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Beloit Memorial Hospital
Case Study for
CHP Applications

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MIDWEST CHP APPLICATION CENTER

Beloit Memorial Hospital Case Study

1. Site Description

1.1 Background

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 remaining two (2) floors contain the boiler plant and other facilities related equipment. 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.

Another reason that Beloit Memorial Hospital installed this system was to minimize the impact of higher energy costs and susceptibility to power quality issues, which could occur when deregulation becomes a reality. With the ability to produce their own power, Beloit Memorial Hospital will be in a much better negotiating position with the many potential power suppliers that will exist in an open access marketplace.

Also, one (1) of the unique, added benefits of this installation is that it provides approximately 1,500 kW_e of power back to the local utility. This is especially beneficial to the local utility during high peak demand periods or when generating capacity is temporarily reduced due to equipment problems or maintenance.

A brief summary of the benefits of this system is summarized in Table 1 below. Beloit Memorial Hospital has entered into a long-term gas contract for $5.49 MMBTU locking in the savings shown below. 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 already needed electrical system upgrade.

3,000 kW CHP System Economics	
	$223,181
	$1,200,000
	5+ Years
	$5.49 MMBTU
	2.6¢ / kWHr
	0.7¢ / kWHr
	1.0¢ – 1.5¢ / kWHr
	1.8¢ – 2.3¢ / kWHr
	$400 / kW

Table 1: CHP System Economics

Figure 1: Beloit Memorial Hospital Facilities

1.2 Site Characteristics

Beloit Memorial Hospital has approximately 340,000 square feet of space and the hospital operates 24 hours per day, 365 days per year. While considering the equipment needed to modernize the current electrical distribution system, Beloit Memorial Hospital decided to address the need for additional air conditioning capacity, which led to the installation of a 3,000 kW_e CHP plant. The installation of this 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. The largest demand for hot water is in the morning from roughly 8:00 am to 1:00 pm when many of the patients are taking showers and the breakfast and lunch dishes are washed, and during the 5:00 pm to 8:00 pm time period when the dinner dishes are being washed. The CHP system 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 usually operate 24 hours/day, 365 days/year creating fairly consistent electrical and thermal loads. They also typically have high thermal loads and high hot water, steam and cooling heating loads to meet the need for daily showers, laundry, and dishwashing requirements, as well as 24/7 cooling requirements during the cooling season, which could be significant depending on the hospitals location.

2. CHP Project Information

2.1 Project Schedule

A summary level project schedule is shown below to show the approximate durations for the major phases of this project. The project took roughly a year from inception to commercial operation.

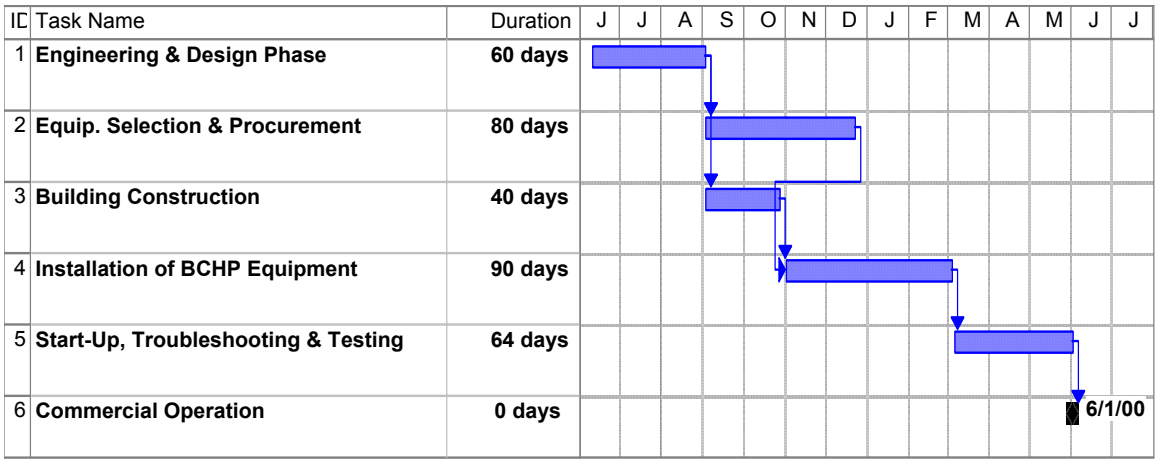

Figure 2: Beloit Memorial Hospital Overall Summary Level Project Schedule

2.2 Design and Engineering

Beloit Memorial Hospital selected Ballard Engineering of Rockford, IL to design, engineer, install and start up the 3,000 KW distributed power/CHP system. Ballard Engineering designs power plants for industrial, commercial and institutional facilities. Their unique design/build capability provides a turnkey approach to power plant design, which can simplify the overall project management and system

integration aspects of the project. Beloit Memorial Hospital was very pleased with the overall design of the CHP application and the service provided by Ballard Engineering during the installation, start-up and operation of the facility.

Ballard Engineering's scope of work consisted of ten (10) major features as listed below.

2.2.1 Remove and replace the two (2) old emergency generators. One was a Fairbanks Morse 400 KW and the other a 330 KW Cummings generator.

