NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT 110 EAST 59TH STREET, NYC

October 9, 2013

110 East 59TH Street, NYC

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.

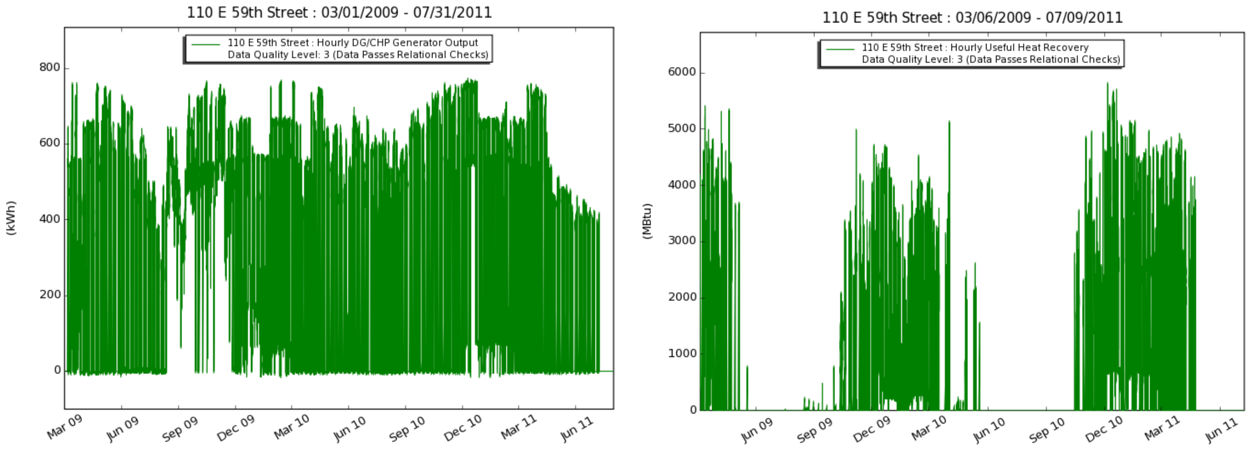

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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

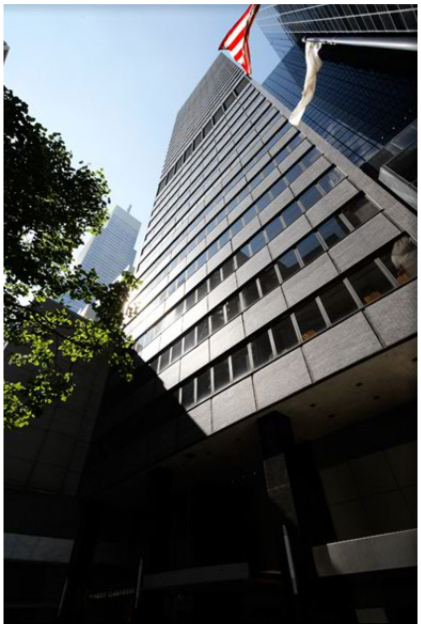

FIGURE 2 110 EAST 59TH STREET, NYC

110 East 59th Street is a 37 story office building in mid-town Manhattan built in 1989.

THE SYSTEM

The CHP system at 110 East 59th Street consists of eight (8) 100-kW Elliott microturbines. The turbines have roughly a 105-kW gross output to cover the operation of the onboard gas compressor and controls, resulting in a net output of 800 kW for the entire plant. Electricity is being fed into only one of the three facility utility feeds.

The turbines have integrated hot water heat recovery, with a parallel piping arrangement. Each turbine pulls hot water from a return header and injects heated hot water to a supply header. There is a dump radiator for system stability and heat rejection.

The turbines are electrically connected into two groups of four turbines each. These two groups are connected to one of the three utility feeds into the building. The other two feeds are unaffected by the operation of the CHP system. The grouping of turbines and selection of the associated utility feed was performed to maximize the opportunity for electrical operation. The turbine groups are sized to be very close to the continuous baseload for the selected service.

Heat from the turbine heat recovery loop can be used to meet thermal loads in the facility via a heat exchanger (for heating season operation), or directly used by an absorption chiller (see Figure 3). The thermal loads include:

- Space heating to the building secondary hot water return (isolated by HX)
- Direct hot water use by a new absorption chiller

Heat not recovered (typically at startup, or low load conditions) will be wasted, first by a bypass exhaust damper in each turbine, then, if necessary, by heat rejection by a dump radiator located on the heat recovery loop.

The absorption chiller is tied into the building's primary chilled water return. Condenser water for this chiller will be provided by the building's condenser water circuit (tie-in on the return side to the condenser). The absorption chiller will not have its own cooling tower.

The CHP hot water loop is isolated from the building's hot water loop by a brazed plate heat exchanger. The HX is located upstream of the steam-to-hot water tube-bundle, to allow the CHP system to meet the largest possible fraction of the building heating load.

The heat recovery loop typically operates between 140°F - 205°F supply temperature, and returns to the microturbine arrays at between 105°F - 180°F. The loop flow rate is 280 gpm, and the heat recovery loop contains a 30/70 mixture of propylene glycol and water.

