NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT THE HILTON NEW YORK

October 9, 2013

Hilton New York

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: kWh/h versus time and Useful MBtu/h versus time.

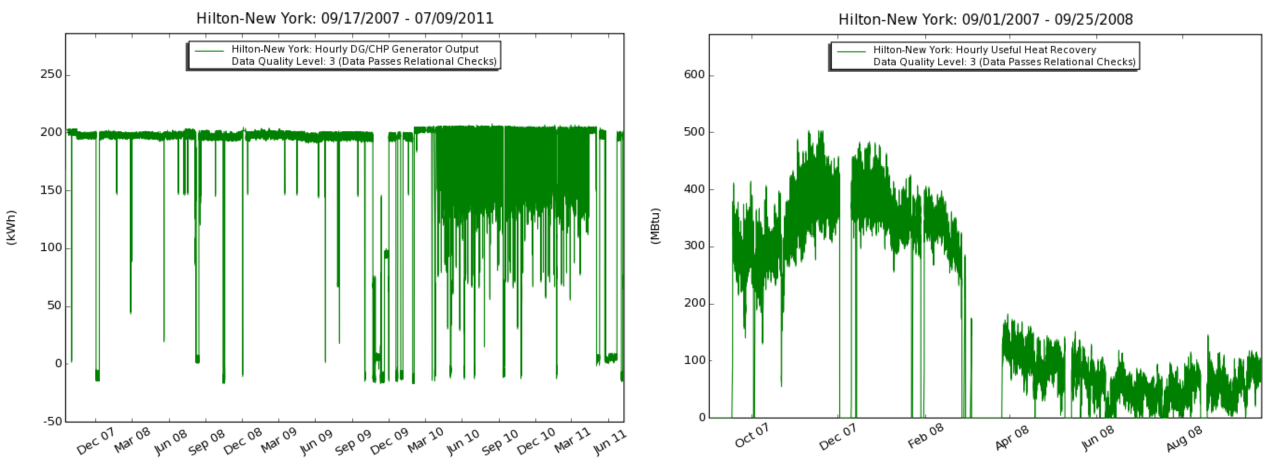

FIGURE 1 NYSERDA CHP WEBSITE PERFORMANCE GRAPHS

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 NEW YORK HILTON HOTEL

The Hilton New York is the largest hotel in the city. The 46 story building houses 1,980 guest rooms and over 150,000 square feet of space dedicated to banquet facilities, meeting rooms and exhibition halls. The electric demand at the hotel averages more than 3 MW. Equally significant heating loads are incurred.

Energy can account for 6% or more of the operating costs incurred by hotels. Although use of electricity tends to dominate, hotels generally have continuous, sizeable heating loads as well. These conditions favor CHP technologies though the lack of free space and concerns about disturbing guests limits the appeal of large engine driven systems. Fuel cells have many characteristics that make them attractive in these situations: they do not vibrate, make much noise or have a visible exhaust. Corporate initiatives targeting environmentally benign technologies also encouraged Hilton's interest in fuel cell systems.

THE SYSTEM

The hotel installed a 200 kW fuel cell on a 4th floor mezzanine. The electricity produced by the fuel cell offsets utility purchases. Heat recovered as a byproduct of the fuel cell's operation provides a portion of the hotel's domestic hot water (DHW) requirement.

FIGURE 3 INSTALLED FUEL CELL AND GAS BOOSTER

The hotel's CHP system is configured on a 200 kW phosphoric acid fuel cell unit (FCU). Natural gas is supplied from a gas pressure booster that slightly increases the inlet pressure. Hydrogen is stripped from the gas and combined with atmospheric oxygen to produce electricity at a conversion efficiency of 35%. The system's electrical output is maintained near its rated value because of the hotel's high demand. The fuel cell can operate in parallel with the utility or operate isolated from the grid in case of an emergency. Heat recovered from the process is in the form of hot water through separate high (250°F max) and low (~140°F) temperature loops. Heat from the high temperature loop is currently being rejected to the atmosphere through a dry cooling coil. The lower temperature water is being used to produce DHW adding more than 15% to the overall system efficiency at design conditions.

The FCU installed at the Hilton provides 200 kW power output, and up to 900 MBtu of heat rejection. The fuel cell unit (FCU) itself, fuel gas booster, and dry cooler are all located on the 4th floor setback roof. The fuel gas booster increases the natural gas supply pressure, and ensures that the fuel cell receives a constant and stable fuel flow. The dry cooler is used to reject unused heat from the fuel cell operation to the atmosphere.

A plate frame heat exchanger (HX) is used to transfer useful heat from the FCU operation to the building DHW system, and also allows isolation between the two systems, ensuring that either the building hot water or the fuel cell can operate independently. The fuel cell DHW piping and dry cooler are piped on independent fluid loops.

