NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT THE SHOPRITE SUPERMARKET

October 9, 2013

Shoprite Supermarket

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.

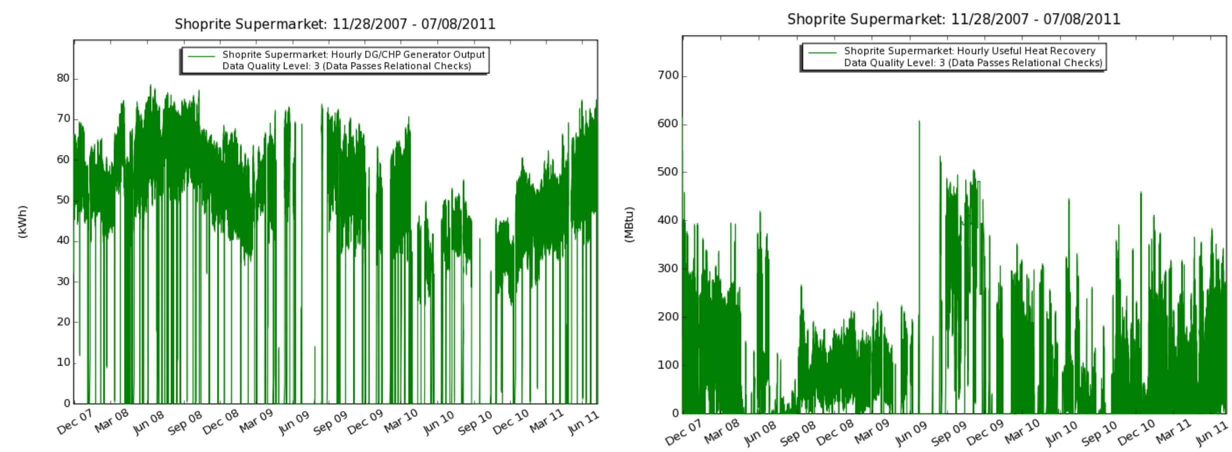

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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 SHOPRITE SUPERMARKET BROOKLYN, NEW YORK

Grocery stores across the state generally operate on small margins while incurring significant energy costs. The ShopRite Supermarket in Brooklyn, NY is typical. The nature of the operation and space conditions are unique compared to other commercial buildings and put special demands on the HVAC&R systems.

ShopRite recently installed a packaged 140 kW CHP module designed to provide base load electric service. Waste heat recovered from the engine is used for space conditioning as well as to augment the performance of the store's refrigeration system. This approach helps maximize the overall CHP efficiency.

THE SYSTEM

The CHP system at ShopRite is configured using a natural gas fueled, 140 kW engine-generator set that was supplied as a pre-packaged module. Electricity is produced in parallel with the utility grid though all of the energy is consumed on-site. Heat recovered as hot water from the engine coolant jacket and exhaust is used to operate an absorption chiller, regenerate a desiccant dryer or reject to the atmosphere, depending on immediate needs. Chilled water from the absorption machine is circulated in series with an electric chiller and used to subcool liquid refrigerant being distributed to the display cases. This produces a low temperature refrigeration effect equal to the amount of cooling provided by the absorption chiller. The chilled water can also be circulated through the engine intercooler to enhance performance.

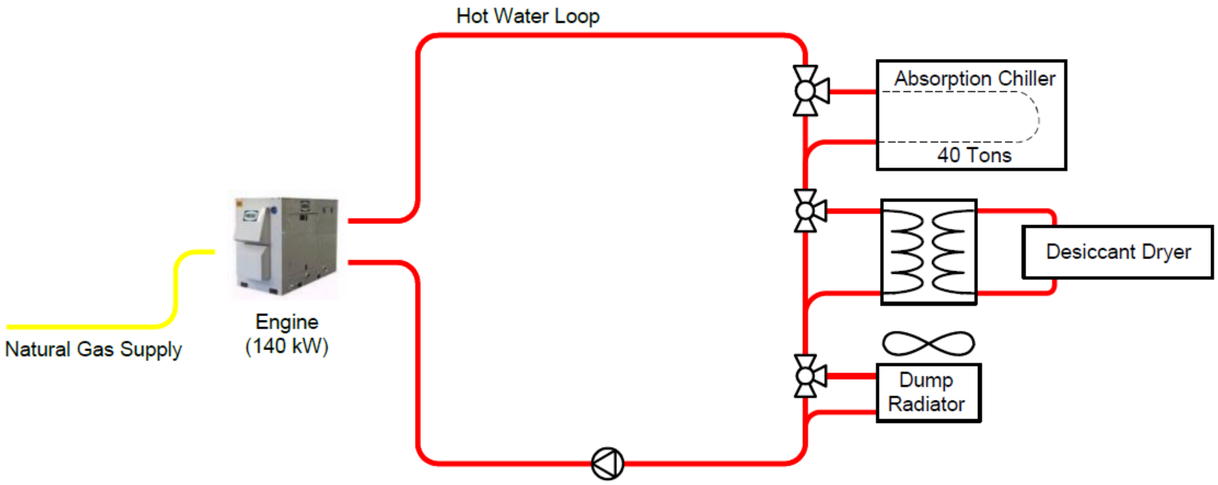

FIGURE 3 SIMPLIFIED CHP SCHEMATIC

FIGURE 4 EQUIPMENT INSTALLATION

FIGURE 5 GENERATOR (RIGHT) AND ABSORPTION CHILLER (LEFT)

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.

Table 1 provides the data results taken since December, 2007.

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-07	744	42,350	559.2	102.8	25.3%	18.0%	43.4%
January-08	744	34,443	469.0	92.9	24.6%	19.4%	44.0%
February-08	672	34,468	476.0	101.3	24.2%	20.9%	45.1%
March-08	743	43,781	578.2	96.9	25.3%	16.4%	41.8%
April-08	720	24,757	338.4	29.1	24.5%	8.4%	32.9%
May-08	743	41,701	554.2	13.6	25.2%	2.4%	27.6%
June-08	714	39,187	536.6	90.8	24.4%	16.6%	41.0%

[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.