2.2.2 Provide approximately 1,500 KW worth of power for the entire hospital.

2.2.3 Provide approximately 1,500 KW worth of power to the local utility company.

2.2.4 Provide heat to drive a 434-ton Carrier model number 16JB047 hot water absorption chiller, or heat for the facility's existing heating loop.

2.2.5 Provide heat for domestic hot water usage.

For Building Heating:	6.733 MMBTU heat exchanger from the exhaust end of the water jacket.
For Domestic Hot Water Usage:	6.149 MMBTU heat exchanger from the auxiliary loop.

2.2.6 Design the system to operate on natural gas or diesel gas in the event of an emergency.

2.2.7 Provide on-line emergency power for the entire facility in the event of a utility failure. The previous equipment only provided the capability to handle emergency loads only, not the loads of the entire facility.

2.2.8 Provide the utility company with an "on-call" system to reduce utility load or grid shortfalls.

2.2.9 Maintain the entire CHP system at 69.8% efficiency, or better.

2.2.10 Remove and replace the older 12KV cables which were old and cracking and a potential problem. These cables were located internally to the hospital.

2.3 CHP Configuration and Equipment

In order for Ballard Engineering to supply the ten (10) items listed in section 2.2, nine (9) major components were identified, engineered, procured and installed at Beloit Memorial Hospital. These items are listed below.

2.3.1 A two (2) level, 3,250 sq. ft. building to house the engine room and control room.

2.3.2 Two (2) Fairbanks Morse dual fuel 900 RPM, 1,500 KW engine generator sets.

2.3.3 One (1) 6,000 AMP tiebreaker, two (2) 3000 AMP, 480V automatic generator breakers.

2.3.4 A 12 KV automatic main service breaker.

2.3.5 One (1) 434-ton Carrier model number 16JB047 single stage hot water absorption chiller.

2.3.6 Heat exchangers.

- Shell and tube heat exchanger, 7.66 MMBTU/HR used as a back up for cogenerated heat to drive the absorption chiller.
- Sondex plate and frame heat exchanger, 6.733 MMBTU/HR, 450 GPM.
- Sondex domestic hot water heat exchanger, 6.149 MMBTU/HR, 800 GPM.

2.3.7 Two (2) Cain 2.389 MMBTU/HR/generator set finned tube heat recovery units, Model # UTR1.)

2.3.8 Two (2) outdoor excess heat rejection radiators. (1 jacket water and 1 auxiliary water)

2.3.9 A graphic system for monitoring and record keeping of all major equipment readings.

An overall layout of the new building and the orientation of the major equipment included in the CHP system are shown in Figure 4 below.

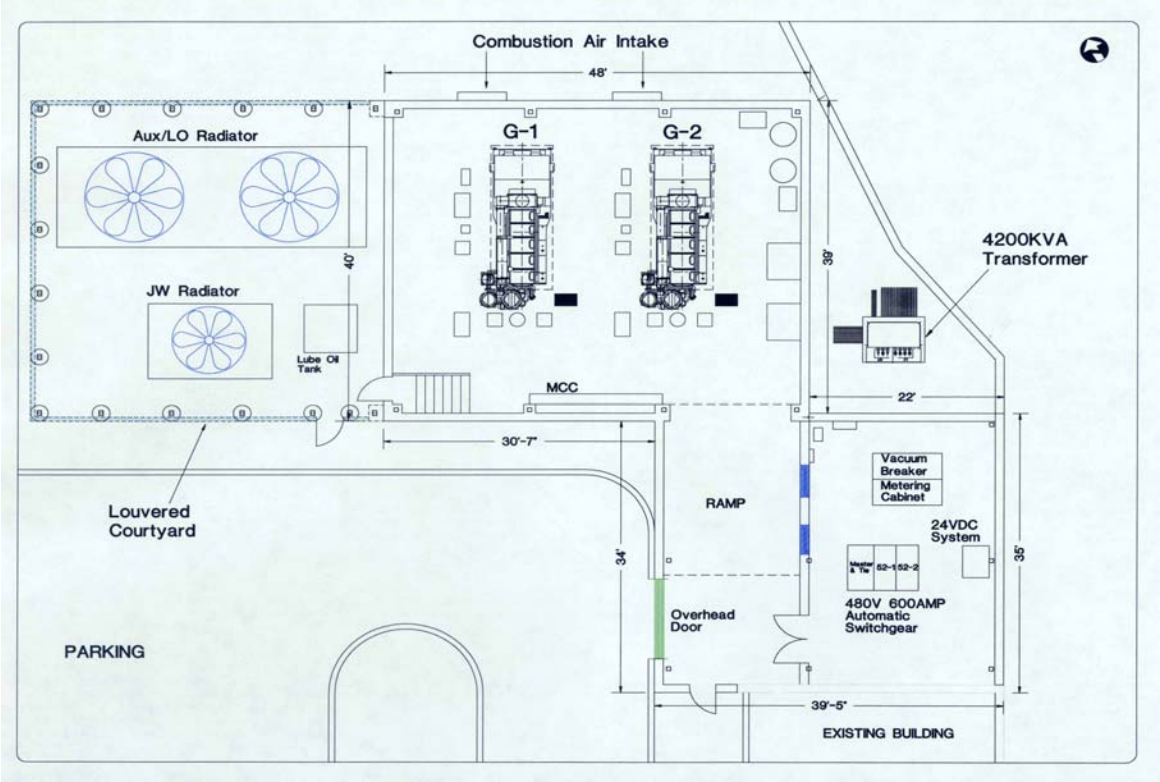

Figure 3: CHP Overall General Arrangement Drawing

A few pictures of some of the items that comprise the CHP system are shown below.