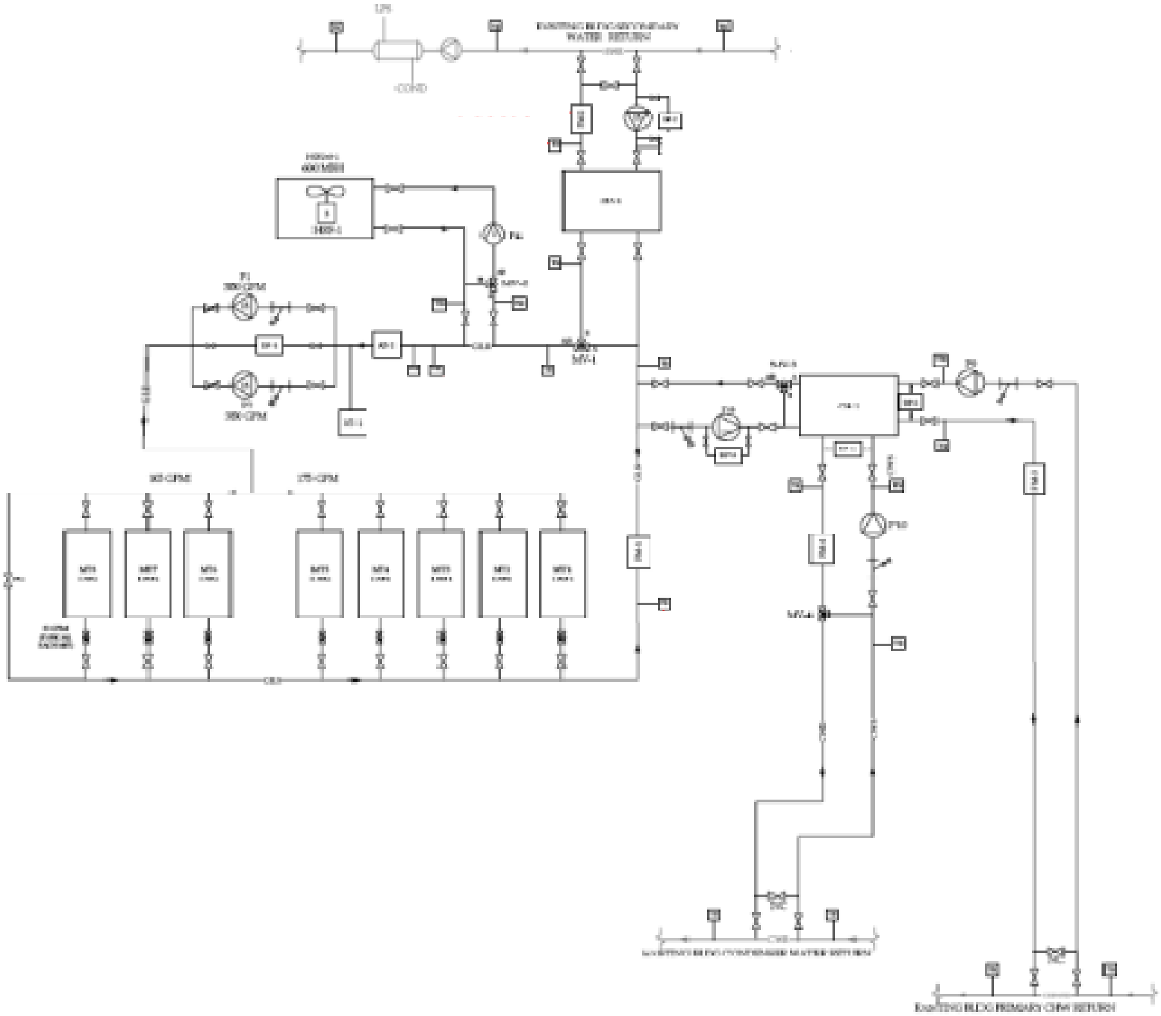

FIGURE 3 HEAT RECOVERY SCHEMATIC

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 January 2010.

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-10	744	199,715	3,121.1	606.2	21.4%	19.0%	40.5%
February-10	672	220,784	3,419.5	807.6	21.6%	23.2%	44.8%
March-10	744	200,727	3,103.5	405.5	21.6%	12.8%	34.5%
April-10	720	194,426	3,091.9	71.5	21.0%	2.3%	23.3%
May-10	744	140,789	2,285.4	62.3	20.6%	2.7%	23.3%
June-10	720	167,287	2,801.7	-	20.0%	0.0%	20.0%
July-10	744	214,677	3,672.1	-	19.6%	0.0%	19.6%
August-10	744	200,327	3,403.2	-	19.7%	0.0%	19.7%
September-10	720	146,588	2,457.8	-	20.0%	0.0%	20.0%
October-10	744	164,247	2,660.9	136.2	20.7%	5.0%	25.7%
November-10	720	188,960	2,968.7	534.5	21.3%	17.7%	39.0%
December-10	744	318,651	4,937.4	1,192.7	21.6%	23.7%	45.3%
January-11	744	265,535	4,153.1	1,186.0	21.4%	28.0%	49.4%
February-11	672	205,785	3,299.6	886.6	20.9%	26.3%	47.2%
March-11	744	223,497	3,532.5	906.9	21.2%	25.2%	46.3%
April-11	720	163,475	2,698.6	373.4	20.3%	13.6%	33.8%
May-11	744	106,196	1,886.1	-	18.8%	0.0%	18.8%
June-11	720	102,901	1,944.9	-	17.7%	0.0%	17.7%
July-11	743	97,214	1,903.1	-	17.1%	0.0%	17.1%
Total preceding 12 months	**8759**	**2183376**	**35845.65**	**5216.271**	**20.4%**	**14.3%**	**34.6%**

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

Table 1 presents annual data showing microturbine electric efficiency in the low 20.4% (HHV) range which is expected. Useful thermal performance is very low especially since an absorption chiller is available for cooling. The data, in fact, shows that during June through September 2010 and May through July 2011 no useful

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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.

thermal energy data was recorded, indicating that during the cooling season useful thermal energy recording was not possible. The average recorded useful heat fuel efficiency from January – March 2010 was 18.3% and during the same period in 2011 increased to 26.5%.

OPERATING SUMMARY

During the 21,191 hours that met the range and relational checks 43.8% of the time, the CHP system was producing 400 kWh/h or greater.

This site is operated by an ESCO with a power purchase agreement with the site. Following the weekly power profiles for December 2010 (Figure 7), March 2011 (Figure 9) and June 2011 (Figure 11), one can see the operating focus was on the rate tariff structure ending in June 2011 where weekdays are dedicated to peak demand reduction and weekends the system is off.

Figure 2 shows the heat recovery use solely for space heating beginning in September 2011, peaking in December and ending in May.

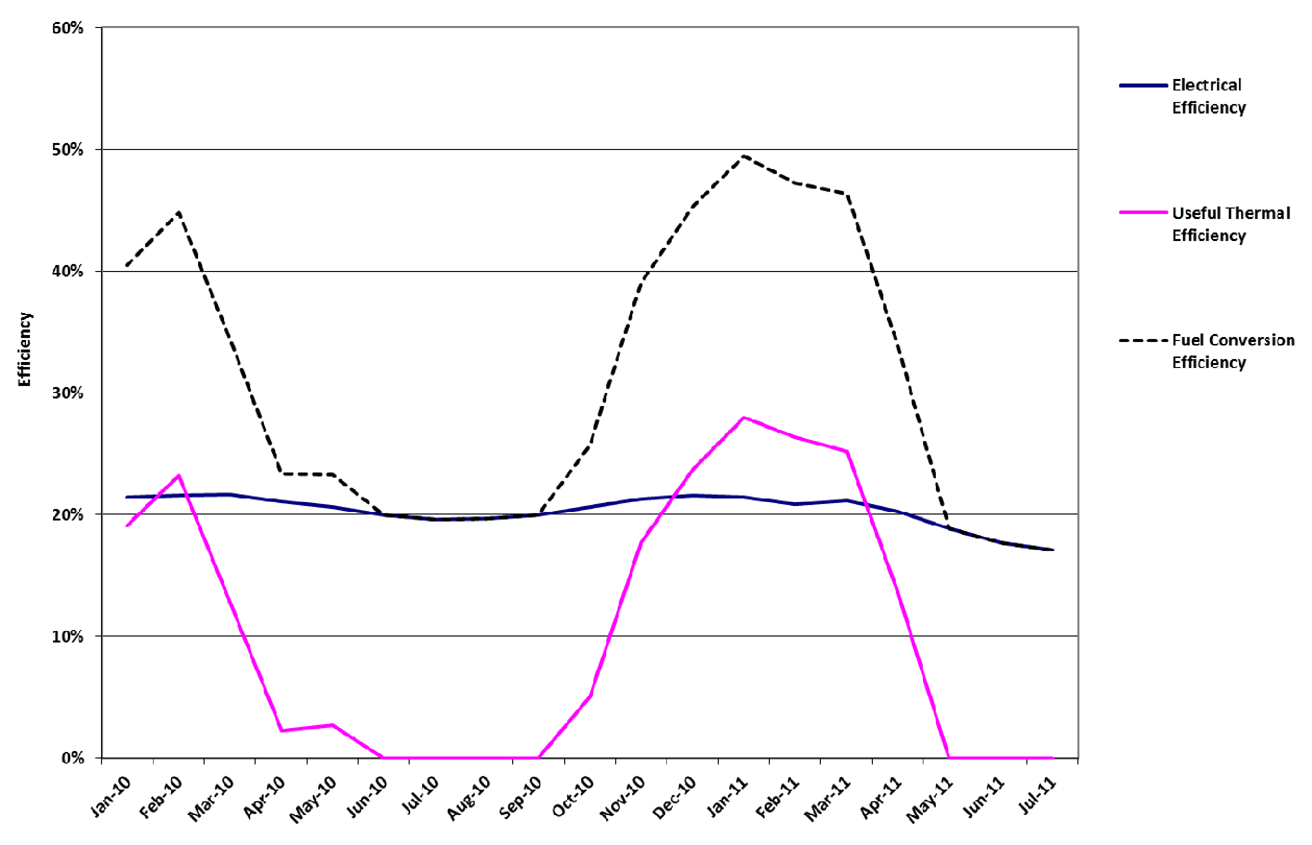

FIGURE 4 CHP SYSTEM EFFICIENCY BY MONTH

Figure 4 provides operating efficiency showing declining electric efficiency in the spring of 2011.

