NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT THE PRICE CHOPPER

October 9, 2013

Price Chopper Colonie

NYSERDA New York State Energy Research and Development Authority

DISCLAIMER OF WARRANTY

DISCLAIMER OF LIABILITY

DISCLAIMER OF ENDORSEMENT

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.

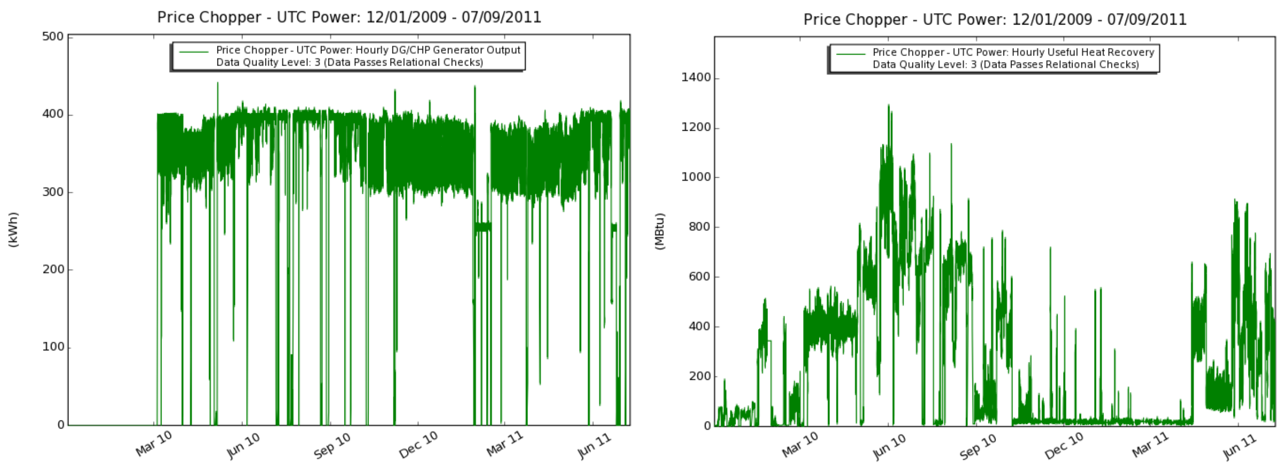

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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 PRICE CHOPPER STORE FRONT COLONIE, NEW YORK

Price Chopper's new 69,000-square-foot concept store and pharmacy in Colonie, New York, meets approximately 60 percent of its energy needs with a next-generation PureCell Model 400 fuel cell system from UTC Power.

THE SYSTEM

The PureCell 400 fuel cell is installed behind the supermarket. The fuel cell (FC) has separate electrical feeds for parallel operation with the utility or to provide backup power when isolated from the grid. The fuel cell is able to provide 400 kW of electrical power and up to 1.7 million Btu/h of heat. If fully utilized, the fuel cell can obtain a thermal efficiency near 90%.

The UTC Power fuel cell converts heat exhaust into heating and cooling, turning potential waste into usable energy. Heat is provided via separate low grade (140°F max) and high grade (200°F max) hot water loops. This converted exhaust heat provides the Price Chopper in Colonie, New York with heat and hot water year-round, dehumidifies the air supplied to the refrigerated case isles to save energy and improve comfort and sub-cools liquid refrigerant to the store's refrigerated cases.

FIGURE 3 FUEL CELL INSTALLED REAR OF THE STORE

Most of the thermal output from the FC is used to provide space conditioning and water heating for the store. The low temperature loop supplies 140°F water to meet space heating loads including hot water coils and radiant floor heating circuits.

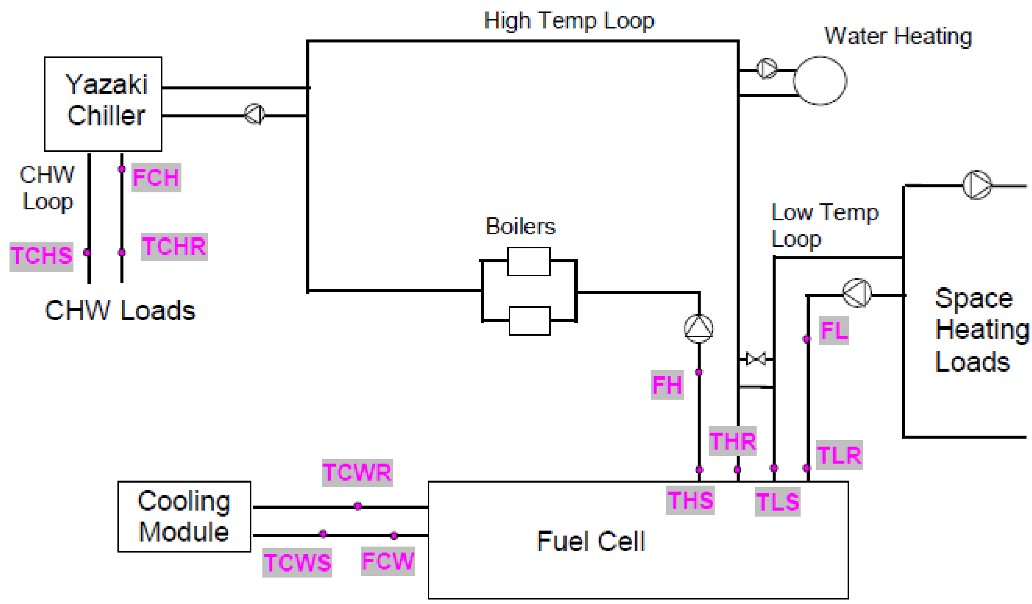

FIGURE 4 SCHEMATIC OF HEAT TRANSFER LOOPS IN FUEL CELL SYSTEM

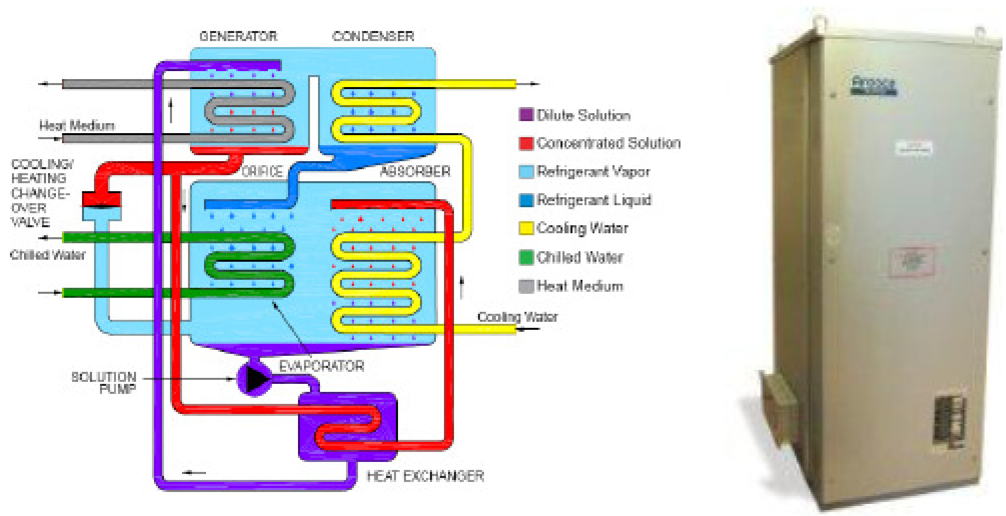

FIGURE 5 YAZAKI HOT-WATER-DRIVEN SINGLE EFFECT ABSORPTION CHILLER (FROM WWW.YAZAKIENERGY.COM)

The high temperature loop supplies 220°F water to 1) the Yazaki chiller or 2) the DHW tank loads. Water from the high temperature loop can also be injected into the low temperature loop if extra heat is required for space heating (see Figure 4 and Figure 5).

