NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT 666 5TH AVENUE, NEW YORK CITY

October 9, 2013

666 5th Avenue, New York City

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.

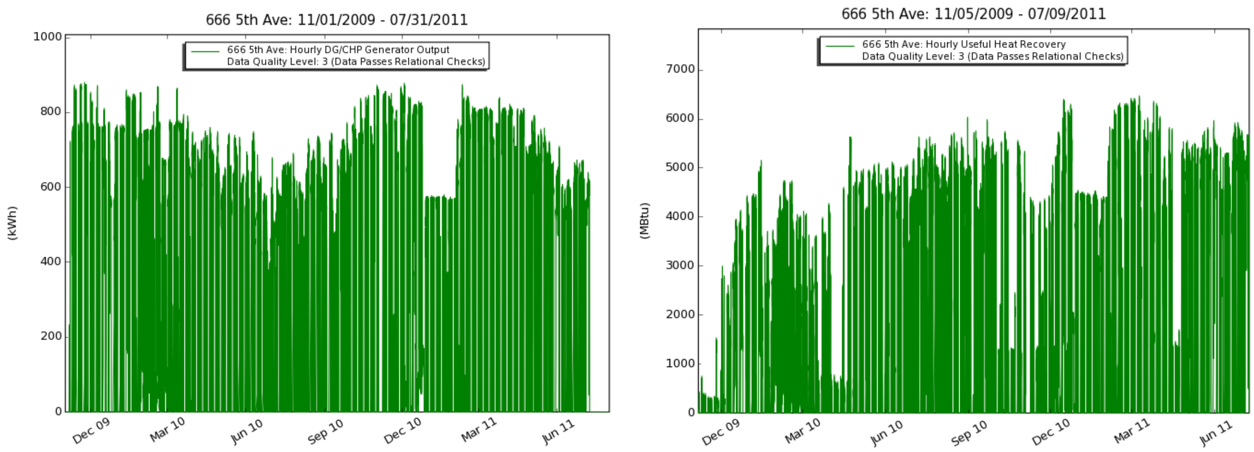

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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 2 666 5TH AVENUE, NEW YORK CITY

Tishman Realty and Construction built the 1,500,000-square-foot (139,000 m^2) tower in 1957. It was designed by Carson & Lundin and the building was called the Tishman Building. One of its most famous exterior features is the prominent 666 address emblazoned on the top of the building. The other distinctive exterior features are embossed aluminum panels.

THE SYSTEM

The CHP system at 666 5th Ave consists of ten 100 kW Elliott microturbines. Each microturbine has roughly a 105 kW gross output to cover the operation of the onboard gas compressor and controls, resulting in a net output of 100 kW (1 MW for the entire turbine array).

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 one group of four turbines, and one group of six turbines. These two groups are connected to two of the four 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 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 these services.

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 absorption chiller (see Figure 3). The thermal loads include:

Space heating to the building dual temperature loop (isolated by HX) (winter, approx. 5.4 MMBtu/h)

Direct hot water use by an absorption chiller (summer, approx. 4.3 MMBtu/h)

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

The loop will typically operate between 140°F - 205°F supply temperature, and return to the microturbine arrays at between 105°F - 180°F. The loop flow rate will be 350 gpm, and the heat recovery loop will contain a 30/70 mixture of propylene glycol and water.

At full load the generators will consume approximately 13,500 std. cubic feet (sft^3) of natural gas per hour (1,350 sft^3 per hour each).

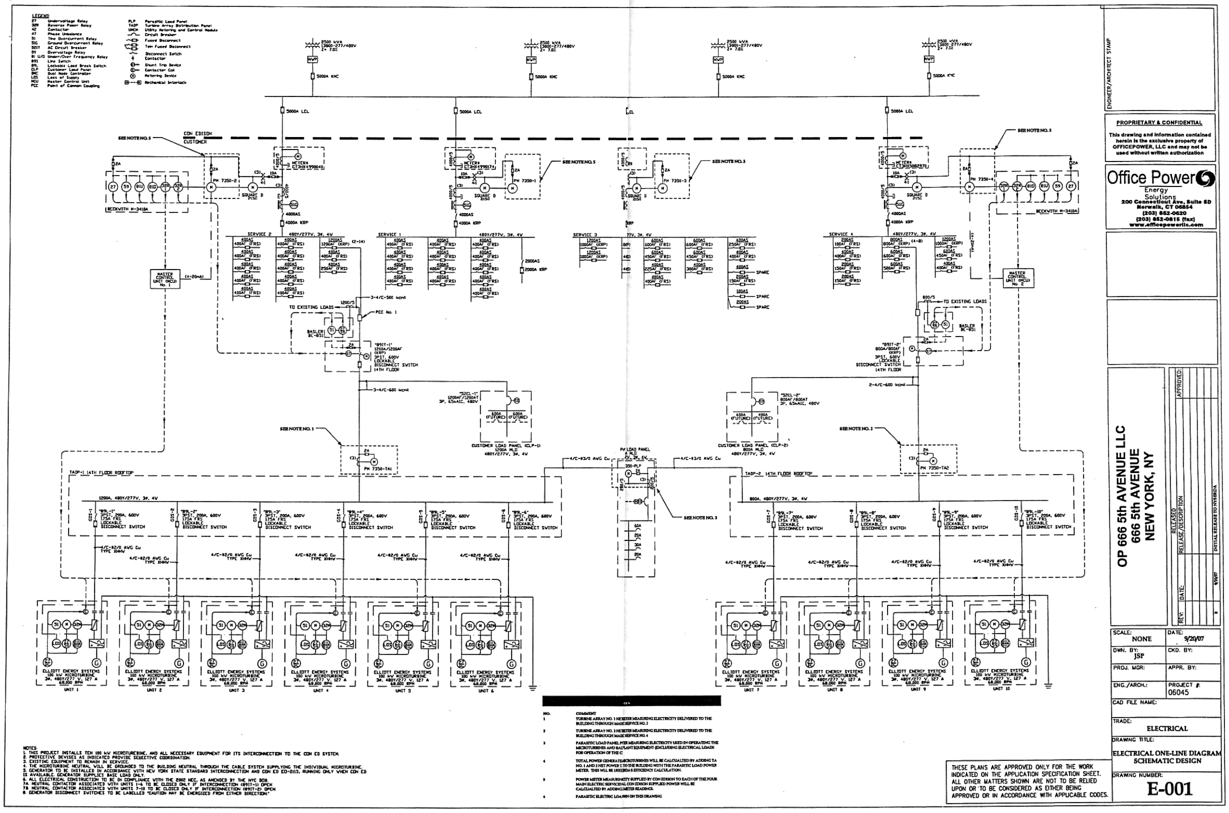

FIGURE 3 SINGLE LINE WIRING DIAGRAM

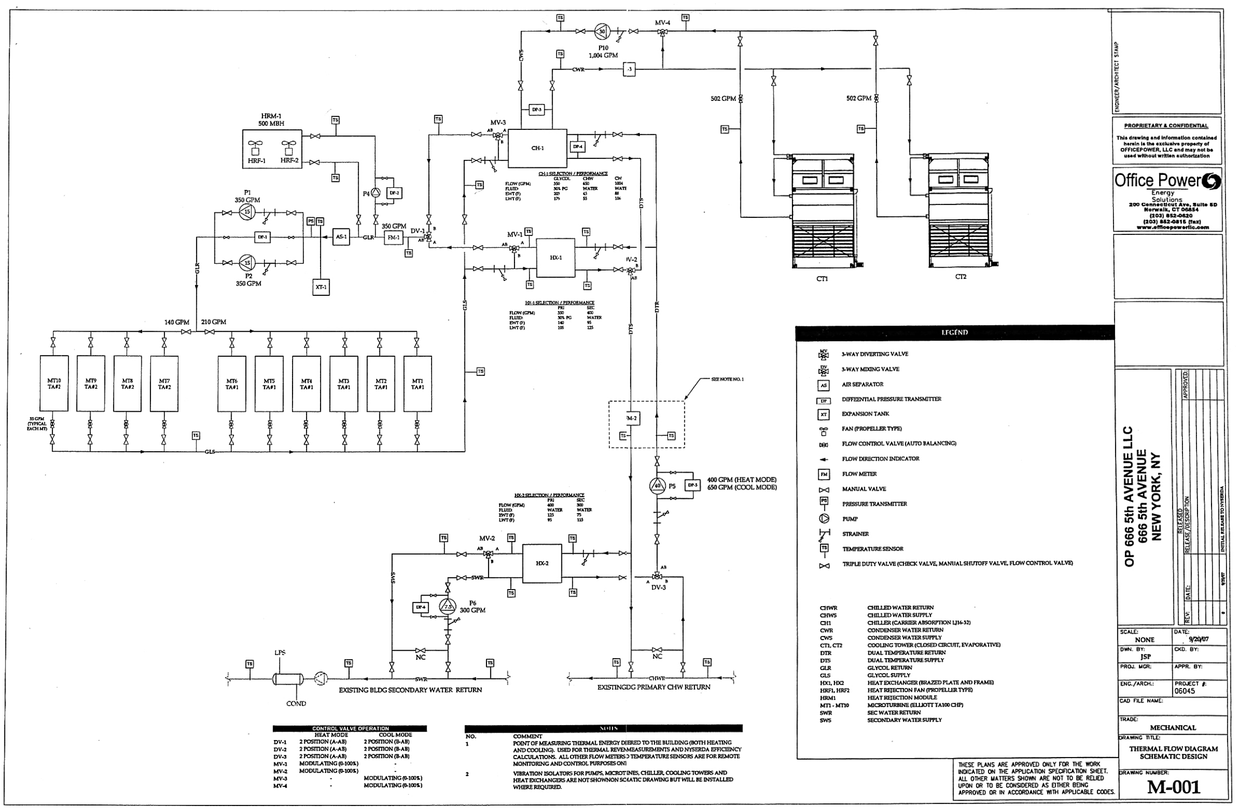

FIGURE 4 HEAT RECOVERY LOOP (HOT WATER HEAT EXCHANGER & ABSORPTION CHILLER)

OPERATING SUMMARY

The CHP system at 666 5th Avenue is operating well, in that, the generators and heat recovery systems are functioning.