POWER GENERATION AND USEFUL THERMAL OUTPUT

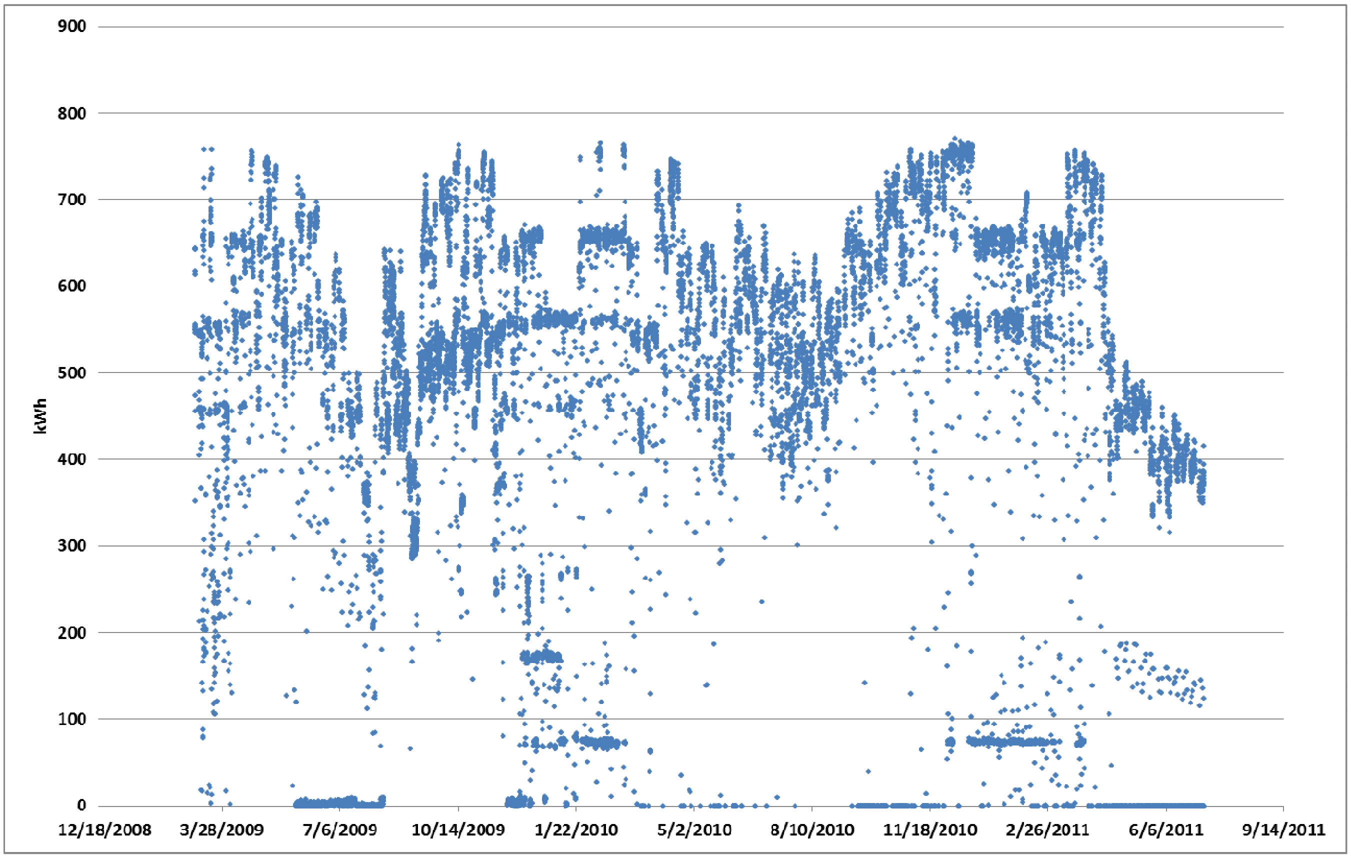

FIGURE 5 CHP POWER OUTPUT VERSUS TIME

Figure 5 provides power data showing consistent winter peak power capability at 760 kWh in 2009, 2010 and 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. Figure 6 also shows the system is operating on an electric load following pattern and there are indications of systems coming offline in approximately 100 kW blocks during parts of the annual operating cycle.

