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University of Illinois at Chicago East Campus

(Including White Paper of West Campus Facility)

Midwest Regional Application Center
CHP for Buildings

Case Study MAC #2001-001

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1. Site Description

1.1 General

In the early 1990's, a University owned and operated power plant was considered as a solution to meet the increasing energy demand of the campus. In 1993, University of Illinois at Chicago (UIC) began generating power in a cogeneration plant on the East Campus to serve just that campus. In the fall of 2001, UIC will begin generating power in a second BCHP plant on the West Campus, about a mile apart from the East Campus plant. The two plants will be linked and operated as a single plant to serve the two campuses and any planned future expansions.

This is the first case study conducted for the East Campus Building Cooling, Heating, and Power (BCHP) Plant, almost a decade after the facility was first envisioned. This case study also briefly outlines the new West Campus cogeneration plant.

1.2 Site Location

The University of Illinois at Chicago is located just south west of the downtown area. The East Campus BCHP Plant is located at 1100 South Morgan Street, just a block south of the main campus. It mainly consists of two buildings, one accommodating the managing offices and the centralized cooling plant, the other the centralized heating and electrical generating plants.

1.3 Site Characteristics

The plant currently serves almost the entire East Campus. It is electrically connected to 29 buildings out of the 33 that form the East Campus. Electrically it serves a total gross area of slightly more than 3.8 million ft^2 (approximately 350,000 m^2) out of the global campus area of approximately 4.5 million ft^2 (equivalent to about 412,000 m^2). Moreover, it is connected through a heating loop and a cooling loop to 27 of those 29 buildings, excluding only about 227,000 ft^2 (21,000 m^2) from thermal energy delivery. Finally, it is connected to the neighboring St. Ignatius High School and Holy Family Church with a lower temperature-heating loop, to which the University sells hot water for heating.

All the University buildings generally have a high occupancy load factor because the University offers early and late classes, weekend events, summer courses, and it keeps service and recreational facilities open extended hours to meet students' needs.

2. Market Segment Evaluation

2.1 Market Potential

University and college facilities are generally good candidates for BCHP applications because they have extended hours of operation, they operate during the entire year, and probably most important, they are often heated and cooled by central district heating and cooling plants.

Because of the cold winters and hot summers in Chicago, it is regionally well suited for BCHP applications. Also because it is a metropolitan center, there is a higher expectation for buildings to be comfortably heated or air-conditioned.

3. Technical Description

3.1 Original System Configuration

The BCHP plant at UIC has evolved over the years. Originally the facility served as a central heating and cooling facility with no power generation. Cogeneration capability was first installed in 1993. The first cogeneration plant simply employed two engine-generators with heat recovery systems, four hot water generators, and four electrical centrifugal chillers. Since then the central plant has seen three major upgrades. In 1996, the old chillers were replaced with three new and significantly more efficient centrifugal chillers. In early 2000, three new High Temperature Hot Water Generators (HTHWGs) (~80% efficiency) were purchased to replace the existing ones (~70% efficiency), and two smaller engine-generators with heat recovery systems were added to the facility. In September 2000, a two-stage hot water-fired absorption chiller was installed as a base-load chiller. From the first day on, the plant has been intended to work in parallel with the local electrical utility, Commonwealth Edison (ComEd).

3.2 BCHP Versus Baseline Plant

This case study compares the operation of the UIC East Campus BCHP plant for calendar year 2000, referred to as the BCHP Plant, against a plant without cogeneration of electricity that can be considered as the more conventional alternative, which will be referred to as the Baseline Plant.

The Baseline Plant will be the same as the BCHP Plant, except without the onsite generation of electricity. It will provide hot and chilled water via the central plant to the campus buildings in the same manner as the BCHP Plant. The electrical energy from the engine-generators is assumed to be replaced by electricity from the local utility, ComEd. Additional fuel provided to the HTHWGs will compensate for the loss of the recovered thermal energy from the engine-generators. Table 3-1 provides a comparison of the equipment considered in the analysis for the BCHP and Baseline Plant.

