



Beloit Memorial Hospital Cooling, Heating, & Power (CHP) Plant

Site Description

Beloit Memorial Hospital (BMH) was opened in 1970 as a single eight (8)-story building of which the first six (6) floors are occupied with approximately 187 beds. The hospital has approximately 340,000 square feet of space and operates 24 hours per day, 365 days per year.

Faced with the need to upgrade its electrical distribution system and to address other energy capacity issues that developed over the years, Beloit Memorial Hospital decided to add a distributed energy system, instead of simply upgrading or replacing the existing equipment. This new 3,000 kW_e distributed energy system provides maximum flexibility to both the hospital and the local electric and gas utility company, Alliant, in regards to electricity, heating, air conditioning, and hot water usage.

The CHP plant helps the hospital with its heating and cooling requirements by using the recovered heat from the generation of electricity to provide additional heating and cooling capabilities. The CHP equipment normally operates from approximately 8:00 am to 10:00 pm Monday thru Friday, 52 weeks per year and supplies all of the domestic hot water for the facility. 95% of the hot water usage occurs during the hours that the CHP system is operating.

In general, hospitals are very good candidates for CHP applications because they operate 24/7, 365 days/yr., have high thermal loads (high hot water, steam and cooling heating) loads to meet the need for daily showers, laundry and dishwashing requirements.



Figure 1: Beloit Memorial Hospital Facilities

CHP Configuration

BMH selected Ballard Engineering of Rockford, IL to design, engineer, install and start up the 3,000 KW CHP system. The major components of this system are listed below.

- Two (2) Fairbanks Morse dual fuel 900 RPM, 1,500 KW engine generator sets.
- One (1) 6,000 AMP tiebreaker, two (2) 3000 AMP, 480V automatic generator breakers.
- A 12 KV automatic main service breaker.
- One (1) 434-RT Carrier (model number 16JB047) single stage hot water absorption chiller.
- Heat exchangers.
 - One (1) shell and tube heat exchanger, 7.66 MBTU/HR used as a back up for cogenerated heat to drive the absorption chiller.
 - One (1) Sondex plate and frame heat exchanger, 6.733 MBTU/HR, 450 GPM.
 - One (1) Sondex domestic hot water heat exchanger, 6.149 MBTU/HR, 800 GPM.
- Two (2) Cain 2.389 MBTU/HR/generator set finned tube heat recovery units, (Model # UTR1.)
- Two (2) outdoor excess heat rejection radiators. (1 jacket water and 1 auxiliary water)
- A graphic system for monitoring and record keeping of all major equipment readings.

A two (2) level, building was constructed to house the engine generator sets and the control room.

Figure 2 to the right is a simplified process flow diagram of the BMH CHP system. The hospital started commercial operation of the plant on June 1, 2000 and ran for approximately three (3) months before shutting down due to the rising costs of natural gas. The plant was started up again on April 1, 2001 and is scheduled to operate from 8:00 am to 10:00 pm Monday thru Friday, 52 weeks per year.

The Fairbanks Morse engines act as both a peaking and emergency power source for the hospital. The CHP system is designed to automatically back up the entire hospital if the utility's power supply is interrupted.

Figure 3 shows one (1) of the Fairbanks–Morse Generator sets.



Figure 3: Fairbanks–Morse Gen. Set

BMH is also able to sell electricity back to the local utility as well as produce air conditioning for the facility in the summer and hot water heat for the building in the winter. The air conditioning is made using the Carrier 434 ton absorption chiller (Figure 4) fired by hot water generated from engine exhaust.