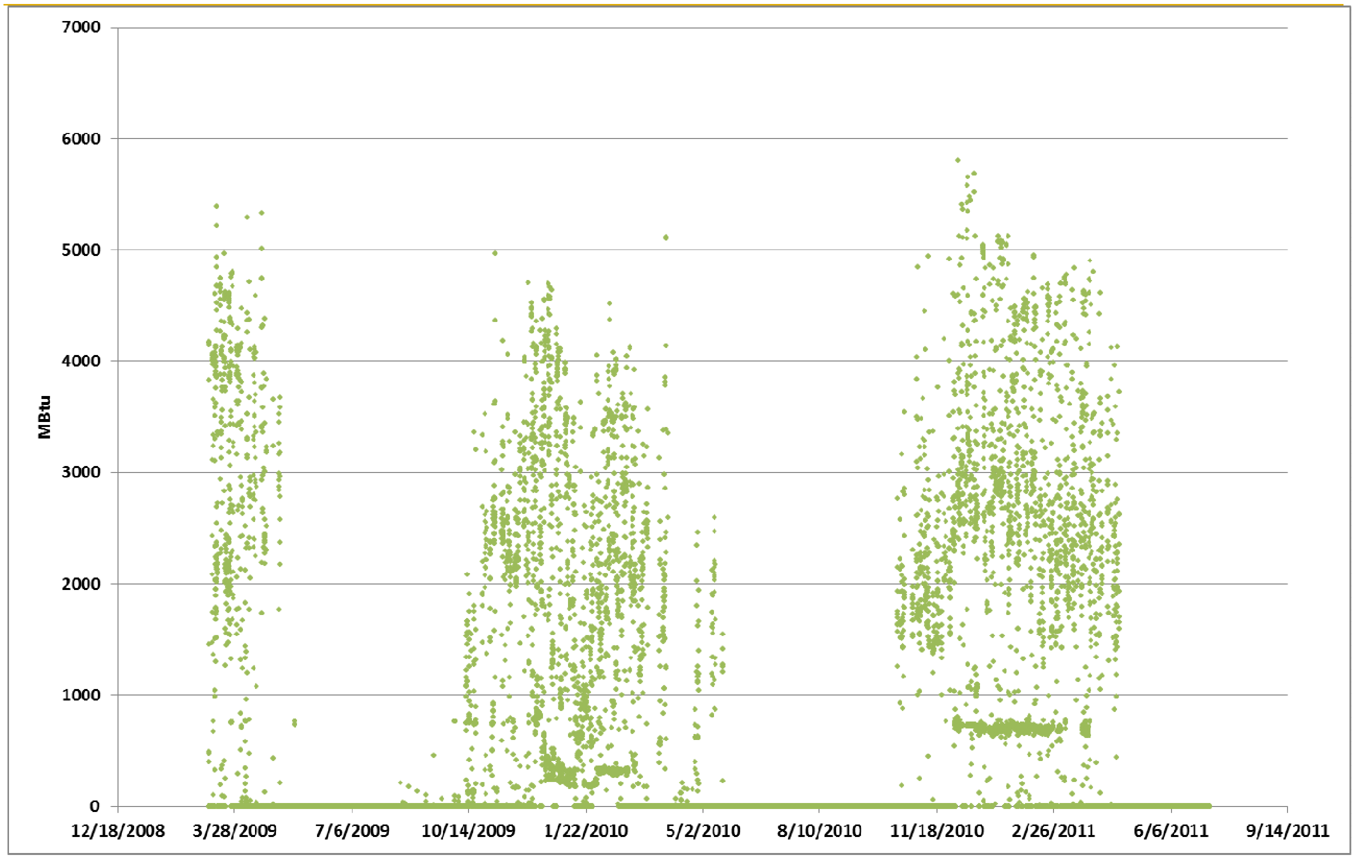

FIGURE 6 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 7 shows that thermal energy is matched for winter heating and no domestic hot water or summer cooling is provided, indicating significant heat is dumped during the spring, summer and fall seasons.

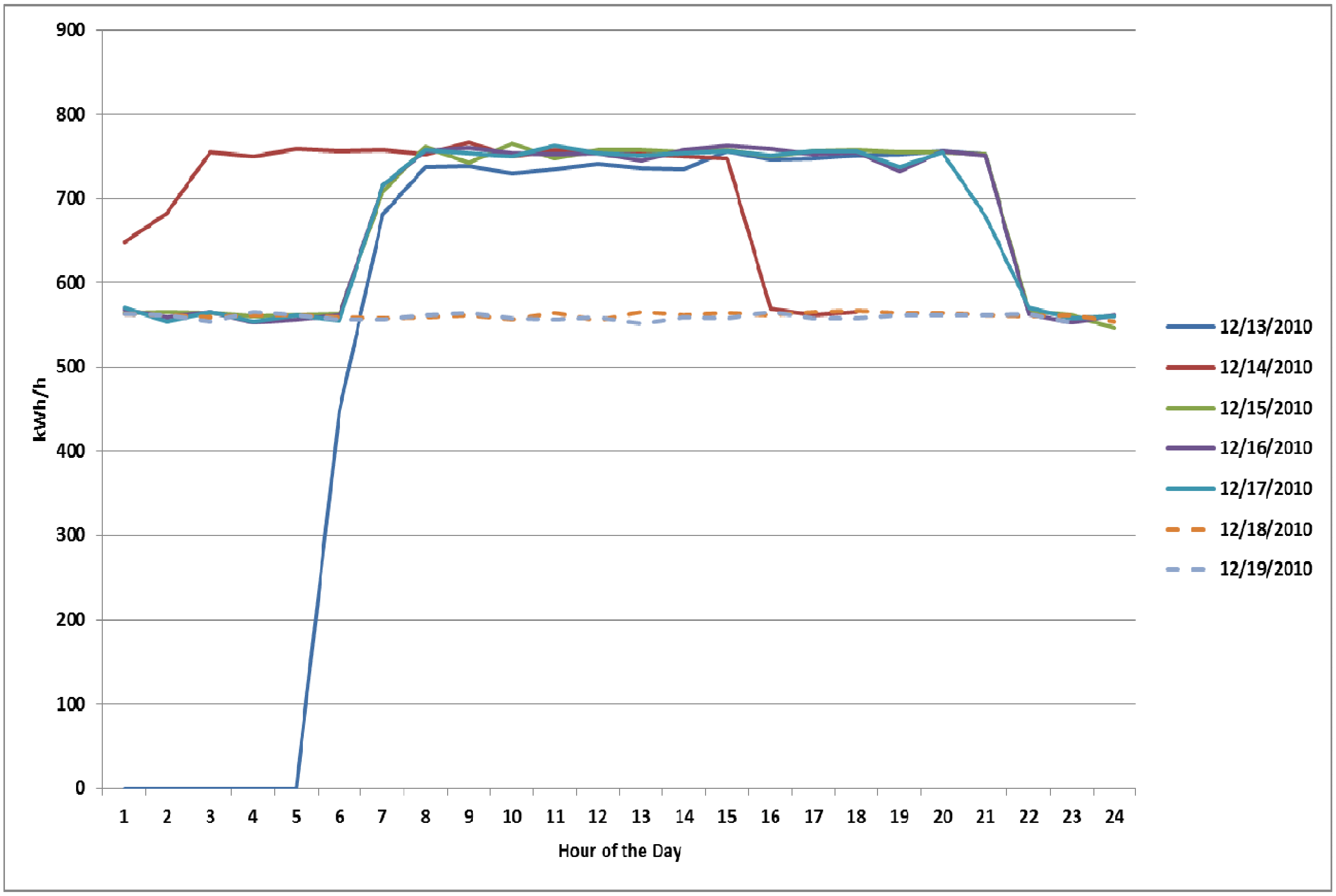

FIGURE 7 CHP POWER OUTPUT VERSUS TIME

Figure 8 covers the time period from December 13 - 19, 2010 providing CHP system power output by hour of the day pattern for the time period. December 18 is a Saturday. Figure 7 shows 24 x 7 likely six units generally operate between 500 and 600 kWh through about 5 AM, and then all eight units produce about 760 kWh/h to about 11 PM on weekdays only and then ramp back down to about 670 kWh/h. The overarching sequence appears to be operationally oriented versus load following or rate tariff constrained at this time.