Table 3-1 BCHP Versus Baseline Plant Energy Generators

	Electric Supply	Operational	Per Unit		BCHP	Total		Baseline	Total	
2	Cooper-Bessemer	1993	6.3	Mw e	Yes	12.6	Mw e	No	0	Mw e
2	Wärtsilä	2000	3.8	Mw e	Yes	7.6	Mw e	No	0	Mw e
						20.2	Mw e		0	Mw e
	Heating Equipment									
4	Exhaust Gas Recovery	2000	Various		Yes	30	MMBTU/h	No	0	MMBTU/h
2	Jaket Water Heat Recovery	2000	4	MMBTU/h	Yes	8	MMBTU/h	No	0	MMBTU/h
2	High Temperature Hot Water Generators	2000	75	MMBTU/h	Yes	150	MMBTU/h	Yes	150	MMBTU/h
1	High Temperature Hot Water Generators	2000	50	MMBTU/h	Yes	50	MMBTU/h	Yes	50	MMBTU/h
						238	MMBTU/h		200	MMBTU/h
	Cooling Equipment									
	Hot Water Fired Absorption Coolers	Various	Various		Yes	1500	Tons	Yes	1500	Tons
3	Electric Centrifiual Chillers	1996	2000	Tons	Yes	6000	Tons	Yes	6000	Tons
1	Absorption Cooler	2001	1000	Tons	Yes	1000	Tons	No	0	Tons
						8500	Tons		7500	Tons

3.3 BCHP System Design

3.3.1 Electrical Parameters

3.3.1.1 Overview

The East Campus BCHP Plant generally runs 24 hours per day and 7 days a week. The majority of the time the East Campus plant generates sufficient electricity to meet its demand. At times when site demand exceeds generation, power is purchased from the utility. When the East Campus generates electricity in excess of its demands, the excess is sold back to the utility. The power is metered on the two incoming 69 kV lines supplying power to the East Campus facility.

3.3.1.2 Electrical Generation Prime Mover

The prime movers employed at the East Campus CHP plant are:

- 2 Cooper-Bessemer 20-cylinder LSVB dual-fuel reciprocating engines driving Ideal Electric generators each rated at 6.3 MW_e. These engine-generators have been retrofitted with catalytic oxidizers to reduce emissions.
- 2 Wärtsilä 18V-28SG natural-gas reciprocating engines driving ABB generators each rated at 3.8 MW_e. These engine-generators are fitted with afterburners to reduce the amount of unburned hydrocarbons and provide additional heat to the recovery systems. *{The Wärtsilä engine-generators have been operational only since July of 2000.}*

3.3.1.3 Backup/Standby Power

During the first six months of 2000, the utility provided supplemental power to the University. Since the Wärtsilä engine-generators were placed in operation in July 2000, the University has enough generation capacity to supply all of its electrical demands; the utility only provides standby service.

3.3.1.4 Grid Supply

Full back-up power is available from the grid. The three-phase service is provided at 69 kV and the University is responsible for its own electrical distribution. Subsequently the University drops the voltage from this switchyard to 12kV for on-site distribution. The University has owned all of the on-site East Campus distribution system from the time of original construction. In 1999 the University replaced the utility owned on-campus switchyard, which converts the electric power from 69 kV to 12 kV, with all new University owned equipment.

3.3.1.5 Interconnection Requirements

The University installed interconnection protection equipment that was specified by the Utility in response to a fault study paid for by the University back when it installed the Cooper-Bessemer engine-generators. The initial cost of the original protection equipment, which has subsequently been replaced by newer equipment by the University, was approximately $250,000. This cost is included in the total installation cost of the equipment.

3.3.2 Fuel Supply Description

The fuel supplied to the East Campus plant is primarily natural gas at a nominal 150 psi. The plant also uses #2 fuel oil to start the Cooper Bessemer engine-generators; #2 fuel oil constitutes about 1½% of the fuel when the engine is operating on natural gas. Occasionally #6 fuel oil is used to run the heating boilers, but was not used during the year 2000. The Copper Bessemer engine-generators can also be operated utilizing #2 fuel oil, but were not during the year 2000.

3.3.3 Thermal Recovery Systems

3.3.3.1 Hot Water

The thermal recovery hot water systems employed at the East Campus are:

- 4 Exhaust Gas Heat Recovery Systems for each of the engine-generators for a total power of 30 MMBTU/h (8.8 MW_{th});
- 2 Jacket Water Heat Recovery Systems applied to each Cooper engine-generator for a

total power of 8 MMBTU/h (2.4 MW_{th}).

The energy recovered from the jacket water of the two Cooper engine-generators is sold to the St. Ignatius High School and Holy Family Church through a 190°F (88°C) water loop. The higher quality energy recovered from the exhaust gases of all the engines is delivered to the campus through a 400°F (205°C) water loop. When additional hot water is needed, one or more HTHWGs are started to supply the additional thermal load.