July-08	744	43,854	605.0	1.3	24.3%	0.2%	24.5%
August-08	744	39,667	547.7	1.1	24.2%	0.2%	24.4%
September-08	720	43,408	605.2	47.2	24.0%	7.6%	31.6%
October-08	744	43,074	617.8	52.5	23.3%	8.3%	31.7%
November-08	720	40,189	600.6	50.8	22.4%	8.3%	30.7%
December-08	744	40,834	611.6	70.0	22.3%	11.2%	33.6%
January-09	743	37,047	587.9	58.7	21.1%	9.8%	30.9%
February-09	672	27,881	452.8	31.7	20.6%	6.9%	27.5%
March-09	719	30,426	469.7	48.0	21.7%	10.0%	31.7%
April-09	720	21,343	387.4	27.9	18.4%	7.1%	25.5%
May-09	744	14,397	219.3	24.7	22.0%	11.0%	33.0%
June-09	720	5,817	93.3	13.2	20.9%	13.9%	34.8%
July-09	744	16	0.4	0.2	13.1%	54.4%	67.5%
August-09	744	10,430	159.4	30.2	21.9%	18.5%	40.4%
September-09	668	37,472	566.0	136.8	22.2%	23.7%	45.9%
October-09	719	38,534	597.3	17.6	21.6%	2.9%	24.5%
November-09	720	37,752	588.9	21.4	21.5%	3.6%	25.0%
December-09	744	3,768	64.1	5.3	19.7%	8.1%	27.7%
January-10	743	8,743	148.3	14.7	19.7%	9.7%	29.5%
February-10	672	23,269	378.2	28.9	20.6%	7.5%	28.1%
March-10	693	24,707	415.6	22.5	19.9%	5.3%	25.2%
April-10	623	8,475	201.5	17.1	14.1%	8.3%	22.4%
May-10	744	15,019	317.2	17.2	15.8%	5.3%	21.2%
June-10	719	16,328	326.7	31.8	16.7%	9.5%	26.3%
July-10	743	25,741	510.8	27.6	16.9%	5.3%	22.2%
August-10	743	21,045	434.8	4.1	16.2%	0.9%	17.1%
September-10	719	55	2.5	1.6	7.3%	62.3%	69.6%
October-10	742	4,320	90.7	19.6	15.9%	21.2%	37.1%
November-10	718	27,066	557.4	23.2	16.2%	4.1%	20.3%
December-10	718	23,135	409.8	7.6	18.9%	1.8%	20.7%
January-11	743	33,650	523.9	16.9	21.5%	3.2%	24.6%
February-11	671	30,167	471.6	10.9	21.4%	2.3%	23.7%
March-11	718	34,317	523.8	16.2	21.9%	3.0%	24.9%
April-11	719	27,975	421.6	16.7	22.2%	3.9%	26.1%
May-11	743	35,968	531.2	44.4	22.7%	8.2%	30.8%
June-11	719	40,760	593.2	77.3	23.0%	12.8%	35.8%
July-11	741	36,904	537.2	77.0	23.0%	14.1%	37.0%
Total preceding 12 months	**8694**	**315,362**	**5,097.7**	**315.3**	**20.7%**	**6.1%**	**26.8%**

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

Data acquisition issues from this site have caused sporadic data gaps ranging from one hour to multiple weeks which accounts for the data gaps.

OPERATING SUMMARY

This is a single 140 kW reciprocating engine generator based CHP system with useful heat recovery to supply thermal energy for a 40 RT absorption chiller and a desiccant dehumidifier. The chiller is to supply additional cooling to the supermarket and the desiccant dehumidifier is to provide humidity control.

The average electrical efficiency for the last 12 months of operation was 20.7% which is largely due the low load factor on the engine averaging under 40 kWh/h for the year. The Useful Thermal Efficiency for this 12 month period was only 6.1%. Supermarkets are difficult thermal hosts.

