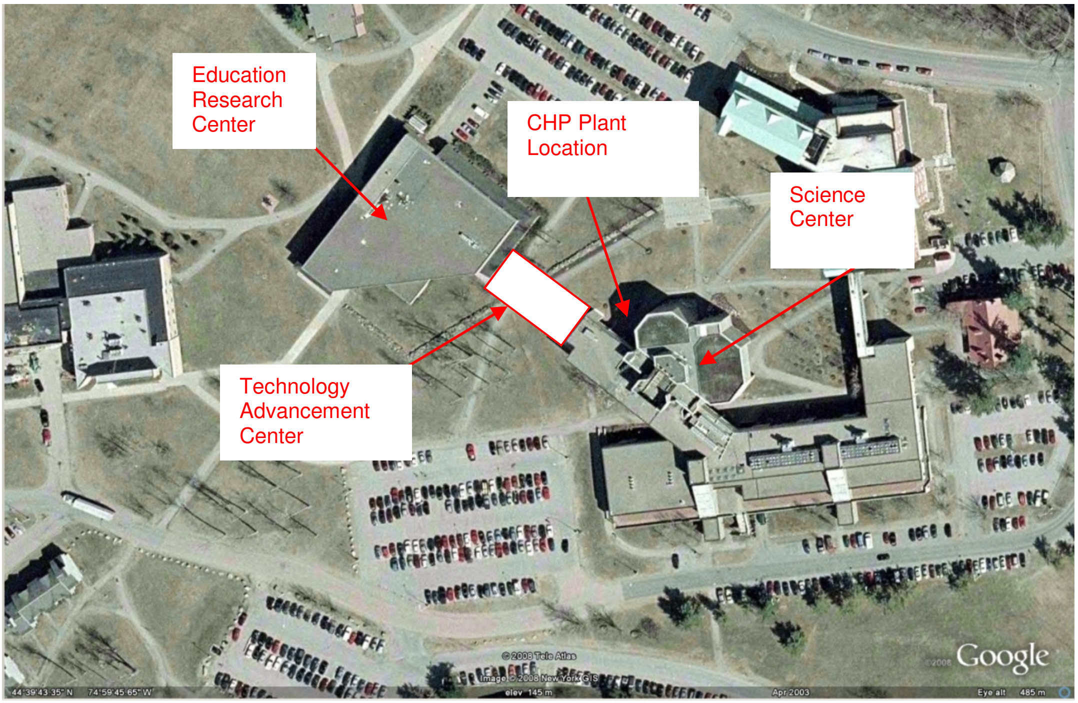


FIGURE 2 SITE OVERVIEW

The primary building served by the CHP system is the infill addition called the Technology Advancement Center, between the Education Research Center and the Science Center (Figure 2).

FIGURE 3 TAC INFILL ADDITION

THE SYSTEM

The CHP system at Clarkson University consists of three (3) 65-kW Carrier microturbines and a Carrier absorption chiller packaged onto a Carrier Pure Comfort system (Figure 4). The turbines have a combined gross output of 195 kW. The system uses heat from the turbine exhaust to drive an absorption chiller/heater that provides chilled and hot water to two buildings on campus. The system has a maximum chilled water output of 100-125 tons, and a maximum hot water output of 798 MBtu/h. It can provide cooling or heating separately, but not simultaneously. No dump radiator is utilized for rejection of excess heat; instead turbine exhaust is bypassed around the chiller.

The CHP system provides electricity, hot and chilled water to the Technology Advancement Center (TAC). Hot water is also provided to the science center as backup for the campus hot water system (but manual tie in valves are operated for this configuration). Also, excess electricity (above what the TAC requires) is provided to the Science Center building.

FIGURE 4 MICROTURBINES AND CHILLER BUILDING

Electrical interconnection of the CHP system to the TAC and Science Center buildings are shown in Figure 5. The system will operate in grid parallel mode to meet the full electrical needs of the TAC and partial electrical needs of the Science Center. During a utility outage, the dual mode controller will drop the connection to the Science Center and power the entire TAC building as an emergency load. A manual transfer switch allows the TAC to be powered off the grid while the CHP system is down for any reason.

