COOLING, HEATING, AND POWER IN COLLEGES AND UNIVERSITIES: UNDERSTANDING THE MARKET AND FACILITATING ITS GROWTH

PHASE I

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I. INTRODUCTION

Combined cooling, heating, and power (CHP) has the potential to increase source energy efficiency dramatically and reduce carbon and air pollutant emissions. Combined heat and power produces both electricity and usable thermal energy, converting as much as 80% of the fuel into usable energy. Conventional central station power plants, on the other hand, convert only about a third of the fuel's available energy into usable electric power energy, wasting the thermal energy.

New and emerging CHP system choices include a spectrum of technologies, such as fuel cells, microturbines, and industrial advanced turbine systems, which are more economically attractive, reliable, and versatile. These choices should open new markets for CHP. New thermally driven cooling and humidity control technologies that can use CHP heat output are likewise being demonstrated and developed.

While CHP use in commercial buildings in the US is in its infancy, CHP systems have been used in institutional buildings and on college campuses for decades. A number of data sources, such as the Utility Data Institute and the DOE's Energy Information Administration (EIA), cite 2000-3000 MW of installed CHP capacity in buildings or on campuses. Independent energy organizations, such as the District Energy Library (www.energy.rochester.edu) hosted by the University of Rochester cite numerous CHP installations in educational institutions. The report, District Energy Systems Integrated with Combined Heat and Power, prepared by Mark Spurr of the International District Energy Association, examines these data sources and concludes that the total CHP serving buildings through district energy systems in the United States stands at roughly 3500 MW.

While the overall size of the CHP market in the buildings sector is somewhat uncertain, most agree that colleges and universities, health care complexes, and military bases hold the largest potential for near term growth. The federal government owns and operates hundreds of central plant facilities at military bases, prisons, and campus locations that hold potential for CHP. Some of the factors that drive the favorable economics of CHP in these building types are:

- Multiple building loads under common ownership, so that electricity, heating, and cooling loads can be aggregated and served by a central system that is larger, more efficient, and more cost effective than several smaller systems
- Close proximity of buildings, which ensures that connecting buildings with hot water/steam/chilled water piping is not cost prohibitive.

- Buildings are occupied by "owners," not leased to tenants, making a higher degree of control and comfort desirable. Common ownership reduces the market uncertainty of speculative commercial office leases and supports the capital investment in central plant and distribution network. Many research facilities and critical care functions require the higher reliability of service from a central plant.
- Occupancy levels are generally high, with students or patients occupying the facilities around the clock, creating high load factors that help amortize the investment in CHP systems.

COLLEGE AND UNIVERSITY ENERGY SYSTEMS

Many universities have long used district energy systems or campus energy systems as a means of controlling utility costs and managing capital and space costs more efficiently. Central plant systems serve multiple institutional buildings and deliver "ready-to-use" thermal services directly to these buildings in the form of chilled water, steam, or hot water. District or multi-building systems that serve a single institution in a campus setting can eliminate the need for multiple boilers and furnaces to provide heating and electrically driven chillers for air conditioning in individual buildings, thus offering significant economies of scale.

Recovery of waste heat produced during power generation is a particularly important part of these campus systems. The recovered thermal energy can be used directly for district heating, converted to hot water district heating or steam can drive chillers to make chilled water for cooling. Or, in some cases, the CHP system may be sized to meet the thermal requirements of the campus, with electric power generation as a secondary product. District cooling may be delivered via chilled water through underground piping systems. It may be more localized with steam-driven absorption chillers distributed closer to the cooling loads and linked to a central steam system. District cooling systems or distributed absorption chiller systems can significantly reduce peak power demand by displacing some or all of the electrically driven chiller peak demand for individual buildings and by improving the cost effectiveness of thermal energy storage in hybrid configuration systems.

PROJECT OBJECTIVES

The objectives of this project, to be accomplished over multiple phases, is to gather and use available information, experiences and data on existing CHP installations in colleges and universities:

- To document the benefits and the lessons learned about barriers and hurdles to implementation and how to successfully deal with them

- To assess common attributes of successful CHP installations and identify institutions with strong potential for new or expanded CHP systems
- To develop appropriate outreach materials and the communication network to facilitate education of decision makers at these prospective CHP sites

This initial phase of the project consisted of three tasks: conducting a census of college and university CHP systems, creating case studies on select colleges and universities, and documenting lessons learned and barriers/hurdles to implementation. This information is presented on the following pages.

II. ACCOMPLISHMENTS

The work was conducted during the timeframe from September 2001 until January 2002. There were three primary components to the work: design, development and deployment of a web-based survey; design, development and execution of a multi-channel census; and research and development of case studies on institutions with unique or differentiating installations of district energy systems. Each of these components provides a different perspective of what is happening in the central plant and facilities departments with regard to district energy and combined heat and power at the nation's colleges and universities. The findings were compiled into this report during January 2002.

RESEARCH POPULATION

The institutions contacted for this study were identified from several industry listings. These listings are maintained by IDEA, the Association of Higher Education Facilities Officers (APPA), and the District Energy Library at the University of Rochester. Not all the institutions in the listings have central plants, but institutions that have central plants are most likely to be found within at least one of these lists. The total number of institutions comprising the populations in the aggregated and assimilated list was one thousand two hundred and eight (1208).

WEB-BASED SURVEY

The web-based survey was designed and implemented during September to provide qualitative insights. The survey included thirty questions ranging from basic system metric information to topics such as challenges to current expansion plans and the possible roles for government as a catalyst to the expansion of combined heat and power in the college and university sector. The qualitative survey was created using a web survey tool called Zoomerang. A sample survey can be found in Appendix I. Potential respondents from the industry lists were emailed the survey URL along with a cover letter from IDEA and a series of follow-up emails were sent to request participation. Eighteen responses were received.

CENSUS

The census was designed to capture quantitative data about the installed equipment base at these institutions. The census was conducted from September 2001 through December 2001, with responses still trickling in during January 2002. Institutions from the three lists were contacted by multiple means – phone, email, and fax – but phone calls were the primary contact method. Collecting census data was a labor-intensive process, requiring extensive calling and interviews to assemble detailed facility information, but this was the only way to ensure a decent data capture rate. Institutions that were known to have central plants or that were most likely to have them were called first. In all, 436 institutions were contacted. Of these, 130 reported that they had central plants, 39 reported no central plant, and 267 did not respond or have not yet responded. A sample of the census form can be found in Appendix II.

CASE STUDIES

Ten institutions were profiled in case studies. The intent of the cases is to demonstrate a variety of technical applications or operational approaches to central energy systems on the nation's campuses. It is our intention that that the stories presented here will provide helpful insights to others looking to expand their district energy systems or integrate innovative technologies such as combined heat and power.

These cases were selected for at least one of several reasons. Some, such as Cornell, were chosen for their innovative use of environmentally sustainable energy sources such as deep lake water cooling. Others, such as Slippery Rock, were chosen as examples of technological innovation to address emissions restrictions through co-firing of natural gas with coal. Still others, like MIT, were chosen for their insight into regulatory issues facing colleges and universities looking to transition electric demand away from the local utility to on-site generation. The cases were developed from October through January with the assistance of facilities directors from the universities. Each case study report will include a "champion" who will serve as contact person for those seeking greater detail or additional insights.

The case studies include:

- Cornell University
- Massachusetts Institute of Technology
- Princeton University
- Rutgers University (pending)
- Slippery Rock University
- Stanford University
- University of California, Los Angeles
- University of North Carolina at Chapel Hill
- University of Pennsylvania
- University of Texas at Austin

III. RESULTS OF THE STUDY

The research conducted over the past several months yielded several major pieces of information. The first is the set of tables containing census data for the colleges and universities. This data includes, but is not limited to, system capacities, annual fuel expenditures, size of distribution networks, and types of equipment installed. The second is a set of qualitative responses providing insights into barriers to progress and opportunities for government involvement. Third is a set of contemporary case studies highlighting best practices, innovation, and lessons learned from institutions with district energy systems in place. The cases are presented in Section V, while other data is presented below.

CENSUS COMPILATION

As noted earlier, census data was collected from October 2001 through January 2002. Institutions that were known to have central plants or that were most likely to have them were called first. In all, 436 institutions were contacted. Of these, 130 had central plants, 39 had no central plant, and 267 did not respond. A breakdown of the number of institutions contacted by source list is shown below.

	OVERALL STATS	IDEA MEMBER LIST	ROCHESTER LIST	IDEA WEB LIST	APPA LIST
Finished surveys	130	51	19	2	57
Finished, no central plant	39	2	1	0	36
Contacted but has not yet responded	267	30	24	0	213
To be contacted	772	2	7	3	760
Total	*1208*	*85*	*51*	*5*	*1066*

The results presented for the census are for the 130 institutions reporting central plant information. While the number of institutions reporting information does not represent the entire universe of central plants on university campuses, it does represent a significant percentage of them. The data we received was of good quality and provides us with a good initial sense of what the typical campus installation looks like and what is going on in the market today vis a vis expansions and replacement of current equipment. As noted earlier, census data continues to be submitted even now.

If efforts to collect data are continued, it will be easier to construct a fuller picture of the marketplace. The recommended path forward is presented in Section VI. What is presented graphically in this section is a snapshot of the information received as of early January 2002.

Detailed information is presented in tabular format in the appendix. The information is split into tables in this manner:

- System longevity information

- Heating system summary data
- Heating equipment detail
- Cooling system summary data
- Cooling equipment detail
- Electricity generation system summary data
- Electricity generation equipment detail
- Expansions in planning stage – heating
- Expansions in planning stage – cooling
- Expansions in planning stage – electricity generation
- Expansions under construction—heating
- Expansions under construction—cooling
- Expansions under construction—electricity generation

Summarized and tabulated information (as of early January 2002) is presented here:

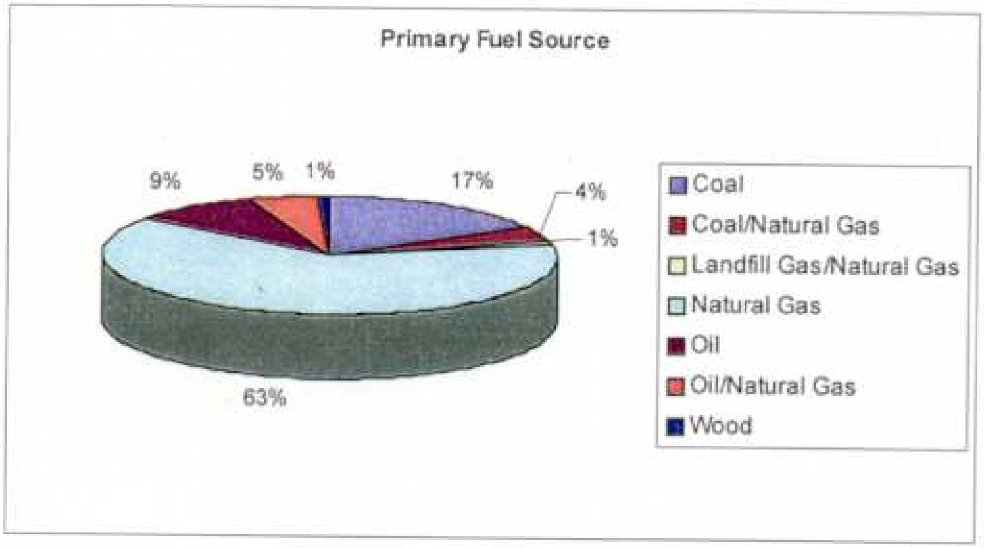
Heating Capacity

Most central plant facilities include heating capability. Of the 130 institutions that reported having a central plant, 119 reported data on heating capacity. Below are statistics calculated based on the 119 institutions that provided this data. The reporting unit for heating capacity is pounds of steam assuming a heat content of 1197 BTU/pound of steam at a nominal pressure of 150 psig saturated steam. The aggregate heating capacity of the respondents equals 39 million pounds of steam per hour.

Sum of all capacity	*39,092,540lbs/hr*
Mean installed capacity	*328,509lbs/hr*
Median installed capacity	*206,000lbs/hr*
Range	*6,000 - 3,300,300lbs/hr*

Primary Fuel Source

Natural gas was the most commonly identified primary fuel source on campus. The chart is based on 121 institutions reporting fuel source data. Following natural gas in order of use was oil, coal, and other.



Annual Fuel Expenditures

Ninety institutions reported fuel cost data. If data was provided only in terms of volume consumed, the following average cost assumptions were used: natural gas, $4/MCF or $0.40/therm; oil, $1.60/gallon; coal, $40/ton. Respondents were asked to provide fuel consumption data for the last full calendar year (2000). Fuel consumption was not normalized for weather, nor was it requested in form to reflect an "average annual volume." The intent of this inquiry was not to discern individual institutional purchasing habits, but more to develop an overall scale for fuel consumption in the aggregate for this sector. In the aggregate, the respondents reported total annual fuel consumption in excess of $234 million.

Total Fuel Expenditures at All Institutions	*234,261,000 dollars*
Mean Annual Fuel Expenditure	*2,602,900 dollars*
Median Annual Fuel Expenditure	*1,500,000 dollars*
Range	*30,000 - 18,683,000 dollars*

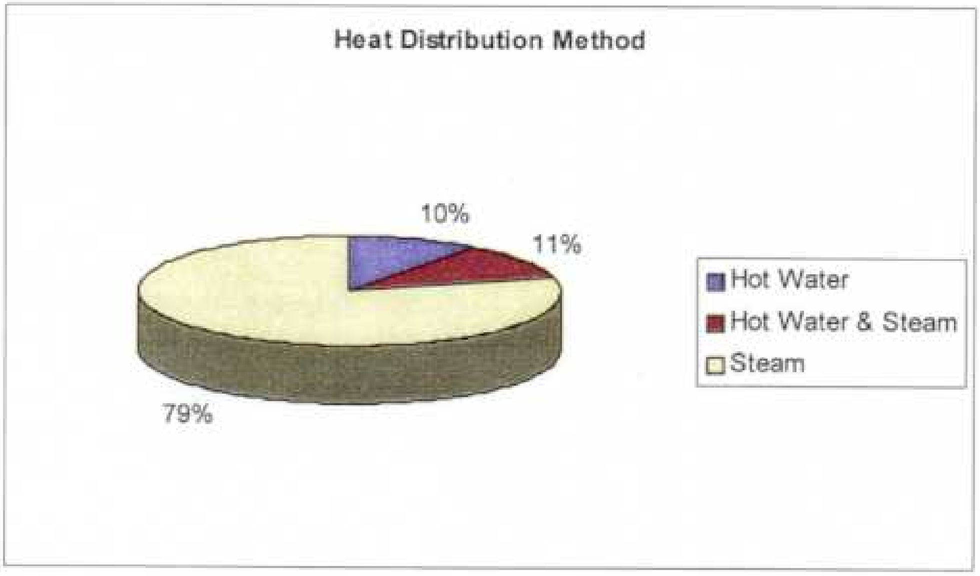
Length of Heating Pipe Installed on Campus

Ninety-one institutions reported data on the length of steam or hot water distribution piping. Total pipe length is equal to the combined linear feet (not trench feet) of supply and return piping, including mains, trunks, and service laterals connecting to user buildings. The total aggregate length of heating pipe (supply and return) reported by respondents was 4.2 million linear feet or approximately 795 miles.

Sum	*4,199,163linear feet*
Mean	*46,145linear feet*
Median	*21,000linear feet*
Range	*2,000 - 245,000linear feet*

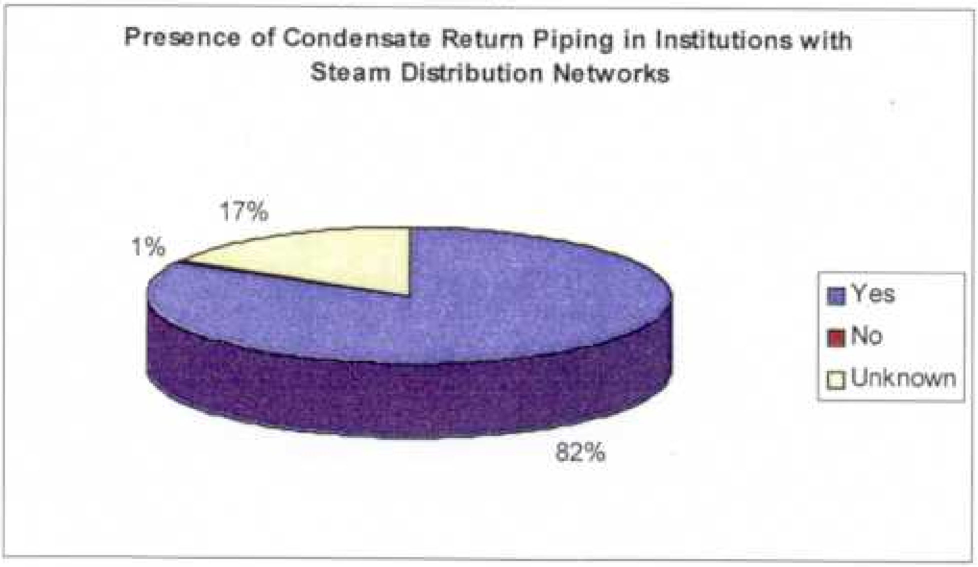
Heat Distribution Method

120 institutions reported the method they used to distribute heat to campus buildings. Steam was by far the most commonly used medium of heat distribution, followed by hot water district heating.



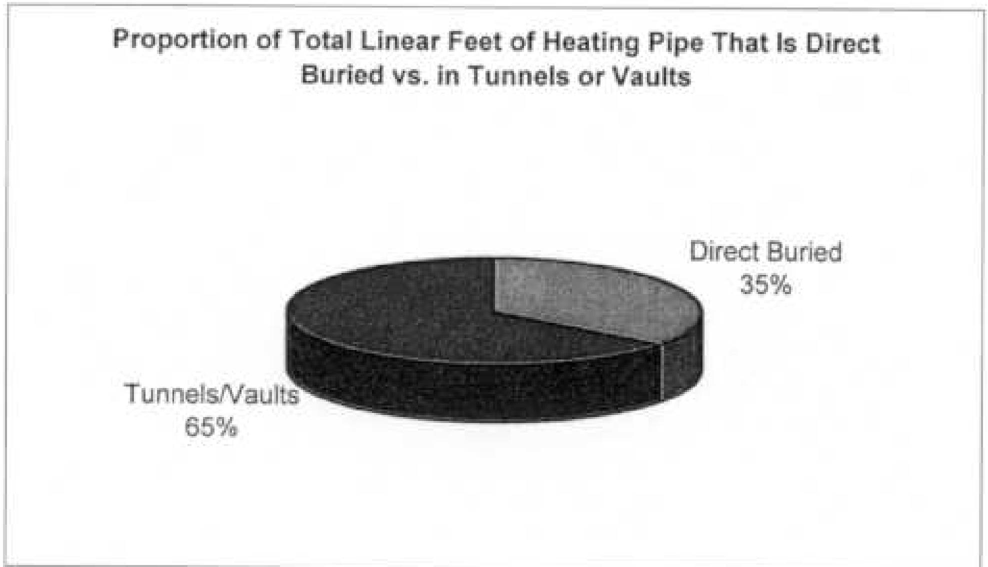
Implementation of Condensate Return Systems

108 institutions had steam distribution systems on campus. 82% of those reported having a condensate return system, 1% reported not having condensate return, and 17% did not provide any information.



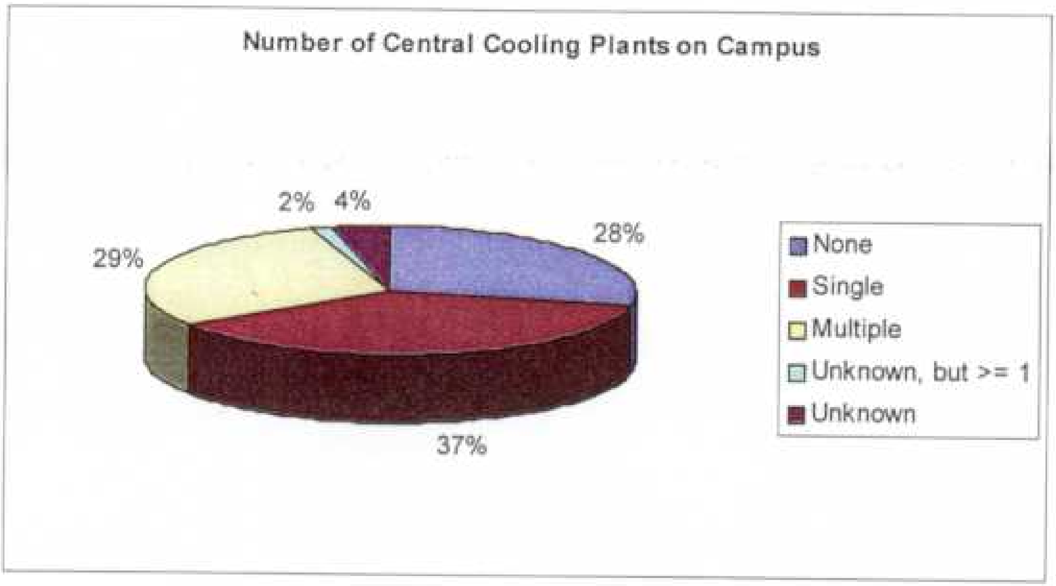
Heating Pipe Construction

77 institutions provided data on both heating pipe length and construction. These figures were combined to derive the proportions of total length of heating pipe across all campuses that is direct buried or in tunnels and vaults. We found that heating pipe is more commonly found in tunnels or vaults as opposed to being direct buried.