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 March 4, 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
March-10	735	242,309	2,321.1	259.7	34.9%	11.0%	45.9%
April-10	719	252,287	2,555.5	295.2	33.0%	11.3%	44.4%
May-10	740	252,492	2,559.1	565.8	33.0%	21.7%	54.7%
June-10	720	271,399	2,750.4	660.4	33.0%	23.5%	56.6%
July-10	722	215,582	2,266.4	502.6	31.8%	21.7%	53.6%
August-10	743	257,224	2,654.8	550.0	32.4%	20.3%	52.7%
September-10	720	273,527	2,688.8	521.5	34.0%	19.0%	53.1%
October-10	744	250,223	2,332.1	249.2	35.9%	10.5%	46.4%
November-10	720	245,685	2,253.5	298.6	36.5%	13.0%	49.5%
December-10	744	260,471	2,396.5	344.7	36.4%	14.1%	50.5%
January-11	739	238,975	2,304.9	392.3	34.7%	16.7%	51.4%
February-11	672	197,666	1,801.8	184.7	36.7%	10.0%	46.8%
March-11	744	239,389	2,219.5	132.5	36.1%	5.9%	41.9%
April-11	706	242,343	2,241.9	172.8	36.2%	7.6%	43.7%
May-11	732	258,191	2,467.1	255.4	35.0%	10.1%	45.2%
June-11	720	218,512	2,172.2	448.9	33.7%	20.3%	53.9%
July-11	743	277,209	2,745.2	390.3	33.8%	13.9%	47.7%
Total preceding 12 months	**8718**	**2,957,840**	**28,885**	**4,825**	**34.3%**	**16.4%**	**50.6%**

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

Table 1 presents annual data showing the engine-based CHP systems electric efficiency at 34.3% (HHV) range which is expected for this size fuel cell. Useful thermal performance is very low at 16.4% for the period (HHV based on fuel input). The low thermal efficiency is indicative of four factors:

1. Supermarkets are a difficult application for consistent hot water thermal loading year-round
2. the system is set to generate full power regardless of thermal load
3. the low temperature nature of the thermal energy available from the fuel cell ~ 50% at 220°F and 50% at 140°F (the latter energy source is particularly difficult to convert into useful energy in this application), and
4. the low grade flow meter operates intermittently during the winter of 2010-2011. The meter is replaced on April 14, 2011. There were also problems with the intermittent lockouts with the low grade pump during that period.

Nevertheless, the peak useful thermal energy was only 23.5% in June of 2010.

[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.

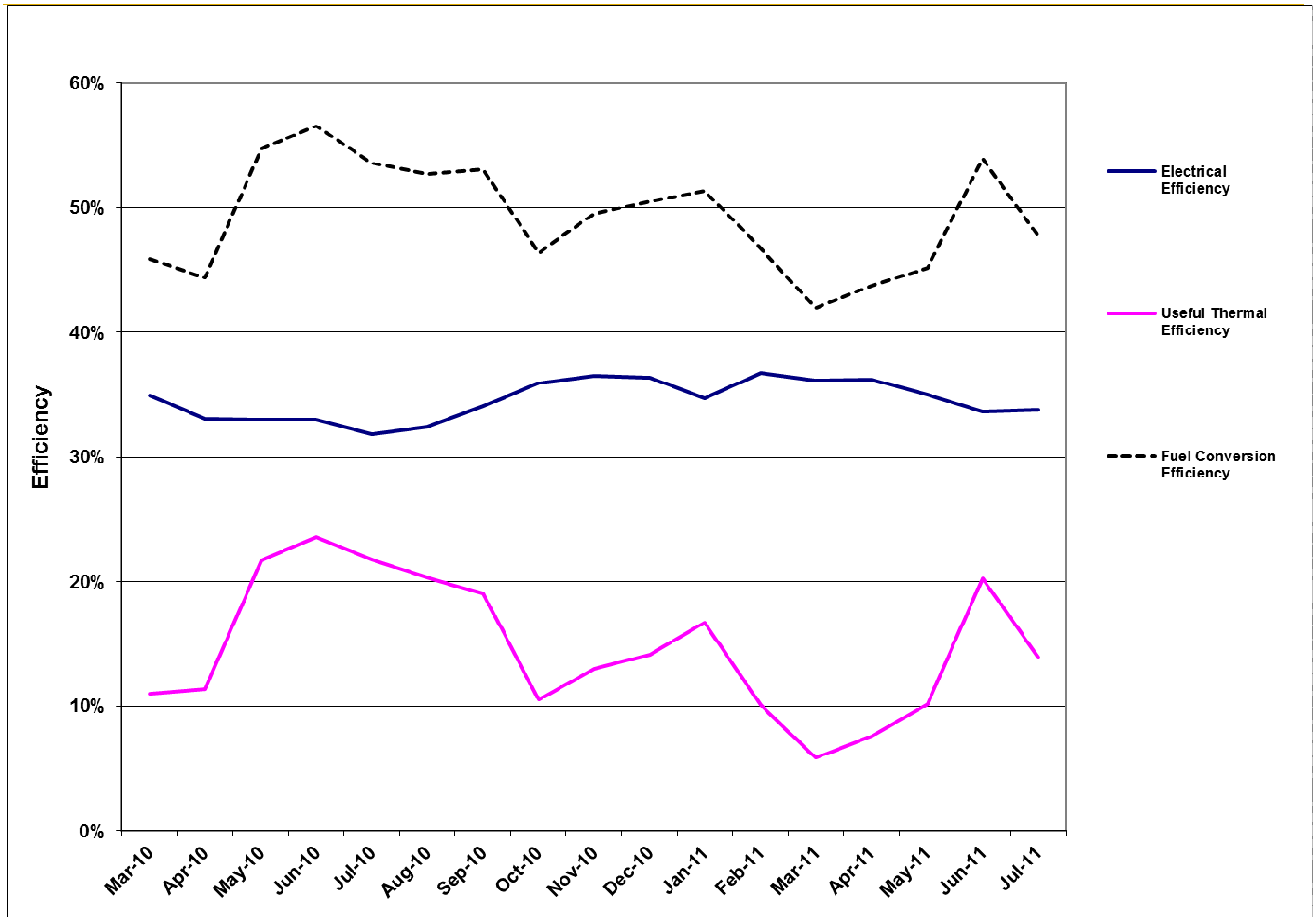

FIGURE 6 ELECTRIC, THERMAL AND FUEL CONVERSION EFFICIENCY BY MONTH MARCH- DECEMBER 2010

Figure 6 provides operating efficiency during the March – December 2010 time period showing higher energy efficiency as the ambient temperature decreases. The low thermal energy efficiency (useful heat recovery) is very low for the following reasons:

There are three systemic issues during the measured period.

1. The low grade flow meter had intermittent problems and the low grade loop pump occasionally locked out.
2. The absorption chiller has never worked consistently due to problems with cooling tower fan control (the two speed tower trips when it goes to high speed).
3. The operating sequence delivering heating/domestic hot water gave boiler operation priority over waste heat recovery.

These issues need to be corrected to properly assess the useful heat recovery potential on this site.

OPERATING SUMMARY

The CHP system consists of one fuel cell generator with a nominal capacity of 400 kW.

