NYSERDA CHP Assessment Report

ASSESSING THE CHP PLANT AT THE BURRSTONE ENERGY CENTER

October 9, 2013

Burrstone Energy Center

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 six fundamental output graphs: kW/h versus time and Useful MBtu/h versus time for the three power independent systems (hospital, nursing home and college) that thermally feed the hospital.

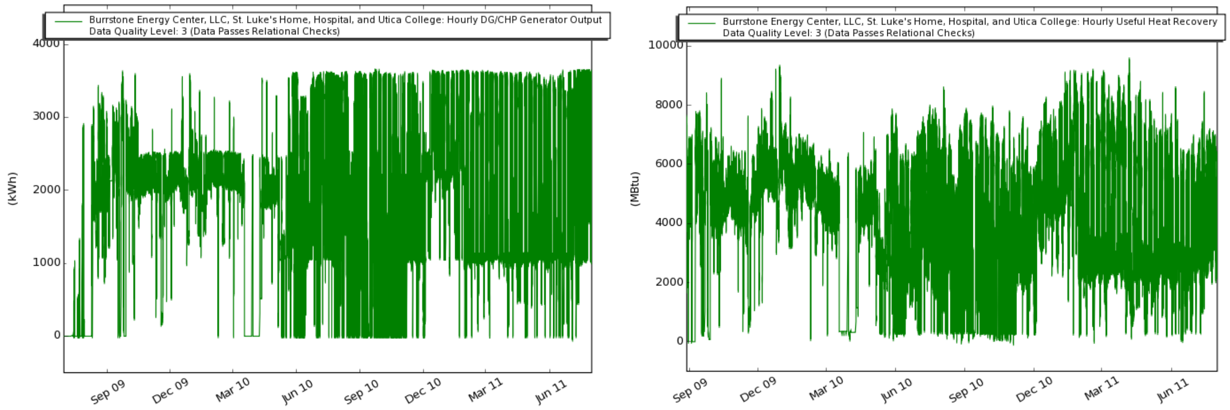

FIGURE 1 BURRSTONE – TOTAL ENERGY CENTER ELECTRIC AND USEFUL THERMAL OUTPUT

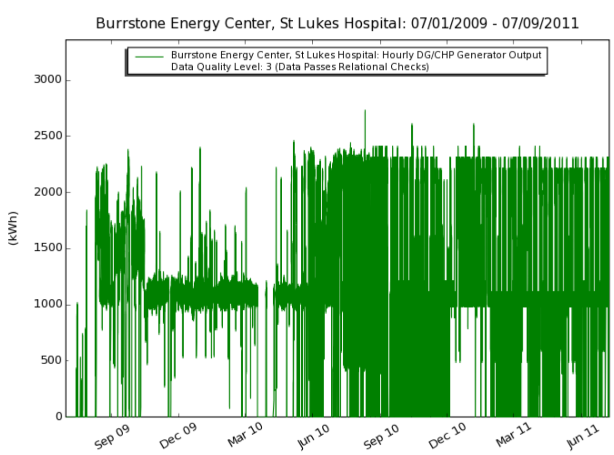

FIGURE 2 BURRSTONE – ST. LUKE'S HOSPITAL ELECTRIC OUTPUT

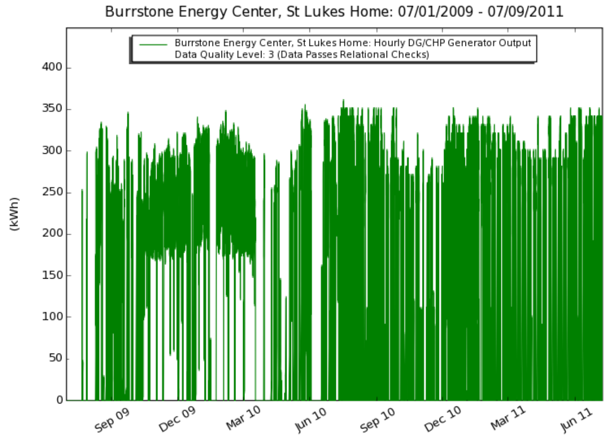

FIGURE 3 BURRSTONE – ST. LUKE'S NURSING HOME ELECTRIC OUTPUT

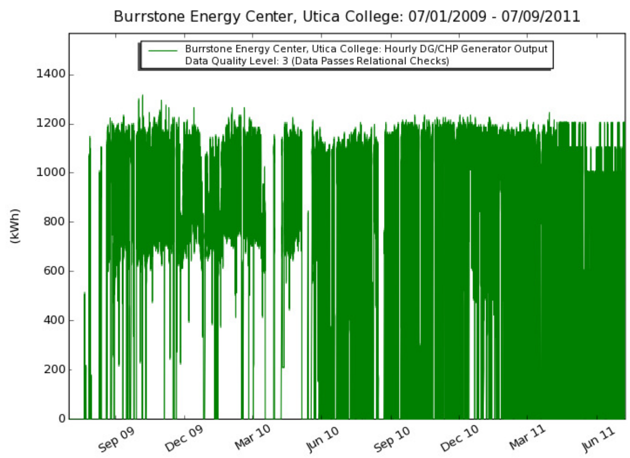

FIGURE 4 BURRSTONE – UTICA COLLEGE ELECTRIC OUTPUT

This report provides explanation for system performance trends and anomalies by further assessing the data supporting these six graphs and, where necessary, conducts interviews of the developers, owners and operators.

THE SITE

The cogeneration plant on the St. Luke's campus of Faxton-St. Luke's Healthcare creates both electricity for use at Faxton-St. Luke's and Utica College and both electricity and steam for St. Luke's Hospital. This plant provides all of the power at St. Luke's Hospital, 75% of the power at Utica College, and 50% of the power at St. Luke's nursing home.

The facility is made up of four engines that run on natural gas, all of which are between 60-80 percent efficient. The excess heat produced by the engines is captured and either transported to the facilities for heat or to make steam for the hospital.

St Luke’s hospital maintains three separate health care facilities serving residents of the Mohawk Valley community. Collectively these three facilities employ 2,643 people, primarily within the local community, and support the following number of units:

(1) St Luke's Hospital - Acute Care : 266 beds

(2) St Luke's Home - Long Term Care: 160 beds

(3) Utica College is a four-year college located on 128 acre campus in Utica, New York. There are currently 2,372 students enrolled in both full-time and part-time programs, and a total of 454 employees (instructional and administrative) to support operations at the College.

FIGURE 5 FAXTON-ST. LUKE’S AND UTICA COLLEGE CAMPUS

THE SYSTEM

The Burrstone Energy Center project encompasses a total of four (4) on-site generators with a total nameplate capacity of 3.63 MW as follows:

(2) 1,100 kW natural gas -fired spark ignited engines to serve the electric power needs of the hospital. Electricity generated can supply the hospital or be exported to the grid when economic conditions permit.

(1) 1,100 kW natural gas -fired spark ignited engine to serve the electric power needs of Utica College. Electricity generated can supply the college or be exported to the grid when economic conditions permit.

(1) 330 kW natural gas -fired spark ignited engine to serve the electric power needs of the Nursing Home. Electricity generated can supply the nursing home and cannot be exported to the grid.

The engines provide thermal energy to St Luke's Hospital. Waste heat from the engines is used to produce high pressure steam (100 psig), hot water, and chilled water through the use of absorption chillers.

FIGURE 6 BURRSTONE ENERGY CENTER

FIGURE 7 ENGINE IN ENCLOSURE WITH HEAT RECOVERY HEAT EXCHANGERS (UPPER FOREGROUND)

FIGURE 8 ENERGY CENTER UNDER CONSTRUCTION

FIGURE 9 HEAT RECOVERY HEAT EXCHANGER INSTALLATIONS

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 and Figure 10 provide compiled data results taken from the three systems since all thermal energy from all the generators flows to the hospital.

TABLE 1 COMBINED 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
January-10	744	1,582,189	17,061.7	4,220.3	31.0%	24.3%	55.3%
February-10	671	1,490,303	16,829.3	3,458.9	29.6%	20.1%	49.8%
March-10	742	968,993	10,855.9	2,127.3	29.9%	19.2%	49.1%
April-10	658	936,072	10,657.2	2,209.9	29.4%	20.3%	49.7%
May-10	732	1,163,013	13,024.1	2,613.4	29.9%	19.7%	49.6%
June-10	718	1,176,220	13,356.6	2,187.4	29.5%	16.1%	45.5%
July-10	740	1,832,054	20,959.8	3,646.4	29.2%	17.1%	46.3%
August-10	739	1,591,969	18,185.4	3,125.7	29.3%	16.9%	46.1%
September-10	716	1,351,213	15,219.9	2,569.9	29.7%	16.6%	46.3%
October-10	729	1,012,551	11,361.5	1,929.4	29.8%	16.6%	46.5%
November-10	716	1,131,112	12,303.3	2,297.0	30.8%	18.3%	49.1%
December-10	741	1,838,418	20,388.6	3,939.8	30.2%	18.9%	49.1%
January-11	743	1,893,145	20,955.4	4,087.5	30.2%	19.1%	49.4%
February-11	670	1,341,136	14,365.7	2,931.1	31.2%	20.0%	51.2%
March-11	743	1,607,554	17,608.9	3,433.6	30.5%	19.1%	49.7%
April-11	667	1,367,277	14,546.2	2,597.3	31.5%	17.5%	49.0%
May-11	718	1,462,810	15,474.7	2,878.1	31.6%	18.2%	49.9%
June-11	712	1,406,085	14,968.5	2,584.9	31.4%	16.9%	48.4%
July-11	741	1,820,208	19,326.3	3,213.5	31.5%	16.3%	47.8%
Total preceding 12 months	**8635**	**17,823,478**	**194,704.4**	**35,587.8**	**30.6%**	**17.9%**	**48.5%**

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.

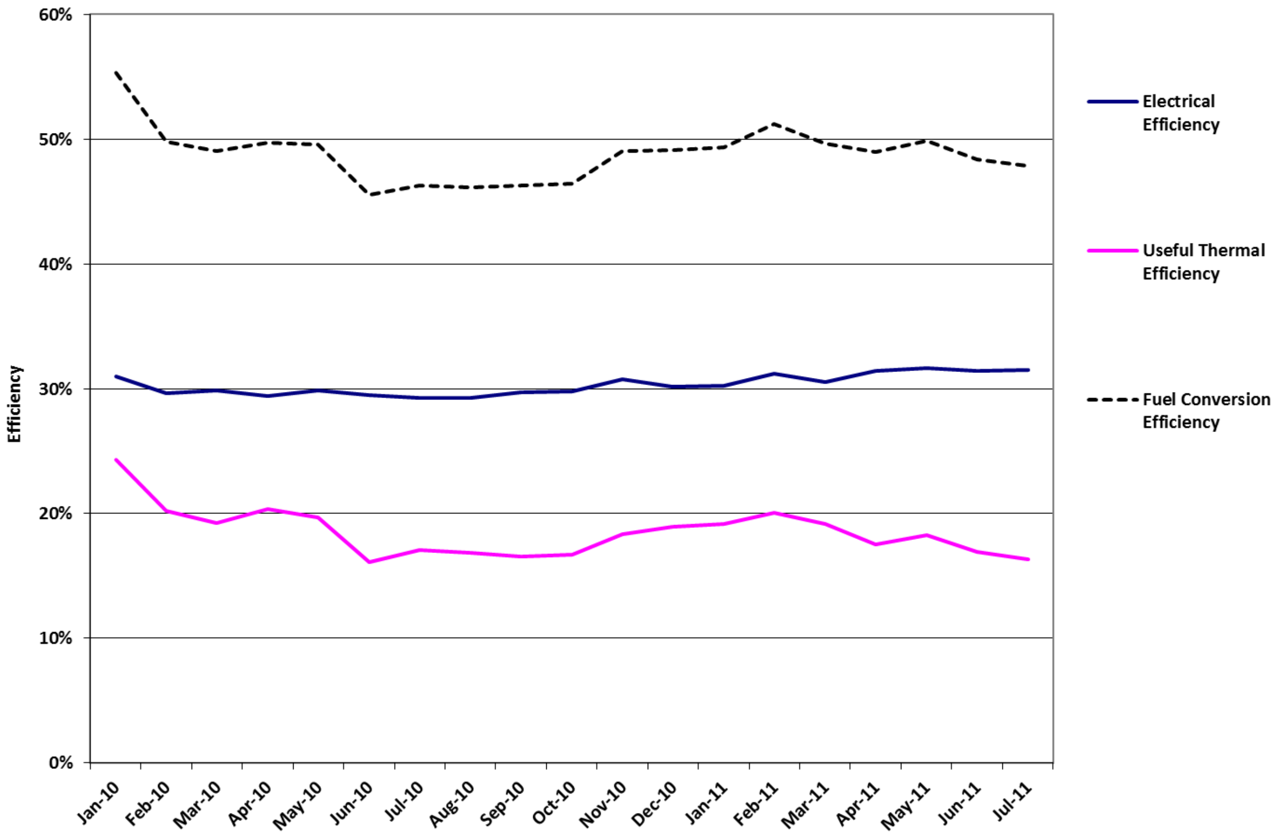

FIGURE 10 COMBINED SYSTEM EFFICIENCY

OPERATING SUMMARY

The Burrstone Energy Center has operated in two modes. The initial operation, Period 1 (2009 - ~May 15, 2010), was a general electric load following mode. In the case of the nursing home, where no export of power to the grid is permitted, this meant operating 30 kW less than the building load requirement when the electric rates permitted. For the hospital, this meant operating one engine generator basically full time. The Utica College engine generator also operated in electric load following mode. The second period (~May 15 to December 2010) operation was based on control algorithms designed to economically reduce real-time daily peak demand. Hour by hour decision to operate was based upon prior demand and current real-time pricing for the next hour.

