NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT 717 5TH AVENUE NEW YORK CITY

October 9, 2013

717 5TH Avenue New York City

NYSERDA New York State Energy Research and Development Authority

DISCLAIMER OF WARRANTY

Information contained on this web site is provided "as is," without warranty of any kind. In particular, the New York State Energy Research and Development Authority ("NYSERDA"), its employees, officers, and members, and the State of New York, make no warranties or representations, expressed or implied, as to the fitness for a particular purpose or merchantability of any product, apparatus, downloaded computer software product, service, or the usefulness, completeness, or accuracy of any processes, methods, downloaded computer software product, or other information contained, described, disclosed, or referred to herein. NYSERDA, its employees, officers and members, and the State of New York, make no representation that the use of any product, apparatus, process, method, downloaded computer software product, or other information will not infringe on privately owned rights.

DISCLAIMER OF LIABILITY

In no event shall NYSERDA, its employees, officers or members, or the State of New York be liable for any direct, indirect, punitive, incidental, special, or consequential damages or any damages whatsoever including, without limitation, damages for loss of use, data, or profits, arising out of or in any way connected with the use or performance of this web site, the provision of or failure to provide services, or for any information, software, products, services, or graphics obtained through this web site, or otherwise arising out of the use of this web site, whether based on contract, tort, strict liability, or otherwise, even if NYSERDA, its employees, officers and members, and the State of New York have been advised of the possibility of damages.

DISCLAIMER OF ENDORSEMENT

Reference to any specific product, service, process, or method by trade name, trademark, service mark, manufacturer or otherwise on this web site does not constitute an implied or expressed recommendation or endorsement, or favoring by NYSERDA, its employees, officers or members, or the State of New York, and shall not be used for advertising or product endorsement purposes.

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.

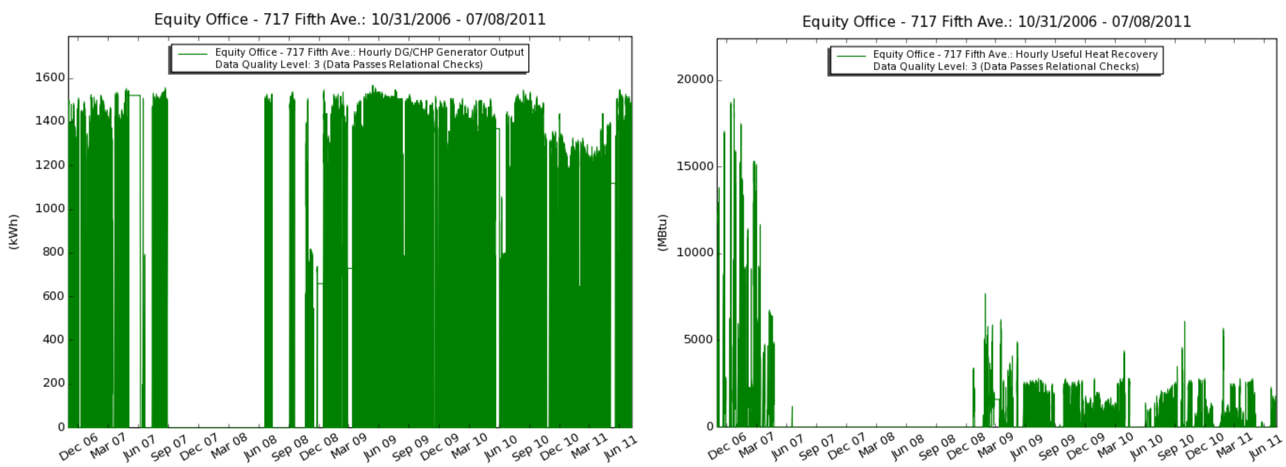

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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

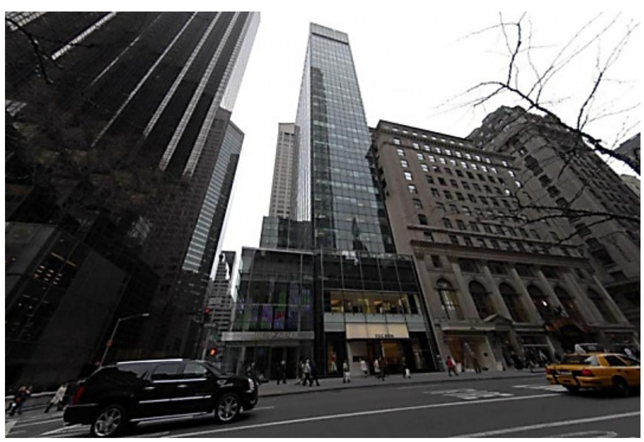

FIGURE 2 717 FIFTH AVENUE

The 26-story building operated by Equity Office Properties at 717 Fifth Avenue is considered "Class-A" commercial space. Steam supplied by ConEdison was used year round to provide space heating and air conditioning. The peak electrical demand exceeded 2.1 MW at the height of the summer cooling season.

717 Fifth Avenue offers 450,000 ft^2 of premier office space to tenants in the center of Manhattan. Although fully occupied, maintaining client satisfaction requires the building services to meet high standards. The site's management viewed the application of CHP technology as an economical means to help assure the expected quality could be delivered.

THE SYSTEM

The CHP system was installed at the building to reduce its dependence on purchased utilities. Two 820 kW generators now produce 60% of the site's electricity and offset more than half of the thermal demands while operating at a maximum CHP efficiency of 73% HHV.

The CHP system is configured on two engine-generator sets that run during the on-peak and mid-peak periods reducing consumption of utility power at the most expensive time of day. Synchronous generators were used so power can still be supplied to the building in the event of a prolonged blackout. The system was built up from pre-assembled modules that form a sound attenuating structure on the 15th floor setback. Heat recovered from the engines is recovered as hot water that is used to provide space conditioning.

FIGURE 3 ENGINE MODULES INSTALLED SIDE-BY-SIDE ON ROOF

The engine-generator sets are both natural gas fueled and were shipped as modular skids with the related ancillaries already installed in order to minimize the work required onsite. Electricity is produced in parallel with the grid, though the generators can be isolated and supplement the output of the site's emergency generator in case of a utility outage. The system's electrical output is modulated, as necessary, to follow the site load; no electricity is exported. Heat is recovered from each engine as hot water that can be used for space heating or circulated through an absorption machine to produce chilled water for air conditioning, depending on seasonal requirements. Excess heat is rejected to the atmosphere through radiators included on the equipment skids.