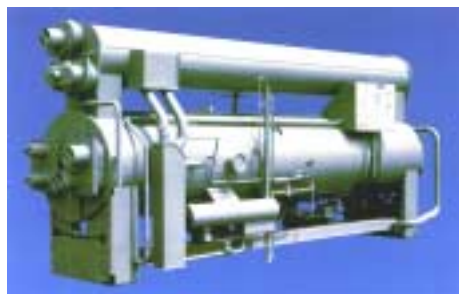


Figure 4: Carrier Absorption Chiller

The hospital's electrical distribution system consists of three (3) electrical buses, which are all supplied from the

CHP system with 100% back-up capacity. GE-Zenith controls supply the paralleling switchgear, which is designed to parallel with the local utility. This allows the hospital to take advantage of the utility's curtailment rate by supplying all of their own electric power.

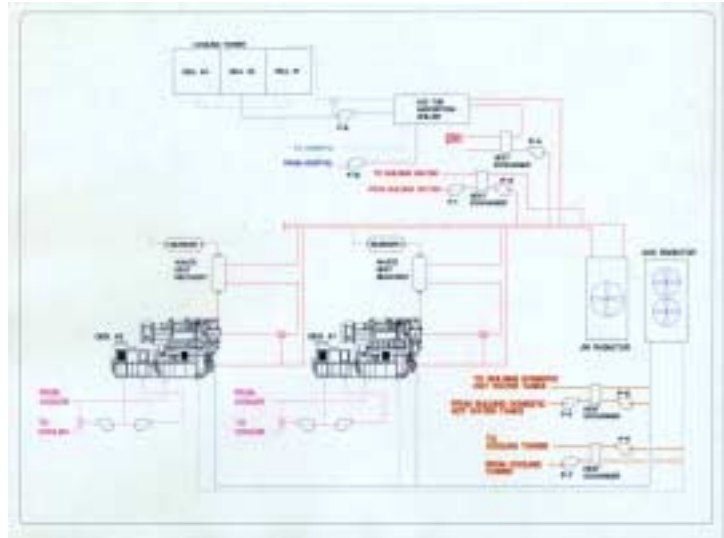


Fig. 2: Simplified Process Flow Diagram of CHP System

Financial Statistics

Table 1 below provides a brief summary of the benefits of the CHP system installed by the hospital. The CHP cost of \$1,200,000 is only for the equipment associated with CHP system. The total project cost of upgrading and replacing the existing electrical distribution equipment **and** adding the CHP equipment was approximately \$3,000,000. The CHP system provided a revenue source to help finance the electrical system upgrade.

3,000 kW CHP System Economics	
Annual Savings:	\$223,181
CHP Only, Project Cost:	\$1,200,000
CHP Only, Simple Payback:	5+ Years
Natural Gas Cost:	\$5.49 MMBTU
Electricity Generation Cost:	2.6¢ / kWhr
Maintenance Cost:	0.7¢ / kWhr
Heat Recovery Savings:	1.0¢ – 1.5¢ / kWhr
Equivalent Electrical Cost:	1.8¢ – 2.3¢ / kWhr
CHP System Cost / kW:	\$400 / kW

Table 1: CHP System Economics

Energy/Financial Analysis Overview

Based on actual data from the local utility and the hospital, an analysis of the utility costs was conducted and is summarized in the charts and tables shown on this page.

The following actual to date parameters were used:

- Maintenance costs: \$0.0066 / KWH
- Mfg. heat recovery rates:
 - 6.733 MMBTU/HR (Bldg. hot water)
 - 6.149 MMBTU/HR (Dom. hot water)
- Engines run at 100% capacity during oper. hrs.
- Operating hours: M-F 8:00am to 10:00pm
- All hot water produced by heat recovery is used

Figures 5 and 6 show the amount of electricity generated and sold back to the utility and the amount of gas used.