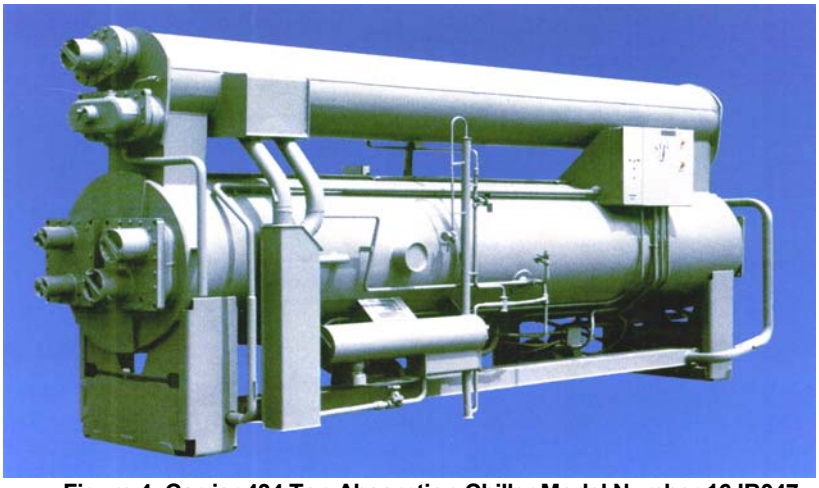

Figure 4: Carrier 434 Ton Absorption Chiller Model Number 16JB047

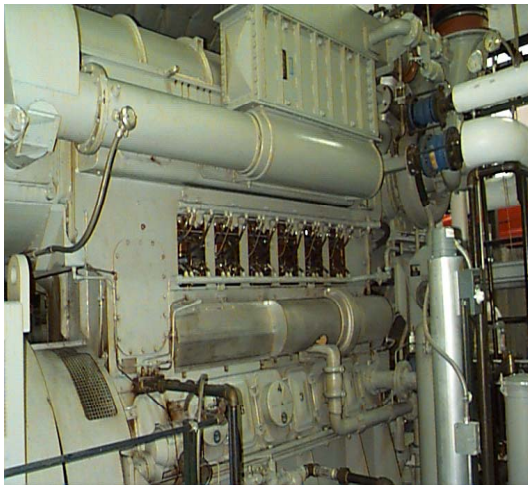

Figure 5: Fairbanks – Morse Generator Set

Figure 6: GE Zenith Energy Commander in the Control Room

2.4 CHP Operation

Beloit Memorial Hospital started commercial operation of the plant on June 1, 2000 and ran for approximately three (3) months before shutting down due to the unprecedented rising costs of natural gas in the winter of 2000/2001. The higher cost of natural gas diminished the benefits of operating the CHP equipment. 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. Beloit Memorial Hospital purchased a 12-month futures contract for natural gas to better manage the cost of natural gas, which fluctuated widely during the winter of 2000/2001. Since the price of natural gas has a large impact regarding the economics of operating this facility, the 12 month futures contract will minimize the unpredictability of the price of natural gas, which will allow the plant to operate 52 weeks per year during the hours stated. The hospital determined that the breakeven cost for natural gas is approximately $9.60 / MMBTU to make it beneficial to operate the CHP system.

The Fairbanks Morse engines act as both a peaking and emergency power source for the hospital. These engines are considered for emergency power because they are dual fuel engines capable of running on diesel fuel. However, they are normally operated on natural gas to keep the costs and emissions low.

Beloit Memorial Hospital is also able to sell electricity back to the local utility as well as produce air conditioning for the facility in the summer, which further helps to reduce the utilities peak demand load. The air conditioning is made using rejection heat from the engine to supply hot water to the Carrier 434 ton absorption chiller. Hot water produced by the CHP system is used for hot water heat for the building in the winter.

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 to allow the hospital to take advantage of the utility's curtailment rate. The CHP system is designed to automatically back up the entire hospital if the utility's power supply is interrupted.

The basic configuration and flow of the CHP equipment is summarized in the simplified Process Flow Diagram shown below.