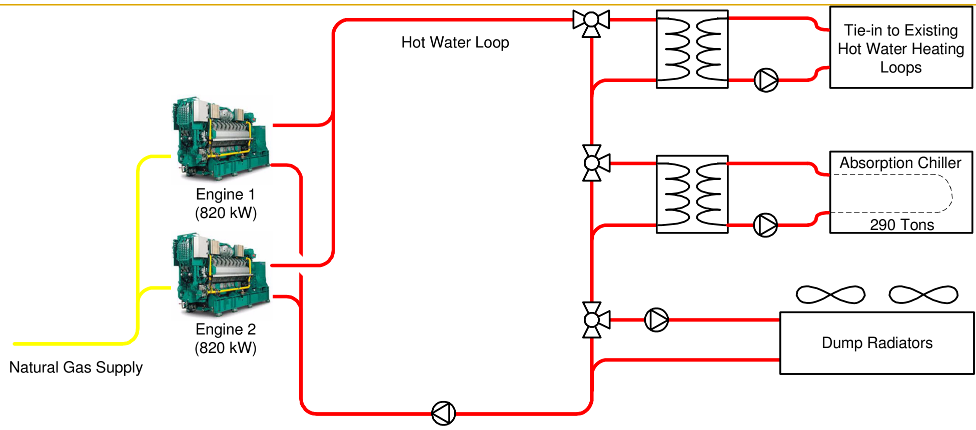

FIGURE 4 SIMPLIFIED CHP SYSTEM SCHEMATIC

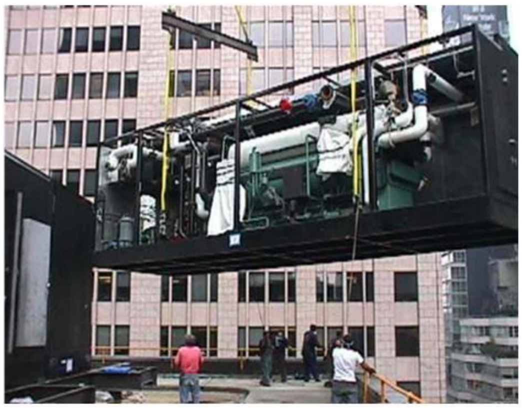

FIGURE 5 ABSORPTION MACHINE MODULE INSTALLATION

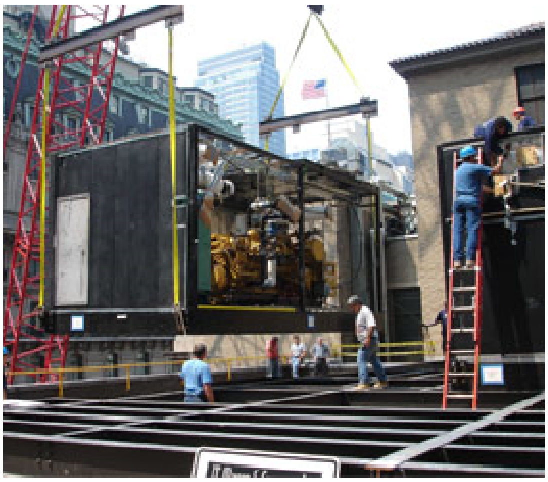

FIGURE 6 ENGINE GENERATOR MACHINE MODULE

FIGURE 7 FINISHED SOUND ATTENUATION ENCLOSURE

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. The CHP plant at 717 Fifth Avenue began operation in November of 2006. During the initial operation, no fuel consumption data was available.

Table 1 provides the data results taken since December, 2008. During 2008, there was limited fuel consumption data which precluded an efficiency measurement. It is clear from the data available that the thermal performance of this system is problematic.

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
December-08	414	138,880	1,547.0	136.7	30.0%	8.7%	38.7%
January-09	667	250,680	2,438.0	56.2	34.4%	2.3%	36.7%
February-09	353	150,320	2,159.0	294.6	23.3%	13.4%	36.7%
March-09	430	169,930	2,419.0	71.3	23.5%	2.9%	26.4%
April-09	671	296,971	4,170.0	106.5	23.8%	2.5%	26.3%
May-09	698	306,380	4,251.0	128.5	24.1%	3.0%	27.1%
June-09	675	347,982	4,840.0	274.0	24.1%	5.6%	29.6%
July-09	689	356,691	5,007.0	326.8	23.8%	6.4%	30.2%
August-09	685	248,809	3,498.0	161.4	23.8%	4.5%	28.3%
September-09	660	313,120	4,696.0	50.0	22.3%	1.0%	23.4%
October-09	680	306,791	4,533.0	165.9	22.6%	3.6%	26.2%
November-09	550	237,090	3,541.0	143.0	22.4%	4.0%	26.4%

[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.

NYSERDA

December-09	640	293,872	4,456.0	99.7	22.1%	2.2%	24.3%
January-10	626	293,971	4,345.0	144.5	22.6%	3.3%	25.9%
February-10	616	266,230	4,004.0	128.5	22.2%	3.1%	25.4%
March-10	627	281,210	4,267.0	168.3	22.1%	3.9%	25.9%
April-10	582	265,214	2,098.0	40.7	42.3%	1.9%	44.2%
May-10	436	180,930	-	-	-	-	-
June-10	654	189,952	2,310.0	42.6	27.5%	1.8%	29.3%
July-10	690	306,292	4,433.0	149.9	23.1%	3.3%	26.4%
August-10	664	340,112	4,813.0	189.8	23.6%	3.9%	27.5%
September-10	475	237,610	3,575.0	81.0	22.2%	2.2%	24.5%
October-10	530	208,520	3,080.0	97.9	22.7%	3.1%	25.8%
November-10	630	238,549	3,539.0	107.5	22.6%	3.0%	25.5%
December-10	701	273,017	4,171.0	87.9	21.9%	2.1%	24.0%
January-11	701	267,880	4,041.0	43.5	22.2%	1.1%	23.2%
February-11	634	233,650	3,488.0	119.0	22.4%	3.3%	25.8%
March-11	673	281,892	4,347.0	73.0	21.7%	1.6%	23.3%
April-11	676	274,427	4,194.0	106.1	21.9%	2.5%	24.4%
May-11	355	136,041	2,030.0	4.3	22.4%	0.2%	22.6%
June-11	656	311,629	4,462.0	10.6	23.4%	0.2%	23.6%
July-11	641	302,289	4,453.0	57.5	22.7%	1.3%	24.0%
Total preceding 12 months	**7336**	**3,105,617**	**46,193.0**	**978.1**	**22.5%**	**2.1%**	**24.6%**

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

OPERATING SUMMARY

Examining Table 1, Figure 8, and Figure 9, it is readily apparent that power performance from this CHP system has been consistently in the 22% to 23% HHV range, except for a few anomaly months where fuel reporting skewed the performance. The real story is the lack of useful thermal energy.

The business model for the power purchase agreement on this site induces the operator to generate electricity to reduce on-peak power to maximize return. There is not enough value given the thermal energy.