In this scheme, for example, the negotiated price per hour had the nursing home as last priority. This explains the shift in operating performance after May of 2010.

Electricity economics drive the operation of this site. Since the hospital and college engine generators can export to the grid, there are times where the electric export benefit is significant and the generators are run regardless of the electric power load of the respective sites or the thermal load of the hospital.

CONSOLIDATED POWER GENERATION AND USEFUL THERMAL OUTPUT

In December 2010, the logic controlling the dispatch routine was modified to account for the added costs of allowing a higher peak utility import demand for each day. This resulted in more run time for the engines.

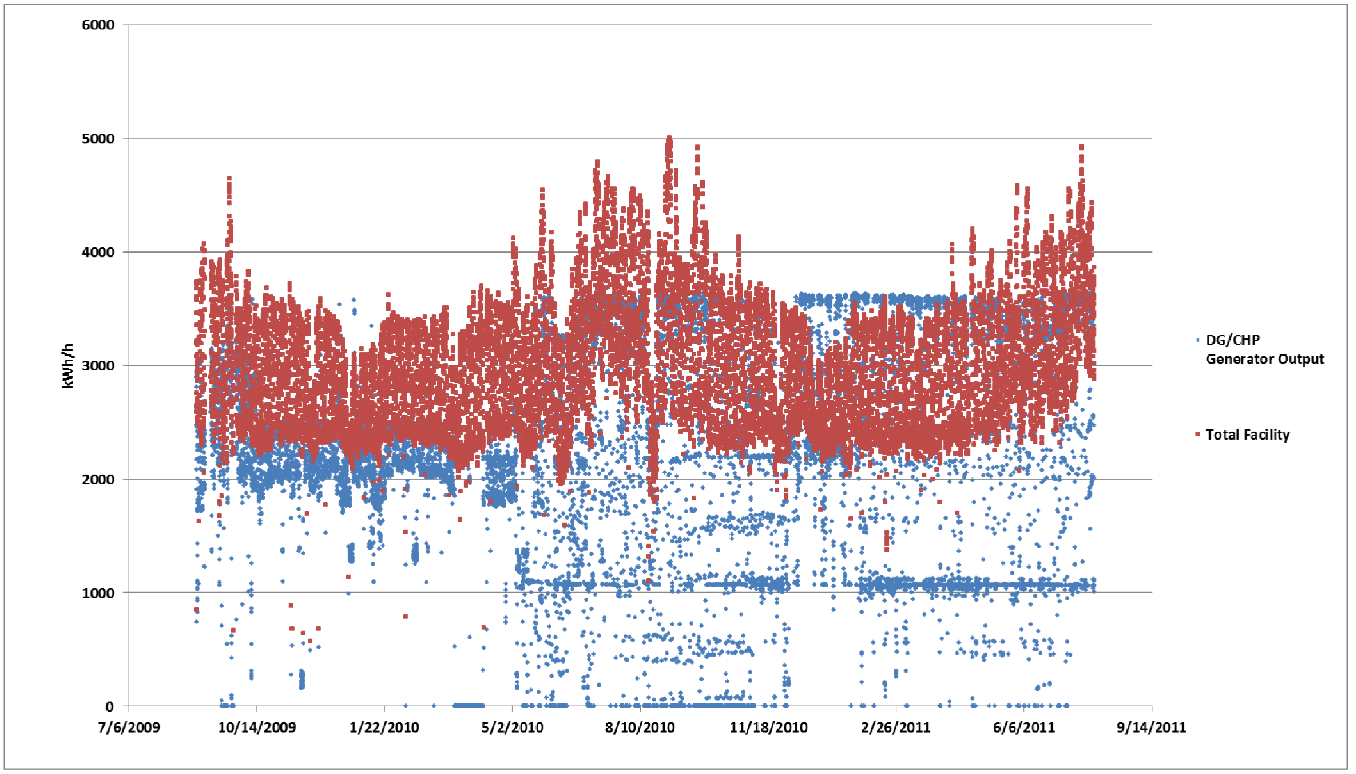

FIGURE 11 COMBINED NURSING HOME, HOSPITAL AND COLLEGE ELECTRIC LOAD (RED) AND TOTAL ENERGY CENTER KWH OUTPUT VERSUS TIME (BLUE)

Figure 11 shows electric load following pattern up through May of 2010 and a shift to real-time demand reduction and energy savings operation after that time.

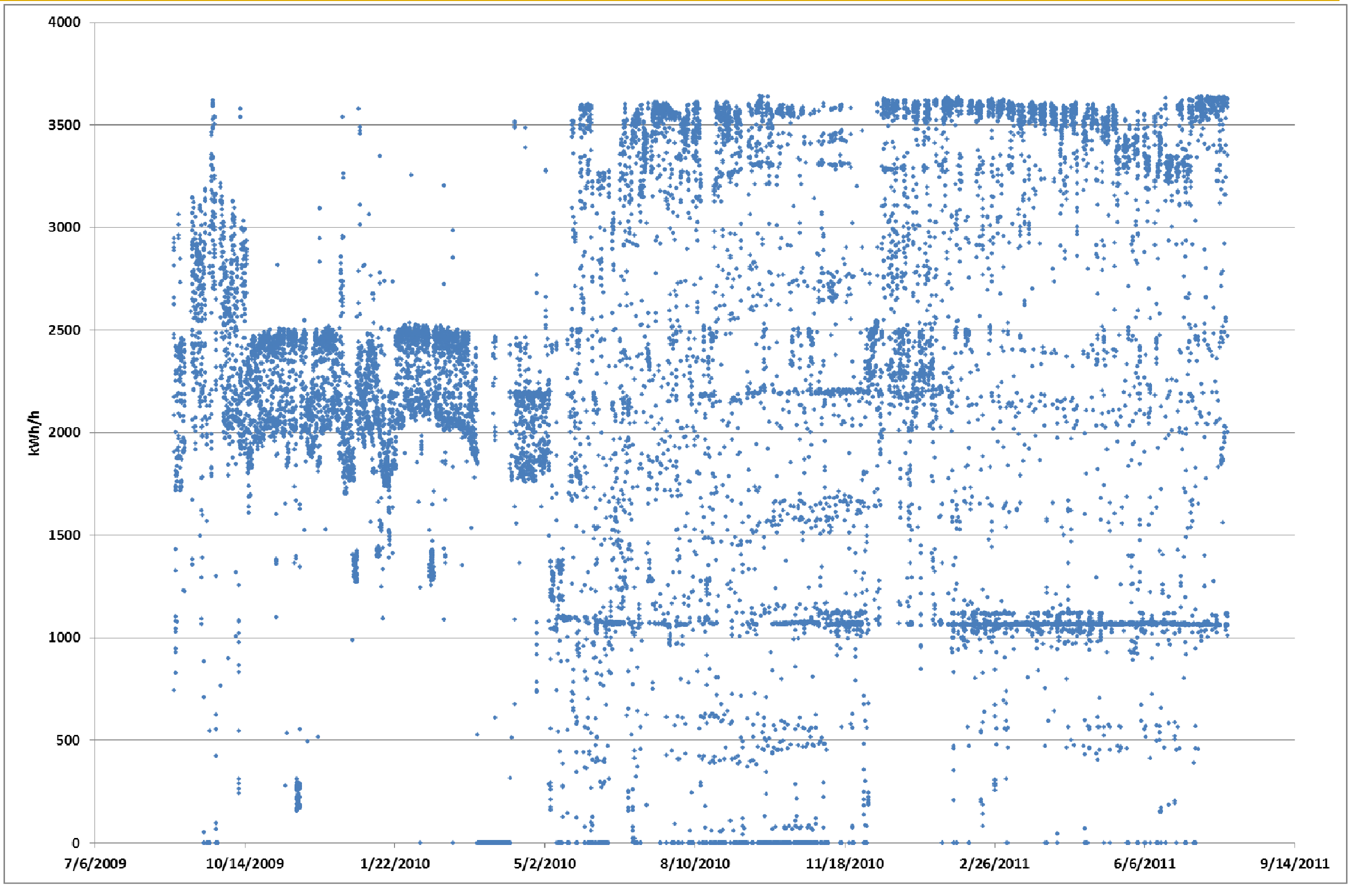

FIGURE 12 TOTAL ENERGY CENTER ELECTRIC POWER OUTPUT PROFILE

Figure 12 isolates the generator output to better view the operating sequence shift.

FIGURE 13 TOTAL ENERGY CENTER USEFUL THERMAL ENERGY OUTPUT PROFILE

Figure 13 shows a maximum useful thermal energy of about 9,130 MBtu/h during the winter of 2011. The hospital is the only user of thermal energy from the Burrstone Energy Center. Note that simply calculating an equal amount of thermal energy capacity to the power produced at 3.13 MWh/h would yield 12.400 MBtu useful thermal energy capacity, versus the 8,000 to 9,000 MBtu shown above clearly indicating a system operating on electric load following mode.

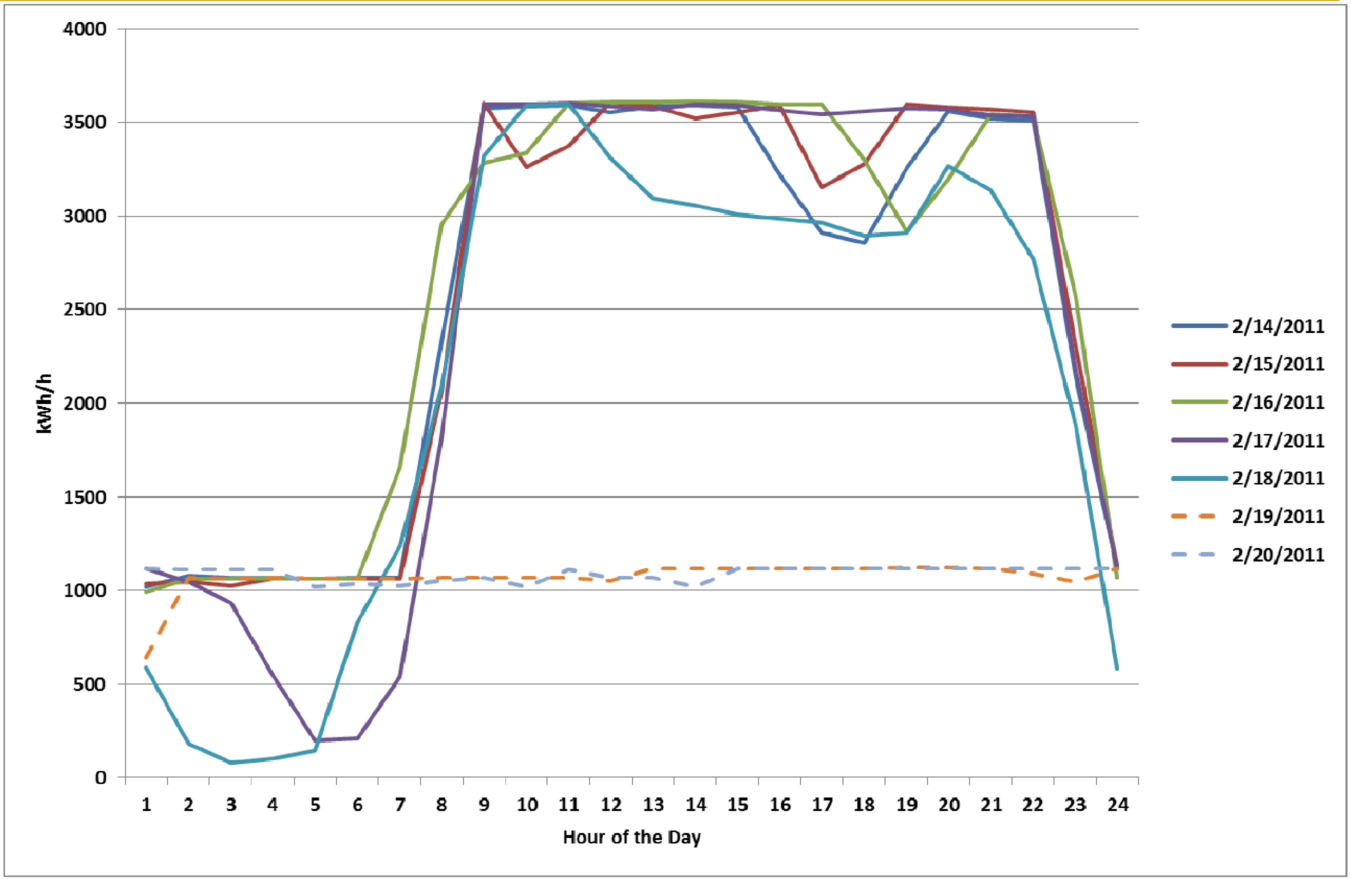

FIGURE 14 TOTAL ENERGY CENTER ELECTRIC POWER OUTPUT PROFILE

Figure 14 shows the combined generator output for all three sites. During this week in February, the weekday power curves show typical morning start patterns, peak period operation and evening shutdown. During this week, the hospital used a weekend base load of about 1 MWh/h, even on Saturday when no thermal energy was shown to be recovered. This system, including all engine generators, is operating on a sophisticated electric rate following algorithm.