Number and Capacity of Cooling Plants

Of 130 institutions, 48 had one central cooling plant, 38 had multiple plants, 37 had none, 2 had an unknown number (but at least one), and 5 did not report the number of plants. Capacity statistics were calculated based on responses from 85 institutions providing data. The total aggregate cooling capacity reported by respondents was 830,000 Tons.

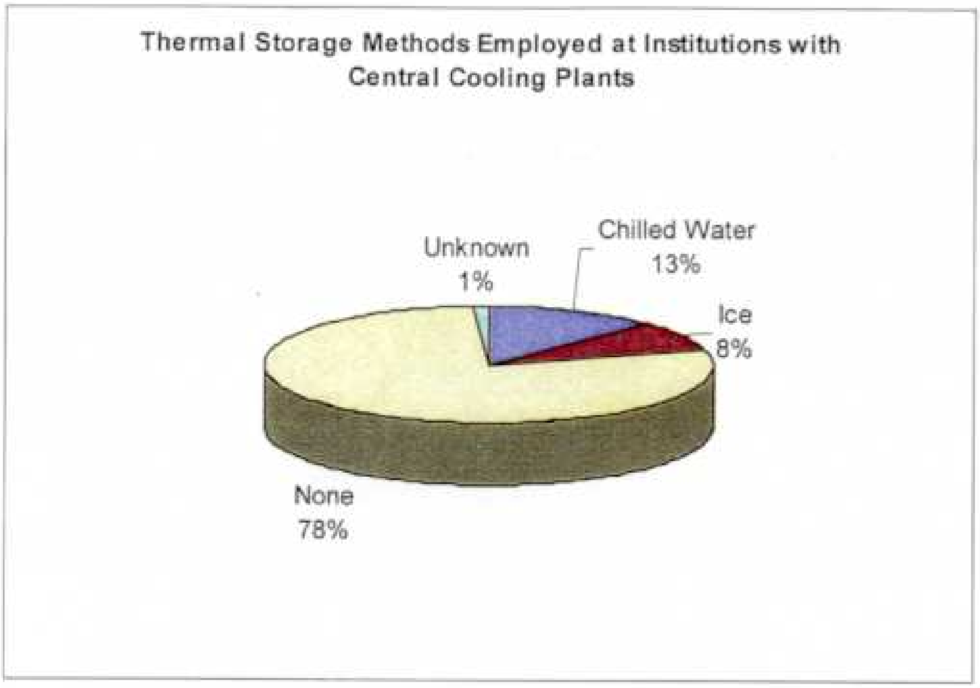


Sum of all cooling capacity	*829,910 Tons*
Mean cooling capacity	*9,764 Tons*
Median cooling capacity	*5,400 Tons*
Range	*580 - 44,000 Tons*

Thermal Storage

The majority of cooling systems do not employ thermal storage technology. Of 88 institutions with cooling systems, 69 had no thermal storage, 11 had chilled water storage, 7 had ice storage, and 1 did not provide data. 16 of the 18 institutions with thermal storage provided capacity information for their thermal storage systems.

16,840,000	*gallons total chilled water storage (10 institutions reporting)*
139,900	*ton-hrs total ice storage (6 institutions reporting)*



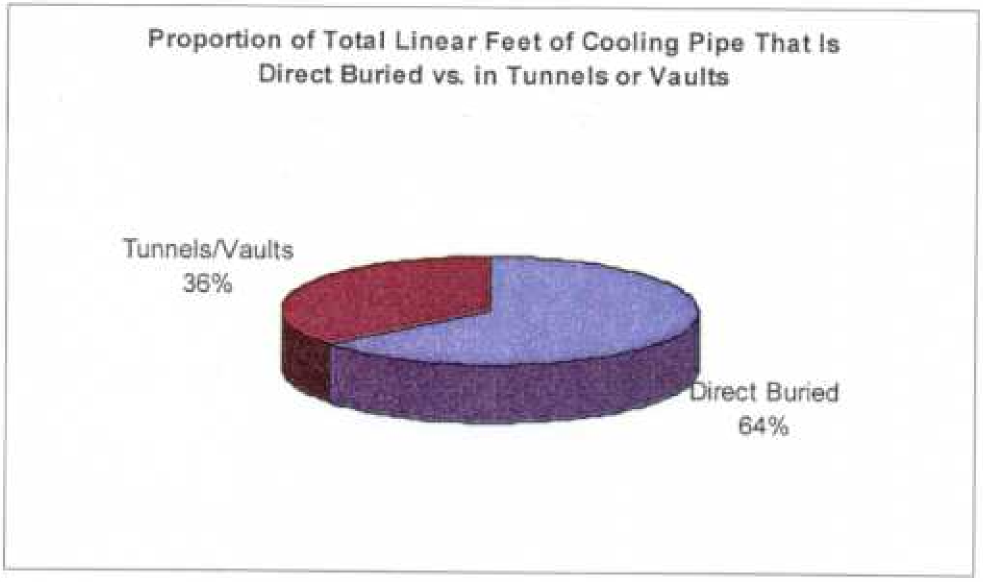
Length of Cooling Pipe Installed on Campus

64 institutions reported data on the amount of cooling pipe installed on campus. Pipe lengths include supply and return piping. The aggregate length of district cooling pipe reported by respondents was 1.44 million linear feet of supply and return piping or approximately 272 miles.

Sum	*1,436,618 linear feet*
Mean	*22,447 linear feet*
Median	*16,000 linear feet*
Range	*2,000 - 89,228 linear feet*

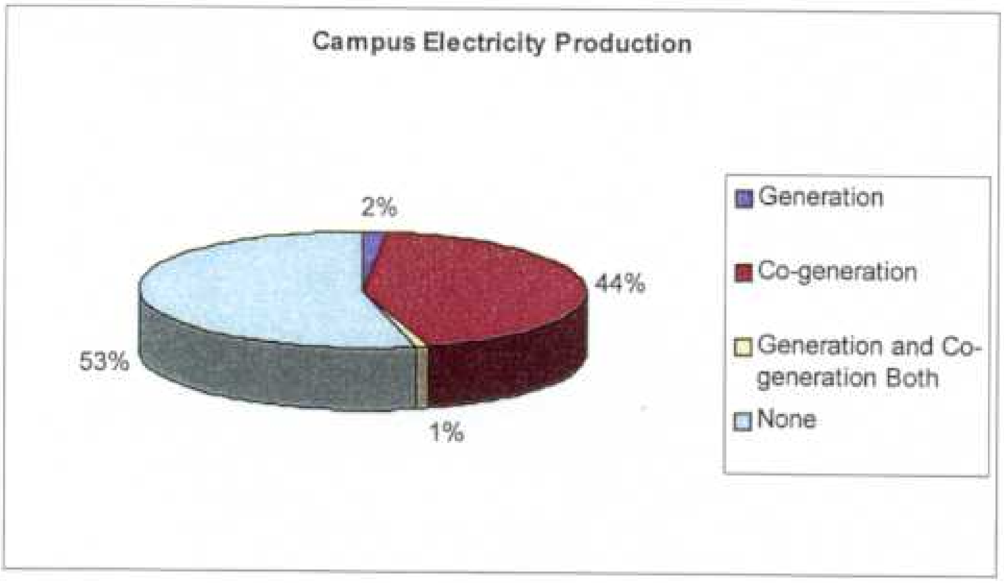
Cooling Pipe Construction

61 institutions provided data on both cooling pipe length and construction. These figures were combined to derive the proportions of total length of cooling pipe across all campuses that is direct buried or in tunnels and vaults. We found that cooling pipe, unlike heating pipe, is more commonly direct buried as opposed to being found in tunnels or vaults.

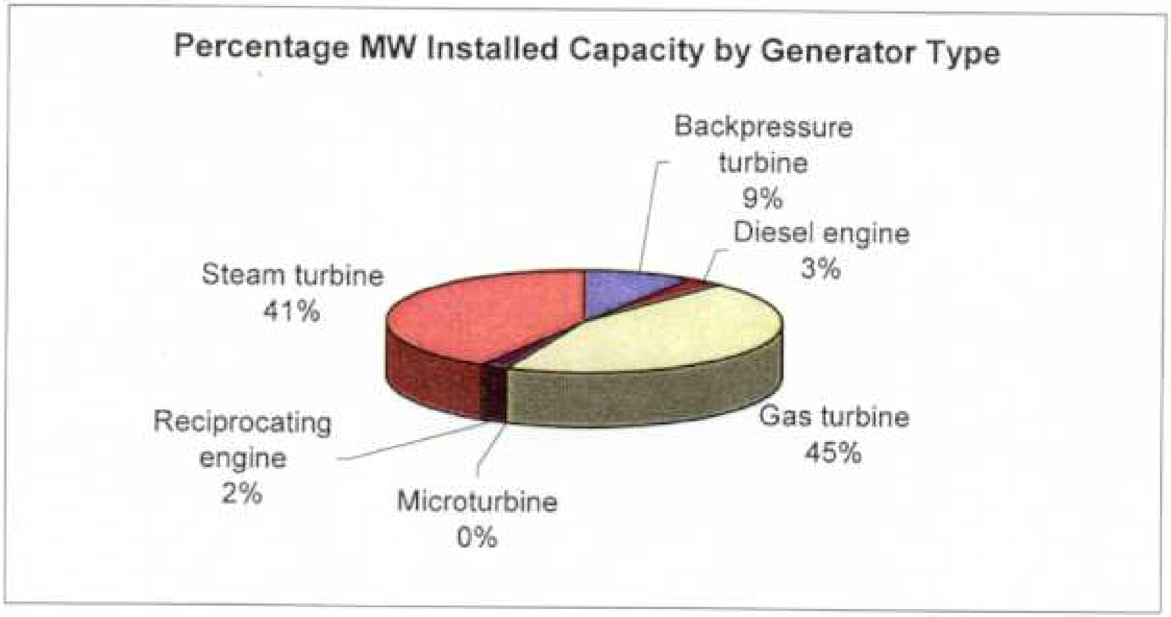


Electrical Generation

A surprisingly large number of schools with central plants co-generate power. Of 128 schools reporting, 45% said they co-generate power on campus. Of the two schools that only *generate*, one has capacity installed for emergency backup power only, and the other generates power to meet regular campus demand. Respondents reported a wide range of generation technologies and capacities. The range of equipment selection varies from the largest unit, a 45 MW GE LM 6000 gas turbine, to the smallest reported unit, a 0.18 MW Capstone microturbine.



Total installed generation capacity	*947.715MW*
Average installed capacity per institution	*16.34MW*
Median installed capacity per institution	*7.45MW*
Range	*0.18 - 85MW*



Percentage of Energy Requirements Met

Ranges vary widely within each category, but the percentages of campus energy requirements met are distinctly different for heating, cooling, and power. It should be noted that respondents don't track this figure uniformly for heating and cooling. Some institutions use operational metrics such as percentage of campus energy usage served by the central plant, while others use percentage of building square footage served. These two numbers are not identical substitutes, as not all buildings on campus are equally energy intensive. The number, however, does provide us with a good guideline to understand at a basic level if there is room for further expansion of district energy systems on campuses and what ratio of thermal and electrical energy needs are met by the central plant system.

	Heating	Cooling	Electrical
Average percentage of campus needs met	84%	67%	49%
Range of responses	19-100%	8-100%	0-100%

QUALITATIVE RESPONSES FROM WEB-BASED SURVEY

Responses to qualitative questions were collected through a web survey tool called Zoomerang. A copy of the survey instrument can be found in Appendix I. The survey is also available over the web at:

http://www.zoomerang.com/survey.zgi?8H7M1S2RVQS71XRRMX3EMKKT

The survey was emailed to 285 people, and eighteen responses were received, representing seventeen colleges and universities. One response was from an industry service provider working on contract at a university setting. The qualitative questions inquired about challenges to current expansion plans, asked for ideas as to what things the government could do to make implementing CHP solutions easier, asked respondents to rank in order of usefulness various possible programs, and gauged interest in government funding for CHP projects on campus.

Challenges to Current Expansion Plans

Respondents were asked what the biggest challenges to their current expansion plans were. They were asked to give each item a rating: Not a concern, Small concern, Major concern, or Barrier to progress. Capital constraints, environmental regulations, and technical issues were more likely to be cited as concerns than choice of technologies, lack of clear utility interconnection standards, or utility counteroffers. Ratings for fuel price uncertainty exhibited greater variance; this is probably due to a number of factors, including proximity to fuel source, geography, local distribution company charges, and fuel market economics. Below is a chart showing number and percentage of responses in each category for each potential challenge.

Challenges to Current Expansion Plans				
Rating given:	Not an issue	Small concern	Major concern	Barrier to progress
Capital constraints	1 6%	4 24%	9 53%	3 18%
Convincing decision makers of economic benefits	3 18%	8 47%	5 29%	1 6%
Complexity of implementation	7 41%	4 24%	5 29%	1 6%
Air emissions restrictions	6 35%	4 24%	5 29%	2 12%
Space constraints	5 29%	3 18%	8 47%	1 6%
Fuel price uncertainty	6 35%	2 12%	6 35%	3 18%

Current life remaining in existing equipment	4 24%	9 53%	4 24%	0 0%
Regulatory uncertainty	6 35%	6 35%	5 29%	0 0%
Lack of clear technology choices	10 59%	6 35%	1 6%	0 0%
Lack of clear utility interconnection standards	9 53%	5 29%	3 18%	0 0%
Utility counteroffers (backup rates, exit fees, or negotiated programs and discounts)	9 53%	5 29%	1 6%	2 12%

Based on the weighted average of the responses, these items ranked as follows, from largest barrier to smallest concern:

Largest barrier: Capital constraints
Fuel price uncertainty
Space constraints
Convincing decision makers of economic benefits
Air emissions restrictions
Current life remaining in existing equipment
Complexity of implementation
Regulatory uncertainty
Utility counteroffers
Lack of clear utility interconnection standards
Smallest concern: Lack of clear technology choices

Things the DOE or Other Government Agencies Can Do to Make It Easier to Implement District Energy and CHP Solutions on Campus

We gave respondents the ability to provide a freeform answer to this question. Their unedited responses are provided below:

Respondents views on what the DOE or other government agencies could do to make it easier to implement district energy and combined heat and power solutions
Establish a coherent national energy policy

For a standard electric chiller/steam boiler central plant – example of simple straightforward additions to improve efficiency will *[sic]* all assumptions clearly identified.
Get EPA to favor CHP
If expansions were desired, State would need to fund them.
Listen to the people who actually operate, maintain and design these facilities. Do not put so much creditability in accounts *[sic]* and other that are not familiar with the industries.
Make funds available
Not considered of importance in our situation.
Offer very reasonable financing or incentives for private industries to construct district utility plants. I would also be open to any DOE sponsored research projects to be conducted on our campus.
Provide economic incentive programs
Provide emissions/permitting incentives.
Provide evaluation tools/metrics
Sell the worth to executive level Institutional governance. Introduce state Governors to value in paying attention to infrastructure.
Solve the fuel price volatility problem and put a limit on LDC delivery and local tax charges to bring CHP within the range of feasibility. We pay the LDC $1.08 plus 5% of our city gate deliveries for MBTUs at our burner. Yet our commercial electricity is a bargain at .071 summer and .052 winter.
Standardize utility requirements and fees for CHP
Work with EPA to reduce regulatory barriers to non-profit higher education institutions. Provide grants/funding to higher education (colleges and universities), and not necessarily in the form of tax credits or financial incentives to private entities.

Ranking of Services in Order of Helpfulness in Implementing Cooling, Heating, and Power Projects on Campus

Respondents were asked to rank a list of eight possible services from most helpful to least helpful (scale of 1 to 8) in order of how helpful they would be. Seven respondents provided ranking information, and ten misread the question and provided a *rating* of each item on a scale from most helpful to least helpful. The forced rankings provided by the seven respondents gives us insight into which programs would be preferred over others. The rating also serves a purpose, as it shows in absolute terms the usefulness or lack thereof of a potential service.

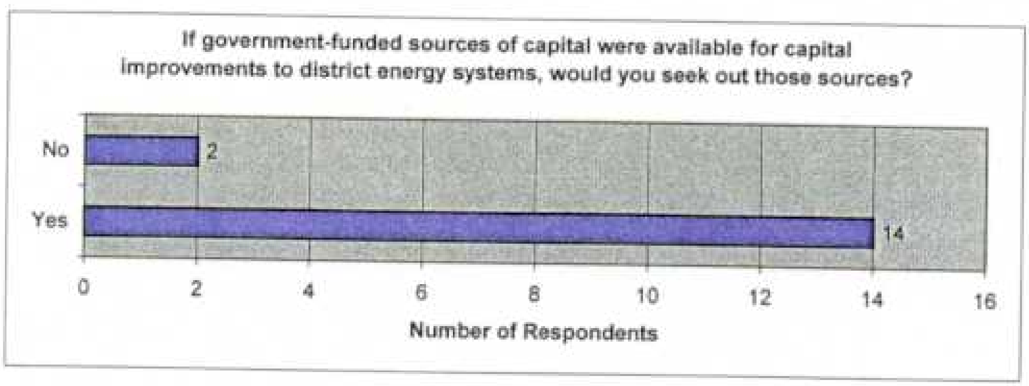
The rankings showed that items involving financial help were ranked higher than others, but all items were viewed to have positive impact, as none of them had an average rating worse than five.

Service	Average ranking for item	Rank among rankings (preference)
DOE-sponsored task force of respected experts	6.000000000	5
Matching funds for construction	1.285714286	1
Government-sponsored revolving fund	3.285714286	3 (tie)
Feasibility study funding	3.285714286	3 (tie)
Clear national utility interconnection standards	6.714285714	8
Net metering	6.285714286	6
Tax credits for cooling, heating, and power investments by private firms	6.428571429	7
Tradeable tax credits for public institutions	3.142857143	2

Service	Average rating for item
DOE-sponsored task force of respected experts	4.400000000
Matching funds for construction	2.400000000
Government-sponsored revolving fund	4.000000000
Feasibility study funding	3.000000000
Clear national utility interconnection standards	3.500000000
Net metering	4.333333333
Tax credits for cooling, heating, and power investments by private firms	4.888888888
Tradeable tax credits for public institutions	4.777777778

Availability of Government-funded Sources of Capital

Respondents were asked if government-funded sources of capital were available whether they would seek out those sources. 14 out of 16 respondents replied in the affirmative.



IV. KEY FINDINGS

The college and university segment represents a large market for combined heat and power. The complex and sensitive nature of the research conducted on campuses necessitates a reliable energy source. The round-the-clock nature of energy demand and the already-installed district energy systems on campuses make CHP systems an effective choice. There is already a large amount of CHP capacity installed on campus, and there remains opportunity for expansion. As universities grow in size and increase the amount of research conducted on campus, there will be opportunity for further CHP adoption.

OPPORTUNITY FOR INCREASED CHP ADOPTION

As noted above, the round-the-clock energy demand and already-in-place district energy infrastructure make the college and university segment an ideal customer for CHP. The additional investment required to implement CHP is much less, given that a majority of the infrastructure required is already in place, making CHP implementation financially and technically feasible.

Yet, only 45% of campuses co-generate power today. At those schools with co-generation capability, only about 49% of the campus electrical needs are met. In contrast, the vast majority of schools with district energy systems have thermal capacity, with 84% of campus needs met. Since CHP utilizes the same thermodynamic process to generate both power and thermal energy, there is opportunity to bring the amount of electricity generated up to parity. Of course, different campuses have differing levels of thermal and electrical load, and the heat output representing a percentage of steam demand is not the same as the power output representing the same percentage of electrical demand. Nevertheless, there is room to expand power co-generation on campus using the existing thermal load.

When institutions retrofit, renovate, expand, or rebuild their heating plants, they can implement co-generation as part of the project. It should be noted it is easier to add co-generation to an existing thermal distribution network than to add thermal capability to a pure electrical plant.

THE PRIMARY HURDLES TO IMPLEMENTATION ARE FINANCIAL

Capital constraints, economic concerns, environmental regulations, and infrastructure issues (space constraints) presented the biggest challenges to expansion plans. Capital constraints in particular were rated the biggest challenge. Understanding and choosing technologies and making engineering decisions did not rank as major concerns. Addressing the capital constraints issue may spur adoption of CHP.

THERE IS A BROAD RANGE OF ENVIRONMENTALLY FRIENDLY TECHNOLOGY OPTIONS THAT CAN BE APPLIED TO DISTRICT ENERGY AND CHP IMPLEMENTATION TODAY

Energy systems implementation is complicated by the diverse nature of energy source availability and cost, local environmental regulations, and relations with neighborhood groups. These factors may make an energy solution that is acceptable in one region difficult to implement in another.

New technologies and approaches, however, have been pioneered at different institutions; these innovative approaches can be applied at other sites around the country. Examples include lake source cooling, landfill gas-fired co-generation, and natural gas co-firing at a coal-fired plant. Sharing information on these success stories can reduce the learning curve for others and increase the successful implementation rate of proposed CHP and district energy projects. Examples of some of these projects can be found in the case studies presented in Section V.