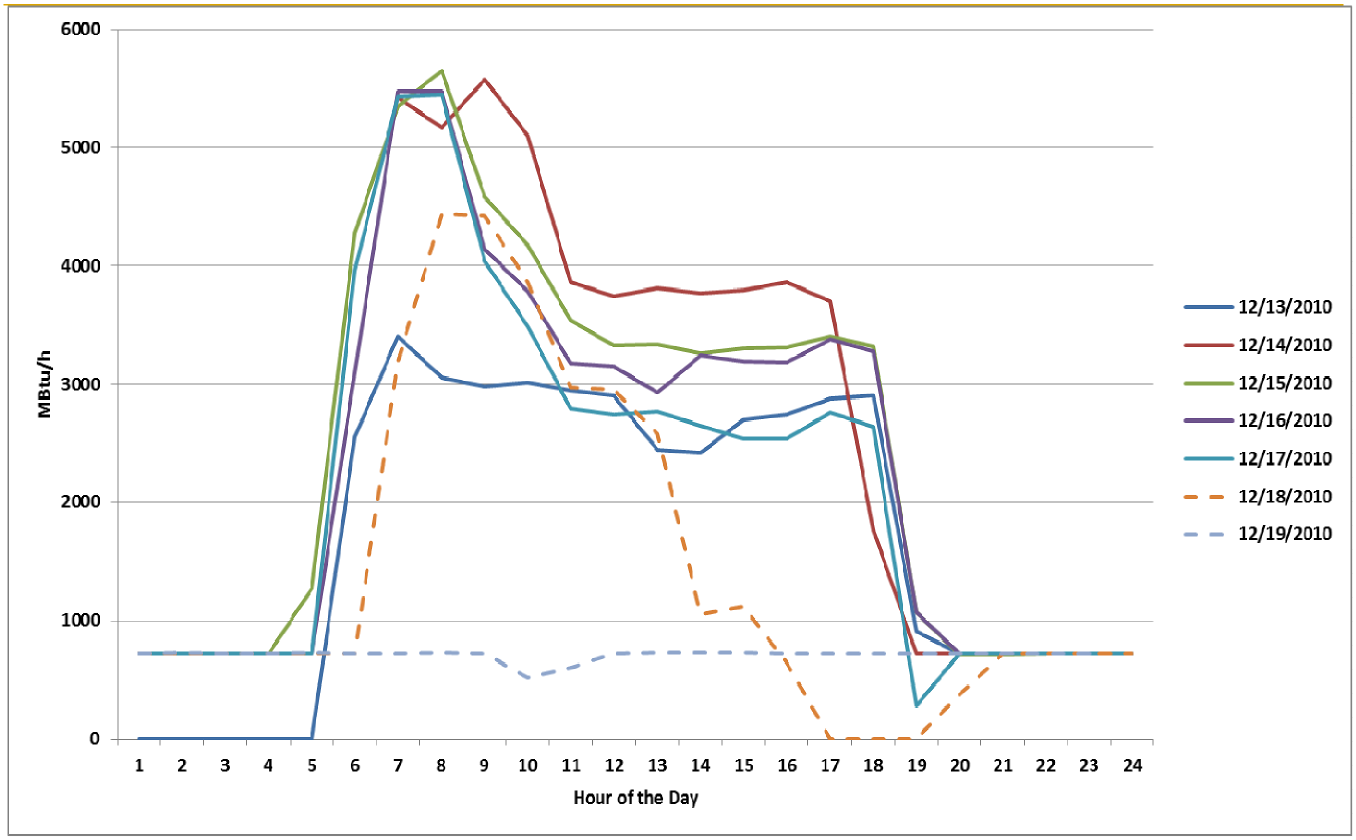

FIGURE 8 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 8 shows general weekday heating patterns with morning domestic hot water production. This pattern continues through Saturday and then the system delivers little useful heat on Sunday.

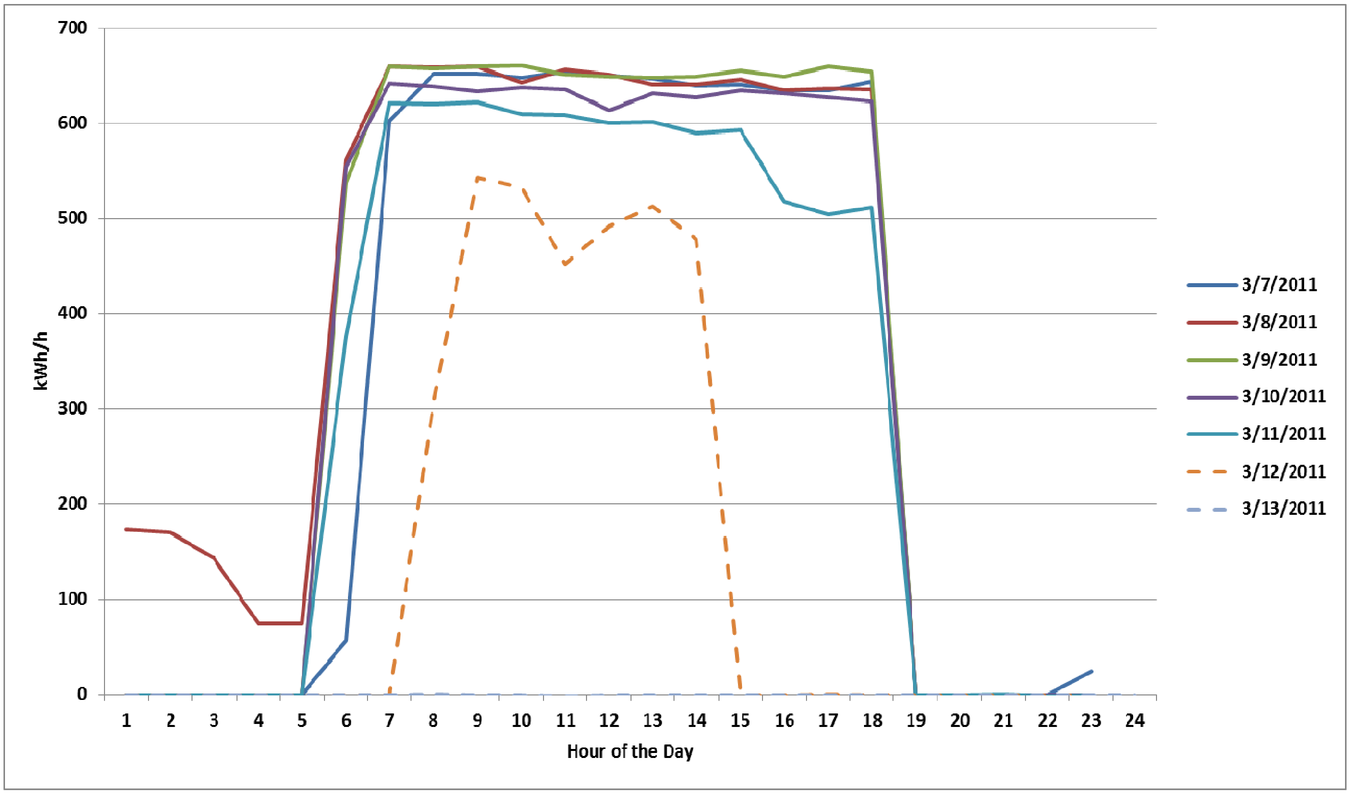

FIGURE 9 CHP POWER OUTPUT VERSUS TIME

Figure 9 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. The system was started at 5 AM on Monday morning and the microturbine array ran producing between 625 and 670 kWh/h until 6 PM when they shut down. Saturday, six units started at 8 AM and shut down at 3 PM and no units ran on Sunday.