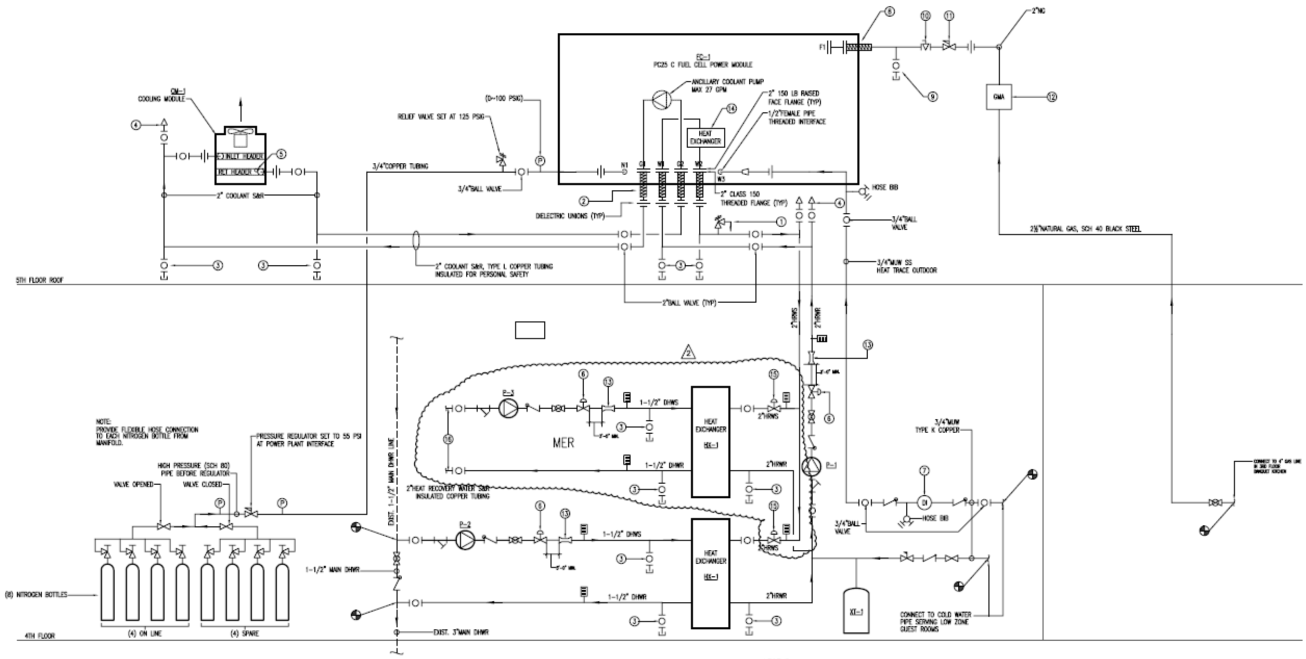

FIGURE 4 FUEL CELL AND HEAT RECOVERY SYSTEM SCHEMATIC

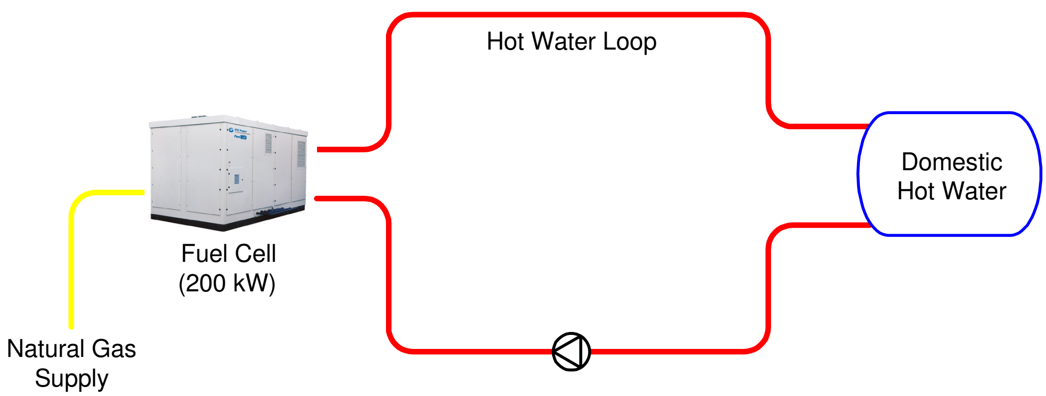

FIGURE 5 SIMPLIFIED SCHEMATIC

FIGURE 6 INSTALLED FUEL CELL AND DRY COOLER ON 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 September 17, 2007.

Data acquisition has been quite good and reliable, providing electric power and fuel consumption operating information over the monitoring period. In fact, Table 3 shows remarkably high percentages of quality data for the entire measured performance period with power, fuel and useful thermal percentages at 98.1%, 97.8% and 100.0% respectively. Useful heat recovery data has been bad since September 2008.

During the first six months of operation (September 2007 – March 2008), the FCU displayed a much higher CHP efficiency. The higher level of heat recovery during this period resulted in an average CHP efficiency of 53% HHV, compared to an electrical efficiency of 36% HHV during the same period.

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
Sep-07	324	65,001	618	93.2	35.2%	14.8%	50.0%
Oct-07	744	147,495	1,405	204.2	35.1%	14.2%	49.4%
Nov-07	720	142,330	1,316	268.8	36.2%	20.0%	56.2%
Dec-07	742	107,887	978	204.5	36.9%	20.5%	57.4%

[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.

Jan-08	720	142,351	1,297	229.2	36.7%	17.3%	54.0%
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Mar-08	744	147,226	1,364	18.7	36.1%	1.3%	37.5%
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May-08	744	146,188	1,423	50.3	34.4%	3.5%	37.8%
Jun-08	720	142,262	1,432	33.2	33.2%	2.3%	35.5%
Jul-08	743	147,104	1,500	28.8	32.8%	1.9%	34.7%
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Jun-11	720	47,698	812	0.0	19.6%	0.0%	19.6%
Jul-11	732	122,078	1,380	0.0	29.6%	0.0%	29.6%
Total	**8,604**	**1,496,525**	**16,208**	**0.0**	**30.9%**	**0.0%**	**30.9%**

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

OPERATING SUMMARY

During the 33,537 hours that met the range and relational checks 88.8% of this time, the CHP system delivered above 200 kWh/h (Figure 14).

Figure 7 shows that the fuel to power efficiency of the system is slightly higher in 2010 versus the initial operating year in 2007. Figure 7 data clearly shows that no viable heat recovery data was collected after September 2008.

This system has exhibited consistent electric performance and sporadic recovered thermal energy performance.

