

# Combined Heat and Power Systems in University Environment

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## ABSTRACT

Combined heat and power (CHP) technology is still underutilized in the building sector due to the concern of insufficient economic returns related to the seasonal heating and cooling loads and the initial costs of installing these applications. In order to justify the use of CHP systems, the thermal energy created has to be used in a fashion that is favorable to the building's environment. The thermal load is used for heating, hot water, and thermal-driven cooling and humidity controls. This includes a variety of CHP technologies along with absorption chillers or desiccant dehumidification systems.

This article provides a summary on some of the CHP installations in university environment. The constant influence of changing technologies and higher utility rates has forced universities and colleges to make energy management improvements. The literature survey on these universities is not vast because the new and improved systems are still in their beginning years and have not established concrete success stories. They have, however, shown enormous decreases in consumption and begun to establish very profitable returns on their investments.

**Key Words:** CHP, building sector, university central plant, district heating, power reliability

## INTRODUCTION

Many colleges and universities are starting to show great concern about energy management programs. Utility management and conservation has become a universal concern for the institutional sector with the

involvement of deregulation, rolling blackouts and increasing electric rates. Universities and colleges have always relied on the stability of their utilities to provide reliable power at a fair cost.

Deregulation has opened the gates for competition among utility providers. This competition has allowed for less strict federal control over the providers, which adversely has caused an increase in rate structures. Also, the concern for power reliability has forced utility providers to increase their power supply to keep up with the growing demand. Many universities have contractual agreements with utility providers that were once considered stable and relatively low business expenses. However, with the increase in security features and rate structure, these contracts are being reorganized, and universities are finding out that this once stable expense is becoming a major fluctuating cost.

Energy management is not just monitoring the price of natural gas and electricity. It involves paying attention to all energy related issues, including facilities and maintenance staff, new equipment, capital investments and leasing, and critical risk elements such as the failure of the energy infrastructure due to faulty management principles and maintenance [5].

In order to move forward in this ever changing energy infrastructure, universities need to pay close attention to their present energy policies. So much concern is emphasized on new architecture and constructions for physical appeal, that many times the supply to these buildings are outdated, making them less efficient.

This article provides a summary on some of the CHP installations in university environment. The results from a survey to develop data in cooling, heating and power in the college and university sector is summarized first, followed by the review of CHP installations in three universities. As a first step in carrying out energy management projects, the facility assessment process is discussed. Campus administrators are starting to realize the importance of upgrading their energy systems through energy outsourcing, so the issue of outsourcing is also addressed.

## UNIVERSITY CASE STUDIES

Enrollment at U.S. Universities and Colleges continues to rise, which is putting a strain on the energy systems of campuses across

the nation. The United States Department of Education (ED) estimates that in 2005 college enrollment reaches 16.3 million. By 2011, more than 17 million students will be attending university and colleges, which is a 16% increase from 2001 [2]. In order to compete with the rise in demand from student enrollment increases, universities and colleges have to make changes within themselves to cater to the needs of their "customers," the students. Over the past decade, some universities and colleges have made the adjustments by successfully meeting the needs of the increasing numbers of students.

### **ORAL and US-DOE Study**

Oak Ridge National Laboratory (ORAL) and United States Department of Energy (US-DOE) performed a study to develop data in cooling, heating & power in the college and university sector. The study was performed to identify different technologies, sizes, locations and plans for growth and was also used to understand the hurdles and challenges faced in order to assist the CHP market growth. The data were compiled from a population study from the International District Energy Association (IDEA), the University of Rochester, and the Association of Higher Education Facilities Officers (PAPA). Data were collected from web-based surveys for qualitative feedback, email, fax, phone, and extensive interviews for case studies. About 16.8% of the total population and 42.5% of the contacted population responded [9].

From the study, it was learned that there was a large range of technologies. Because some of the central plants were designed in the early 1980's, many universities have had to establish extension plans to incorporate cooling requirements. The different drivers for the systems were campus growth, power reliability, replacement and economics. For heating capacity, 145 institutions reported for a total capacity of 42,825,585 lbs/hr of steam. The steam capacity ranged from 6,000 lbs/hr to 3,300,000 lbs/hr.

Campus cooling capacity for 107 reporting institutions averages 6,804 tons. Thermal storage is another process used to help maintain the campus cooling requirements. Fifteen institutions reported using chilled water storage with a total capacity of 18,123,000 gallons. Ice storage is used at 10 institutions for a total capacity of 191,700 ton hours.