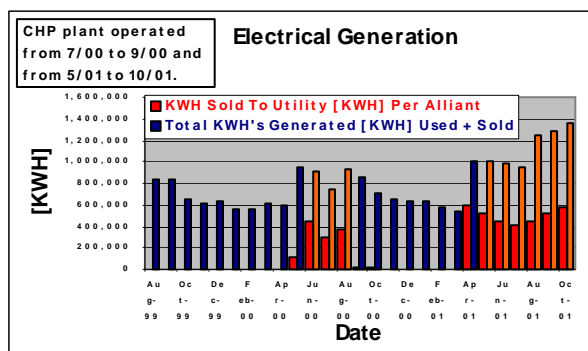


Figure 5: Electrical Generation

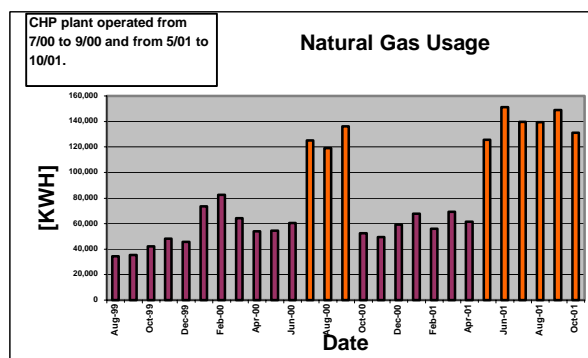


Figure 6: Natural Gas Usage

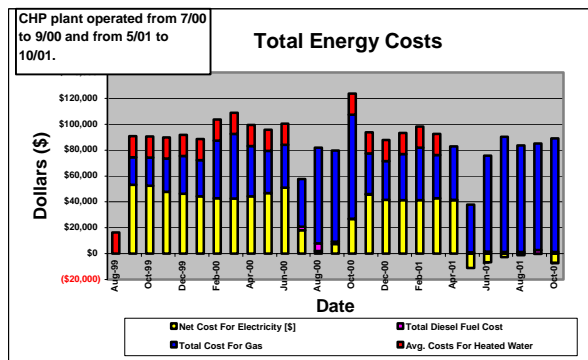


Figure 7: Total Energy Costs

Figure 7 shows the total amount BMH paid for energy during the past two (2) years.

Results

As indicated by Figures 5 thru 7, when the CHP system was operating, natural gas usage increased significantly, and correspondingly, the costs for natural gas as well. However, during the same time period the net cost for electricity decreased significantly as a result of generating electricity and selling back the excess electricity

Item	BCHP Plant	Baseline Plant
REVENUE / SAVINGS		
Electricity Sold Back to Utility [KWH/yr.]	6,043,886	0
Money Rec'd From Sale to Utility [\$/yr.]	\$218,789	\$0
Avoided Costs Power Gen'd & Used [\$/yr.]	\$253,774	\$0
Avoided Costs to Heat Water [\$/yr.]	\$195,989	\$0
TOTAL REVENUE	\$668,552	\$0
EXPENSES		
Wages to Support Power Generation	\$0	\$0
Diesel Fuel For Power Generation	\$18,405	\$0
Natural Gas Purchased From Alliant	\$907,477	\$389,367
Electricity Purchased From Alliant	\$149,634	\$306,777
Maint. Costs Assoc. With Power Generation	\$66,000	\$0
Other Costs Assoc. With Power Generation	\$0	\$0
TOTAL ALL EXPENSES	\$1,141,515	\$696,144
TOTAL COSTS (Expenses - Revenue)	\$472,964	\$696,144

generated by the CHP system to the local utility.

Table 2: CHP Economics

Table 2 above summarizes the results of the data collected since the CHP system was installed. The CHP system has not operated every month during the past year; however, in the future, BMH plans to operate the equipment year round, Monday thru Friday from approximately 8:00 am to 10:00 pm.

This is dependent on the contract price that is paid for natural gas. If the contract cost of natural gas exceeds the breakeven point (currently \$9.64/MMBTU), BMH will reevaluate the economics associated with the CHP system, and decide whether to continue operating the system.

As Table 2 highlights, the amount of natural gas purchased was increased to power the gen-sets. However, this additional cost is offset by the lower amount paid for electricity to the local utility, as shown in Figure 7.

Assumptions Used in Analysis

- Totals are based on 12 months of operation using prorated totals from monthly averages where less than 12 months of actual data is available.