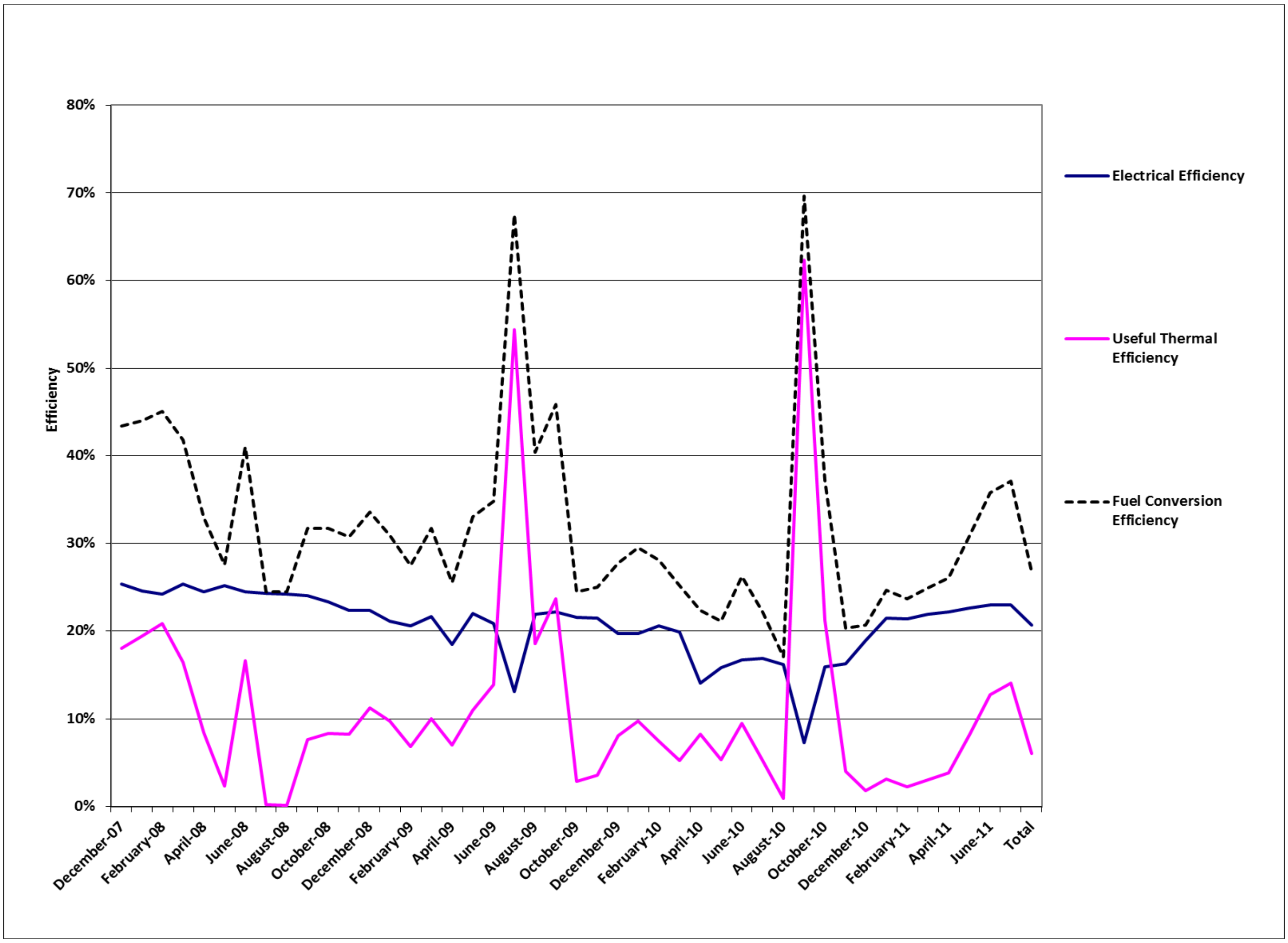

FIGURE 6 CHP SYSTEM EFFICIENCY BY YEAR

POWER GENERATION AND USEFUL THERMAL ENERGY

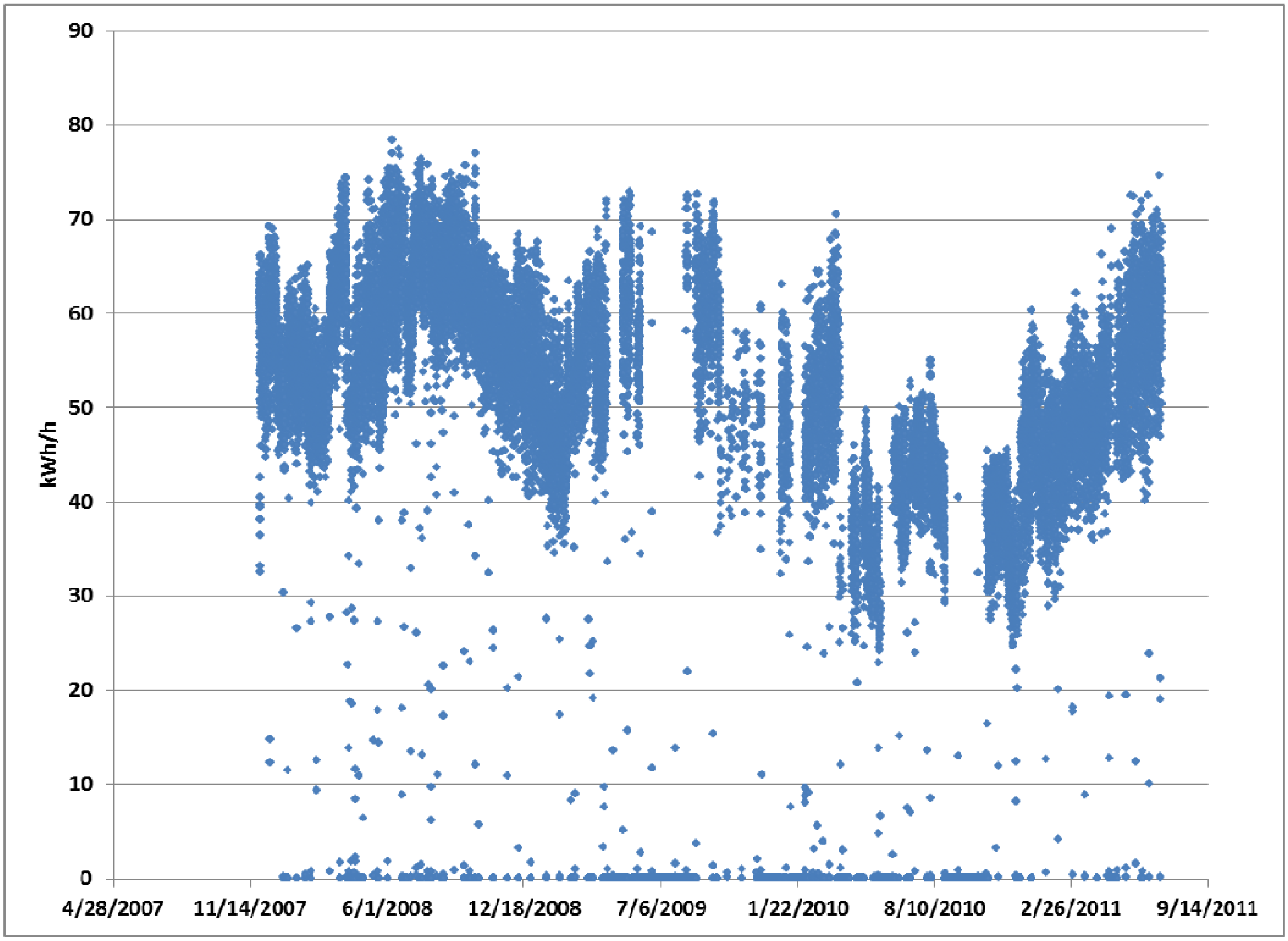

FIGURE 7 CHP POWER OUTPUT VERSUS TIME

Figure 7 shows that the power delivered to the supermarket generally ranges between 25 kWh/h and 78 kWh/h which is substantially below the 140 kW rating of the engine. The power curve shows that the CHP system is producing less than capacity.

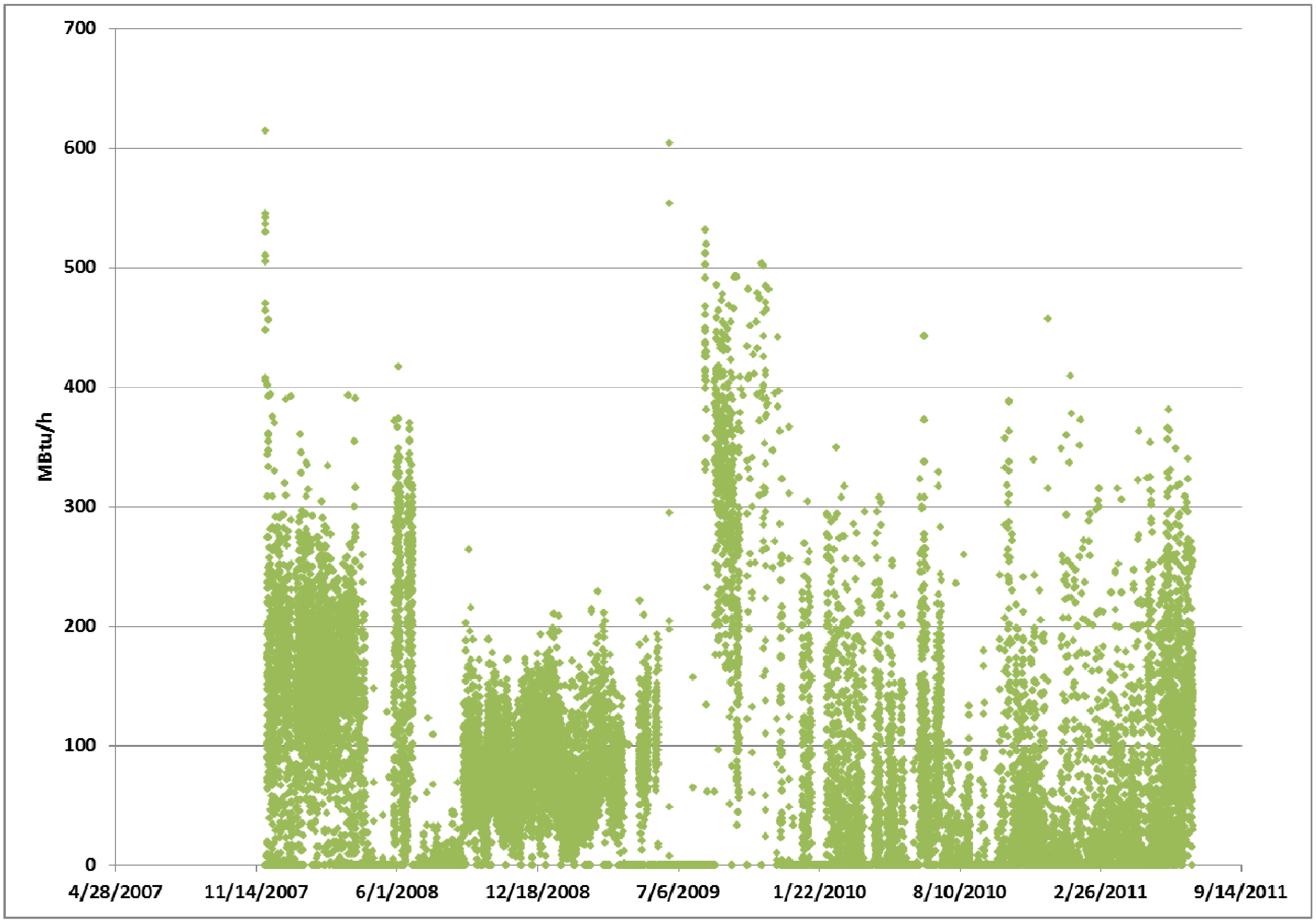

FIGURE 8 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Useful thermal energy in the supermarket ranges between 0 and 500 MBtu/h. A 140 kW generator should be capable of producing over 500 MBtu/h in useful thermal energy. Figure 8 shows that most of the useful thermal heat recovered is considerably below the system's capacity.