Table 1 shows the fuel to power efficiency of the microturbine array operating at a CHP Fuel Use Efficiency of 59.1%. This is the combination of the power generation efficiency of 20.4% (HHV) for the microturbines (First Law) and 38.7% for the useful heat recovery (Second Law).

Further examination of Table 1 and Figure 5 shows that power generation efficiency during the shoulder and winter months (October through April) averaged 21.7%, while May – September averaged 19.0%. This 10% performance difference is typical of Brayton Cycle machines.

Examining the Fuel Conversion Efficiency in Table 1 and Figure 5 and the ambient temperatures in Figure 6, it is clear that the shoulder months provided the poorest performance which is to be expected from an office building.

666 5th Avenue represents a typical New York City high rise office building with little or no space conditioning requirements in the shoulder (fall and spring) months which result in the reduced requirement for useful thermal energy.

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
August-10	718	257,097	4,424.2	1,957.1	19.4%	43.4%	62.8%
September-10	695	231,366	3,922.5	1,674.4	19.7%	41.8%	61.6%
October-10	722	228,029	3,566.4	881.7	21.4%	24.2%	45.6%
November-10	692	190,493	2,867.3	610.1	22.2%	20.9%	43.1%
December-10	676	268,324	4,196.0	1,861.9	21.4%	43.5%	64.9%
January-11	723	187,234	2,834.0	1,448.2	22.1%	50.1%	72.2%
February-11	655	237,666	3,623.7	1,469.2	21.9%	39.7%	61.7%
March-11	721	281,144	4,258.8	1,495.7	22.1%	34.4%	56.5%
April-11	698	220,319	3,518.8	924.7	21.0%	25.8%	46.7%
May-11	722	252,356	4,350.4	1,754.0	19.4%	39.5%	58.9%
June-11	698	255,697	4,613.2	2,120.4	18.5%	45.1%	63.6%
July-11	720	291,091	5,424.7	2,615.2	18.0%	47.3%	65.2%
Total preceding 12 months	**8440**	**2,900,816**	**47,599.7**	**18,812.5**	**20.4%**	**38.7%**	**59.1%**

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

[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.