Since the Wärtsilä engine-generators and their heat recovery systems were only operating for the last 6-month period of the case study, more recovered thermal energy will be available in the future than is shown in this case study.

3.3.3.2 Absorption Cooling

There are several absorption chillers, activated by the hot water loop, located in two buildings on campus for a total capacity of 1350-ton (4.8 MW_{th}).

The plant has recently been supplied with a 1000-ton (3.5 MW_{th}) Trane two-stage absorption chiller that is also activated by the hot water loop. The benefit of utilizing this absorption chiller is not taken into consideration in this case study since it has only been in use since the Summer of 2001, which is beyond the time-frame of the BCHP Plant analysis. Therefore, the performance of the actual plant in the future is expected to be higher than described in this case study.

3.3.4 Non-Recovery Thermal Systems

3.3.4.1 Heating

Heating hot water is supplemented by three dual fuel (natural gas/#6 fuel oil) HTHWGs, two rated at 75 MMBTU/h (22 MW_{th}) and one rated at 50 MMBTU/h (15 MW_{th}).

3.3.4.2 Cooling

Three York International electric centrifugal chillers each rated at 2000 ton (7.0 MW_{th}), for a total of 6000 ton (21.0 MW_{th}) are utilized to supply chilled water to the central cooling system. The water chilled within these machines is delivered to the campus through a 38°F (3.3°C) water loop; variable speed pumps keep the return temperature fixed at a temperature of ~55°F (12.7°C).

3.4 Baseline System Configuration

3.4.1 Energy Supply Parameters

3.4.1.1 Electrical Supply Description

The electrical supply system for the Baseline configuration assumes all electricity is purchased from ComEd, with no onsite generation.

3.4.1.2 Fuel Supply Description

The fuel supply system for the Baseline configuration is the same as that for the BCHP configuration.

3.4.2 Thermal Systems

3.4.2.1 Heating

Hot water is provided for building heating by three dual fuel (natural gas/# 6 fuel oil) HTHWGs, as described in the BCHP plant Section 3.3.3.

3.4.2.2 Cooling

Three York International electrical centrifugal chillers as described in Section 3.3.4.2 for the BCHP plant are considered to supply chilled water to the central cooling system. The decentralized absorption chillers use hot water generated in the HTHWGs. This results in increased energy usage on the HTHWGs for the Baseline case.

4. Energy Analysis (Baseline versus BCHP)

4.1 General

During the case study year (2000), the CHP Plant converted 812,000 MMBTU (857,000 GJ) of chemical energy stored mainly in natural gas (with a small quantity in #2 fossil oil) into 83,000 $MWhr_e$ (299,000 GJ) of net electricity and 138,000 MMBTU (145,000 GJ) of recovered heat achieving a generation efficiency of approximately 52%. Moreover, during the first half of the year the University purchased supplemental electricity to completely meet it's electrical load and supplemental natural gas throughout the year to meet its thermal load.

It is important to know the sum of these values because it represents the thermal load of the East Campus. For the purpose of this case study, the thermal load is assumed to be the same for both the BCHP Plant and the Baseline Plant and establishes the bases for the analysis.

4.2 Electrical Parameters

The electrical consumption for the East Campus facility is shown in Table 4-1. Electrical consumption remains the same for the Baseline case since the electrical and thermal loads in the plant remain the same. The only difference between the Baseline and the BCHP facilities is that there is no onsite electrical generation and additional fuel is consumed to replace the recovered thermal energy that is not being supplied by the engine-generators.

The electricity purchased from the utility is continuously metered by the utility at the delivery substation. However, there is no metering device to constantly record electric parameters, such as energy flow, time of day usage, or peak power consumption, for the electricity generated or consumed by UIC. Instead, an operator records the net energy flow from meter readings at the end of the day. While it is possible to calculate the amount of electricity delivered to the campus, the information, such as peak and off-peak electric power consumption and peak demand needed to accurately estimate the annual electrical costs for the baseline plant, is not available. Assumptions used in the financial analysis in this case study are described in Section 5.1.