OUTREACH TO STAKEHOLDERS IS KEY TO SUCCESS

Successful projects were accomplished by satisfying all those who had a stake in the project. Stakeholders will differ from project to project, but almost always include parties outside the institutional or facilities engineering community. The projects at UNC-Chapel Hill and Cornell were successful because they incorporated and accepted active participation by members of the communities in which the projects were built. In the case of MIT, the local utility complained that it wasn't adequately involved in the planning process. While involving additional parties in the process increases complexity and may appear to slow down the permitting process, it actually builds relationships and is critical to building support for the project.

ADDING CAPACITY IS NOT THE ONLY WAY TO INCREASE OUTPUT

As the need for energy grows, the obvious solution is to construct more and larger plant facilities. Adding capacity is not the only way to meet the growing needs of the college and university segment. Examining the existing infrastructure and adjusting operating practices can yield benefits in efficiency that may help avoid or defer investments in capacity expansion. Installing updated controls, revising maintenance practices such as water treatment, or implementing thermal storage to shift demand are just some examples of what can be done to make better use of resources already on campus.

COMMERCIALIZATION OF NEW TECHNOLOGY IS NEEDED

There are a number of technological innovations that can be brought to bear on the district energy/CHP market, but these are still too costly, making them infeasible for most applications. As long as each application is an expensive, custom installation, market growth will be stagnant. Standardization and an increase in volume (and commensurate reduction in cost) will benefit adoption of these technologies.

THERE IS A NEED FOR STILL OTHER NEW TECHNOLOGIES TO MAKE ADDITIONAL CHP INVESTMENT ATTRACTIVE

As they expand, schools may not need a whole new full-sized central plant, but facilities managers also don't want the increased cost of managing a number of small in-building systems. There is an opportunity to create smaller-scale, centralized CHP plant solutions for campus extensions.

MEMBERS OF THE INSTITUTIONAL MARKET MAY BE ABLE TO INVEST IN PROJECTS WITH LONGER PAYBACK PERIODS

Unlike publicly traded corporations, which are focused on quarterly financial results, colleges and universities are more able to plan and invest for their infrastructure needs over the long term. While there are limits to this flexibility, it does make this segment more willing to invest in large CHP projects that have longer payback periods. Efforts to increase CHP adoption should be targeted to receptive segments such as this one.

CHP AND DISTRICT ENERGY CAN BE UTILIZED ACROSS THE NATION

We found examples of CHP implementation across all regions of the country. The benefits of CHP and district energy transcend state lines and congressional districts. It is fitting for a federal agency to step up and be the advocate for increased adoption of these technologies.

ONE SIZE DOES NOT FIT ALL

It is not appropriate to push only one technology or design approach to all district energy projects. There are many local issues that require flexibility and a willingness to improvise (indigenous fuel supply, resources, costs, policies, neighbors, regulations). These issues call for a range of available tools, techniques, and approaches to designing and implementing district energy systems.

V. CASE STUDIES – "LESSONS LEARNED"

This section contains case studies that were prepared as part of the project. The intent of the cases is to demonstrate a variety of technical applications or operational approaches to central energy systems on the nation's campuses. It is our intention that that the stories presented here will provide helpful insights to others looking to expand their district energy systems or integrate innovative technologies like combined heat and power.

Cornell University
The Cornell case shows us how a natural resource can be used to provide a renewable, environmentally friendly means to cool the campus. It also shows us how the university involved the community in an open, forthright process to secure approval for the project.

Massachusetts Institute of Technology
The MIT case discusses the concerns around regulatory issues, utility interface interconnections, and exit fees, highlighting some of the pitfalls of markets that are still in the process of deregulation.

Princeton University
The Princeton case focuses on implementation challenges faced when it built a gas-fired, combined-cycle plant. Topics include project planning, vendor relations, commissioning, and contractual provisions that protect the university.

Rutgers University (pending)
This case is still under development and will be available shortly.

Slippery Rock University
Slippery Rock needed to make modifications to its coal-fired central heating plant to achieve emissions compliance. Traditional solutions such as scrubbers or baghouses can be costly or impractical depending on the site. The university used natural gas co-firing of its existing boilers to meet emissions requirements.

Stanford University
Stanford built the largest ice storage facility west of Chicago to meet the cooling needs of the campus. The university is able to reduce costs because it uses a weekly run cycle and never operates an electric chiller during peak demand hours.

University of California, Los Angeles
The case showcases an application of fuel flexibility. UCLA uses recovered landfill gas to co-fire its cogeneration plant. The university also used an

innovative approach to financing to make the project financially attractive. It has achieved laudable emissions reductions.

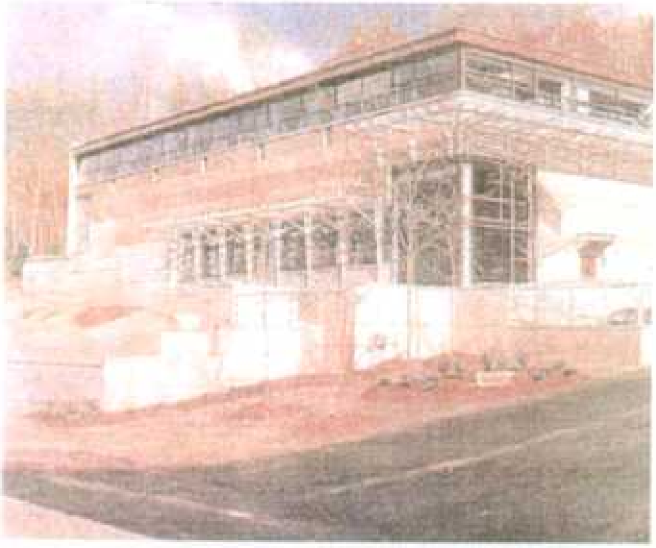
University of North Carolina at Chapel Hill
The UNC case discusses ways to implement clean coal firing in a neighborhood setting, focusing on technology, siting, permitting, and neighborhood relations.

University of Pennsylvania
This case shows how a multi-pronged approach to energy projects, including efficiency improvements, can yield high impact cost savings and environmental benefits.

University of Texas at Austin
UT-Austin has developed a very reliable central utilities system. The case examines how this was accomplished and what is being done to ensure the system remains as reliable in the future.

Creating a Sustainable Future: Cornell University Works with Community to Implement Lake Source Cooling

Keywords: Lake source cooling, Community input, Environmental review process, District energy



Introduction

The Department of Utilities and Energy Management at Cornell University operates the university's thermal energy system. This system includes both the production and distribution of steam – with electric cogeneration – and chilled water. The department also owns and operates an electric substation and distribution system, potable water production and distribution, sewerage systems, and a campus-wide energy management and building operations system. These systems serve over 300 buildings, covering over 13 million square feet.

One of the things that make Cornell's energy services operation stand out is its enterprise-based business model. The operations are run similar to those of a private, for-profit utility, with the exception that no profit is made. Among the similarities:

- All loads are metered
- Billing is meter-based
- All costs are tracked separately
- Capital investment, including debt service, is recovered in the rate
- Rates are set by dividing cash flow needs by projected sales units
- New projects must meet or exceed defined hurdle rates

This approach helps the department maintain its competitiveness with external or distributed energy options.

Central Heating Plant and Cogeneration

The central heating plant at Cornell provides steam and power for approximately 250 buildings. The steam is distributed across campus via 25.8 miles of underground supply and return piping, and is produced by six boilers, fueled by coal, gas, and oil. 8 MW of electric power are generated by two steam turbines driven by the boilers. Following are some CHP system metrics:

Boilers: four operating at 400 psig, two operating at 200 psig

Steam capacity: 600,000 lbs/hr total for six boilers

Peak steam load (winter): 360,000 lbs/hr

Average steam load: 127,000 lbs/hr

Generators: two back-pressure steam turbine generators, exhausting steam at 60 psig

Annual electric production: 30 million kWh

Recent Initiatives

The university is always working to enhance its system efficiency and reliability. To that end, Cornell has implemented numerous special projects in recent years. Among them are:

- Lake source cooling
- Chilled water thermal storage
- Cooling tower and creek based "free cooling" projects
- Boiler replacements/rebuilds
- Distribution system replacement
- Cogeneration
- Electric power improvements
- Installation of baghouses on coal boilers
- Predictive emissions monitoring
- Upgrading of controls/unmanned operation
- Infrared surveying
- Digital utility mapping

Lake Source Cooling Project Background

Four major factors influenced Cornell's decision to undertake the Lake Source Cooling initiative: the phaseout of CFC's, aging equipment, growing cooling loads, and rising energy costs. Six of the university's eight chillers could not be converted to non-CFC operation, and therefore would need to be replaced outright. Given the large capital outlay required to replace and expand cooling capacity, the university decided to investigate nontraditional alternatives to create a sustainable, long term solution to the campus' cooling needs.

Cornell chose lake source cooling (LSC) because it was a technologically simple cooling method, utilizing a natural, non-polluting, and renewable resource. The project uses the cold, deep water of nearby Cayuga Lake to cool a closed loop extension of the present campus chilled water network without the need for mechanical refrigeration (all the heat added to the lake is released each winter).

LSC System Description

Loop-to-loop: open lake water loop connected to closed campus loop via heat exchanger (see figs).

Capacity: 16,000 tons of cooling

Lake source water temp: 39-41° F

Lake return water temp: 48-56° F

Campus loop supply water temp: 45° F

Campus loop return water temp: 60° F

Lake source intake pipe: 10,400 ft long, 250 ft deep

Campus loop pipe: 12,000 ft each for supply and return

Campus Distribution Pumps: Five between-the-bearings, radially split, double suction, dual volute pumps, designed and built to API Standard 610; 600 HP each; design point of 6,600 gpm @ 280 ft of head; pump speed 1800 rpm; output controlled by variable frequency drives

Heat exchangers: Seven, arranged in parallel, with total effective surface area of 102,000 ft^2; design duty of 3000 tons @ 4600gpm and ΔT of 16° F per unit, accomplished with LMTD 2.6 ° F and pressure drop of 16 psi

Lake Water Pumps: Three self-lubricated, enclosed impeller, open lineshaft, vertical turbines; 350 HP each; design point of 13,000 gpm @ 80 ft of head; pump speed 1200 rpm; output controlled by variable frequency drives

Getting Community Approval to Move Forward with the Project

Cornell conducted an analysis of LSC's feasibility from 1994 to 1998. The university's board of trustees authorized about $4 million to cover research, land acquisition, and permitting costs for the preliminary stages of the project.

The university was granted easements by the Ithaca City School District and the City of Ithaca, negotiated easements with five private property owners, and purchased eighteen acres for the heat exchange facility.

The university involved the community much more than it normally does when undertaking building projects. Cayuga Lake is a valued and protected resource for people living in the Finger Lakes region, and Ithaca residents are very active in local politics. Any project that could impact the lake would receive intense scrutiny.

Cornell deployed a comprehensive public outreach program which included the following components:

- Nine newsletters mailed through calendar 1998 to over 1000 especially interested or involved individuals, including public officials, residents who live along the pipeline route, and leaders of environmental, recreational and other groups
- Thousands of leaflets distributed to answer questions and encourage public interest and involvement
- Briefings for news media and community leaders at every major decision point or event, with resulting media coverage and discussion in public forums
- Public meetings held in and for the community
- Door-to-door survey in 1994 of residents on or near the proposed route of the pipeline
- Random phone survey of 400 residents in 1996, to gauge public opinion on and awareness of the project
- Educational exhibits and demonstrations at the Sciencenter and the Ithaca Festival
- Over fifty talks before local and regional agencies, community service organizations, environmental and recreational groups, and at professional conferences

Furthermore, Cornell always maintained that if there was any indication that the project would harm the lake, it would be abandoned. Despite the proactive nature of these outreach programs, a citizens group formed to oppose the project. There were concerns ranging from effects on lake water temperature to potential increases in nutrient levels to effects on marine life.

Most of the concerns were unfounded or mitigated by elements of the project design, but the burden was still upon the university to prove that the project would have no substantial negative effects on the lake.

The university overcame this hurdle by conducting an open and forthright environmental review process, which involved applying for 17 local, state, and federal agency approvals. The public was made aware of hearings and meetings. Three years were spent monitoring and mapping out the lake's ecology, making Cayuga Lake one of the most studied bodies of water in the world. Over $3 million was spent on internal reviews and consultant's studies. The research concluded with a 1,500-page environmental impact statement.

From the earliest start of the environmental study, an independent scientific oversight committee was convened from the Cornell Center for the Environment. This committee was composed of faculty trained and respected for their knowledge in the four lake impact areas of study. This committee is still in place to provide further review and oversight of the data monitoring program with the project in operation.

Construction began in 1998 and operation started summer 2000.

Project Impact

After $58 million of investment, the project has begun to yield many benefits. Among them:

- Lake source cooling uses only 13% of the electricity required by the old campus cooling system, reducing demand by over 20 million kWh/yr
- The burning of over 19 million pounds of coal annually has been eliminated, along with the associated impacts of mining, transportation, and ash removal
- CO_2 emissions are reduced by over 56 million pounds per year
- Sulfur oxides are reduced by 645,000 lbs/yr
- NO_X is reduced by 55,000 lbs/yr
- 40,000 pounds of CFC refrigerants were eliminated from the system
- Reliance on HFC's is reduced. HFC's are known greenhouse gases and potentially have unknown environmental impacts
- Excavation for pipeline resulted in numerous improvements to public roadways, utilities, and sidewalks resulting in $1.3 to 1.5 million in infrastructure updates at no expense to the City of Ithaca
- The Ithaca City School District saved $100,000 on a chiller it otherwise would have needed, and $750,000 in cooling costs over the next 20 years

Cornell was able to implement an environmentally friendly and efficient cooling system because of its willingness to make a large investment up front and because of the openness with which it embraced community involvement.

With detailed, quality environmental information it was able to convince community members that there would be no detrimental effects on the lake, thereby preserving a vital community resource while meeting the growing needs of the Cornell campus. The Cornell University district energy system won the International District Energy Association System of the Year award in 2001, and continues be an example of leadership in energy efficiency and reliability.

Project Contact Person

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In the depths of Cayuga Lake, the water temperature remains a constant 39 - 41°F. A 63-inch diameter by 10,400 foot long intake pipeline made of High Density Polyethylene (HDPE) carries water from a depth of 250 feet to a heat exchange facility at the lake's shore. Here, the cold water is pumped through a bank of stainless steel heat exchangers where heat is absorbed from a second, separate flow of water coming from the campus (the two flows never mix). This second flow of water, cooled to 42 – 45 °F is pumped back to campus (3 miles away) via 12,000 trench feet of 42" welded steel supply and return pipes. The chilled water is used to cool laboratories and other building spaces. The lake water is warmed to 48-56°F and returned to the lake about 500 feet from shore through a specially designed diffuser.

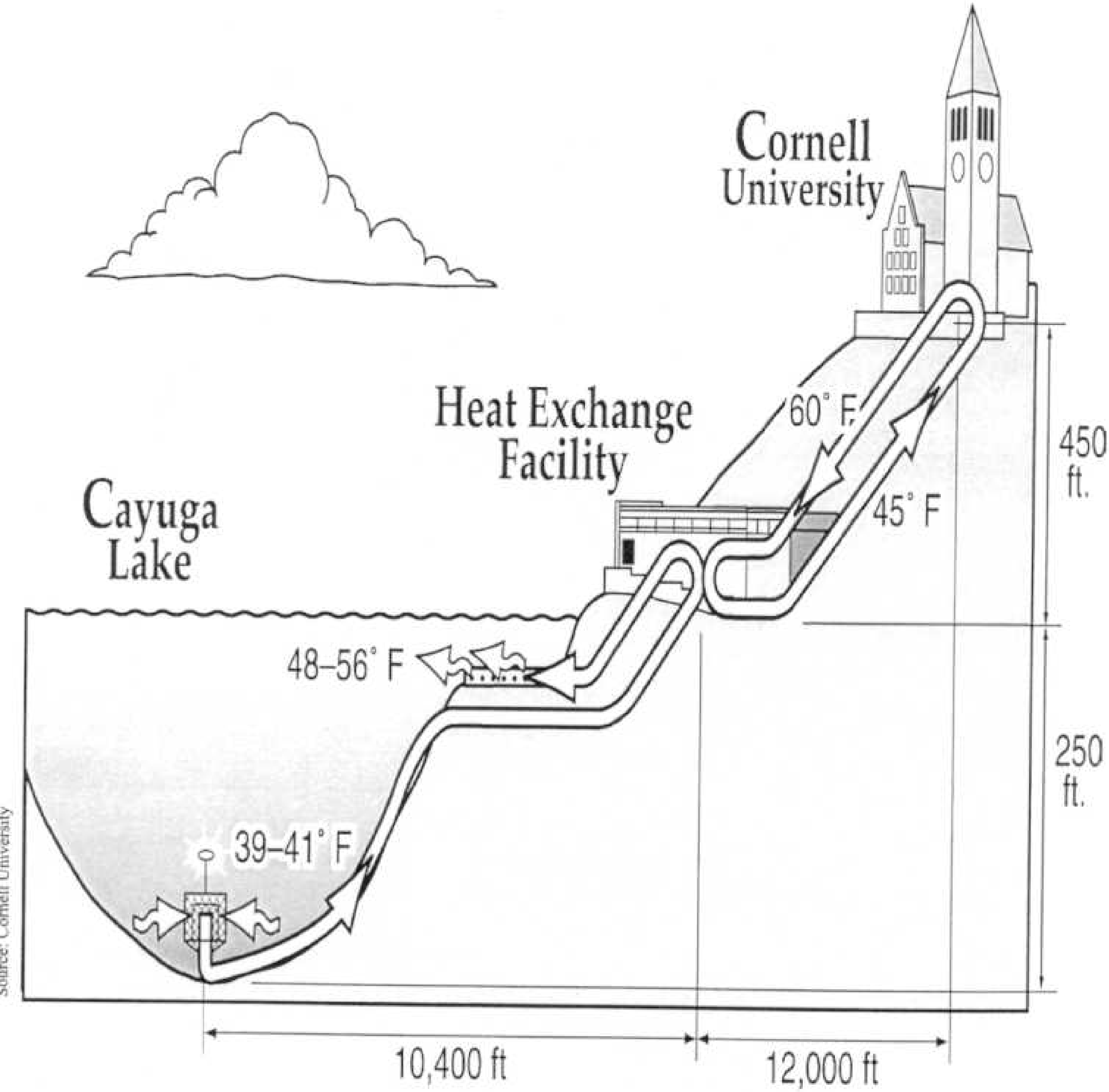
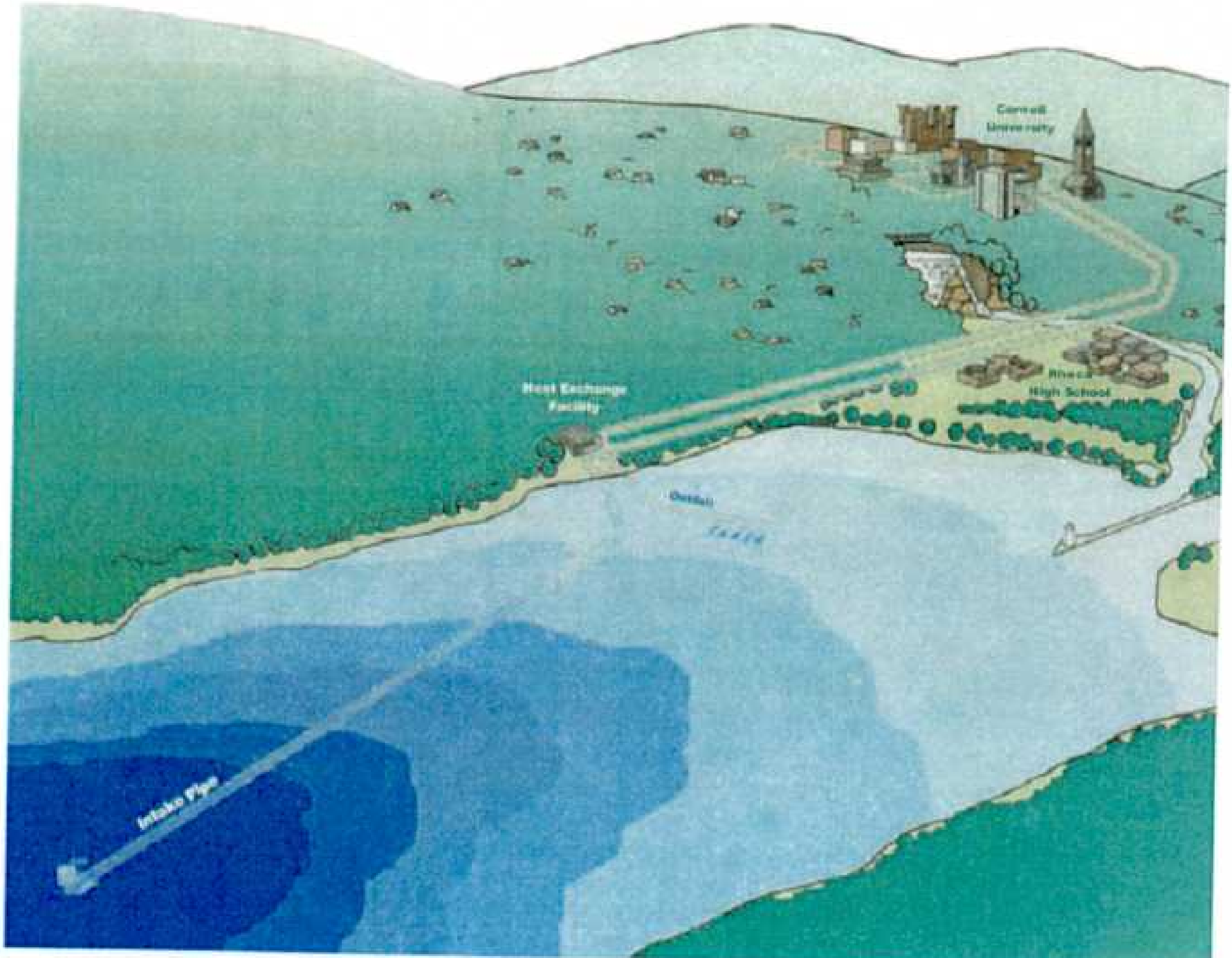


Figure 1

Perspective view of LSC transmission piping

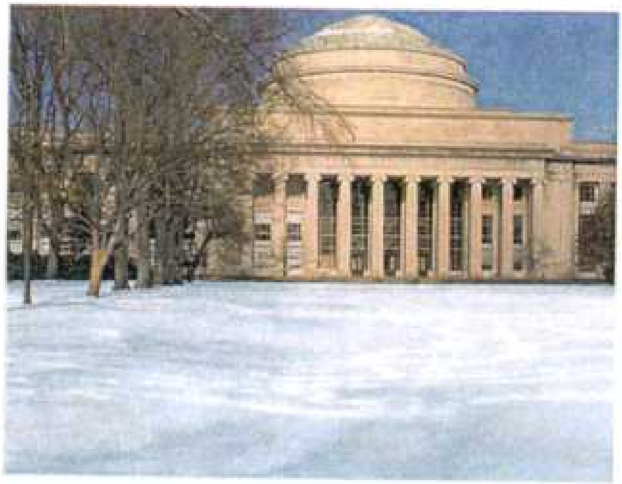


Source: Cornell University

Figure 2

MIT Settles Regulatory Battle over Customer Transition Charges

Keywords: Cogeneration, customer transition charge, deregulation, stranded cost, PURPA



Project Background

The Massachusetts Institute of Technology (MIT) is a world-renowned center for leading research and learning. Much of that research is dependent upon a stable, reliable power supply. Electricity for the campus was supplied by the local utility, Cambridge Electric Light Company (CELCo), and suffered from occasional outages. In 1985, in response to rate hikes from CELCo, MIT investigated the possibility of on-campus power generation. Through cogeneration, MIT could save millions of dollars over the life of the project, as well as improve the reliability of its electrical power supply. It could also reduce its impact on the environment by utilizing the latest in emission reduction technology.