The results of the survey also showed that of the 158 reporting, 65 (41%) generate and/or cogenerate electricity. The power generation at these universities ranged from 0.18 MW to 85 MW systems totaling

967.92 MW. The equipment used ranges from 0.18 MW Capstone micro-turbine to a 45 MW GE LM 6000 gas turbine.

A very important factor in the survey is the percentage of the campus' needs that have been met. Some campuses meet the full system requirements, while others were designed to handle average demand and not peak loads. About 83% of all heating needs, 68% of all cooling needs and 49% of all power needs are met by cogeneration systems.

### **Louisiana State University**

Louisiana State University (LSU) is the largest university in the State of Louisiana. LSU is located in Baton Rouge, Louisiana and has a population of 34,000 faculty staff and students. LSU sits upon a 650-acre main campus with 160 buildings. As early as 1989, the administration at LSU noticed that there was going to be a need for major university expansion to handle growth. As part of the university expansion project, they wanted to overhaul the heating and cooling systems of more than 100 buildings throughout campus. By implementing major energy efficient retrofits through a performance contract, Sempra Energy Solutions and LSU projected more than \$4.3 million annually could be saved in energy consumption costs [5].

The original central power plant at LSU serviced a small number of buildings and the university had to maintain eight additional facilities in order to service the remaining buildings on campus [6]. The overall efficiency and reliability of the central power plant and eight additional facilities decreased over the years because of constant modifications to the system and additions of buildings to the campus. The performance contract with Sempra Energy was sought out in 1998.

The end result of the entire project was not necessarily the first vision of LSU. Initially, the plan was to use chilled water generation from a turbine-driven chiller that could handle the variable campus wide cooling loads, coupled with a waste heat recovery system from the turbine that would provide steam distribution for the entire campus. The rate structure that was contracted with the local utility precluded electric generation. Sempra Energy Service's system consisted of a 5,000 hp gas turbine directly driving a 6,300-ton chiller and producing 115,000 lbs/hr of steam by using a waste heat boiler and supplemental firing.

This installation saved the University approximately \$4.7 million in energy cost savings per year. The project also had a significant benefit for the climate. It annually saved approximately 39 million standard cubic

**Table 1. CHP in Louisiana State University**

Louisiana State University			
CHP System	Energy Produced	Reduced Emission	Energy Cost Saving
5,000 hp gas turbine with 6,300-ton chiller	115,000 lbs/hr of steam	CO <sub>2</sub> - 2,,200 tons	\$ 4.7 million/year
		NO <sub>x</sub> - 530 vehicles	

feet (scoff) of natural gas (emitting 2,200 less tons of CO<sub>2</sub>) compared to conventional separate heat and power generation. The annual avoided NOX emissions are equivalent to the annual emissions of 530 vehicles [6]. Table 1 provides a summary of this CHP system.

Even though the project was a success, it did not stop here. With the help of GE Energy and Bernhard Mechanical Contractors, LSU was able to improve this system and generate their own electricity. GE Energy provided Bernhard Mechanical Contractors with an LM2000 aero-derivative gas turbine to be used at LSU. The turbine was placed into the central power plant at LSU in a cogeneration application rated at 17.5 megawatts [7]. The turbine will run approximately 24 hours a day and produce up to 150,000 lbs/hr of steam. This system will cover the baseline electrical and maximum steam load of the Baton Rouge campus [1]. The main plant will interface with the existing campus-wide energy management system for control, instrumentation, monitoring and dispatch of chilled water for all cooling, electrical power and steam.

The university will continue its connection with the local utility provider, Entergy Gulf States, in order to meet electrical demand that cannot be provided by the new CHP system. The connection will also allow the campus to be supplied with electricity when its system is down for maintenance.

### **University of Illinois at Chicago**

In the early 1990s, the University of Illinois at Chicago's (UIC) energy demand grew and the central heating and cooling plant needed substantial upgrades and replacements. The University of Illinois at Chicago was formed in 1982 by the consolidation of two campuses: the Medical Center campus and the Navy Pier campus. UIC is located just west of Chicago's Loop and is the largest university in the Chicago area. UIC represents a strong faction of the educational, technological

**Table 2. CHP Systems in University of Illinois at Chicago**

University of Illinois at Chicago			
CHP System	Energy Produced	Energy Cost Saving	Payback Period
20.2 MWe System with 1,000 ton absorption chiller	238MMBtu/h of thermal energy 2,350 tons of cooling	\$ 7 million/year	5.3 Years
37.2 MWe System	360,000 lbs/hr of steam from waste heat 360,000 lbs/hr of steam from boilers		

and cultural fabric of the region [3].