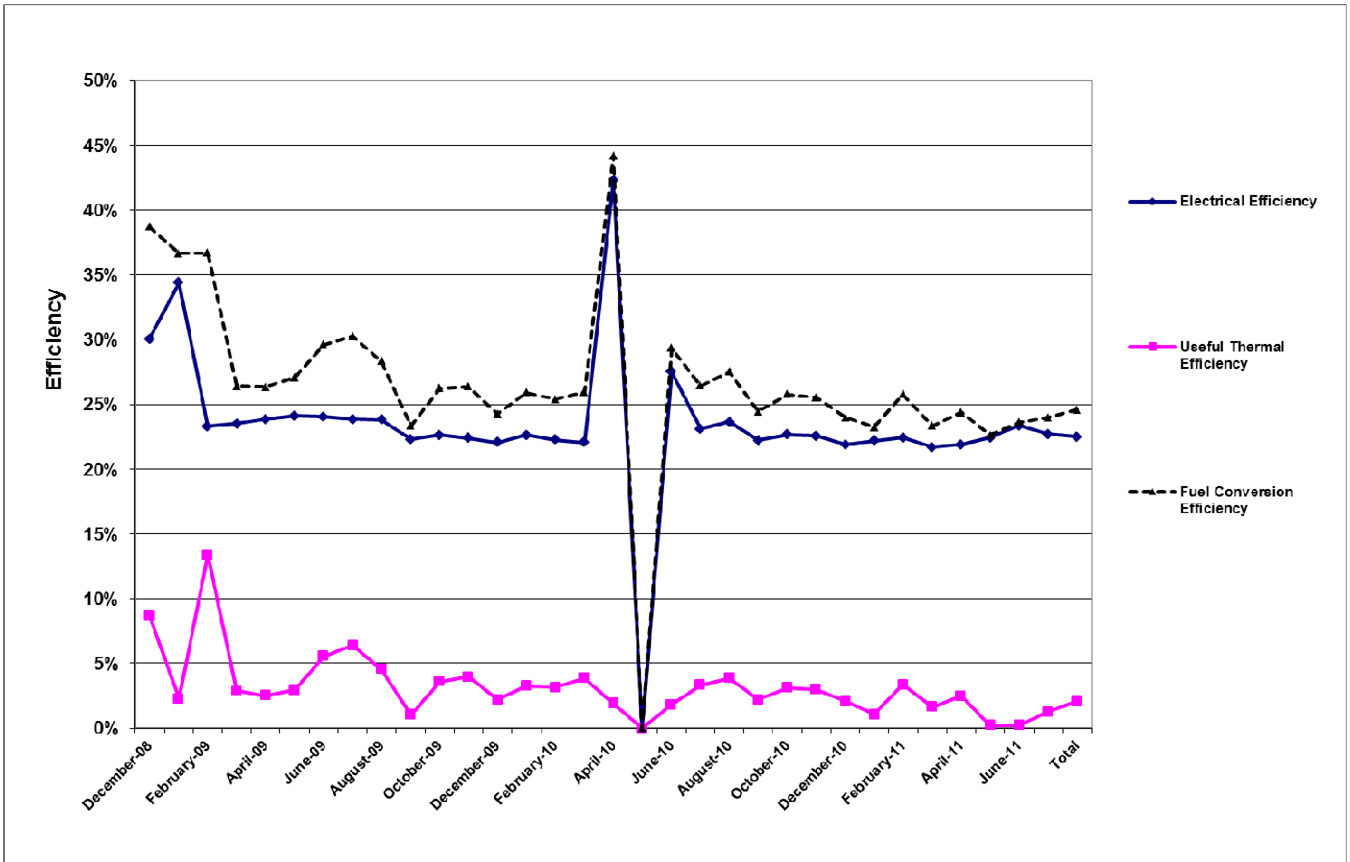

FIGURE 8 CHP SYSTEM EFFICIENCY BY HALF YEAR

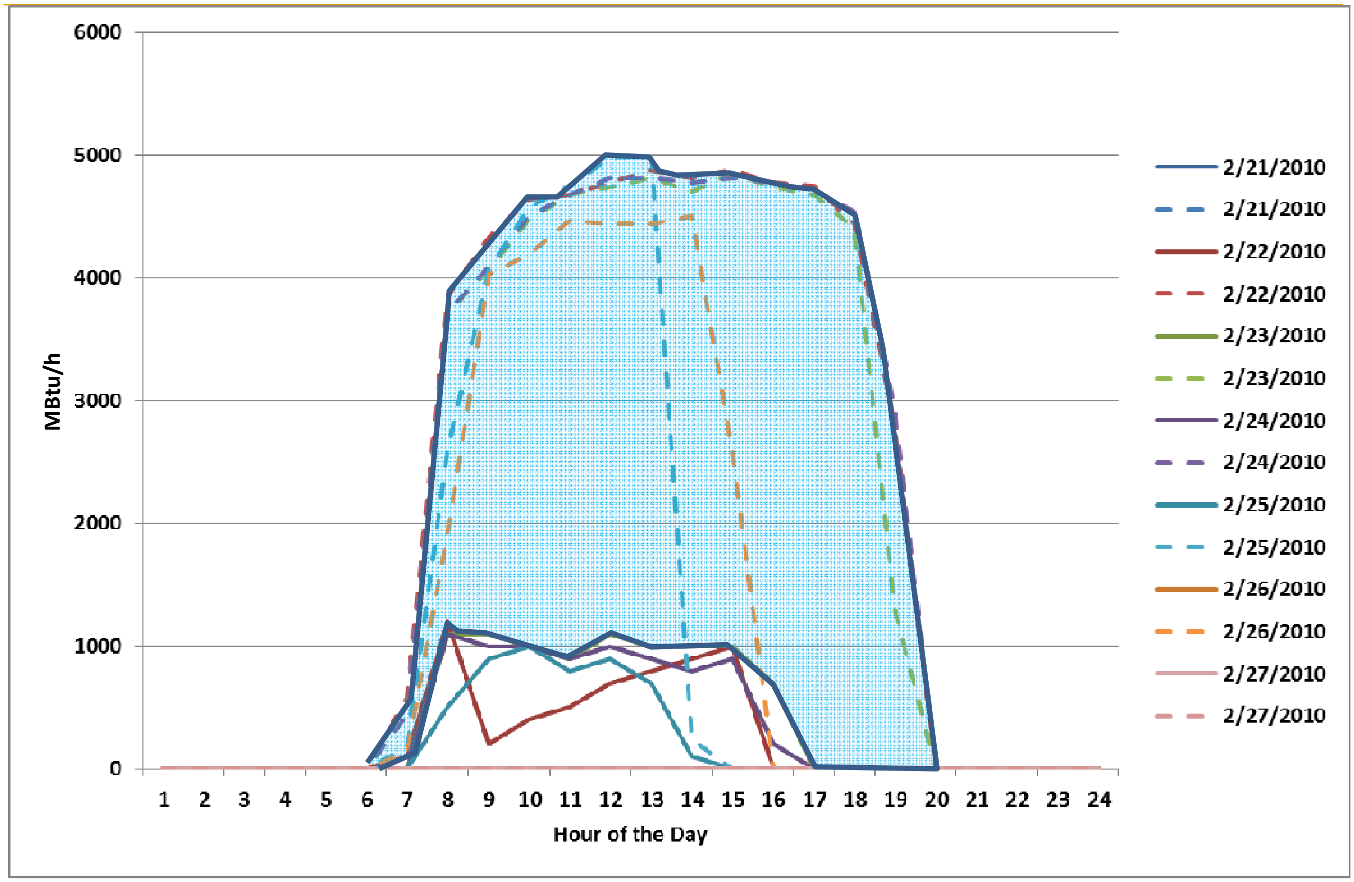

FIGURE 9 POWER VERSUS USEFUL THERMAL ENERGY

Figure 9 depicts the energy efficiency issue with this system/application. The dashed lines represent hourly power produced by the CHP system in MBtu/h. The solid lines depict the useful thermal energy, again in MBtu/h used by the building. A well designed CHP engine-based plant ideally would show about the same amount of useful thermal energy as power. Therefore, the blue shading would be indicative of the lost thermal energy on a fully loaded day.

