NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT THE SCHWAB HOUSE

October 9, 2013

Schwab House

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.

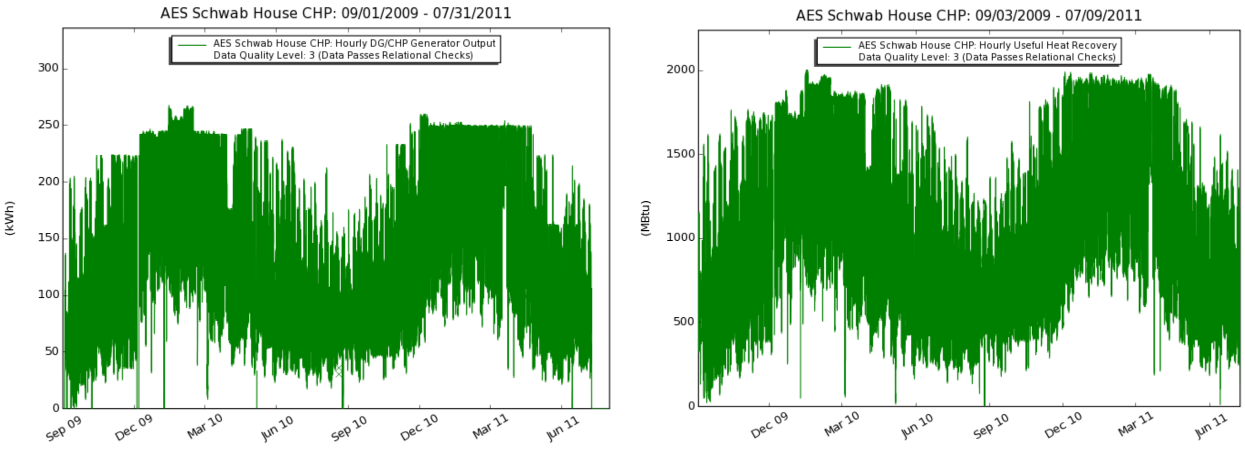

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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 SCHWAB HOUSE NEW YORK CIITY

In 1907, steel magnate, Charles M. Schwab, moved into his new, 75-room mansion designed in French chateau-style by Maurice Hébert on the block bounded by 73rd and 74th Streets, West End Avenue and Riverside Drive. The Schwab mansion was torn down in 1948.

The opulent Schwab edifice was replaced by a 17-story, 654-unit apartment building, appropriately named Schwab House, in 1950. The redbrick structure, designed by Sylvan Bien, occupies about 60 percent of the site with landscaped courtyards providing light and air for the building's indented form. Today the Schwab House is a 650 unit condominium occupying 1 million sq. ft.

THE SYSTEM

The CHP system runs in parallel with the Consolidated Edison grid and the recovered waste heat is used to provide space heating and domestic hot water for the building, and drive an absorption chiller system capable of producing more than 20 tons of cooling for the first floor lobby and hallway common area. The CHP system consists of four Aegen Thermopower TP75LE modules for a combined output of 300kW and thermal output from each of 523,000 BTUH.

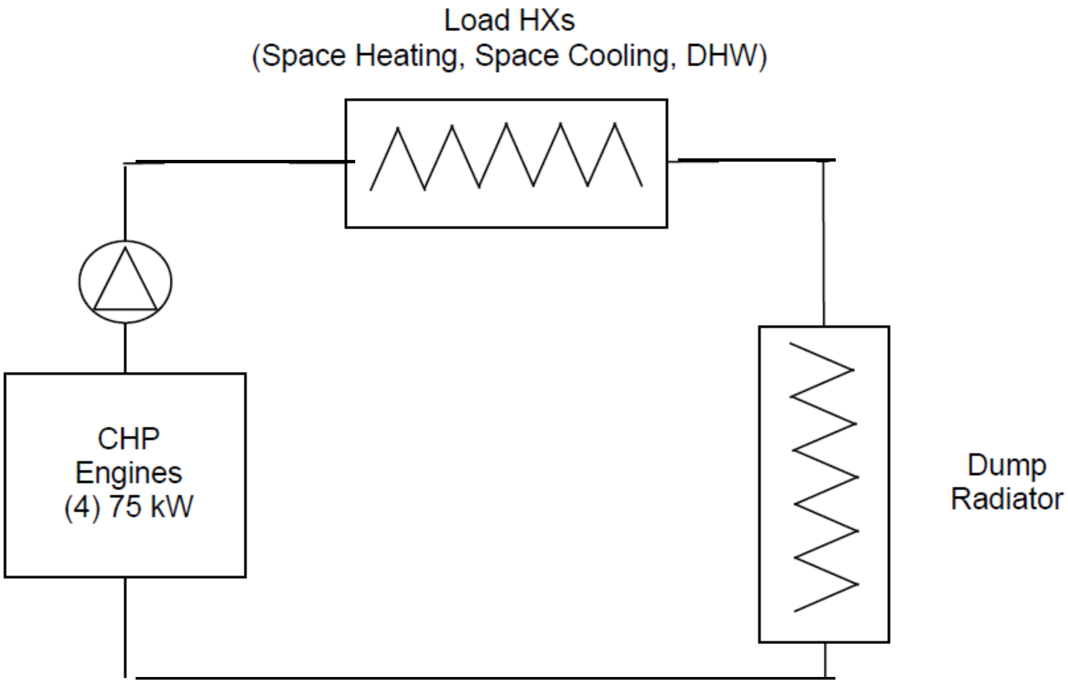

FIGURE 3 CHP SYSTEM SCHEMATIC

FIGURE 4 FOUR 75 KW ENGINE GENERATORS

PERFORMANCE

TABLE 1 SYSTEM EFFICIENCY[1]

	Net Electric Output (kWh)	Natural Gas Use (MCF)	Useful Heat Output (MMBtu)	Electrical Efficiency	Useful Thermal Efficiency	Fuel Conversion Efficiency
February-10	132,096	1,886.8	1,006.4	23.4%	52.3%	75.7%
March-10	120,815	1,775.9	929.9	22.8%	51.3%	74.1%
April-10	93,387	1,408.8	741.6	22.2%	51.6%	73.8%
May-10	75,206	1,202.7	600.6	20.9%	49.0%	69.9%
June-10	74,585	1,151.0	593.8	21.7%	50.6%	72.3%
July-10	66,350	1,050.2	534.7	21.1%	49.9%	71.1%
August-10	58,584	945.6	480.6	20.7%	49.8%	70.6%

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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.

September-10	60,266	960.1	484.1	21.0%	49.4%	70.4%
October-10	67,127	1,071.2	546.6	21.0%	50.0%	71.0%
November-10	92,203	1,419.8	734.6	21.7%	50.7%	72.5%
December-10	135,286	2,044.0	1,047.4	22.1%	50.2%	72.4%
January-11	146,300	2,210.20	1,126.90	21.9%	49.5%	71.4%
February-11	131,900	1,996.70	1,015.30	21.9%	49.3%	71.2%
March-11	141,200	2,128.80	1,093.10	22%	49.8%	71.8%
April-11	101,100	1,585.80	788.2	21.1%	48.3%	69.4%
May-11	74,100	1,198.00	588.6	20.5%	47.7%	68.2%
June-11	66,800	1,103.50	540.2	20.1%	47.5%	67.6%
July-11	59,600	997.9	488.2	19.8%	47.5%	67.3%
Total preceding 12 months	**975,904**	**14,916.0**	**7,700.3**	**21.9%**	**50.6%**	**72.5%**