- *Avoided costs for power generated and used are based on the costs that would have been charged by the local utility if the same amount of power was not generated on-site. Actual data from BMH was prorated and a cost of \$0.026/kWh was used to calculate the savings.*
- *Avoided costs to heat water are based on the estimated costs required for gas that would have been charged by the utility if the waste heat was not recovered by the on-site generator system. Estimates are calculated as:*
For Building hot water: 6.733 MMBTU/hr. x 14 hrs/day x \$5.49/MMBTU x 5 days/wk. x 52 wks/yr. = **\$134,550/yr.**
For Domestic hot water: 6.149 MMBTU/hr. x 50% x 14 hrs/day x \$5.49/MMBTU x 5 days/wk. x 52 wks/yr. = **\$61,440/yr.**
Total Avoided Costs: \$134,550 + \$61,440 = \$195,990/yr
- *Existing plant personnel are used for the operation of the CHP plant, therefore there are no additional labor costs associated with the operation of the CHP plant.*

Based on the total costs data from Table 2, the CHP plant provides an estimated savings of **\$223,181 (\$696,144 – \$472,964)** which correlates to a **32.1%** savings for the past twelve (12) months. These savings are affected by the natural gas price. Table 3 shows the impact on the savings generated from the CHP plant as a function of the average gas price paid. As gas prices rise, the savings realized from the CHP system is lowered.

Natural Gas Average Price [\$/MMBTU]	Savings	
	Savings [%]	Savings [\$]
2.0	87.18%	\$412,115
2.5	76.29%	\$385,047
3.0	66.70%	\$357,979
3.5	58.18%	\$330,911
4.0	50.58%	\$303,843
4.5	43.74%	\$276,775
5.0	37.56%	\$249,707
5.5	31.95%	\$222,639
6.0	26.83%	\$195,511
7.0	17.84%	\$141,435
8.0	10.19%	\$87,299
9.0	3.60%	\$33,162
9.64	0.00%	\$0
10.0	-2.13%	(\$20,974)

Table 3: Natural Gas Cost Savings Analysis

Additional Considerations

The local utility company, Alliant, is very positive towards distributed energy (DE) technologies. Consequently, they were willing to finance part of the CHP system at a very low interest rate, which helped BMH economically justify this project. Also,

Alliant's readiness to adopt DE technologies helped promote the relationship between the utility and BMH. This is because the technology can be mutually beneficial to both parties. The DE user can supply electricity to the utility during times of heavy demand, while generating its own electricity during peak demand times, which minimizes the load on the utility. Also, using waste heat to produce air conditioning further reduces the load on the utility during peak demand times.

BMH was able to take advantage of its relationship with the manufacturer of the gen-sets, Fairbanks Morse (FM), a local neighbor of the hospital. FM is a major contributor to the hospital and as a result of this relationship, BMH and FM worked closely together to negotiate a substantial discount on the typical market value of these gen-sets.

These two (2) financial benefits greatly improved the overall economics of the project and the ability to justify the project more easily.

Lessons Learned

BMH learned the following lessons during the implementation of this project.

- *Local utility support is very helpful in the overall project economics and to sell excess power back to the utility.*
- *Provide sufficient accessibility around the generator sets for maintenance.*
- *Use a fire tube instead of a finned tube type of heat exchanger because soot collects in the fins and it is difficult to clean them.*
- *Install shields around air intakes to prevent engine exhaust gases (diesel fumes) from being sucked in and distributed throughout the hospital. BMH recommends installing a fan designed to propel the exhaust higher than the air intakes of the HVAC system.*
- *Specify the ability of the gen-sets to switch from diesel fuel to natural gas and back again with the flip of a switch. This allows uninterrupted operation upon the loss of gas supply.*
- *Install silencers on the gen-sets, which help minimize the external noise or design in the necessary equipment or sound-absorbing materials can be incorporated.*
- *Consider the impact of gas prices during the project approval phase.*

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