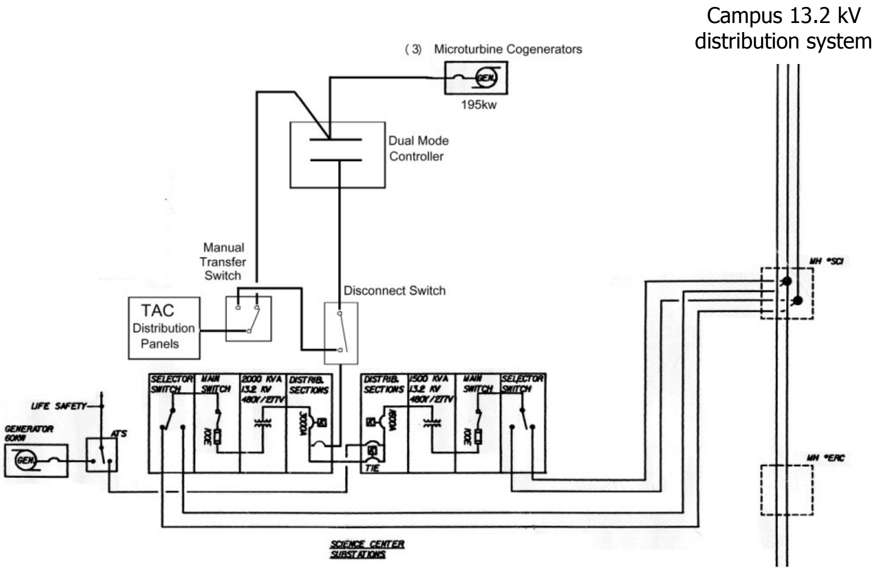
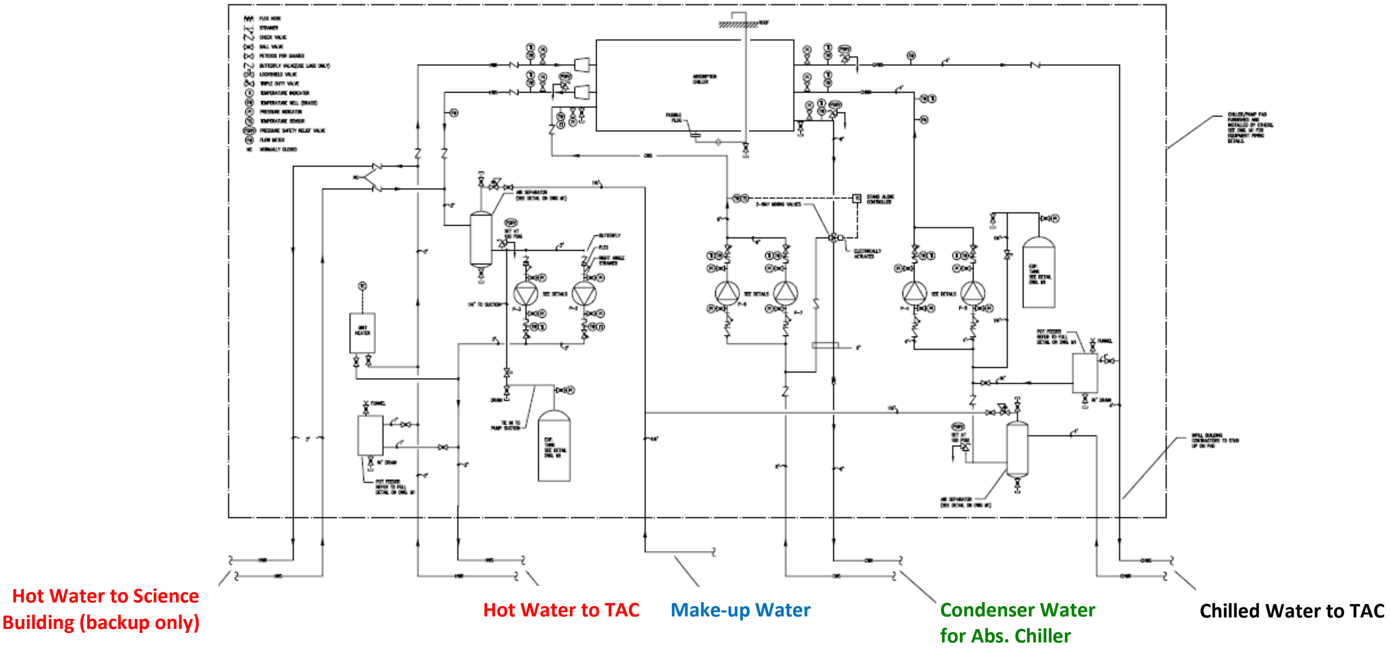


FIGURE 5 ELECTRIC INTERCONNECTION SCHEMATIC

Hot and chilled water produced by the system are piped directly into common supply and return headers in each building. The chilled water headers in each building are also connected to the campus central chilled water loop, for backup purposes. Hot water piping is confined to each building, but is connected to the campus steam system for supplemental heat. Figure 6 displays a process-piping diagram of the CHP system, showing the connections to the two buildings.


Hot Water to Science Building (backup only)

Hot Water to TAC

Make-up Water

Condenser Water for Abs. Chiller

Chilled Water to TAC

FIGURE 6 CHP SYSTEM PROCESS-PIPING DIAGRAM

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.

OPERATING SUMMARY

No fuel data is available from this site; therefore, no efficiency calculations can be made.

During the 17,475 hours that met the range and relational checks 98.4% of this time, the CHP system delivered greater than 125 kWh (Figure 13).

Examining operating data during the winter and early summer of 2010, where reliable thermal and power data was available, one could infer some level of performance. Since no fuel consumption was available from the site, inference of efficiency is the only means of providing any understanding other than an assessment of durability. Since the three microturbines were generally operating at about a combined average of 175 kWh/h, and the fuel consumption through about 80°F ambient is about 2,526,000 Btu/h for the three microturbines, this yields an electric efficiency of about 24% HHV. The average useful thermal energy is about 250,000 Btu/h and this yields a Useful Thermal Energy Efficiency of about 10% HHV. Therefore, an inferred system efficiency for this site over the course of its operation is only about 34%.

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
January-09	235	45,455	-	100.6			
February-09	622	120,379	-	192.1			
March-09	689	129,331	-	152.9			
April-09	667	124,239	-	84.6			
May-09	711	108,016	-	155.9			
June-09	632	95,369	-	163.9			
July-09	665	94,797	-	184.9			
August-09	685	102,372	-	166.8			
September-09	685	109,929	-	175.8			
October-09	706	124,165	-	119.3			
November-09	697	125,836	-	36.8			
December-09	701	121,174	-	26.2			
January-10	634	122,463	-	208.6			
February-10	647	125,185	-	180.8			
March-10	699	129,934	-	112.9			

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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.

April-10	708	122,400	-	105.1			
May-10	705	112,012	-	140.6			
June-10	208	31,270	-	48.3			
July-10	667	94,141	-	154.8			
August-10	721	107,310	-	152.0			
September-10	668	105,144	-	150.1			
October-10	725	125,094	-	136.5			
November-10	703	110,375	-	148.1			
December-10	725	128,872	-	279.6			
January-11	700	133,389	-	236.9			
February-11	564	107,563	-	223.4			
March-11	706	134,101	-	201.4			
April-11	0	-	-	-			
May-11	0	-	-	-			
June-11	0	-	-	-			
July-11	0	-	-	-			
Total preceding 12 months	**5512**	**951848.8**	**0**	**1528.017**			