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

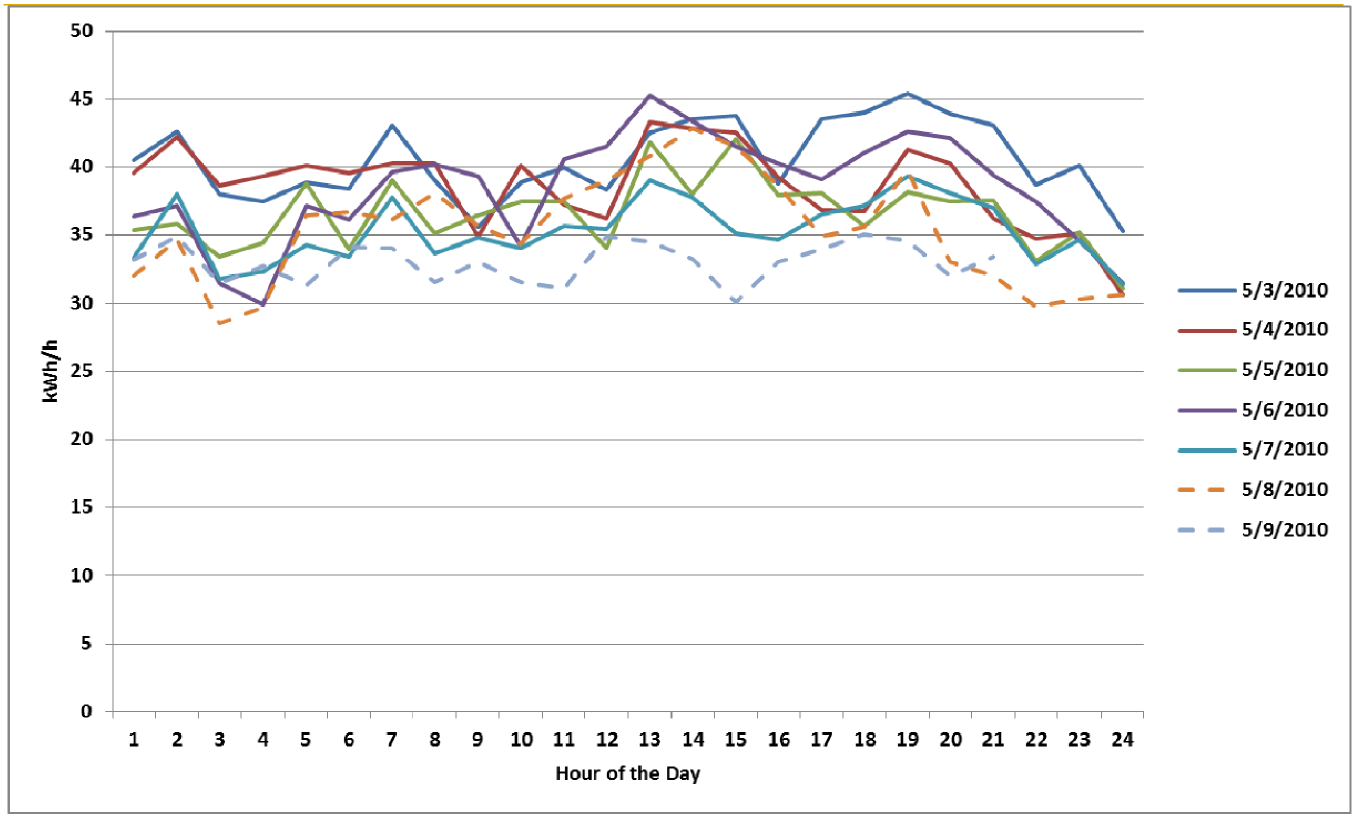

FIGURE 9 CHP POWER OUTPUT VERSUS TIME

Figure 9 covers the time period from May 3 – 9, 2010 providing CHP system power output by hour of the day pattern for the time period. May 8 is a Saturday. Figure 9 shows that all days exhibit a similar usage pattern. Note that the capacity of the generator is 140 kW and it is only producing between 30 and 45 kWh/h this week.

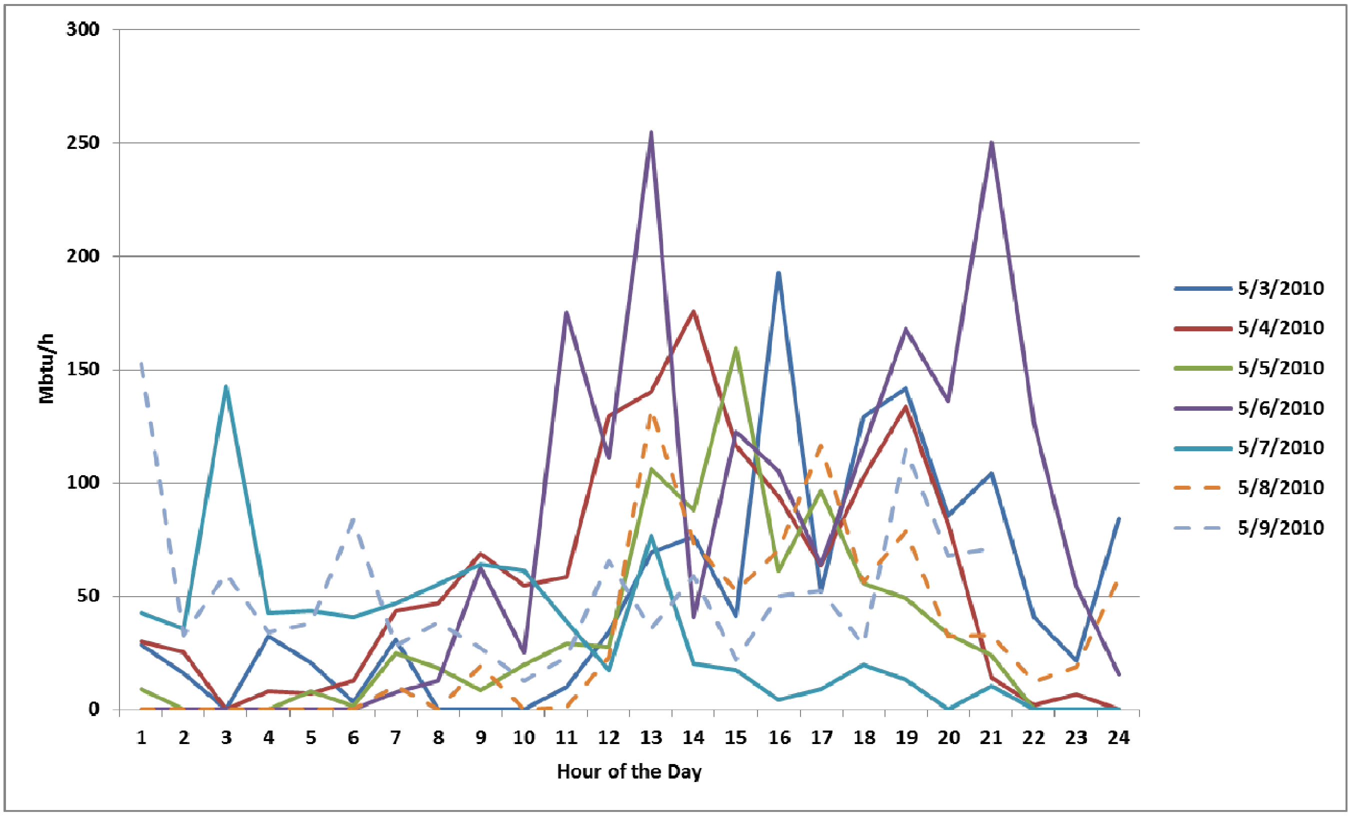

FIGURE 10 CHP USEFUL THERMAL OUTPUT VERSUS TIME

The useful CHP recovered heat thermal load profiles from May 3-9, 2010 (Figure 10) show consistently low thermal usage 24 x 7. May 8 is a Saturday. Note that the generator performance in Figure 9 should be capable of between 100 and 150 MBtu/h.