During the 6,611 operating hours between March 4, 2010 and December 25, 2010 that met the range and relational checks 63.8% of this time, the CHP system delivered between 550 and 400 kWh/hr (Table 3). The average electric performance for all 6,611 hours of operation was 372 kW/hr or about 93% of the installed nameplate (net) capacity.

POWER GENERATION AND USEFUL THERMAL ENERGY

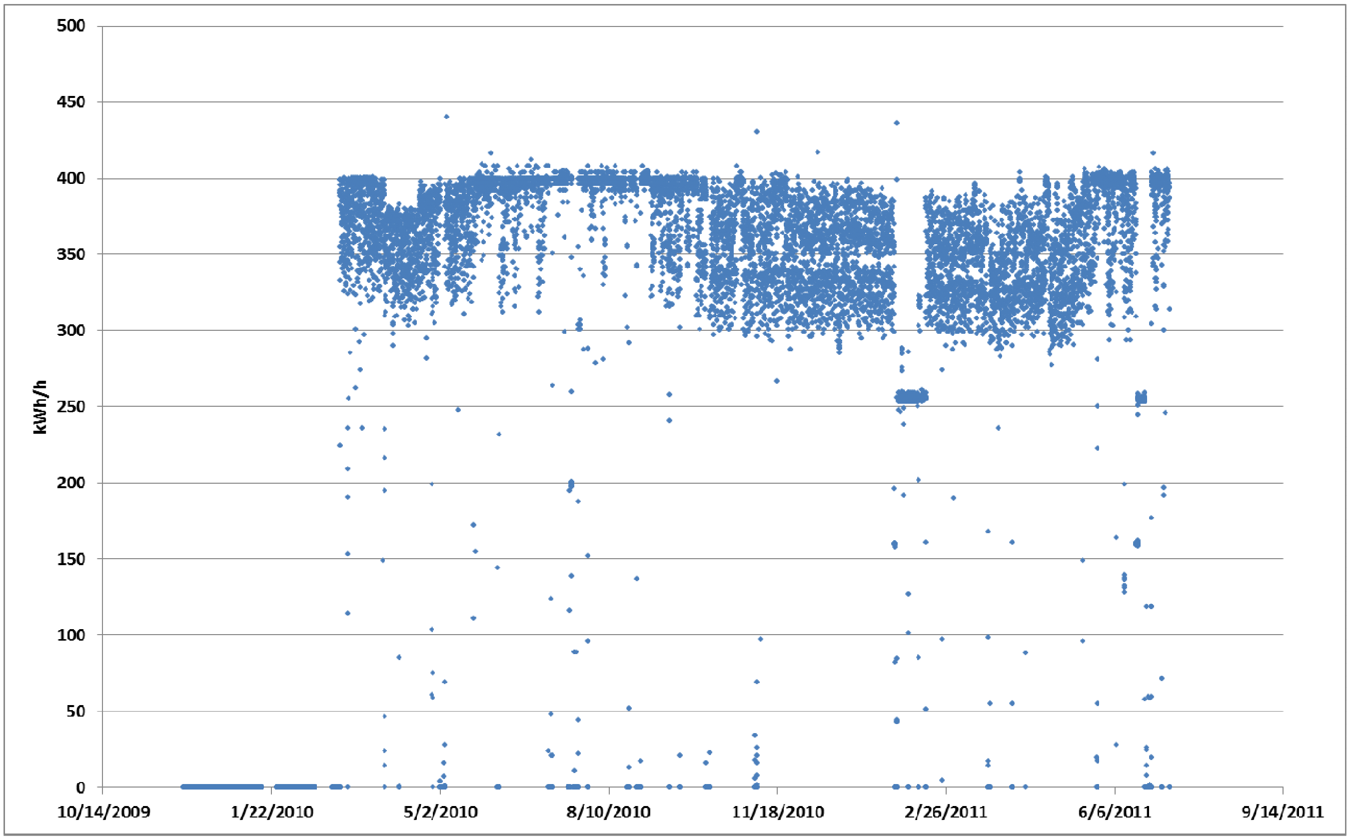

FIGURE 7 CHP POWER OUTPUT VERSUS TIME

Figure 7 indicates an electric load following pattern in the winter, spring and fall because most days show a range on power from 300 kWh/h to 400 kWh/h each day. In the summer the power band narrows indicating a requirement to reduce power demand.

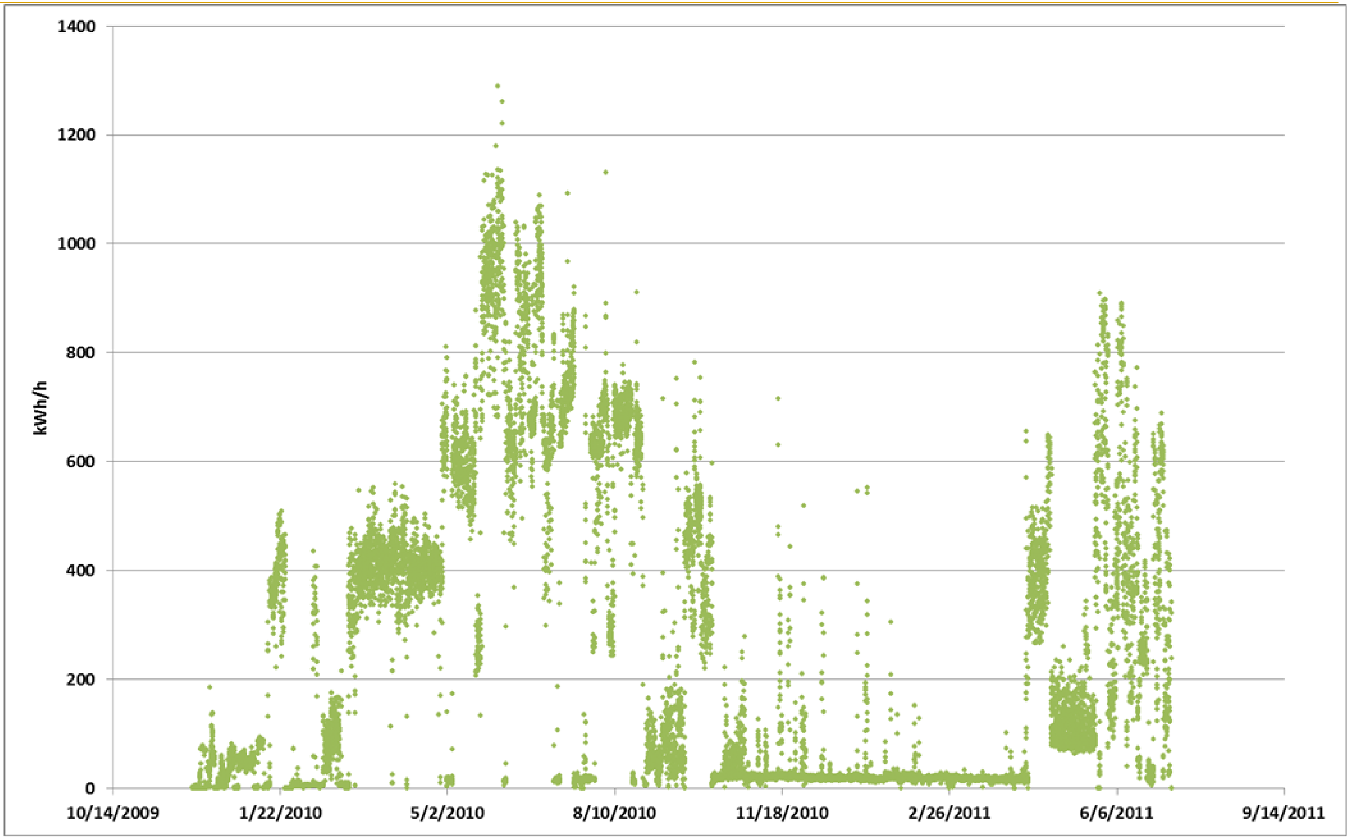

FIGURE 8 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 8 data can be viewed in three periods of performance and represents three systemic issues during the measured period.