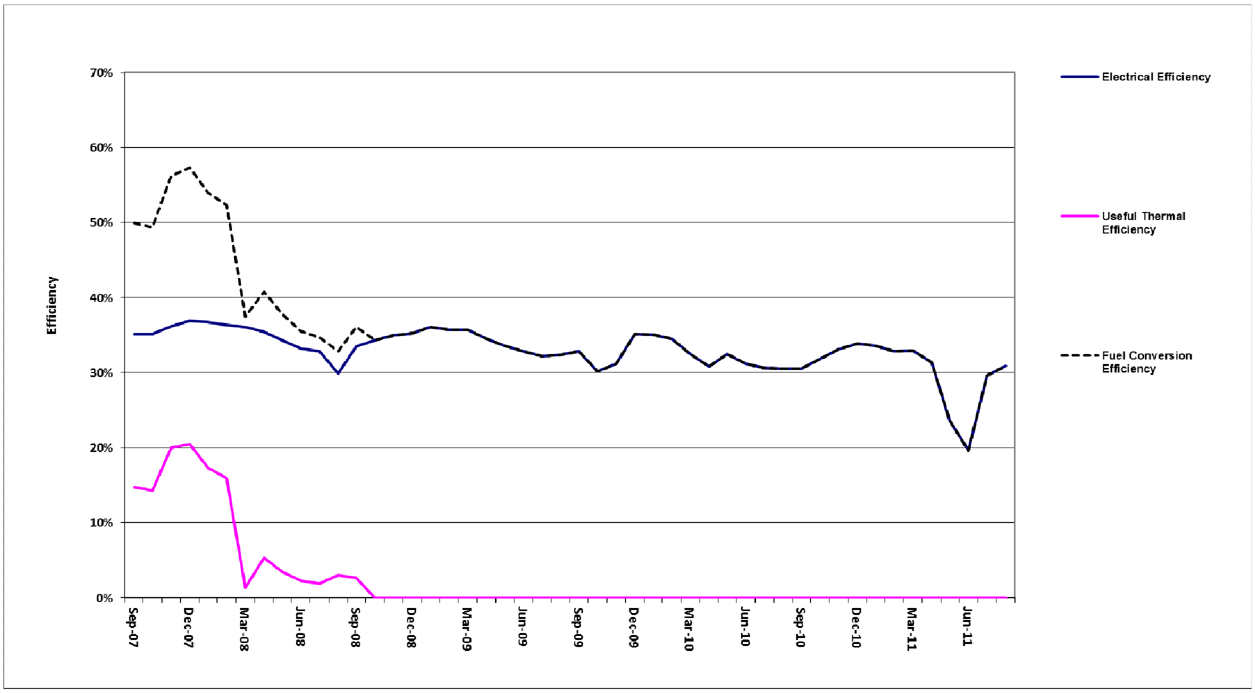

FIGURE 7 CHP SYSTEM EFFICIENCY BY YEAR

The fuel cell useful recovered thermal energy is used to heat the hotel's domestic hot water (DHW) system through a glycol loop and plate frame heat exchanger (Figure 8).

FIGURE 8 CHP SYSTEM EFFICIENCY BY YEAR

Performance monitoring of the thermal load was accomplished through measurements performed on the glycol side of the system. Glycol flow was established during system operation between September 2007 and September 2008 prior to the glycol loop temperature sensor failing. The fuel cell has been producing 180°F-190°F glycol supplied to the heat exchanger, and returning the glycol back to the fuel cell unit at approximately 170°F. Beginning in May 2008, the supply and return temperatures began to approach each other, and the glycol temperature supplied from the fuel cell began falling. By June 2008, there was very little temperature difference across the glycol loop, and useful heat recovery from fuel cell operation was minimal.