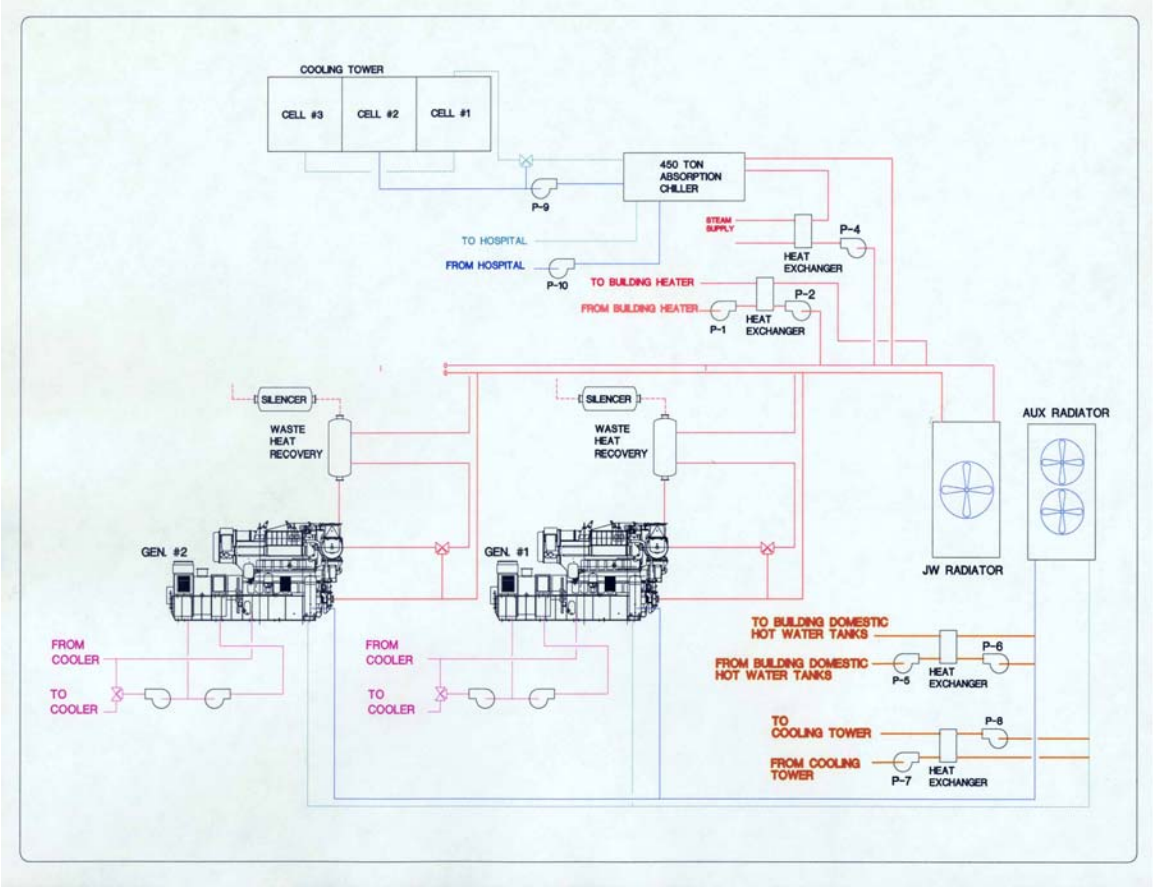

Figure 7: Simplified Process Flow Diagram of BCHS System

3. Energy / Financial Analysis

3.1 Financial Statistics

Approximate cost of facility modernization and upgrade:	**$1,800,000**
Approximate cost for the entire 3,000 KW CHP system:	**$1,200,000**
Approximate cost for the entire upgrade **and** CHP system:	**$3,000,000**
Payback for facility modernization only:	**None**
Simple payback for CHP equipment only:	**Approximately 5 years** [$1,200,000/$223,181 = 5.4 yrs.]
Simple payback for entire upgrade including CHP equipment:	**Approximately 13 years** [$3,000,000/$223,181 = 13.4 yrs.]

3.2 Assumptions/Actual Data

The following assumptions, or actual data (thru December, 2001), were used for the energy analysis conducted on this plant.

3.2.1 Maintenance Costs: $0.0066 / KWHR (actual thru December, 2001)

3.2.2 Manufacturer's Heat Recovery Rates

3.2.2.1 6.733 MMBTU/HR For Building Hot Water (Available during co-gen operation, 14hrs/day)

3.2.2.2 6.149 MMBTU/HR For Domestic Hot Water (50% of Available Hours)

3.2.3 Operation Availability

3.2.3.1 The engines run at 100% capacity during operating hours of 8:00 am to 10:00pm. (Actual operating hours)

3.2.3.2 The engines are available off peak, if necessary.

3.2.4 All hot water produced by heat recovery is used by the hospital. (Actual case while operating)

3.3 Discussion of Results

The charts below summarize the electrical usage and costs associated with the hospital.