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2. The absorption chiller has never worked consistently due to problems with cooling tower fan control (the two speed tower trips when it goes to high speed).
3. The operating sequence delivering heating/domestic hot water gave boiler operation priority over waste heat recovery.

These issues need to be corrected to properly assess the useful heat recovery potential on this site. Note that on the following weekly graphs, weekend days are highlighted as dashed lines to quickly distinguish their operating characteristics.

The fuel cell is in the electric load following mode in the winter months. There are three systemic issues during the measured period.

1. The low grade flow meter had intermittent problems and the low grade loop pump occasionally locked out.
2. The absorption chiller has never worked consistently due to problems with cooling tower fan control (the two speed tower trips when it goes to high speed).
3. The operating sequence delivering heating/domestic hot water gave boiler operation priority over waste heat recovery.

These issues need to be corrected to properly assess the useful heat recovery potential on this site.

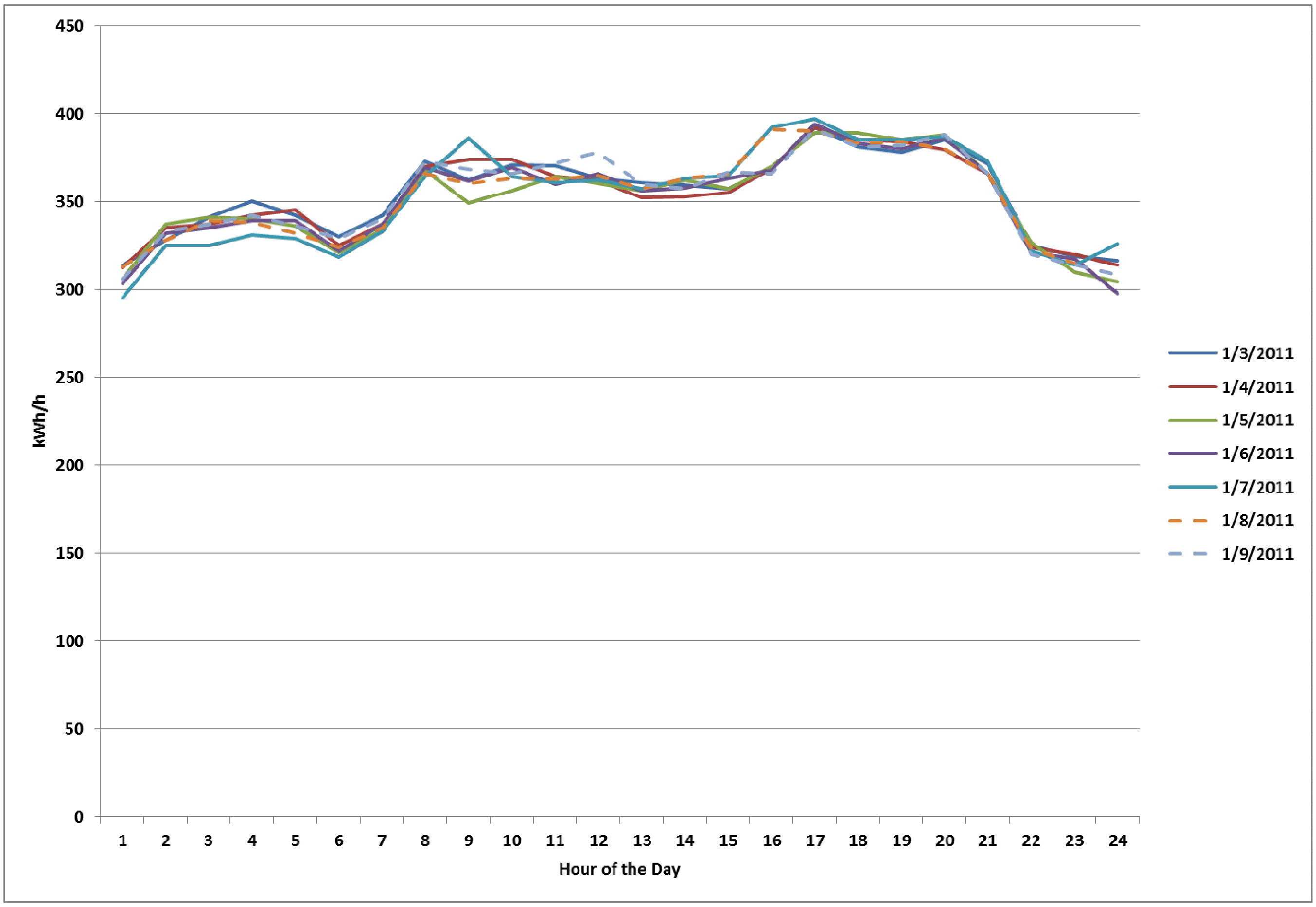

FIGURE 9 CHP POWER OUTPUT VERSUS TIME

Figure 9 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. The electric output from the fuel cell is consistent day-to-day and indicative of electric load following.