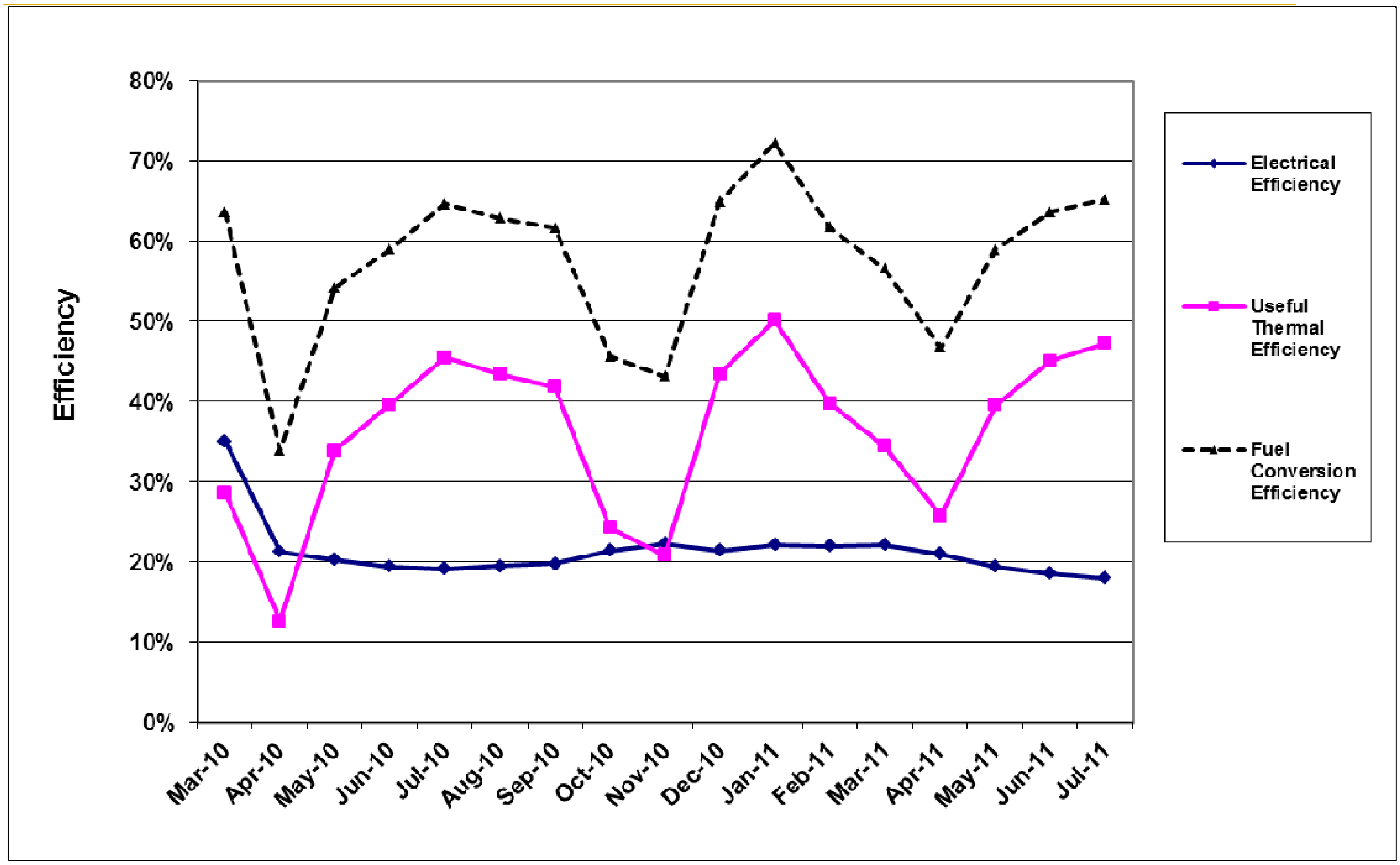

FIGURE 5 CHP EFFICIENCY DATA

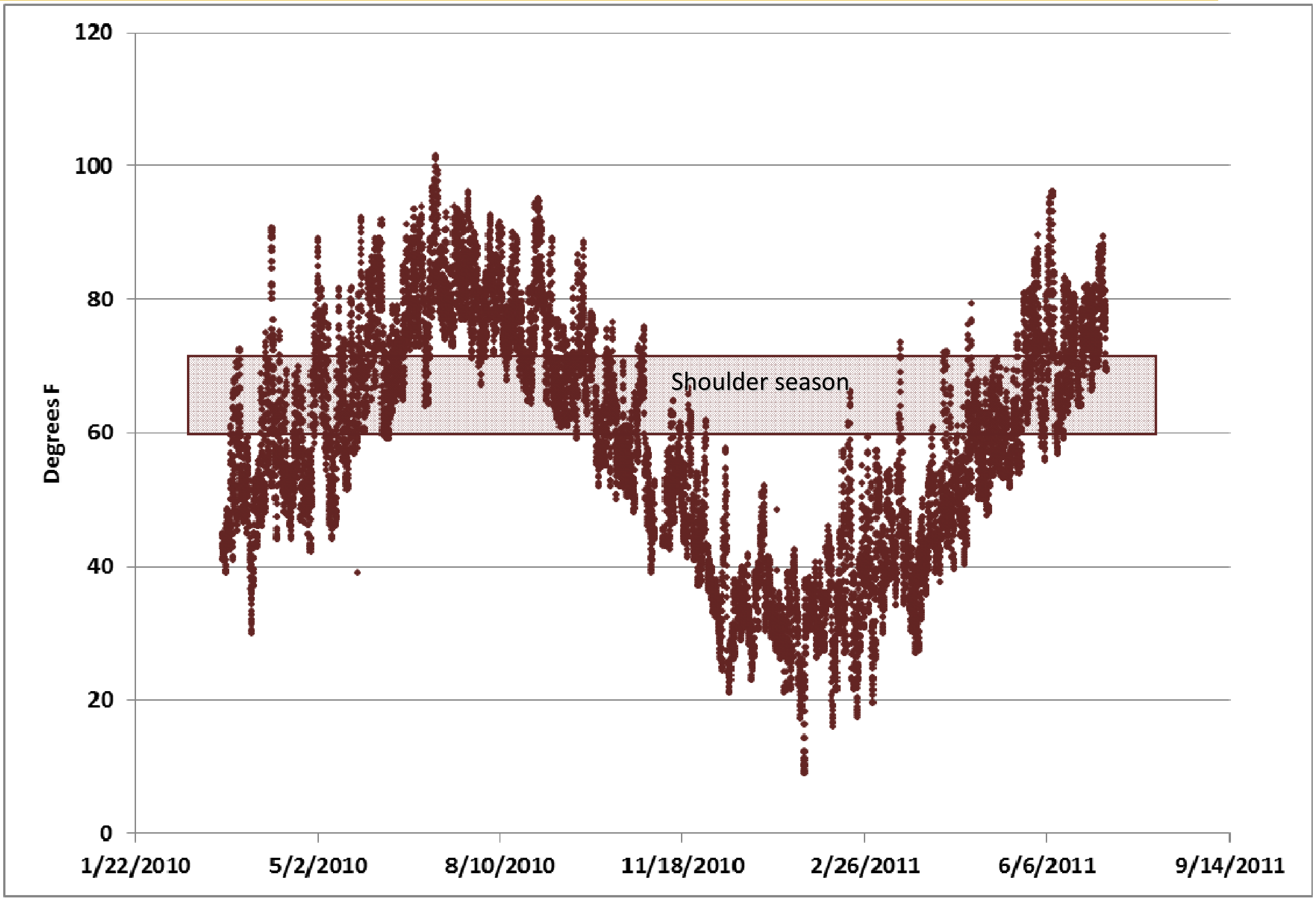

FIGURE 6 AMBIENT TEMPERATURE

POWER GENERATION AND USEFUL THERMAL ENERGY

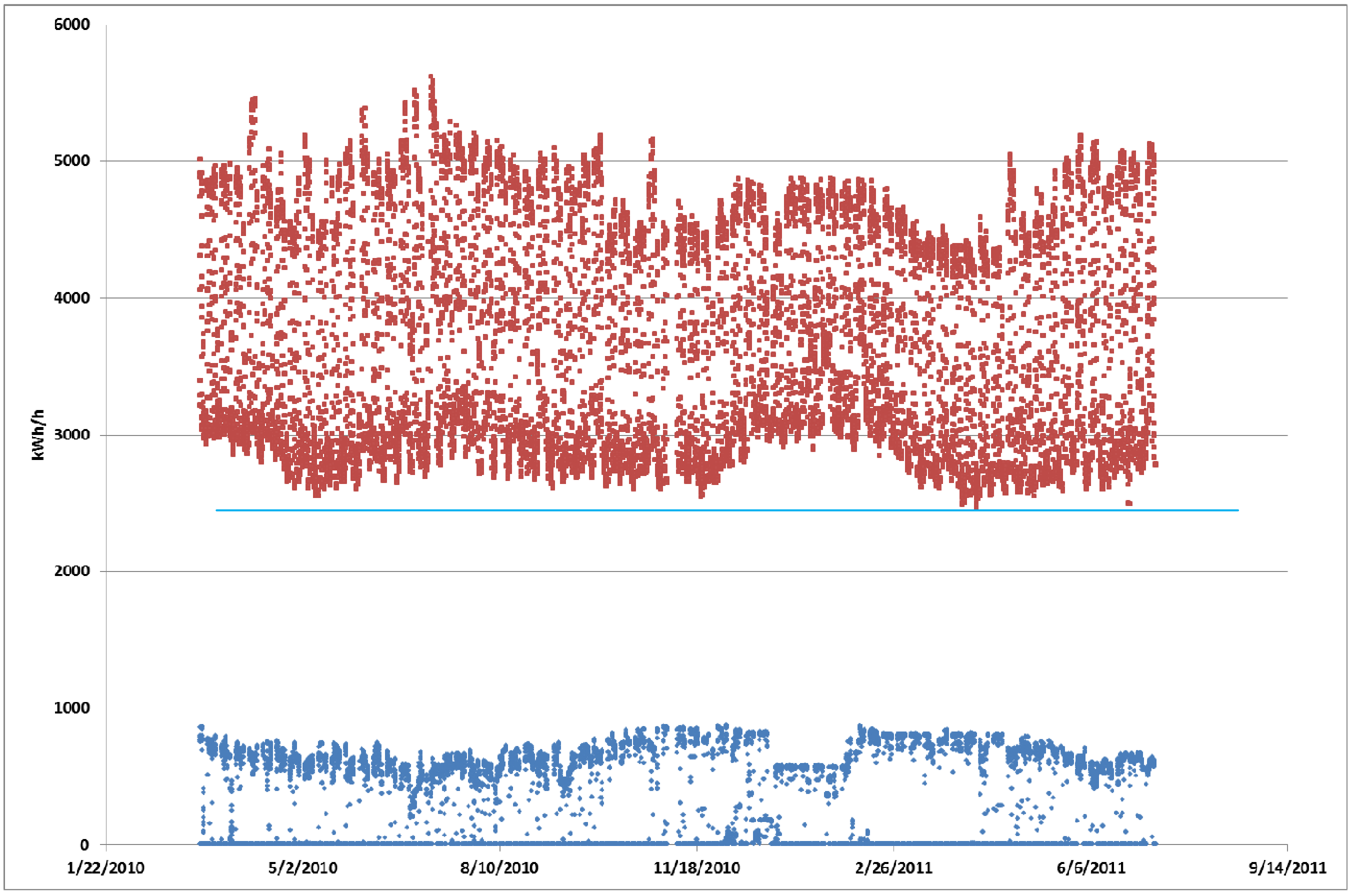

FIGURE 7 CHP POWER OUTPUT VERSUS TIME

Figure 7 provides 666 Fifth Avenue's building level electric load profile (red) and the microturbine array's power generation profile (blue). The array's maximum net electrical power during the period is 865 kW. The building's electric power needs range from 2,540 – 5,600 kW.