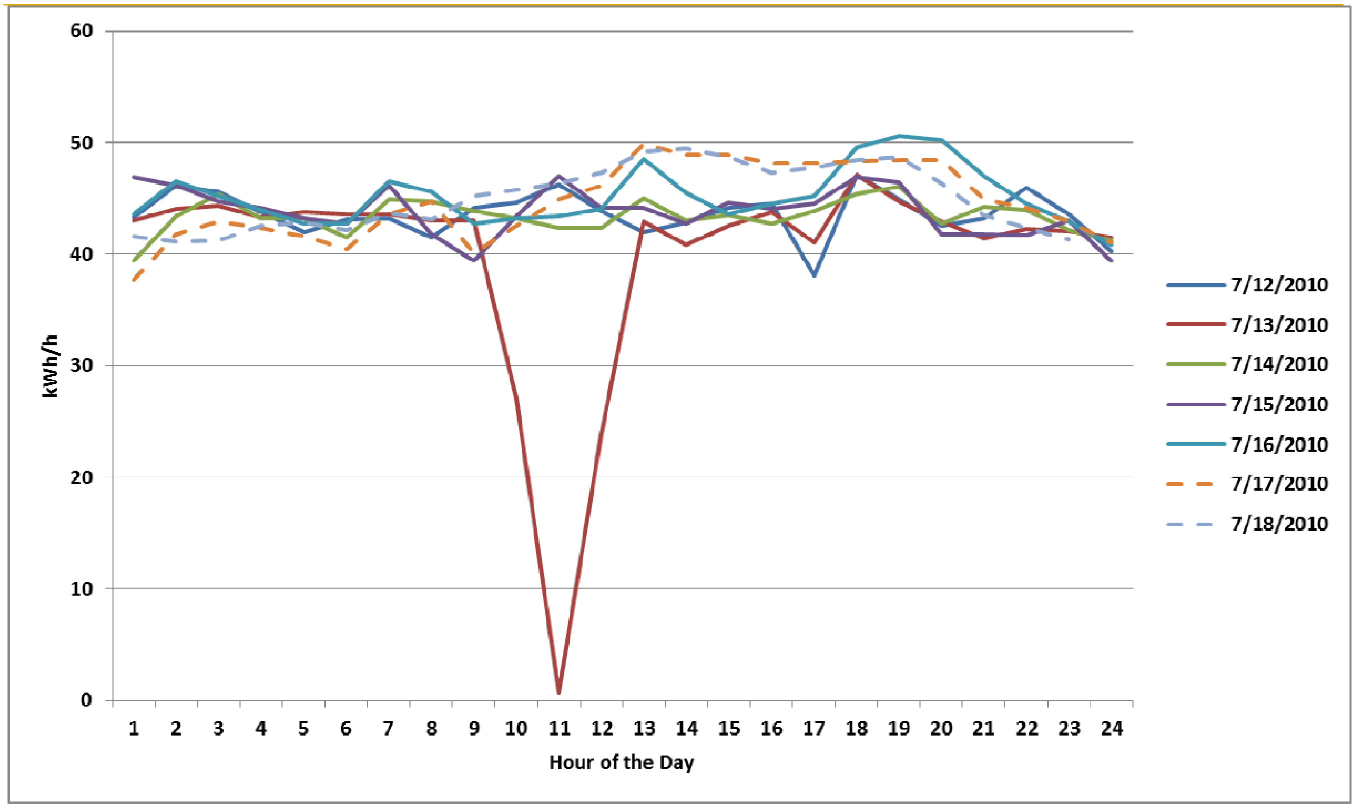

FIGURE 11 CHP POWER OUTPUT VERSUS TIME

Figure 11 covers the time period from July 12-18, 2010 providing CHP system power output by hour of the day pattern for the time period. July 17 is a Saturday.