POWER GENERATION AND USEFUL THERMAL ENERGY

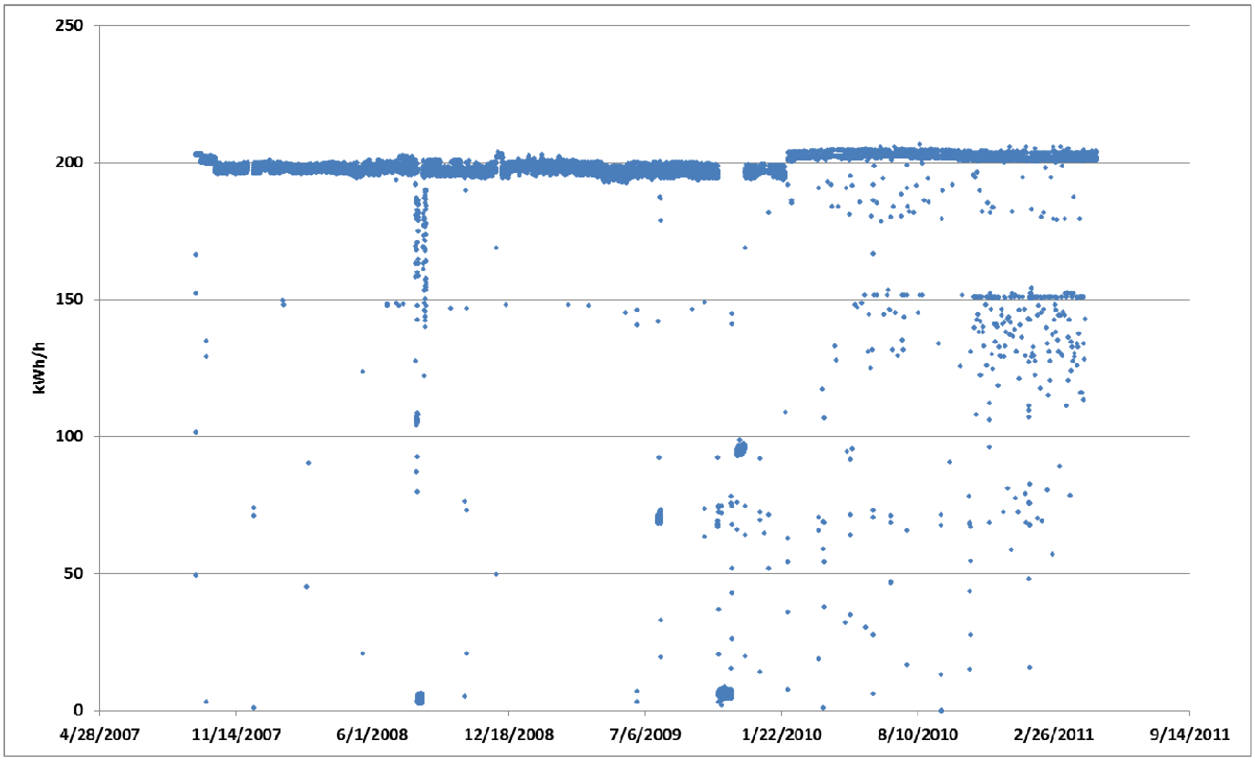

FIGURE 9 CHP POWER OUTPUT VERSUS TIME

Figure 9 shows that the fuel cell is being operated at full power output on a 24/7 basis.

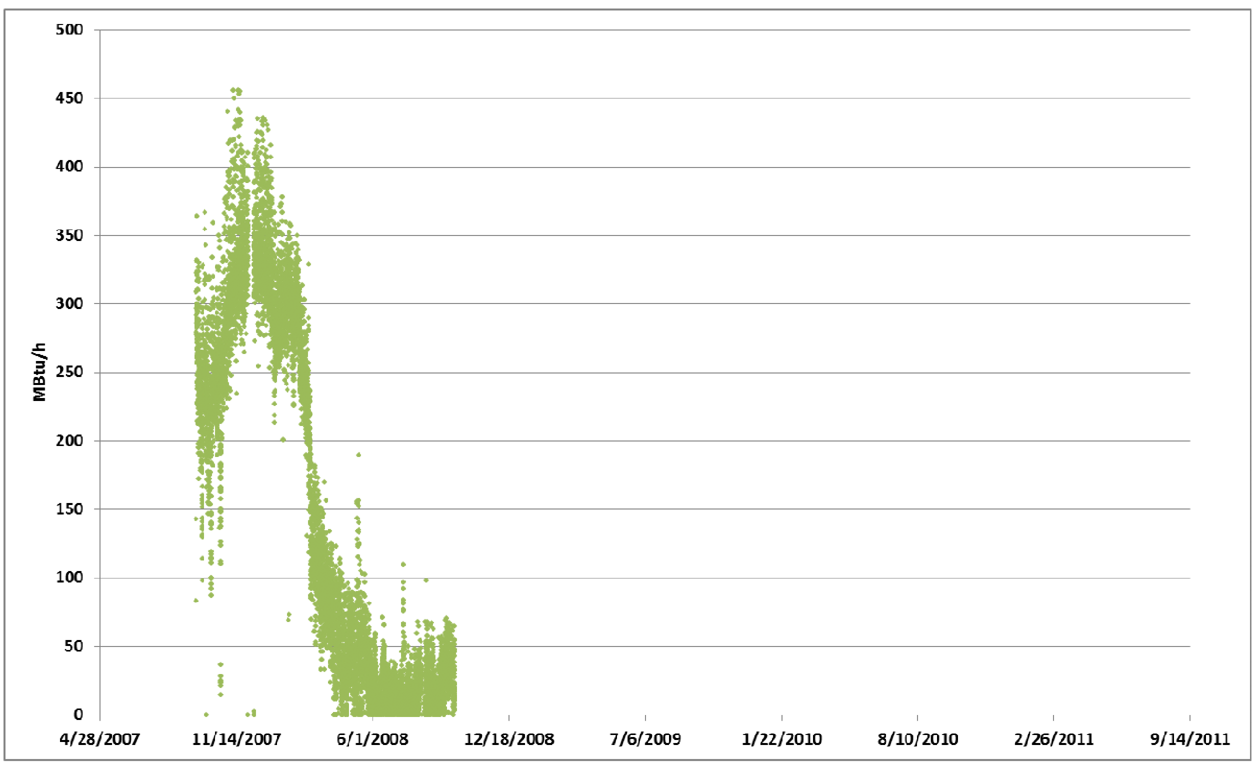

FIGURE 10 CHP USEFUL THERMAL OUTPUT VERSUS TIME

Figure 10 shows a period of limited thermal recovery from November of 2007 to September of 2008. This low level of useful thermal energy recovery was due to the physical design of the system. From September 2008 onward the useful thermal recovery data was invalid.