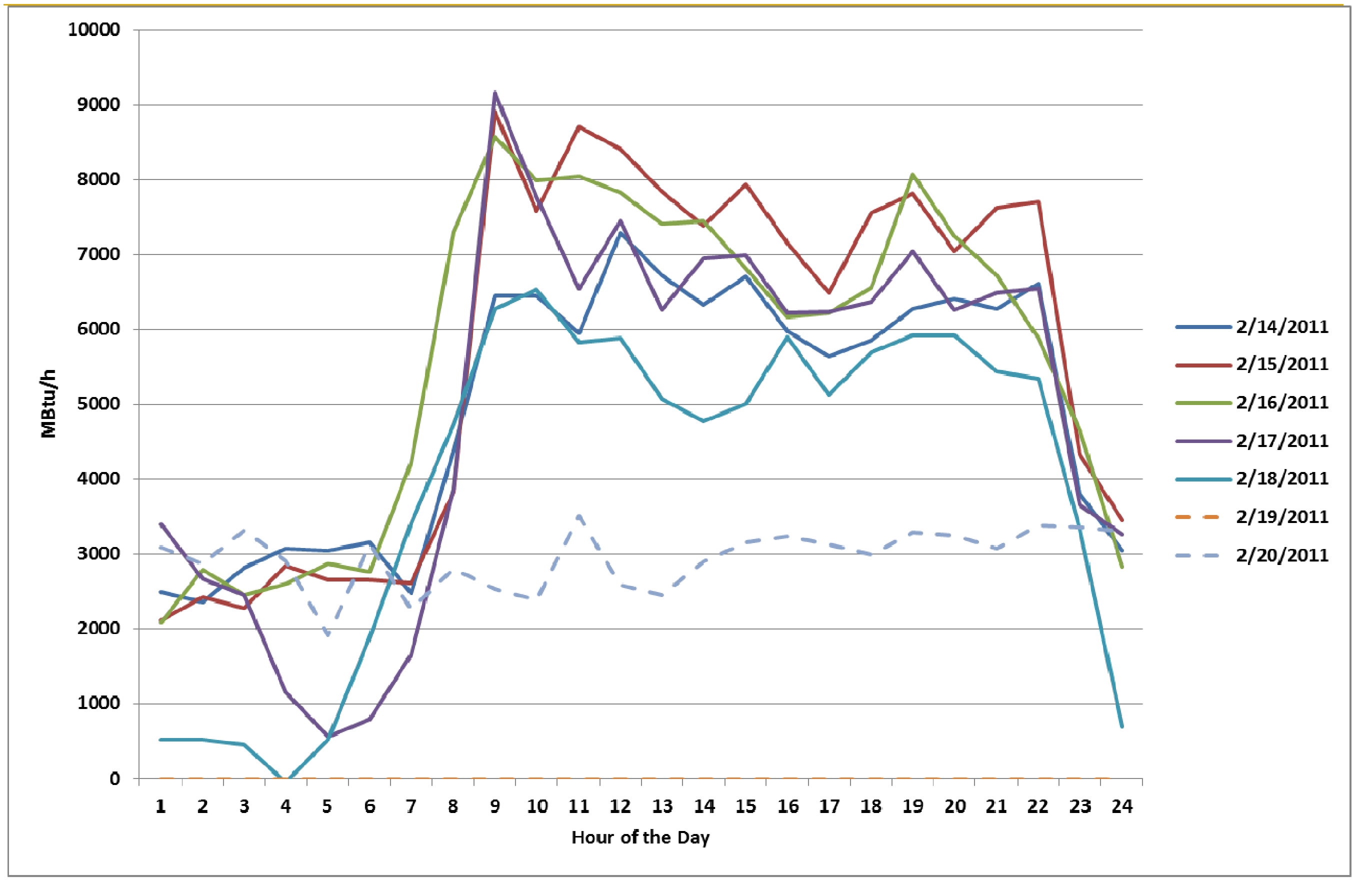

FIGURE 15 TOTAL ENERGY CENTER USEFUL THERMAL ENERGY OUTPUT PROFILE

Figure 15 shows the thermal load of the hospital which is less than the thermal capacity of all the engine generators shown operating in Figure 14.

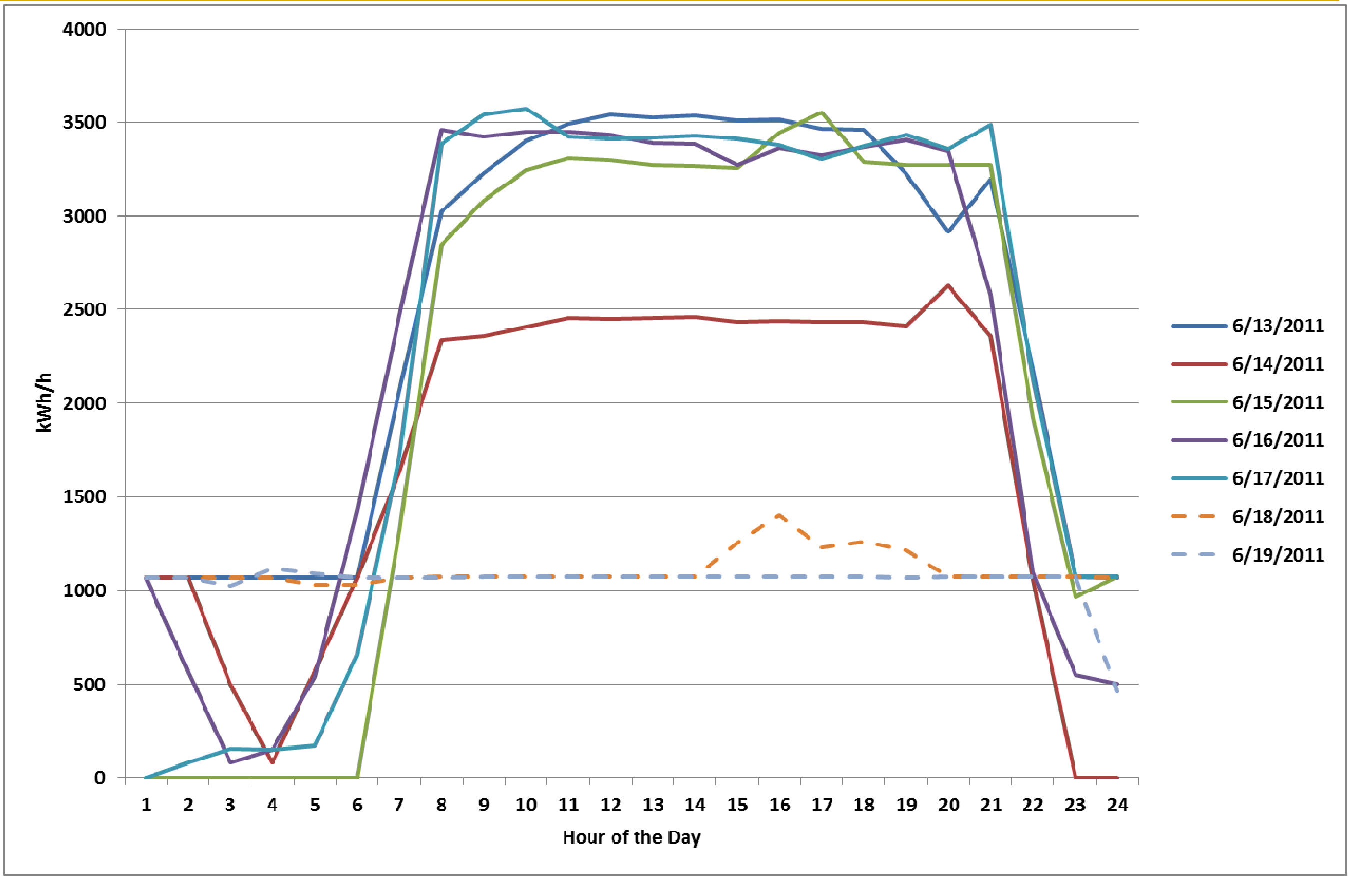

FIGURE 16 TOTAL ENERGY CENTER POWER OUTPUT PROFILE

Figure 16 shows the combined generator output for all three sites similar to Figure 14. During this week in June, the weekday power curves show typical morning start patterns, peak period operation and evening shutdown. During this week, the hospital used a weekend base load of about 1 MWh/h. This system, including all engine generators, is operating on a sophisticated electric rate following algorithm.

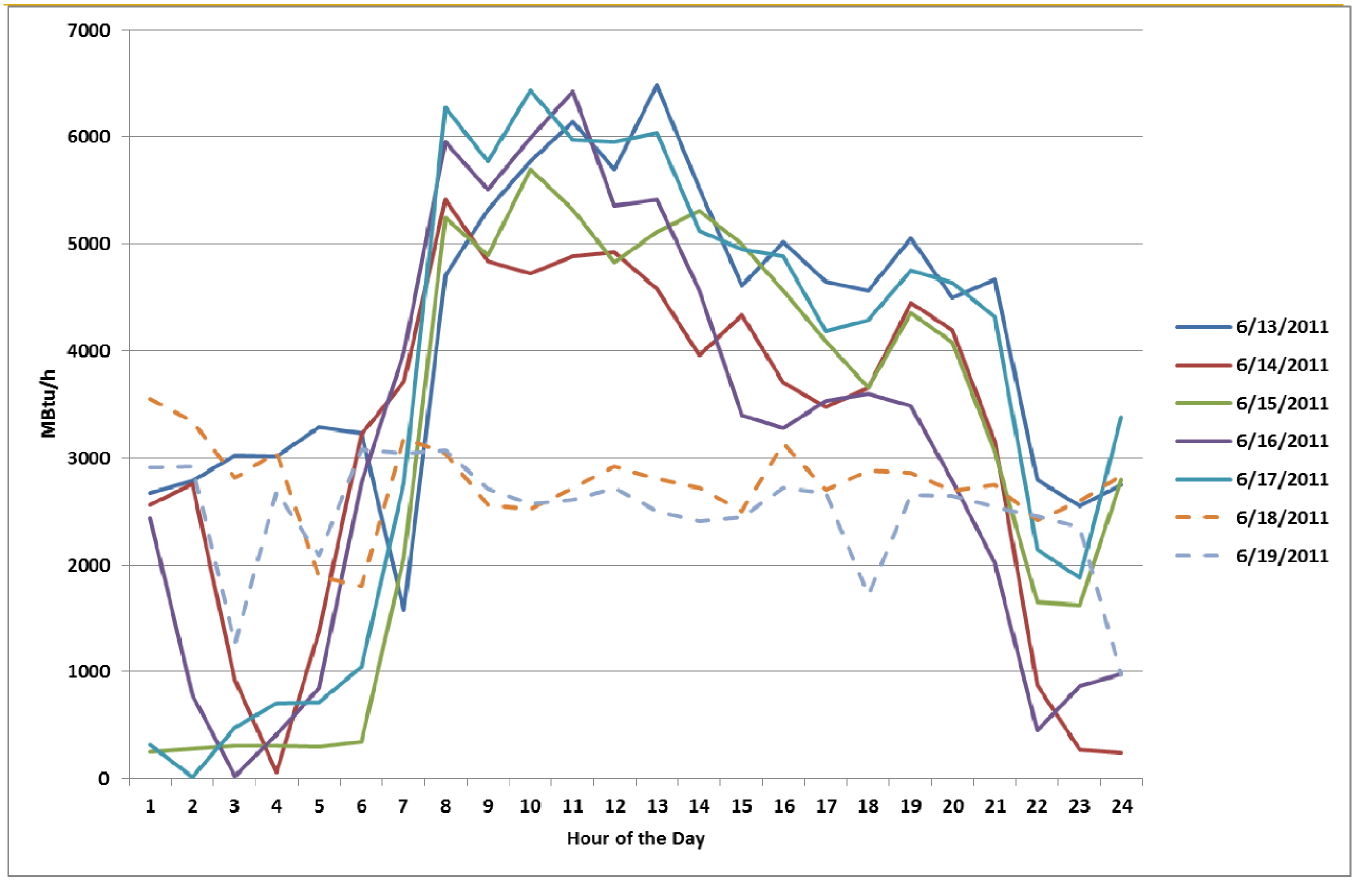

FIGURE 17 TOTAL ENERGY CENTER USEFUL THERMAL ENERGY OUTPUT PROFILE

Figure 17 shows the thermal load of the hospital which is less than the thermal capacity of all the engine generators shown operating in Figure 16. In fact, comparing Figure 17 to Figure 15 the graph shows that weekday summertime operation uses less thermal energy than in the winter. Note that the hospital has an absorption chiller but it does not fully utilize the output.