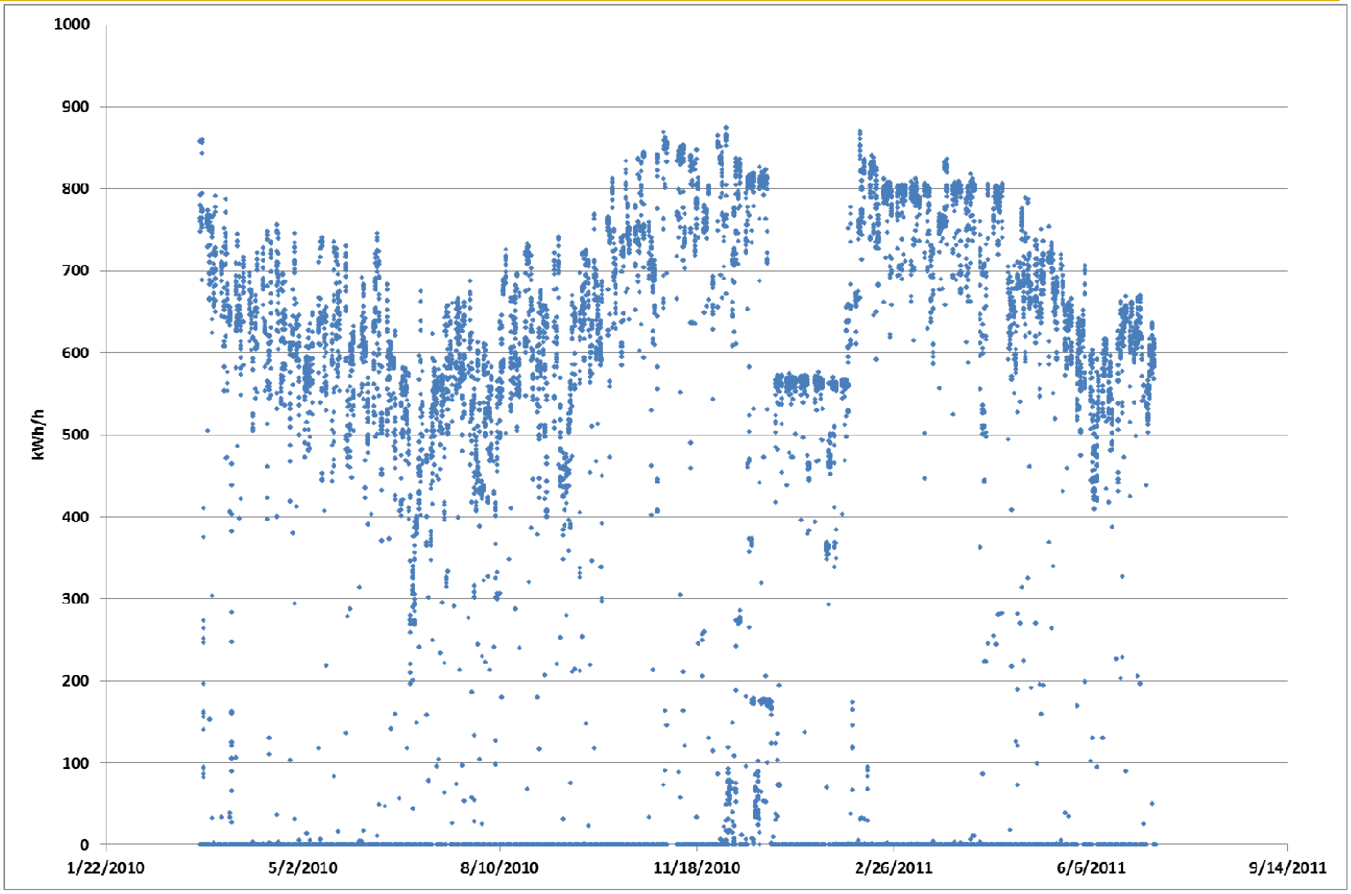

FIGURE 8 CHP POWER OUTPUT VERSUS TIME

Figure 8 is a scatter plot of the array's power output. During peak operating times (winter 2010/2011), with eight units operating, the array's output approached 900 kWh/h. Figure 8 exhibits a classic Brayton Cycle power output versus ambient temperature characteristic. Only six microturbines were not operating during the month of January 2011.

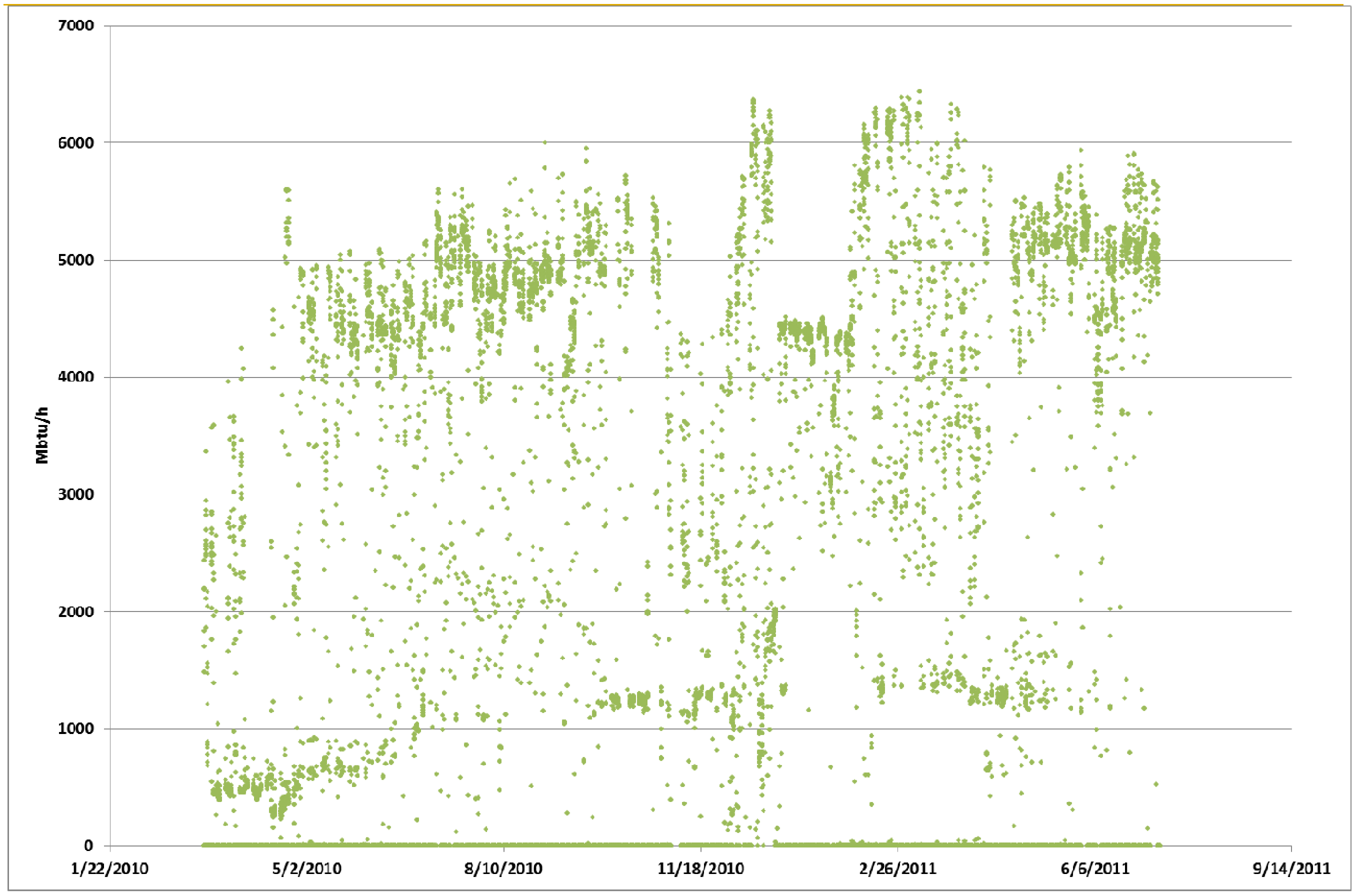

FIGURE 9 THERMAL POWER OUTPUT VERSUS TIME

Figure 9 is a scatter plot of the array's useful thermal output. Comparing Figure 9 with Figure 8, it is apparent that the array is providing maximum power according to a prescribed schedule and the thermal energy is applied to the available load.

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

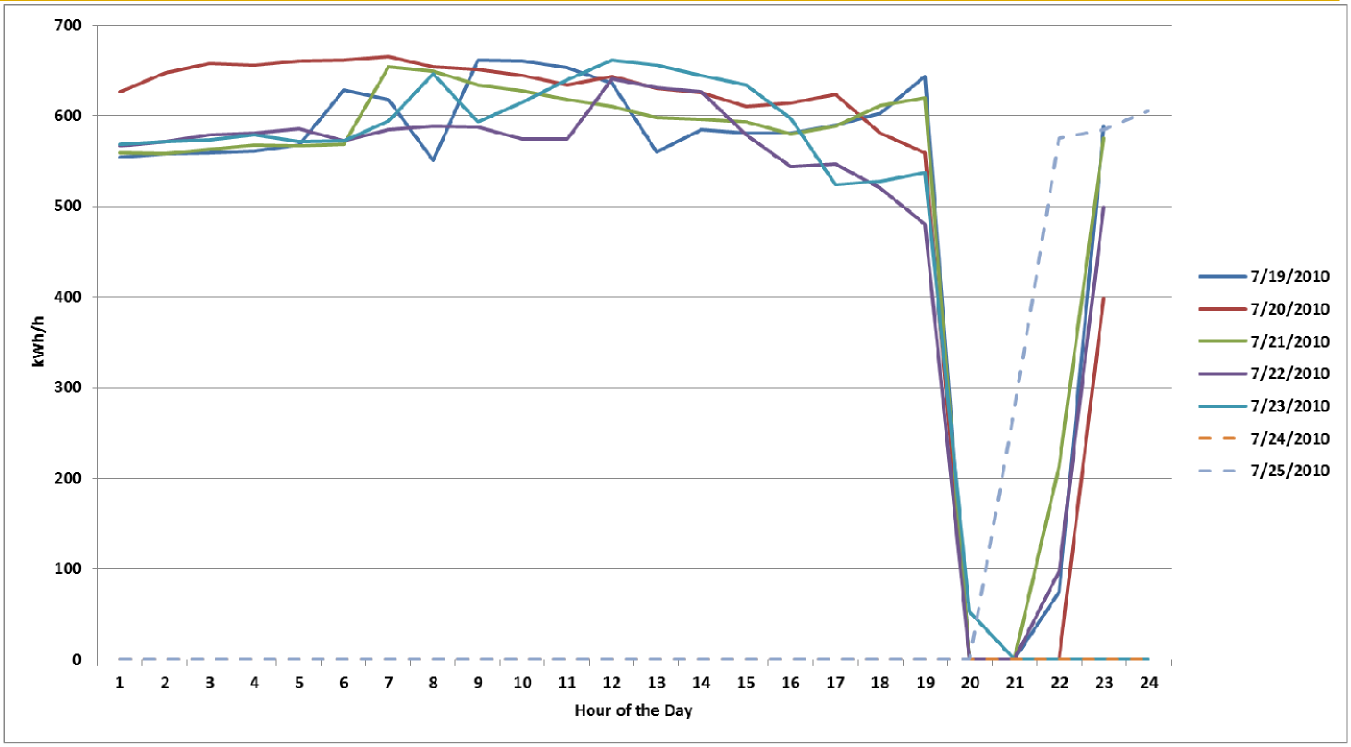

FIGURE 10 CHP POWER OUTPUT VERSUS TIME

Figure 10 data shows an operating schedule where six units in the array run from midnight through 7 PM, shut down about four hours, and then go back to full load. The array is shut down on weekends (July 24 & 25).