Table 4-1 Annual Electric Usage (2000) ***[$KWhr_e$]***

	Peak Demand	Generated	Sold Back *(a)*	Purchased	Delivered to Campus	
Jan-00	14,804	4,303,000		3,408,350	7,711,350	
Feb-00	15,189	4,442,000		2,412,107	6,854,107	
Mar-00	14,789	3,991,000		3,871,198	7,862,198	
Apr-00	14,115	6,050,000		1,191,880	7,241,880	
May-00	15,872	2,337,000		7,126,306	9,463,306	
Jun-00	18,825	7,626,000	-2,048,486		5,577,514	*(a+b)*
Jul-00	18,816	10,511,930		2,301,092	12,813,022	*(c)*
Aug-00	17,872	10,043,177	-1,924,448		8,118,729	
Sep-00	18,276	9,917,480	-2,935,595		6,981,885	
Oct-00	17,169	8,213,500	-454,397		7,759,103	
Nov-00	14,600	8,432,130	-1,335,542		7,096,588	
Dec-00	14,139	7,427,830	-358,719		7,069,111	
TOTAL		83,295,047	-9,057,187	20,310,933	94,548,793	
(a)	Negitive value implies electricity was sold back to the Utility.					
(b)	Warsila Engine generators began operation.					
(c)	For accounting reasons, these values are based on 15-days of metering.					
(d)	For accounting reasons, these values are based on 46-days of metering.					

4.3 Thermal Requirements

4.3.1 Thermal Loads

The thermal energy provided by the BCHP Plant is shown in Table 4-2. There is no difference between the thermal loads of the Baseline plant and the BCHP plant because the thermal loads between the two cases remain the same. The only difference is that the thermal load is supplied by the HTHWGs instead of having part of the load provided by recovered heat.

Table 4-2 Annual Thermal Energy Provided (2000) ***[MMBTU]***
(BCHP and Baseline Case)

	Recovered	HTHWG	Delivered
Jan-00	7,905	48,960	56,865
Feb-00	9,289	43,276	52,565
Mar-00	17,728	44,571	62,299
Apr-00	15,700	16,528	32,228
May-00	8,533	8,424	16,957
Jun-00	9,720	2,548	12,268
Jul-00	14,323	4,037	18,360
Aug-00	11,621	0	11,621
Sep-00	12,660	8,201	20,861
Oct-00	9,497	32,282	41,779
Nov-00	7,887	31,792	39,679
Dec-00	13,312	52,123	65,435
TOTAL	138,175	292,742	430,917

4.4 Fuel Usage

The East Campus facility uses natural gas as the primary fuel for heating and for the generation of electricity. Number 2 diesel fuel is used during the start-up of the Cooper-Bessemer engine-generators. It also constitutes a small percentage (1½%) of the fuel when the engine-generators are operating. Number 6 fuel oil is used to operate the HTHWGs for the campus hot water system. Table 4-3 provides the actual fuel consumptions for the BCHP Plant and the estimated values for the Baseline Plant.

Table 4-3 Annual Total Fuel Usage (2000)

	BCHP Plant	Baseline Plant
Natural Gas	1,178,356 MMBTU	538,645 MMBTU
#2 Fuel Oil	169,517 gallons	0
#6 Fuel Oil	0	0

5. Financial Analysis (Baseline versus BCHP)

5.1 Assumptions

For the purposes of this case study, assumptions will need to be made to allow for the analysis of the BCHP Plant to the Baseline Plant. It is assumed that 48% of the total monthly electrical consumption occurs during peak periods, with the remaining 52% occurring during the off-peak periods. This assumption is reasonable since the University has an appreciable load at night and during weekends, due to both classes and student activities. In order to obtain the total peak electric demand for the campus in any given month, the nominal CHP plant capacity in that month is added to the peak demand purchased from the utility for that month. This is a valid assumption since the CHP onsite electric generation plant is run at full load during peak demand times. The analysis also takes into consideration that the electrical generation plant capacity was upgraded six months after the beginning of the case study time period.

5.2 BCHP Project Cost

The total cost of the Cooper-Bessemer engine-generators in 1993 (including installation) was about $15M. The installation of the two Wärtsilä engine-generators in 1999 was approximately $10M, while the absorption chiller cost an additional $.66M in 2000. Therefore the cost of the BCHP upgrades totaled about $25.6M over seven years.

The BCHP equipment represents an additional cost to the central heating and cooling plant, since the installed HTHWGs and the electric centrifugal chillers are capable of supplying the full campus thermal demand. The thermal recovery systems employed by the BCHP Plant are only used to offset the thermal load supplied by that equipment. None of the equipment assumed in the Baseline configuration is replaced or downsized by any of the BCHP equipment.