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

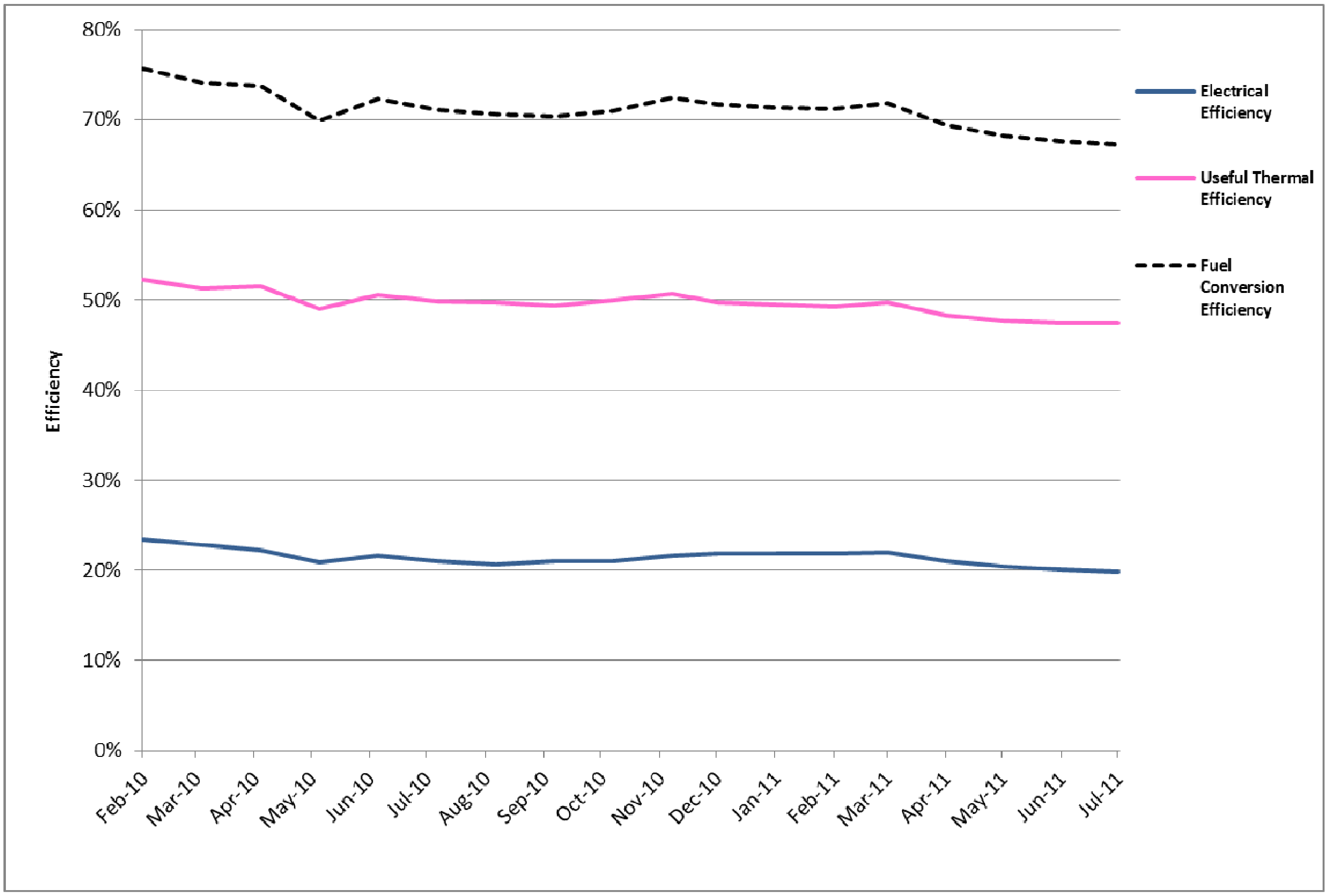

FIGURE 5 ELECTRIC, THERMAL AND FUEL CONVERSION EFFICIENCY BY MONTH

Figure 5 provides operating efficiency during the February 2010 – July 2011 time period showing a slight decline in CHP electric efficiency in the summer due to a drop in power output (lower engine part load heat rate) and a slight increase in useful thermal efficiency performance because the low power output means a higher percentage of thermal energy. The electrical efficiency of the engines is relatively poor at this site (22% instead of 27%) because the engines cycle on and off independently to meet the thermal load. The controls are setup so that each engine is independently controlled and shuts down when its high temperature limit is reached.

OPERATING SUMMARY

During the 8,720 operating hours in 2010 that met the range and relational checks 52% of this time the CHP system delivered between 50 and 125 kW/hr (Figure 15).

This CHP system is thermal load following which accounts for the high useful thermal energy efficiency and consequent high fuel conversion efficiency.

POWER GENERATION AND USEFUL THERMAL ENERGY

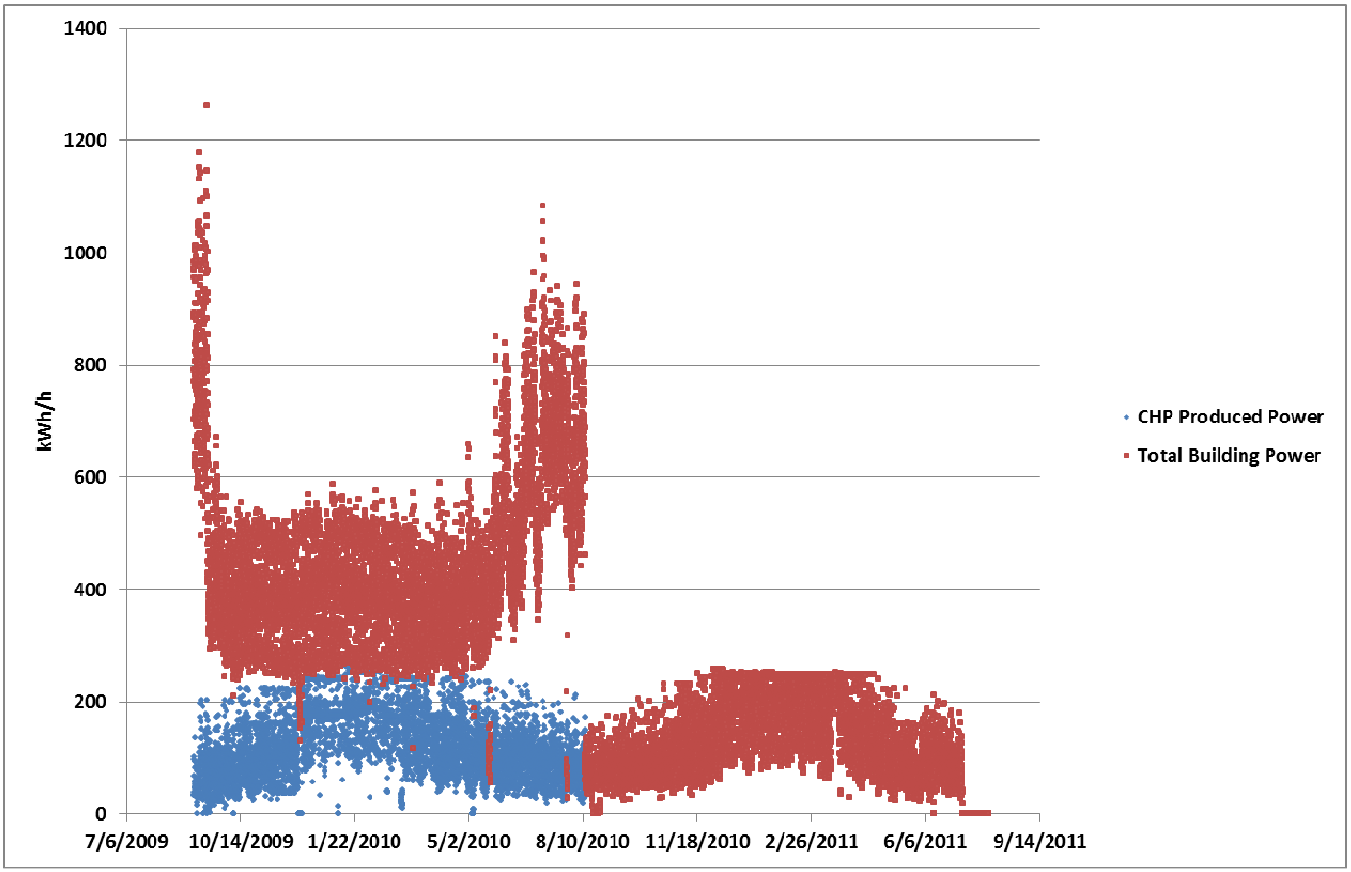

FIGURE 6 TOTAL BUILDING VS. CHP POWER OUTPUT VERSUS TIME

Figure 6 shows the electric load profile for Schwab House is air conditioning dominated, rising from 280 to 550 kWh/h in the winter of 2010 to 600 to 1,000 kWh/h in the summer of 2010. Note the convergence of building and CHP output in August of 2010, which in reality was the failure of the utility data acquisition system.