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

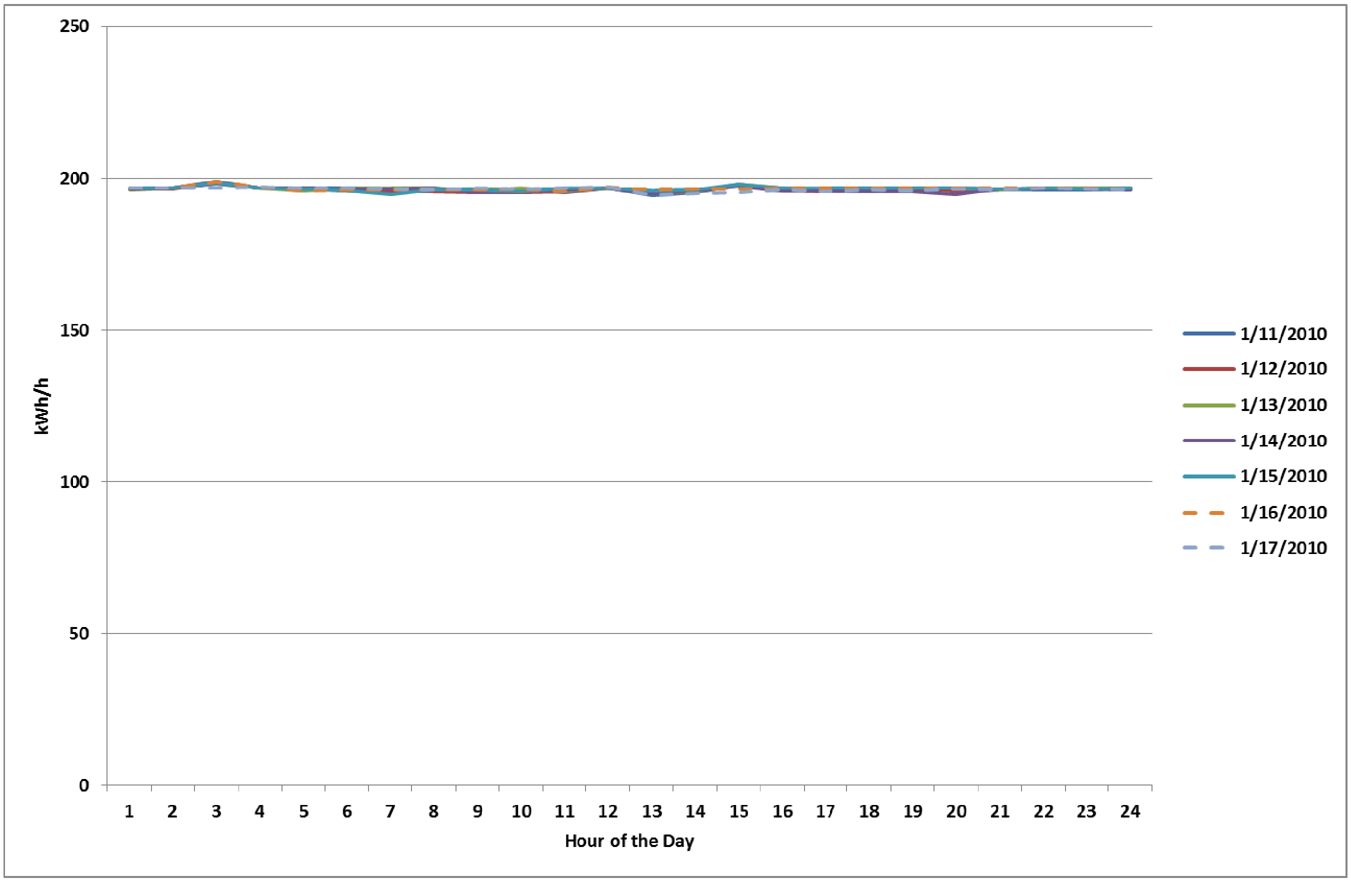

FIGURE 11 CHP POWER OUTPUT VERSUS TIME

Figure 11 covers the time period from January 11-17, 2010 providing CHP system power output by hour of the day pattern for the time period. January 16 is a Saturday. Figure 11 shows all work days and the weekends have similar power production patterns delineating the operating mode is full capacity 24 x 7.