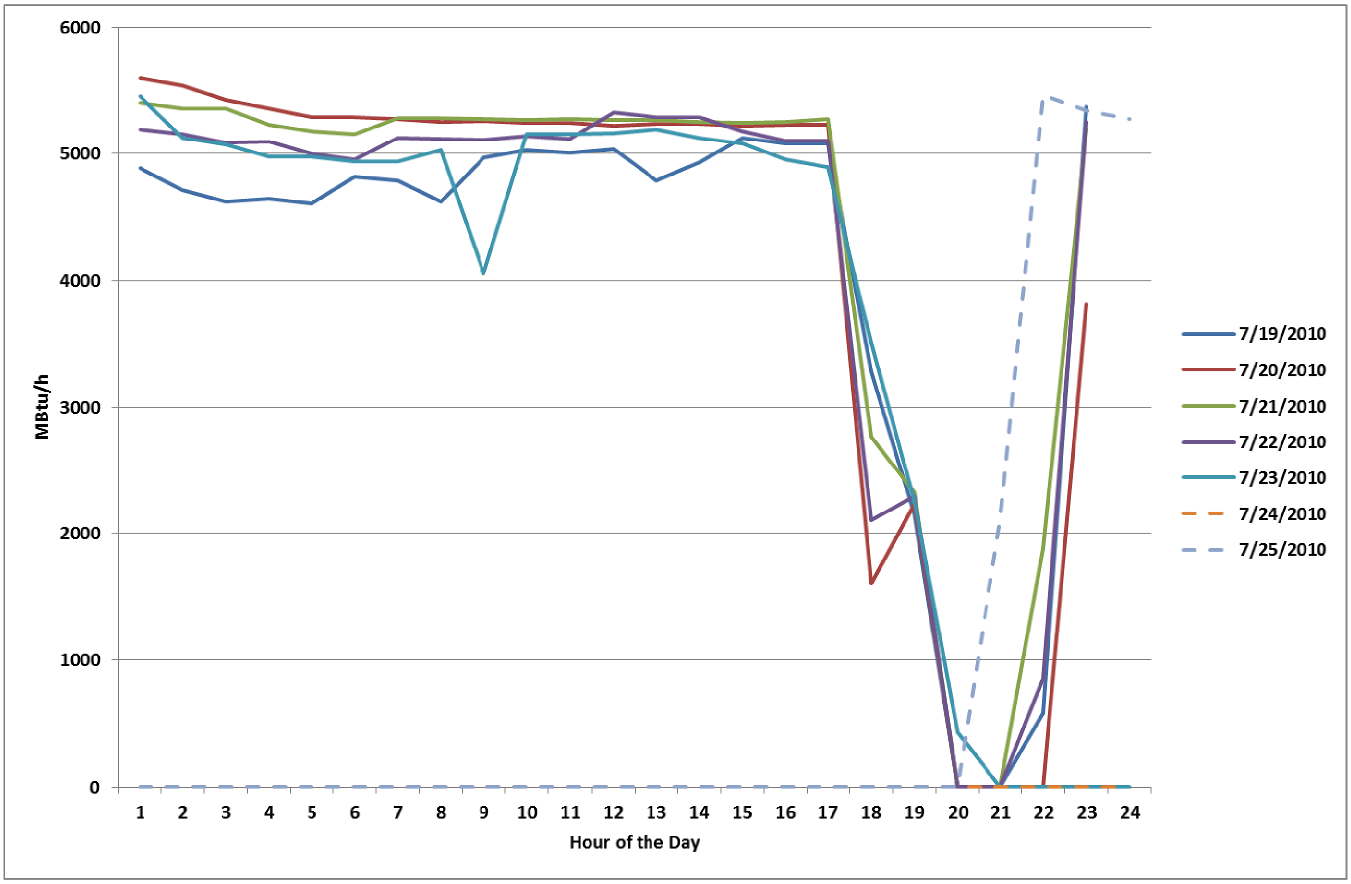

FIGURE 11 THERMAL OUTPUT VERSUS TIME

In Figure 11, we see good correlation with the useful thermal energy supplied by the array and the power generated.

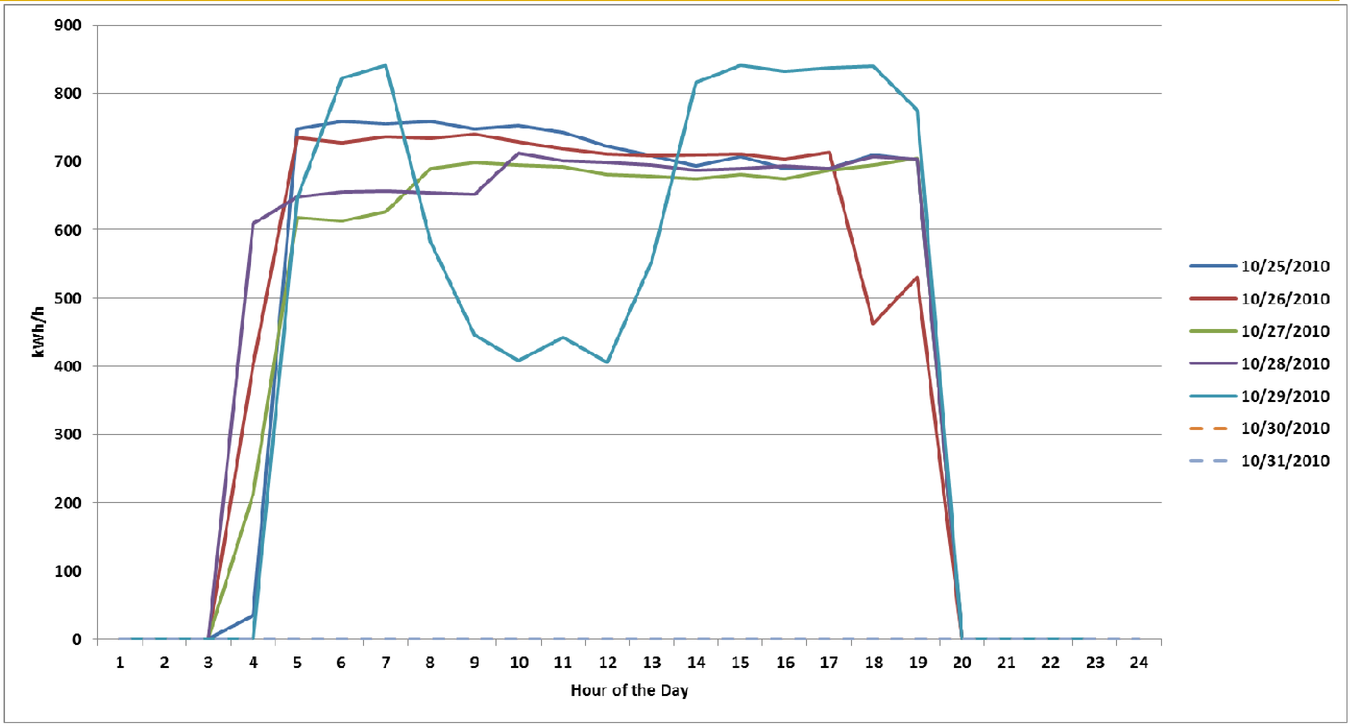

FIGURE 12 CHP POWER OUTPUT VERSUS TIME

Figure 12 presents a tighter operating schedule starting between 3 and 4 AM and shutting down between 7 and 8 PM. Higher array loading is indicative of higher heating loads. Note that October 30 and 31 (Saturday and Sunday) the array was not operating.