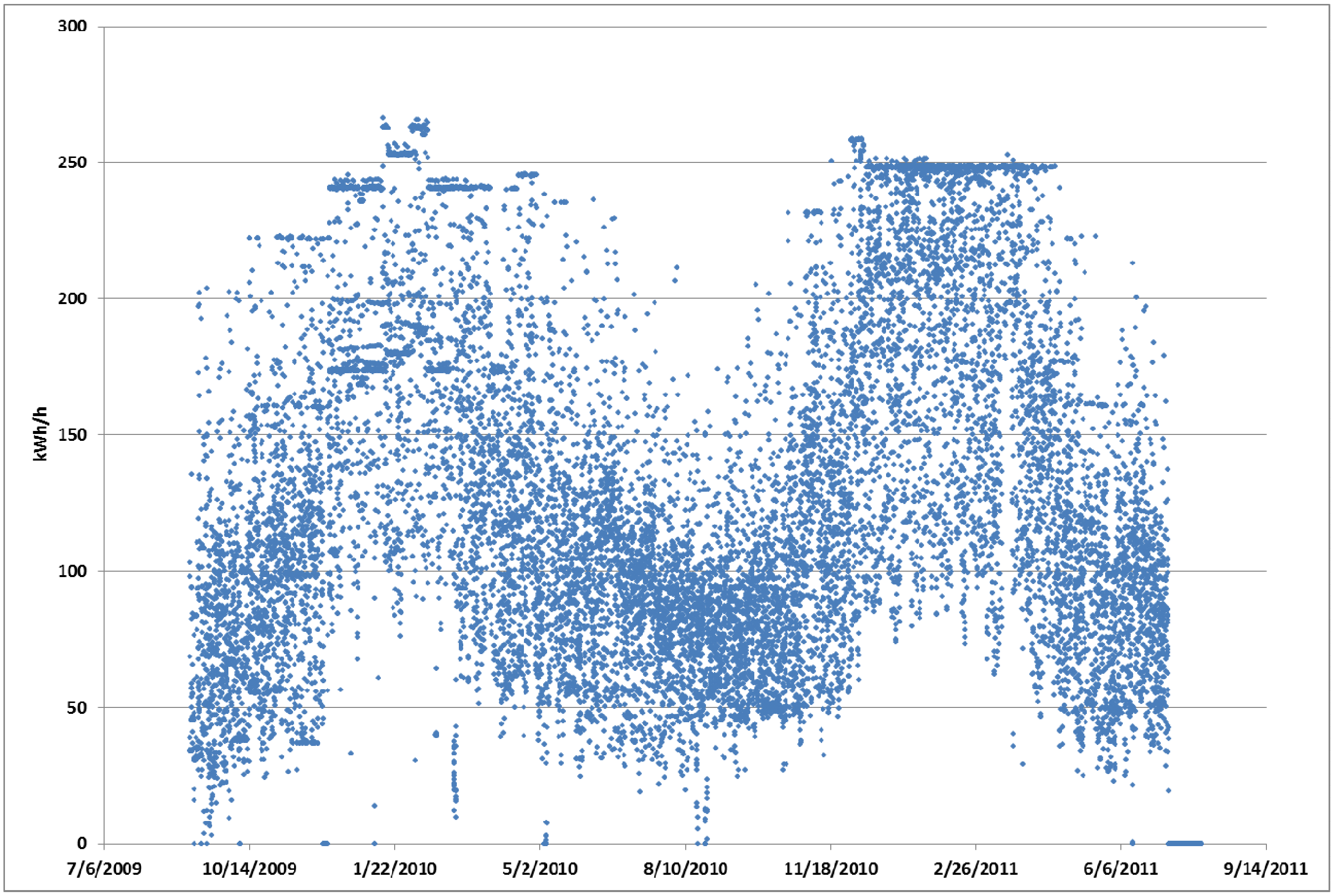

FIGURE 7 CHP POWER OUTPUT VERSUS TIME

Figure 6 shows the electric load profile for Schwab House is air conditioning dominated. This CHP plant is thermal load following. Note that capacity limits are reached in the winters of 2010 and 2011.

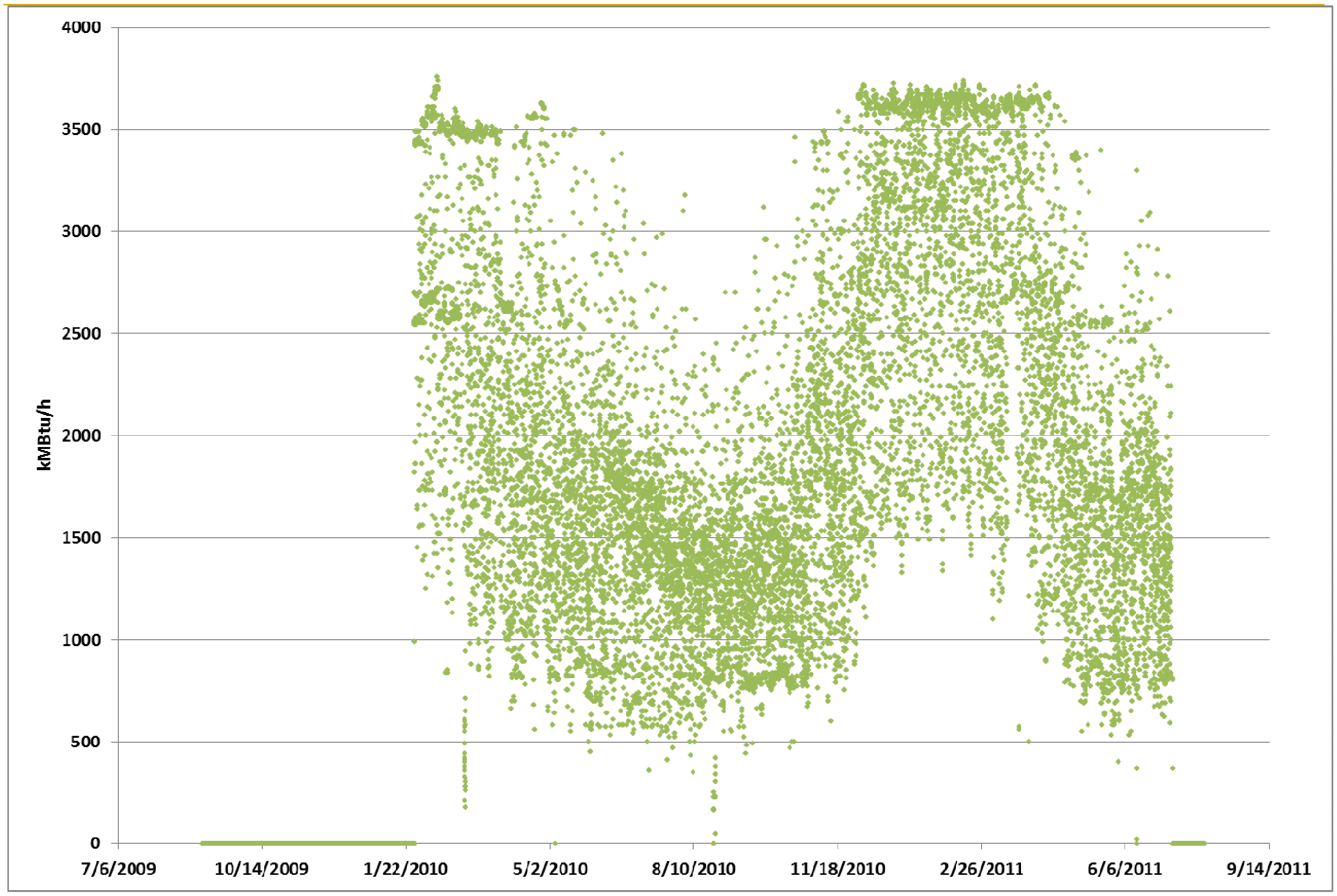

FIGURE 8 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 8 shows the heating dominated thermal load profiles for the CHP system. Note that capacity limits are reached in the winters of 2010 and 2011.