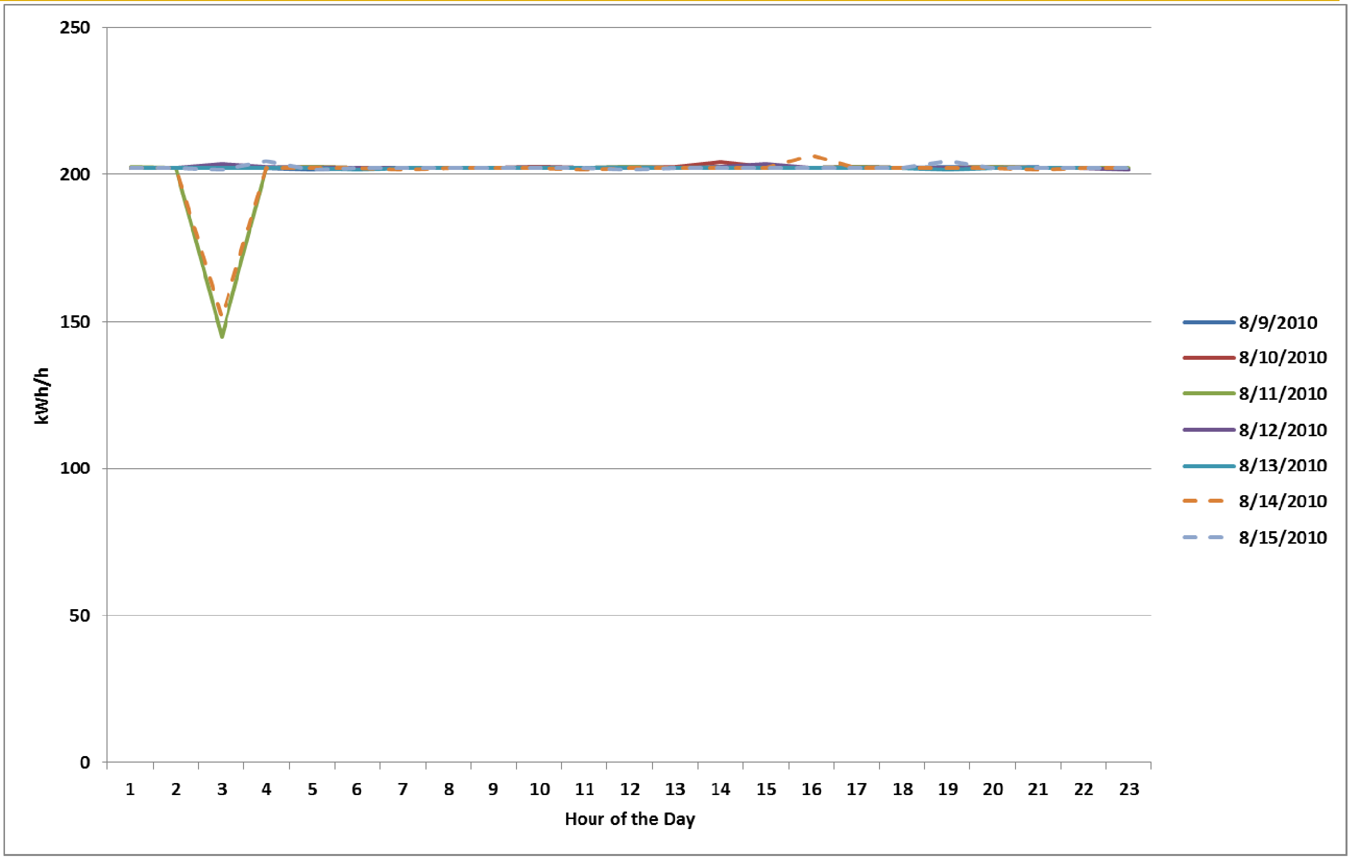

FIGURE 12 CHP POWER OUTPUT VERSUS TIME

Figure 12 covers the time period from August 9-15, 2010 providing CHP system power output by hour of the day pattern for the time period. August 14 is a Saturday. Figure 12 shows all work days and the weekends have similar power production patterns delineating the operating mode is full capacity 24 x 7.

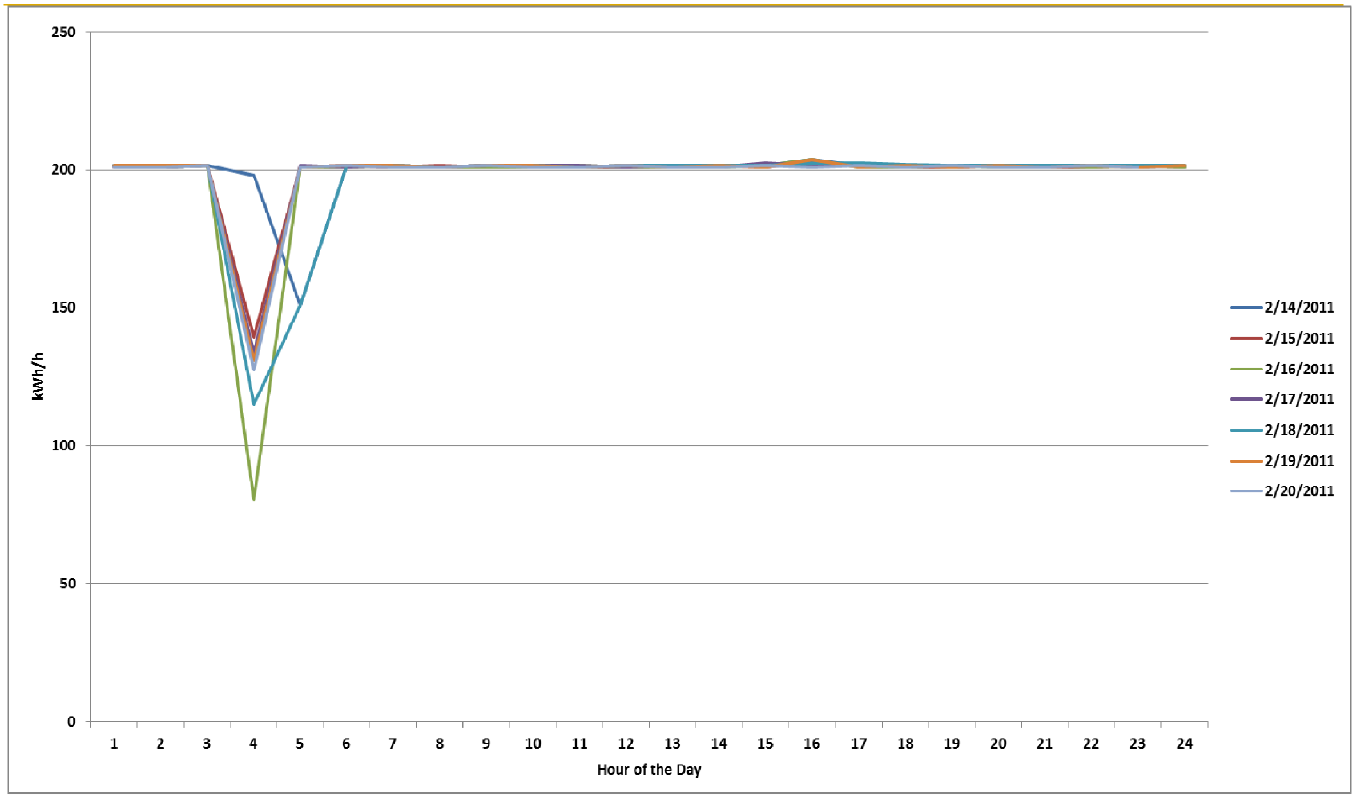

FIGURE 13 CHP POWER OUTPUT VERSUS TIME

Examining the November 2010 through April 2011 timeframe of Figure 9 and Figure 10, two observations can be made. There is a slight change in the power output with some data points lower than full output and there is no registered useful thermal heat recovery. Figure 13 shows that between 3 and 5 AM (February 14-20, 2011) the fuel cell power output is reduced between 50 and 125 kWh/h.