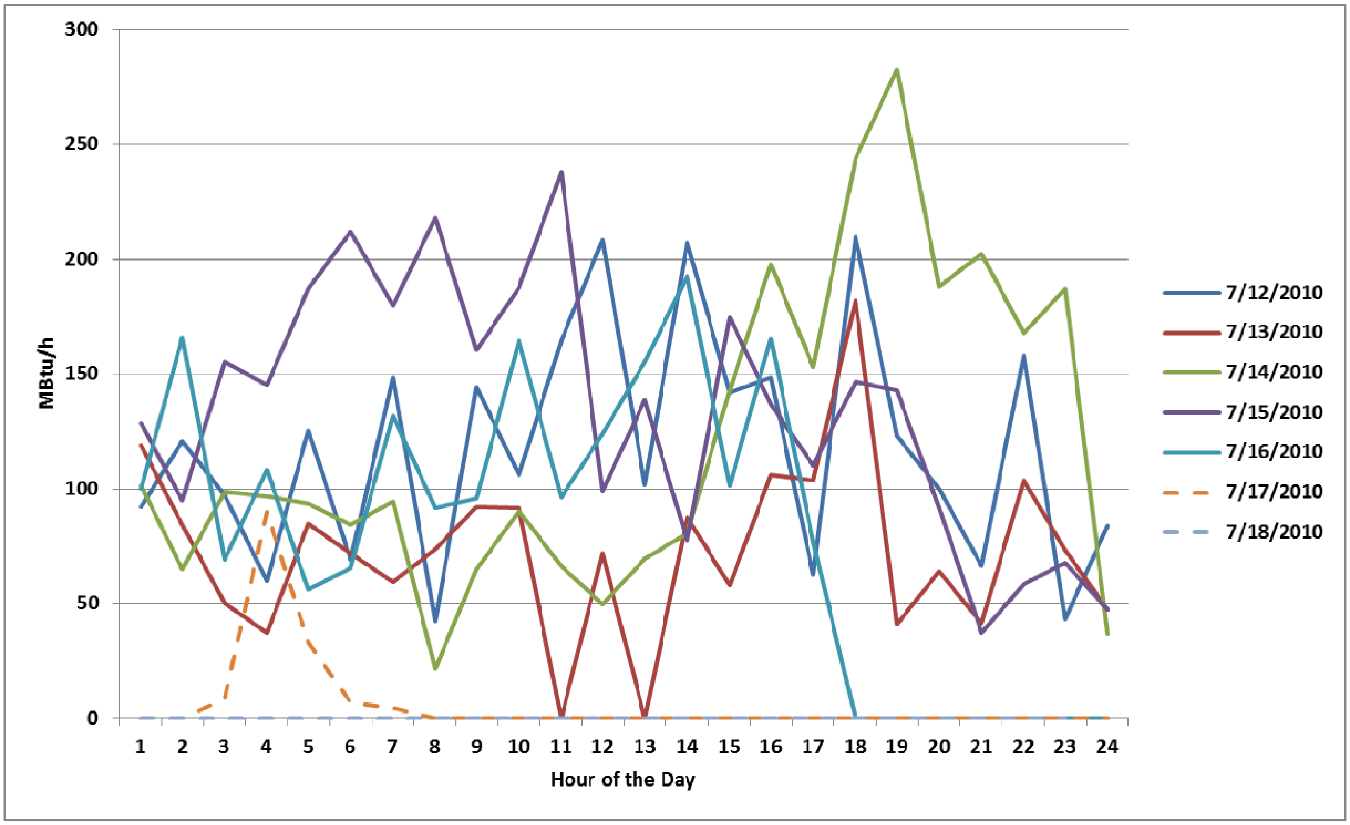

FIGURE 12 SELECTED DAY CHP USEFUL THERMAL OUTPUT VERSUS

Figure 12 covers the 24 hour useful CHP recovered heat thermal load profiles from July 12-18, 2010. Figure 12 shows low useful thermal usage for most weekdays. Saturday and Sunday drop to zero. July 17 is a Saturday.

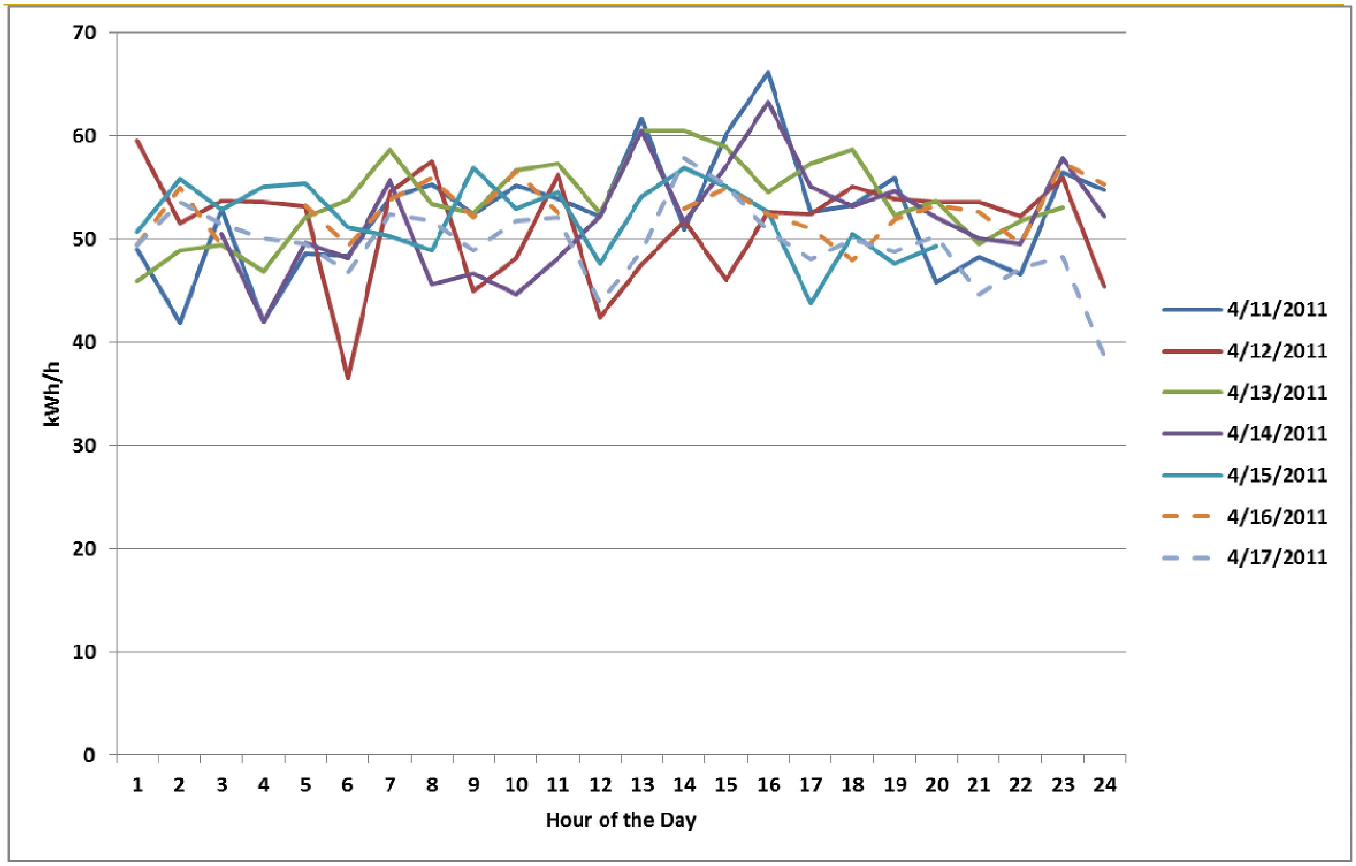

FIGURE 13 CHP POWER OUTPUT VERSUS TIME

Figure 13 covers the time period from April 11 - 17, 2011 providing CHP system power output by hour of the day pattern for the time period. April 16 is a Saturday.