5.3 Annual Costs

5.3.1 Operating Costs

5.3.1.1 Electrical Costs

<u>BCHP Plant</u>

Actual electric bills were used to calculate the electric costs for the BCHP Plant. The applicable rates and riders specified in the ComEd tariff book “ComEd Tariffs” in effect for the East Campus facility are as follows:

- Rate 6L, Large General Service -- Time-of-Day, which defines monthly, demand, and energy charges for a delivery with maximum demand established during on-peak period higher than 1,000~kW;
- Rate 18; Stand By Service – This rate is applicable to any customer who has installed their own electric generating facility (or uses the output of a third party company) and/or uses ComEds electric service as a standby, reserve, or auxiliary service;
- Rider 6, Optional/Non-Standard Facility;
- Rider 7, Meter Lease;
- Rider 11, 69 kV Service Credit.

The utility charges for electricity totaled $1,131,845 (excluding electricity sold back to ComEd) at an average cost of 5.57¢ per kWhr; this cost reflects that significant amounts of the kWhrs purchased were made off-peak when utility charges per kWhr are low. The total annual cost of electricity generated by the BCHP Plant was $4,710,244 at an average cost of 5.65¢ per kWhr. This cost does not account for the savings from the recovered heat. The total cost of electricity for the University was $5,842,089 at an overall average of 5.63¢ per kWhr.

Baseline Plant

A detailed estimated bill for the Baseline Case was developed in accordance with the rates and riders specified on the ComEd tariff book "ComEd Tariffs." The estimation includes:

- Rate 6L, Large General Service -- Time-of-Day, which defines monthly, demand, and energy charges for a delivery with maximum demand established during on-peak period higher than 1,000~kW;
- Rider IFC, Instrument Funding Charge;
- Rider 16, Franchise Cost Additions;
- Rider 21, Renewable Energy Resources (monthly charge);
- Rider 23, Municipal and State Tax Additions;
- Rider 31, Decommissioning Expense Adjustment Clause.

The utility rates above were applied to the monthly delivered electricity quantities as indicated on Table 4-1 assuming that 48% of the kilowatt-hours were consumed during the peak demand time. Summing the estimated monthly electrical costs resulted in an estimated yearly electrical cost of $6,710,545 yielding an average cost of 7.10¢/kWhr.

5.3.1.2 Fuel Costs

BCHP Plant

The University purchases its natural gas on the wholesale market under contract and pays Peoples Gas Company a transport fee to deliver it to the facility. The annual cost for natural gas was $3,804,883 for gas used to generate electricity and $1,674,764 for the hot water system, for a total natural gas bill of $5,479,647. $177,477 was expended on #2 fuel oil to generate electricity. No #6 fuel oil was used during 2000. The total fuel cost for the entire BCHP Plant was $5,657,124.

Baseline Plant

In order to provide the estimated fuel costs for the Baseline Plant, actual monthly expenditures in terms of cost per MMBTU have been applied to the estimated quantities of natural gas that would need to be purchased. These quantities have been evaluated by dividing the monthly thermal energy delivered to the campus, as listed in Table 4-2, by an average boiler efficiency of 80%.

The estimated yearly natural gas bill was $2,462,380, which resulted in an average cost of $4.683 per MMBTU. No #2 or #6 fuel oil use was assumed.

5.3.1.3 Other Costs

BCHP Plant

The operating costs for the BCHP plant for wages are calculated to be $481,400 for the generation portion of the plant and $886,600 for the central heating/cooling plant, and $204,619 for general salaries, for a total cost of $1,572,619.

The maintenance costs were calculated to be $120,000 and $58,200 for the generation and central heating/cooling plants respectively, for a total of $178,200. Maintenance for both the Cooper-Bessemer and Wärtsilä are generally performed in-house. Initially for the Cooper-Bessemer units, Cooper-Bessemer performed maintenance for the first scheduled maintenance. The second maintenance was performed by UIC maintenance, with supervision by Cooper-Bessemer, and since the third scheduled maintenance UIC maintenance personnel performed solely the maintenance. For the Wärtsilä engine-generators, several maintenance staff personnel were sent to Sweden to receive extensive training on the engine-generators. UIC personnel perform all maintenance on the Wärtsilä units, except in special instances. Water-sewer costs were $57,723 and $52,437, again for the electrical and central heating/cooling plant respectively, for a total of $110,160.