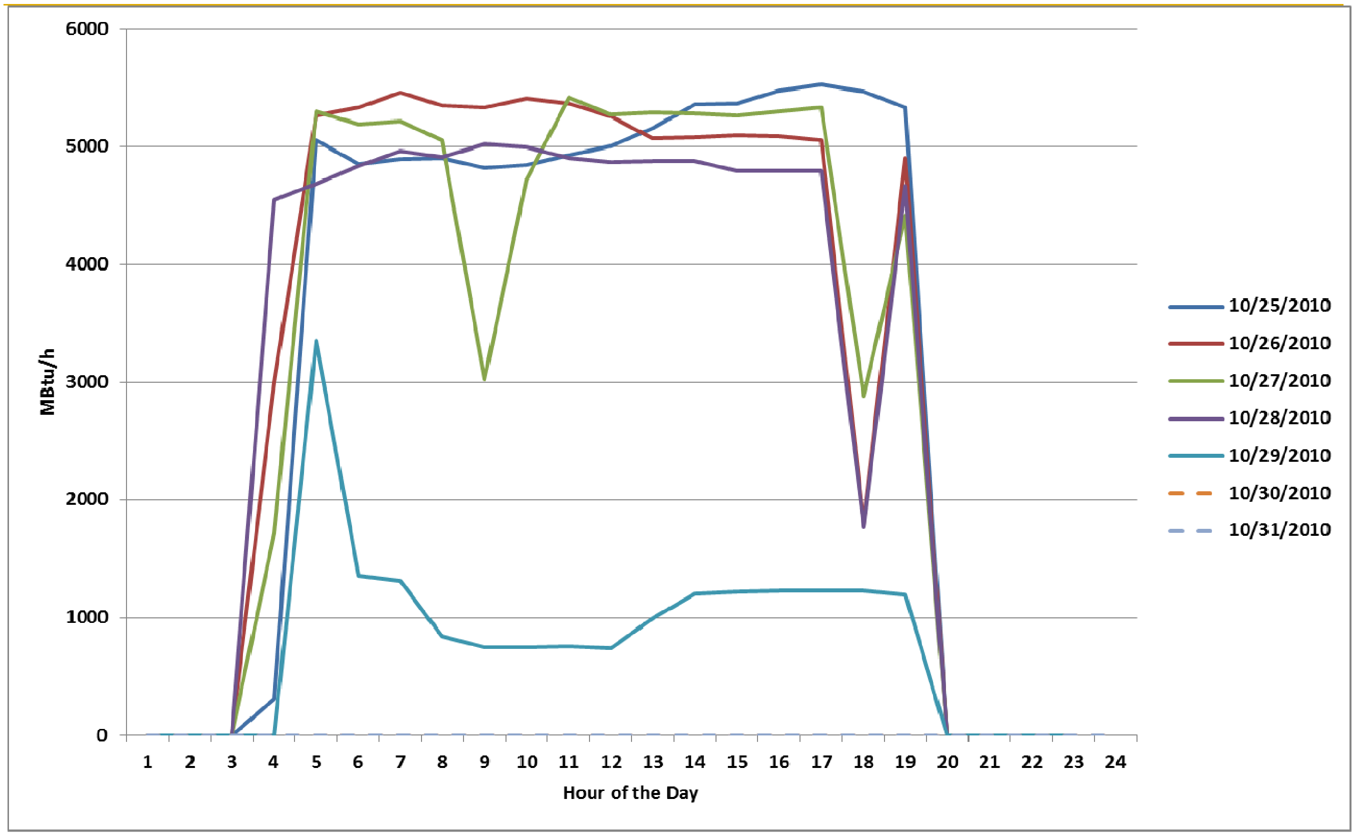

FIGURE 13 THERMAL OUTPUT VERSUS TIME

The useful heat data in Figure 13 shows a correlation with the array's power profile in Figure 12.

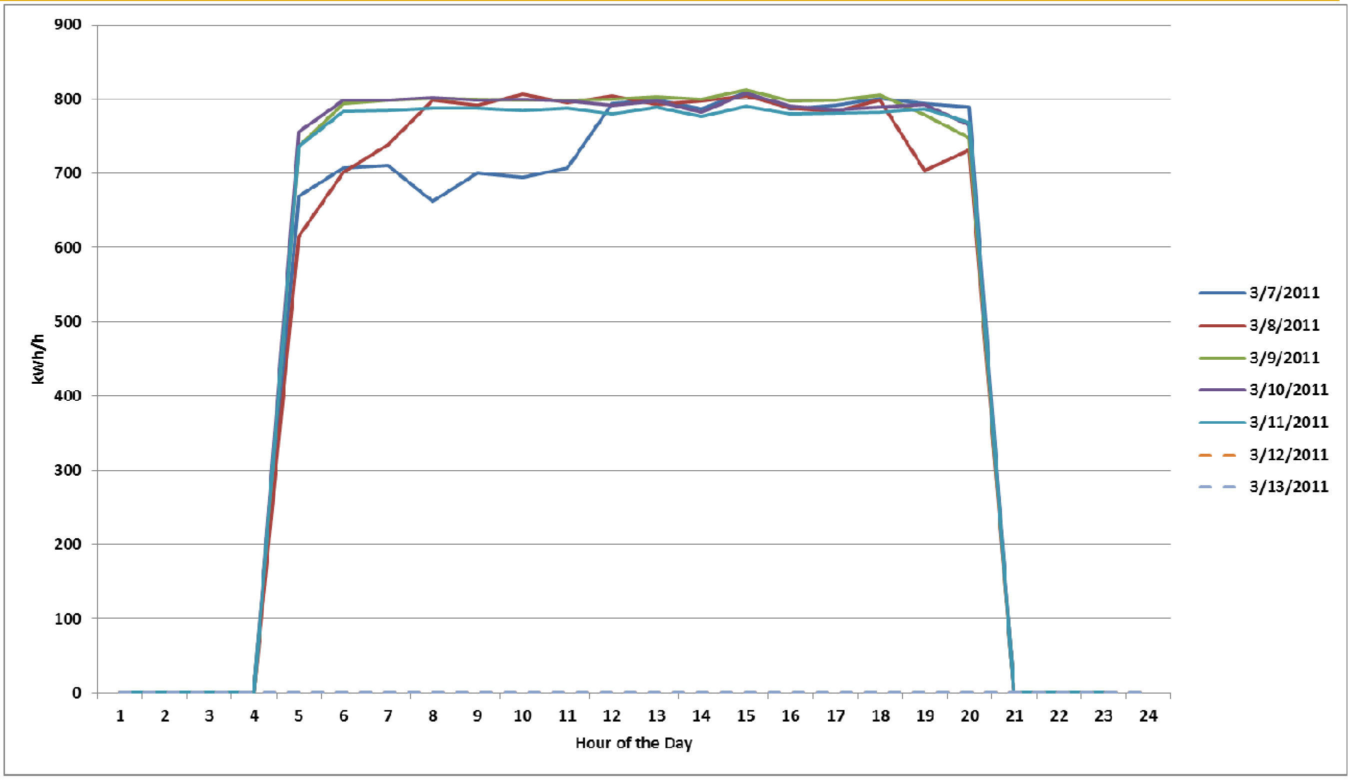

FIGURE 14 CHP POWER OUTPUT VERSUS TIME

Figure 14 shows improved operating characteristics with the array starting on weekdays between 4 and 5 AM and shutting down between 8 and 9 PM, and consistent performance around 800 kWh.