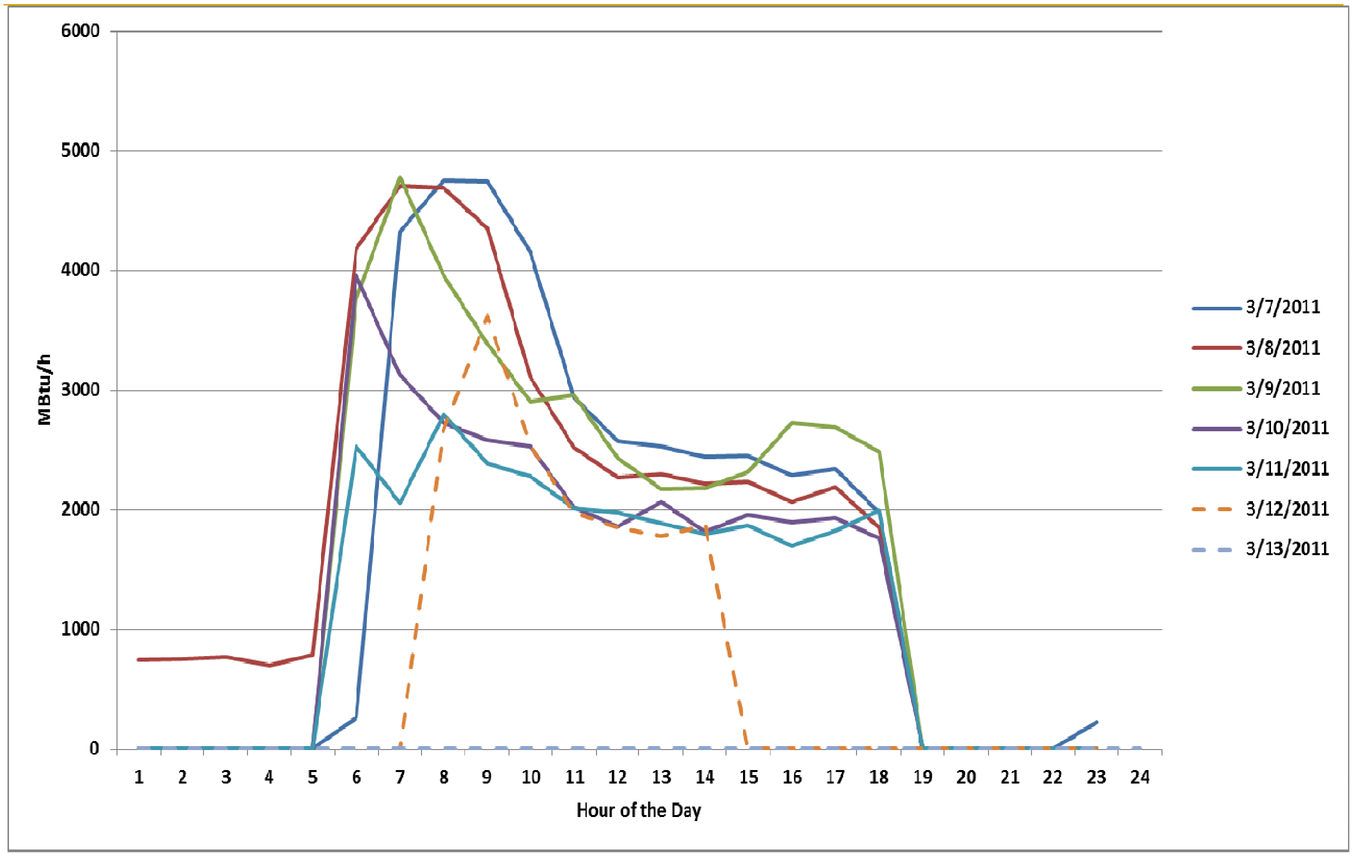

FIGURE 10 USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles show general weekday heating patterns with morning domestic hot water production. This pattern continues through Saturday and then the system is shut down on Sunday. (Figure 10).

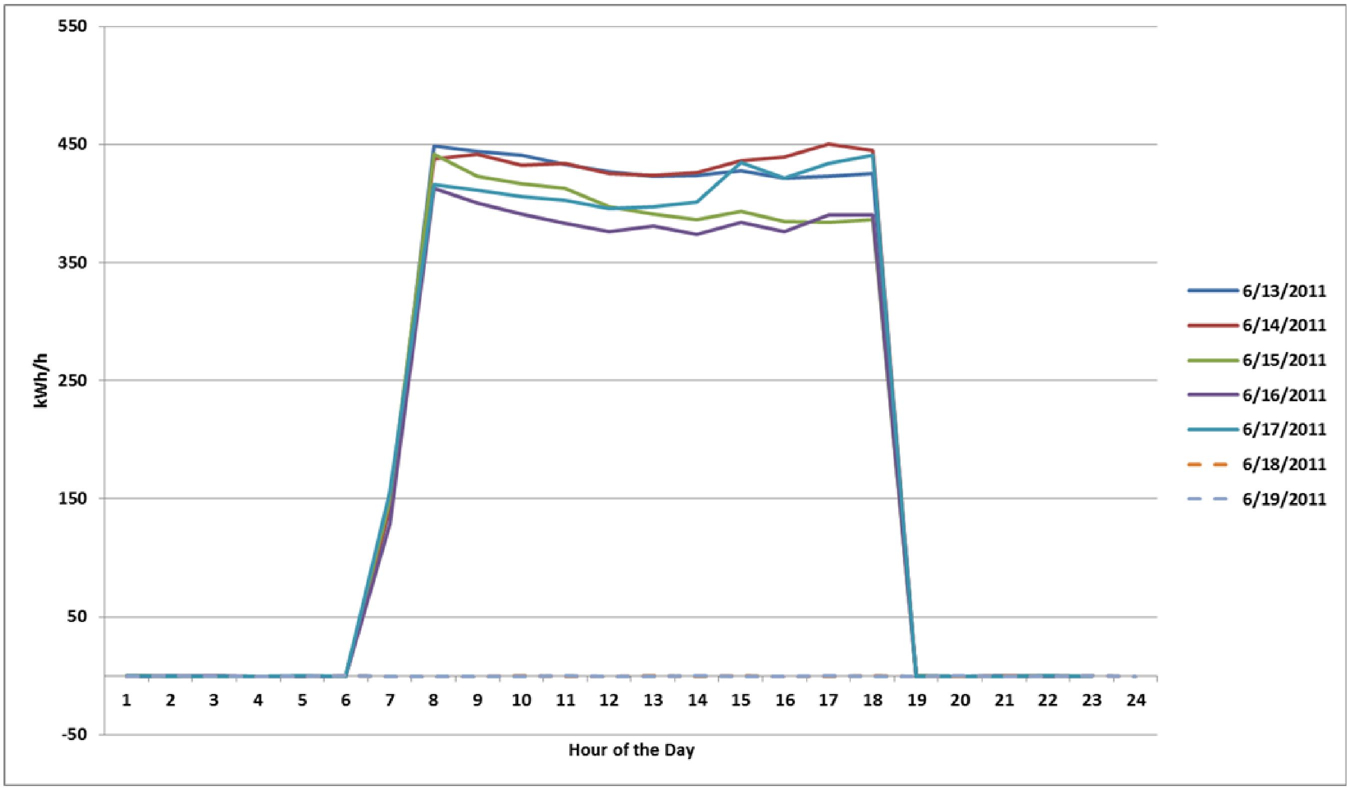

FIGURE 11 CHP POWER OUTPUT VERSUS TIME

Figure 11 shows a marked change in operating characteristics. The microturbine array for the weekdays started at 7 AM and was shut down at 6 PM. Since no heat recovery occurs in the summertime, this array functions as a peak shaver.