A $40 million state-of-the-art cogeneration plant was designed and built in the early 1990's and became operational in 1995. The plant design employed a number of technological innovations – some developed specifically for this project – to achieve remarkably low emission levels. The new plant was expected to cut utility costs by about 14% over a twenty-five year period and cut emissions by 45%, the equivalent of 13,000 automobile round trips into Cambridge per day.

Normally, this kind of success story would be hailed far and wide as an example of technological innovation benefiting the environment, all while meeting customer needs. CELCo, however, saw a threat in MIT's new facility. The new plant was to provide for three quarters of MIT's electrical needs – a load which until then was supplied by CELCo. The utility claimed it had made investments to ensure adequate future supply for the MIT campus; those investments would now be stranded (this was prior to electricity deregulation in Massachusetts). CELCo assessed MIT a $6,000,000 customer transition charge to recover the expense.

System Description

Cogeneration: combustion turbine generates electricity; turbine exhaust drives heat recovery steam generator (HRSG) to generate steam for heating and cooling (see Fig. 1).

Electric generation capacity: 22 MW

Steam generation capacity: 165,000 lbs/hr

Steam pipe length: 25 miles

Combustion turbine: 22 MW(e) dual-fuel combustion turbine with low emissions burner developed by MIT Combustion Research Facility and ABB; primary fuel is natural gas, secondary fuel is oil

Heat recovery steam generator: driven by 1000° F combustion turbine exhaust plus supplementary dual-fuel firing

Dispute Over the Rate for Supplemental Power

Regulations required utilities such as CELCo to enter into long-term contracts to ensure adequate future supply for its customers. These contracts required initial investments totaling into the millions of dollars for some large customers. MIT was CELCo's second largest customer after Harvard University, but the new cogeneration plant would change the amount and nature of MIT's power demand. In 1994, MIT and CELCo went before the state Department of Public Utilities (DPU) to determine the rates CELCo would charge the university for standby, maintenance, and supplemental power.

In early 1995, each party returned with a proposed rate structure. CELCo's proposed rates included a customer transition charge (CTC). MIT objected to the charge, and arguments were heard from both sides, as well as from the state Attorney General and other local electric utilities.

MIT's argument revolved around the following six points:

- The DPU didn't have statutory authority to approve the CTC, which was an exit fee, not a rate, per se
- The imposition of a CTC on a "qualifying facility" was in conflict with PURPA requirements that utilities provide non-discriminatory, cost-based standby and maintenance power to such facilities
- CELCo failed to identify any investment or costs incurred to serve MIT, or any other large customer
- The DPU's regulations do not authorize charging stranded costs to a qualifying facility
- The CTC constitutes an improper tying arrangement in violation of antitrust laws
- Since MIT gave notice of its plans before the effective date of the CTC, the application of the CTC was retroactive ratemaking

MIT also provided specific arguments disputing the way the CTC was calculated. The DPU claimed it did have authority to act, and found, that on most counts, CELCo's analysis was fair and accurate; it allowed the CTC to remain in effect. When recalculated under the DPU ruling, the CTC came to be about 25% smaller, at a sum of $4.5 million.

Appealing the Decision

MIT began paying the charge, with the understanding it would be refunded if a verdict was found in its favor. It brought the matter before FERC, on the basis that the CTC violated PURPA. In early 1996, FERC ruled that the CTC did not violate PURPA, and that the charge could stand. It did not make a decision, however, on the calculation of the CTC amount, leaving that decision to the state and the DPU.

The university's next move was to file an appeal in Massachusetts' Supreme Judicial Court (SJC). In September of 1997, the SJC ruled favorably for MIT.

The court declared that the fact-finding in the DPU case was not sufficient to counter MIT's claims that the DPU acted in an arbitrary fashion. It also stated that the DPU had not followed its own established precedents, and that the rate calculations were not done correctly.

The SJC also noted that MIT had made it fairly clear since 1985 that it was evaluating on-site generation, and it could not determine whether the stranded costs in question were prudently incurred. The court also felt that the DPU had not adequately addressed MIT's concerns over this matter, instead taking CELCo's arguments at face value.

The court referred the matter back to the DPU for reevaluation, but there was no resolution during the second round of discussions at the DPU.

During this time, the energy landscape in Massachusetts changed:

- Several New England nuclear power plants went offline for regulatory reasons, reducing the available capacity in the region
- By March of 1998, the state's Electric Utility Restructuring Act took effect, governing the deregulation of the industry and defining how stranded costs and self-generation exit fees were to be handled
- In 1999, CELCo and its parent company, Commonwealth Energy, merged with Boston Edison, creating a new entity called NSTAR

The Restructuring Act created a stranded cost recovery pool. As a result, the only amount under contention between NSTAR and MIT was the CTC paid until March 1998.

NSTAR and MIT resolved their differences through direct negotiations; the result was a refund of $1.7 million, representing half of the CTC, plus resolution of some other minor issues.

Conclusion

Cogeneration is an energy generation approach that is encouraged by the federal government because of its ability to increase efficiency at the nation's power facilities.

But the MIT case shows that projects cannot be launched with only the technical benefits in mind. It is also important to take into account the actions and reactions of external entities as well as understand the regulatory implications of any decisions made. With deregulation occurring at different paces in different states, the electricity market across the US is undergoing numerous changes, presenting potential pitfalls for institutions that don't understand the nature of those changes.

The MIT case, however, also shows us that, despite these pitfalls, there is still considerable value in implementing energy efficient systems, and a clear and well-thought out project can yield many benefits.

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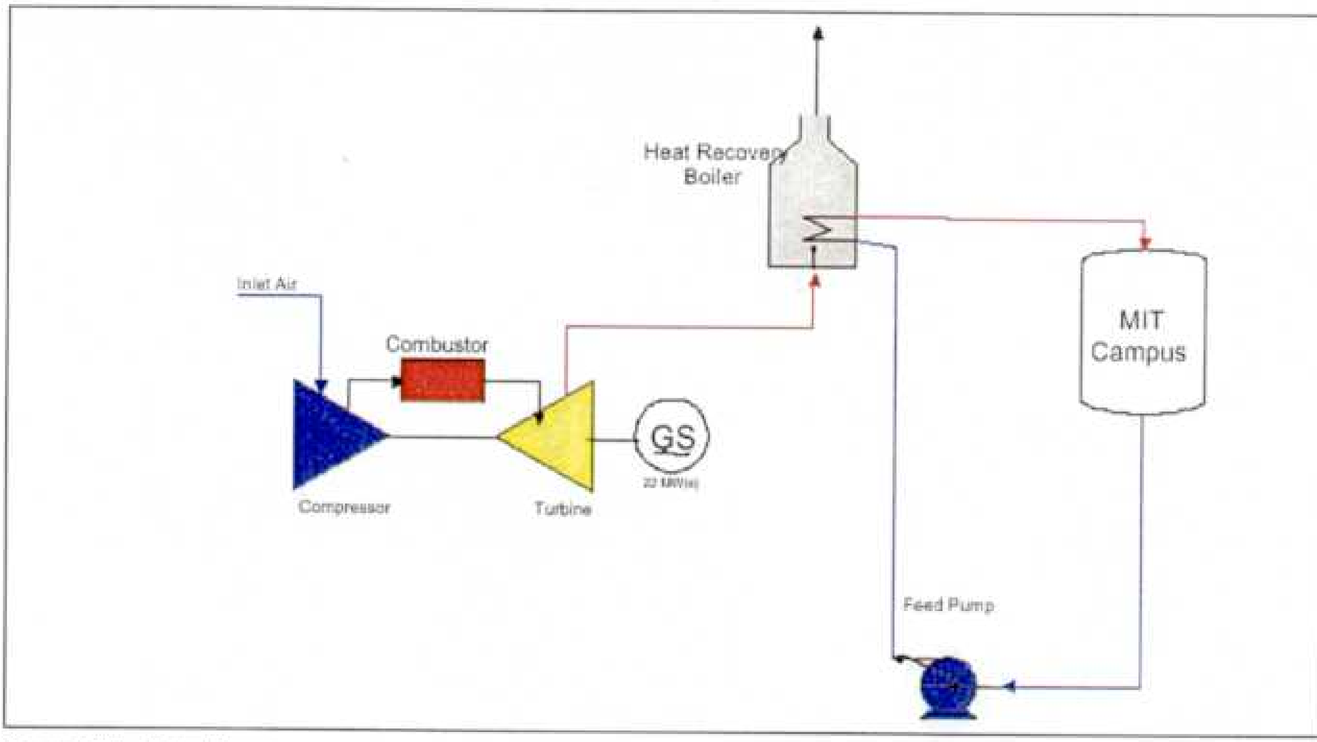
The MIT Cogeneration Plant uses a gas-fired combustion turbine to drive a 22 MW generator. Exhaust gases leave the turbine at 1000 ° F, and are directed to the heat recovery boiler to create steam for use on campus.



Source: MIT, Alstom Power

Figure 1

Princeton University Uses Combined Cycle Gas Turbines to Renew Central Plant, Expand Capacity, and Reduce Energy Costs

Keywords: Cogeneration, Combined cycle, District energy

Project Background

Princeton University is one of the nation's oldest and most prestigious academic institutions. The campus is continually changing and growing. In the mid-1980's there were plans to build a new materials science institute, electronics and mechanical engineering building, swimming pool and biology building. These and other construction projects represented a potential 5-10% growth in campus building space over the next fifteen years.

Princeton realized that it would soon have to increase its steam capacity. Princeton's electrical demand had already increased on average by half a megawatt per year during the 1980's. Making the right energy choices could have significant beneficial impact on the university.

System Description

The new cogeneration plant consists of a GE LM1600 gas turbine generator coupled with a heat recovery steam generator and duct burner. It has two auxiliary boilers to provide peak steam requirements and backup capacity.

The generator operates in parallel with the local electric utility. Gas is supplied by the same utility company and is compressed to burner pressure with a reciprocating natural gas compressor.

Emissions are controlled on the turbine with water injection and a carbon monoxide burning catalyst. This new plant was sited next to the existing chilled water plant.

Capacities:

Electric capacity: 14.6 MW

HRSG Steam generation capacity: 182,000 lbs/hr

Auxiliary steam generation capacity: 240,000 lbs/hr from natural gas and oil-fired boilers

Cooling capacity: 15,700 tons of cooling (10,100 tons from steam absorption chillers, 5,600 tons from electric chillers)

Choosing an Energy Source for the Future

In the mid-1980's Princeton's Facilities Department began to evaluate options to replace its aging central plant. The old plant had many deferred maintenance items, required replacement of oil storage tanks, and could not provide the needed capacity to satisfy campus steam demand.

In 1985, the university considered building a coal-fired circulating fluidized bed boiler, but later scrapped the idea in favor of building a gas-fired cogeneration plant. Environmental requirements in the State of New Jersey would not favor a coal burning plant and local approvals would have been impossible to overcome.

In 1987 non-destructive analysis of the old boilers showed an expected end of life around 1998-2001. This presented an opportunity to completely re-evaluate infrastructure choices and build a new plant from the ground up. Cogeneration was studied because the local electric utility had some of the highest rates in the country. The university was paying a demand charge of roughly \$10/kW/month to PSE&G for electrical power plus \$0.065/kWh for on peak electrical consumption. A new Cogeneration Plant provided Princeton with a means to reduce this energy cost, replace old boilers, and add capacity and other equipment.

A presentation was made to the Building and Grounds Committee of the university's Board of Trustees in December 1991. Preliminary approval to move forward was granted in early 1992, and bids for the gas turbine package were received that spring. The contract was awarded to European Gas Turbines of Houston, TX.

The design and construction processes went relatively smoothly, with the only challenges being ones that were beyond the project's immediate control.

Getting the Necessary Permits to Move Forward

Generally, the faster way to construct a plant is to seek permits during the construction period, essentially running the permitting and construction processes in parallel. The university administration, however, was more cautious in devoting funds to the project and insisted that permits be secured before any equipment could be purchased.

This eventually became a bottleneck for the project, as the New Jersey Department of Environmental Protection (DEP) took a longer time than anticipated to approve the permit, and it wasn't clear to the university what the allowable emissions levels would be. A proposed design based on the European Gas Turbine engine was submitted, and the design was approved by the DEP in December 1993. After the DEP approval process was completed, the university briefed the Princeton regional planning board on the project. After the planning board's approval was secured, the university gave the go ahead for the purchase and installation of equipment. Five months that could have been used for construction were lost, but construction finally began in 1994 and was completed in 1996.

Working with Vendors in a Consolidating Market

Permitting issues weren't the only concerns on the project. A larger concern was working through merger-related issues with the turbine vendor. During the project, European Gas Turbines (EGT) sold its North American operations to Stewart & Stevenson. The deal stipulated that all of European's work in the US would be transitioned to Stewart & Stevenson. The Princeton engine package was the last unit to be built by EGT in North America, which primarily affected the commissioning process. Essentially, Stewart and Stevenson was responsible for starting up a unit designed and built by another vendor. This caused some confusion in the startup process and created some finger pointing between the two companies.

Furthermore, after the dust began to settle on the first merger, Stewart & Stevenson was in turn purchased by GE, creating another round of transitions. This happened after the engine was commissioned but if affected the maintenance agreement. Another team had to learn the specifics of the EGT package before they could be efficient at maintaining it.

Project Impact

- Reduced annual NOx output by 113 tons[1]
- Increased annual CO output by 98.7 tons[1]
- Reduced annual SO_2 output by 37.1 tons[1]
- Reduced particulates by 7.2 tons[1]
- Reduced annual CO_2 output by 17 tons[2] or 13.1%
- Decreased annual energy costs by $3 million
- Increased electrical reliability (grid plus cogeneration plant) rating to 99.999%

Notes

[1] When compared to old plant. Does not take into account emissions created by utility company when generating power for the University.

[2] When cogeneration is compared to equivalent utility generator and heating boiler combination. This change means that Princeton will meet the Kyoto Protocol.

Lessons Learned

Vendors – The university researched all the companies that bid on work to ensure their capability to supply quality equipment on schedule. What it did not anticipate, was that its turbine packager would sell out its North American manufacturing and that its auxiliary boiler manufacturer would get bought out during the course of the project. Princeton was protected with a good engine package purchase contract, which seamlessly transitioned into a full maintenance contract – both with liquidated damage clauses.

Politics – In 1987, the new plant concept was presented and approved up to the Vice Presidential level when the current president announced his retirement. The project was put on hold until a new president was recruited and then had time to deal with this issue, which caused a project postponement of several years.

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Slippery Rock University Uses Natural Gas Co-firing to Achieve Compliance with Environmental Regulations

Keywords: Co-firing, Coal/natural gas, Emissions, Pollution, District energy

Project Background

Slippery Rock University is a small, state-run liberal arts college about fifty miles north of Pittsburgh. The university has a central plant which provides district steam for over 2 million square feet of campus space.

In 1971, in response to EPA Act Title 5, the State of Pennsylvania enacted a code setting forth standards regulating atmospheric emissions from power plants, central boiler plants, incinerators, and other fossil fuel combustion facilities. These standards set acceptable levels for emissions of sulfur oxides, nitrogen oxides, fly-ash particulate (opacity), and other substances determined to be harmful to the environment.

In November 1990, the Pennsylvania Department of Environmental Protection (PADEP) found Slippery Rock in violation of these standards. During a plant inspection performed by PADEP that month, visible emission readings from the central boiler plant's stack were in excess of 60 percent for a total duration of 20 minutes. Under the law, a single reading of 60 percent opacity or greater requires correction.

In March of 1991, PADEP performed stack emissions tests at the plant, and found that Boilers 1 & 2 were producing emissions in excess of the allowable 0.4 pounds per million BTU's of heat input.

System Description

Coal-fired boilers: Two Babcock & Wilcox boilers fitted with underfeed ram, retort-grate stokers, 20,000 lbs/hr each; two Keeler boilers with traveling-grate stokers, capacity of 14,000 and 23,000 lbs/hr each.

Fuel input: B&W boilers use nut-sized coal; Keeler boilers use pea-size coal

Steam generation capacity: 77,000 lbs/hr

Average campus steam demand: 55,000 lbs/hr

Designing the Initial Solution

The state provided $4 million to design and construct improvements to the central boiler plant in order to bring the facility into compliance with emissions standards. The Request for Project Action describing the initiative called for adding pollution control equipment, specifically mechanical multiclone dust collectors, to achieve compliance.

The state advertised the project, and eventually appointed Gannett Fleming, Inc. (GF), a Harrisburg, Pennsylvania engineering firm, as designer for the plant. GF conducted its analysis and was concerned that the use of multiclone dust collectors could conceivably fall short in meeting emissions requirements under all conditions of operation. In fact, the situation could be aggravated if the fuel supply was switched to coal with a higher percentage of fixed carbon and ash. After much analysis GF determined that the project would require baghouse collectors to meet PADEP's requirements.

Boilers 1 and 2 would continue to run on coal with baghouse collectors attached, and Boilers 3 and 4 would be converted to natural gas.

The project proceeded through the fund allocation process and the project was activated in August of 1997 and ready for construction bidding in early 1998.

Shifting Directions

During the design phase and subsequent delay, the Gas Research Institute (GRI) and the local gas utility, Consolidated Natural Gas (CNG), met with the university and introduced the concept of co-firing systems as a means to meet air quality requirements.

Co-firing was presented as a viable solution because it reduces particulate emissions in two ways. First, co-firing a clean-burning fuel provides an oxidizing environment above the coal surface, providing a more complete burnout of coal products from combustion. Second, firing the clean fuel from opposite directions creates vortices that cause additional agitation and mixing of furnace gases. This increases the residence time of combustion products in the furnace, further improving the opportunity for complete fuel burnout.

The project, however, had already been put out to bid, and design of the system had already been completed. Despite this, GRI and CNG persevered, and eventually were successful in convincing the appropriate agencies that co-firing should be applied to this project. Ultimately, a directive was issued to GF to commence a redesign of the project using co-firing technology.

The goal was to test Boiler 1 as a single unit and determine if emission requirements could be met while firing no more than 20% natural gas and 80% coal. If it were determined that greater percentages of natural gas were required to meet emissions goals, then the decision would be made to revert to the design using baghouse collectors.

Due to the revised scope of work, and since only Boilers 1 & 2 were to remain on coal, the project was split into two phases – one for the updates to Boilers 1 & 2, and another for the conversion of Boilers 3 & 4 to natural gas.

Implementing a Solution

Modeling of the proposed solution was conducted to determine what level of natural gas firing would provide optimum opacity reduction. Optimum opacity reduction occurred with 10-20% natural gas firing. Under that amount, the benefits of co-firing are not as noticeable, and above those levels, the increase in furnace turbulence results in additional ash being carried to the stack.