Baseline Plant

The expenditures for operations, maintenance, and water-sewer fees for the Baseline Plant were assumed to be the same as for the BCHP Plant central heating/cooling plant plus the cost of the general salaries for a total of $1,201,856. It reasonable to expect the costs associated with that aspect of the plant to be the same.

5.3.2 Total Costs

For the BCHP Plant, the annual costs are based on the actual monthly expenditures paid by the University. For the Baseline Plant, estimates have been made for the annual cost of electricity and natural gas. Annual costs are summarized in Table 5-1.

Table 5-1 Total Annual Costs

	BCHP Plant	Baseline
INCOME		
Sold electricity	$ 135,858	N/A
St Ignatius School	$ 70,827	N/A
GENERAL EXPENSES		
Salaries	$ 204,619	$ 204,619
ELECTRICAL EXPENSES		
Electricity Wages	$ 481,400	N/A
Electricity Fuel Oil	$ 177,477	N/A
Electricity Gas	$ 3,804,883	N/A
ComEd Electricity	$ 1,131,845	$ 6,710,545
Electricity Water/Sewer (a)	$ 57,723	N/A
Maintenance	$ 120,000	N/A
HEATING & COOLING EXPENSES		
Heating & Cooling Wages	$ 886,600	$ 886,600
Heating & Cooling Fuel Oil	$ -	$ -
Heating & Cooling Gas	$ 1,674,764	$ 2,462,380
Heating & Cooling Water/Sewer (b)	$ 52,437	$ 52,437
Maintenance	$ 58,200	$ 58,200
TOTAL	$ 8,443,263	$ 10,374,782

(a) City Water and Sewer Service for engine cooling towers
(b) City Water and Sewer Service for chiller cooling towers

6. Financial Considerations

Based on Total Costs for the year 2000, BCHP provides an estimated savings of $1,931,518, which correlates to a 18.62% savings for the year 2000. However, these savings are lower than experienced in previous years because expenses for natural gas during several months in 2000 were uncharacteristically high, averaging $4.63/MMBTU with peak prices over $10/MMBTU, compared to previous years where prices were in the $2.50 to $3.00/MMBTU range. A sensitivity analysis was performed assuming the same information for both the BCHP and Baseline Plant, but assuming various average natural gas prices fixed for the year. As seen in Table 6-1estimated savings are very sensitive to gas prices.

Table 6-1 Savings for Various Natural Gas Average Prices

Natural Gas Average Price [$/MMBTU]	Savings	
2.5	36.18%	$3,349,512
3.0	31.80%	$3,029,657
3.5	27.66%	$2,709,802
4.0	23.74%	$2,389,947
4.5	20.03%	$2,070,093
4.683	**18.62Error! Not a valid link.**	**$1,931,518**
5.0	16.50%	$1,750,238

The original 12.6 MW_e East Campus Plant that began operation in 1993 cost approximately $15M and had a planned payback of 10 years. The cost of the installation was actually paid back in 7.5 years, with an average annual savings of about $2M. The addition of the 7.6 MW_e engine-generator and the 1000-ton absorption chiller in 2000 cost an estimated additional $10.6M and had a planned payback period of 10 years. For the year 2000 the plant achieved $1.9M in savings, even with only 6 months of operation with the additional 7.6 MW, no absorption chiller benefits, and with all time high annual average gas prices of $4.60/MMBTU. Savings are expected to be higher in 2001.

7. Operability Analysis (Baseline versus BCHP)

7.1 Efficiency

During the case study year (2000), the CHP generation plant converted 812,000 MMBTU (857,000 GJ) into 83,000 MWh_e (299,000 GJ) of net electricity and 138,000 MMBTU (145,000 GJ) of recovered heat, achieving a source generation efficiency of approximately 52%.

Taking into consideration conversion efficiencies and transport of energy from the source, the BCHP Plant represents a 14.15% energy savings over the energy required by the Baseline Plant, as shown in Table 7-1

Table 7-1 Comparison of Energy Efficiency Considering Source Energy

		Purchased		Efficiency	Source Equivalent	
BCHP	Gas	1,178,356	MMBTU/yr	90%	1,309,284	MMBTU/yr
	Electric	11,250,746	kWh/yr	30%	127,995	MMBTU/yr
					1,437,279	MMBTU/yr
Baseline	Gas	538,646	MMBTU/yr	90%	598,496	MMBTU/yr
	Electric	94,548,793	kWh/yr	30%	1,075,640	MMBTU/yr
					1,674,136	MMBTU/yr
				Reduction	236,856	
					14.15%	

7.2 Reliability

The East Campus facility provides nearly 100% of the power consumed during the utility defined peak period.