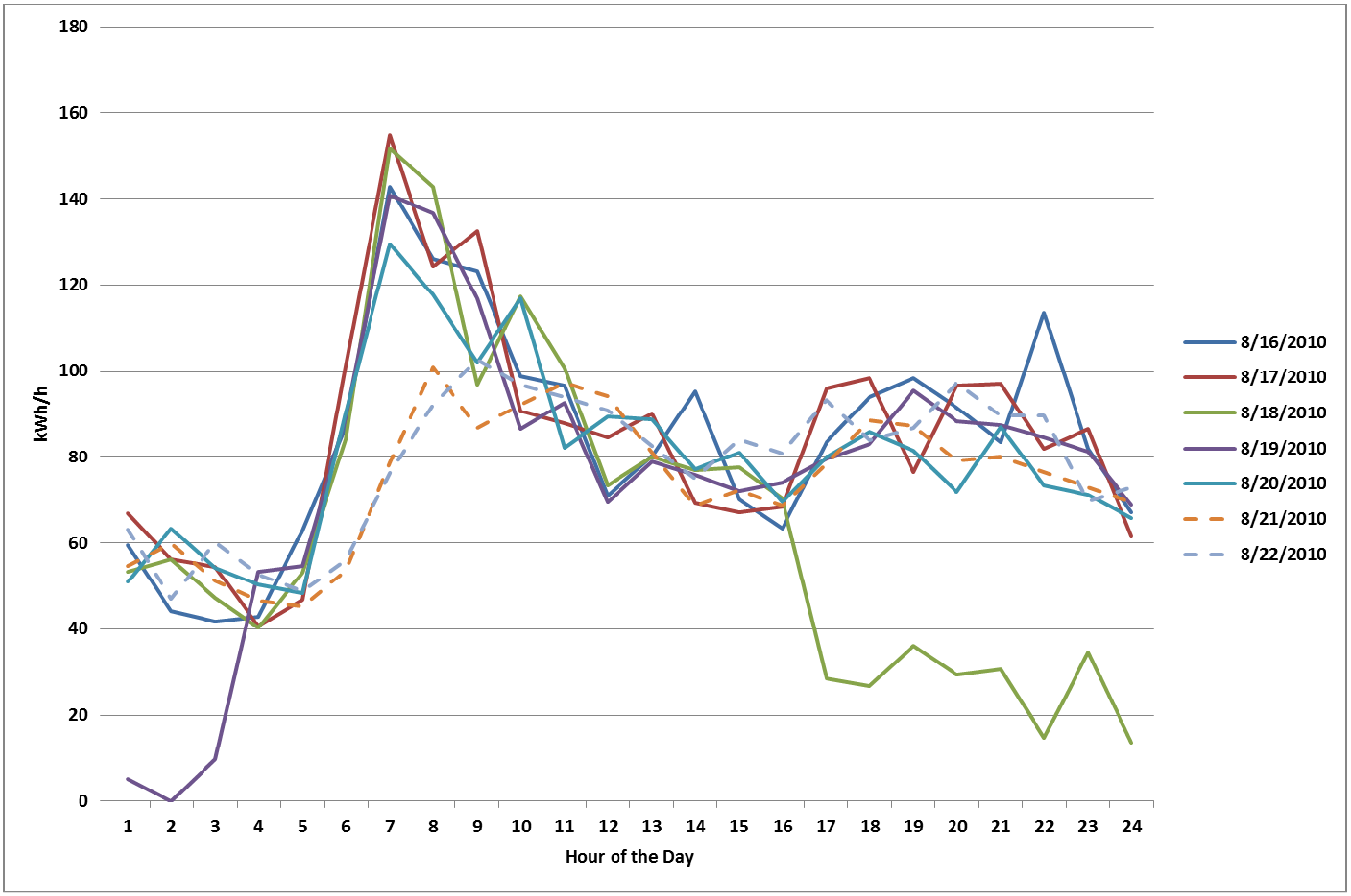

FIGURE 9 CHP POWER OUTPUT VERSUS TIME

Figure 9 covers the time period from August 16 – 22, 2010 providing CHP system power output by hour of the day pattern for the time period. August 21 is a Saturday. Examining Figure 10 (useful thermal energy) it is easy to see the engines are in thermal load following mode.