POWER GENERATION AND USEFUL THERMAL OUTPUT

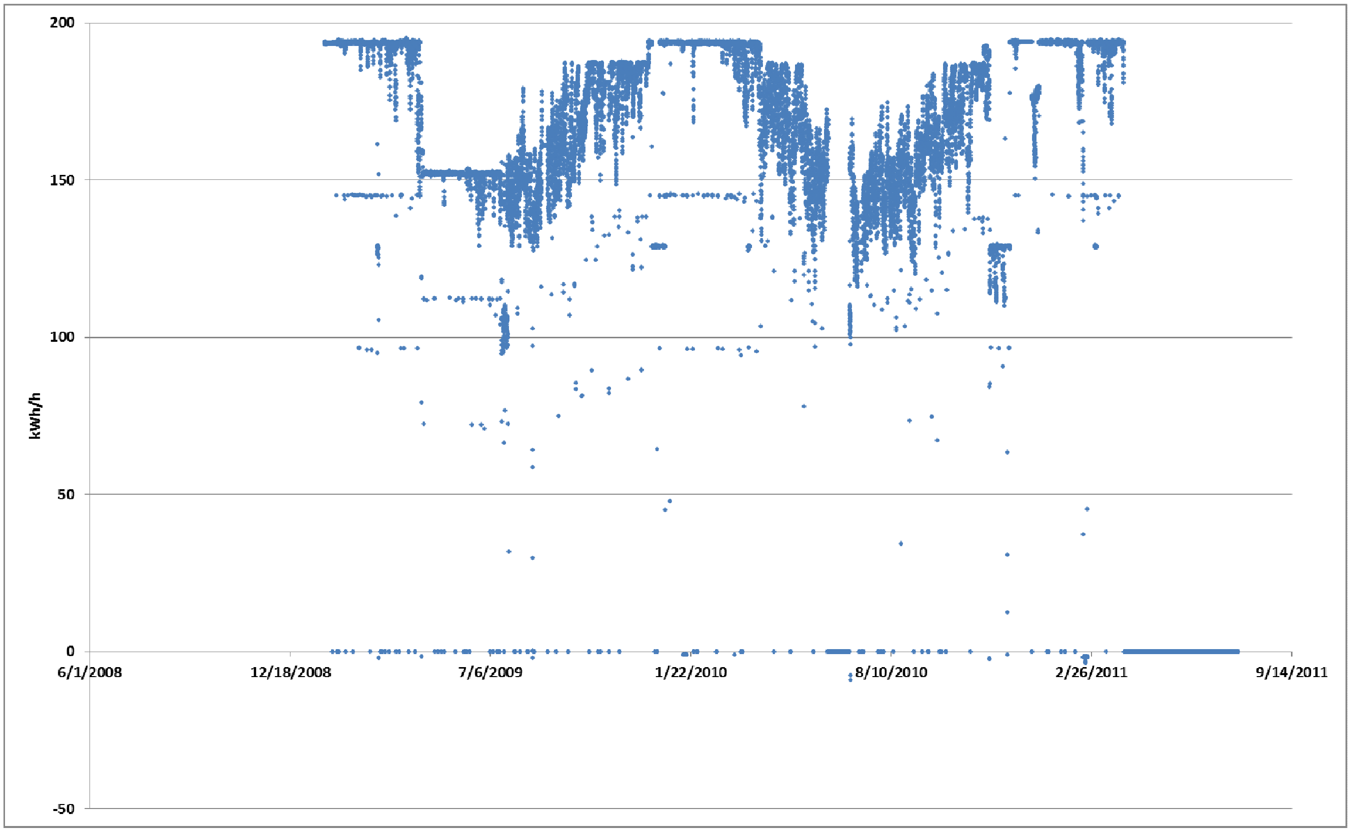

FIGURE 7 CHP POWER OUTPUT VERSUS TIME

Figure 7 provides power data showing consistent winter peak power capability at 193 kWh in 2008/2009, 2009/2010 and 2010/2011, indicating the power capacity of the system has not degraded with time. The classic Brayton cycle performance reduction is clearly shown during the summers of 2009 and 2010. The system shut down around the end of March 2011. Figure 7 also shows the system is delivering maximum power when operating.