The Cooper-Bessemer units have been running for over 50,000 hours without a major overhaul and have been 95+% operational other than for routine scheduled maintenance. While they are operated almost exclusively on natural gas, their ability to operate on #2 diesel fuel provides additional flexibility during times when natural gas prices may be high, such as the winter of 2000-01 when gas prices exceeded $10/MMBTU. Also, since the Cooper-Bessemer units can operate on #2 diesel fuel, credit can be taken for them as emergency power units, such as is mandated for hospital emergency power. Units fueled solely by natural gas cannot, since natural gas is considered an interruptible fuel.

8. Installation Analysis (Baseline versus BCHP)

The additional space required for the addition of the Wartsilla engine - generators was added to the construction plans at the time the HTHWGs were installed.

The design phase of the first project took six to eight months, with installation taking approximately another 18 months.

9. Environmental Considerations

When the two Wärtsilä engine-generators were installed in 2000, the University was able to replace four of the older boilers with smaller boilers because of the recovered waste heat from the engine-generators. By replacing the old boilers, the University was able to use the emission credits to install the Wärtsilä engine-generators at the East Campus facility.

The University recently installed catalytic oxidizers on the Cooper-Bessemer engine-generators and afterburners on the Wärtsilä engine-generators to receive emission credits, which were applied to the installation of the engine-generators at the West Campus facility. Emission testing has not yet been performed on these retrofitted engines.

A comparison was made estimating the emissions from the BCHP Plant to the Baseline Plant. For source term values, the EPA source terms given in AP-42 for Commercial natural gas boilers and 4 stroke natural gas combustion engines were used. The utility generation source term for Illinois was used from E-Grid. As shown in Table 9-1 it is possible to achieve significant overall emission reductions.

Table 9-1 Estimated Emissions Comparison

		Boiler			Engine			Utility			TOTAL
				Emission			Emission			Emission	Emissions
		Emission Factor		Ton/yr	Emission Factor		Ton/yr	Emission Factor		Ton/yr	Ton/yr
BCHP	CO_2	1.176E+02	lb/MMBTU	21,525.0	1.100E+02	lb/MMBTU	44,683.6	1,387.44	lb/MWh	7,804.9	74,013.6
	NOx	4.900E-02	lb/MMBTU	9.0	1.948E-01	lb/MMBTU	79.1	4.35	lb/MWh	24.5	112.6
	SO_2	5.880E-04	lb/MMBTU	0.1	5.880E-04	lb/MMBTU	0.2	11.93	lb/MWh	67.1	67.5
	Energy	365927 MMBTU/yr			812429 MMBTU/yr			11251 MMBTU/yr			
Baseline	CO_2	1.176E+02	lb/MMBTU	31,685.0				1,387.44	lb/MWh	71,873.5	103,558.6
	NOx	4.900E-02	lb/MMBTU	13.2				4.35	lb/MWh	225.3	238.5
	SO_2	5.880E-04	lb/MMBTU	0.2				11.93	lb/MWh	618.0	618.2
	Energy	538645.6 MMBTU/yr						103606 MMBTU/yr			
								Reductions	CO_2	29,545.0	28.53%
									NOx	125.9	52.79%
									SO_2	550.7	89.11%

10. Barriers, Incentives, and Lessons Learned

10.1 Regulatory

The process of obtaining the siting permit for the first engine-generator installation took longer and was more involved than any of the other siting permits. When the first generators were installed, a significant amount of time was spent with the Illinois Environmental Protection Agency (EPA), familiarizing them with the details of the installation and convincing them that the Best Available Control Technologies (BACT) were employed in the design. The original permitting took nearly a year, requiring a substantial educational effort. Subsequent siting permits have been progressively easier to obtain.

10.2 Financial

The educational status of the University allows it to borrow money through tax-free financing at rates lower than the commercial rates. This allows the University to finance projects at a lower cost and provides for a greater return on investments.