PERFORMANCE SUMMARY

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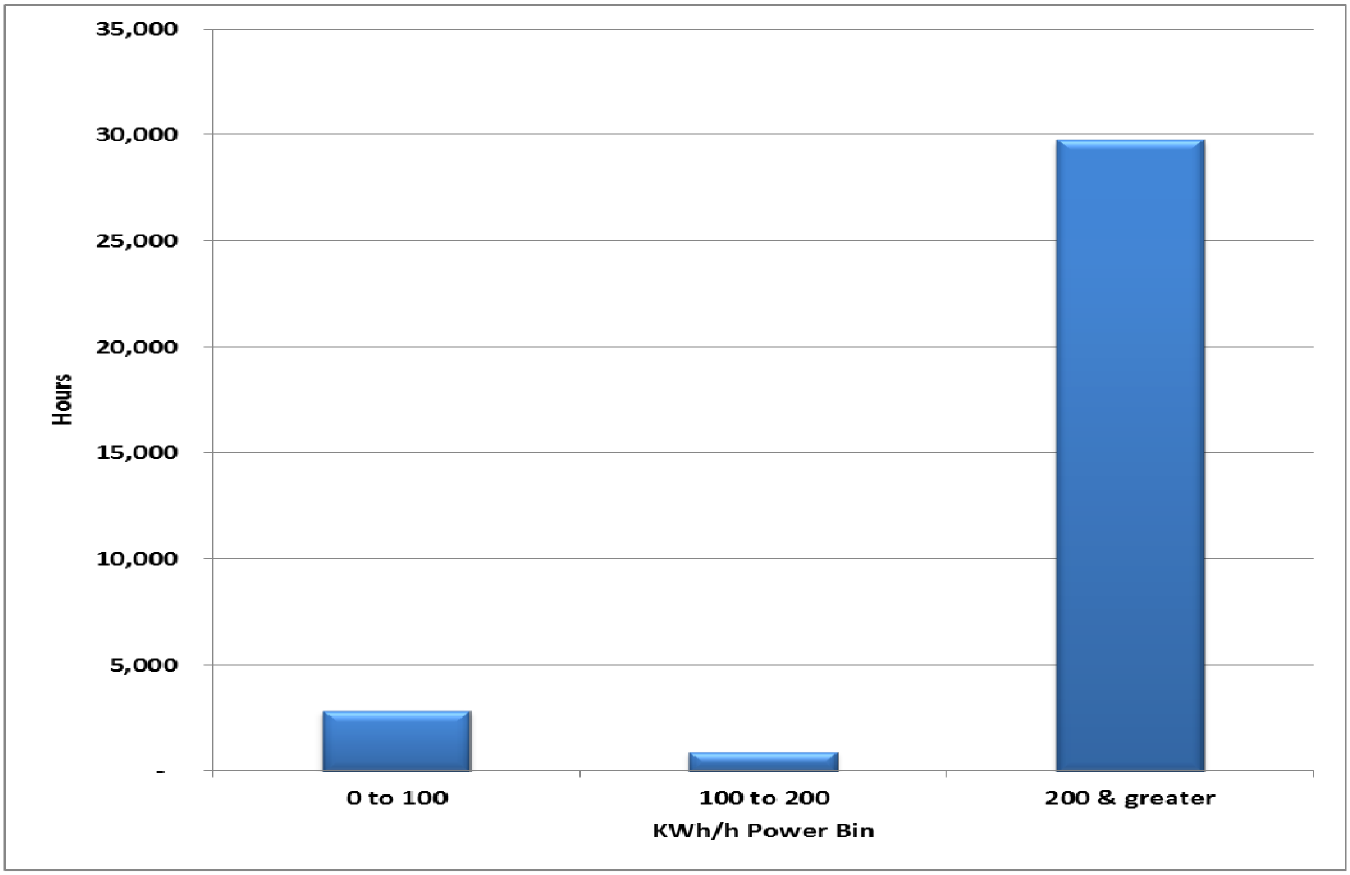

FIGURE 14 PERFORMANCE BY POWER BINS

LESSONS LEARNED

TABLE 2 SYSTEM EFFICIENCY[2]

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

The site is served by a single 200 kW phosphoric acid fuel cell with useful waste heat used to provide domestic hot water.