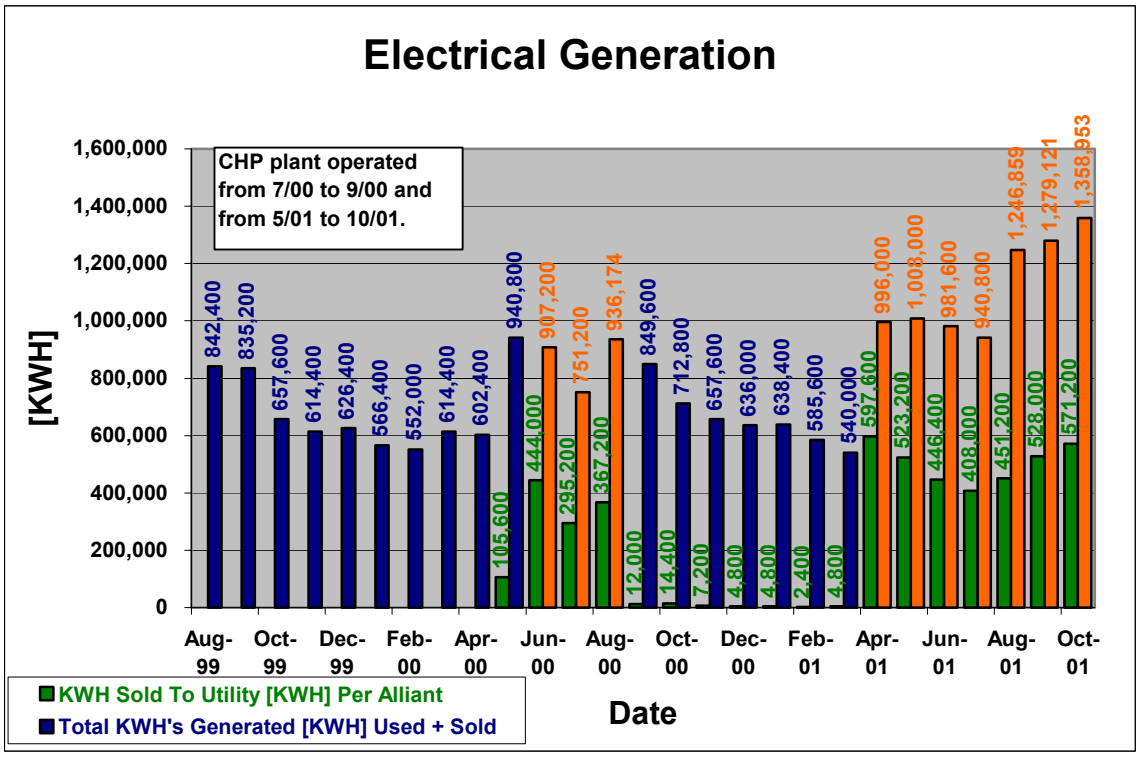

Table 2: Electrical Generation

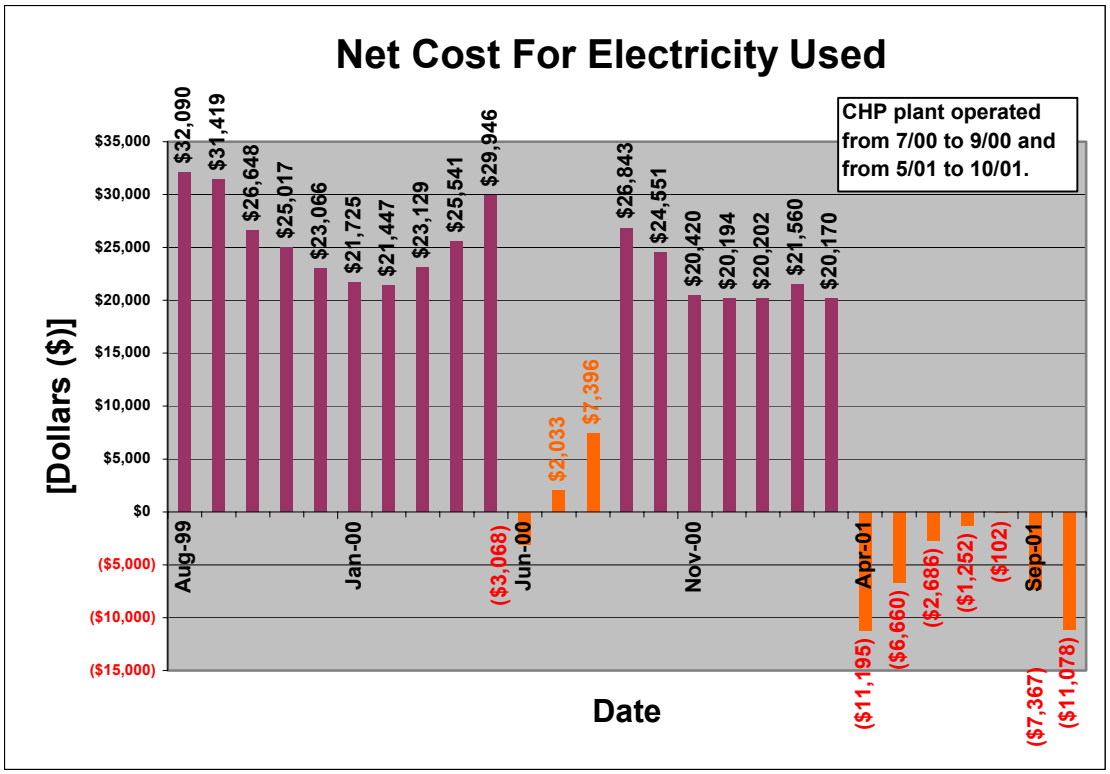

Table 3: Electricity Costs

The charts below summarize the natural gas usage and costs associated with the hospital.