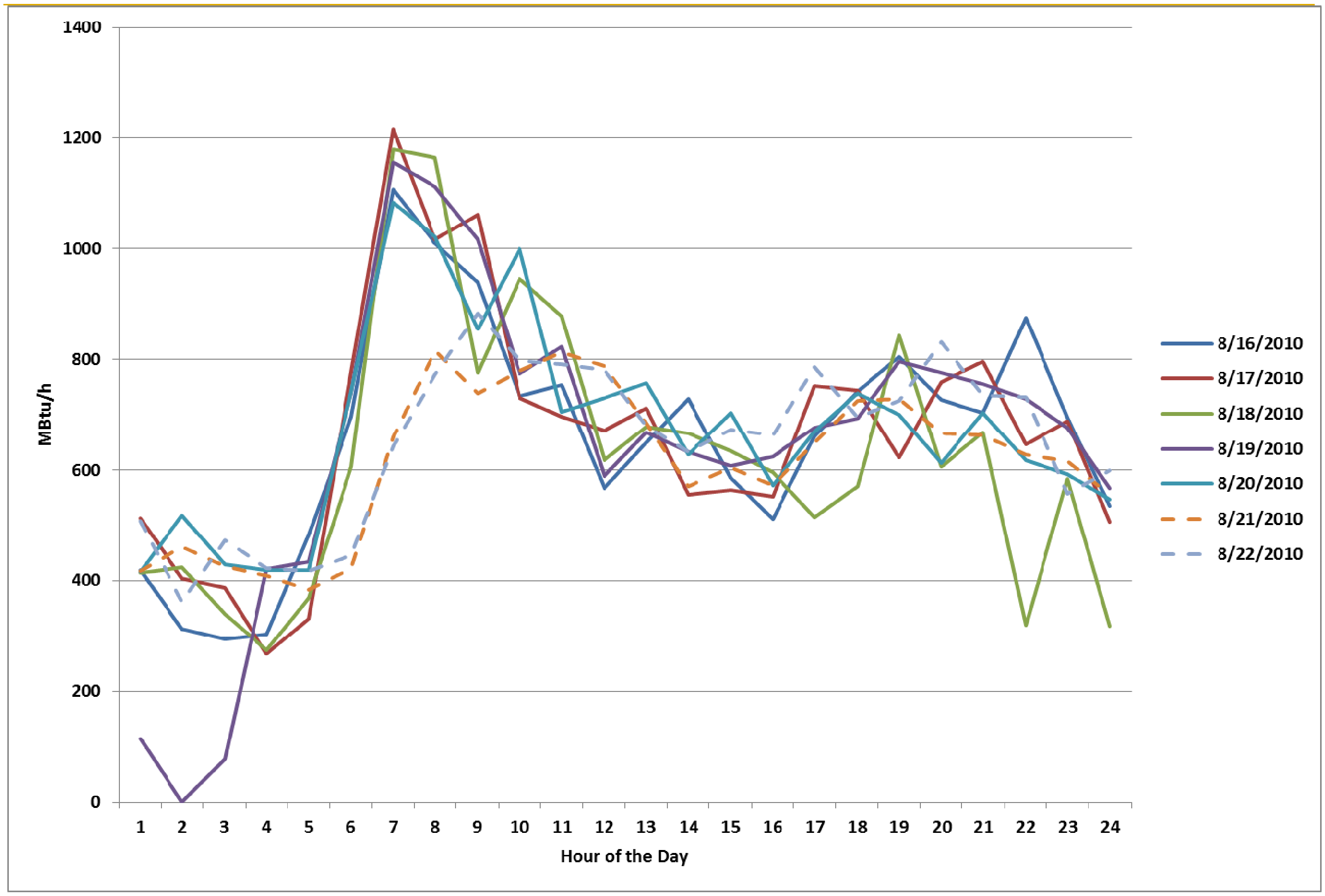

FIGURE 10 CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from August 16 – 22, 2010 (Figure 10) show a very consistent thermal load pattern. August 21 is a Saturday.

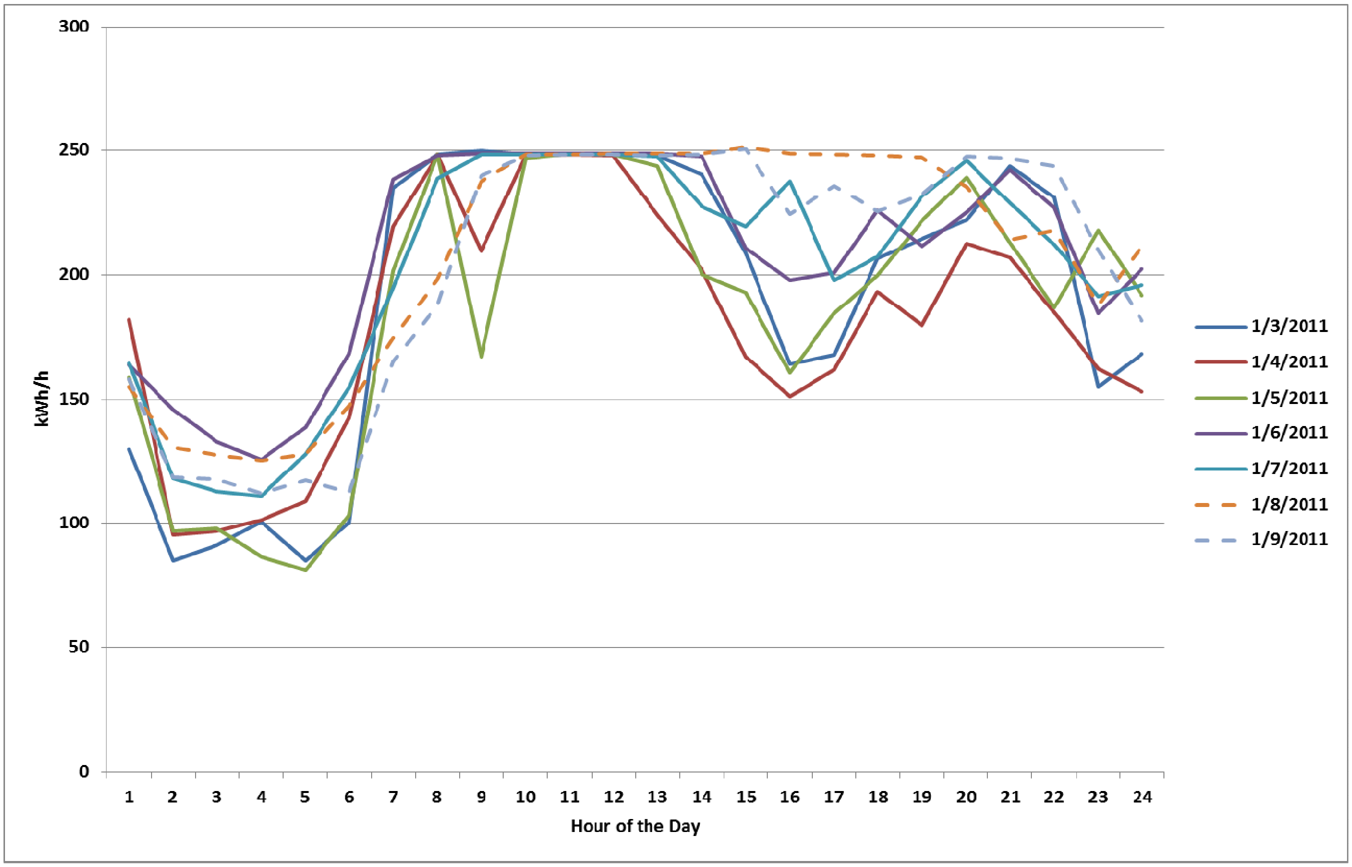

FIGURE 11 CHP POWER OUTPUT VERSUS TIME

Figure 11 covers the time period from January 3 – 9, 2011 providing CHP system power output by hour of the day pattern for the time period. January 8 is a Saturday.