POWER GENERATION AND USEFUL THERMAL OUTPUT BY SITE

St Luke's Hospital

This CHP system should be viewed in a combined sense where the only site specific issue is the electric output compared to the electric load, as the discrete thermal data sensors are not accurate.

One hospital CHP generator (1,100 kW) generally ran in electric load following mode during August 2010, and both generators (totaling 2,200 kWh) ran in real-time energy and demand savings mode from September 2010 onward.

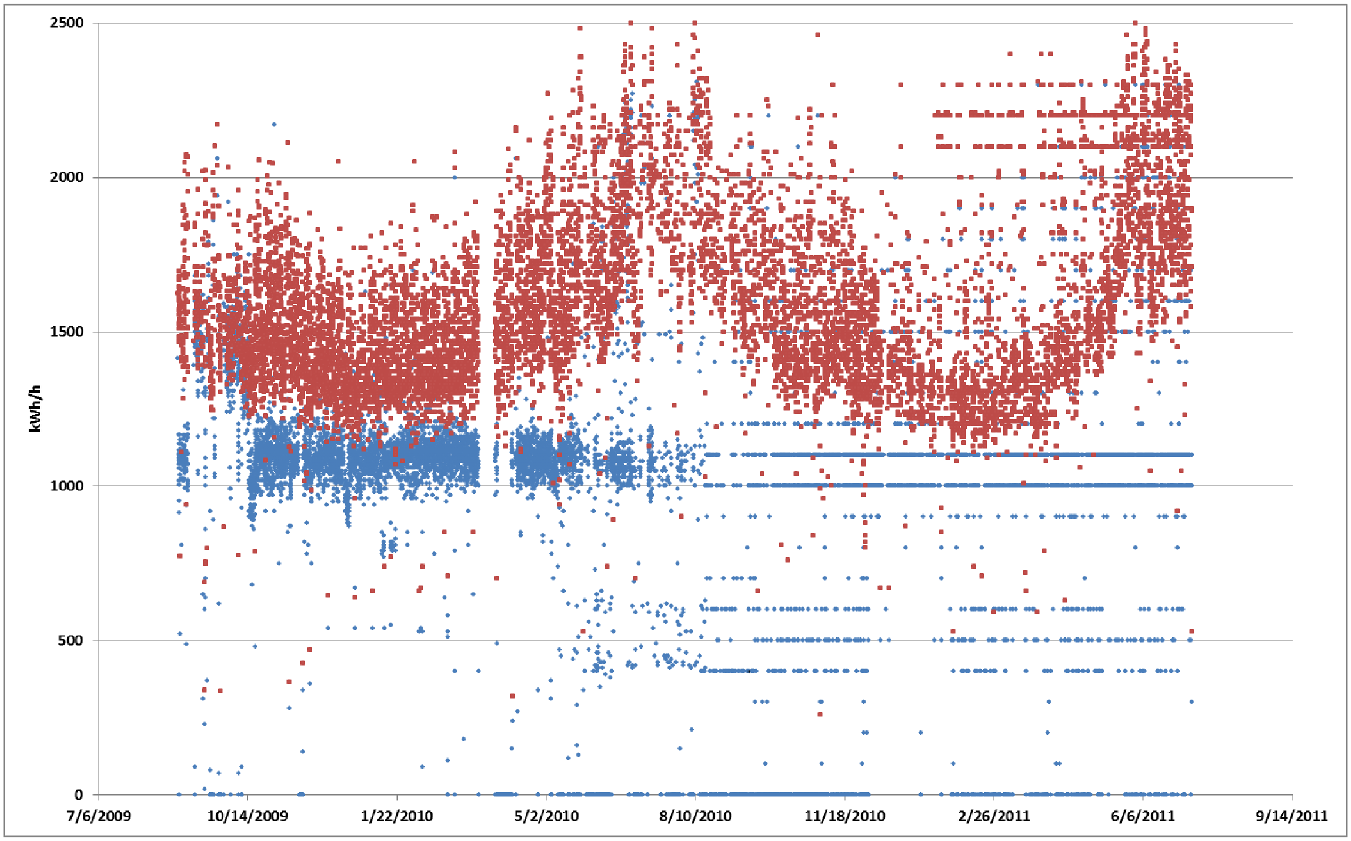

FIGURE 18 TOTAL HOSPITAL ELECTRIC LOAD (RED) AND DEDICATED GENERATOR KWH OUTPUT VERSUS TIME (BLUE)

October 2009 through September 2010 (Figure 18) shows electric load following pattern and, from September 2010 onward, that data shows shift to real-time demand reduction and energy savings operation. Figure 19 isolates the generator(s) output to better view the operating sequence shift. Note the change in power data beginning in August of 2010 occurs because hourly cumulative data is presented.