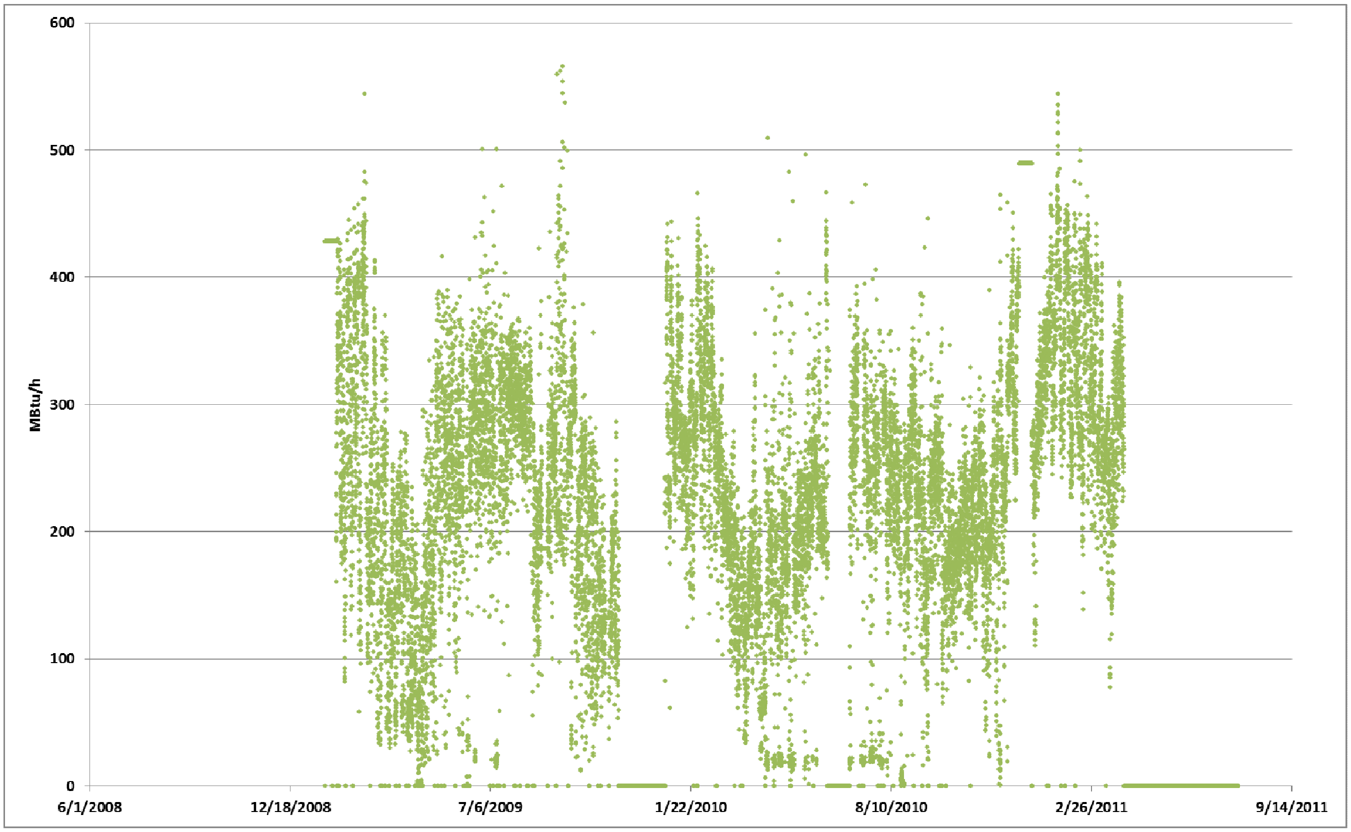

FIGURE 8 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 8 shows that thermal energy is well matched for winter heating and summer cooling. More excess heat is dumped during the spring and fall seasons. It should be noted that the CHP system thermal capacity is 798 MBtu/h.

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

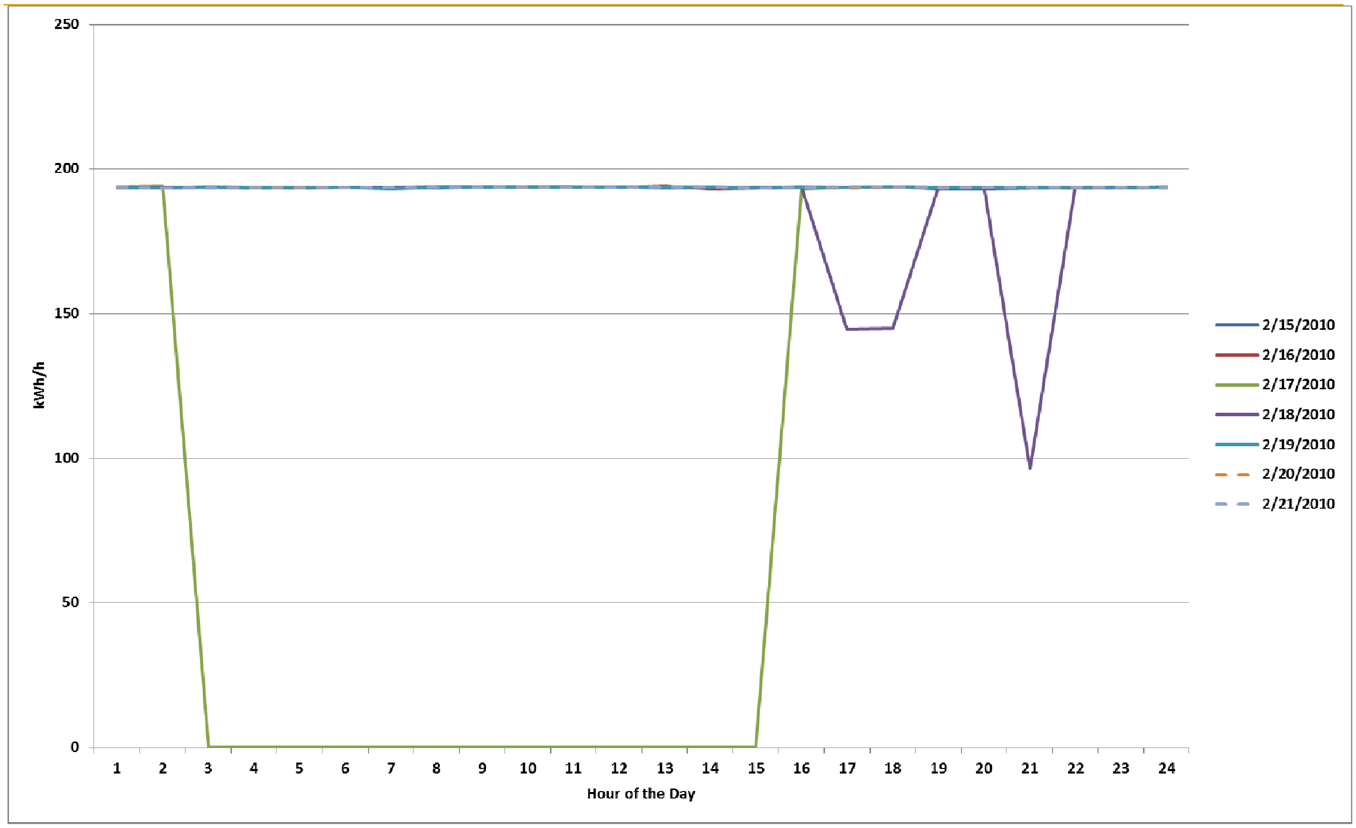

FIGURE 9 CHP POWER OUTPUT VERSUS TIME

Figure 9 covers the time period from February 15-21, 2010 providing CHP system power output by hour of the day pattern for the time period. February 20 is a Saturday. Figure 9 shows that all days have similar power output consistent with full power 24 x 7, except when one or more of the three microturbines is offline.