In order to meet the growing demands of the campuses' 27,000 students, UIC decided to install a 12.6 MWe CHP system. This project was started in 1993. This system was not quite large enough to handle the load, so an additional 7.6 MWe was installed with a 1,000 ton absorption chiller to total 20.2 MWe. This system consists of four reciprocating engine-generator sets, two 6.3 MWe (natural gas or number 2 fuel oil fired) and two 3.8 MWe (natural gas fired) [4]. The recovered heat from the generation supplies 38 MMBtu/h of thermal energy combined with 200 MMBtu/h of thermal energy generated from three high-temperature hot water boilers to produce enough heat in the winter and drive 2,350 tons of cooling through an absorption chiller in the cooling months.

Early in 2002, a second plant began operation on the West campus that provides an additional 37.2 MWe and offsets the heating and steam demands of the several hospitals and other buildings on the West Campus. The West Campus has the maximum heat potential of 360,000 lbs/hr of steam from the recuperation of waste heat and an additional 360,000 lbs/hr from previously existing boilers. The West Campus will utilize three Solar Taurus 70 combustion turbines rated at 7 MWe and three 5.4 MWe Wärtsilä 18V34SG lean-burning, reciprocating engines [3].

Without cogeneration, UIC expected to pay electricity costs of \$9.4 million and natural gas costs of \$5.8 million annually, totaling \$15.1 million. The costs savings with this project are significant. The annual

utility cost of operating with the cogeneration system installed is approximately \$350,000 in electricity and natural gas/number 2 fuel costs of \$7.6 million, totaling annual costs of \$8 million. The operating cost of UIC is reduced by approximately \$7 million, with a payback period of 5.3 years, plus operating and maintenance costs of the system [11]. Table 2 provides the summary of these CHP systems.

The University will remain connected to the grid to allow for the purchase of needed electricity and will maintain connections that allow for the University to sell power to the grid. A distributed control system (DCS) runs the thermal system and a power management system operates the electrical generation. The unique set up of this system will allow for the numerous parts to operate independently or operate with the flexibility needed to meet the variable requirements as a whole.

### **University of Maryland—College Park**

The CHP Integration Test Center was designed to create a new understanding of how to integrate CHP into institutional and commercial buildings. This center is sponsored by the DOE's Office of Power Technologies (OPT), Office of Distributed Energy Resources (DER), CHP Program and the University of Maryland's Center for Environmental Energy Engineering. Support for this program is provided by Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), Brookhaven National Laboratory (BNL), and the National Renewable Energy Laboratory (NREL). The Chesapeake Office Building at the University of Maryland—College Park (UMCP) was chosen as a test site by CHP Integration Test Center for a CHP system. The Chesapeake building is a 200 employee administration building at the edge of the University's campus covering 52,700 square feet and is considered an ideal test site since it represents a medium sized commercial building, which is the size of 23% of U.S. buildings [8].

The four-story Chesapeake building was built in 1991 and is powered completely by electricity. Heating and cooling are provided by the building site since it is located on a far edge of campus. A detailed study was performed on the building to determine the building's baseline energy usage, which included examinations of load profiles, energy distribution, HVAC controls and mechanical equipment design. The building was designed and built with two cooling zones, allowing the test center personnel the opportunity to test two separate CHP systems. The original design included an air-conditioning variable air volume (VAV)

**Table 3. CHP Systems in University of Maryland—College Park**

University of Maryland - College Park		
CHP System	Reduced Emission	Energy Cost Saving
2 EDACs Existing 90-ton AC unit Kathabar desiccant dehumidifier	CO <sub>2</sub> – 55%	\$ 10,000/year
75 kW Microturbine Existing 90-ton AC unit ATS desiccant dehumidifier Broad absorption chiller	CO <sub>2</sub> – 40%	\$ 25,000/year

system served by two 90-ton direct expansion (DX) electric rooftop units (RTUs). Electric reheat coils in the VAV boxes are used for heating and each RTU serves one of two zones, each consisting of two floors. The new CHP system was integrated into the existing system.

Table 3 provides a summary of the two CHP systems installed. The first system is comprised of two natural gas-powered, engine-driven Goettl air conditioners (EDACs), an existing 90-ton rooftop air conditioning unit, and a Kathabar desiccant dehumidifier. The gas fired engines provide waste heat, which is used to produce steam to the desiccant dehumidifier. The dehumidifier supplements the cooling load on the EDAC and RTU by drying supply air, a function typically done by the mechanical cooling of the EDAC and RTU alone. Yearly savings for this system are approximately \$10,000 with a 55% reduction in CO<sub>2</sub>.