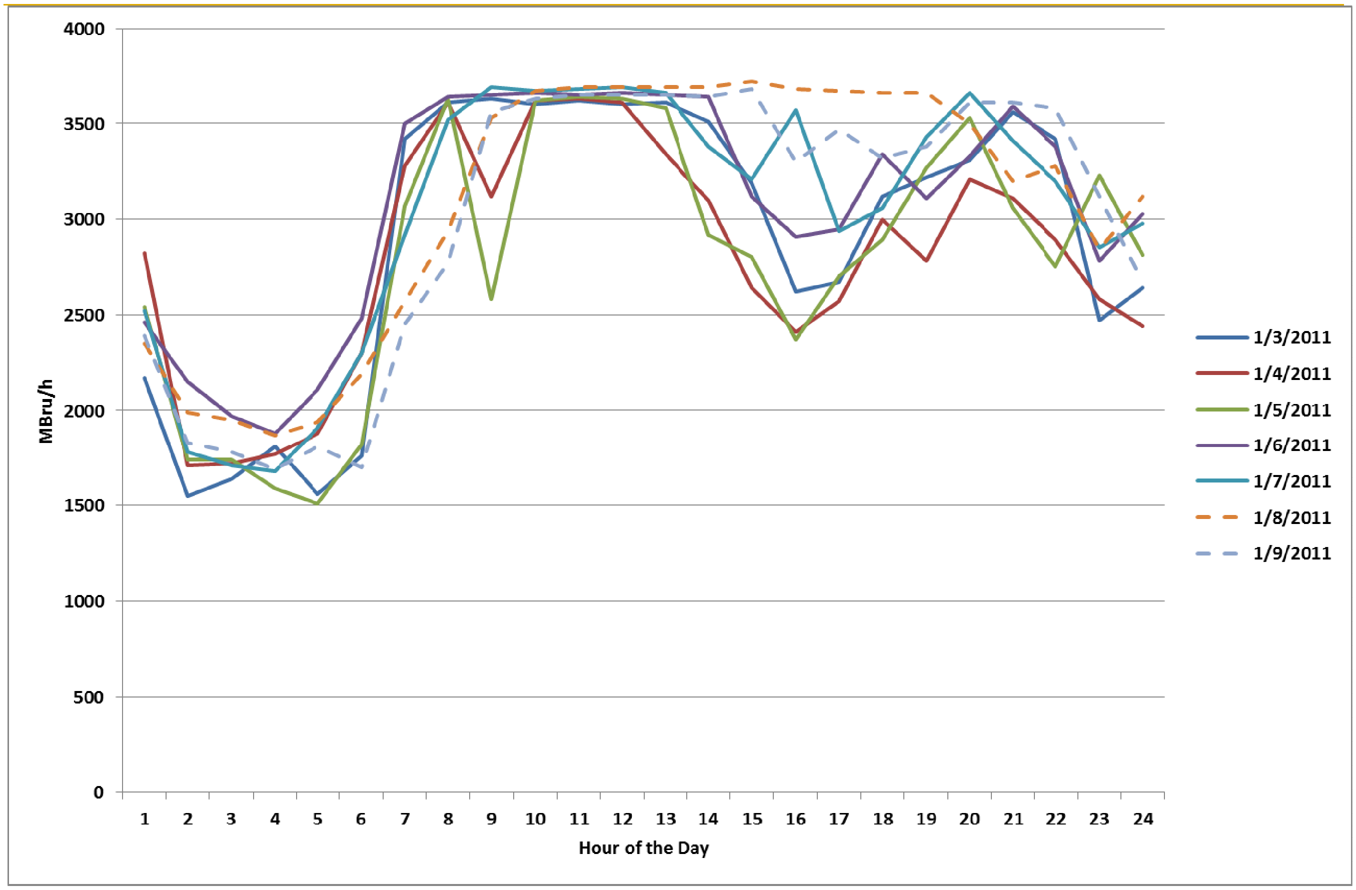

FIGURE 12 SELECTED DAY CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from January 3 – 9, 2011 (Figure 12). January 8 is a Saturday.

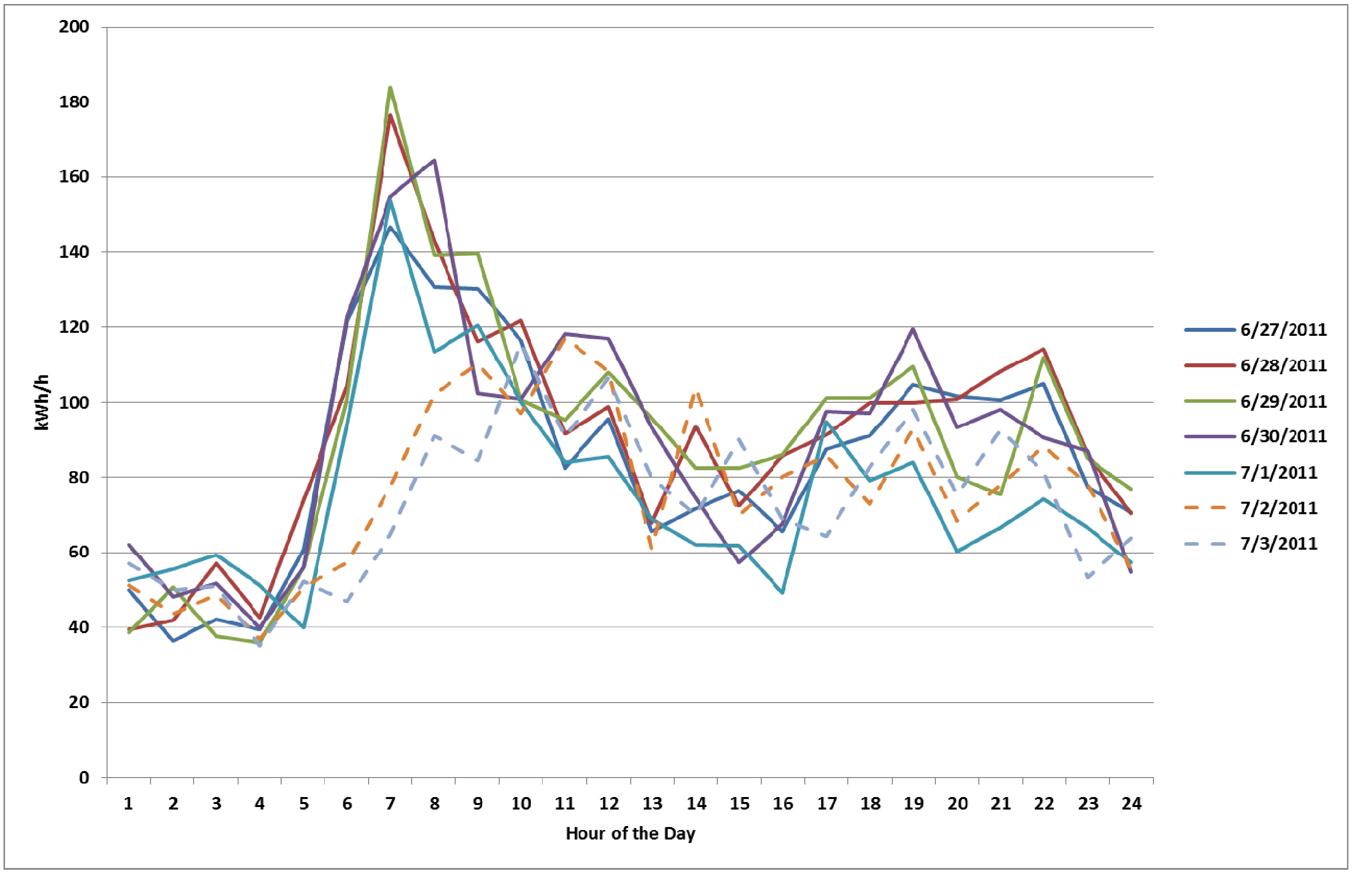

FIGURE 13 CHP POWER OUTPUT VERSUS TIME

Figure 13 covers the time period from June 27 – July 3, 2011 providing CHP system power output by hour of the day pattern for the time period. July 2 is a Saturday.