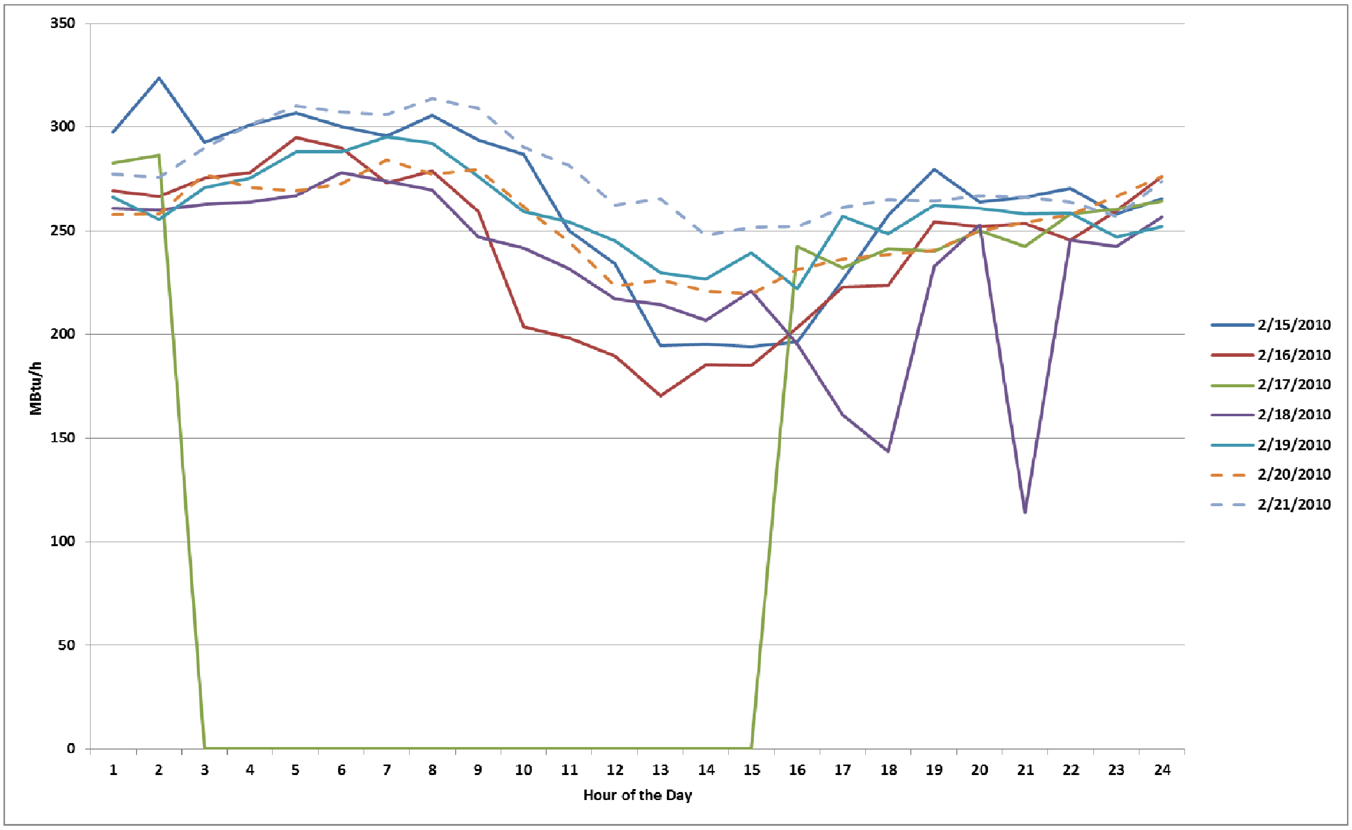

FIGURE 10 CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from February 15-21, 2010 (Figure 10) show a very consistent thermal load pattern. February 20 is a Saturday. The useful thermal load profile follows a general heating load profile for a university building holding temperature during the cold nighttime with internal activity during the day. (Figure 9) It should be noted that the CHP system thermal capacity is 798 MBtu/h. The useful thermal energy recovered for this week is in the range of 25% to 37.5% of the available capacity.