POWER GENERATION AND USEFUL THERMAL ENERGY

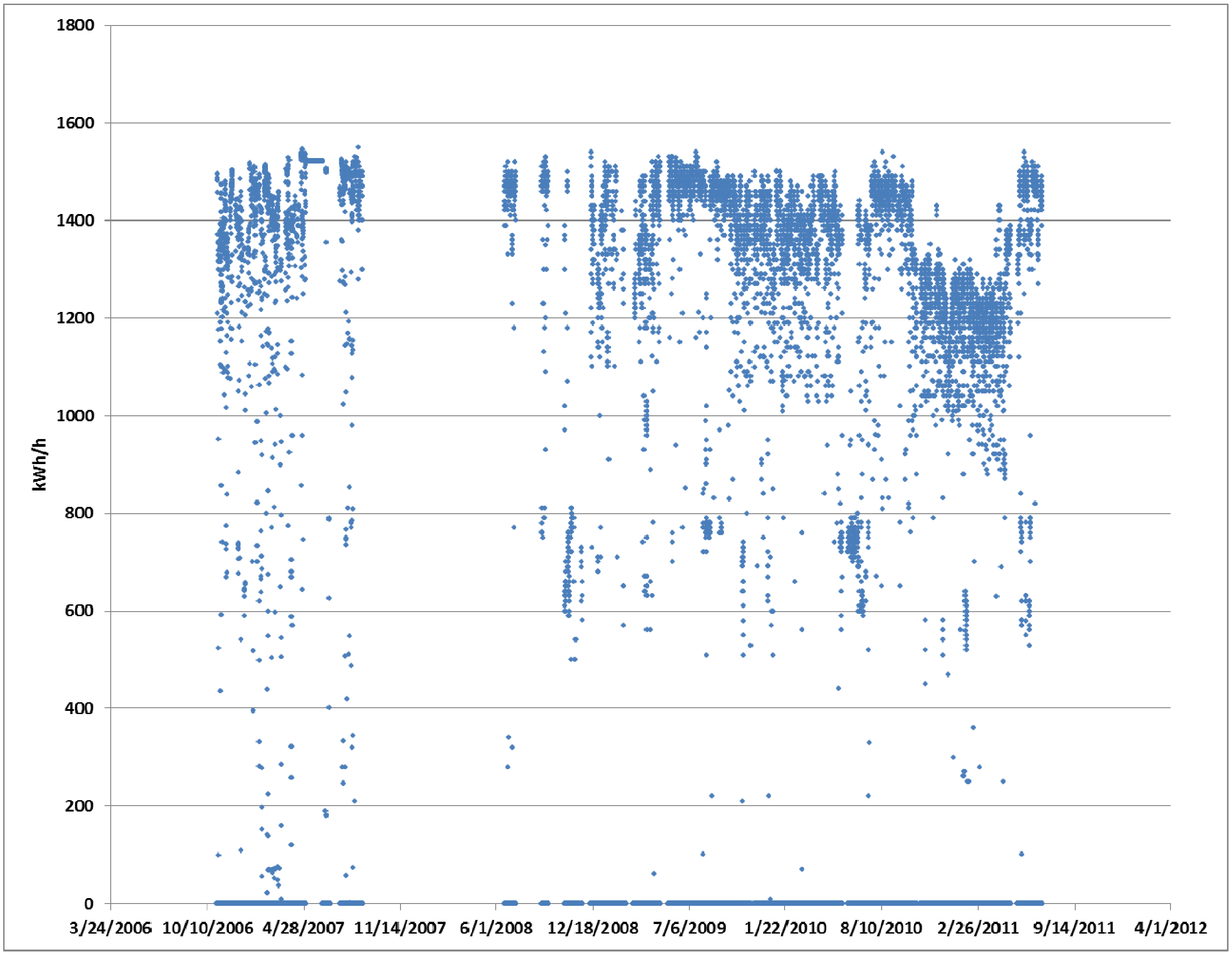

FIGURE 10 CHP POWER OUTPUT VERSUS TIME

Figure 10 presents data since April of 2007.

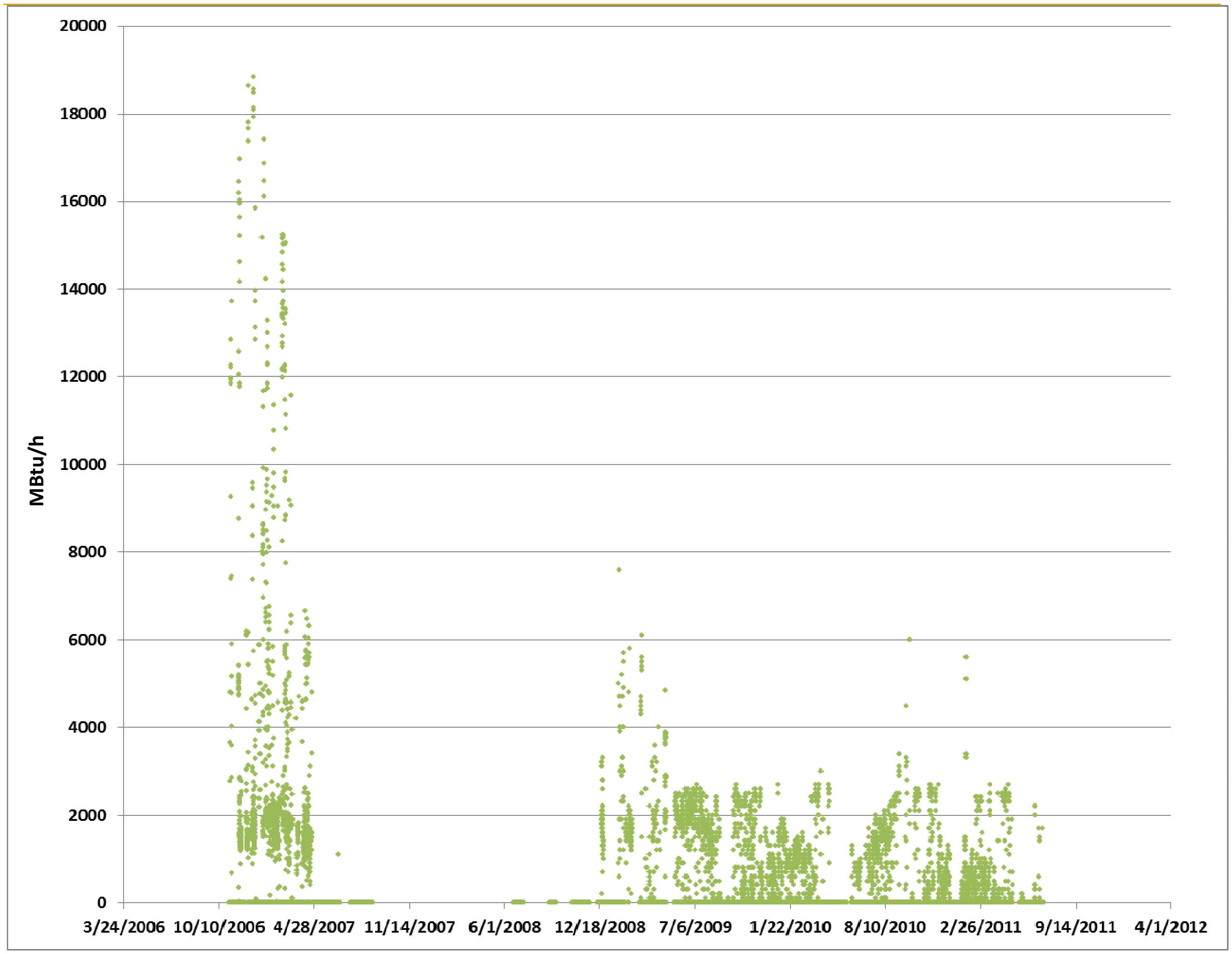

FIGURE 11 USEFUL THERMAL ENERGY SUPPLIED TO THE BUILDING

The 2006/2007 recovered thermal energy reported in Figure 11 must be erroneous data that passed through the quality check because converting the maximum power produced during that time (1,5000 kWh/h) into MBtu terms is 5,120, which is well under the 18,000 MBtu/h reported.