The local electric utility (ComEd) rate structure is structured in such a way that it could be viewed as a disincentive to BCHP. ComEd costs for standby power are high, $2.99 per plant rated kilowatt of the BCHP generation capacity per month. Although the rated generation capacity of the plant is 20.2 MW, ComEd is charging standby rates on 12 MW. This is because the probability of more than 12 MW of CHP Power going down at any one time (all 4 engine - generators) is very low. These standby power costs, however, still represent a sizeable annual charge to the University from ComEd of over $430K per year. In addition, any electricity that is sold back (based on net monthly electrical flow) to ComEd is purchased by them at a nominal amount of 1.5¢ per kWhr for off peak power, and 2.5¢ per kWhr for on peak power. At these rates, it is not economic for the University to sell back power to the utility. There are also large penalties and costs imposed for any electricity used during unscheduled outages of the University generation plant.

For the above reasons, the University normally operates it's plant on an electric load following basis, thus not generating excess electricity to be sold back to the utility. However, at times (usually for short durations) it is more economical to operate the plant in the thermal load following mode, and if excess electricity is generated, it is sold back to ComEd at the prescribed rates. During the analysis period, substantial levels of electricity were sold back to the Utility during the months of June, August, September, and November (see Table 4.1). This was due to the need to run special operational tests with the newly installed engines, thus resulting in excess power being generated.

ComEd also requires a fault study be completed and fault protection equipment be installed. The University spent $250,000 on fault protection equipment when it installed its first engine-generators in 1993. For smaller facilities this could be a significant disincentive for installing BCHP.

10.3 Business Practices

The UIC central Cooling, Heating, and Power plant is set up intrinsically as a non-profit center. The Utilities Operation at UIC established an operating budget under a revolving (Ledger 3) account and is paid a fee for the delivery of energy to the Chicago campus. Any funds that are saved through energy efficiency measures can be used to further enhance the physical plant. This serves as an incentive to finance a BCHP project.

One of the barriers to BCHP in a University environment is that there is little incentive to save money through energy conservation. For operational personnel, they are provided an annual budget established to cover the cost of supplying energy to the installed campus facilities. Individual departments are not charged directly for their energy usage. When UIC conceived the installation of it’s first cogeneration plant, it was considered to be risky because it was not commonly done. Nearly 10 years later, time has proven the risk to be minimal and the savings accrued from the plant has been used to finance other energy efficiency improvements, including the installation of additional generation and thermal recovery systems.

White Paper: West Campus Cooling, Heating and Power Plant

The West Campus Cooling, Heating, and Power (CHP) Plant is located at 1717 W. Taylor in Chicago, adjacent to an existing steam plant that serves the entire campus, including the hospital and its facilities. It resides in a newly restructured building that accommodates the operating offices, the centralized heating plant, and the electricity generating plant. For the time being, no central cooling plant is installed. However, an engineering firm is performing a feasibility study.

Technical Description

The West Campus plant will be electrically connected to the East Campus plant through a 69 kV tie line that will allow the operation of both plants as a single plant providing a high degree of flexibility and reliability.

The West Campus CHP Plant features the following devices:

- 3 - Natural gas Wärtsilä engine-generators, each rated at 5.4 MW_e
- 3 - Natural gas Solar Taurus turbine-generators, each rated at 7.0 MW_e. These turbines require gas pressure to be increased to 300 psi from the nominal 150 psi delivered to the site.
- 3 - Dual fuel (natural gas/#6 fuel oil) boilers
- 3 - Exhaust Gas Heat Recovery Systems with duct burners on each of the Solar Turbines that are capable of providing a total capacity of 90,000 lb/hr (11.3 kg/s) to 360,000 lb/hr (45.4 kg/s) of steam.

The old steam plant employed seven boilers producing steam at 440°F (227°C) and 150 psi (1,034 kPa), four of which have been retired and their thermal energy replaced by the new central plant heat recovery systems.

Construction

Construction of the West Campus will likely take approximately 14 months; this is slightly faster than the construction of the East Campus facility.

Energy Analysis

The plant is scheduled to come on-line in the late 2001; therefore, no operating data is available.

Financial Analysis

The total cost: of the plant is estimated to be $38M. The payback goal is 7 years based on an estimated annual savings of $7M. The first full year of operation will be 2002.

Environmental Considerations

The siting permits for the facility were readily obtained. As part of the agreement for the siting permit, the University retired four of the old boiler units on the West Campus and retrofitted catalytic oxidizers on the two Copper-Bessemer units and installed afterburners on the Wärtsilä engine-generators on the East Campus.

No actual emission information is available.