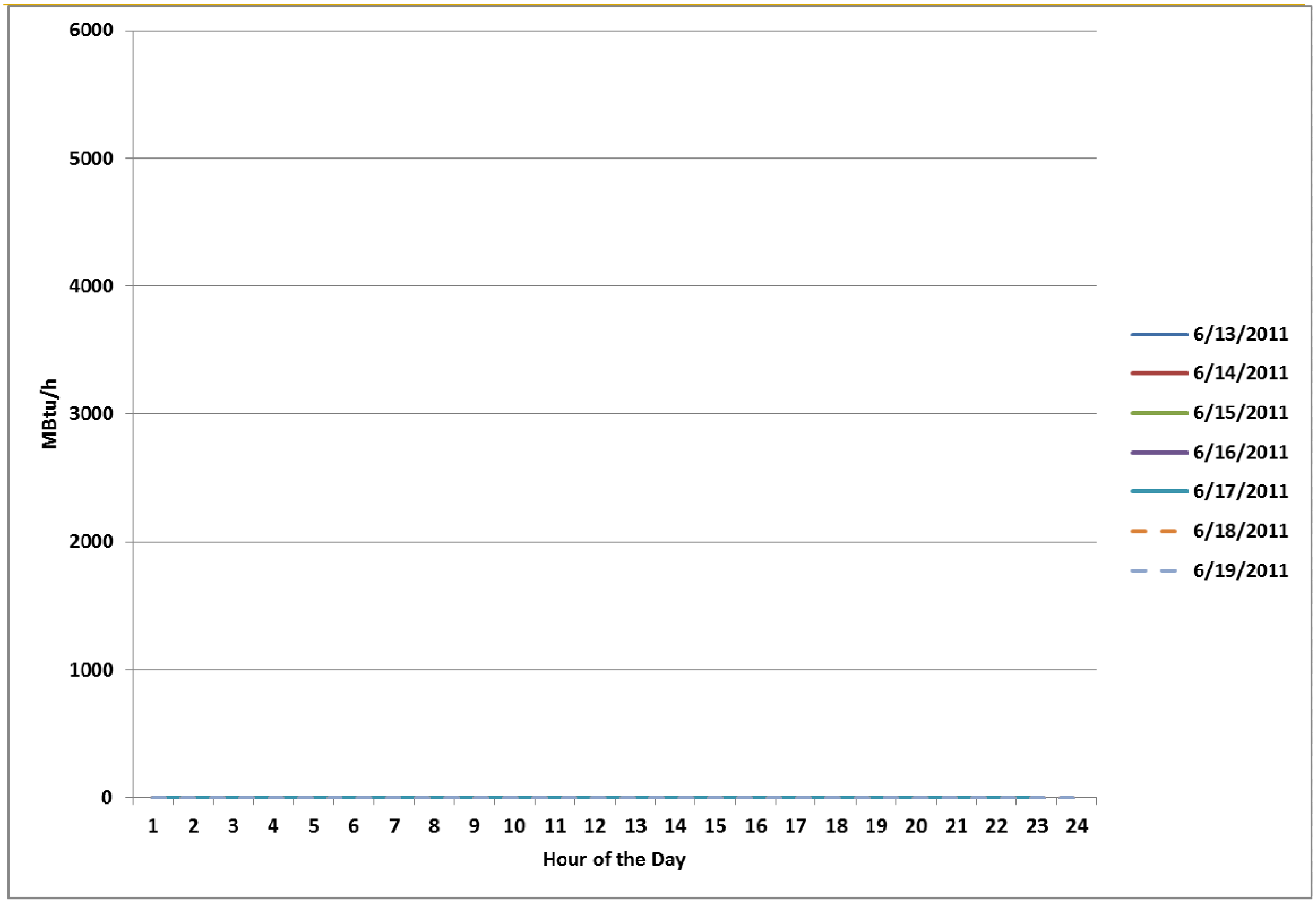

FIGURE 12 USEFUL THERMAL OUTPUT VERSUS TIME

Figure 12 shows that no useful heat is recovered during this week of summer operation.

PERFORMANCE SUMMARY

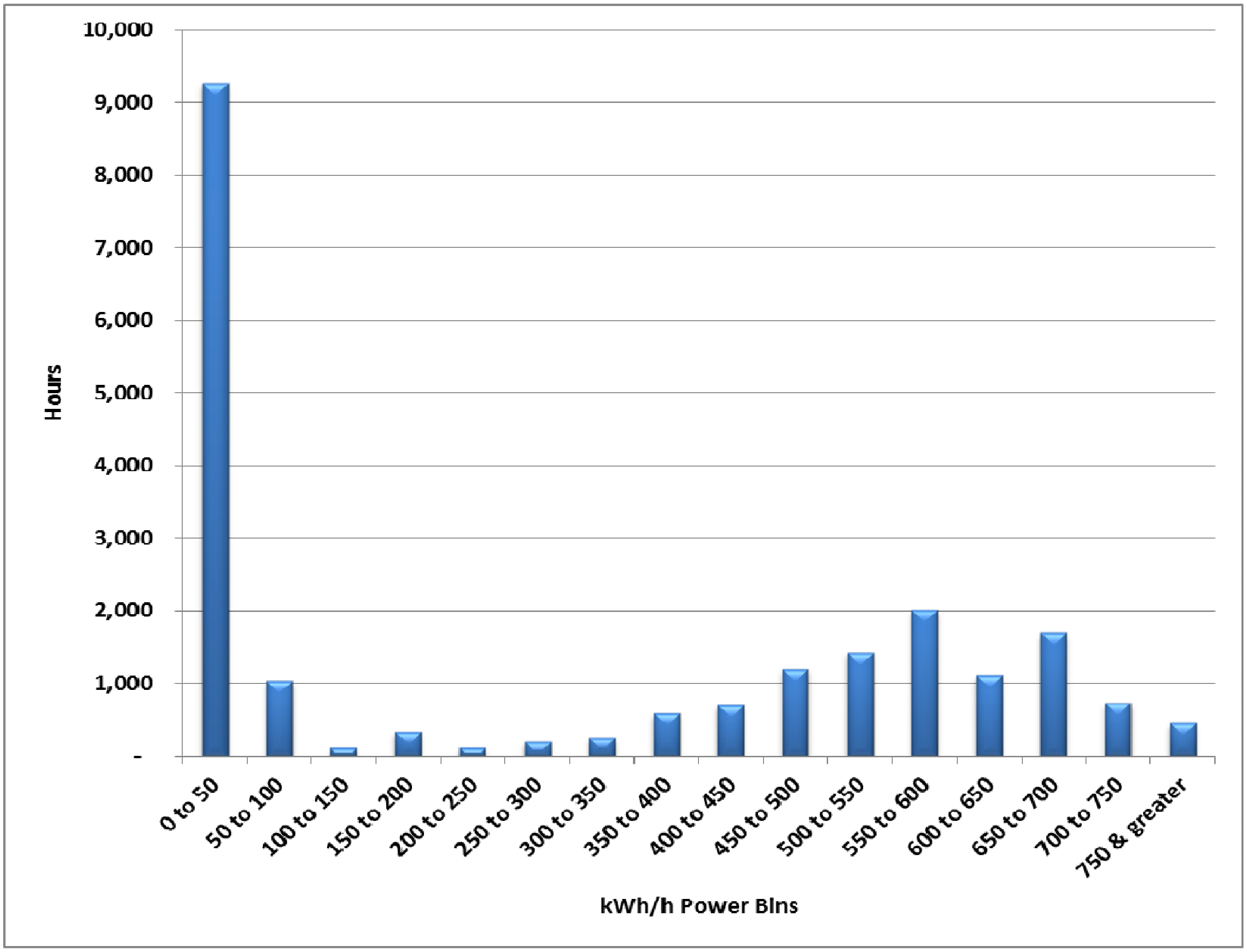

FIGURE 13 PERFORMANCE BY POWER BINS

During the 21,191 hours that met the range and relational checks 43.8% of the time, the CHP system was producing 400 kWh/h or greater.

LESSONS LEARNED

Table 1 provides the data results taken since January 2010.