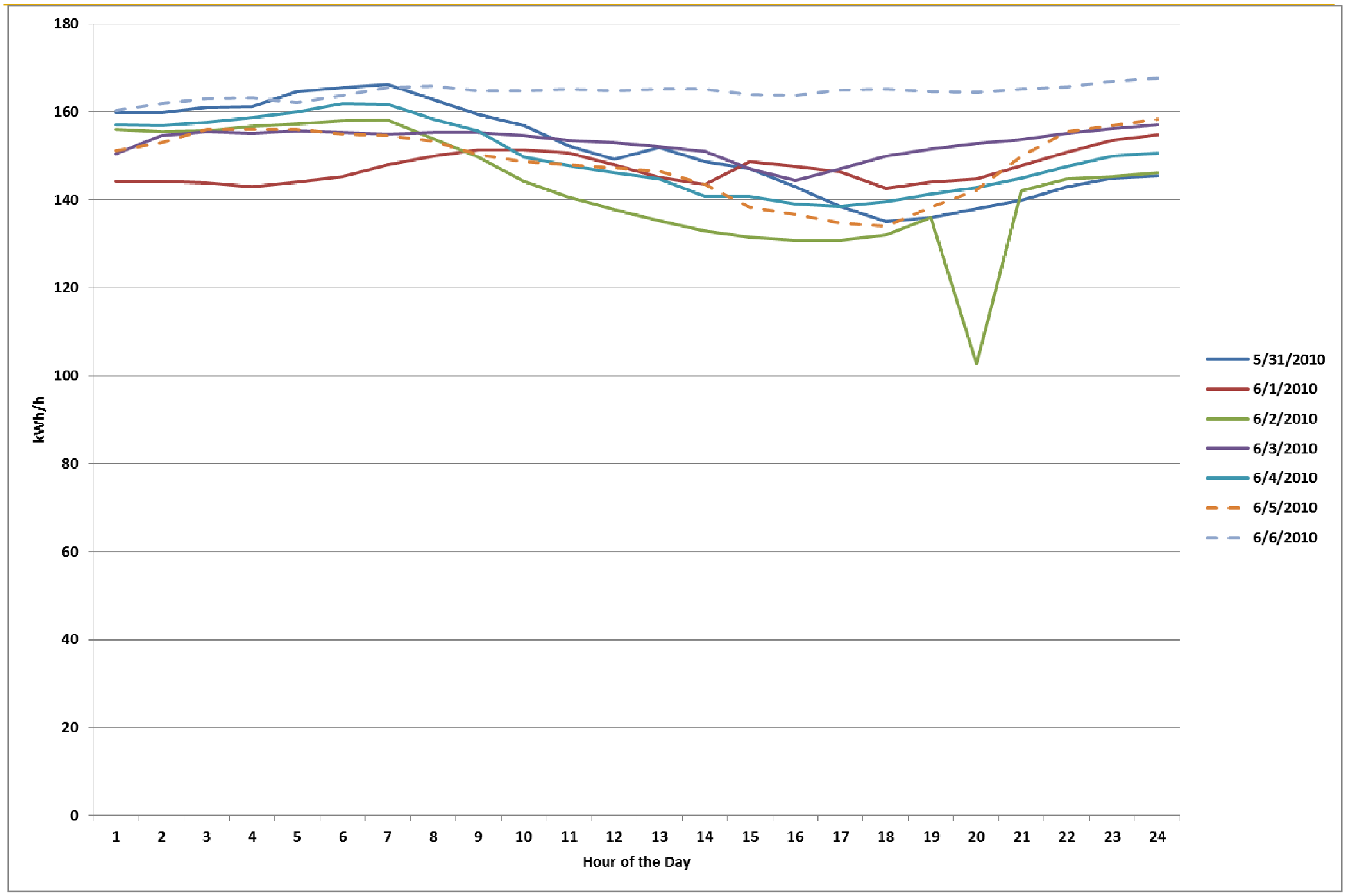

FIGURE 11 CHP POWER OUTPUT VERSUS TIME

Figure 11 covers the time period from May 31-June 6, 2010 providing CHP system power output by hour of the day pattern for the time period. June 5 is a Saturday. Figure 11 shows that all days have similar load consistent with full power 24 x 7. Figure 9 and Figure 11 profiles differ slightly in that the high power flat line in Figure 9 is indicative of low ambient temperature operation (power limited by microturbine control system), and Figure 11 is showing full power operation varying with ambient temperature (see Figure 13). Examining the useful thermal pattern for the same week shows that the system is being controlled to produce full-load electric power during this time (see Figure 12).

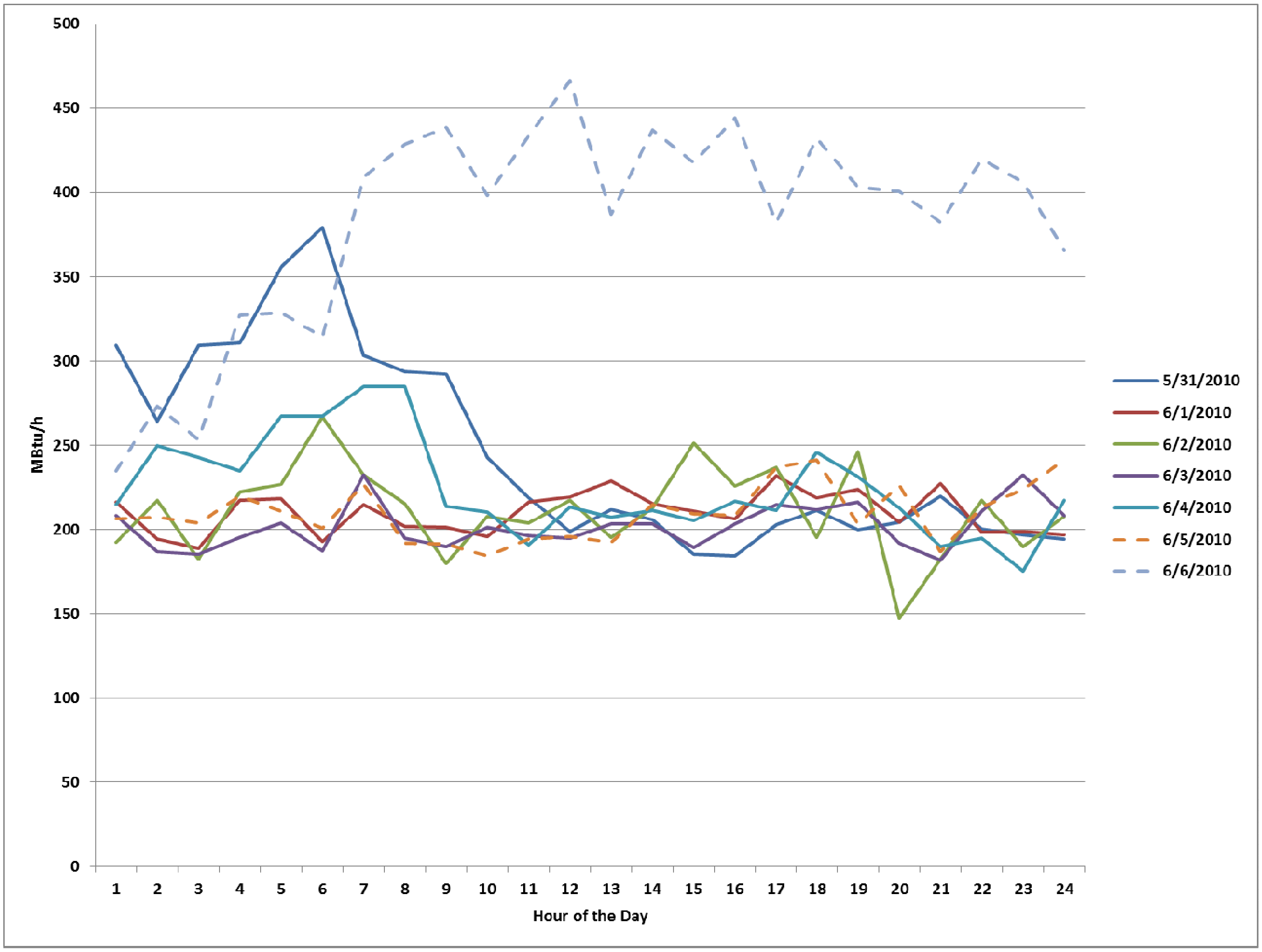

FIGURE 12 SELECTED DAY CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 12 shows the 24 hour useful CHP recovered heat thermal load profiles from May 31-June 6, 2010. The useful thermal load profile follows a general heating load profile for a university building holding temperature during the cool nighttime with internal activity during the day. The exception to the pattern is Sunday June 6. Here the pattern has changed which likely indicates switching over the system for heating/hot water to space cooling. (Figure 11) It should be noted that the CHP system thermal capacity is 798 MBtu/h. The useful thermal energy recovered for this week is in the range of 25% to 56% of the available capacity.