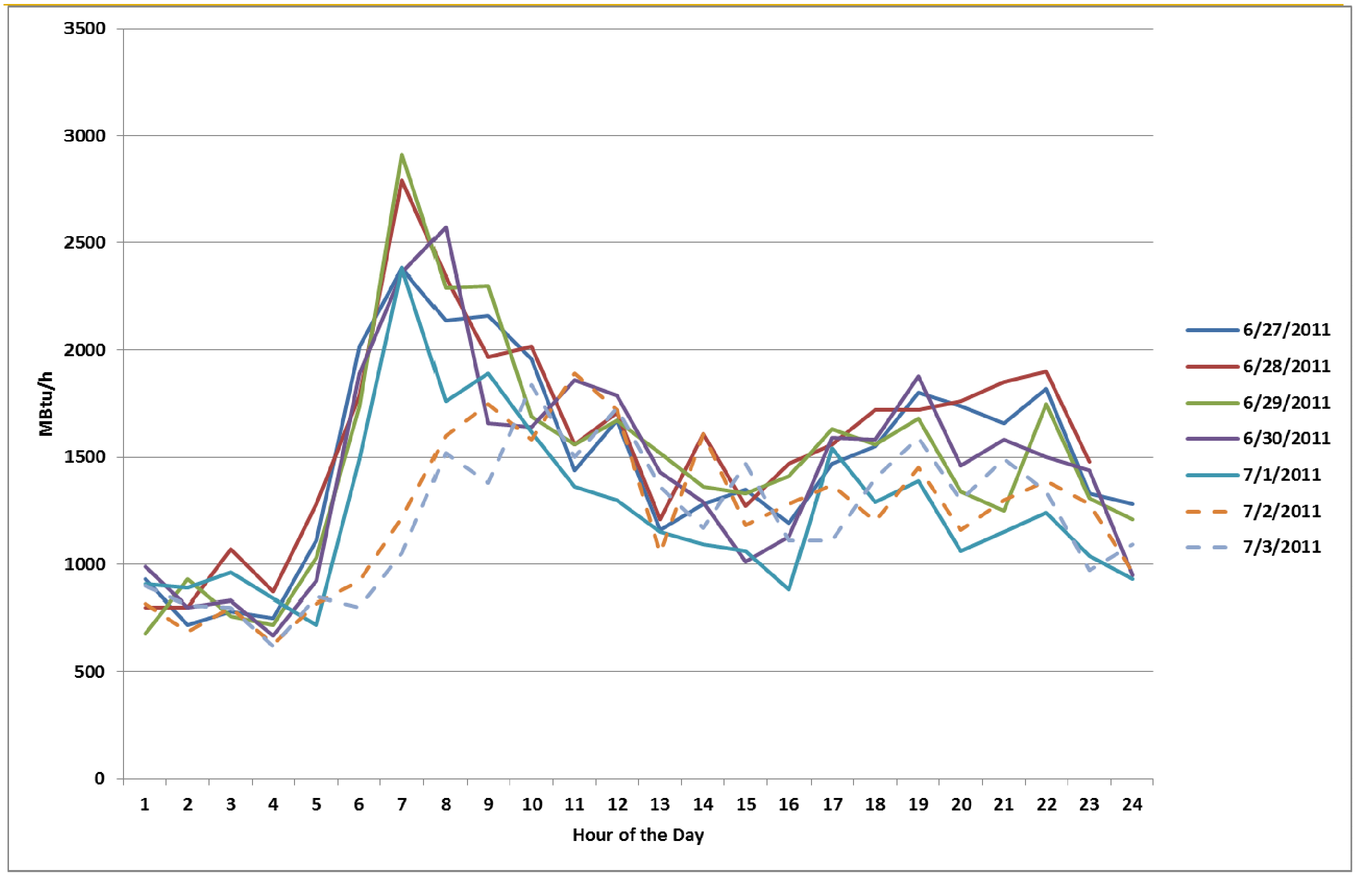

FIGURE 14 SELECTED DAY CHP USEFUL THERMAL OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from June 27 – July 3, 2011 (Figure 14). July 2 is a Saturday.

PERFORMANCE SUMMARY

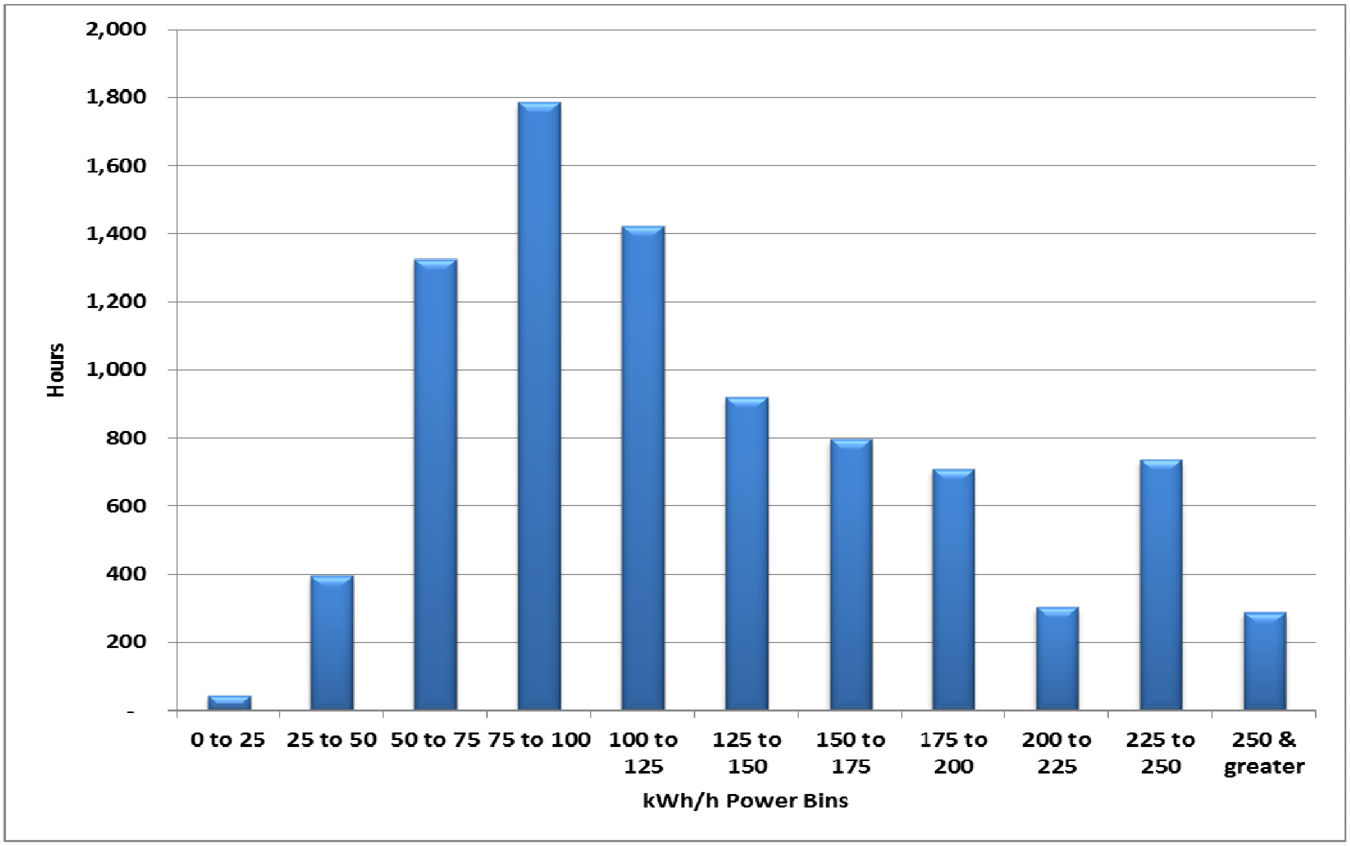

FIGURE 15 PERFORMANCE BY POWER BINS

During the 8,720 operating hours in 2010 that met the range and relational checks 52% of this time, the CHP system delivered between 50 and 125 kW/hr (Figure 15).

LESSONS LEARNED

TABLE 2 SYSTEM EFFICIENCY[2]

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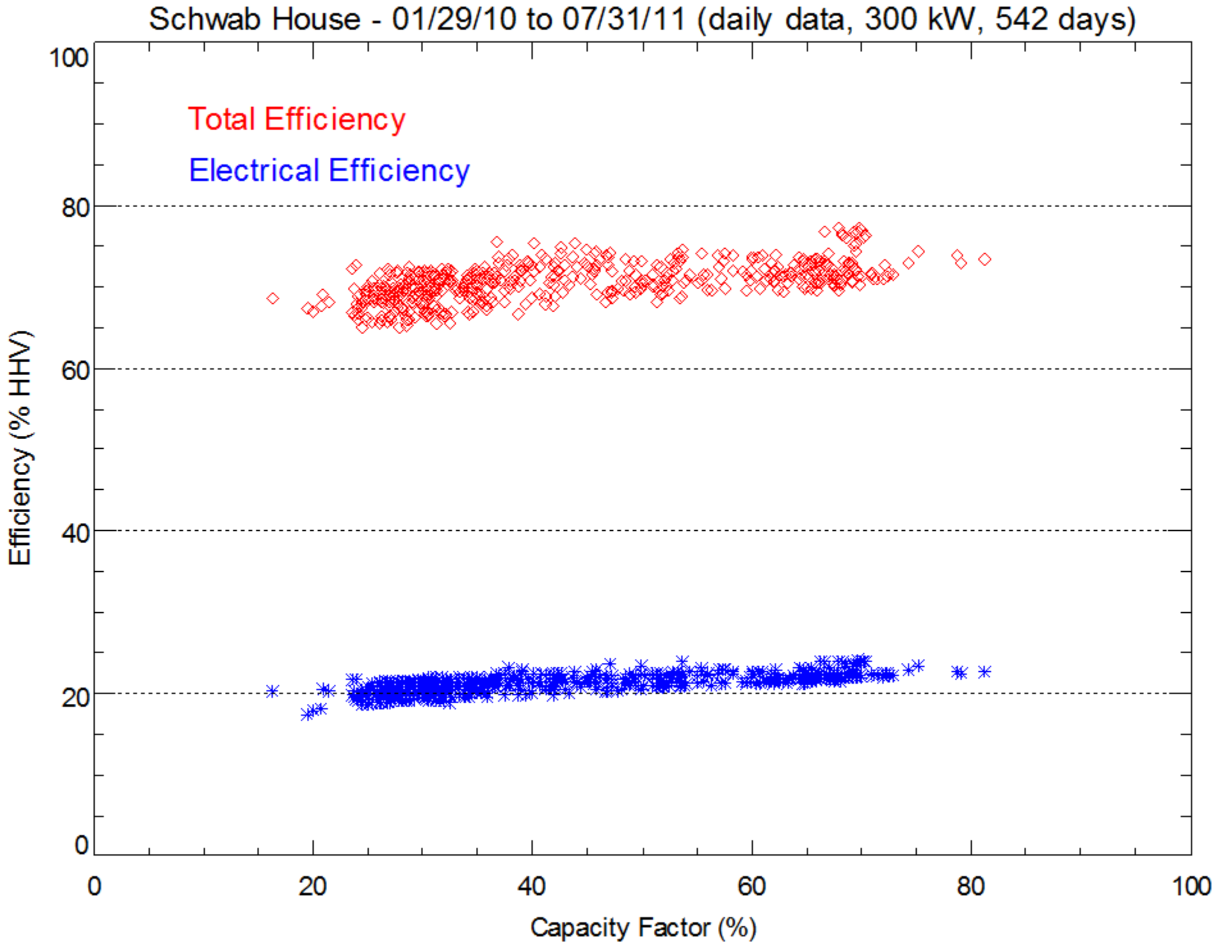