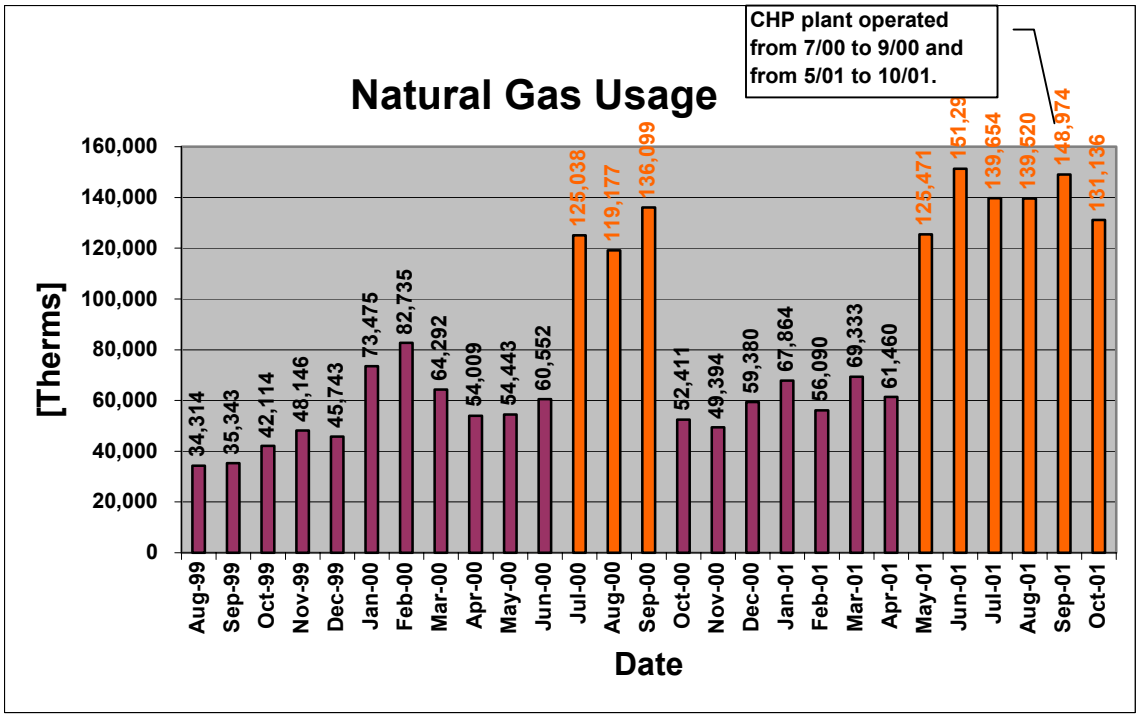

Table 4: Natural Gas Usage

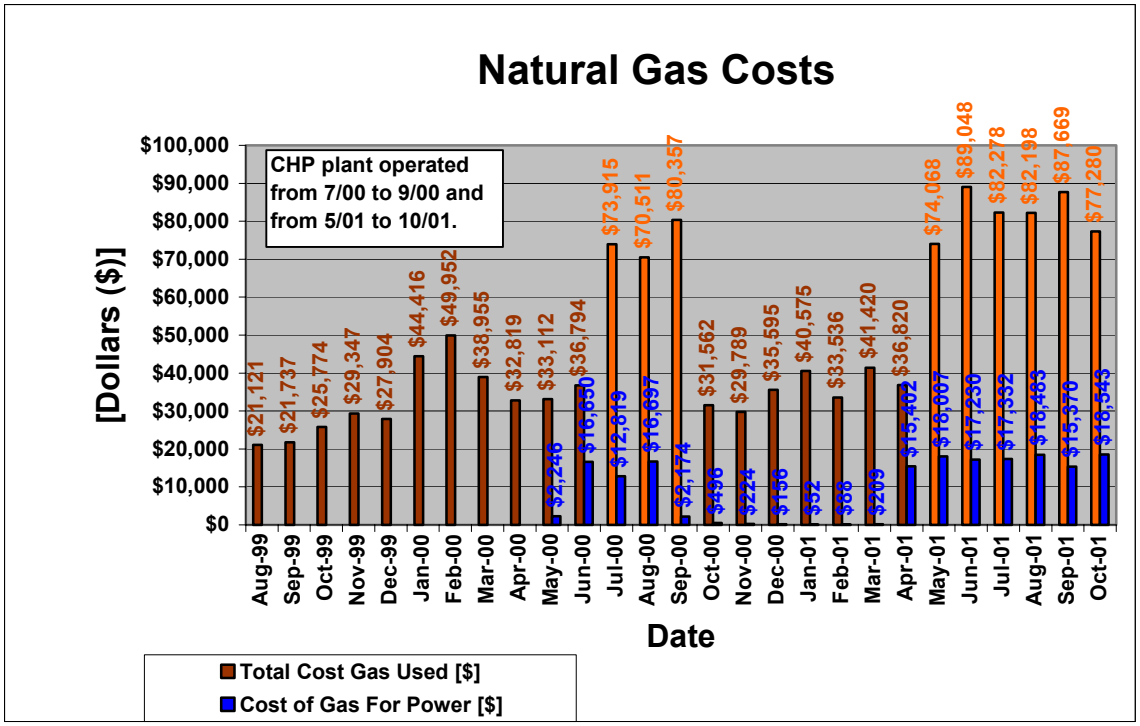

Table 5: Natural Gas Costs

As indicated by the four previous charts, when the CHP system was operating, the natural gas usage increased significantly. 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 generated by the CHP system. Table 6 below shows the total energy costs from all sources for reference. The total cost from May, 2001 thru October, 2001 is actually lower by the negative net cost for electricity amount.