The modeling also analyzed the effects of different physical arrangements of the gas burners on opacity. The optimal arrangements were implemented on Boiler 1, but, due to structural interference from a large steel building column, it was not possible to position the over-fire burners in the optimal location on Boiler 2.

The co-firing design was implemented, and testing occurred in October 2000. The average of tests performed on Boiler 1 yielded an acceptable emissions rate, and tests on Boiler 2 yielded a rate slightly in excess of the acceptable emissions limit. The results were submitted to PADEP in November of that year, and ultimately the agency granted conditional approval requiring both boilers be co-fired with a minimum of 5865 cfh of natural gas (20% full load) as contrasted to 16-19% natural gas as fired during the actual test runs. It is felt that these limits will be reduced when the boilers are retested at the conclusion of Phase II.

Key Learning

The results of the co-firing demonstration show that this approach can provide an effective means of reducing particulate emissions and plume opacity from stoker coal-fired boilers. The capital and operating costs of the technology are competitive with competing alternatives such as baghouses.

Co-firing can be implemented with the use of numerous clean fuels. In addition to natural gas, these include low- and medium-Btu gas from coal gasification, landfill gas, and perhaps even low-viscosity No. 2 fuel oil.

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Stanford University Stays Cool by Building Large Scale Central Ice Plant

Keywords: Ice storage, chilled water distribution, district energy

Project Background

Like many universities, Stanford University has had a central chilled water system in place for many years. By the early 1990's, the system in place, which had been expanded and modified numerous times over the previous thirty years, was no longer adequate to meet the growing chilled water needs of the campus.

The primary constraint was the 30,000 ton-hour stratified chilled water storage tank, which was not large enough to handle the demand placed upon it and which required chillers to be operated during peak hours. A replacement for the chilled water storage tank had to be found. The university decided to implement ice-based thermal storage to expand the plant's capacity and to eliminate production during costly peak hours.

System Description

Cogeneration with Ice Thermal Storage: Natural gas-powered combined cycle power plant owned and operated by Cardinal Cogen, commissioned 1987. Ice plant built in 1999.

Electric capacity: 49.9 MW total; 39.2 MW gas turbine, 10.7 MW steam turbine driven by HRSG

Steam output pressure: 125 psig

Backup boiler plant: four 125 psig, 80,000 lbs/hr, boilers built in 1957

Ice plant: Internal melt system; three electric rotary screw chillers using R-717 ammonia; 25% ethylene glycol/water mix for energy transfer to ice coils; 90,000 ton-hours nominal storage capacity, 120,000 ton-hours allowing ice bridging across coils; 4 million gallon tank volume

Cooling capacity: 20,000 tons

Peak cooling load: 16,000 tons

Chilled water supply temp: 38-41° F

Chilled water return temp: 58° F

Limitations of Previous Equipment

Prior to building the ice plant, Stanford cooled the campus using thermal storage technology. Water was chilled and stored in a stratified tank, which was used to feed the chilled water distribution system. The existing chilled water storage tank, however, had some limitations. First, the tank was not large enough to meet all the demand for the campus and two hospitals. Second, the tank was not designed for optimal performance. Its depth-to-width ratio was too small, and during periods of rapid flow, the tank would become de-stratified, reducing the efficiency of the system.

Charting a Course for the Future

The economics favored adding storage capability rather than simply adding chillers to the cooling network. There were three major drivers behind this:

First, adding storage was a more reliable and cost effective way to ensure that cooling capacity was available around the clock for critical activities at the two hospitals dependent on the system – Stanford Hospital and Packard Childrens' Hospital – as well as on the rest of the campus.

Second, thermal storage allowed load shifting to off-peak hours, saving considerable amounts of money that would otherwise be spent buying electricity during peak hours.

Third, Stanford could minimize the risk of paying penalties for using more power than it had contracted for. The campus cogeneration plant was – and is – a qualifying facility under PURPA, owned and operated by Cardinal Cogen, a GE subsidiary. The contract between Stanford and Cardinal, entered into in the early 1980's, established maximum demand levels for the university, with the surplus power sold by Cardinal to the local utility. If Stanford exceeded its quota, it would have to reimburse Cardinal with lost capacity payments, and could possibly face de-rating of its contract. The university's demand grew faster than the increases allowed for in the contract, and in the late 1990's, Stanford exceeded its allowed average demand during peak hours by about 5 MW. Adding thermal storage to take advantage of off-peak power would reduce that overage by about 2 MW.

With the economics of district cooling and thermal storage still making sense, the university looked at different ways to enhance its cooling capacity.

The ideal solution would have been to construct a large new stratified chilled water storage tank on a higher elevation portion of central campus. Such a location, however, did not exist. The central campus was relatively flat, with a maximum height differential of forty feet, and it was fairly densely built up.

The university also looked at satellite plant locations, but the area around the central campus was also densely built up, and there were many competing interests for alternative use of the space. Furthermore, the costs to lay piping from remote locations made that option infeasible.

In the end, the existing rectangular tank provided the best site, and its 24'X150'X150' dimensions were ideal for ice storage. The height was well-suited to stacks of coils, and the shape worked well for ice. It was decided that the campus would shift to ice storage and utilize the existing site to meet its cooling needs.

Designing and Building the Facility

The existing chilled water tank was open to the atmosphere and was non-treated, leaving the water open to contamination. The university wanted to begin treatment of the circulated chilled water as part of this project.

Due to the characteristics of the different materials used in construction – the ice coils were made of galvanized steel, whereas the distribution pipes were made of ductile iron, steel, and copper – the ideal treatment for circulated chilled water differed from the ideal treatment for water around the ice coils. It would be better to treat the two areas independently.

For this reason, an internal melt system was chosen, rather than the external melt approach typically used in applications this large. Most internal melt systems have a capacity of 10,000-20,000 ton-hours, but Stanford's was to weigh in with a nominal capacity of 90,000 ton-hours.

In the Stanford plant, ammonia refrigerant is used to make the ice, and an ethylene glycol solution circulates between the ice and the building load.

Surprisingly, there weren't any regulatory complications in getting the plant approved. Because of the quantity if ammonia used in the plant, the facility had to comply with the local toxic gas ordinance. Specifically, the plant had to comply with an H-7 occupancy and participate in the state's accidental release prevention and protection program. Although the university did not launch an aggressive PR campaign, it did emphasize to the public the environmental friendliness of the project. The result was a relatively painless approval process.

Planning and Scheduling: Making the Most of an Efficient Resource

Most institutions with thermal storage still run their chillers 24 hours a day, but use the storage to augment their cooling capacity, generating ice or chilled water that can be "burned" during daytime peak hours. This is typically done on a cycle that repeats daily.

When deciding the run cycle for the new ice plant, Stanford did some thinking and realized that the combination of its large plant size, the low level of weekend chilled water demand, and off-peak weekend electric rates made a weekly-based cycle more effective. Ice is built nonstop over the weekend and at night during the weekdays. By Monday morning, the maximum ice capacity level has been reached. The ice is rationed so it burns off between Monday and Friday, leaving none by Friday evening, at which point full production begins again (see Fig 1). This allows Stanford to completely avoid running its chillers during peak rate hours, producing annualized demand savings of $300,000 plus an additional $300,000 per year saved by using off-peak power rather than peak power.

Lessons Learned and Advice to Others Looking at Ice Storage

There were a number of things learned from implementing the project. First, ice storage implementation is more complex than traditional chilled water systems, and the service requirements are more complex, as well. Stanford has contracted out service for the ice plant.

Second, the decision to use ammonia should be considered carefully. Stanford originally had a zero release tolerance policy, but this proved impractical; the frequency of small ammonia releases demanded a re-evaluation of that policy. The plate and frame heat exchangers proved to be the most problematic piece of equipment, and were the source of many ammonia leaks.

Furthermore, the contractors all had different levels of expertise in different areas, making knowledge transfer and coordination more difficult. While it is arguably impossible to find a perfectly complementary set of partners, it is beneficial to align them as best as possible.

On the operating side, the weekly run cycle works very well for the university, and since most colleges have a similar cooling demand curve, other plants with ample capacity should also look into such a cycle to entirely eliminate running chillers during peak hours.

Project Impact

The addition of the ice plant provided the following benefits to Stanford:

- Reduced peak electric demand by 10 MW compared to the level that would have been sustained if a conventional chilled water plant had been built
- Reduced actual electric demand by 2 MW, even while adding additional cooling capacity
- Reduced average summer daytime load by 5 MW
- Developed the ability to drop water supply temperature from 44° F to 38° F during periods of high demand, thereby increasing distribution capacity by 40%

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Ice is created during off-peak hours, and burned during peak hours. The size of the ice storage at Stanford allows the university to build enough ice on the weekends to last most of the week. The chillers are operated all weekend, and during off-peak hours during the weekdays. As a result, Stanford does not run its chillers at all during peak hours.

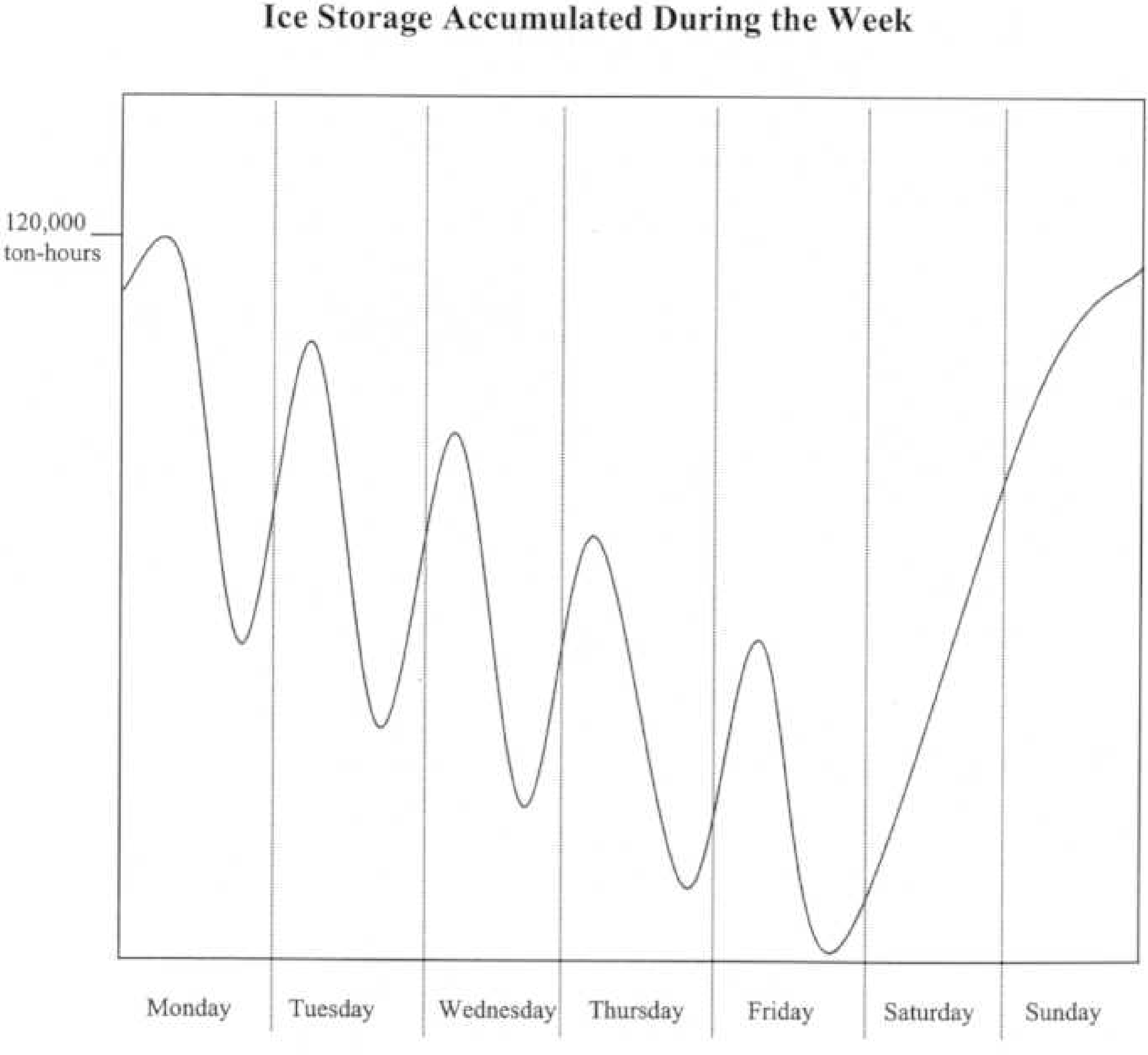

Figure 1

UCLA Reduces Operating Costs and Air Pollution with LFG-fueled Cogeneration

Keywords: Cogeneration, CHP, Landfill gas, LFG, Brownfield

Project Background

The University of California Los Angeles is located in the Los Angeles basin, long known for both its persistent smog and strong environmental regulations. As the University's energy needs grew in recent years, it was challenged with aging cooling equipment (with rising failure rates) and decreased funding from the state.

UCLA needed to develop new sources of energy, but wished to do so in an environmentally friendly manner. The university had already set aggressive goals for itself with respect to minimizing its impact on the environment, and was implementing numerous demand side management initiatives. This project was an opportunity to begin achieving those goals on the supply side.

Four objectives were identified: increasing system reliability, meeting energy needs efficiently, improving the environment, and reducing cost. The solution employed to meet these objectives involved co-firing the university's cogeneration plant with a blend of natural gas and landfill gas.

System Description

Combined heat and power (CHP): Two 14.5 MW combustion turbine generators fueled by mix of natural gas (65%) and landfill gas (35%); two heat recovery steam generators (HRSG) driven by the combustion turbines; one condensing steam turbine electric generator

Heating capacity: 234 MMBTU/hr

Annual heat production: 730 billion BTUs

Electric capacity: 43 MW

Annual electric production: 250 GWh

Cooling capacity: 16,600 tons with 5,300 tons reserve

Annual cooling production: 870 billion BTUs

Cooling energy source: Two steam turbine-driven centrifugal chillers and one electric-driven chiller; four single stage absorption chillers for additional chilled water production

Chilled water distribution: 6.5 miles of underground pipe to 24 buildings; flow provided by three 14,000 gpm variable-speed pumps

Chilled water supply temp: 42° F

Designing a Suitable Solution

To achieve its efficiency objective, UCLA needed a solution that could squeeze every last bit of energy out of a clean-burning fuel source. Cogeneration was the way to go, since the plant could generate both electricity and thermal energy from the same process, resulting in double the efficiency of separate processes. Natural gas was chosen to fuel the plant, which would satisfy 85% of the campus' electric needs.

UCLA, however, did not stop there. It asked the question whether or not any alternative fuels may be available, and found an answer just five miles off campus.

The Mountaingate landfill was a 375-acre waste facility containing 21 million tons of solid waste. It had been closed and converted to a golf course in 1975. Gas from the landfill was being flared off to prevent buildup, but was not being used for any power generation-related purpose. Landfill gas is a valuable source of energy, with heat content of approximately 500 BTUs per cubic foot – about half that found in commercially marketed natural gas.

UCLA worked out an arrangement with GSF Energy, Inc., operators of the landfill's gas control and recovery plant, to purchase purified methane gas, which was then piped 4.5 miles to the campus. UCLA then compressed the gas to about 500 psi and blended it with natural gas to fuel combustion at the campus Energy Services Facility (ESF). The landfill gas replaces one third of the natural gas that the plant otherwise would have burned, saving about $250,000 annually.

LFG use is not the only form of innovation at UCLA. Conventional cooling towers use up a lot of water during normal operation, and the university decided instead to use grey water recovered from campus buildings in the cooling system. The result is a savings in water usage by the system of 70 million gallons per year.

Financing Approach

There are many "good" projects which don't end up being implemented because of financing issues. The causes range from outright lack of economic feasibility to unwillingness of investors to shoulder too much risk. From a technical perspective, the UCLA cogeneration project looked like a good one, but fiscal issues could have threatened the project's survival.

First, the state government was already becoming conservative in its outlays to the university system. Funding for the University of California system was curtailed severely during the early 90's, when California's defense-based economy started to slow down. UCLA was not likely to squeeze additional funding for the project out of the state legislature.

Second, the state's debt rating was a variable dependent upon many other factors. Using state revenue bonds to finance the project would introduce that variability into the cost of the project, potentially making it unfeasible.

It was decided that the best course of action was to isolate the project's funding from external factors by issuing Certificates of Participation to lenders. The certificates are essentially loan agreements paid back with the operating savings realized by the new system. This approach allowed UCLA to ensure that the cost of borrowed funds accurately reflected the financial soundness of the project.

The cogeneration system required an initial investment of $188 million, which will be paid off over 22 years. After that, it will provide savings of over $25 million over its anticipated life span.

Partners

UCLA partnered with the following firms to design and build the cogeneration facility.

Design: Parsons Municipal Services, Inc.
Construction: Kiewit Pacific
LFG supply: GSF Energy, Inc.
Local utility: Los Angeles Dept. of Water &Power

Project Impact

The LFG project has already had a positive impact on both UCLA and its surroundings.

- Reduction of overall campus emissions by 34%
- Elimination of over 20,000 lbs of CFCs from 18 building-mounted chillers
- Replacement of 1/3 of natural gas usage with LFG
- Elimination of need to flare off 4 million ft^3 of LFG per day
- Benchmark BACT for NO_X in Los Angeles basin reduced from 9ppm to 6ppm
- Annual 36-ton reduction in smog-forming pollutants in LA basin
- Water usage reduced by 60% (70 million gallons/year) by utilizing campus grey water

Beyond its environmental contributions, the plant has also benefited the community during times of crisis. During the 1994 Northridge earthquake, thousands of people served by the Los Angeles Department of Water and Power lost service. UCLA's Energy Systems Facility was able to supply 20,000 homes with power during that time.

UCLA is now adding additional chilled water thermal storage capacity, which will allow it to minimize the amount of time the plant must run during peak electric demand hours.

The university won the International District Energy Association's System of the Year award in 1997, and regularly hosts representatives from other universities that are interested in developing their own environmentally friendly power generation solutions.

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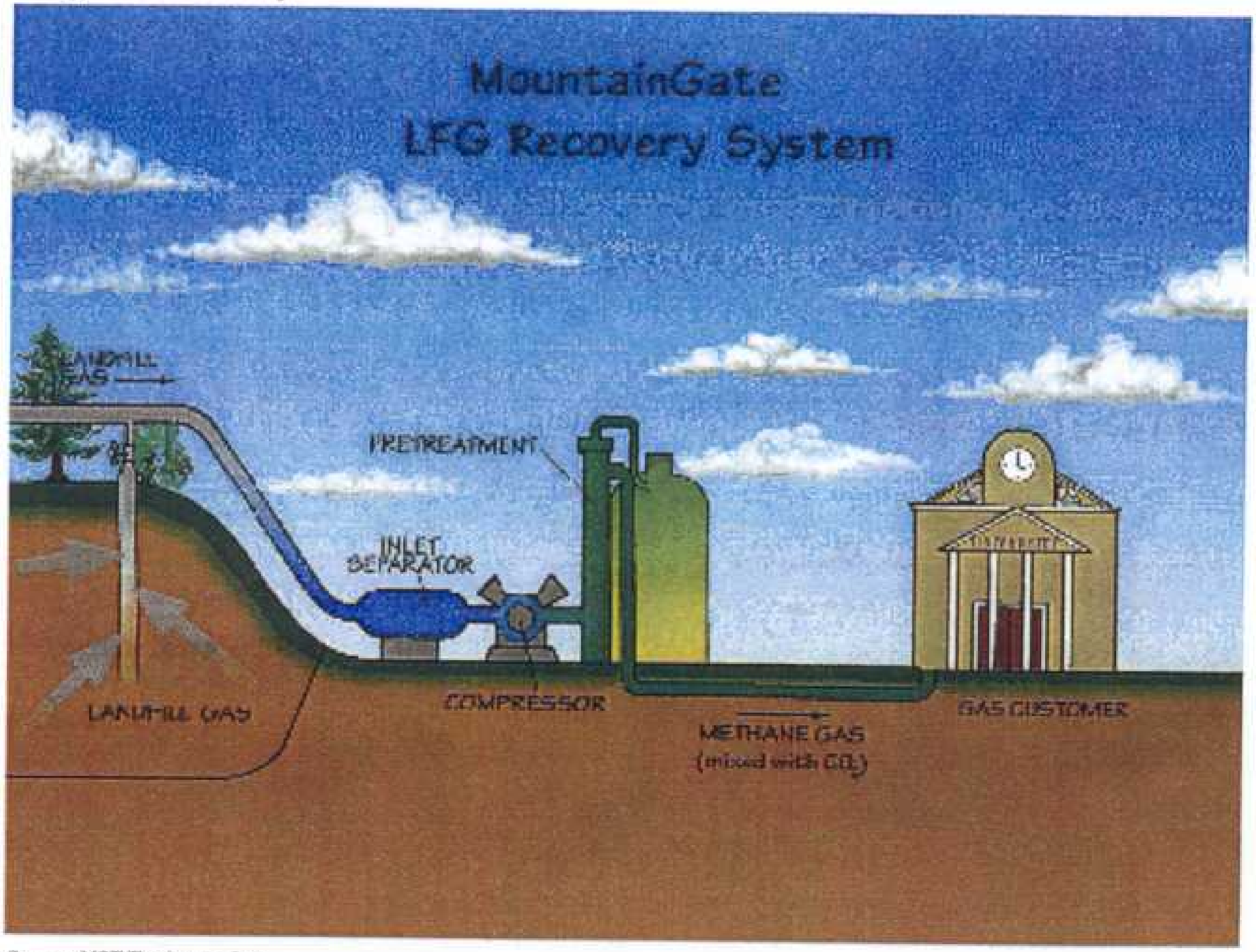
Landfill gas is drawn out of the Mountaingate facility, cleansed of impurities, and then piped 4.5 miles to the UCLA campus, where is it blended with natural gas. The resulting mixture is used to co-fire the UCLA Energy Services Facility.