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)

This office building site uses eight 100-kw Elliott microturbines and had an absorption chiller installed in 2012 to provide both heating and cooling. The above data and Figure 14 below reflect heating and DHW as the cooling was added in March.

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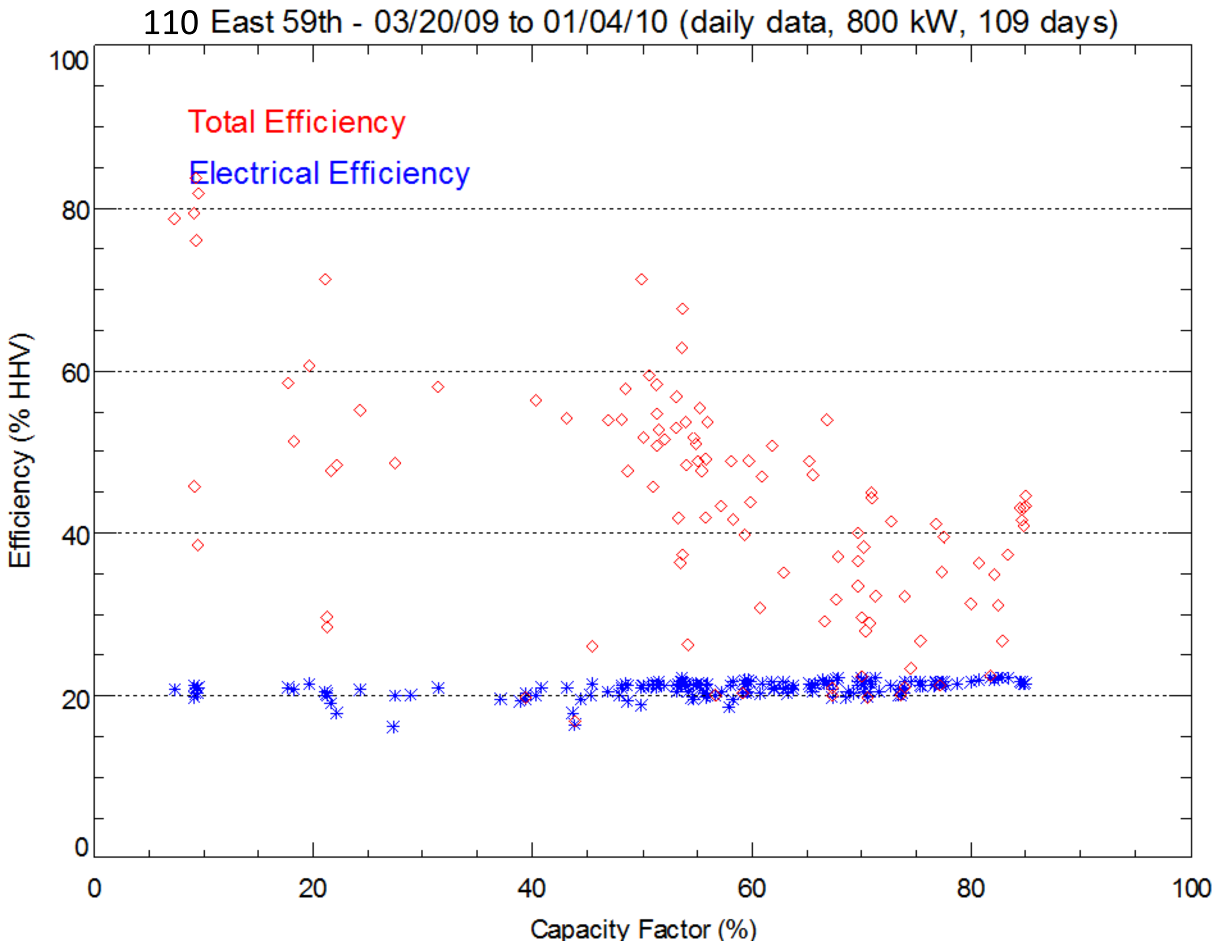

FIGURE 14 CAPACITY FACTOR[3]

Capacity Factor (Figure 14) presents the CHP generated power efficiency over the time period (109 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 10% and 85% of the generating capacity at about 20.4% power efficiency (HHV). This power generation is typical of this capacity of microturbine. The useful thermal energy (heating only) operated at high efficiency during the winter months (upper grouping) and lower during the summer months averaging only 14.3% thermal efficiency (HHV). Note the heat recovery increases as the capacity is reduced which merely reflects higher thermal recovery during lower power production.

This micro-turbine based CHP system demonstrated two key performance issues:

1. Thermal loads in an office building are relatively limited with respect to the electric loads. The addition of an absorption chiller (March 2012) to use the available heat in summer will increase the annual fuel conversion efficiency, but the heating efficiency is quite low.
2. Not all generation technologies have the same electrical generation efficiencies. Microturbines tend to have a lower electrical efficiency. Electrical efficiency is a key factor affecting the performance of a CHP system.

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[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 is computed from the difference of the accumulated energy production values reported by the ALC system. The difference between the current 1-minute accumulator value and the previous accumulator value is the total energy produced by the microturbine arrays, during that 1-minute period. The columns of origin for these data points are labeled “Turbine Array 1 Net Energy Export” and “Turbine Array 2 Net Energy Export” in the data files received from the Obvius logger. This 1-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 a 30-minute running average of the high density pulses from the two Roots gas meters, as measured by the ALC system. The logger samples this running average and reports 1-minute average data for the gas flow. The columns of origin for these data points are labeled “Gas Meter 1” and “Gas Meter 2” in the data files received from the Obvius logger. The 1-minute raw data is then averaged into hourly data.
3. **Useful Heat Recovery (total MBtu)** The useful heat recovery is calculated by the recorded temperature difference across the water side of the glycol heat exchanger, and the flow through the water side of the heat exchanger. The heat transfer will be calculated on a 1-minute basis, and then summed into hourly data. When the glycol flow meter is installed, useful heat recovery will be calculated on the glycol side of the HX.

This CHP system provides electric generating efficiency for the last 12 months of 20.4% HHV with a falling efficiency in the most recent three months which correspond with a falloff in power produced. Such data should trigger a response. The average useful thermal efficiency is only 14.3%. Not having a viable summertime thermal load is problematic.

Data Collection and quality for this site is at 100% for two of the three critical parameters (power, fuel and useful thermal energy) (see Table 3).

TABLE 3 PERCENTAGE OF GOOD DATA

	Percentage of Good Data		
	Power	Gas Use	Useful Heat
January-10	100.0%	93.5%	100.0%
February-10	100.0%	96.0%	100.0%
March-10	100.0%	96.2%	100.0%
April-10	100.0%	96.4%	100.0%
May-10	100.0%	96.6%	100.0%
June-10	100.0%	96.8%	100.0%
July-10	100.0%	96.6%	100.0%
August-10	100.0%	96.1%	100.0%
September-10	100.0%	97.2%	100.0%
October-10	100.0%	97.2%	100.0%
November-10	100.0%	96.7%	100.0%
December-10	100.0%	95.7%	100.0%
January-11	100.0%	94.8%	100.0%

February-11	100.0%	96.1%	100.0%
March-11	100.0%	96.0%	100.0%
April-11	100.0%	96.7%	100.0%
May-11	100.0%	97.2%	100.0%
June-11	100.0%	96.9%	100.0%
July-11	100.0%	97.0%	100.0%