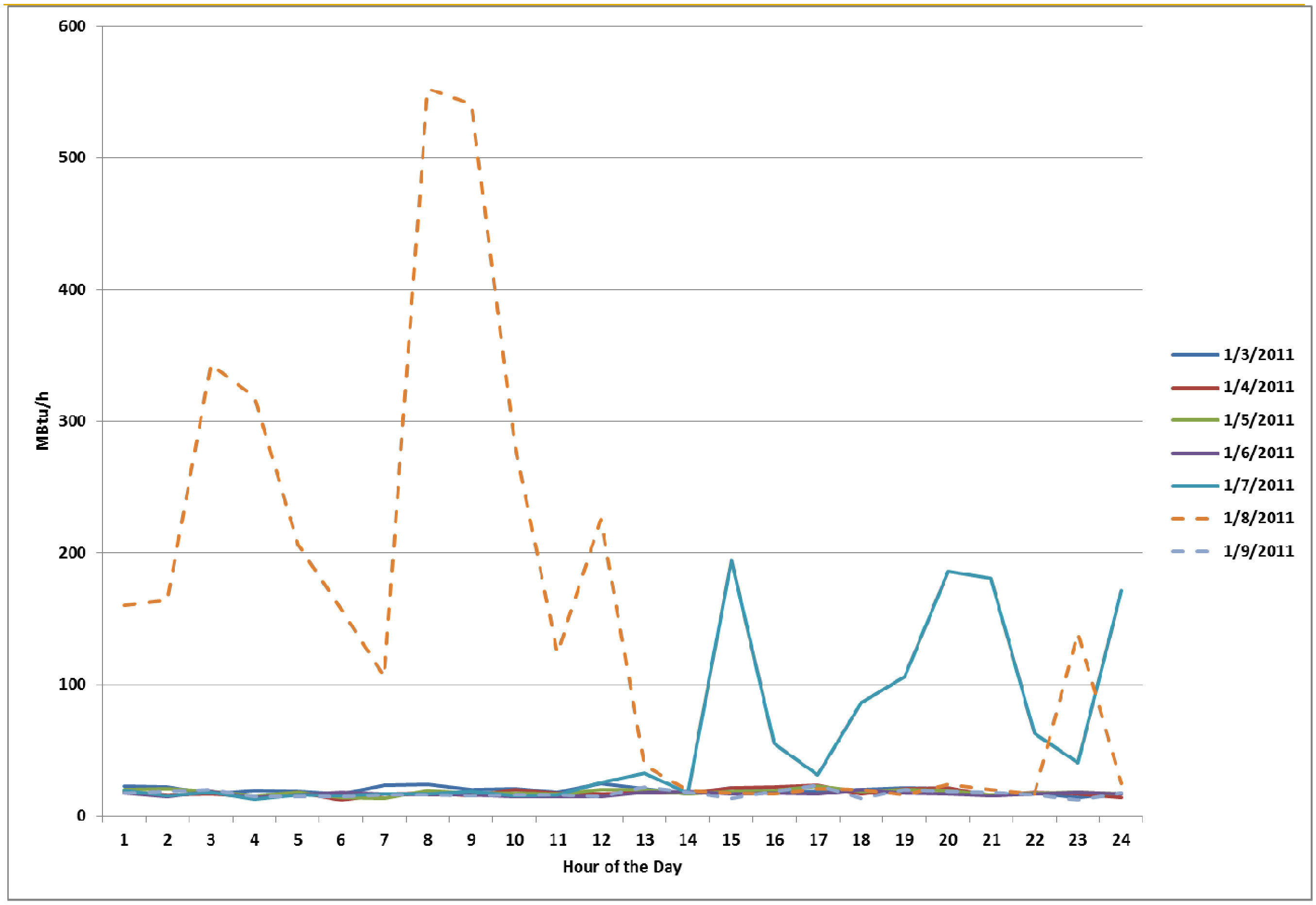

FIGURE 10 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 10 shows the 24 hour useful CHP recovered heat thermal load profiles from January 3 – 9, 2011. January 8 is a Saturday. This graph indicates virtually no heat recovery being measured.

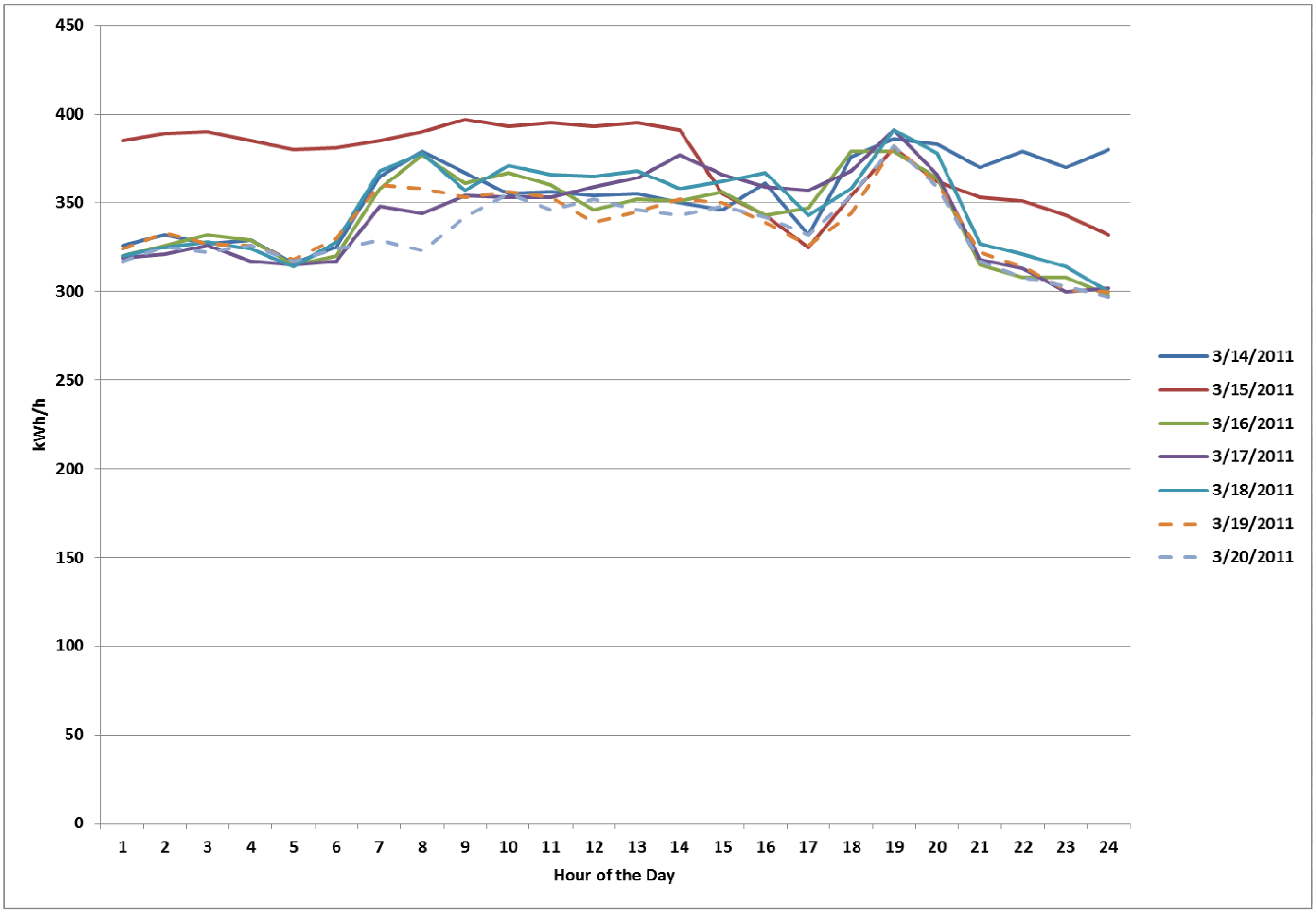

FIGURE 11 CHP POWER OUTPUT VERSUS TIME

Figure 11 covers the time period from March 14 – 20, 2011 providing CHP system power output by hour of the day pattern for the time period. March 19 is a Saturday. The electric output from the fuel cell is consistent day-to-day and indicative of electric load following.