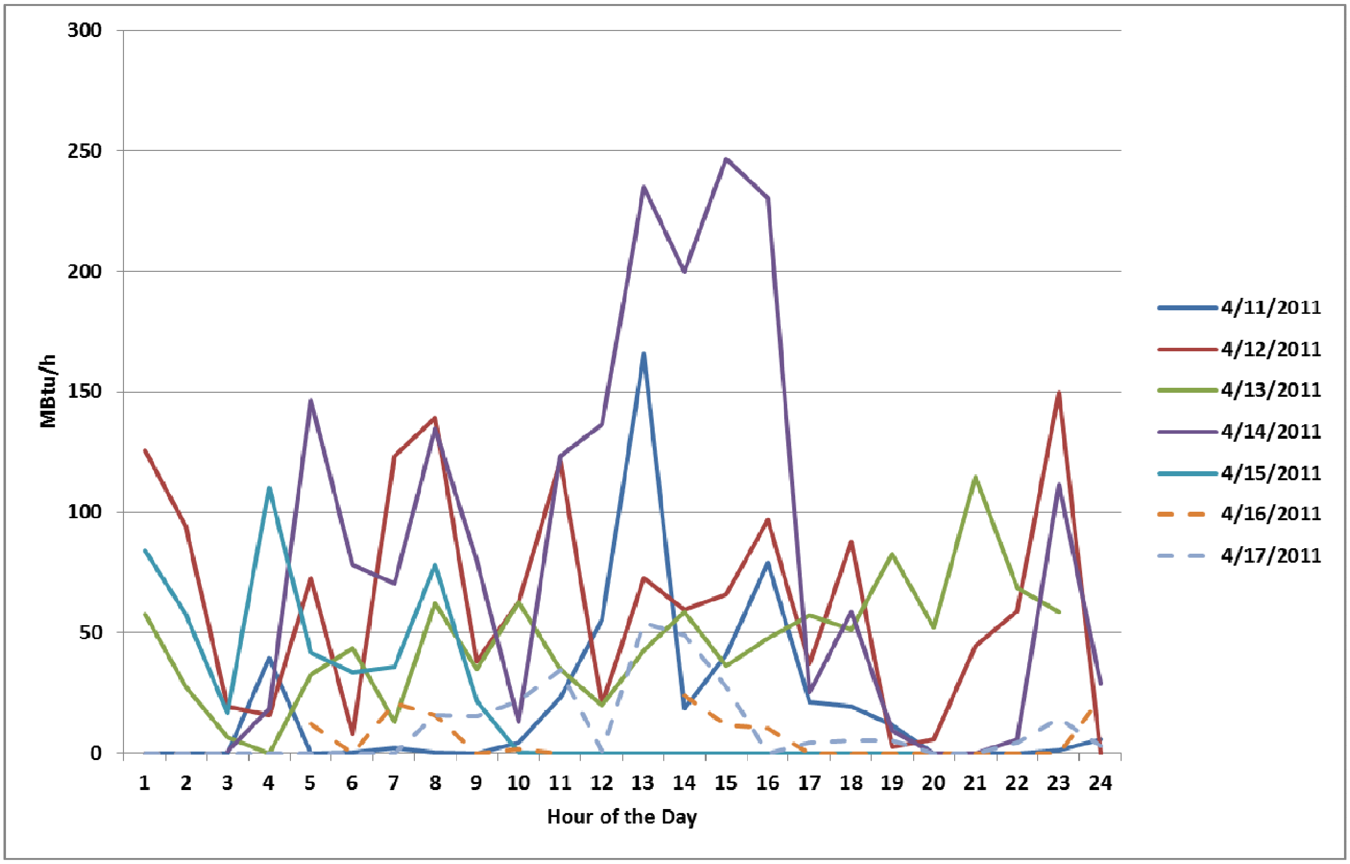

FIGURE 14 CHP POWER OUTPUT VERSUS TIME

The 24 hour useful CHP recovered heat thermal load profiles from April 11 – 17, 2011 (Figure 14) generally show consistently low thermal loading 24 x 7. April 16 is Saturday.

PERFORMANCE SUMMARY

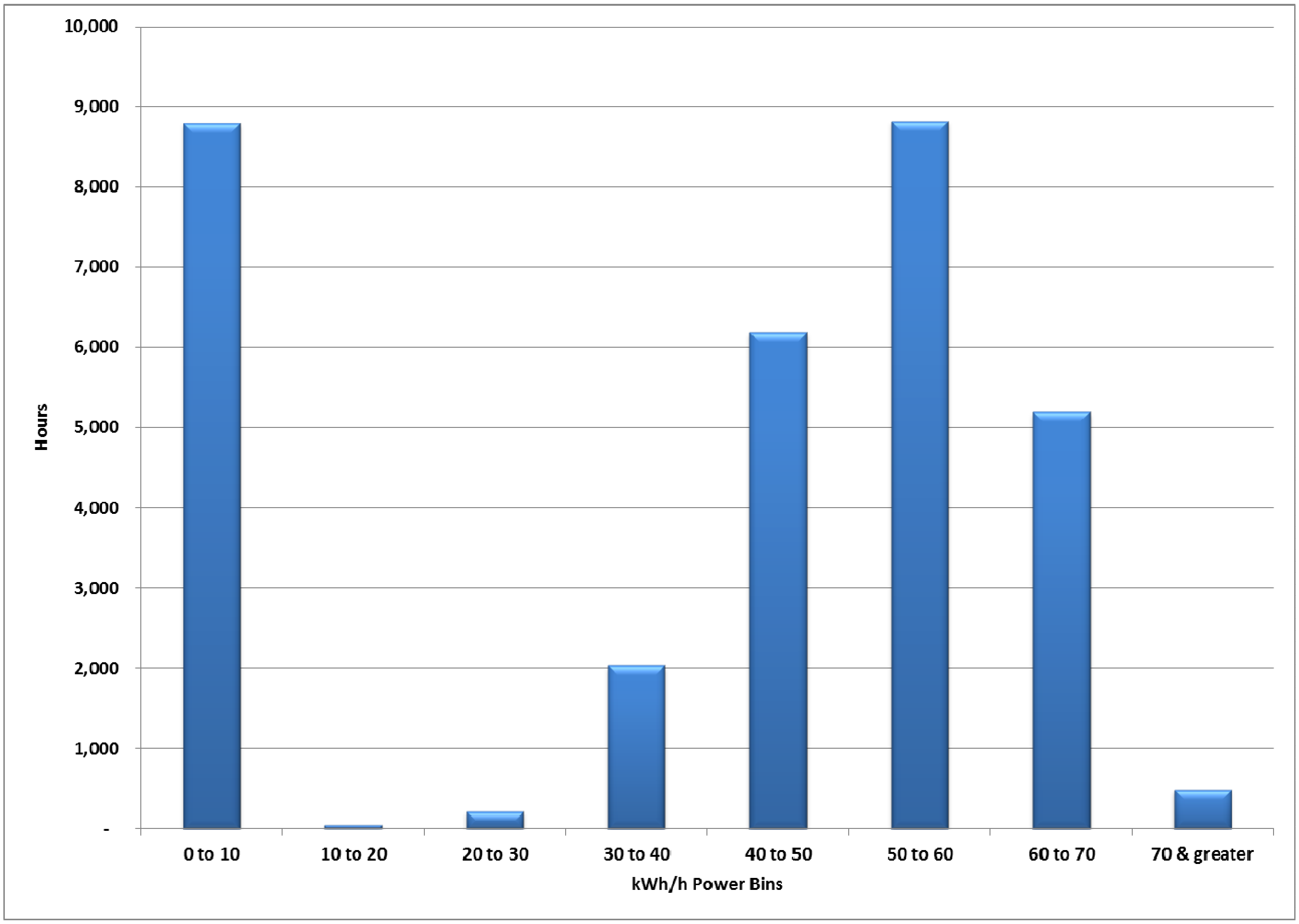

FIGURE 15 PERF0RMANCE BY POWER BINS

During the 31,784 hours that met the range and relational checks 65.1% of the time, the CHP system was producing 40 kWh/h or greater.

LESSONS LEARNED

TABLE 2 SYSTEM EFFICIENCY[2]