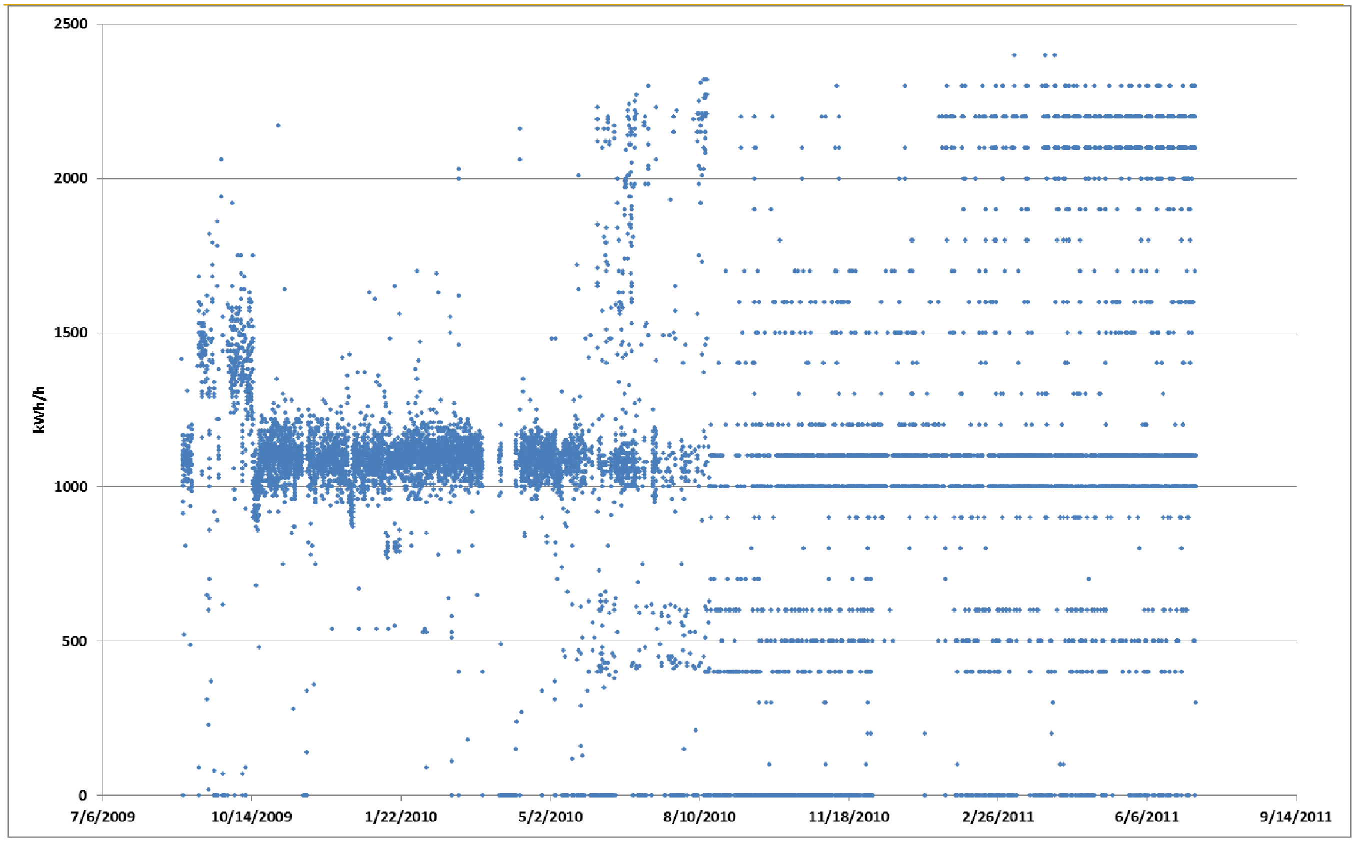

FIGURE 19 DEDICATED GENERATOR KWH OUTPUT VERSUS TIME

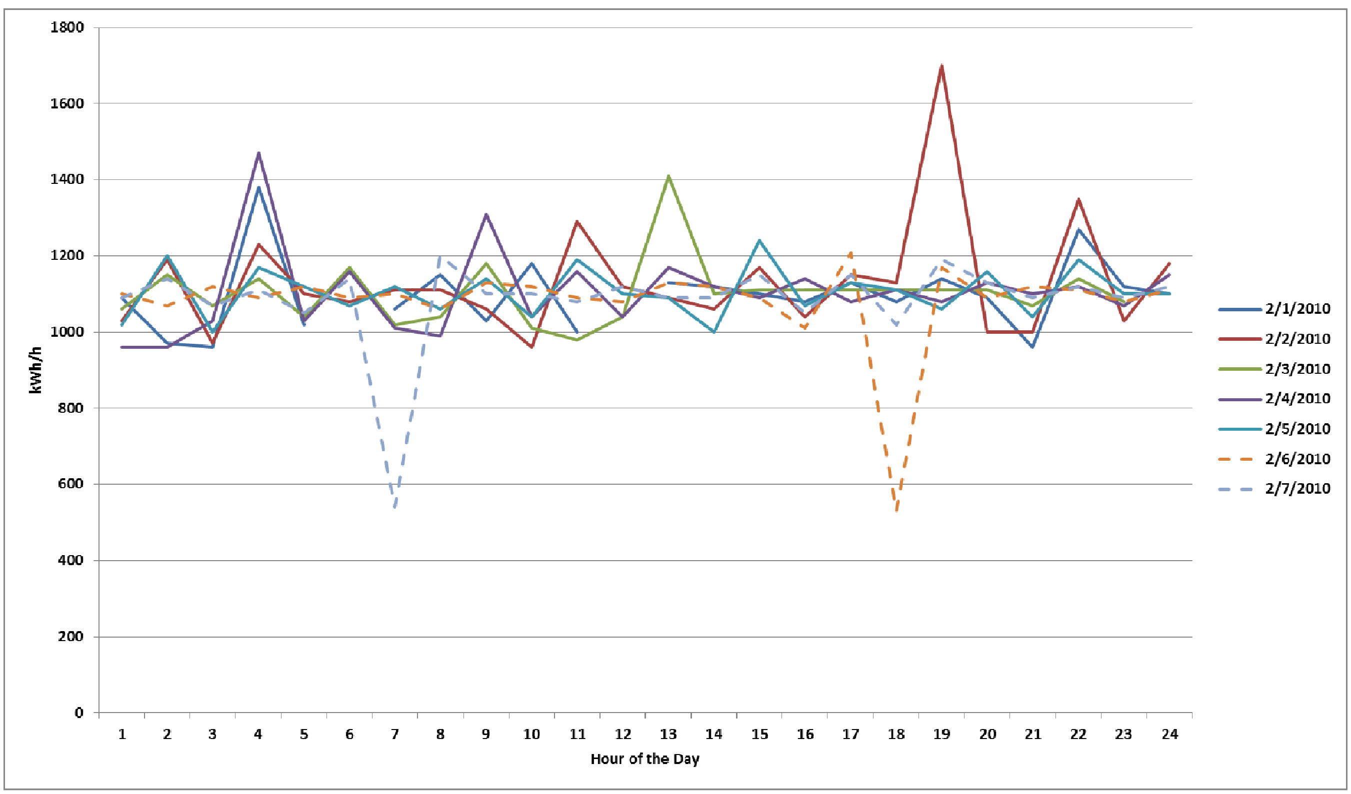

FIGURE 20 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

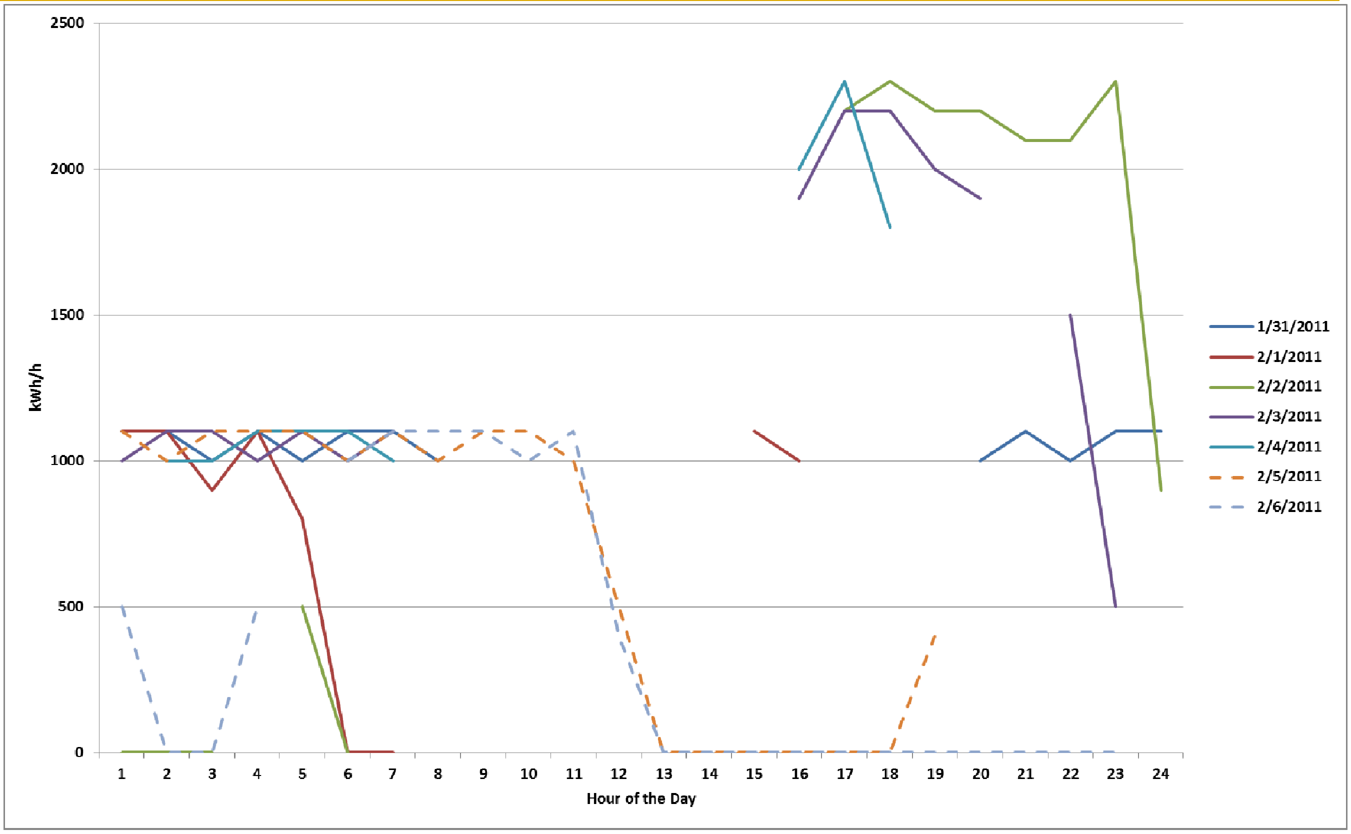

FIGURE 21 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

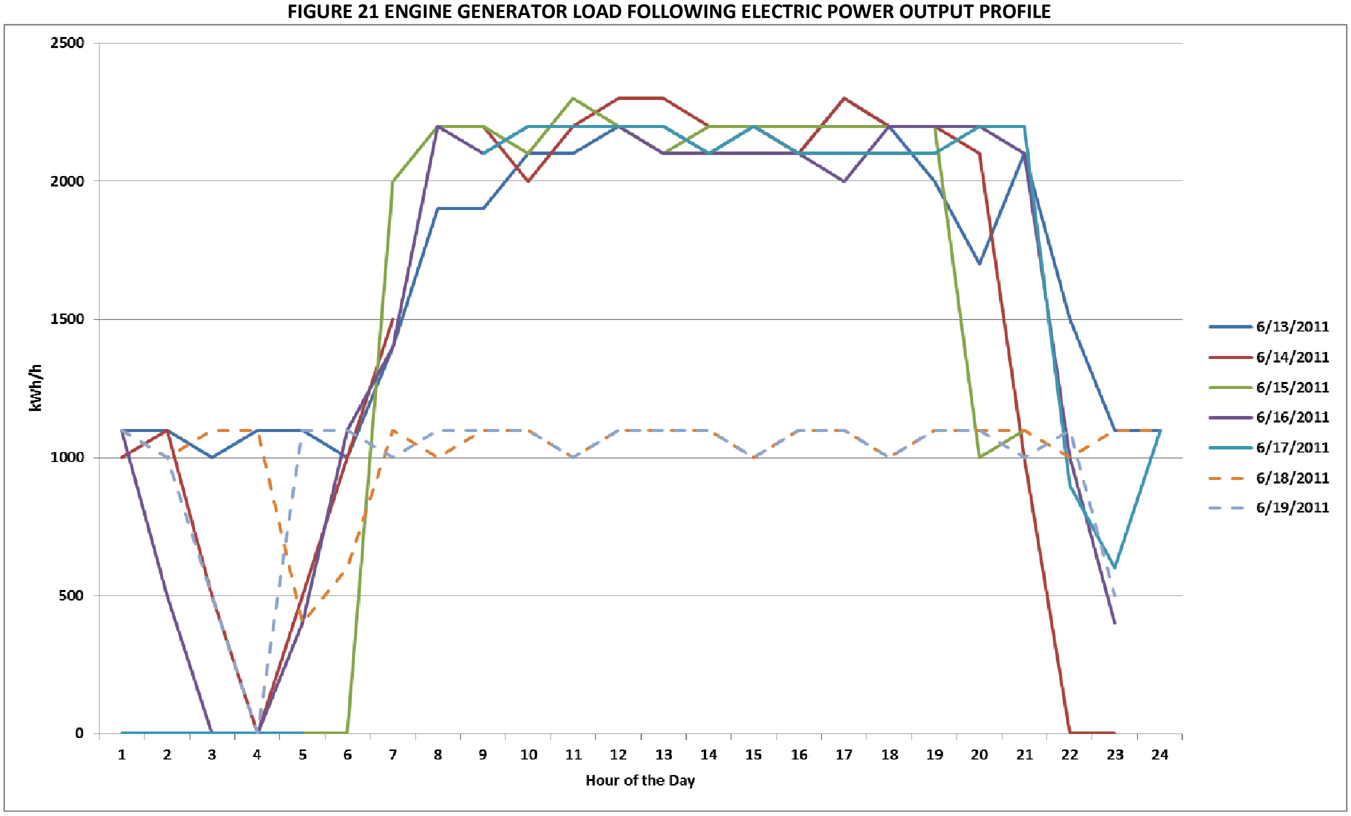

FIGURE 22 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

St Luke's Nursing Home

This CHP system should be viewed in a combined sense where the only site specific issue is the electric output compared to the electric load, as the discrete thermal data sensors are not accurate.

The nursing home CHP generator (330 kW) ran in electric load following mode generally through August 2010 and in real-time energy and demand savings mode from September onward. Note that the generator is the least efficient (~26% HHV) and operates against a different rate structure than the hospital or college.

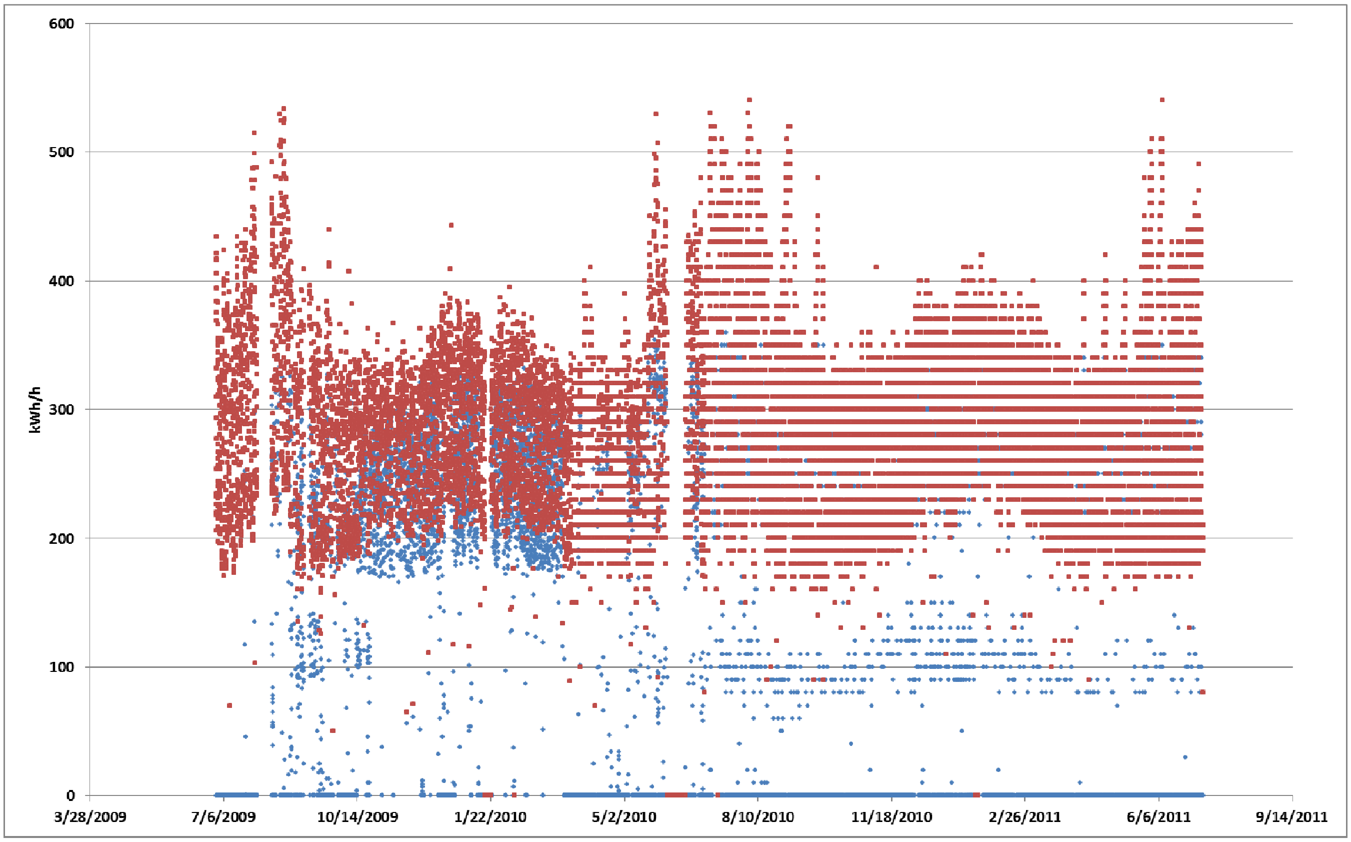

FIGURE 23 TOTAL NURSING HOME ELECTRIC LOAD (RED) AND DEDICATED GENERATOR KWH OUTPUT VERSUS TIME (BLUE)

Period 1 (Figure 23) shows electric load following pattern and Period 2 shows shift to real-time demand reduction and energy savings operation. Figure 24 isolates the generator output to better view the operating sequence shift. Note the change in power data beginning in April of 2010 occurs because hourly cumulative data is presented.