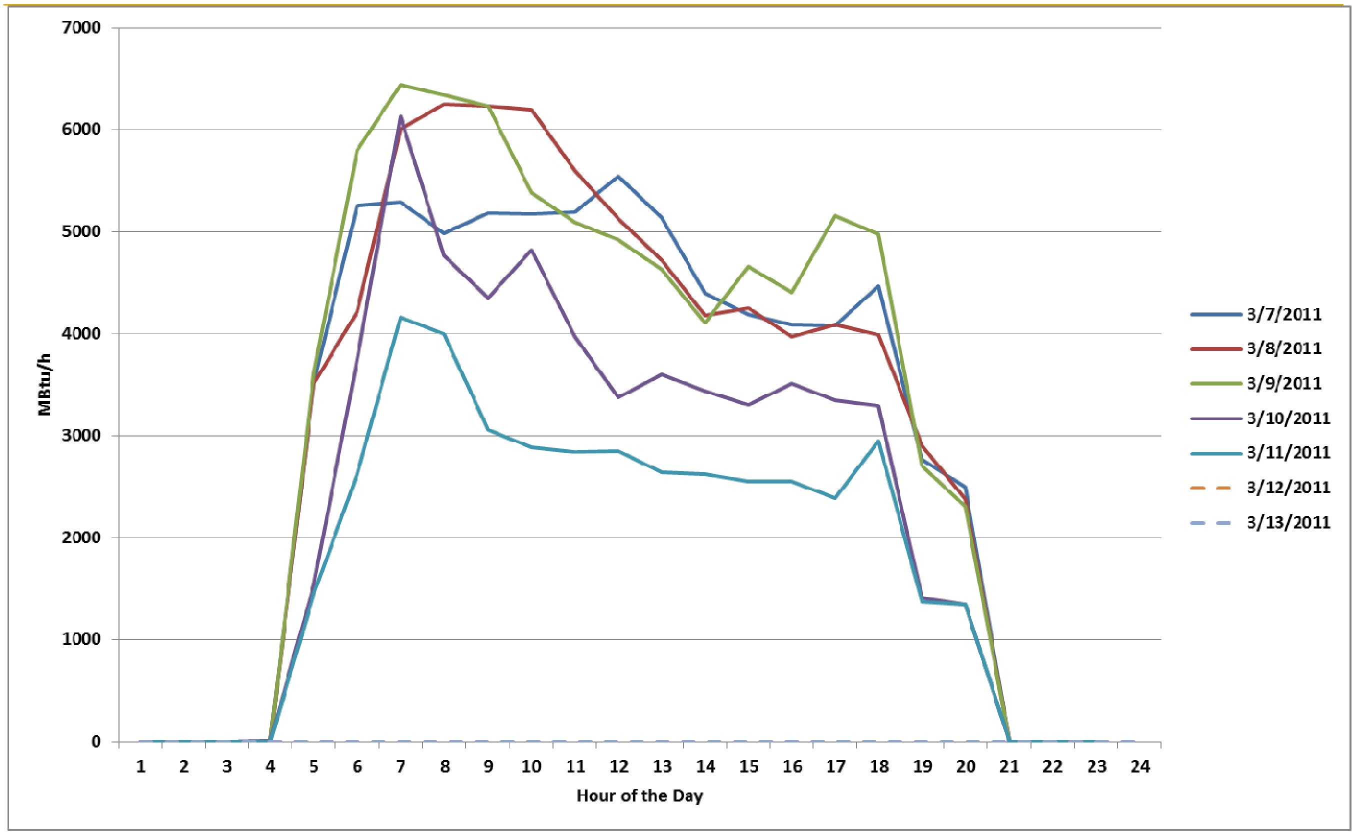

FIGURE 15 THERMAL OUTPUT VERSUS TIME

Figure 15 shows some correlation with the array's power profile in Figure 14, but clearly demonstrates that this system is operating as an electric demand reducing system device where there is not enough heat load to use all the waste heat generated during this week.

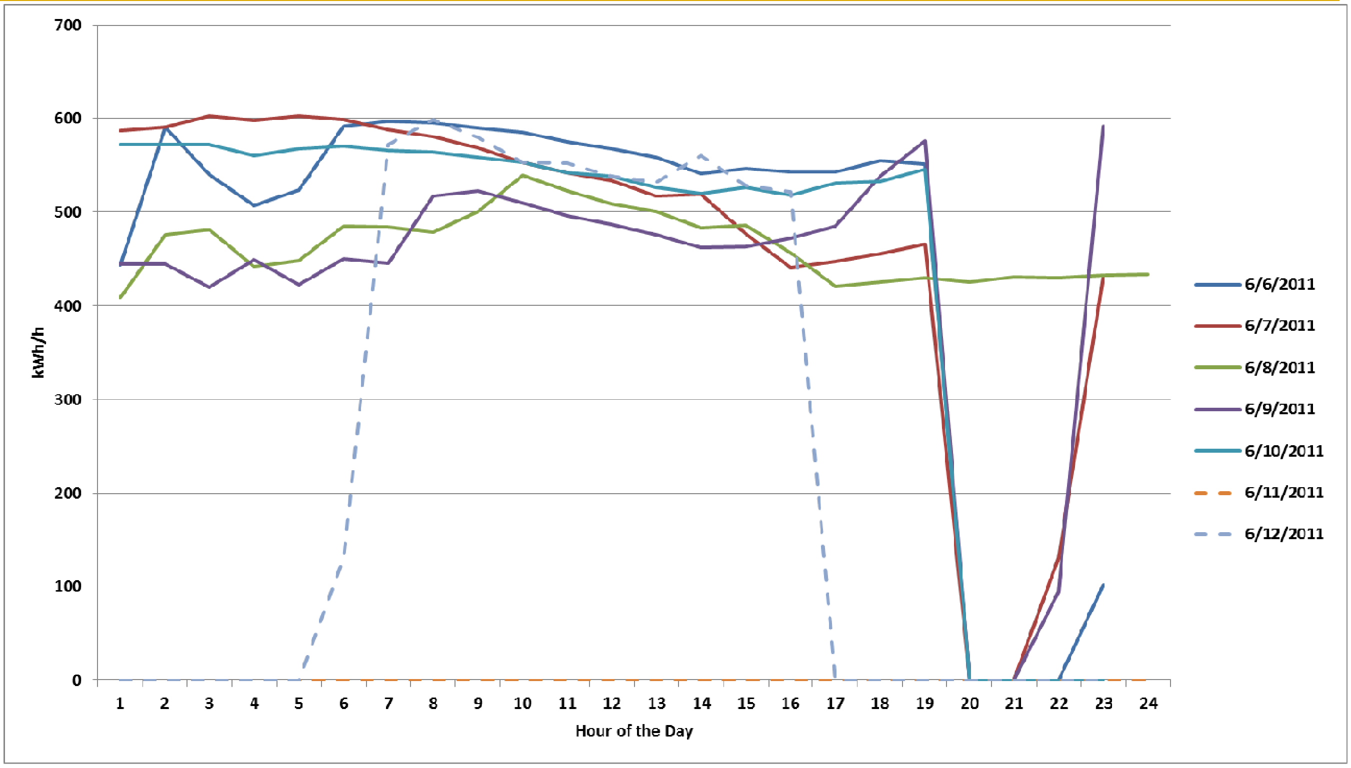

FIGURE 16 CHP POWER OUTPUT VERSUS TIME

Figure 16 (June 2011) shows a similar summertime operating profile to Figure 10 (July 2010) indicating a shift in strategy for summer operation.

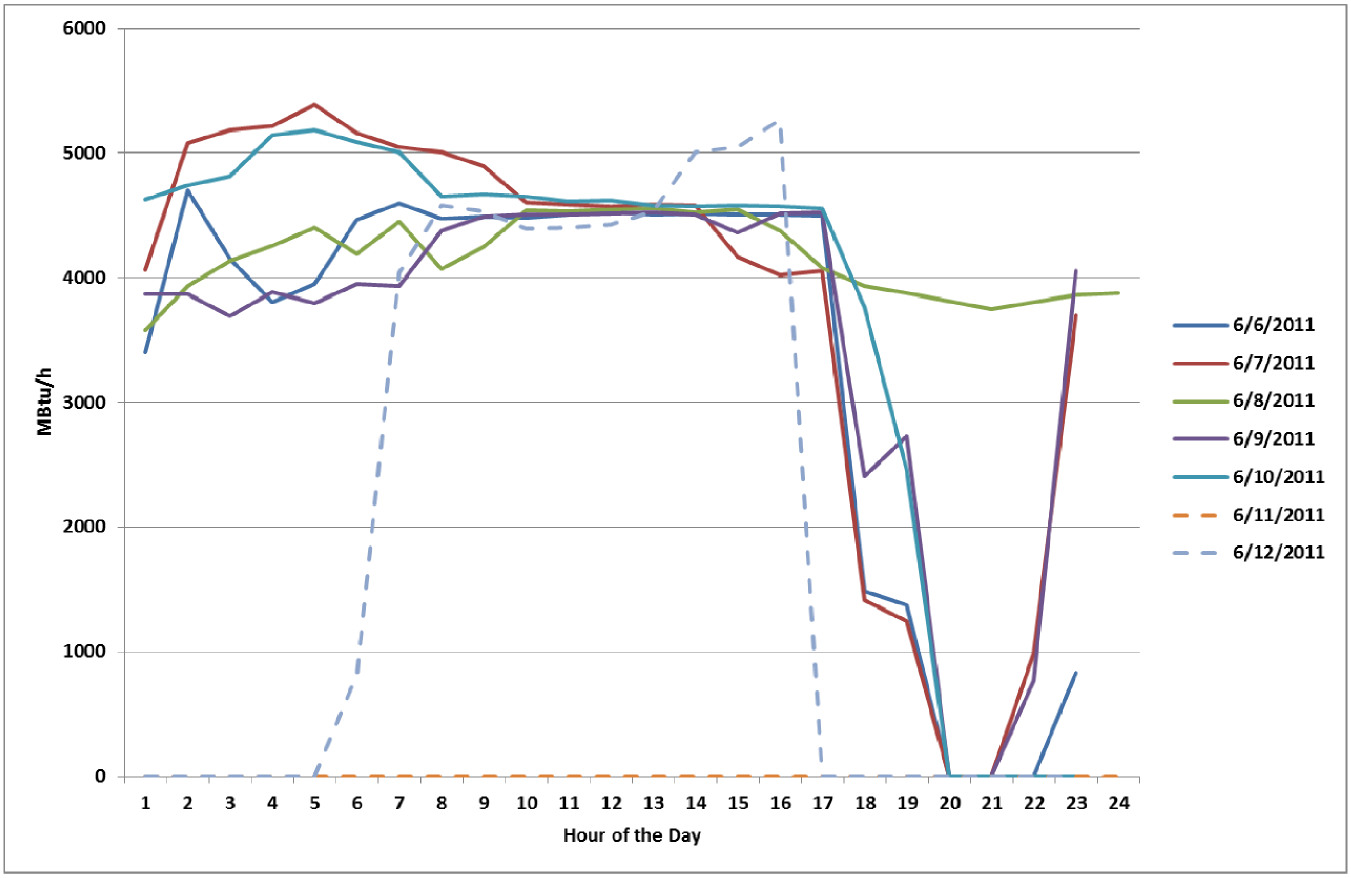

FIGURE 17 THERMAL OUTPUT VERSUS TIME

Figure 17 shows good correlation with the array's power profile in Figure 16.