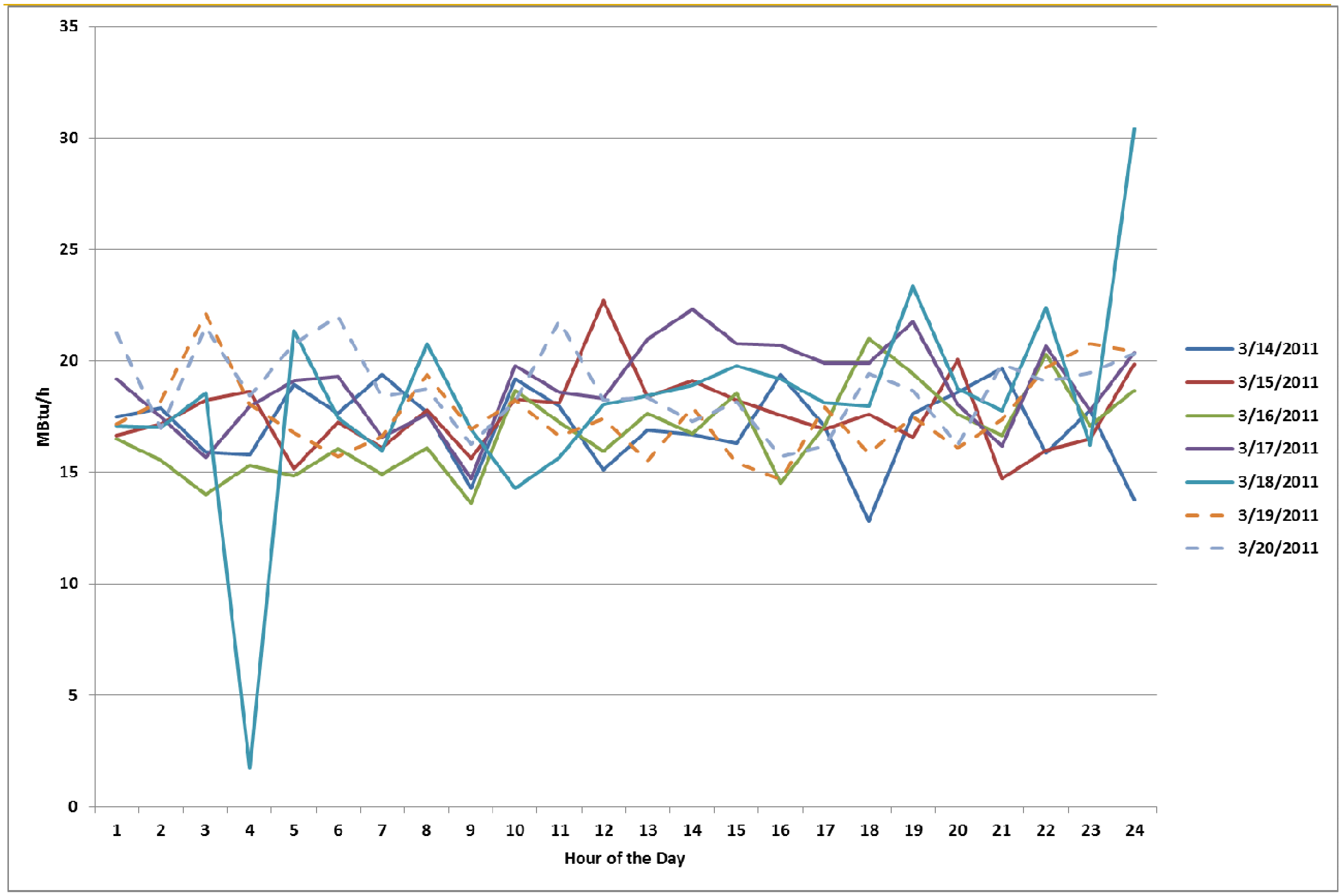

FIGURE 12 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 12 shows the 24 hour useful CHP recovered heat thermal load profiles from March 14 – 20, 2011. March 19 is a Saturday. This graph indicates virtually no heat recovery being measured.

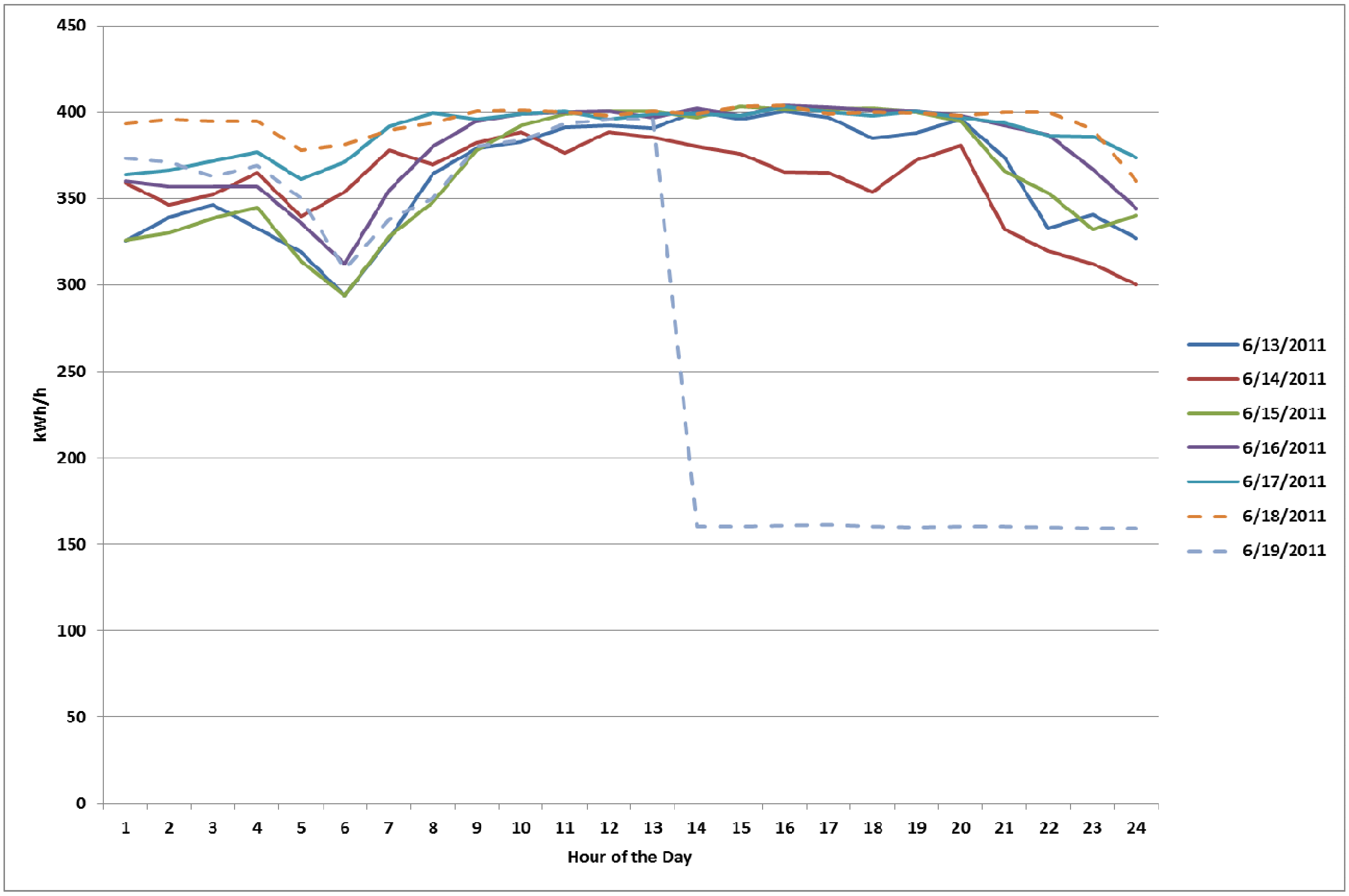

FIGURE 13 CHP POWER OUTPUT VERSUS TIME

Figure 13 covers the time period from June 13 – 19, 2011 providing CHP system power output by hour of the day pattern for the time period. June 18 is a Saturday. The electric output from the fuel cell is consistent day-to-day and indicative of electric load following. Note: Sunday power output fell leading to a shutdown June 24, repair and back on line June 28.