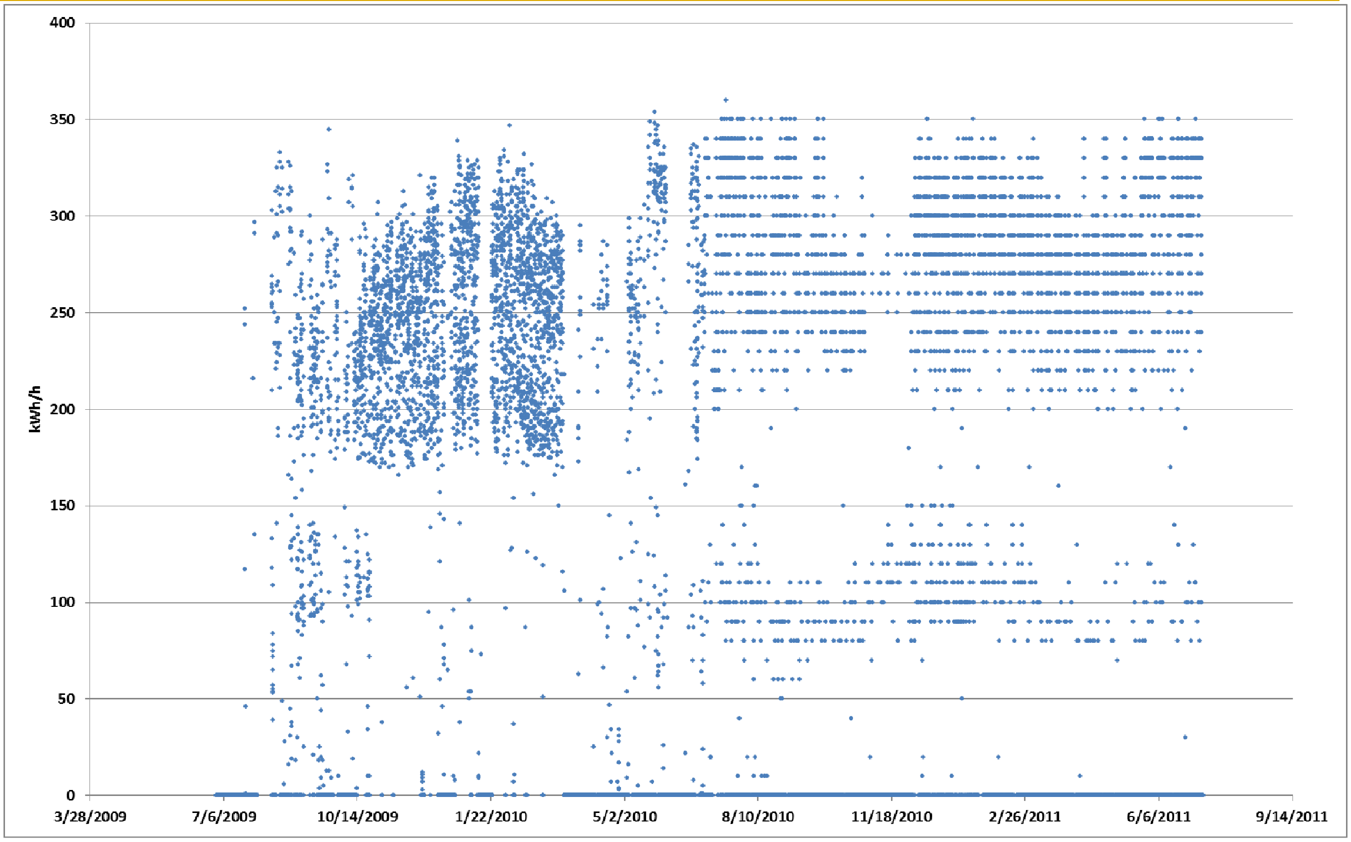

FIGURE 24 DEDICATED GENERATOR KWH OUTPUT VERSUS TIME

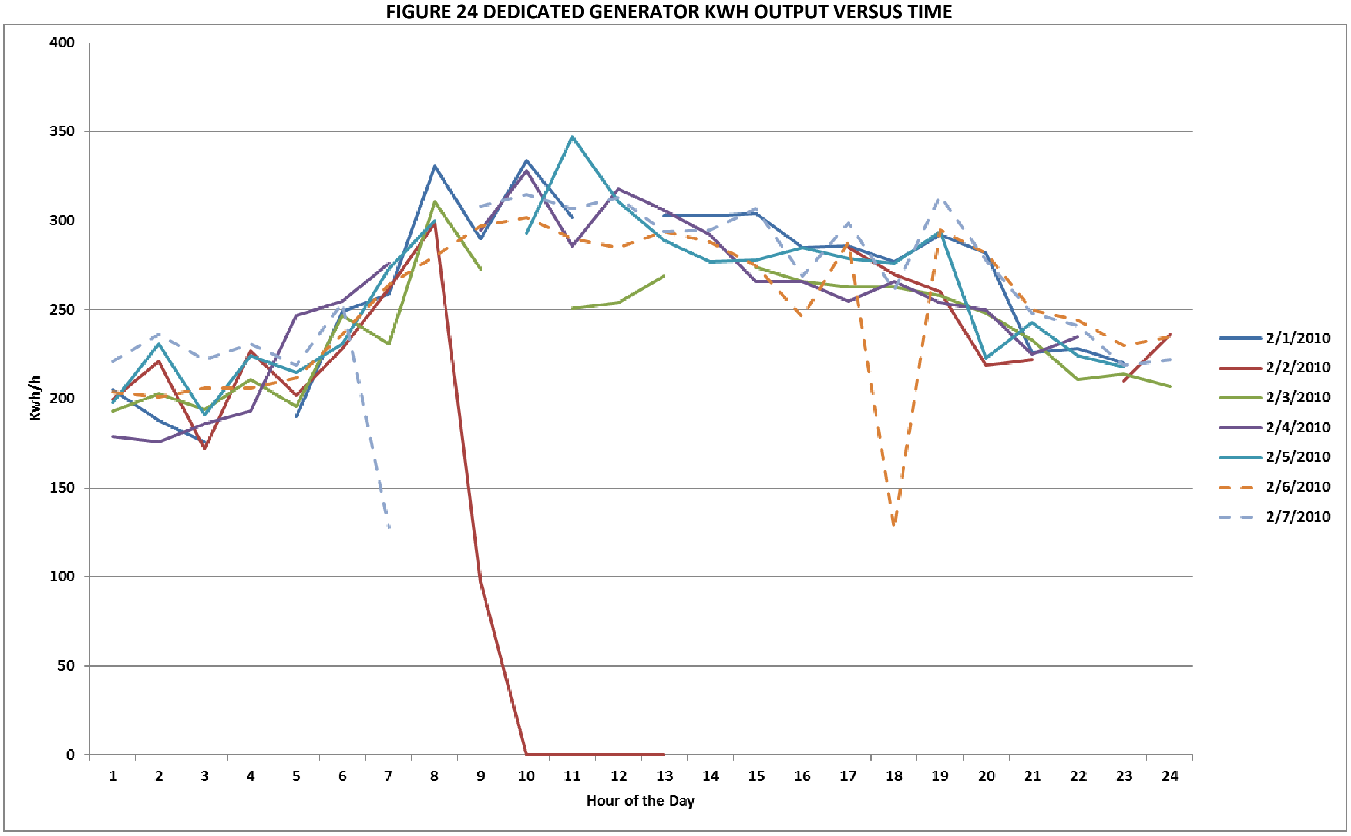

FIGURE 25 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

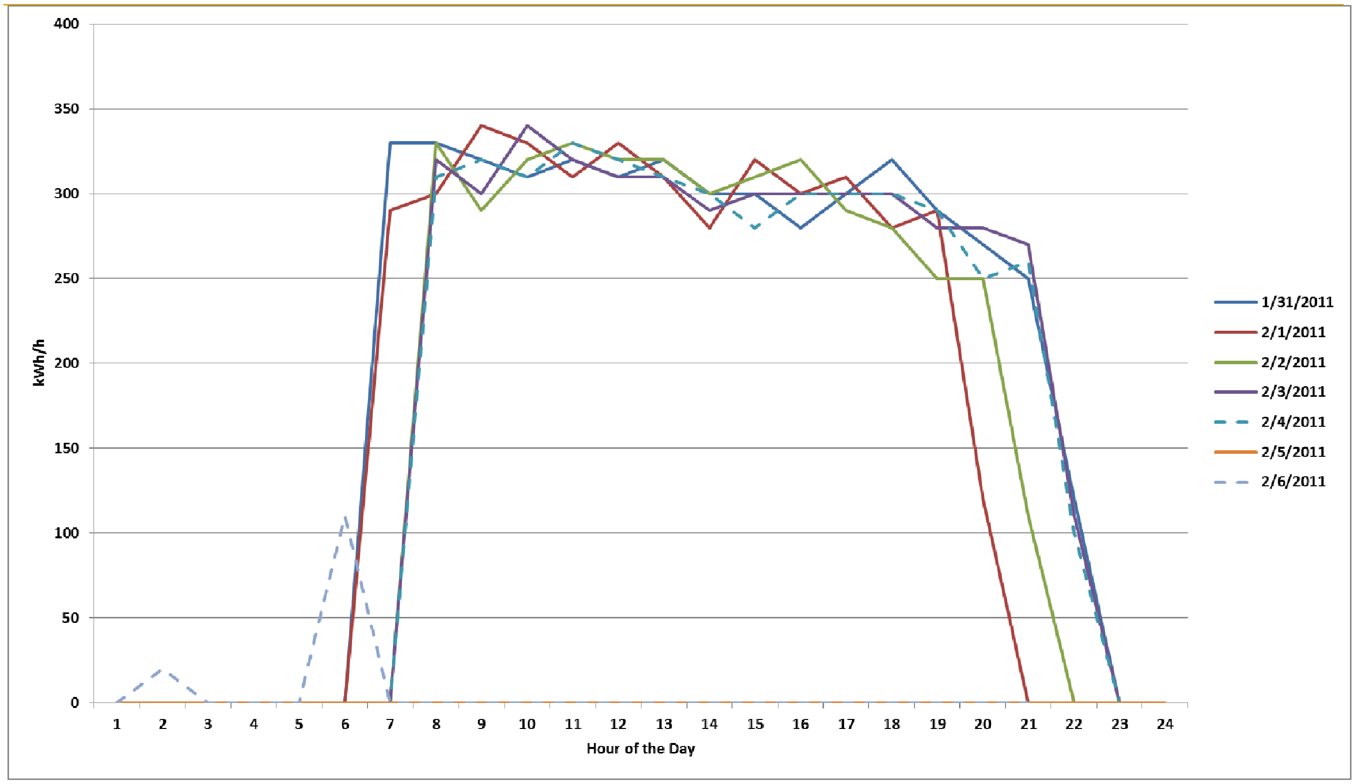

FIGURE 26 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

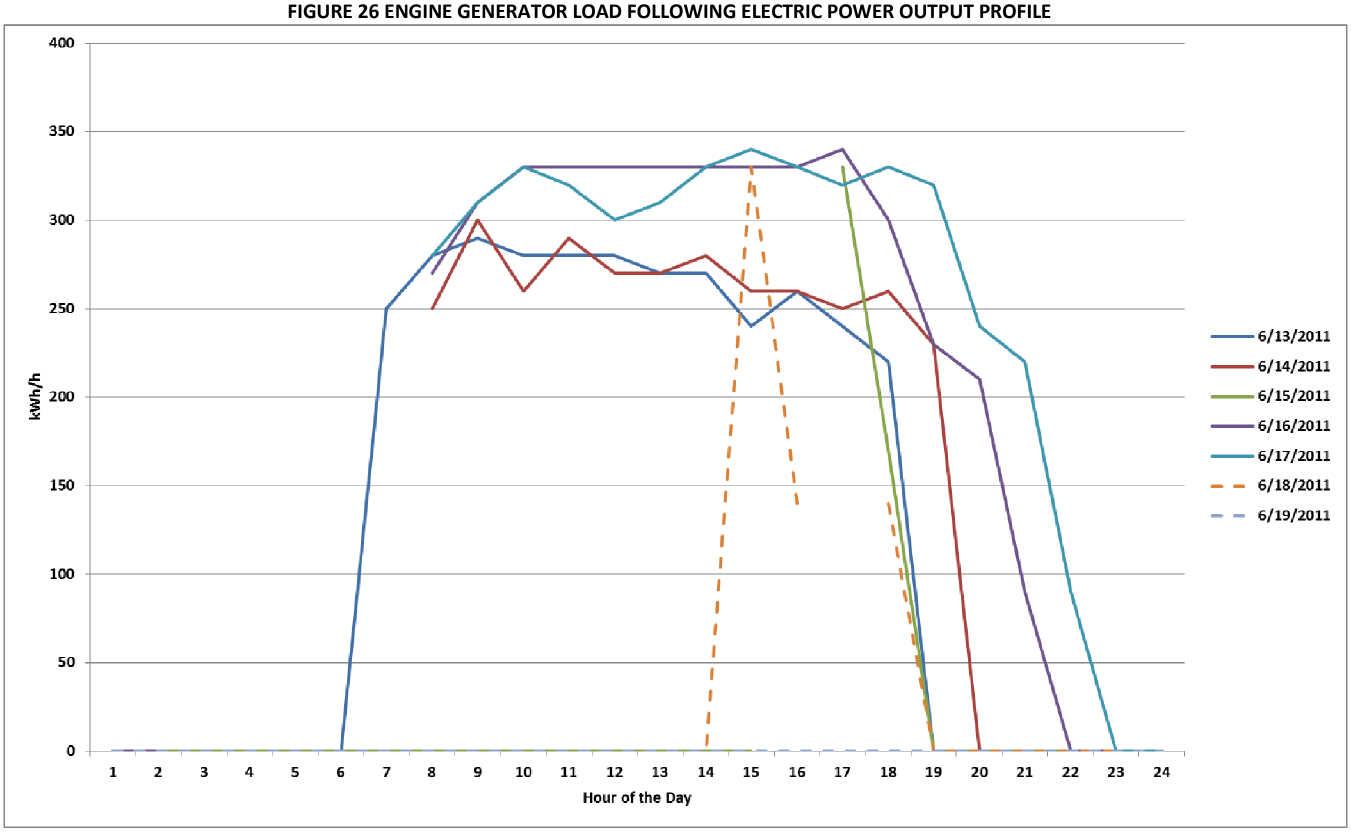

FIGURE 27 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

Utica College

This CHP system should be viewed in a combined sense where the only site specific issue is the electric output compared to the electric load, as the discrete thermal data sensors are not accurate.

This is the college engine. The heat (steam and hot water) goes to serve the hospital thermal loads. A global dispatch system (for all three facilities: college, hospital, home) chooses to run the system to meet the thermal loads and provide electricity. Since this facility has more expensive electric power, it often makes sense to run this system first.

In December 2010, the dispatch algorithms were modified to consider the as-used demand. This change tended to keep the college engine on more consistently from 6 am to 9 pm each weekday.

One college CHP generator (1,100 kW) ran in electric load following mode through April of 2011 and in real-time energy and demand savings mode from April 2011 onward.