The second system includes a Honeywell Parallon 75 kW micro-turbine, an existing 90-ton rooftop air conditioning unit, an ATS desiccant dehumidifier, and a Broad absorption chiller, which supplements electrical power for the building to cool and dry air. The microturbine generates all electrical power for the building and the waste heat from the microturbine exhaust powers the absorption chiller and the dehumidifier. The absorption chiller assists the existing RTU in providing air conditioning for this system, while the dehumidifier dries the ventilation air for the building, a function normally performed by the RTU and absorption chiller. Together, these interactive components efficiently supply air conditioning for the second system and supplement the power requirement for the entire building. Annual savings for this system is forecasted to be \$25,000 with a 40% reduction in CO<sub>2</sub> [12].

## FACILITY ASSESSMENT AND OUTSOURCING

The facility assessment process is an overview of the physical and functional attributes of an existing facility or to understand the financial requirements needed to maintain the building. Facility assessments are performed by most companies on a regular basis in order to develop ways of improving operating costs. Frequently, a facility assessment is used to develop an analysis of the cost to renovate versus the cost to replace.

Facility assessments on campuses allow the campus administration to get an economic overview of how much maintenance a building or group of buildings needs in order to operate at maximum efficiency. A facility assessment includes an examination of the physical condition and the functional condition of a building. The physical condition of a building involves the review of the mechanical and electrical systems, structural integrity and building envelope. It also includes hazardous materials, accessibility and sustainability. The functional conditions of the assessment examine the needs of the students including educational standards, technology, acoustics and lighting, and suitability to purpose.

In analyzing energy management plans, other assessment elements play a more definitive role. If the facility assessment includes more than one facility, or perhaps even the entire campus, there are additional elements that must be taken into account, including the following [10]:

Utility lines—If the facility's staff has no idea where utility lines are placed, a survey must be completed to capture this information.

Energy efficiency—In this step, analysis of present building construction is reviewed to see if improvements can be made to lower electrical cost, by using more efficient means of lighting, insulation and temperature control.

Utility capacity—As mentioned above, it must be determined if there is adequate utility capacity to serve facilities for both current and projected uses. But energy issues also come into play when looking at site issues. For example, if renovating multiple buildings, is it better to keep localized heating and cooling or consolidate it into a central plant?

Power cogeneration and self generation—This step looks at the possibility of generating power on campus to reduce peak load conditions that result in high utility rates. For instance, can photovoltaics or microturbines be installed?

Once the facility assessment is complete, it's ready to be put to use. Many times outsourcing the expertise of energy professionals is the best

move. After identifying the possible solutions to the problems, an assessment establishes quantitative results to identify areas of greatest concern, which will help show cost savings analyses and to make implementations. The assessment team also needs to begin research on the most up to date technologies and look into enrollment trends to determine if the changes to be made are necessary for future advancements.

Campus administrators are starting to realize the importance of upgrading their energy systems through energy outsourcing. An energy service firm can help universities on not only the supply side, but also on the demand side of their operation. On the supply side, these firms can help acquire energy supplies for the utility providers under terms that will assure price stability and reliability. It is far easier for a third party consulting firm to achieve price stability and reliability than for the university administration themselves, because administrators lack the expertise and compiled research on the ever changing technology and regulations. On the demand side, the advancements of technology provide opportunities for far more efficiency in energy usage and consumption. For instance, energy analysis and monitoring of energy consumption over multi-site operations has allowed control over temperature and lighting from a control center that removes the human error of manual controls. Also, artificial intelligence and separate networks help energy users guarantee their environment by avoiding costly voltage fluctuations. Demand side control has the largest change in technological advancements. Energy professionals are far more equipped to provide universities with the most efficient and profitable recommendations.

Successful outsourcing requires the full control of the outsourcing firm. Administration might be involved in all implementation decisions, but these firms need complete creative control in all studies and data collection. This control allows the university to free up internal resources and transfer the risk of today's volatile energy market place. Many times, the outsourcing firms will take up ownership of the infrastructure, providing the university very little liability for design and operational malfunctions.

## CONCLUSION

The energy system in each university system was designed and performed differently, which made the management unique to their situ-

ations. Lessons learned from the university energy management projects involved maintaining fuel flexibility, power reliability, reducing campus emissions, utilization of alternative fuels, and interconnection capabilities and regulations with various utility providers.

Combined heat and power for institutional sectors is not a new concept. The constant influence of changing technologies and higher utility rates has forced universities and colleges to make energy management improvements. The literature survey on these universities is not vast because the new and improved systems are still in their beginning years and have not established concrete success stories. They have, however, shown enormous decreases in consumption and begun to establish very profitable returns on their investments.

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