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

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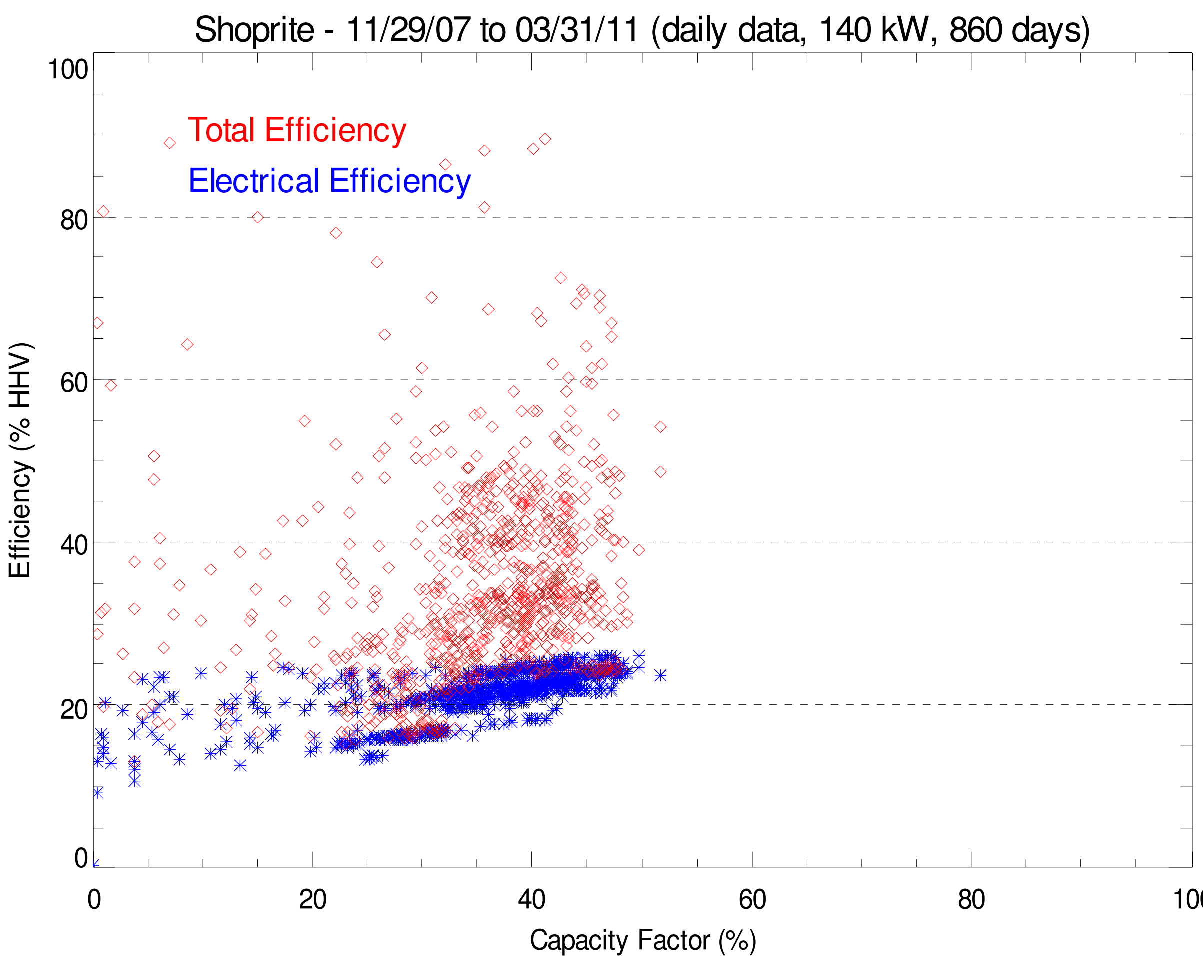

FIGURE 16 CAPACITY FACTOR[3]

[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.

Capacity Factor (FIGURE 166) presents the CHP generated power efficiency over the time period (860 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 1% and 48% of the generating capacity at about 20.7% power efficiency (HHV) during the last 12 months of Table 2. The electric capacity is load limited by some means which cannot be determined from the data available (no total site electric energy data). The useful thermal energy (liquid refrigerant subcooling through an absorption chiller and desiccant dehumidification) operating efficiency during the most recent 12 month period in Table 2 averaged 6.1% thermal efficiency (HHV). The time phased useful heat recovery indicated more capacity in the winter than in the summer which reinforces the conclusion below that the heat recovery system is problematic at this site.

This complicated system provided heat to the several potential thermal loads, including a desiccant unit and an absorption chiller for year-round subcooling. While some "useful" heat was recorded, it seems likely that the chiller never operated properly more than a few hours. Therefore, none of the heat ever was usefully applied to meet any loads. It is difficult to commission and operate chillers to meet this type of subcooling load.

At complicated sites, recording the total useful heat recovery as provided by the NYSERDA website is not that useful in describing how the system operates. More detailed data is required to accurately describe and assess system 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 comes from a 15-minute accumulator for the power produced by the engine. The column of origin for this data point is labeled “Generator Total Energy Product” in the data files received from Connected Energy. The difference between consecutive records is assigned as the energy produced by the engine for that interval. This 15-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 15-minute accumulator for gas flow. The column of origin for this data point is labeled “Natural Gas to Engine Cumul” in the data files received from Connected Energy. The difference between consecutive records is assigned as the gas consumed by the engine for that interval. This 15-minute gas data is then summed into hourly data.
3. **Useful Heat Recovery (total MBtu)** The Unused Heat Recovery comes from a 15-minute average for the utilized heat recovery rate. The column of origin for this data point is labeled “Total Heat Used Rate” in the data files received from Connected Energy. The rate data is converted to energy, in MBtus, for the interval and then summed into hourly data.

The average electrical efficiency for the last 12 months of operation was 20.7% which is largely due the low load factor on the engine averaging under 40 kWh/h for the year. The Useful Thermal Efficiency for this 12 month period was only 6.1%. Supermarkets are difficult thermal hosts. This particular site chose to add absorption cooling to the store which often does not require cooling dust to refrigerated case cooling of the store which was a limiting issue.

Having a realistic understanding of the thermal load that can be served by the CHP system is essential to realize performance prediction. In this case, not matching thermal load with capacity caused two performance issues. The first issue was the engine was not fully loaded and the second was the thermal energy available was much more than the store could use.

Data Collection and quality for this site for much of the period is in the high 99/100% range for the three critical parameters (power, fuel and useful thermal energy); however, for a few months thermal data quality was lower, including October 2009 where it reached 9.4%. (Table 3).

TABLE 3 PERCENTAGE OF GOOD DATA

	Percentage of Good Data		
	Power	**Gas Use**	**Useful Heat**
December-07	100.0%	99.9%	99.9%
January-08	100.0%	100.0%	100.0%
February-08	100.0%	100.0%	100.0%
March-08	99.9%	99.9%	100.0%
April-08	100.0%	100.0%	100.0%
May-08	99.9%	99.5%	100.0%
June-08	99.2%	100.0%	100.0%
July-08	100.0%	100.0%	100.0%
August-08	100.0%	99.9%	100.0%
September-08	100.0%	100.0%	100.0%
October-08	100.0%	99.9%	100.0%
November-08	100.0%	99.9%	100.0%
December-08	100.0%	100.0%	100.0%

January-09	99.9%	99.9%	100.0%
February-09	100.0%	100.0%	100.0%
March-09	99.9%	99.6%	100.0%
April-09	100.0%	99.4%	100.0%
May-09	100.0%	100.0%	100.0%
June-09	100.0%	100.0%	99.6%
July-09	100.0%	100.0%	100.0%
August-09	100.0%	100.0%	88.6%
September-09	99.4%	99.4%	67.4%
October-09	99.9%	99.9%	9.4%
November-09	100.0%	100.0%	14.4%
December-09	100.0%	100.0%	96.2%
January-10	99.9%	99.9%	93.1%
February-10	100.0%	97.5%	80.5%
March-10	99.6%	97.0%	90.9%
April-10	99.8%	99.8%	98.1%
May-10	100.0%	100.0%	98.5%
June-10	99.9%	99.9%	98.5%
July-10	99.9%	99.9%	100.0%
August-10	99.9%	99.9%	99.6%
September-10	99.9%	99.9%	99.9%
October-10	99.7%	99.7%	99.1%
November-10	99.7%	99.6%	97.1%
December-10	99.7%	99.6%	95.8%
January-11	99.9%	99.6%	73.9%
February-11	99.9%	99.9%	81.1%
March-11	99.7%	99.7%	84.7%
April-11	99.9%	99.9%	92.5%
May-11	99.9%	99.9%	88.3%
June-11	99.9%	99.9%	90.6%
July-11	99.7%	99.9%	82.4%