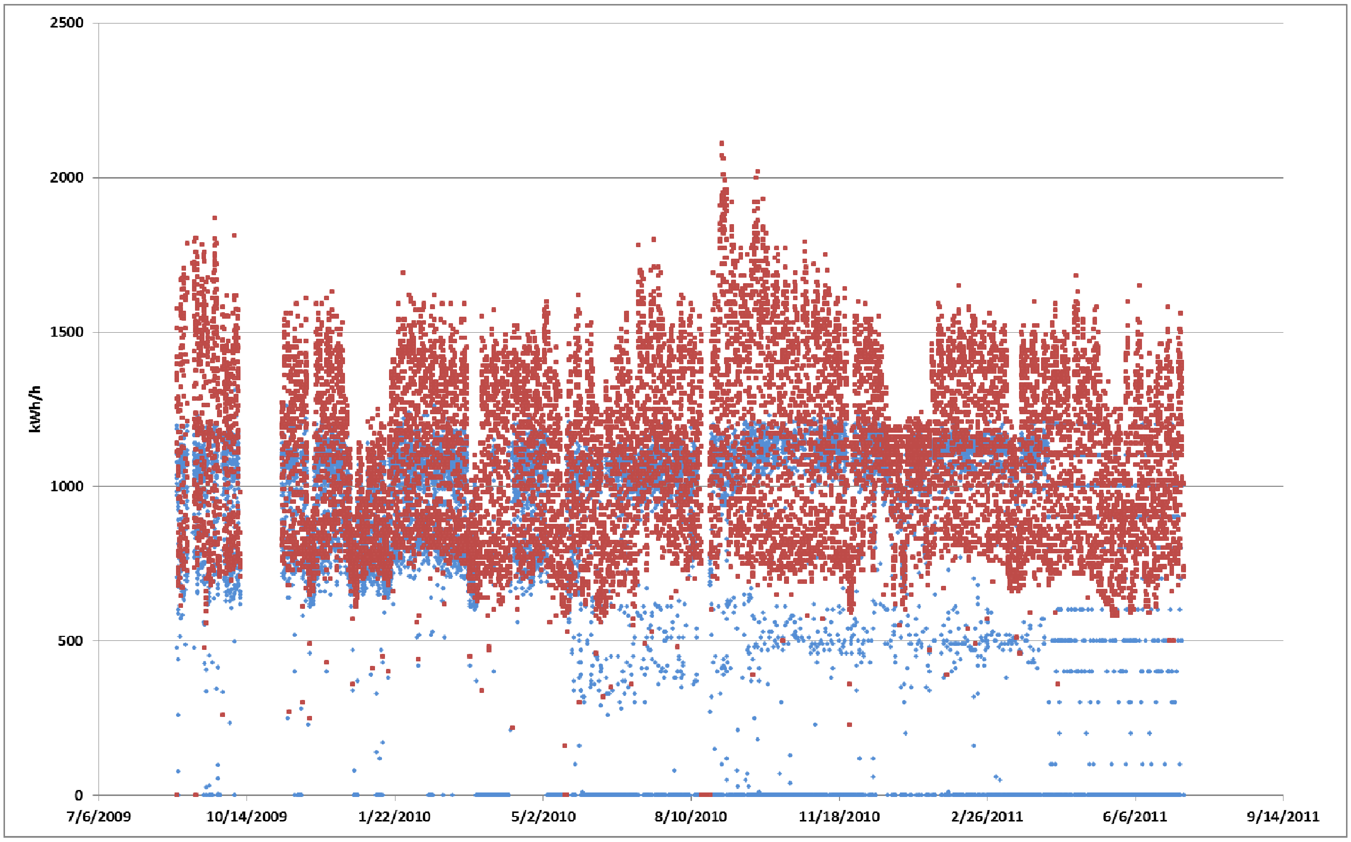

FIGURE 28 TOTAL COLLEGE ELECTRIC LOAD (RED) AND DEDICATED GENERATOR KWH OUTPUT VERSUS TIME (BLUE)

Period 1 (Figure 28) shows electric load following pattern and Period 2 shows shift to real-time demand reduction and energy savings operation. Figure 29 isolates the generator output to better view the operating sequence shift. Note the change in power data beginning in March of 2011 occurs because hourly cumulative data is presented.