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

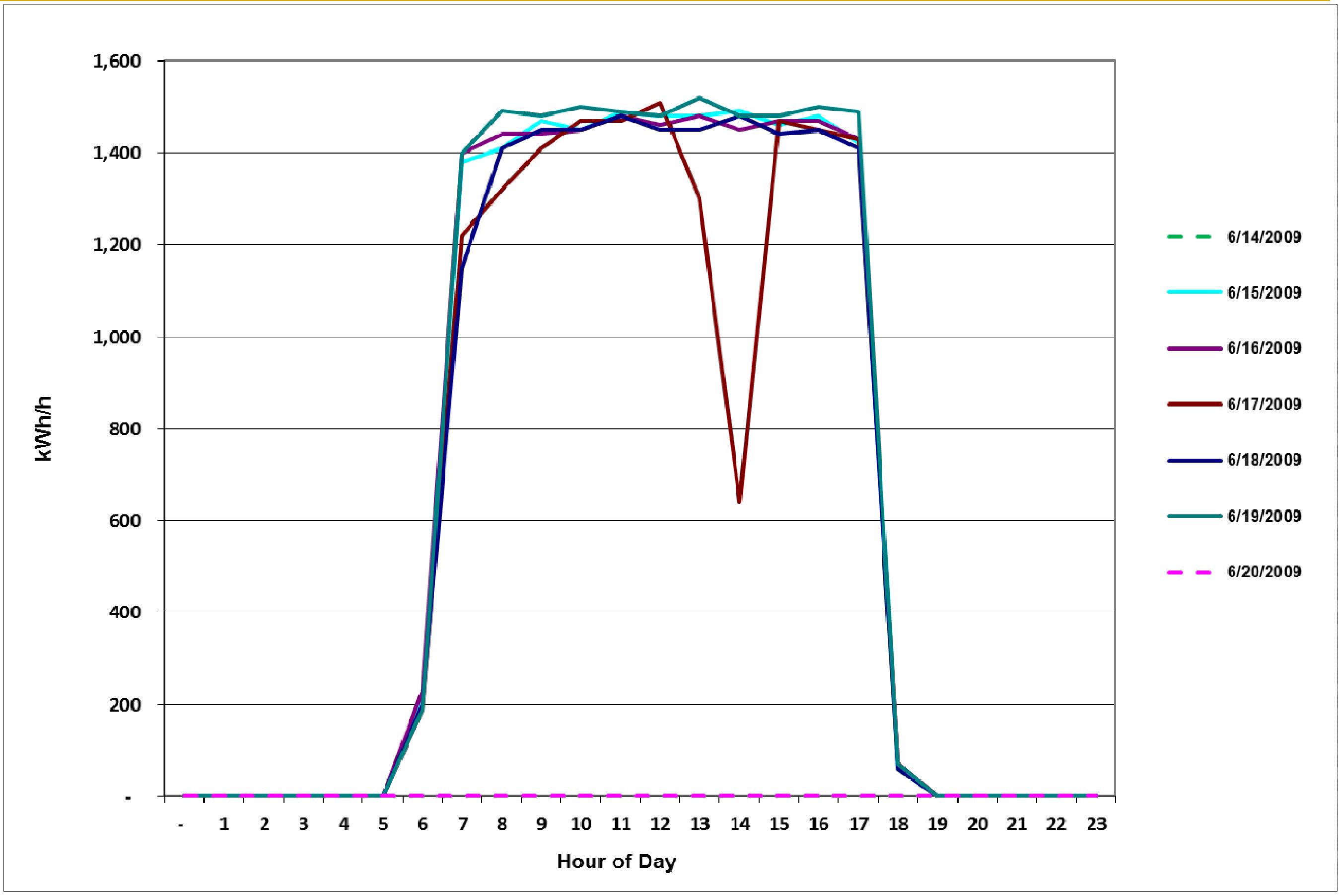

FIGURE 12 CHP POWER OUTPUT VERSUS TIME

Figure 12 covers the time period from June 14-20, 2009 providing CHP system power output by hour of the day pattern for the time period. June 14 and 20 (Sunday and the following Saturday) the system is not operating which is expected from an office building of this type. Figure 12 shows that all weekdays begin operation between 6 and 7 AM and shut down between 7 and 8 PM operating in a pattern suggesting electric load following.

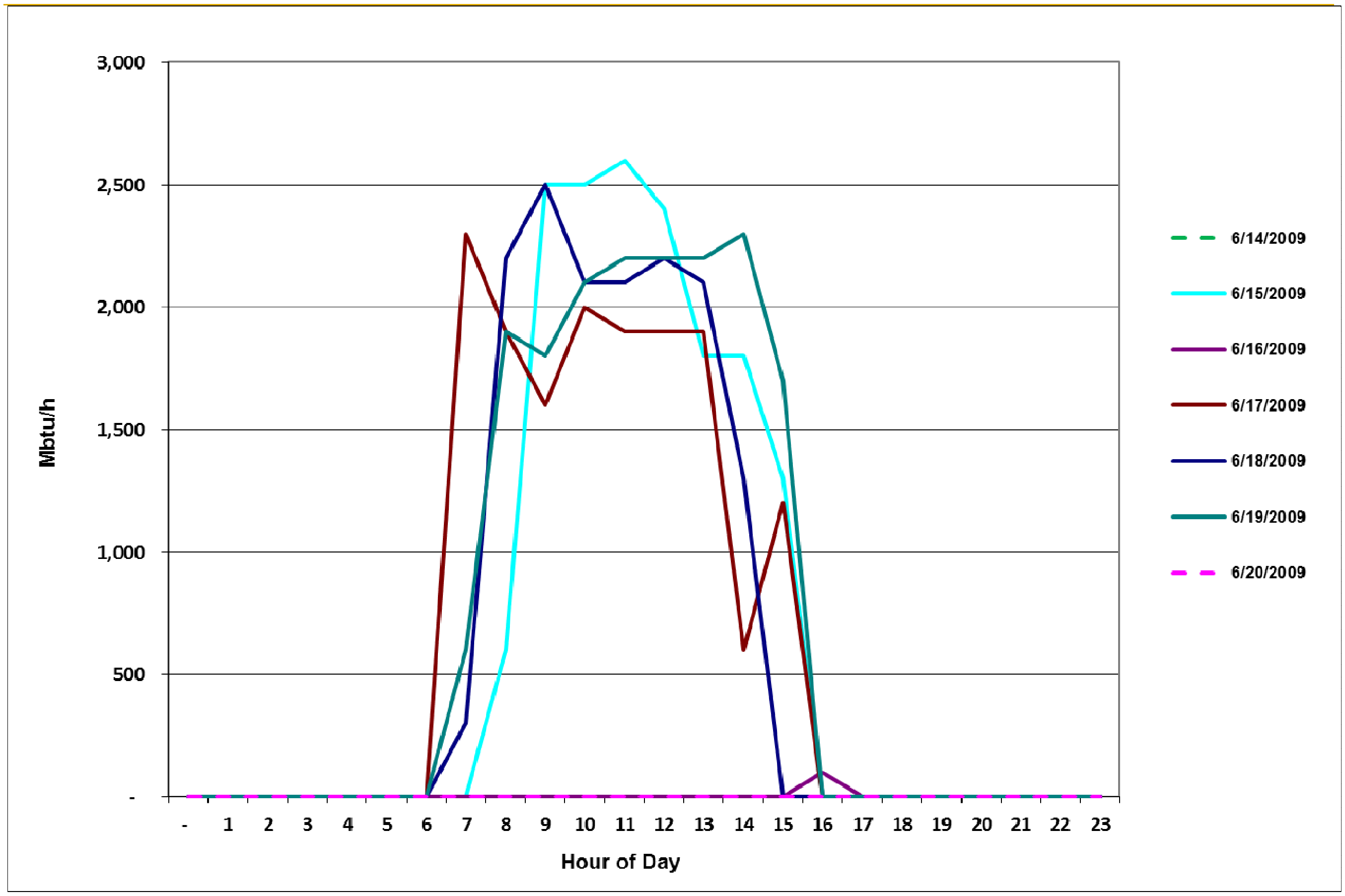

FIGURE 13 SELECTED DAY CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from Figure 13 show a consistent thermal load pattern, but very low in terms of the CHP system thermal capacity.