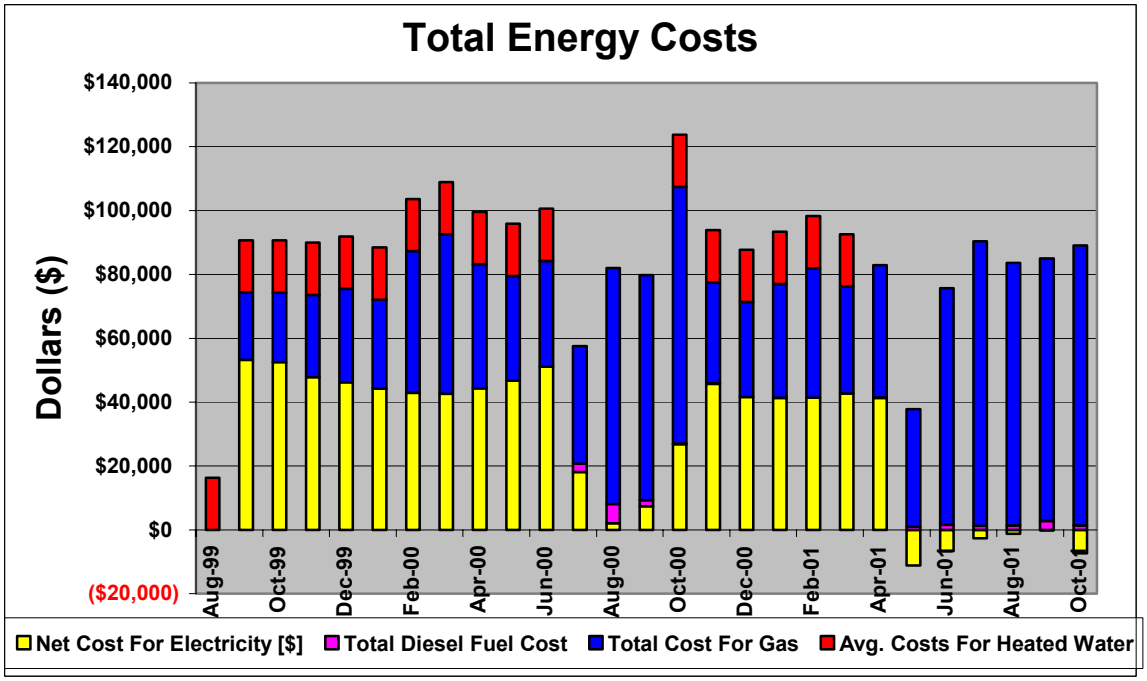

Table 6: Total Energy Costs

Table 7 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, Beloit Memorial Hospital plans to operate the equipment year round, Monday thru Friday from approximately 8:00am to 10:00pm. 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 calculated at $9.64/MMBTU), Beloit Memorial Hospital will reevaluate the economics associated with the CHP system, and decide whether to continue operating the system.

As Table 7 below highlights, the amount of natural gas purchased was increased for the CHP plant to power the Fairbanks Morse generator sets. However, this additional cost is offset by the lesser amount paid for electricity from the local utility as highlighted in the table showing an economic comparison of the CHP plant versus the baseline plant. The following notes reference the figures in the Table 7.

Item	BCHP Plant (Note 1)	Baseline Plant (Note 1)
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.] (Note 2)	$253,774	$0
Avoided Costs to Heat Water [$/yr.] (Note 3)	$195,990	$0
TOTAL REVENUE	**$668,552**	**$0**
EXPENSES		
Wages to Support Power Generation (Note 4)	$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

Table 7: CHP Economics

Notes:

1.) The amounts in the columns are based on 12 months of operation using prorated totals from monthly averages where less than 12 months of actual data is available.

2.) Avoided Costs Power Generated and Used refers to the costs that would have to be paid to the local utility if the power was not generated on-site. Actual data from Beloit Memorial Hospital was prorated and a cost of $0.026/kWh was used to calculate the savings.

3.) Avoided Costs To Heat Water refers to the estimated costs required for gas that would have to be paid to the local utility if the waste heat was not generated on-site. BMH has provided estimates for this data, which is calculated below.

a.) Heat recovery building hot water 100% used during co-gen operation, 14 hrs./day, 5 days/wk.

b.) Heat recovery domestic hot water. 50% of available used all hours.

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 Avoid Costs: $134,550/yr. + $61,440/yr. = $195,990/yr.

4.) 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.