FIGURE 16 CAPACITY FACTOR[3]

Capacity Factor (FIGURE 16) presents the CHP generated power efficiency over the time period (542 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 25% and 75% of the generating capacity at about 21.9% power efficiency (HHV) during the last 12 months of Table 2. The useful thermal energy (heating, cooling and DHW) operated at high efficiency during the entire period averaging 50.6% thermal efficiency (HHV).

This was a well-designed simple system that effectively used the available heat by operating in the thermal load following mode.

The engines are controlled such that they independently cycle on and off to follow the thermal loads at this site. As we have observed at other sites with small engines, excessive cycling decreases the electrical efficiency from the steady state value of 27-28% to a much lower value (i.e. 22%).

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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 based on the measurements from four (4) Veris H8035-300 power transducers. The incremental difference in energy output measured in accumulated kWh is summed for the four engines. The parasitic power for the system is measured by a Veris H8053-300 power transducer on the dedicated 208 VAC parasitic load panel. This energy is subtracted from sum of the engine power transducers, to result in the net power output for the system. 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 is based on measurements provided by a pulse output installed on the Con Ed billing meter. The gas consumption is measured as accumulated CF, and the incremental difference in the accumulator is computed for the gas use per interval. The 1-minute raw data is then summed into hourly data.
3. **Useful Heat Recovery (total MBtu)** The useful heat recovery is calculated by the recorded temperature difference across the load heat exchangers (leaving the CHP system and before the dump radiator HX), and the flow through the glycol loop. The heat transfer is calculated on a 1-minute basis, and then summed into hourly data.

Overall, the CHP system appears to have operated consistently in load following mode.

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

TABLE 3 SITE DATA QUALITY

	Percentage of Good Data		
	Power	**Gas Use**	**Useful Heat**
February-10	99.9%	100.0%	100.0%
March-10	100.0%	100.0%	100.0%
April-10	100.0%	99.9%	100.0%
May-10	96.1%	100.0%	96.9%
June-10	100.0%	100.0%	100.0%
July-10	100.0%	100.0%	100.0%
August-10	98.8%	100.0%	98.8%
September-10	100.0%	100.0%	100.0%
October-10	100.0%	100.0%	100.0%
November-10	100.0%	100.0%	100.0%
December-10	100.0%	100.0%	100.0%

APPENDIX A: ADJUSTMENTS TO AEGIS CHP THERMAL DATA AT THE SCHWAB HOUSE

On January 28, 2010 the temperature sensors measuring CHP system glycol loop temperatures were replaced. The existing sensors (Mamac Systems TE-211Z 1000 Ohm RTD with 4-20 mA transmitters) were replaced with a Veris Industries Type II 10k Ohm thermistor. The existing RTD sensors indicated a temperature offset that was overstating the heat rejection to the dump radiator, and understating the useful heat output from the CHP system.

The heat flows in the CHP system are measured using a two temperature difference measurement (from three temperature sensors) and a common flow meter (Figure 17). The system uses a constant flow heat transfer loop and, therefore, any errors in the measured temperature difference result in a proportional difference in the heat transfer calculation.

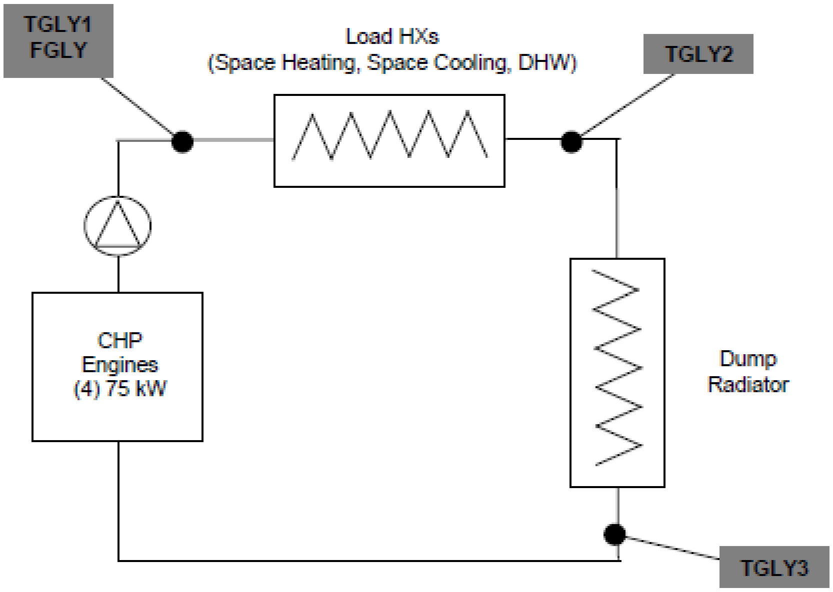

FIGURE 17 SCHWAB HOUSE CHP SYSTEM THERMAL MONITORING

An analysis of the temperature difference data with the RTDs installed was performed during periods in the data set where the engine was shutdown. The temperature difference across the dump radiator (TGLY2 – TGLY3) indicated an offset of 3.5°F between the sensors (when no heat rejection was occurring). The temperature difference data from the CHP engine glycol supply temperature and the temperature leaving the load HX (TGLY1 – TGLY2) indicated a 1.6°F offset in the temperatures.

The impact of these calibration changes on the total volume of heat transfer recorded (September 3, 2009 – March 29, 2010) is shown in Table 4. The useful heat transfer measurement (based on TGLY1-TGLY2) increased by 143,633 MBtu or 3%. The dumped heat transfer measurement (based on TGLY2-TGLY3) decreased by 418,499 MBtu or 92%. This decrease in the dumped heat transfer measurement is consistent with the physical state of the system, where the dump radiator circuit is not in operation during the winter, and has heat traps installed on the radiator piping loop to minimize any natural convection.

TABLE 4 IMPACT OF TEMPERATURE CALIBRATION ON TOTAL VOLUME OF HEAT TRANSFER MEASURED

	Without Adjustments (MBtu)	With Adjustments and Thermistor Replacement (MBtu)	Difference (MBtu)	Relative Error (%)
Useful Heat Transfer	5,217,322	5,360,955	143,633	3%
Dumped Heat Transfer	455,773	37,274	(418,499)	-92%