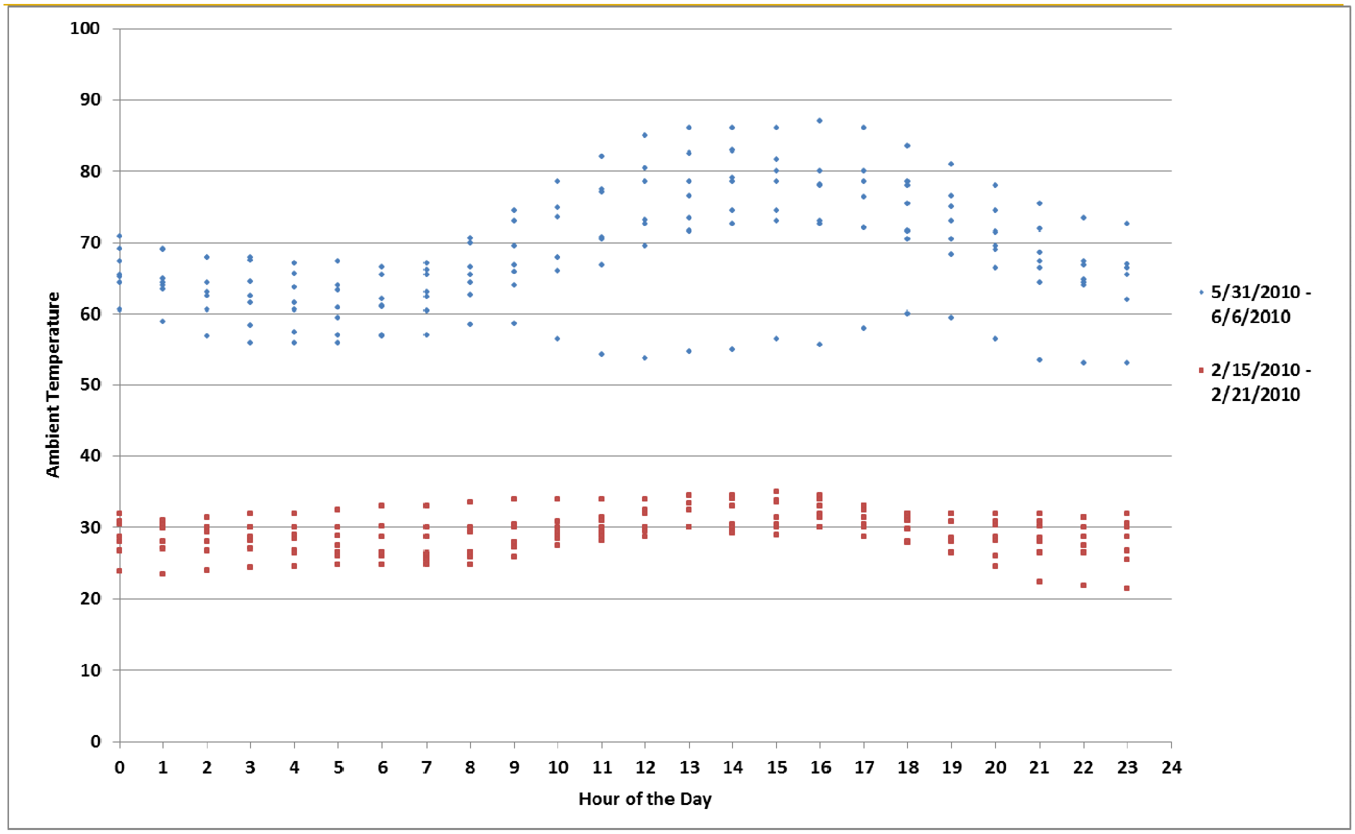

FIGURE 13 AMBIENT TEMPERATURE VERSUS TIME OF DAY AND WINTER VERSUS LATE SPRING

PERFORMANCE SUMMARY

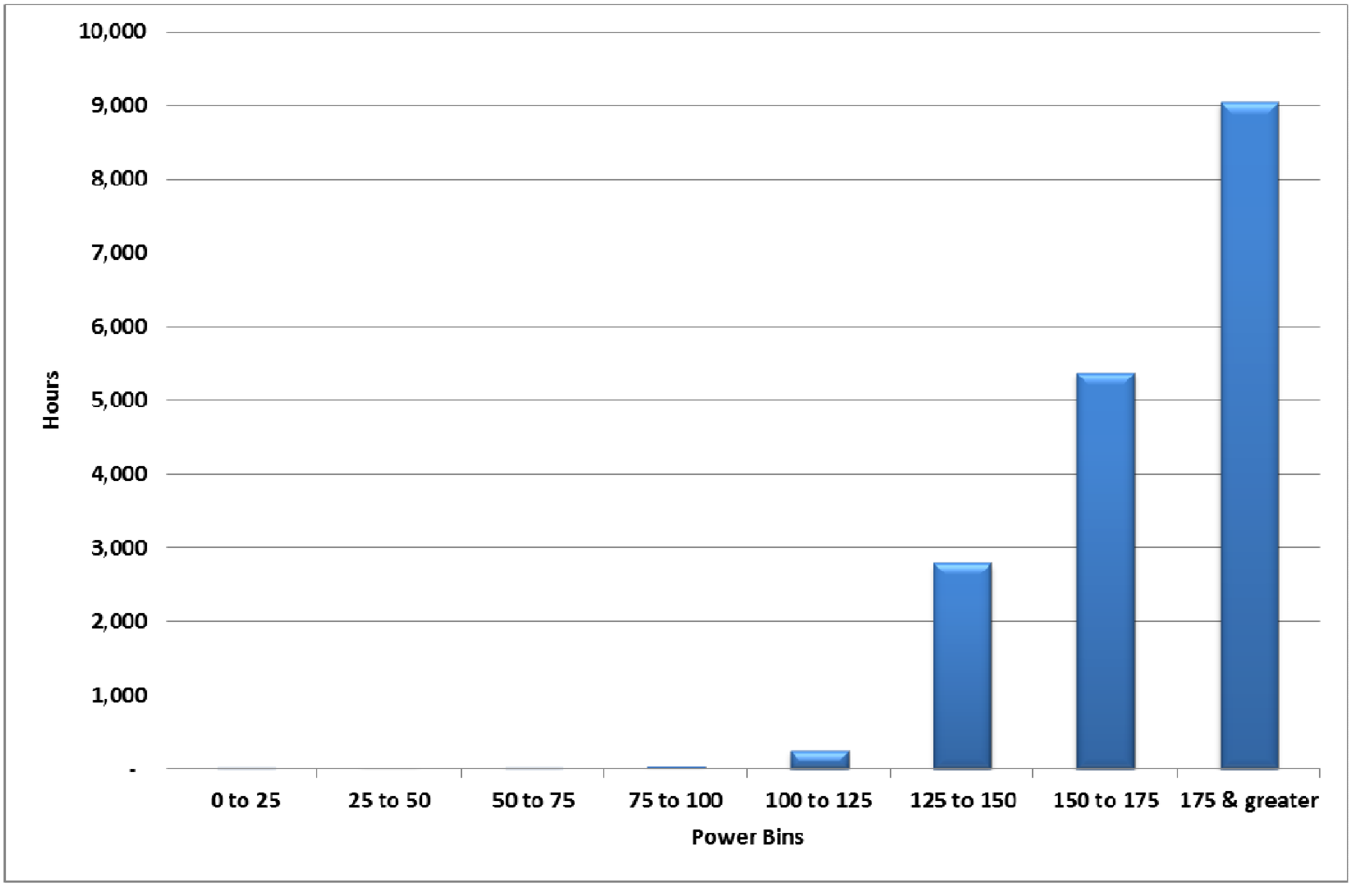

FIGURE 14 PERFORMANCE BY POWER BINS

During the 17,475 hours that met the range and relational checks 98.4% of this time, the CHP system delivered greater than 125 kWh (Figure 14).

LESSONS LEARNED

Note: since no fuel data was provided from the site, a capacity factor graph could not be created.

The Pure Comfort system combines microturbines with exhaust-driven absorption chiller technology. This system is optimized to meet cooling loads, which are relatively modest for this academic building in Northern New York. While the chiller can meet winter heating loads, it is not the most cost effective or efficient means to meet those loads.

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 15-minute data. The column of origin for this data point is labeled “TAC_MICROTURBINE_KW” in the data files received from the Siemens BMS. The parasitic power is subtracted from this power data. This 15-minute interval energy data is averaged into hourly data.
2. **DG/CHP Generator Gas Use (total cubic feet)** The Generator Output Demand comes from 15-minute data. The column of origin for this data point is labeled “TAC_MICROTURBINE_KW” in the data files. The parasitic power is subtracted from this power data. The highest value from the 15-minute data during an hour is used for the Output Demand in the online database.
3. **Useful Heat Recovery (total MBtu)** The Useful Heat Recovery comes from 15-minute data for the hot and chilled water loops. The hot water recovery is calculated using data from the columns: “TAC_MICROTURBINE_HWF “, “TAC_MICROTURBINE_HWR “, “TAC_MICROTURBINE_HWS “. The chilled water heat recovery is calculated using data from the columns: “TAC_MICROTURBINE_CWF “, “TAC_MICROTURBINE_CWR “, “TAC_MICROTURBINE_CWS “. The 15-minute data is averaged for the hourly online database.