Source: NST/Engineers, Inc.

Figure 1

UNC Turns to Coal-fired Cogeneration to Meet Growing Campus Energy Needs

Keywords: Cogeneration, Coal firing, Circulating fluidized bed, Plant siting, Environmental permitting, District energy

Project Background

Power generation has a long history on the campus of the University of North Carolina at Chapel Hill. A man named Joshua Gore brought the first dynamo to the campus in 1890, and the first plant was built soon after in 1895.

The present power generation facility has its roots in a plant built in 1940 on West Cameron Avenue, a half mile from the main campus. This plant was fired by coal and supplied electricity to both the university and the surrounding towns of Chapel Hill and Carrboro.

In the early 1970's, the state legislature decided that UNC should not be in the electric power business, and ordered the university to divest its electric utility assets to Duke Power. After the divestment, UNC generated only 20% of its power needs, purchasing the remainder from Duke Power.

In the 1980's, the university revisited on-site power generation, and in 1988 decided to build a coal-fired cogeneration plant that would provide a clean, reliable source of energy for the UNC campus and hospital.

System Description

Cogeneration: Coal-fired boilers generate steam used on campus as well as for electricity generation

Steam generation capacity: 650,000 lbs/hr

Electric generation capacity: 28 MW

Length of steam pipe: 40 miles, supply plus return

Boilers: Two coal-fired atmospheric circulating fluidized bed (ACFB) boilers, each capable of producing 250,000 lbs of steam/hr; one oil/gas package boiler, capable of producing 150,000 lbs of steam/hr for standby and peaking needs (see Fig. 1 for boiler system diagram).

Auxiliary fuels for coal-fired boilers: 100% MCR natural gas; 70% MCR No. 6 fuel oil

Generator: 28 megawatt steam turbine generator

Central chilled water production: three plants with total cooling capacity of 28,400 tons

Chilled Water Supply Temperature: 42° to 45° F

Length of chilled water pipe: 10 miles, serving approximately 100 buildings

Choosing Coal as a Fuel Supply

The university conducted a study of its utility options from 1983 to 1985. The recommendation was to build a replacement cogeneration facility on the same site as the old West Cameron Avenue plant. This decision provided both utilization of existing infrastructure and reasonable economic payback. The old plant site had links to the rail system, facilitating deliveries of fuel, and was already connected to campus distribution piping.

When it came time to choosing a fuel source, several factors came into play. The university had previously burned coal in its plant, but coal was generally dirtier than natural gas, which had become the fuel of choice for most new plants. But when asked about the availability of natural gas to fuel the new cogeneration plant, the local utility replied that supplies were not available on a cost-effective basis. Coal, however, was still available, and at low cost. Furthermore, the university was familiar with the technicalities of burning coal from its previous experience. It was decided to use coal to fire the new plant.

The university anticipated new source environmental performance standards, and was aware of the need to design a plant that would be clean enough to overcome both regulatory hurdles and the stigma of burning "dirty" coal.

These criteria left it with a choice between implementing circulating fluidized beds (CFB) or using pulverized coal with scrubbers. The economics pointed to using CFB. CFB reduces emissions of acid rain-producing components such as NO_x and SO_2. The reduced NO_x output is the result of the low combustion temperature (1600° F). SO_2 output is reduced by using a limestone additive to precipitate it as calcium sulfate.

Public Review Process

The proposed site of the project was the location of the existing UNC steam plant. There was much opposition to the proposed site, primarily from people who lived in a neighborhood that surrounded the plant. A map of the plant and its surroundings can be seen in Fig. 1.

Despite the opposition, the site proved to be the best place to locate the new plant. It was the only location with existing connections to the electrical substation, the campus steam supply grid, and the railroad. There was also space available on the parcel for construction of a new facility.

In 1986, after much debate, the project was issued a special use permit, with 24 conditions. The conditions included, among other stipulations, the following:

- Planting trees and shrubs to minimize aesthetic impact of the new facility
- Designing structures such that all handling of coal, ash, and limestone is done within enclosed structures
- Transporting waste ash from the plant in covered trucks or rail cars only after it has been wetted down
- Limiting visible emissions from truck unloading of plant material into the landfill to less than 20 percent opacity
- Limiting visible emissions from coal handling at the plant to no more than 10 percent opacity
- Ensuring that no fugitive particulate matter emissions are visible beyond the property line of the plant
- Working with the town to design the external appearance of the plant such that its impact on the neighborhood is minimized

The university moved forward with design and construction, and in 1992 commenced operations at the new plant. The new building featured blue-tinted windows, totally enclosed coal handling, and active coal storage in silos.

The only major issues involved noise abatement. The decorative glass exterior did not provide adequate sound insulation, upsetting some neighbors. The town and UNC worked with an acoustical consultant to minimize the sound emanating from the plant, and succeeded in reducing levels to 50 dB at the property line.

The plant now generates steam for the campus and hospital, and provides one third of the electricity needed on campus. The remaining amount is purchased from Duke Power.

The UNC cogeneration plant has been recognized for its leadership by many. It is a founding partner of the EPA Combined Heat and Power Partnership, and it is the only plant not fired by natural gas to have been awarded an Energy Star Combined Heat and Power Certificate of Recognition.

Project Impact

The cogeneration plant provides many benefits to UNC and the surrounding community:

- Reduces NO_x output by 308 tons annually
- Reduces SO_2 output by 650 tons annually
- Reduces CO_2 output by 10,620 tons annually
- Provides 18,000 tons of ash per year, which is recycled as material for structural fill and other projects
- Utilizes coal, a cost-effective energy source that is currently cheaper than natural gas or other alternative fuel sources, to keep costs low
- Extracts twice as much energy from a pound of coal by using cogeneration to achieve 69% efficiency.
- Provides reliability in excess of 99.85%

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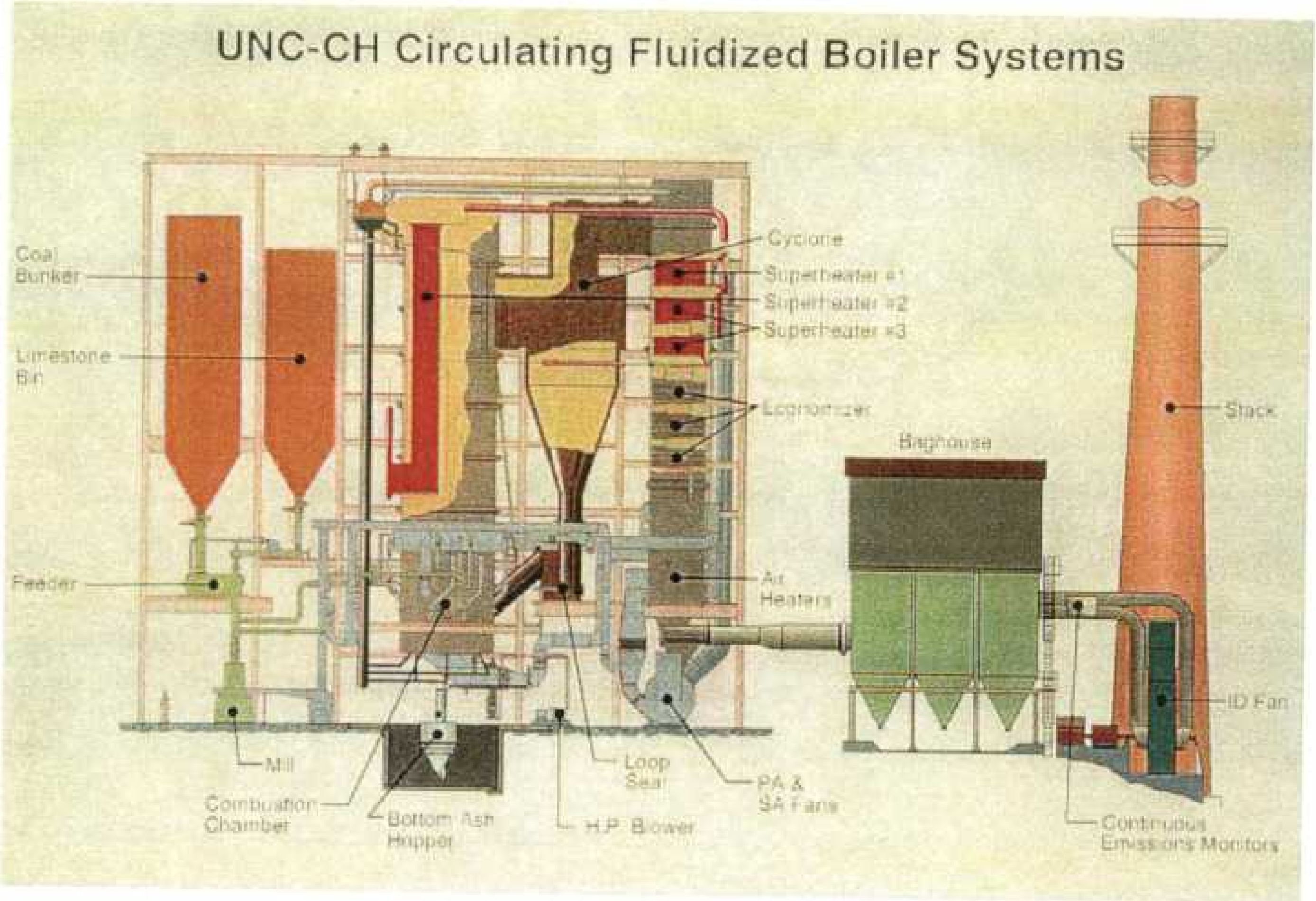
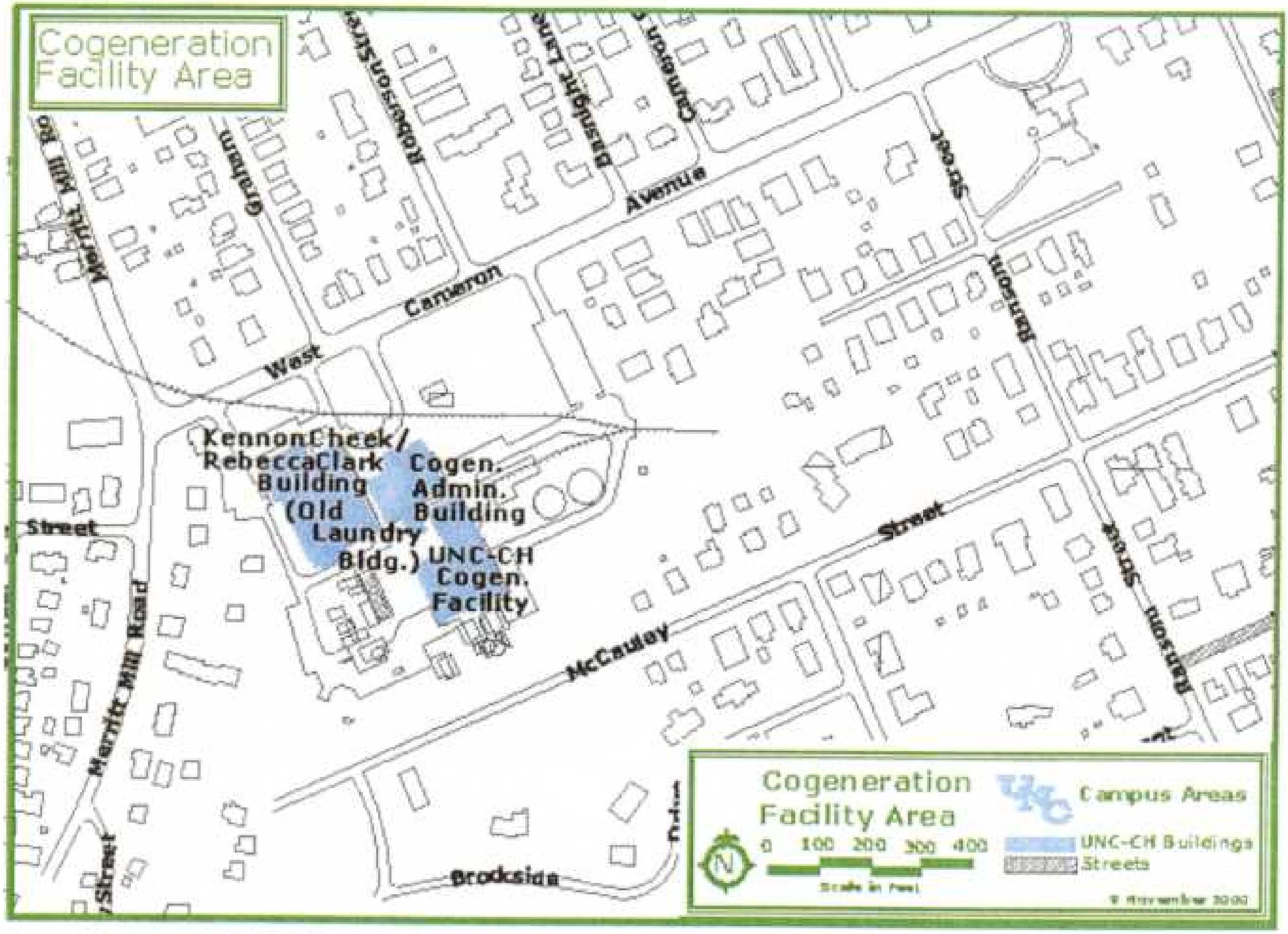
Circulating fluidized beds keep NO_x levels low by burning coal at lower temperatures. They also limit emissions of SO_2 by mixing limestone with the coal in the combustion chamber, converting the SO_2 into an inert part of the residual ash.



Source: University of North Carolina

Figure 1

The University of North Carolina cogeneration plant is surrounded by an off-campus residential area. This increases the importance of clean coal handling and burning operations, as well as that of noise control.



Source: University of North Carolina

Figure 2

University of Pennsylvania Invests in District Energy to Conserve Power and Reduce Energy Costs

Keywords: Conservation, Ice storage, District cooling, District energy

Project Background

The University of Pennsylvania has over 130 buildings and spends between $33 to 35 million a year on energy. Most of this cost is attributable to the purchase of steam and electricity. Steam is used to heat the campus and for various process uses. Electricity is used for both building needs and electric chillers which supply the campus with chilled water.

In light of rising energy costs and a growing awareness of the University's impact on the environment, UPenn embarked upon a plan to reduce energy costs while increasing efficiency. The Division of Facilities Services developed an energy plan which included the following major components:

- Energy-efficient lighting
- Capacitors at University substations
- Utility tariff
- Increased utilization of winter free cooling instead of building chillers by individual departments across campus
- Operational changes to manage and reduce energy demand

System Description

District chilled water with ice storage: Electric chillers create chilled water for campus distribution; Module VI chiller plant has thermal ice storage; steam and electricity are provided by local utilities.

Capacity: 40,000 tons total of cooling; 22,000 ton-hours of ice storage, providing six hours of cooling during peak demand

Length of cooling pipe: 26,000 linear feet, supply and return

Length of steam pipe: 37,000 linear feet, supply only

Using a Multi-pronged Approach to Achieve Results

The best strategies are those that work to achieve an end by multiple means. It is the combination of these efforts that ensures success. UPenn understood that achieving a substantial reduction in energy costs would require efforts in areas spanning capital investment, operational change, behavioral change, and policy change. Each of the components of the energy plan touched on at least one of these areas.

The lighting project calls for replacing lights in University buildings with new energy-efficient fluorescent lights. Any time building maintenance or renovation is underway, installation of energy-efficient bulbs and fixtures is attempted. New lighting equipment has already been installed in several major building projects.

Installation and maintenance of capacitors in substations owned by the University ensures more efficient energy flow and reduced cost.

The University also negotiated a new tariff with the local electric company for the construction of its newest chilled water plant, Module VII, that provided $1 million savings for the University.

Ice thermal storage was maximized to shift electrical demand from chillers to the off peak hours defined by the tariff. At full load, the ice storage facility can provide six hours of cooling for the campus.

The biggest savings were derived from changes in operational practices on campus. In 1998, the University began the following changes:

- The chilled water flow rate throughout the distribution system was reduced. By experimentation, it was determined that a reduction in flow rate could reduce the amount of pumping power required. The chilled water flow rate was reduced by approximately 50% during the winter and 25% during the summer. This reduced electrical consumption by approximately 7,500 MWh annually and resulted in avoided costs of about $400,000 annually.
- The use of free cooling systems on campus was optimized, reducing electrical consumption by 2,600 MWh annually and avoiding $150,000 in costs annually.
- Chilled water chemistry was significantly improved, eliminating chiller fouling problems and improving chiller efficiency by 19%.

The University didn't stop there. It also sought ways to reduce energy consumption on the steam side. There were four major actions targeting steam use reduction:

- Winter space temperatures were adjusted downward from 72 °F to 68 °F.
- Fifteen building air handling units were shut down during overnight periods.
- Steam trap surveys were conducted on the twenty buildings on campus that used the most energy. Traps were replaced as needed.
- Steam demand was monitored more closely.

During the winter period from January 2000 to April 2000, steam consumption was reduced by 5%, resulting in avoided costs of $400,000.

An even larger reduction in electricity usage occurred during the summer of 2001. Concerned about rising energy costs and the energy crisis in the western US, the Facilities Department changed some more operating practices, and asked for cooperation from the University community.

The savings from the summer season would also provide benefits year round. Winter electricity charges were calculated at no less than 80% of peak summer demand. A reduction in peak demand during the summer would yield lower electric rates year round. The result was a 5% reduction in electrical consumption and a 15% reduction in peak demand, avoiding $2,500,000 in costs annually. Among the actions taken:

- Real-time electrical demand from each of the University's six substations was monitored in the Facilities Operations Center. Operational decisions were made based on the demand data, allowing the University to reduce peak electrical demand by 10 MW.
- Chilled water supply temperature was increased during peak days to 50 °F. Allowing supply temperature to increase prevented another chiller from starting, thereby lowering electrical demand and consumption.
- The discharge temperature of building air handling units was increased from 55 °F to 60 °F, and building space temperatures were increased from 72 °F to 78 °F.
- A computer program was implemented to automatically shut down over 100 air handling units during overnight periods.
- On peak days, members of the University community were asked to shut down all unnecessary lighting and equipment. On a few extremely hot days (wet bulb temperatures at 82 °F), building air handling units were shut down for thirty minute intervals, and managers were asked to release non-essential staff early.

Impact of Initiatives

Thus far, the Facilities Department at the University of Pennsylvania has been able to conserve energy and realize avoided costs exceeding $4,000,000 annually by investing in new equipment, updating its operating practices, and working with the University community. Peak electrical demand has been reduced by 10 MW (15%), and electrical consumption has been reduced by 18,000 MWh (5%). Furthermore, steam consumption has been reduced by 5% as well.

Energy conservation at the University of Pennsylvania yields measurable benefit not only to the University, but also to the environment. The table below shows how every incremental effort makes a difference. UPenn achieved a 5% reduction in kWh consumption.

The savings resulting from the University's conservation efforts cleared the way for Penn to make the largest U.S. retail purchase of clean, renewable energy, from the recently commissioned Wind Farms in Western Pennsylvania (20 million kilowatt hours). Combined, these two initiatives have accounted for a reduction of approximately 38 million kilowatt hours per year and their associated harmful air, waste, and water impacts that can be viewed in Figure 1 below.

The initiatives to date focus on the macro-, University-wide picture. The department's next steps are to focus on the micro-view, helping individual schools within UPenn develop their own energy savings programs.

Project Contact Person

For more information about the University of Pennsylvania energy conservation project, contact:

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The University of Pennsylvania

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Percent kWh reduction	Actual kWh reduction	Pounds of CO2 prevented (global warming)	Grams of SO2 prevented (acid rain)	Grams of NOx prevented (acid rain & smog)	Equivalent number of cars off the road	Equivalent acres of trees planted
1.00	3,620,000	5,792,000	29,684,000	9,412,000	507	1,050
2.00	7,240,000	11,584,000	59,368,000	18,824,000	1,014	2,100
3.00	10,860,000	17,376,000	89,052,000	28,236,000	1,520	3,149
4.00	14,480,000	23,168,000	118,736,000	37,648,000	2,027	4,199
5.00	18,100,000	28,960,000	148,420,000	47,060,000	2,534	5,249
6.00	21,720,000	34,752,000	178,104,000	56,472,000	3,041	6,299
7.00	25,340,000	40,544,000	207,788,000	65,884,000	3,548	7,349
8.00	28,960,000	46,336,000	237,472,000	75,296,000	4,054	8,398
9.00	32,580,000	52,128,000	267,156,000	84,708,000	4,561	9,448
10.00	36,200,000	57,920,000	296,840,000	94,120,000	5,068	10,498

Source: University of Pennsylvania Division of Services and Real Estate

Figure 1

UT-Austin Increases Investment in Co-generation to Achieve Greater Utility Reliability and Economy

Keywords: Co-generation, District energy, Chilled water, Redundancy, Condensate treatment, Economics

Background

The University of Texas at Austin has grown over the years into one of the nation's largest research-oriented universities. In the process, it has built a very reliable utility system to ensure that the mission of the university is not disrupted by energy system failures. A testament to the robust design of the systems is the fact that the campus has had only one complete blackout in the past 30 years.