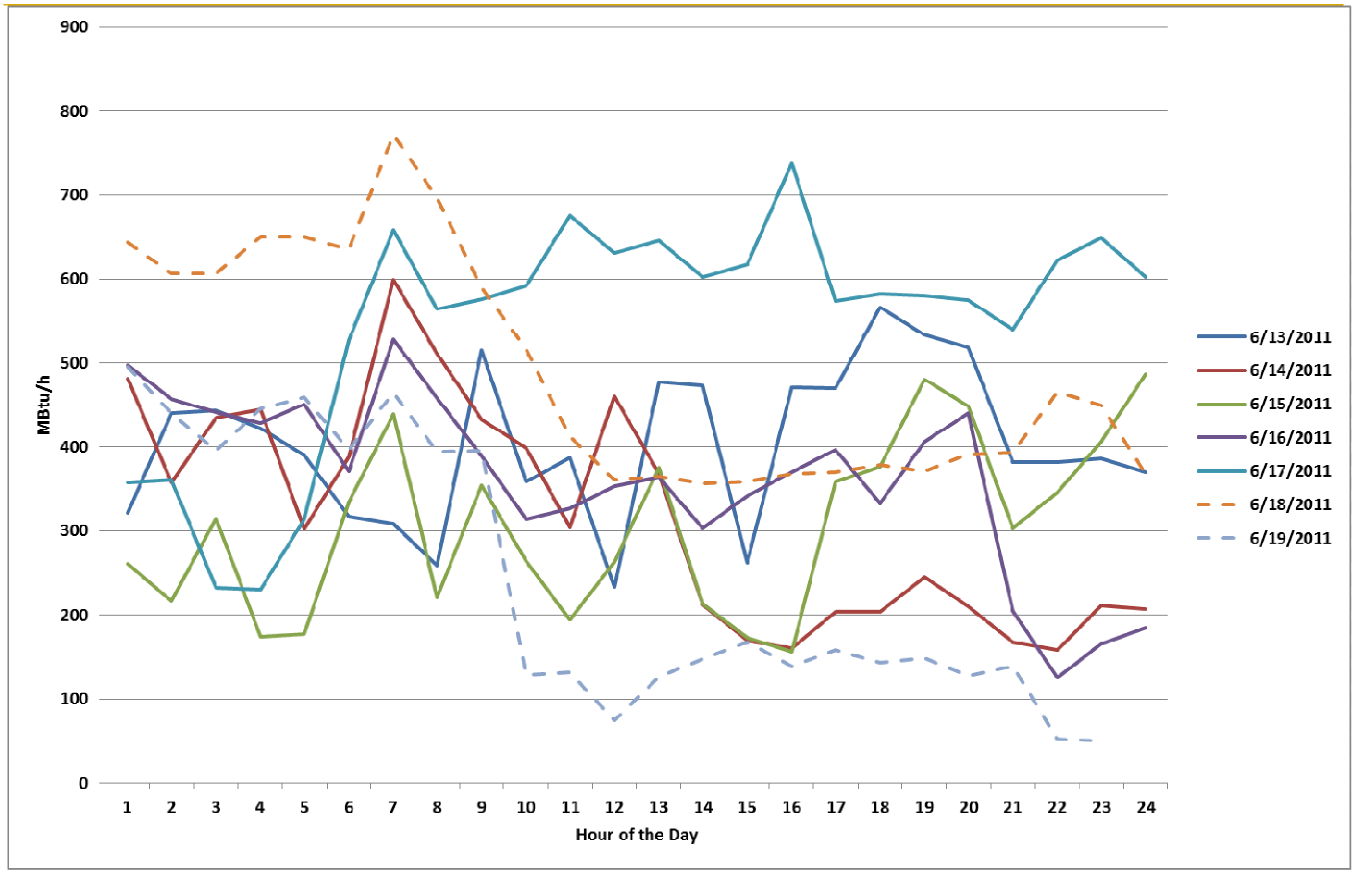

FIGURE 14 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 14 shows the 24 hour useful CHP recovered heat thermal load profiles from June 13 – 19, 2011. June 18 is a Saturday. This graph shows the beginning of thermal energy recovery, although this is considerably below the available thermal energy from the fuel cell.

PERFORMANCE SUMMARY

During the 12,363 hours that met the range and relational checks 88.1% of this time, the CHP system delivered above 300 kWh/h (**FIGURE 15**).

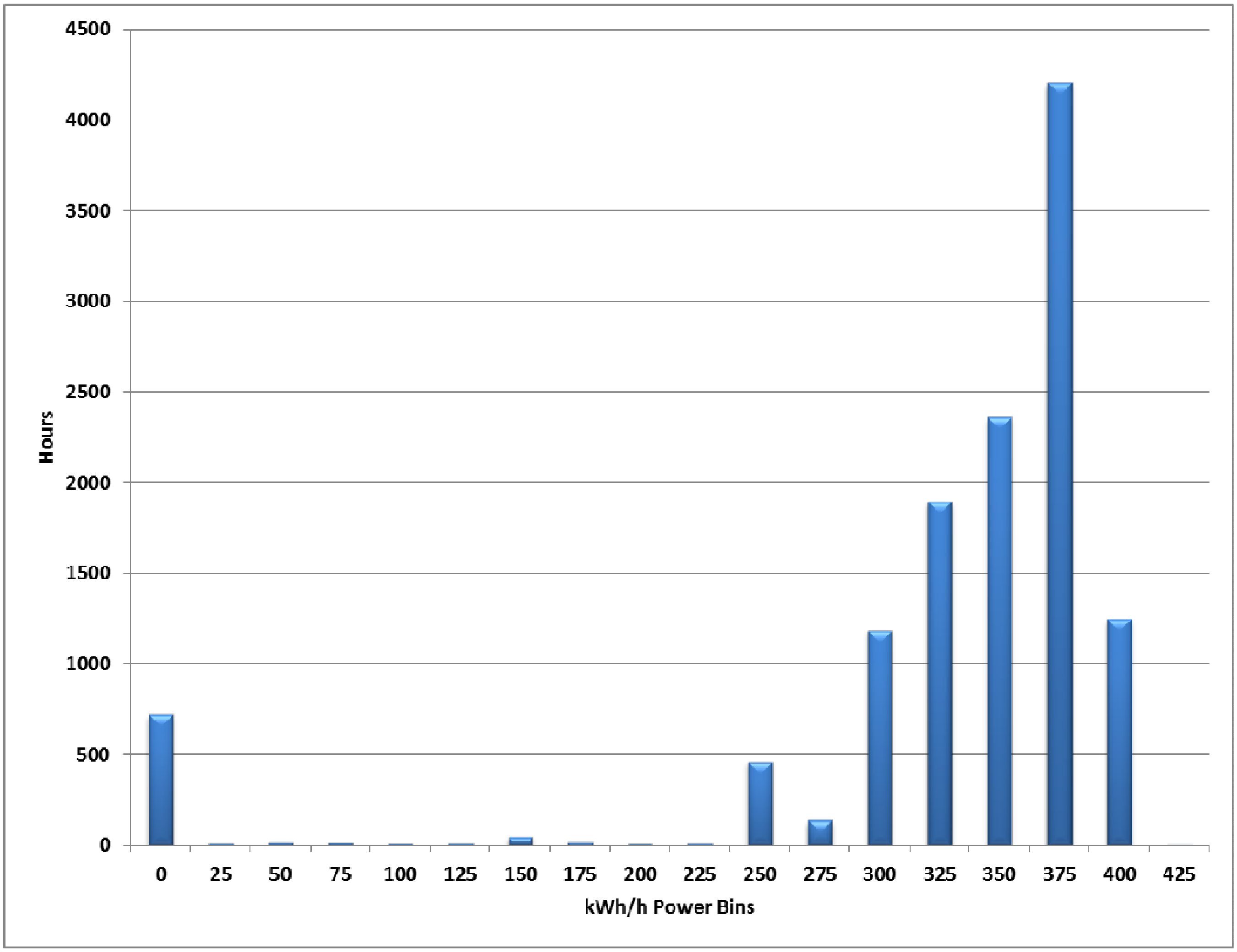

FIGURE 15 PERFORMANCE BY POWER BINS

LESSONS LEARNED

TABLE 2 SYSTEM EFFICIENCY[2]

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

The UTC PureCell 400 fuel cell is installed behind the supermarket. The fuel cell (FC) has separate electrical feeds for parallel operation with the utility or to provide backup power when isolated from the grid. The fuel cell is able to provide 400 kW of electrical power and up to 1.7 million Btu/h of heat. If fully utilized, the fuel cell can obtain a thermal efficiency near 90%. Most of the thermal output from the FC is used to provide space conditioning and water heating for the store. The low temperature loop supplies 140°F water to meet space heating loads including hot water coils and radiant floor heating circuits.