This table shows that based on total costs the CHP plant provides an estimated savings of **$223,181**, which correlates to a **32.1%** savings for the past twelve (12) months based on the baseline total expenses of **$696,144**. These savings are affected by the price of natural gas, which has fluctuated widely during the past year. Table 8 below shows the impact on the savings generated from the BHCP plant as a function of the average gas price paid. As the price of gas rises, 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 8: Natural Gas Cost Savings Analysis

[redacted]

4.1 Environmental Benefits

By replacing some of the existing electrical distribution equipment and lowering the amount of electricity purchased from the local utility, there is an overall reduction in the amount emissions released to the atmosphere, not necessarily all at the hospital itself. Beloit Memorial Hospital does not have actual emissions data for the equipment that was replaced. Therefore, a comparison of actual emissions before and after the CHP equipment was installed is not available.

In lieu of actual emissions data, the CHP system installed was designed to meet the following criteria. The environmental protection agency (EPA) has verified that the CHP system has passed an inspection regarding actual emissions.

NOx Emissions:	17.26 tons/yr./engine operating 4,500 hours/year
SOx Emissions:	2.96 tons/yr. Total
Diesel Fuel Limit:	149,000 gallons/engine/yr. (#2 diesel fuel)
CO Emissions:	34.38 tons/yr./engine operating 4,500 hours/year
Particulates:	1.72 tons/yr.
Total Hydrocarbons:	57.29 tons/yr./engine
Smoke/Bosch:	0.57 tons/yr./engine
VOC's:	5.9 tons/yr./engine

4.2 Financial Considerations

The local utility company, Alliant, that provides power to Beloit Memorial Hospital, is very positive towards distributed energy technologies. Consequently, the utility was willing to finance part of the CHP system at a very low interest rate, which helped the hospital to economically justify this project. Also, Alliant's readiness to adopt distributed energy technologies helps promote the relationship between the utility and the customer. This is because the technology can be mutually beneficial to both parties. The distributed energy user can supply electricity back to the utility during times of heavy demand, while generating its own electricity during peak demand times, which minimizes the load on the utility.

Another financial benefit that Beloit Memorial Hospital was able to take advantage of is the relationship with the manufacturer of the generator sets. The cost of the prime mover (generator sets) is usually the largest component of the overall cost of a CHP system and therefore a major barrier to undertaking this type of project.

Fairbanks Morse a local neighbor of the hospital. Fairbanks Morse is approximately a mile away from the hospital, and is a major contributor to the hospital. Beloit Memorial Hospital and Fairbanks Morse worked closely together to negotiate the purchase of the two (2) generator sets at a substantial discount to the typical market value of these generator sets. As a result of the relationship between the hospital and the generator set manufacturer this barrier was minimized.

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

As discussed earlier in this report, the cost of incoming natural gas can have a great impact regarding the economics of operating the CHP plant. This factor must be considered by potential users using the historical and anticipated costs for natural gas to determine the expected savings and payback of installing a CHP system. BMH minimized their risk by entering into a long-term contract fixing their natural gas costs for the duration of the contract.

4.3 Lesson Learned

Beloit Memorial Hospital learned the following lessons during the implementation of this project.

4.3.1 The support of the local utility is very helpful in the overall economics of the project and for the ability and flexibility to sell excess power back to the utility.

4.3.2 Beloit Memorial Hospital stated that it would be beneficial for the building to be slightly larger to provide enough accessibility around the generator sets and other information.

4.3.3 Beloit Memorial Hospital recommends that a fire tube should be used instead of a finned tube type of heat exchanger because soot collects in the fins and it is difficult to clean them. Ideally, the exhaust gases should go down the tube instead of across the fins. Any build-up of soot, etc. can be more easily cleaned and removed by rodding the tube.

4.3.4 A minor odor problem occurred during the daily start-up of the generator sets because they start up using diesel fuel until approximately 50% of the load is applied to the system. At this time the fuel for the generator sets is switched from diesel to natural gas. Beloit Memorial Hospital installed shields around the air intakes to prevent the exhaust gases (diesel fumes) from being sucked in and distributed throughout the hospital. They recommend that a fan be incorporated in the design to propel the exhaust higher than the air intakes of the HVAC system.

4.3.5 The ability of the Fairbanks Morse generator sets to switch from diesel fuel to natural gas and back again with the flip of a switch is a desired feature. Since the hospital is an interruptible natural gas customer, the engine's capability to automatically switch over to

diesel fueled operation upon the loss of gas supply is a benefit that should be considered for other potential CHP users.

4.3.6 Beloit Memorial Hospital is located in a residential area and the concern for the noise produced by the generator sets was an item the hospital investigated. In order to minimize the noise of the generator sets, the hospital installed silencers to the generator sets, which help minimize the external noise. Potential users of CHP technologies must consider the noise that a generator set makes during the design phase of the project so appropriate equipment or sound-absorbing materials can be incorporated.

4.3.7 Beloit Memorial Hospital mentioned that the impact of gas prices should be considered. Although the drastic increases that occurred in the year 2000 appears to be an extreme case, if gas prices do rise dramatically, it most likely will adversely affect the economics of the CHP system.