FIGURE 29 DEDICATED GENERATOR KWH OUTPUT VERSUS TIME

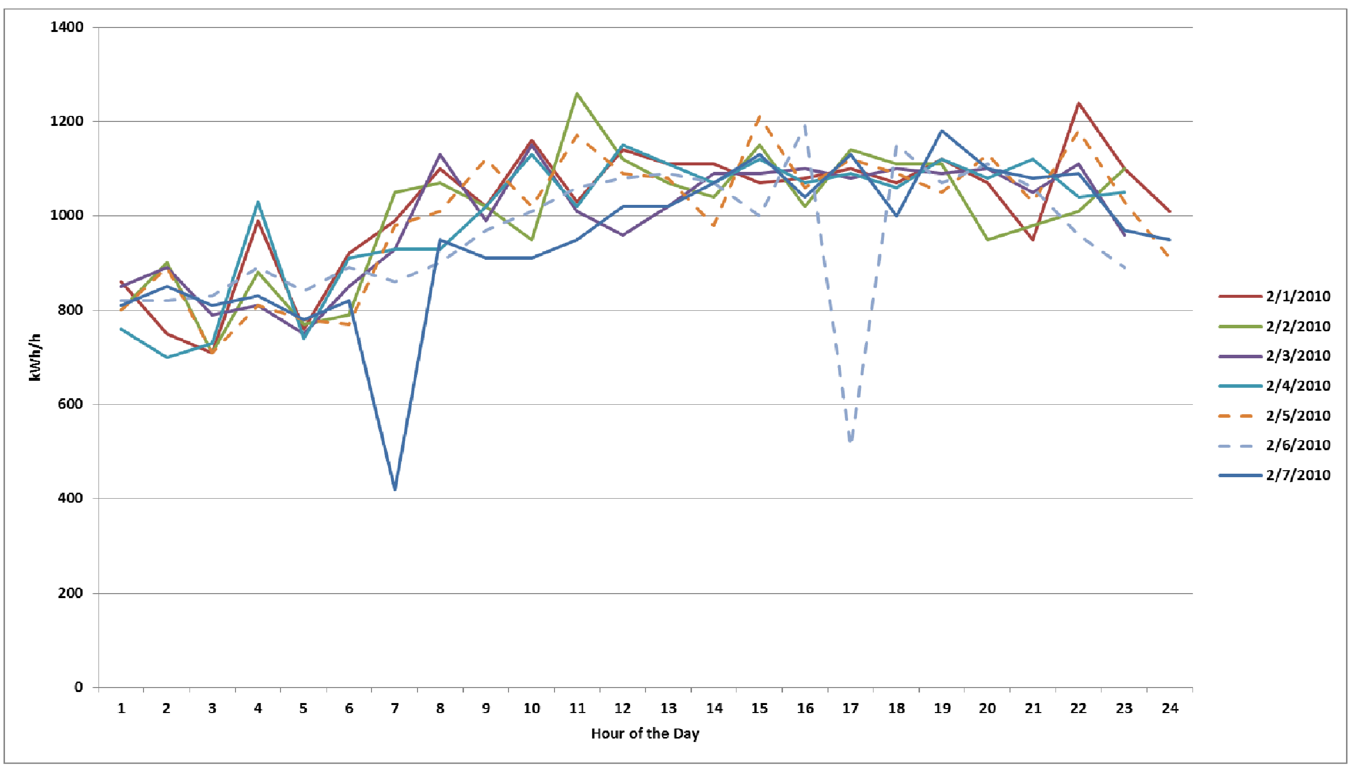

FIGURE 30 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

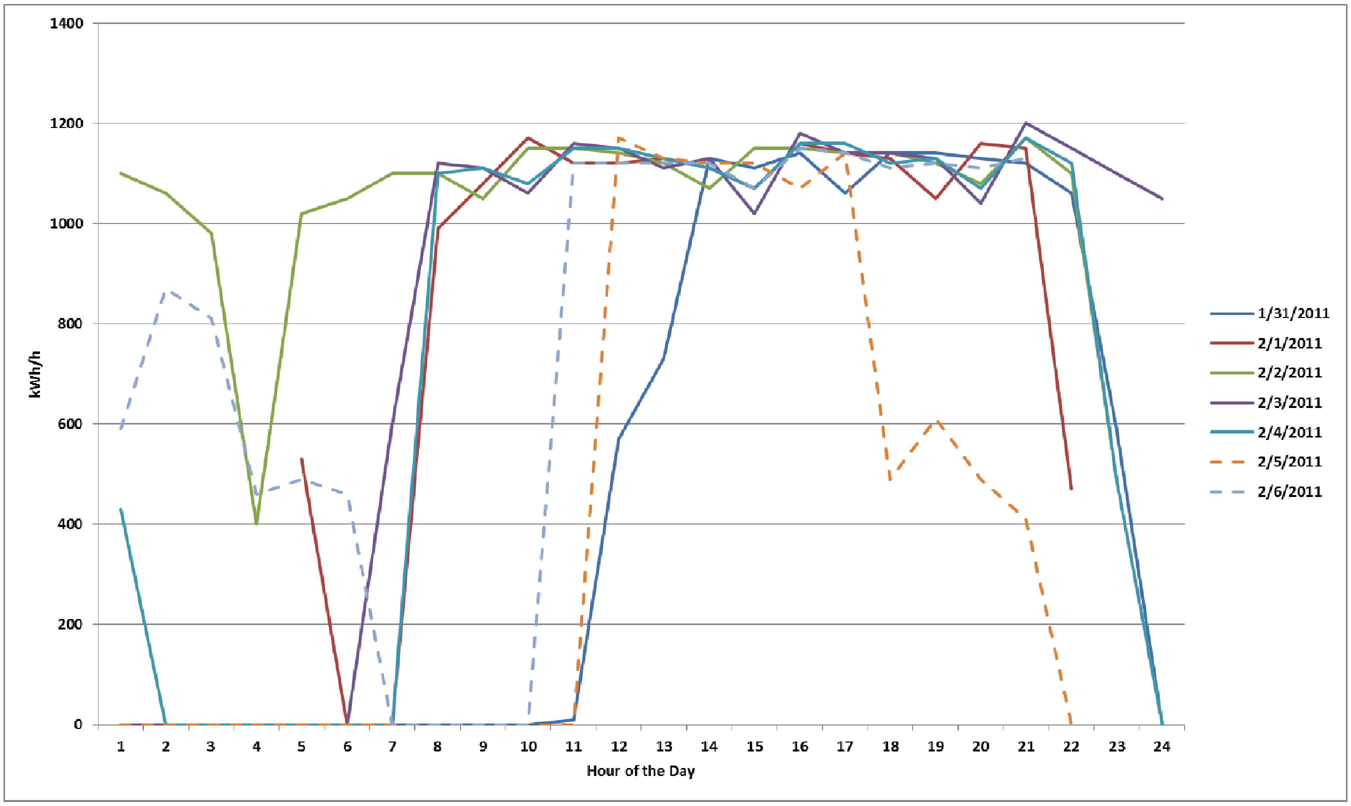

FIGURE 31 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

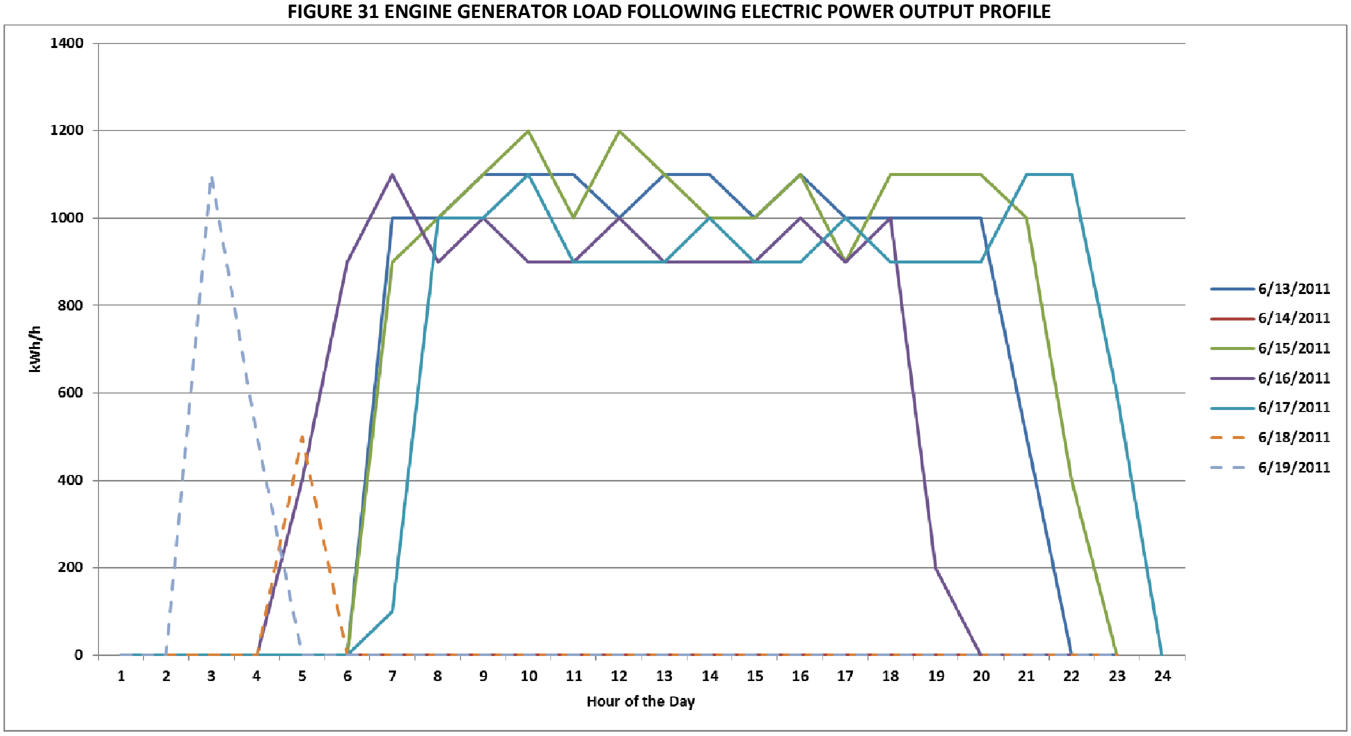

FIGURE 32 ENGINE GENERATOR LOAD FOLLOWING ELECTRIC POWER OUTPUT PROFILE

PERFORMANCE SUMMARY

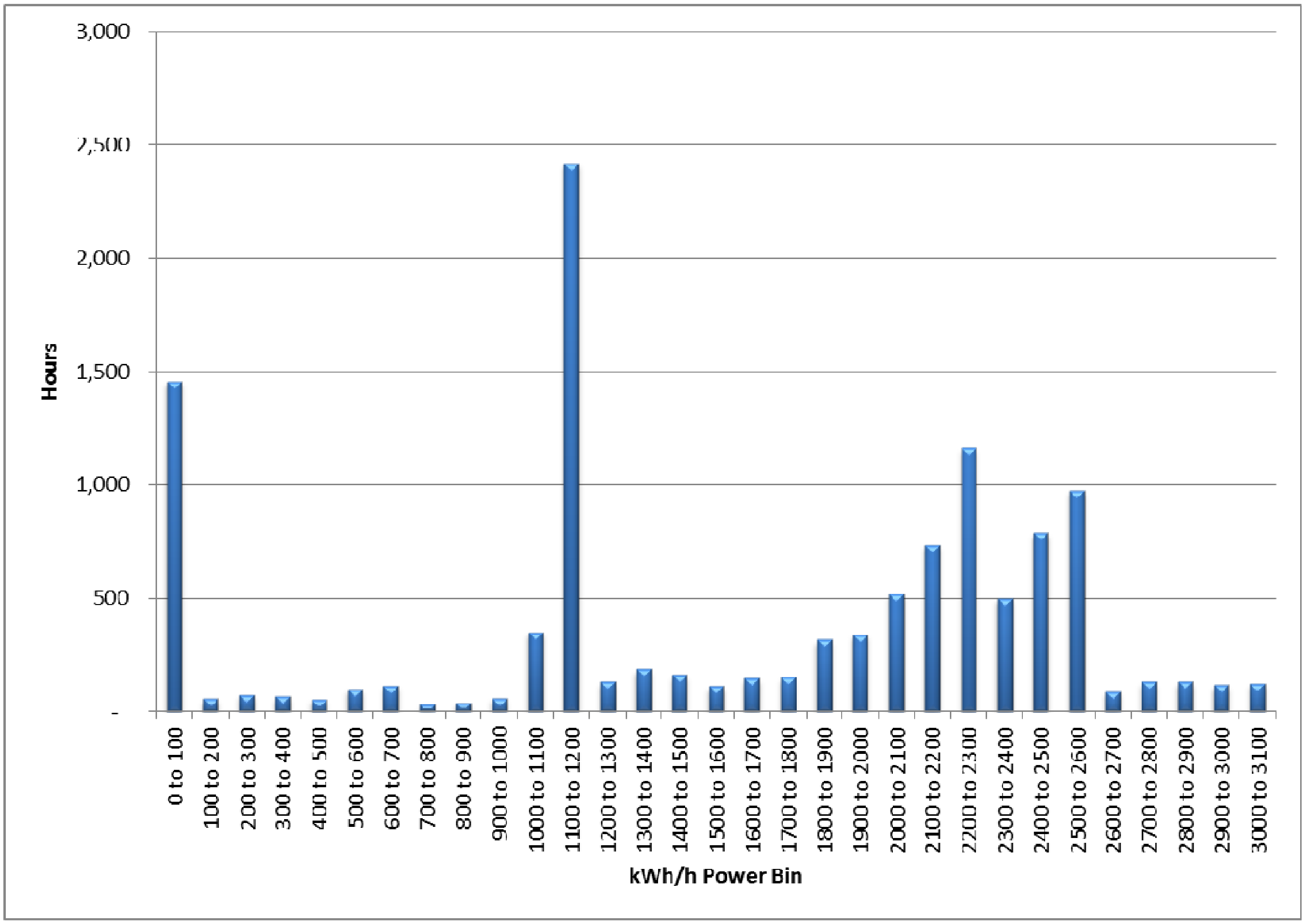

FIGURE 33 PERFORMANCE BY POWER BINS

During the 11,622 hours that met the range and relational checks 40.2% of this time, the CHP system delivered between 2 and 2.6 MWh/h. The system also delivered 1 to 1.2 MWh/h 23.8% of the time, largely for weekend operation. (Figure 33).

LESSONS LEARNED

TABLE 2 COMBINED 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
January-10	744	1,582,189	17,061.7	4,220.3	31.0%	24.3%	55.3%
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December-10	741	1,838,418	20,388.6	3,939.8	30.2%	18.9%	49.1%
January-11	743	1,893,145	20,955.4	4,087.5	30.2%	19.1%	49.4%
February-11	670	1,341,136	14,365.7	2,931.1	31.2%	20.0%	51.2%
March-11	743	1,607,554	17,608.9	3,433.6	30.5%	19.1%	49.7%
April-11	667	1,367,277	14,546.2	2,597.3	31.5%	17.5%	49.0%
May-11	718	1,462,810	15,474.7	2,878.1	31.6%	18.2%	49.9%
June-11	712	1,406,085	14,968.5	2,584.9	31.4%	16.9%	48.4%
July-11	741	1,820,208	19,326.3	3,213.5	31.5%	16.3%	47.8%
Total preceding 12 months	**8635**	**17,823,478**	**194,704.4**	**35,587.8**	**30.6%**	**17.9%**	**48.5%**

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

The Energy Center consists of: two 1,100 kW Cummins natural gas -fired spark ignited engines to serve the electric power needs of the hospital, one 1,100 kW Cummins natural gas -fired spark ignited engine to serve the electric power needs of Utica College, and one 330 kW Cummins natural gas -fired spark ignited engine to serve the electric power needs of the Nursing Home. All useful thermal energy is supplied to the hospital.

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.

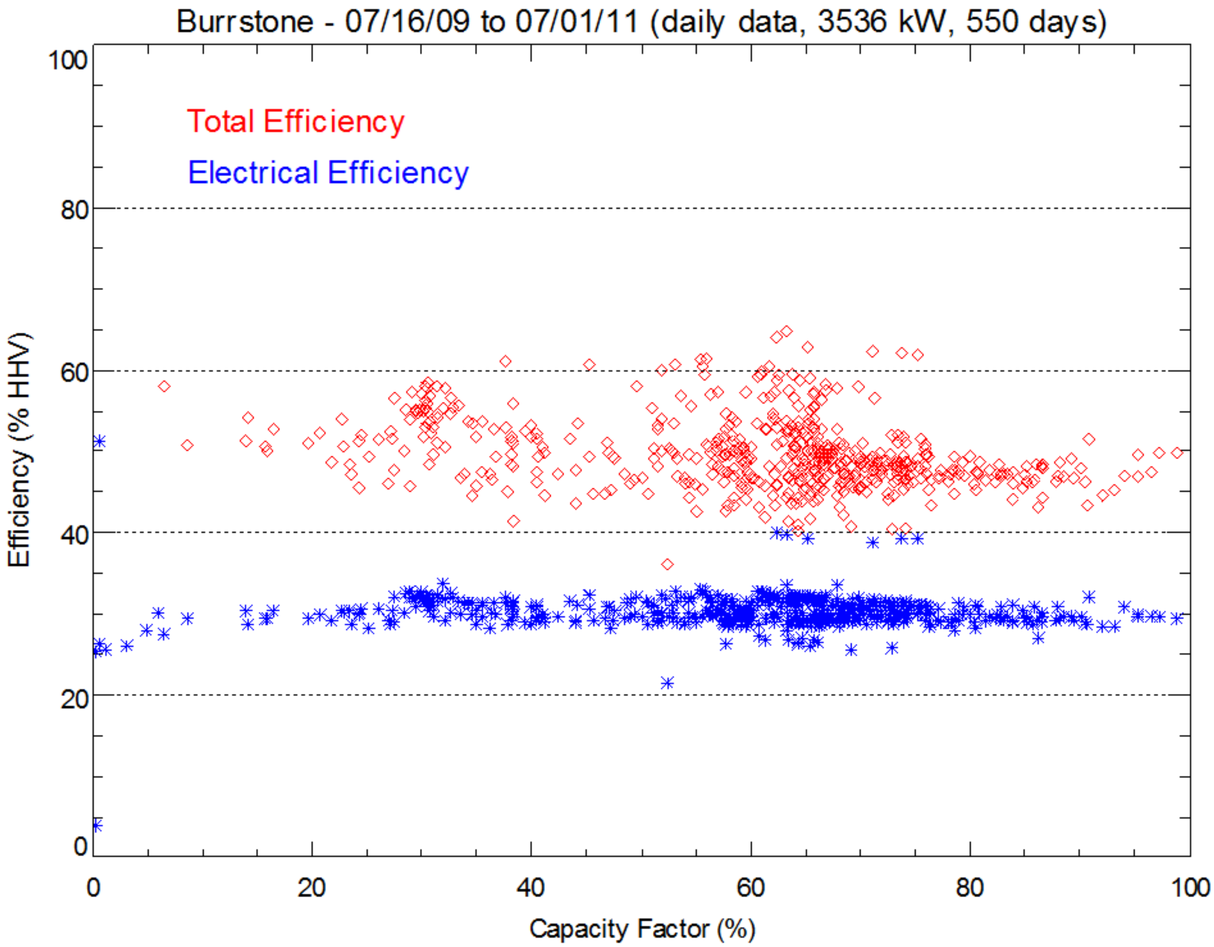

FIGURE 34 CAPACITY FACTOR[3]

Capacity Factor (Figure 34) presents the CHP generated power efficiency over the time period (550 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 between 1% and 100% of the generating capacity at about 30.6% power efficiency (HHV). This site is driven by power pricing including ancillary price signals to support the electric grid which accounts for the wide spread in delivered power. Note the double camel hump in electric efficiency which occurs from the particular engine generators in operation. The useful thermal energy (steam) operates coincidently when power demand is required which accounts for an average of 17.91% thermal efficiency (HHV). Note the heat recovery increases as the capacity is reduced which merely reflects higher thermal recovery during lower power production.

This site is unique in that it served the electric loads in three facilities (hospital, home, college) while meeting the thermal loads in one facility (hospital). Furthermore, each facility has permission to export power (except the nursing home) to the grid and all the facilities are on National Grid's real time pricing. This situation created a large number of possible operating scenarios. To address this issue the site developed and implemented, in 2010, an economic dispatch control system to select the most economically advantageous

[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.

operating scenario for each hour. While an initial feasibility study might have implied that simple thermal load following scenarios would be optimal, there are many periods when this is not the case. The ability to respond to real time electric prices, daily as-used demand charges, and unexpected opportunities to export power to the grid enhanced the economic value of this CHP system.

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 the channels WCOL_GEN, WHSP_GEN, and WHOM_GEN (kW). This power data is converted into kWh and summed across each hour.
2. **DG/CHP Generator Gas Use (total cubic feet)** The data for Generator Gas Input comes from the channel FG (cf/h). The data is averaged into hourly data for the online database.
3. **Useful Heat Recovery (total MBtu)** The Useful Heat Recovery comes from the channels FSCG (lb/h), FW (gpm), TL, and TE (F). FSCG is converted to MBtu/h using 1.0194 MBtu/lb. The heat transfer on the hot water side is calculated:

$$.5 * FW * (TL - TE) = Q \text{ (MBtu/h)}$$

Both channels are converted to MBtu and summed across each hour.

Data Collection and quality for this site for much of the period is in the high 90th percentile or at 100%. (Table 3) Exceptions are April 2011 for all parameters.

TABLE 3 PERCENTAGE OF GOOD DATA

	Percentage of Good Data		
	Power	**Gas Use**	**Useful Heat**
January-10	100.0%	99.7%	100.0%
February-10	99.9%	99.9%	99.7%
March-10	99.7%	99.6%	99.6%
April-10	96.5%	98.7%	98.4%
May-10	98.4%	98.5%	98.3%
June-10	99.7%	99.0%	97.5%
July-10	99.5%	99.5%	98.3%
August-10	99.3%	99.1%	98.4%
September-10	99.4%	98.6%	96.8%
October-10	98.0%	99.9%	96.9%
November-10	99.4%	99.4%	98.2%
December-10	99.6%	100.0%	99.6%
January-11	99.9%	99.5%	95.3%
February-11	99.7%	96.1%	98.8%
March-11	99.9%	99.9%	98.9%
April-11	92.6%	93.3%	89.9%
May-11	96.5%	96.9%	96.5%
June-11	98.9%	99.7%	97.4%
July-11	99.7%	99.5%	98.1%