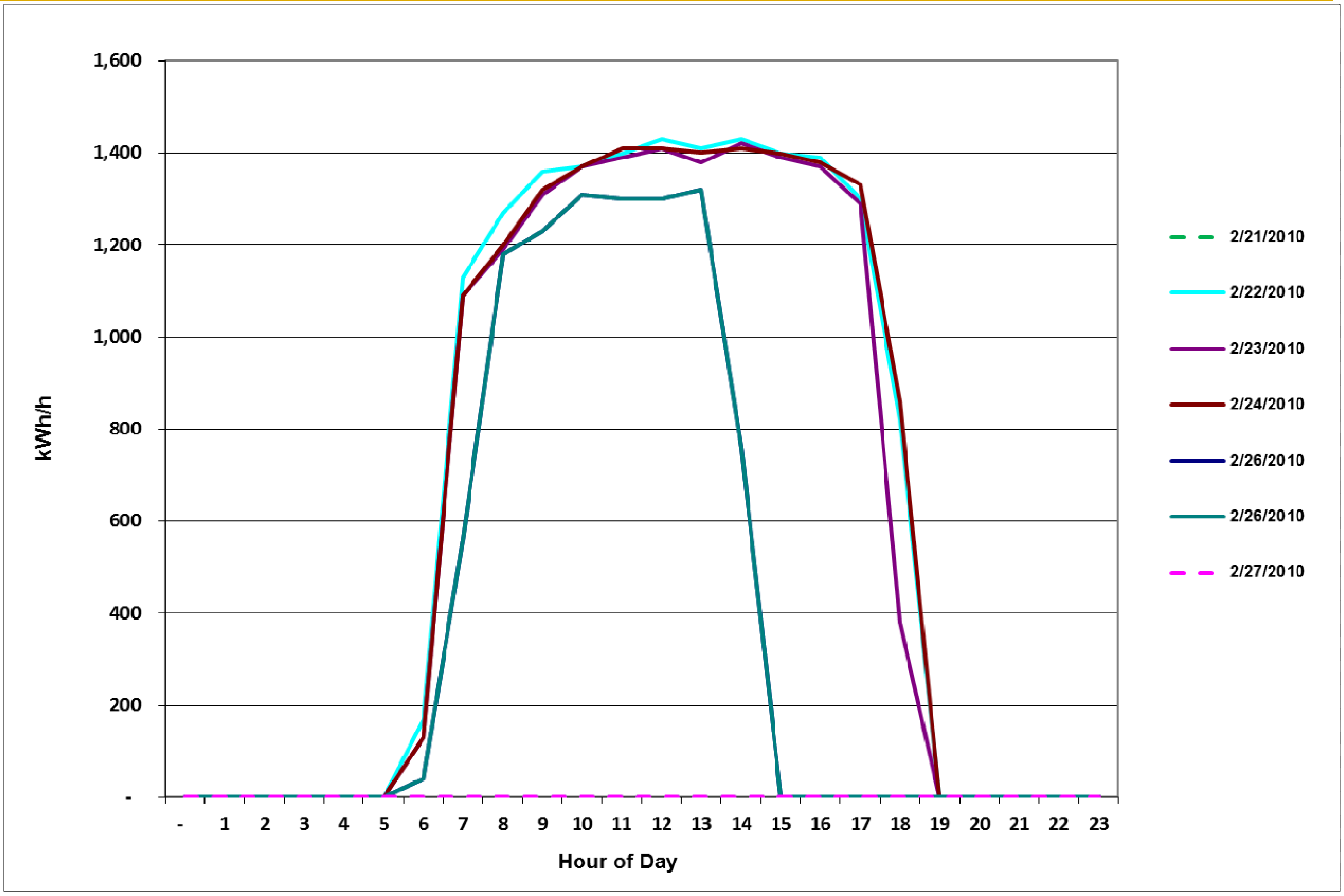

FIGURE 14 CHP POWER OUTPUT VERSUS TIME (AVG. KWH)

Figure 14 covers the time period from February 21-27, 2010 providing CHP system power output by hour of the day pattern for the time period. February 21 and 27 (Sunday and the following Saturday) the system is not operating which is expected from an office building of this type. Figure 14 shows that all weekdays begin operation between 6 and 7 AM and shut down between 7 and 8 PM operating in a pattern suggesting electric load following.

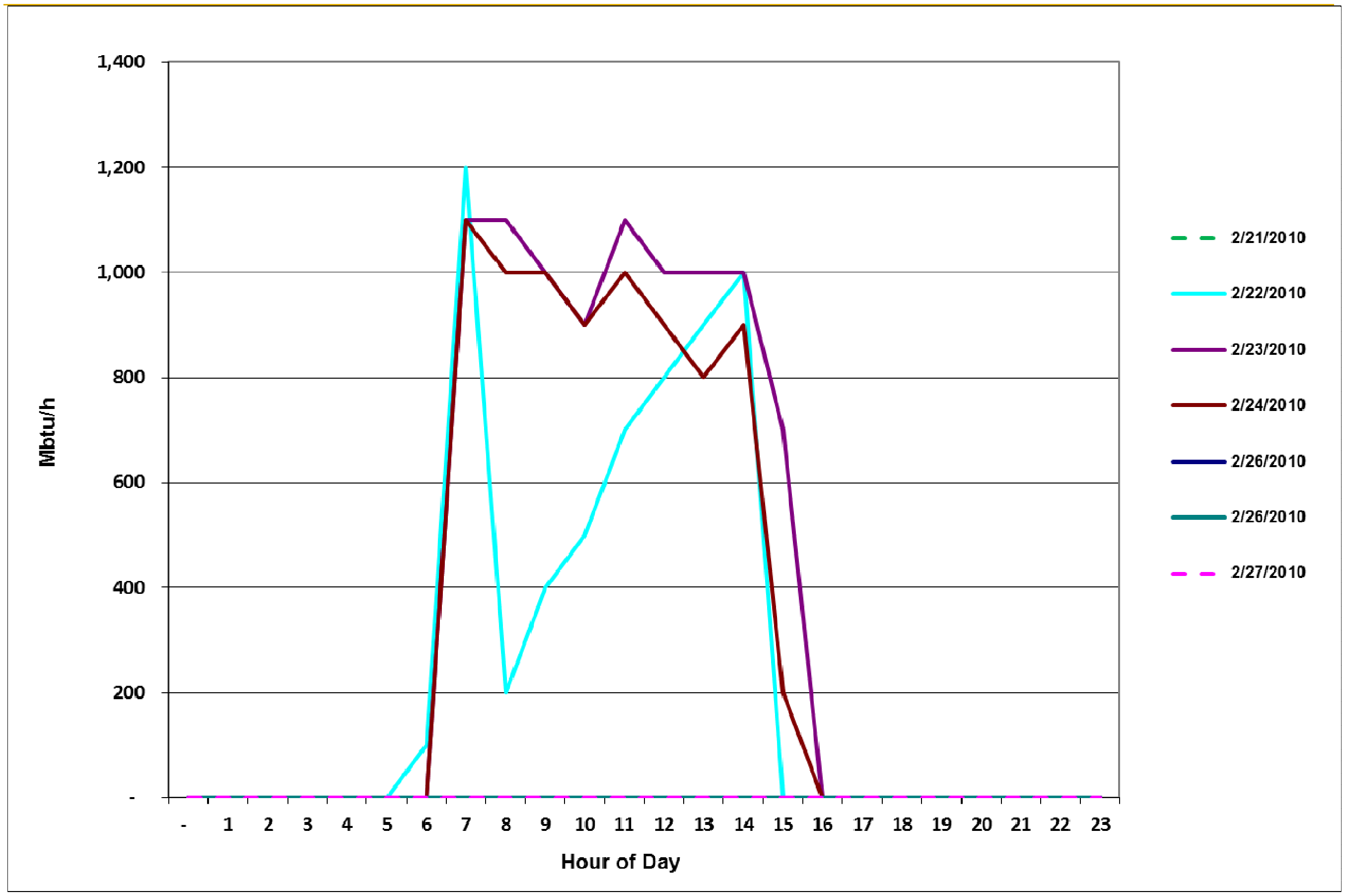

FIGURE 15 CHP USEFUL THERMAL OUTPUT VERSUS TIME (MBTU/HR)

The 24 hour useful CHP recovered heat thermal load profiles from February 21-27, 2010 (Figure 15) show a consistent thermal load pattern, but very low in terms of the CHP system thermal capacity.