PERFORMANCE SUMMARY

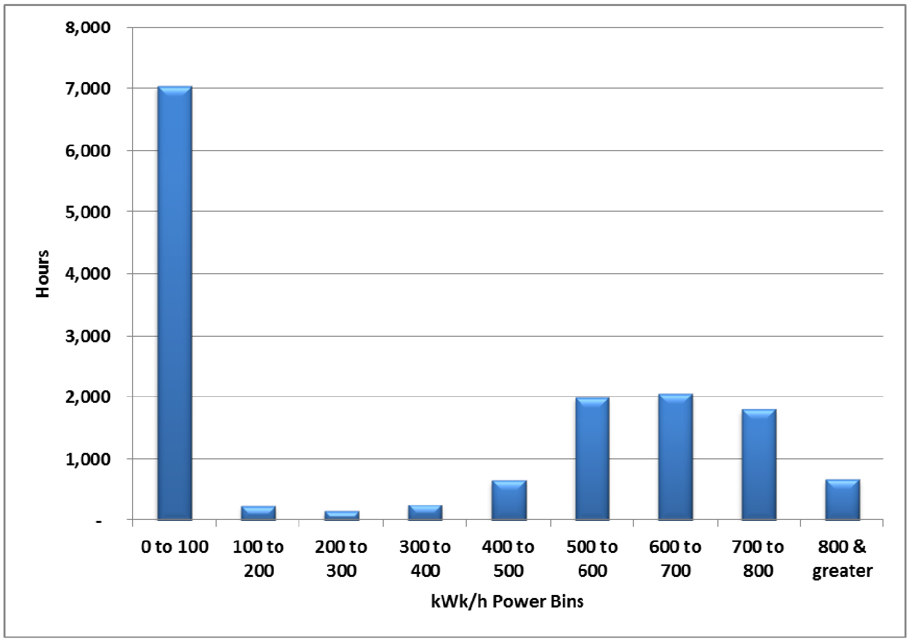

FIGURE 18 PERFORMANCE BY POWER BINS

During the 14,883 hours that met the range and relational checks 47% of the time, the array was either not operating or operating under 100 kWh. Note that this is about double the weekend hours where no array operation was intended. 48% of the time the array delivered greater than 400 kWh. (Figure 18).

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)

This office building uses 10 ELLIOTT 100 KW microturbines and an absorption chiller to provide heating, cooling and DHW.

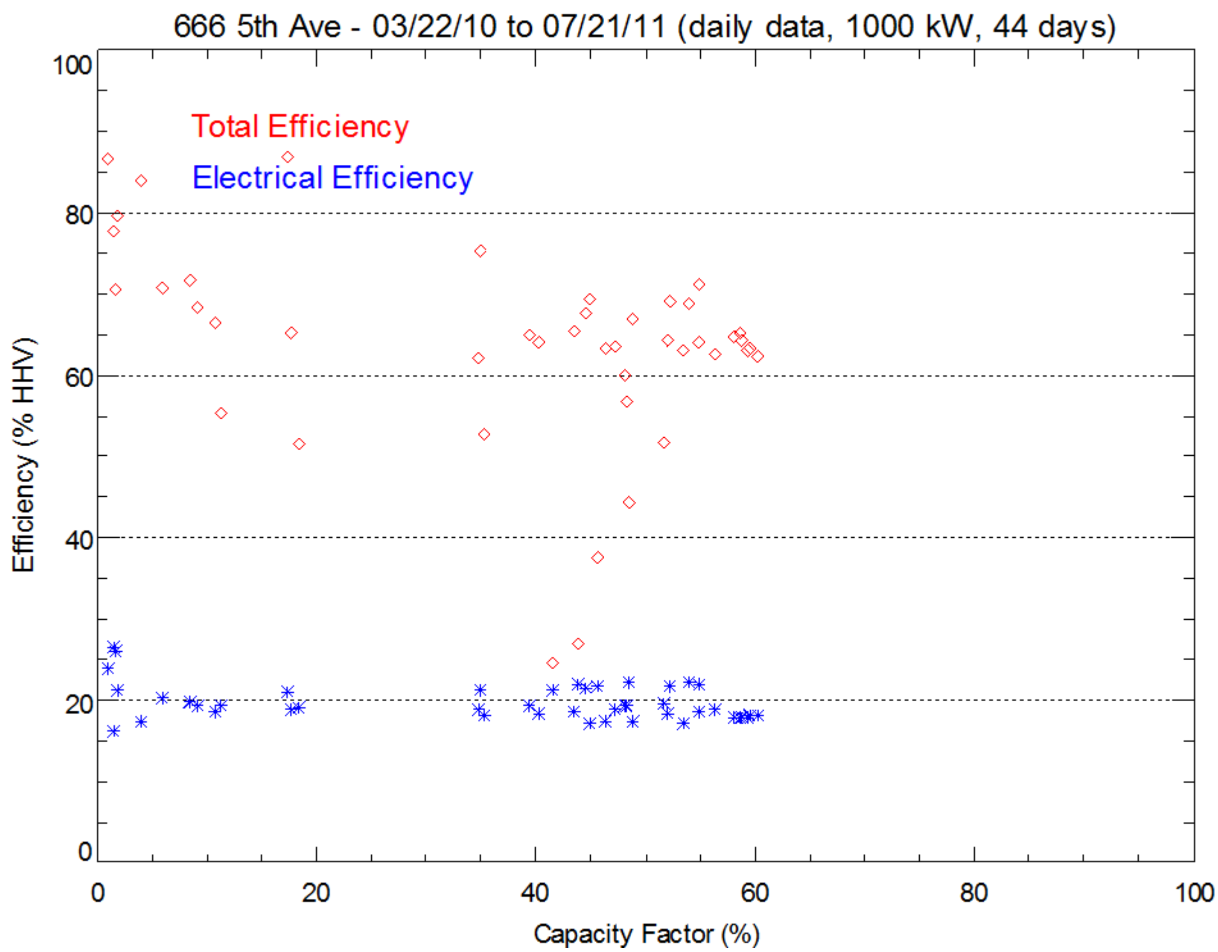

FIGURE 19 CAPACITY FACTOR[3]

Capacity Factor (Figure 19) presents the CHP generated power efficiency over the time period (44 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

[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.

efficiency during the winter months (upper grouping) and lower during the summer months averaging only 38.7% thermal efficiency (HHV). Note the heat recovery increases as the capacity is reduced which merely reflects higher thermal recovery during lower power production.

666 5th Avenue represents a typical New York City high rise office building with little or no space conditioning requirements in the shoulder (fall and spring) months which result in the reduced requirement for useful thermal energy. This system appears to be operating well and exhibits energy efficiency performance that would be expected from microturbines with waste heat integrated with heating, domestic hot water and chilled water systems. An economic evaluation would be important to understand to determine the success of this project.

The microturbines do have a lower electrical efficiency than other power generation technologies, and this efficiency is even lower in the hotter summer periods.

The CHP system relies on scheduled operation that varies with the season based on the expected thermal loads. For example, the turbines are scheduled to operate during the peak period on weekdays (4 am to 9 pm) in the winter and swing seasons. When the absorption chiller is operating, operation is nearly continuous except for a shutdown time at each evening (when chilled water loads are presumably lower). Scheduled operation based on known utility tariff periods and/or expected thermal load patterns is a consistent, simple strategy that results in good overall annual performance.

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. 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.
2. **DG/CHP Generator Gas Input (cubic feet/hour)** A single gas pulse meter represents a running average of high density pulses in cubic feet/hour (CFH). The data logger reports the 1-minute average of these CFH readings. The 1-minute average data is converted into cubic feet / interval and summed into hourly data. Note that only one pulse meter is used, as the utility supplied metering arrangement has changed from the original design.
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.

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

TABLE 2 PERCENTAGE OF GOOD DATA

	Percentage of Good Data		
	Power	**Gas Use**	**Useful Heat**
March-10	96.9%	65.9%	100.0%
April-10	96.8%	100.0%	100.0%
May-10	97.0%	100.0%	100.0%
June-10	96.8%	100.0%	100.0%
July-10	97.6%	100.0%	100.0%
August-10	96.5%	100.0%	100.0%
September-10	96.5%	100.0%	100.0%
October-10	97.0%	100.0%	100.0%
November-10	96.1%	83.3%	83.3%
December-10	90.9%	100.0%	100.0%
January-11	97.2%	100.0%	100.0%
February-11	97.5%	100.0%	100.0%
March-11	96.9%	100.0%	100.0%
April-11	96.9%	100.0%	100.0%
May-11	97.0%	100.0%	100.0%
June-11	96.9%	100.0%	100.0%
July-11	96.9%	100.0%	100.0%