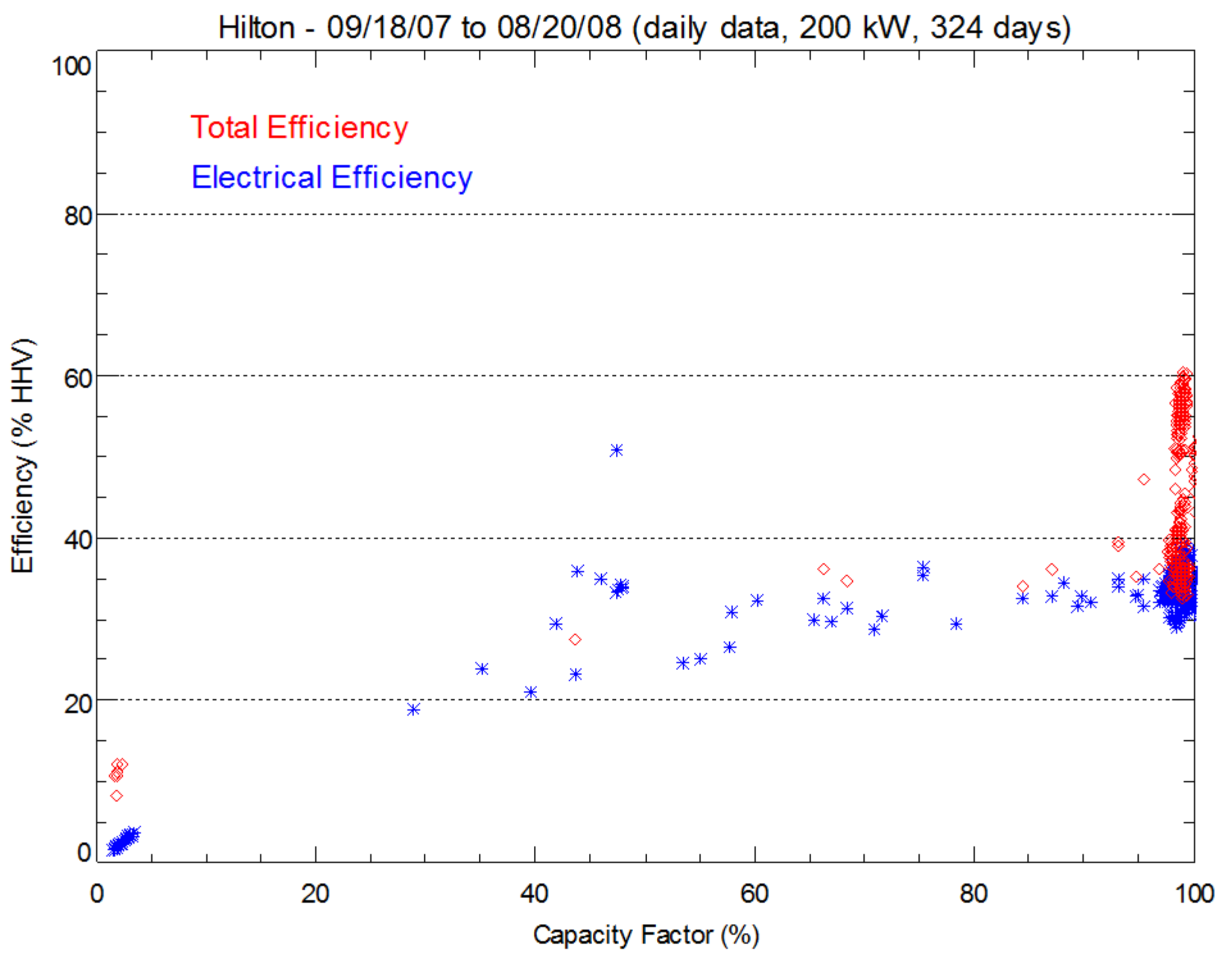

FIGURE 15 CAPACITY FACTOR[3]

[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 15) presents the CHP generated power efficiency over the time period (324 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 30.9% 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 was problematic for the onset and data collection resulted in virtually no useful heat recovery recorded in the data reported in Table 2 ~0% thermal efficiency (HHV). Note the heat recovery for cooling during the summertime in schools is generally limited to staff offices, events and summer school, if provided by the district, yielding limited cooling requirements.

Heat recovery was poor at this site because the heat exchangers between the FCU and DHW system were not configured to use the available waste heat.

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 fuel cell, 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.

This system has exhibited consistent electric performance and sporadic recovered thermal energy performance. The key lessons are:

1. Design and install the thermal heat recovery system correctly
2. Focus on maintaining system performance

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

TABLE 3 SITE DATA QUALITY

	Percentage of Good Data		
	Power	**Gas Use**	**Useful Heat**
Sep-07	45.0%	45.0%	100.0%
Oct-07	100.0%	100.0%	100.0%
Nov-07	100.0%	100.0%	100.0%
Dec-07	99.7%	99.9%	100.0%
Jan-08	96.8%	96.8%	100.0%
Feb-08	99.6%	100.0%	100.0%
Mar-08	100.0%	100.0%	100.0%
Apr-08	100.0%	100.0%	100.0%
May-08	100.0%	100.0%	100.0%
Jun-08	100.0%	100.0%	100.0%
Jul-08	99.9%	99.9%	100.0%
Aug-08	100.0%	100.0%	100.0%
Sep-08	100.0%	99.9%	83.3%
Oct-08	98.0%	99.9%	0.0%
Nov-08	100.0%	100.0%	0.0%
Dec-08	96.9%	99.1%	0.0%
Jan-09	100.0%	100.0%	0.0%
Feb-09	99.9%	100.0%	0.0%

Mar-09	99.9%	100.0%	0.0%
Apr-09	98.3%	98.3%	0.0%
May-09	100.0%	100.0%	0.0%
Jun-09	100.0%	99.9%	0.0%
Jul-09	99.7%	100.0%	0.0%
Aug-09	99.9%	100.0%	0.0%
Sep-09	99.9%	100.0%	0.0%
Oct-09	97.6%	100.0%	0.0%
Nov-09	98.3%	100.0%	0.0%
Dec-09	99.1%	100.0%	0.0%
Jan-10	97.3%	100.0%	0.0%
Feb-10	96.6%	100.0%	0.0%
Mar-10	94.0%	100.0%	0.0%
Apr-10	93.5%	100.0%	0.0%
May-10	96.8%	98.3%	0.0%
Jun-10	97.2%	99.7%	0.0%
Jul-10	97.0%	99.6%	0.0%
Aug-10	96.6%	99.9%	0.0%
Sep-10	97.2%	99.9%	0.0%
Oct-10	97.3%	100.0%	0.0%
Nov-10	98.9%	100.0%	0.0%
Dec-10	98.9%	100.0%	0.0%
Jan-11	97.7%	100.0%	0.0%
Feb-11	98.5%	100.0%	0.0%
Mar-11	98.9%	99.9%	0.0%
Apr-11	98.2%	99.7%	0.0%
May-11	98.3%	100.0%	0.0%
Jun-11	100.0%	100.0%	0.0%
Jul-11	98.5%	99.9%	0.0%