PERFORMANCE SUMMARY

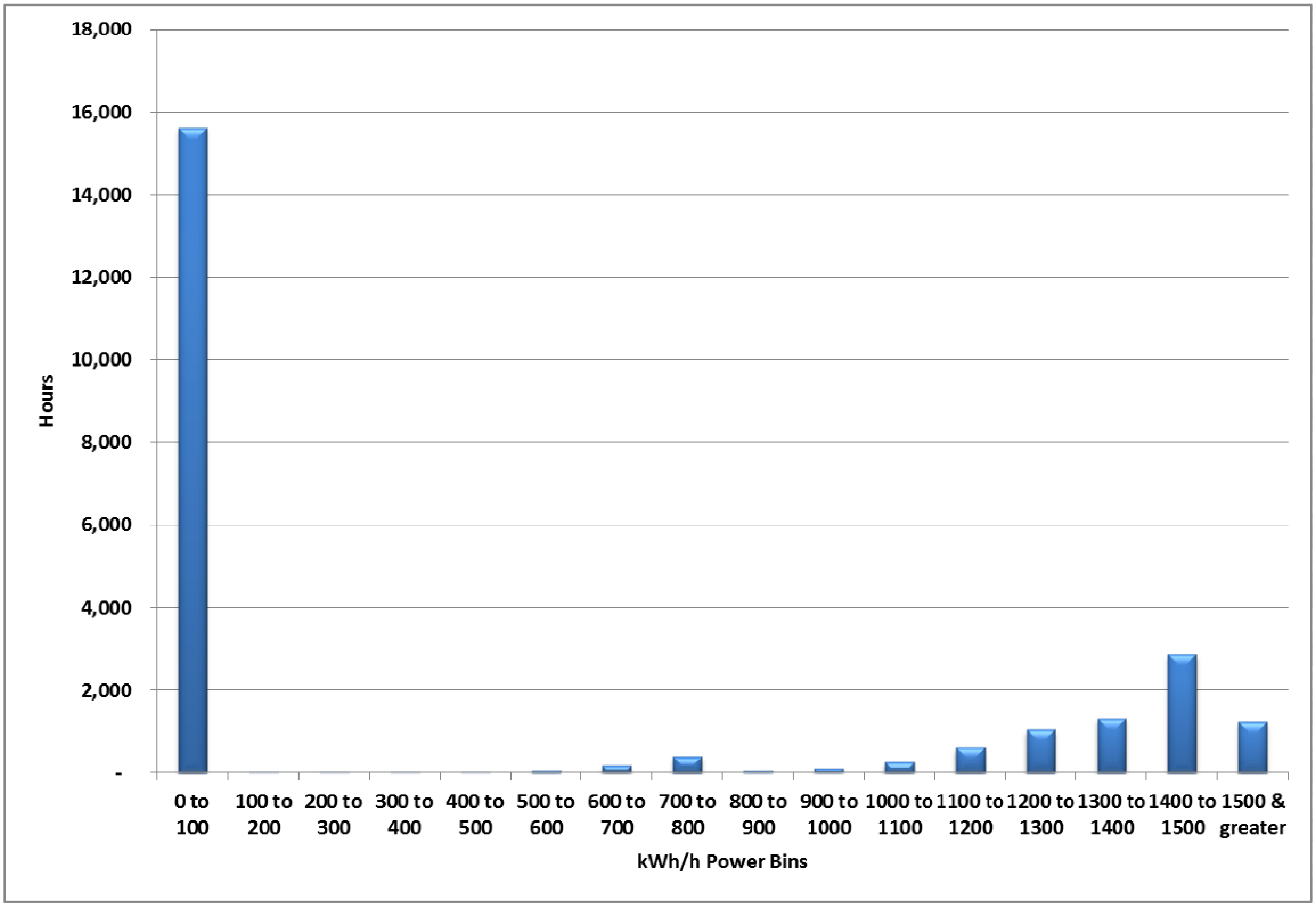

FIGURE 16 PERFORMANCE BY POWER BINS

During the 23,806 hours that met the range and relational checks 65.6% of the time, the CHP system was not operating. 10,816 hours would represent planned non-operational weekends for the duration, and, since about 10 hours per weekday the system is not in operation because of the electric rate tariff, the distribution is what would be expected.

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
December-08	414	138,880	1,547.0	136.7	30.0%	8.7%	38.7%
January-09	667	250,680	2,438.0	56.2	34.4%	2.3%	36.7%
February-09	353	150,320	2,159.0	294.6	23.3%	13.4%	36.7%
March-09	430	169,930	2,419.0	71.3	23.5%	2.9%	26.4%
April-09	671	296,971	4,170.0	106.5	23.8%	2.5%	26.3%
May-09	698	306,380	4,251.0	128.5	24.1%	3.0%	27.1%
June-09	675	347,982	4,840.0	274.0	24.1%	5.6%	29.6%
July-09	689	356,691	5,007.0	326.8	23.8%	6.4%	30.2%
August-09	685	248,809	3,498.0	161.4	23.8%	4.5%	28.3%
September-09	660	313,120	4,696.0	50.0	22.3%	1.0%	23.4%
October-09	680	306,791	4,533.0	165.9	22.6%	3.6%	26.2%
November-09	550	237,090	3,541.0	143.0	22.4%	4.0%	26.4%
December-09	640	293,872	4,456.0	99.7	22.1%	2.2%	24.3%
January-10	626	293,971	4,345.0	144.5	22.6%	3.3%	25.9%
February-10	616	266,230	4,004.0	128.5	22.2%	3.1%	25.4%
March-10	627	281,210	4,267.0	168.3	22.1%	3.9%	25.9%
April-10	582	265,214	2,098.0	40.7	42.3%	1.9%	44.2%
May-10	436	180,930	-	-	-	-	-
June-10	654	189,952	2,310.0	42.6	27.5%	1.8%	29.3%
July-10	690	306,292	4,433.0	149.9	23.1%	3.3%	26.4%
August-10	664	340,112	4,813.0	189.8	23.6%	3.9%	27.5%
September-10	475	237,610	3,575.0	81.0	22.2%	2.2%	24.5%
October-10	530	208,520	3,080.0	97.9	22.7%	3.1%	25.8%
November-10	630	238,549	3,539.0	107.5	22.6%	3.0%	25.5%
December-10	701	273,017	4,171.0	87.9	21.9%	2.1%	24.0%
January-11	701	267,880	4,041.0	43.5	22.2%	1.1%	23.2%
February-11	634	233,650	3,488.0	119.0	22.4%	3.3%	25.8%
March-11	673	281,892	4,347.0	73.0	21.7%	1.6%	23.3%
April-11	676	274,427	4,194.0	106.1	21.9%	2.5%	24.4%
May-11	355	136,041	2,030.0	4.3	22.4%	0.2%	22.6%
June-11	656	311,629	4,462.0	10.6	23.4%	0.2%	23.6%
July-11	641	302,289	4,453.0	57.5	22.7%	1.3%	24.0%
Total preceding 12 months	**7336**	**3,105,617**	**46,193.0**	**978.1**	**22.5%**	**2.1%**	**24.6%**

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

[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.

This office building is equipped with two Caterpillar 820 kW lean burn natural gas engine generator sets and an absorption chiller to provide heating, cooling and DHW.