This enviable record is accomplished though a variety of means, primarily through self-reliance for all its energy needs and redundancy designed into the energy delivery system.

UT-Austin continues to grow. As the university's energy needs increase, the utilities department is adding to its available capacity to ensure that it can continue to provide the same high levels of reliability it does today.

System Description

District steam, chilled water and electricity with co-generation: Redundant capabilities to keep campus supplied with steam, electricity, and chilled water in event of equipment failure

Installed heating capacity: 1,146,000 lbs/hr; two HRSGs with total capacity 346,000 lbs/hr and four watertube boilers with total capacity 800,000 lbs/hr

Cooling capacity: 40,800 tons of cooling, 30,000 tons electric and 10,800 tons steam-driven

Electric generation capacity: 88 MW; 51 MW from gas turbines and 37 MW from steam turbines

Standby electrical power: 25MW from local utility

Steam distribution pipe: 81,316 linear feet, supply and return

Chilled water distribution pipe: 89,228 linear feet, supply and return

Electric distribution: switched multiple bus system

Achieving Cost Effectiveness and Reliability Through Redundant Design

The CH&P plant at UT-Austin has provided very reliable utilities since inception. This reliability is a product of the system design, which consists of a very interconnected system. The HRSG and boiler plant are part of one contiguous steam system, allowing the university to use both sources to generate steam if needed. If a gas turbine and/or HRSG were to fail, standby electrical power (25 MW) from the local utility, Austin Energy, is used to support the electrical system, and one or more of the fired boilers is used to run the steam system, which keeps the steam distribution supported and keeps most of the electrical system on-line via steam turbines. This interconnection of plant equipment is a blessing as well as a challenge due to the complexity introduced to plant operations.

An important factor that enables the plant to operate so economically is that about 10,800 out of 40,800 tons total of refrigeration can be generated using steam turbine-driven chillers. In the summer, when chilling load (28,000 tons peak) is highest and electrical peak load is the highest (56 MW peak out of 88 MW total installed capacity), HRSG-generated steam supports the chilling system. In addition to electrical generation and chilled water support, heating and hot water systems in the 160 campus buildings are also supported by the steam system (See steam system diagram in Figure 1).

The 40,800-ton chiller plant consists of four chilling stations that feed one common chilled water loop through a walkable tunnel system. System reliability is ensured since any one or more of the four stations can support the campus hydraulically as well as satisfy refrigeration needs. Hydraulically, each chilling station is sized to handle the total GPM needs of its station; booster pumps are located at the buildings to support the building needs (See Figure 2 for campus map).

Almost all of the campus facilities are designed with double-ended substations, so that if one transformer were to fail, the remaining transformer can handle 100% of the building load. Almost all facilities also have two feeds for chilled water, steam, and potable water so that if problems develop, those supplies can quickly be rerouted. The electrical distribution system is also designed as a switched multiple bus system that allows for an alternate feed to the bus from another bus should one fail.

Emergency power to campus buildings is provided in one of three ways. One is via traditional stand-by generators. Another is via an alternate feed from a separate bus in the electrical distribution system. This can be done because of the generator redundancy in the plant and electrical distribution system design. The third way is via an outside feed from the local utility that is procured via a separate stand-by electrical agreement, since the university generates power for all of its needs. The latter two options significantly reduce maintenance operations cost of the total existing 15 MW of standby generators.

The university also makes use of recovered water to reduce consumption. The campus consumes about 900 million gallons of domestic water per year. Of that total about 500 million gallons is for plant operations. About 50 million gallons is recovered water derived from once-through cooling water, ground water, rainwater cisterns, water from swimming pools that are drained, and condensate from building cooling coils. This recovered water is separately routed via PVC piping back to cooling towers in the plants and is used as make-up water.

Investing for the Future

UT-Austin continues to invest in its physical plant, making it even more efficient and reliable. It is taking a multi-pronged approach which includes projects related to controls, condensate treatment, and co-generation capacity expansion.

The university has invested about $6,000,000 so far over the last four years in digital controls for the power plant and chilling stations. This effort is expected to be completed within the next three years, with an additional investment of $3 or $4 million. This PLC-based system has dramatically improved reliability, since, prior to the effort, boilers were without burner management systems, and the plants were manually operated. Tripped boilers and significant upsets were commonplace, and while the campus services were not affected significantly, this was creating major operational challenges. The utilities department is now also able to consolidate power plant and chilling station operations with common controls. A reduction in operating costs and improved cross training between power plant and chilling station staffs are expected.

The campus consumes about nine million gallons of distilled water for laboratory use that is derived from the condensate return system. This laboratory application has prevented the use of amines to treat condensate in the past. When a campus facility hot water generator (steam to hot water converter/exchanger) develops a tube leak, raw, untreated water is introduced to the condensate return. The water in Austin is very hard, which further contaminates the condensate.

Studies have indicated the need to start condensate treatment via amines. There have been complications at the boiler plant, resulting in a failure of the 286,000 lb/hr HRSG at a repair cost of $2,000,000. The utilities department will shortly reroute the supply of distilled water from condensate return to the de-mineralized water system. This will now allow them to start treating the condensate system. The return condensate will also include the use of polishers for further treatment. This will be accomplished by 2003 and should resolve these complications.

Finally, the campus is expected to grow by about 1,000,000 more square feet over the next three years. This is causing a strain on the power plant. At a current peak of 56 MW, the firm capacity is 52 MW, and load is projected to grow to 73 MW by

2008. To respond to this growth, the largest cooling tower, constructed in 1958, is being replaced with sufficient capacity to handle the addition of an additional 25 MW steam turbine. This new turbine will increase total capacity to 113 MW and firm capacity to 77MW by 2003/2004. In addition, the department is increasing capacity at the substation from 56 MVA to 100 MVA to respond to the growth by 2003/2004. The substation is the campus' parallel interconnection with Austin Energy that provides 25 MW of stand-by power.

The design of UT-Austin's energy system makes campus-generated power a more cost-effective option compared to power purchased from a utility. A recent study on the option to purchase electricity rather than generate indicates that a 90% "buy" vs. 100% "generate" would cost the campus about $10 million more per year because of the university's need for steam and dependence on steam for chilled water production. This trend of additional cost is consistent even when considering smaller increments of purchased power.

While fuel costs for gas turbine generation would drop proportionally to the amount of electricity purchased, it would also result in increased direct-fired boiler use. This boiler use is needed to support steam use for campus heating/hot water, generation, and chilled water production, and is relatively constant. The reduction in gas turbine generation results in an energy penalty because turbines would now be operating at a less efficient point on the load curve, and the HRSG would proportionately be providing less free steam from the turbine exhaust. The combined electrical purchase and increased natural gas purchase for fired boilers results in an increase in total costs rather than in savings.

Continually Moving Forward

The campus will continue to strive for self-dependence in electricity because the utilities department can still provide the level of reliability and economy in the current market that the campus has enjoyed over the last 70 years. The department will, however, continue to look for future opportunities from the deregulated market, compare this to the need to add further capacity, and respond to the reliability needs.

Project Contact Person

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This case study was prepared by the International District Energy Association on behalf of Oak Ridge National Laboratories. You can reach IDEA at idea@districtenergy.org or http://www.districtenergy.org

Hal C. Weaver Power Plant
Steam System

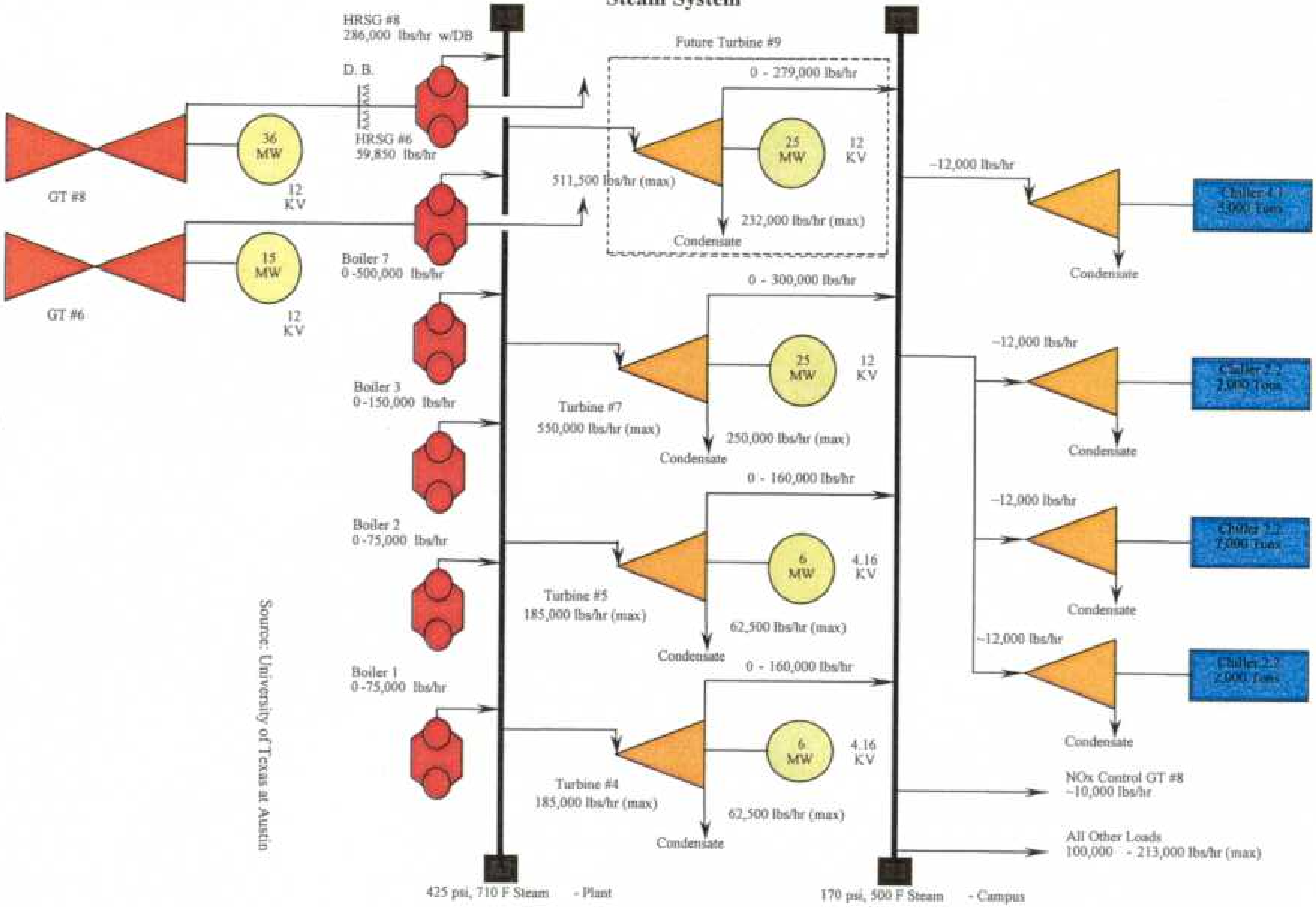
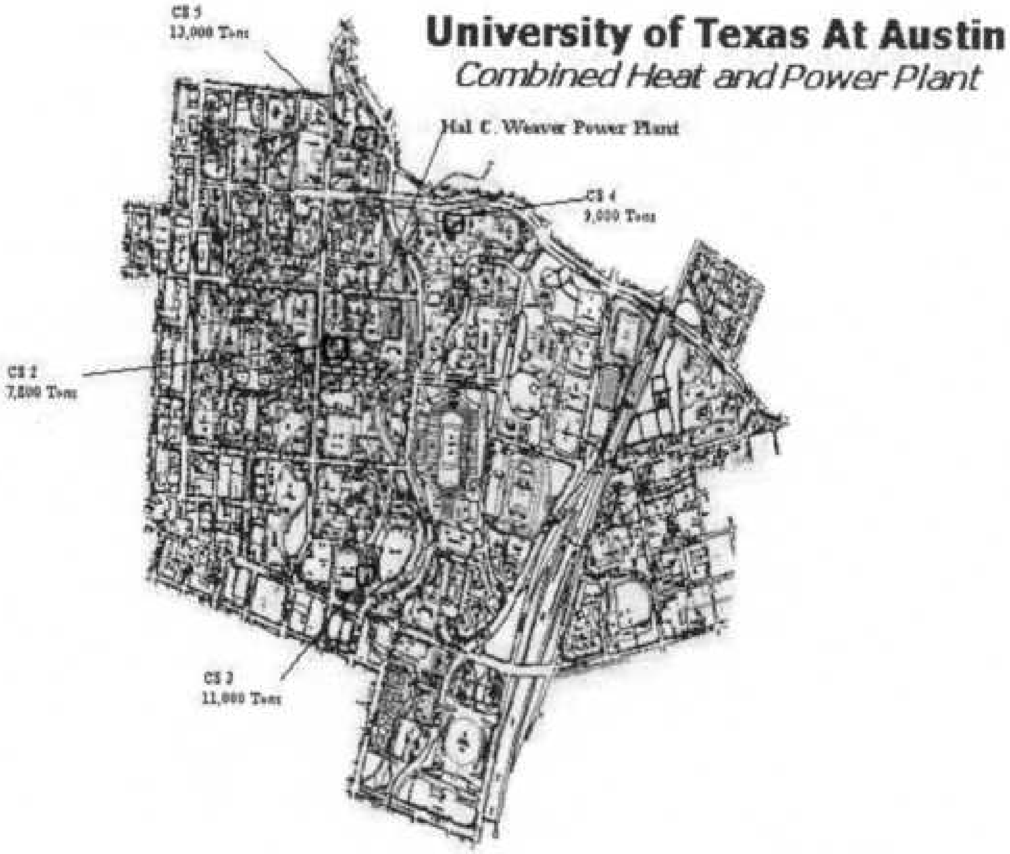


Figure 1

Source: University of Texas at Austin

The Hal C. Weaver power plant provides steam and electricity for the UT-Austin campus. There are four chilling stations that provide chilled water to the campus through a common chilled water loop.



Source: University of Texas at Austin

Figure 2

VI. NEXT STEPS AND PATH FORWARD

NEXT STEPS

The next steps for this phase of the project involve presenting and sharing the data with the community of interest and defining the next phase of the project. Tasks include:

- Presenting findings to date at the IDEA College and University Conference
- Posting results and case studies on the ORNL, DOE, and IDEA websites
- Determine the path forward, including the scope of work, timing, and funding

RECOMMENDED PATH FORWARD

The knowledge gathered so far is very valuable, but there is still more that can be done to unlock the potential of CHP and district energy. It is important to have a factual basis on which to make policy and funding decisions. We recommend the following course of action to move this initiative forward:

Continue Current Census Effort

IDEA contacted 436 institutions numerous times in the process of conducting the census, and received responses from 169 of them. The data received was of good quality, and we feel we have gathered responses from a large percentage of the institutions that have district energy systems in place. Still, given the large number of schools that have yet to be contacted, there is some uncertainty as to actual size of the CHP market for various technology ranges and applications.

IDEA's effort is a bottom-up effort, tabulating individual responses to come up with an aggregate final number. We have catalogued 948 MW of installed capacity through this method. A report conducted by OnSite Energy used a top-down method to estimate CHP installed capacity at institutions in 2000. The figure they arrived at was 1,414 MW. Completing the bottom-up census will close up this gap and will yield a better picture of the true capacity of the market.

IDEA would propose to continue posting the Zoomerang web survey instrument in order to elicit more qualitative input and deeper data from the college and university market segment.

The quantitative survey would also be posted on the IDEA website and allow for college and university personnel to continue to submit system data. Based on our experience, the passive approach of web-based surveys does not generate the activity level desired or result in complete survey submittals, and active solicitation is required to capture empirical data. If funding were available, continuation of telephone contact would be the most efficient and timely method to catalogue the balance of the university sector population.

Find Ways To Make CHP The Clear Choice For Institutions

Further information should be gathered to provide college and university facilities officers with a means to benchmark their systems against others on such factors such as efficiency, cost, reliability, and environmental impact. Outreach materials should be developed to assist in this regard. The case studies and champions developed herein will support outreach. Broader distribution and well-publicized links will increase awareness and stimulate more reporting from the sector.

Participation and membership in IDEA is increasing in the University Physical Plant category. The Annual IDEA College and University Conference brings together physical plant directors from across the country to share operational experiences. University personnel report a preference to interact with practitioners with real time experience in the design, construction, operation and optimization of CHP facilities. Fostering the participation in conferences focused on "users" of technology through sponsorships and promotional support would benefit institutional prospects.

Develop An Economic Analysis Of CHP

An understanding of the economics of the industry will help shed light on which incentives and policy decisions would have the most impact on CHP adoption. DOE is working to develop a financial-modeling tool to perform assessment of CHP potential for users and adopters. Screening tools to assess initial feasibility will help university staff perform preliminary assessments prior to investing time and funds in preliminary engineering, equipment selection and siting issues.

This will help the DOE and other government agencies to better understand what the most effective allocation of financial, human, and other resources would be to stimulate market penetration of CHP.

In the case of public, tax-exempt colleges and universities, a tax credit for CHP installation is perceived as having lower value than other forms of project financial support. Based on feedback from our survey respondents, capital availability is one of the major hurdles to implementation. A well-funded revolving fund might provide the initial capital support needed to reduce project risk and stimulate investment, with participants restoring the fund through operating cost savings once CHP facilities are operational.

Develop A Partnership Program To Accelerate Equipment Standardization

As noted earlier, the high cost and customized nature of siting and installation of new energy technologies hinders adoption and market growth. A partnership of government organizations and private associations and companies should be formed to create dialogue around this issue with the goal of standardizing and commercializing emerging technologies in order to spur CHP and district energy market growth. Colleges and universities, with existing district energy thermal networks and common ownership of property for generation, distribution and use, hold great potential for installation of CHP technologies. Developing standardized interconnections and modular systems will help to reduce project soft costs like engineering, specifications, controls packages, construction, and commissioning practices. With standardization and commercialization, economies of scale in production and installation will positively impact unit pricing, thereby enhancing market penetration.

A nation-wide pilot program, focused on specific CHP technologies at multiple university settings, with participants (industry, user, and engineering) in cost-sharing arrangements, with the charter to design and standardize packages (e.g. valve arrangements, pressure drops, control sequence, and sound attenuation standards) would help to reduce first costs and stimulate market participation.

Study CHP In Other Markets

In other regions, most notably Europe, CHP has higher market penetration than what is seen in the US. There may be some lessons to learn by studying those markets and understanding the underlying factors behind CHP adoption there.

Recently in Britain, deregulation and liberalization of the electric utility industry has actually negatively impacted CHP facility operations due to pricing signals and tariff requirements. However, the CHP industry has responded, and, with support from the federal government, is working to enact policy provisions that would more effectively reduce tariff costs and recognize the environmental advantages of CHP in emissions credits and market pricing.

APPENDIX I. – WEB-BASED SURVEY FORM

Help

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

IDEA/DOE College and University Survey

General Information

1 Please list your name and address in the form below:

Name:

Company:

Address:

City: State: Zip:

2 What college or university are you affiliated with?

3 Please provide the following information about your campus:

Total square footage of occupied buildings on campus (please enter number only):

Number of central plants you own, operate or control (If zero, please skip to question 26):

Total number of square feet of space served by your plant(s):

Number of buildings served:

4 Please list the year the system first commenced operations, and the dates of any major system additions/modifications since then.

Technical Specifications -- Heating

5 What is the total installed heating capacity of your plant (MMBTU/hr)?

6 Please describe your heating equipment in the following format: Brand, model, equipment type, capacity

7 What is the total amount of district heating pipe in your network and what is the breakdown between each of the following types (in linear feet)?

Total (supply plus return):
Steam pipe supply:
Condensate return:
Hot water supply:
Hot water return:

8 In linear feet, how much of the above total pipe is:

Welded steel:
Pre-insulated:
Direct buried:
Carrier pipe in a conduit:
Tunnels:

9 What is the largest diameter of pipe installed in your heating system (inches)?

10 What is the operating pressure (psig) of your heating system?

Technical Specifications -- Cooling

11 What is the total installed cooling capacity and what is the breakdown from each of the following sources (Tons)?

Total installed cooling capacity:
Electric chillers:
Low pressure steam absorption:
High pressure steam absorption:
Steam turbine drive:
Gas-fired chillers:
Chilled water thermal storage:
Ice thermal storage:
Other:

12 Please describe your cooling equipment in the following format: Brand, model, equipment type, capacity

13 What is the total amount of district cooling pipe in your network and what is the breakdown between each of the following types (in linear feet)?