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[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.

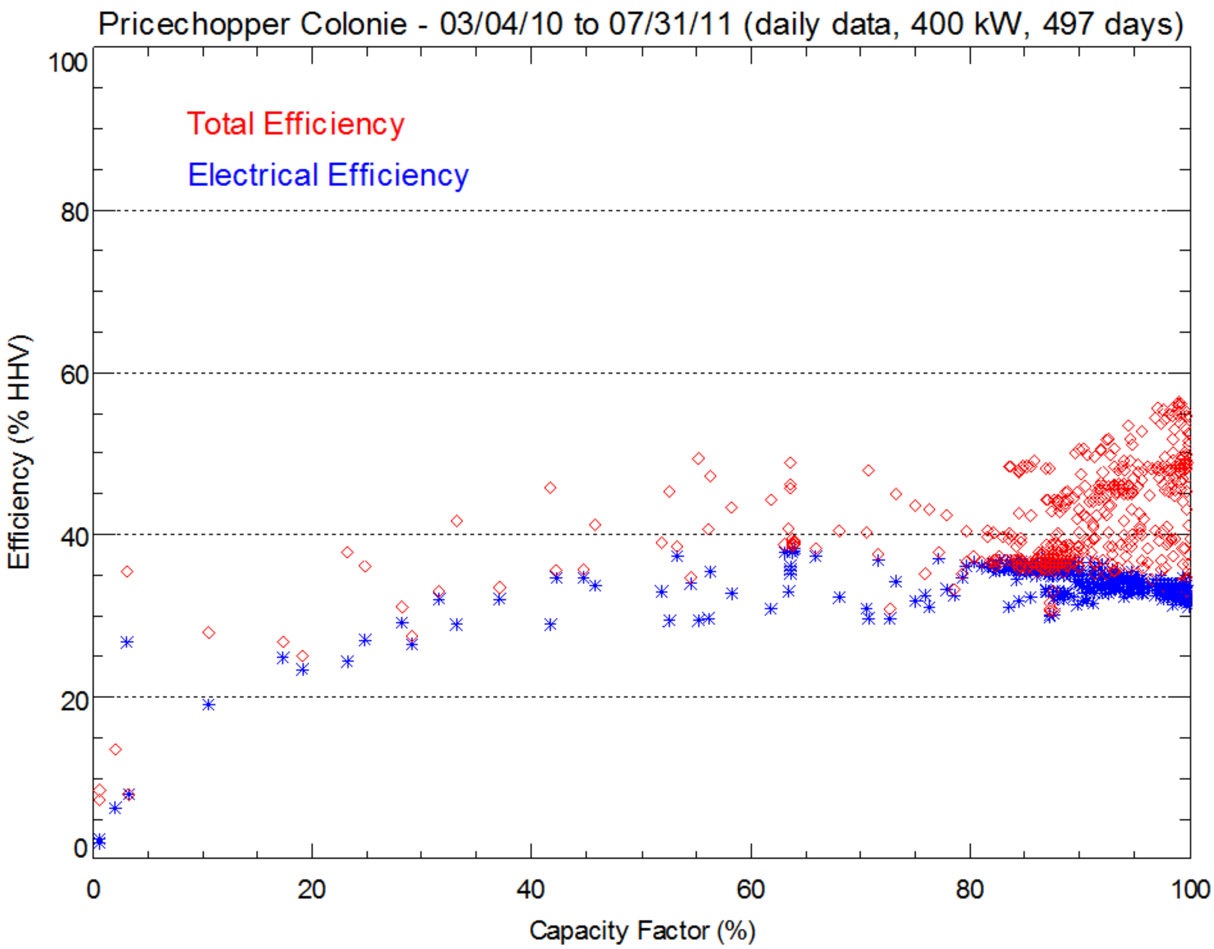

FIGURE 16 CAPACITY FACTOR[3]

Capacity Factor (Figure 16) presents the CHP generated power efficiency over the time period (497 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 operated largely at 100% of generating capacity at about 34.3% power efficiency (HHV). This is the desired and most common fuel cell method of operation. The useful thermal energy (DHW) should operate when required by the load. The heat recovery system provided heating through a radiant floor and cooling through a single effect absorption chiller. The year average thermal efficiency was 16.4% (HHV) ranging from a low of 5.9% in March of 2011 to a high of 23.5% in June of 2010.

The heat recovery system is complicated at this site and there have been control issues with the system. The absorption chiller system has never operated consistently to date due to a control issue with the cooling tower (the breaker trips when the tower goes from low to high stage fan). Also, the low grade loop pump frequently trips on an over-current fault. These issues have explained at least part of the poor performance at this site.

[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 Generator Output comes from the data channel called WFCCUM. This is an accumulator for the generator output. The difference between consecutive intervals is used to determine the output for each hour.
2. **DG/CHP Generator Gas Use (total cubic feet)** The data for Generator Gas input comes from the data channel labeled FG. This channel provides the fuel flow rate in kg/hour and is converted into standard cubic feet and averaged to determine the quantity of fuel used for each hour.
3. **Useful Heat Recovery (total MBtu)** The flow rate, supply temperature, and return temperature of the high and low grade water loop, (FH,THS,THR and FL,TLS,TLR), are used to determine the amount of heat which is rejected from the system. This is determined as a rate which is averaged across the hour.

Applying a fuel cell to a supermarket presents a difficult challenge to high levels of thermal energy recovery. It is particularly difficult to integrated space heating and cooling into a supermarket to maximize energy savings. This particular site experienced flow switch problems requiring time to dissect the problem and make repairs.

The next year's operation will determine the amount of thermal energy actually recovered.

Data collection and quality for this site for much of the period is in the high 90th percentile or at 100%. (Table 3)

TABLE 3 SITE DATA QUALITY

	Percentage of Good Data		
	Power	**Gas Use**	**Useful Heat**
March-10	98.8%	99.2%	96.8%
April-10	99.9%	100.0%	99.0%
May-10	99.5%	100.0%	98.7%
June-10	100.0%	100.0%	99.9%
July-10	97.0%	98.1%	89.5%
August-10	99.9%	100.0%	90.9%
September-10	100.0%	100.0%	93.5%
October-10	100.0%	100.0%	97.7%
November-10	100.0%	100.0%	98.2%
December-10	100.0%	100.0%	99.6%
January-11	99.3%	99.9%	95.3%
February-11	100.0%	100.0%	91.7%
March-11	100.0%	100.0%	98.3%
April-11	98.1%	98.3%	96.1%
May-11	98.4%	99.2%	98.5%
June-11	100.0%	100.0%	91.4%
July-11	100.0%	100.0%	98.1%