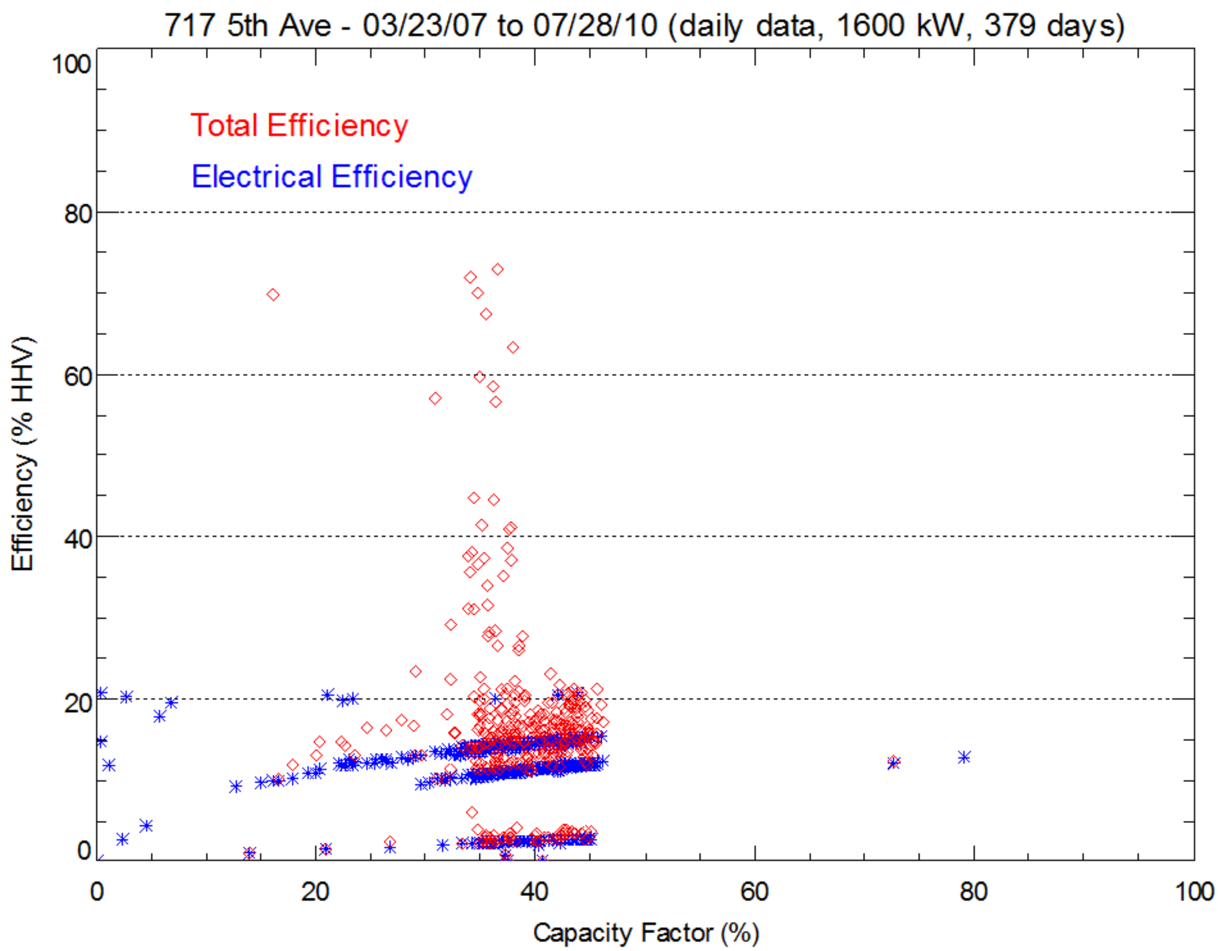

FIGURE 17 CAPACITY FACTOR[3]

Capacity Factor (Figure 17) presents the CHP generated power efficiency over the time period (379 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 generally operated between 12% and 45% of the generating capacity at about 22.5% power efficiency (HHV). The initial observation is that this CHP plant is oversized as currently operated. The three clusters of power data indicates data problems that emanated from the fuel flow meter. The second observation is the uncharacteristic fall-off in electrical efficiency at part-load. The useful thermal energy (heating and cooling only) operated at high efficiency during the winter months (upper grouping) and lower during the summer months, averaging only 2.1% thermal efficiency (HHV). Note the heat recovery increases as the capacity is reduced which merely reflects higher thermal recovery during lower power production.

[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.

NYSERDA

Thermal hot water loads in office buildings are modest in the summer and require cooling to maintain system performance. The useful thermal portion of this project has been problematic from a general performance perspective, as well as, having unresolved data collection issues.

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)** Three power transducers are installed on-site to measure the net generator power. One transducer measures the gross power output of the engines and the other two measure parasitic loads associated with the power generation. The difference between the gross power and the parasitic power is calculated on a 15-minute interval. This 15-minute data is then summed into hourly data for the online database.
2. **DG/CHP Generator Gas Use (total cubic feet)** Data for this point comes from a utility gas pulse output installed on the meter serving the engines. The 15-minute data is summed into hourly data for the online database. The meter has a resolution of 1000 cu.ft., making the data coarse on an hourly basis. The data for this channel is best viewed on a daily basis.
3. **Useful Heat Recovery (total MBtu)** The Useful Heat Recovery is calculated from loop temperature and flow averages on a 15-minute interval. The heat recovery rate is calculated by taking the temperature difference between the loop leaving the engines and before the dump radiator (in °F) and is then multiplied by the flow rate (in gpm) and the heating content factor for pure water (0.488 Btu/h-F-gpm). The 15-minute heat recovery rate is averaged for the hourly data.

The office building CHP system is operated to produce revenue for the third party operator which is logically driven by the economics of the electric rate tariff schedule. To increase the poor thermal performance in this office building setting would likely require increased capital cost and the return would have to be borne by the extra savings generated.

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 40% to a high of 97.8%, and it continues to fluctuate (see May 2011-Table 3).

TABLE 3 PERCENTAGE OF GOOD DATA

	Percentage of Good Data		
	Power	Gas Use	Useful Heat
September-08	43.6%	43.6%	46.7%
October-08	29.4%	28.6%	32.3%
November-08	56.7%	58.1%	60.8%
December-08	55.6%	53.0%	55.1%
January-09	89.8%	83.6%	90.0%
February-09	52.7%	53.4%	43.4%
March-09	58.1%	58.9%	52.3%
April-09	93.2%	93.3%	94.2%
May-09	93.9%	94.5%	45.9%
June-09	93.8%	93.3%	94.3%
July-09	92.6%	93.3%	91.5%
August-09	92.1%	91.7%	96.6%
September-09	91.7%	93.6%	97.8%
October-09	91.4%	92.7%	97.2%
November-09	78.6%	80.7%	81.9%
December-09	86.0%	89.8%	93.3%
January-10	84.1%	87.2%	89.2%
February-10	91.7%	94.2%	94.9%

March-10	86.5%	89.1%	91.0%
April-10	83.3%	71.5%	90.3%
May-10	60.1%	40.6%	65.1%
June-10	90.8%	84.0%	97.4%
July-10	92.7%	92.6%	96.1%
August-10	91.5%	92.3%	94.8%
September-10	76.1%	82.4%	86.4%
October-10	73.2%	74.7%	74.9%
November-10	91.8%	91.4%	93.3%
December-10	94.2%	93.8%	99.1%
January-11	94.2%	93.8%	98.9%
February-11	94.3%	93.3%	98.7%
March-11	92.4%	93.1%	97.4%
April-11	93.9%	93.5%	95.3%
May-11	50.6%	50.6%	53.9%
June-11	91.1%	92.5%	99.3%
July-11	88.5%	90.1%	94.3%