Examining operating data during the winter and early summer of 2010, where reliable thermal and power data was available, one could infer some level of performance. Since no fuel consumption was available from the site, inference of efficiency is the only means of providing any understanding other than an assessment of durability. Since the three microturbines were generally operating at about a combined average of 175 kWh/h, and the fuel consumption through about 80°F ambient is about 2,526,000 Btu/h for the three microturbines, this yields an electric efficiency of about 24% HHV. The average useful thermal energy is about 250,000 Btu/h and this yields a Useful Thermal Energy Efficiency of about 10% HHV. Therefore, inferred system efficiency for this site over the course of its operation is only about 34%.

This application is a university campus technology building that is occupied during the day. Its location is near the Canadian border. It would appear that applying a CHP solution that cannot be dedicated to providing hot water on a consistent basis is problematic.

Clearly, demonstration systems must have all the critical data to measure performance. The lack of fuel data on this project is a significant impediment to understanding system performance.

Table 2 data collection and quality for this site for much of the period is in the mid-80th to mid-90th percentile with the exceptions of November/December 2009, June 2010 and no data after March 2011. Note: no fuel usage data was available.

TABLE 2 PERCENTAGE OF GOOD DATA

	Power	Gas Use	Useful Heat
January-09	31.6%	0.0%	31.6%
February-09	92.6%	0.0%	95.5%
March-09	92.6%	0.0%	95.3%
April-09	92.6%	0.0%	95.7%
May-09	95.6%	0.0%	96.6%
June-09	87.8%	0.0%	89.6%
July-09	89.4%	0.0%	91.3%
August-09	92.1%	0.0%	92.3%
September-09	95.1%	0.0%	90.4%

October-09	94.9%	0.0%	96.1%
November-09	96.8%	0.0%	34.3%
December-09	94.2%	0.0%	11.4%
January-10	85.2%	0.0%	96.5%
February-10	96.3%	0.0%	98.1%
March-10	94.0%	0.0%	96.1%
April-10	98.3%	0.0%	98.9%
May-10	94.8%	0.0%	97.2%
June-10	28.9%	0.0%	29.2%
July-10	89.7%	0.0%	90.5%
August-10	96.9%	0.0%	98.9%
September-10	92.8%	0.0%	93.6%
October-10	97.4%	0.0%	98.1%
November-10	97.6%	0.0%	100.0%
December-10	97.4%	0.0%	98.7%
January-11	94.1%	0.0%	94.6%
February-11	83.9%	0.0%	98.8%
March-11	94.9%	0.0%	96.6%
April-11	0%	0%	0%
May-11	0%	0%	0%
June-11	0%	0%	0%
July-11	0%	0%	0%