Total (supply plus return):
Welded steel:
Pre-insulated:
Direct buried:
Ductile iron:
Tunnels:

14 What is the largest diameter of pipe installed in your cooling system (inches)?

15 What is the total volume (in gallons) of your chilled water system?

Technical Specifications – Electric Generation

16 If you currently generate or co-generate power, what is the total installed capacity (MW)?

17 Please describe your electrical equipment in the following format: Brand, model, equipment type, capacity

Operating Metrics

18 Please list the following heating system operating metrics for calendar year 2000:

Peak sendout level (MMBTU/hr):

Total annual volume of heating sendout (MMBTU/year):

19 Please list the following cooling system operating metrics for calendar year 2000:

Peak cooling demand on your plant (Tons per hr):

Total annual cooling volume (Ton-hours per yr):

20 If you generate power, please provide the following electrical metrics for calendar year 2000:

Peak generating level (MW):

Total electricity production for the year (MWh):

Peak electric demand (MW):

Total electricity purchased from external sources during the year (MWh):

21 What was your annual fuel consumption during calendar year 2000?

Gas (MCF):

Oil (Gallons):

Coal (Tons):

Steam (lbs):

Other (Please specify units):

22 How many employees (FTE's) are assigned to the utilities department?

Plant Operating:

Plant Maintenance:

Distribution Maintenance:

Total:

23 What was your budget for the year 2000?

Capital budget for utilities (Dollars):

Operating budget (Dollars):

24 On average, over the past three years, what percent of the time has the central plant met the system requirements of customers (percentage; e.g., 99.997 availability)?

25 What was your average fuel system efficiency (fuel in/metered energy sendout as a percentage) during calendar year 2000?

Expansion Plans

26 What is the likelihood you will make the following planned improvements to your system over the next three years?

	1 Not planned	2 Preliminary evaluation	3 Currently in design	4 Under construction	5 Commercial operation within 12 months
Expansion of distribution network	1	2	3	4	5
Adding electricity generation (combined heat and power)	1	2	3	4	5
Adding cooling capacity	1	2	3	4	5

Backup generation
1 2 3 4 5

Distributed generation – fuel cell
1 2 3 4 5

Distributed generation – micro turbine
1 2 3 4 5

Distributed generation – backup diesel generators
1 2 3 4 5

Distributed generation – back pressure turbine generators
1 2 3 4 5

Emissions compliance
1 2 3 4 5

In-building cooling, heating, and power
1 2 3 4 5

Plant efficiency upgrades
1 2 3 4 5

Controls enhancements
1 2 3 4 5

Building HVAC upgrades
1 2 3 4 5

Improved metering
1 2 3 4 5

Fuel switching
1 2 3 4 5

27 What are the biggest challenges to your current expansion plans?

1 Not an issue	2 Small concern	3 Major concern	4 Barrier to progress

Capital constraints
1 2 3 4

Convincing decision makers of economic benefits
1 2 3 4

Complexity of implementation
1 2 3 4

Air emissions restrictions
1 2 3 4

Space constraints
1 2 3 4

Fuel price uncertainty
1 2 3 4

Current life remaining in existing equipment

1 2 3 4

Regulatory uncertainty

1 2 3 4

Lack of clear technology choices

1 2 3 4

Lack of clear utility interconnection standards

1 2 3 4

Utility counteroffers (backup rates, exit fees, or negotiated programs and discounts)

1 2 3 4

28 What could the DOE or other government agencies do to make it easier for you to implement district energy and combined heat and power solutions?

29 Please rank each of the following services or support in order of how helpful it would be in implementing cooling, heating and power projects on campus. The most helpful one should be checked under column number one, followed by the second most helpful, checked under column two, and so on.

	1 Most Helpful	2	3	4	5	6	7	8 Least Helpful
DOE-sponsored task force of respected experts	1	2	3	4	5	6	7	8
Matching funds for construction	1	2	3	4	5	6	7	8
Government-sponsored revolving fund	1	2	3	4	5	6	7	8
Feasibility study funding	1	2	3	4	5	6	7	8
Clear national utility interconnection standards	1	2	3	4	5	6	7	8
Net metering	1	2	3	4	5	6	7	8
Tax credits for cooling, heating, and power investments by private firms	1	2	3	4	5	6	7	8
Tradeable tax credits for public institutions	1	2	3	4	5	6	7	8

If government-funded sources of capital were available for capital

30 improvements to district energy systems, would you seek out those sources?

YES NO

Thank you for your time. Your participation in our survey is appreciated. Please click the Submit button below to turn in your responses.

After answering all the questions, click the "submit" arrow below to complete the survey.

SUBMIT

POWERED BY zoomerang

APPENDIX II. – CENSUS SURVEY FORM

Organization Name:			
Your Name:			
And your title is?			
CENTRAL PLANT TOPICS			
Do you have a central plant for heating and cooling the campus?		☐ Y	☐ N
What is the total installed heating capacity?	pounds per hour	MMBtu's per hour	
What types of boilers are operating?			
Type Ex.: Water Tube	Brand Ex: Babcock & Wilcox	Capacity Ex: 60K lbs/hr	Quantity Ex: Two (2)
What is the primary fuel?			
Natural Gas	Oil	Coal	Other
☐	☐	☐	☐
How much fuel you purchase each year, in dollars?	$		
What percentage of building square footage used by the university is served with heating by your central plant(s)? %			
Approximately, what percentage of the university's heating energy demand does the central plant(s) meet?	%		
CHILLED WATER TOPICS			
Do you have a central chilled water system?		☐ Y	☐ N
What is the total installed capacity, in tons?	tons		
Is that in one single plant facility or in multiple locations?	☐ Single	☐ Multiple	
Can you describe the chilled water system?			
Brand Ex.: Carrier	Type Ex.: Electric	Capacity Ex.: 5,000 tons	Quantity Ex.: Three (3)
If you have any stand-alone building chillers, please provide:	# of chillers	total capacity	
Do you have any thermal storage in the capacity mix?		☐ Y	☐ N
If so, is it chilled water or ice storage?	☐ Chilled Water	☐ Ice Storage	
	Brand	Brand	
	Type	Type	
	Volume (gallons storage)	Volume (ton hours)	
What percentage of building square footage used by the university is served with cooling by your central plant(s)? %			
Approximately, what percentage of the university's cooling energy demand does the central plant(s) meet?	%		

COGENERATION TOPICS		
Do you generate or co-generate electricity on campus?	☐ Generate	☐ Cogenerate
What is the total installed capacity (in megawatts)?		MW
Briefly describe the generation system (i.e., gas turbine, steam turbine, etc.)		
Brand	Type	Capacity (MW)
What year did electric generation operations commence?		
Approximately, what percentage of the university's electrical energy demand does the central plant(s) meet?		%

DISTRIBUTION SYSTEMS			
HEAT RELATED QUESTIONS			
Approximately how many total linear feet of heating pipe (**supply & return**) are installed on campus?			
% Direct Buried		% Tunnels/Vaults	
Is the heating by hot water or steam?	☐ Hot Water		☐ Steam
If steam distribution, is it steam supply only or is there a condensate return system?		☐ Steam Supply Only	☐ Condensate Return System
COOLING QUESTIONS			
Approximately how many linear feet of district cooling pipe (**supply & return**) are installed on campus?			
% Direct Buried	% Tunnels/Vaults		
Have you added much piping recently?		☐ Y	☐ N
Do you have any additional comments on your distribution system?			

EXPANSION RELATED QUESTIONS			
What year did your central plant operations begin?			
What is the total square footage of building space used by the university?		sq. ft.	
When was the last expansion or installation of new equipment?			
Do you have plans to expand your central plant or distribution system?		☐ Y	☐ N
Type of Project	Capacity	Planning Stage	
		☐ Currently Planning	☐ Under Construction
		☐ Currently Planning	☐ Under Construction
		☐ Currently Planning	☐ Under Construction
Do you have any unique system characteristics or performance information or are there any "Lessons Learned" in operating or expanding your campus energy system that you would like to share?			

Thank you for your assistance. You may fax this form back to IDEA at 508-366-0019. If you have any questions or comments, feel free to call us at 508-366-9339. Again, thank you.

APPENDIX III. – CENSUS DETAIL DATA TABLES

Detailed information from the census is presented here in tabular format. Results are for institutions that reported data for their central plants. The information is split into tables as follows:

Table 1: Longevity of Central Plant Operations
This table lists the year central plant operations commenced and the year of the last major expansion for each institution.

Table 2: Heating System Data
This table contains information on the number of heating plants, total installed heating capacity, primary fuel, annual fuel expenditures, total linear feet of heating pipe, heat distribution method, presence of condensate return piping, heating pipe construction, and the percentage of heating energy requirements met for each institution.

Table 3: Heating Equipment Detail
The table contains information on boiler types, fuel source, boiler size, and number of boilers for institutions reporting heating equipment data.

Table 4: Cooling System Data
This table contains information on the number of cooling plants, total installed cooling capacity, thermal storage method, total linear feet of cooling pipe, cooling pipe construction, and the percentage of cooling energy requirements met for each institution.

Table 5: Cooling Equipment Detail
The table contains information on chiller types, chiller size, and number of chillers for institutions reporting cooling equipment data.

Table 6: Electricity Generation Data
This table contains information on installed capacity, year electric generation commenced, and the percentage of campus electrical load served.

Table 7: Electricity Generation Equipment Detail
The table contains information on generation equipment type, size, and quantity.

Table 8: Expansion Projects in Planning Stage – Heating
This table notes the timing, capacity amount, and notes for heating-related expansions that are still in the planning stage.

Table 9: Expansion Projects in Planning Stage – Cooling
This table notes the timing, capacity amount, and notes for cooling-related expansions that are still in the planning stage.

Table 10: Expansion Projects in Planning Stage – Electricity Generation
This table notes the timing, capacity amount, and notes for generation-related expansions that are still in the planning stage.

Table 11: Expansion Projects in Construction Stage – Heating
This table notes the timing, capacity amount, and notes for heating-related expansions that are under construction.

Table 12: Expansion Projects in Construction Stage – Cooling
This table notes the timing, capacity amount, and notes for cooling-related expansions that are under construction.

Table 13: Expansion Projects in Construction Stage – Electricity Generation
This table notes the timing, capacity amount, and notes for generation-related expansions that are under construction.

Table 1: Longevity of Central Plant Operations

University	Year Central Plant Operations Commenced	Year of Last Major Expansion
Arizona State University West Campus	1988	1990
Bates College	1997	1997
Bowling Green State University	1999	1999
Brigham Young University	1947	1990
Bucknell University	Early 1900's	2001
Butler University	1997	1997
California Polytechnic State University	1920's	1997
California State University, Northridge	1998	1998
Central Michigan University	1920's	1993
Central Washington University	1975	1999
Clemson University	1950	2001
Cleveland State University	1972	2000
Colby College	1993	2001
College of New Jersey	Early 1900's	1998
College of William and Mary	1952	1991
College of Wooster	N/A	1992
Columbia University	N/A	2000
Connecticut College	1911	1971
Cornell University	1922	2000
Dartmouth University	1898	1996
Denison University	1957	1994
Drake University	1908	1991
Duke University	1929	2000
Duquesne University	N/A	1997
Emory University	N/A	N/A
Georgetown University	1970	1997
Georgia Institute of Technology	N/A	N/A
Goshen College	1904	1991
Harding University	1950	1998
Harvard University	1970	1998
Howard University	1934	1998
Idaho State University	N/A	N/A
Illinois Central College	1974	1988
Illinois Institute of Technology	N/A	N/A
Indiana University – Bloomington	1885	1995
Iowa State University	1884	1999
James Madison University	1997	1997
Johns Hopkins University	1915	2001
Kalamazoo College	1996	1996
Kansas State University	1928	1999
Keane State College	1964	1987
Kutztown University	1948	2000
Lamar University	1970's	N/A
Macallister University	1953	2001
Mansfield University	1800's	2000
Massachusetts Institute of Technology	N/A	1995
Massachusetts Maritime Academy	1970	1995
Medical College of Ohio	1964	2001
Michigan State University	1965	1993
Middle Tennessee State University	1966	1998
Middlebury College	1920's	1999
Minnesota State University at Moorhead	N/A	1995
Montana State University	1922	1995
Mount Holyoke College	1898	2001

University	Year Central Plant Operations Commenced	Year of Last Major Expansion
Northeastern Illinois University	1960's	2001
Occidental College	N/A	N/A
Ohio State University	1918	2001
Oklahoma State University	Early 1980's	2000
Pennsylvania State University	1929	2000
Phoenix College	1938	1995
Pittsburgh State University	1903	1999
Pomona College	N/A	N/A
Purdue University	Early 1900's	1995
Reed College	1913	2000
Rhode Island College	1958	1998
Rhode Island School of Design	1950's	2001
Rochester Institute of Technology	1969	1993
Saint Joseph's College	1921	1983
Saint Joseph's University	1968	2001
San Diego State University	N/A	N/A
San Jose State University	N/A	N/A
Slippery Rock University	N/A	2000
Southern Methodist University	1927	2000
Southern Oregon University	1969	2000
St. Mary's College	1940's	2001
Stanford University	N/A	1999
State University of New York at Potsdam	1953	1967
State University of New York at Stony Brook	1968	2001
Swarthmore College	1911	1995
Syracuse University	1926	1995
Texas A&M University	Pre-1900	N/A
Texas Tech University	1962	2001
Thunderbird, The American Graduate School of International Management	1990	1997
University of Alaska -- Fairbanks	1930's	2000
University of Arkansas	1956	1995
University of California, Berkeley	1904	1986
University of California, Los Angeles	N/A	1994
University of California, Riverside	Mid-1940's	2000
University of California, San Francisco	1960's	2001
University of Central Arkansas	1997	2001
University of Colorado at Boulder	1909	N/A
University of Delaware	1938	1999
University of Evansville	1948	1997
University of Florida	N/A	2001
University of Georgia	1970	2001
University of Idaho	1908	2001
University of Illinois East Campus	1963	2000
University of Iowa	Early 1900's	N/A
University of Louisville	1979	1998
University of Maryland at College Park	1945	2001
University of Massachusetts Amherst	N/A	N/A
University of Memphis	Mid-1960's	2000
University of Miami	1960's	1996
University of Michigan	Late 1800's	N/A
University of Minnesota Duluth	1999	1999
University of Minnesota Minneapolis	1980's	N/A
University of Minnesota St. Paul	N/A	N/A
University of Missouri - Columbia	1892	2001
University of Missouri - Kansas City	1960's	2000

University	Year Central Plant Operations Commenced	Year of Last Major Expansion
University of New Hampshire	1930	2001
University of New Mexico	1897	1985
University of North Carolina at Chapel Hill	1920's	1992
University of Northern Colorado	Mid-1940's	1999
University of Northern Iowa	1883	1989
University of Pennsylvania	Mid-1970's	1999
University of Pittsburgh	1907	2001
University of Rochester	1924	1999
University of South Dakota	1920's	2001
University of Texas at Austin	1910	1988
University of Texas at El Paso	Late 1960's	1999
University of Virginia	1950	2001
University of Washington	1898	2001
University of Wisconsin at Madison	Early 1900's	2000
University of Wisconsin at Milwaukee	N/A	2001
University of Wisconsin at Stout	1965	1973
Virginia Polytechnic Institute and State University	1936	1998
Wellesley College	Early 1980's	1996
Western Michigan University	1924	1992
Williams College	1902	2001
Yale University	1917	2001

Table 2: Heating System Data

University	Heating System Data									
	# of Heating Plants	Total Capacity (lbs/hr)	Primary Fuel	Annual Fuel Expenditures	Total Linear Feet of Heating Pipe (Supply and Return)	Heat Distribution Method	If Heat Distribution Method Is Steam, Is There Condensate Return?	Heating Pipe Construction		% of Campus Energy Requirements Met by Central Plant(s)
								% Direct Buried	% Tunnels/ Vaults	
Arizona State University West Campus	1	15,000	Natural Gas	$ 30,000	N/A	N/A	N/A	N/A	N/A	N/A
Bates College	1	75,000	Oil/Natural Gas	$ 600,000	N/A	Hot Water & Steam	Yes	N/A	N/A	30%
Bowling Green State University	1	255,000	Natural Gas	N/A	24,000	Steam	Yes	0%	100%	97%
Brigham Young University	1	550,000	Natural Gas	$ 1,600,000	18,975	Hot Water & Steam	Yes	55%	45%	75%
Bucknell University	1	210,000	Natural Gas	$ 2,000,000	20,000	Steam	Yes	70%	30%	95%
Butler University	1	61,000	Natural Gas	$ 450,000	N/A	Hot Water & Steam	Yes	100%	0%	90%
California Polytechnic State University	1	60,000	Natural Gas	$ 1,900,000	24,000	Hot Water	N/A	50%	50%	85%
California State University, Northridge	1	50,200	Natural Gas	N/A	20,800	Hot Water	N/A	100%	0%	65%
Central Michigan University	1	300,000	Natural Gas	N/A	31,700	Steam	Yes	0%	100%	75%
Central Washington University	1	210,000	Natural Gas	$ 1,300,000	53,000	Steam	Yes	20%	80%	90%
Clemson University	1	225,000	Coal/Natural Gas	$ 1,600,000	30,000	Steam	Yes	90%	10%	90%
Cleveland State University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Colby College	1	90,000	Oil	$ 500,000	18,000	Steam	Yes	100%	0%	95%
College of New Jersey	1	120,000	Natural Gas	$ 1,200,000	13,200	Steam	Yes	100%	0%	85%
College of William and Mary	1	160,000	Natural Gas	N/A	14,300	Hot Water & Steam	Yes	N/A	N/A	37%
College of Wooster	1	40,000	Coal	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Columbia University	1	400,000	Oil/Natural Gas	$ 4,400,000	43,000	Steam	Yes	N/A	N/A	97%
Connecticut College	1	92,000	Oil	$ 385,000	8,895	Steam	Yes	N/A	N/A	87%
Cornell University	N/A	600,000	Coal	$ 3,760,000	136,200	Hot Water & Steam	Yes	30%	70%	100%
Dartmouth University	1	175,000	Oil	$ 2,500,000	26,400	Steam	Yes	10%	90%	95%
Denison University	1	13,700	Coal	$ 300,000	21,000	Steam	Yes	95%	5%	85%
Drake University	2	67,200	Natural Gas	$ 650,000	8,000	Hot Water & Steam	Yes	90%	10%	70%
Duke University	1	472,000	Coal	$ 1,800,000	95,040	Steam	Yes	67%	33%	N/A
Duquesne University	1	115,000	Natural Gas	$ 2,300,000	N/A	N/A	N/A	N/A	N/A	90%
Emory University	1	400,000	Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Georgetown University	1	300,000	Oil/Natural Gas	$ 3,000,000	20,000	Steam	Yes	60%	40%	75%
Georgia Institute of Technology	2	160,000	Natural Gas	N/A	N/A	Steam	Yes	N/A	N/A	N/A
Goshen College	1	22,400	Natural Gas	$ 250,000	5,000	Steam	Yes	N/A	N/A	80%
Harding University	1	20,000	Natural Gas	$ 300,000	10,000	Hot Water	N/A	30%	70%	80%
Harvard University	N/A	N/A	N/A	N/A	60,000	Steam	Yes	100%	0%	70%
Howard University	1	350,000	Natural Gas	N/A	15,000	Steam	N/A	N/A	N/A	90%
Idaho State University	1	70,000	Natural Gas	N/A	6,000	Steam	Yes	20%	80%	75%
Illinois Central College	1	N/A	Natural Gas	$ 235,000	2,000	Steam	Yes	N/A	N/A	50%
Illinois Institute of Technology	N/A	276,000	Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Indiana University -- Bloomington	1	588,000	Coal	$ 5,000,000	100,000	Steam	Yes	67%	33%	50%
Iowa State University	1	1,000,000	Coal	$ 7,000,000	98,000	Steam	Yes	28%	72%	98%
James Madison University	2	180,000	Natural Gas	$ 825,000	20,000	Steam	Yes	50%	50%	50%
Johns Hopkins University	1	270,000	Natural Gas	$ 1,500,000	N/A	Steam	Yes	25%	75%	80%
Kalamazoo College	1	33,600	Natural Gas	$ 250,000	8,000	Steam	Yes	75%	25%	95%
Kansas State University	1	305,000	Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Keane State College	1	42,000	Oil	$ 1,000,000	13,000	Steam	Yes	N/A	N/A	75%
Kutztown University	1	135,000	Coal	N/A	10,000	Steam	Yes	99%	1%	98%
Lamar University	1	N/A	Natural Gas	$ 900,000	N/A	Hot Water & Steam	N/A	0%	100%	75%
Macalister University	1	102,000	Natural Gas	$ 270,000	8,000	Steam	Yes	7%	93%	80%
Mansfield University	1	7,000	Natural Gas	$ 600,000	N/A	N/A	N/A	100%	0%	98%
Massachusetts Institute of Technology	1	250,000	Natural Gas	N/A	132,000	Steam	N/A	N/A	N/A	100%

Heating System Data

University	# of Heating Plants	Total Capacity (lbs/hr)	Primary Fuel	Annual Fuel Expenditures	Total Linear Feet of Heating Pipe (Supply and Return)	Heat Distribution Method	If Heat Distribution Method Is Steam, Is There Condensate Return?	Heating Pipe Construction: % Direct Buried	Heating Pipe Construction: % Tunnels/ Vaults	% of Campus Energy Requirements Met by Central Plant(s)
Massachusetts Maritime Academy	1	85,000	Oil	$ 200,000	7,500	Hot Water	N/A	97%	3%	90%
Medical College of Ohio	1	250,000	Coal	$ 600,000	55,000	Steam	Yes	0%	100%	100%
Michigan State University	1	1,200,000	Coal	$ 12,000,000	197,000	Steam	Yes	100%	0%	82%
Middle Tennessee State University	1	150,000	Natural Gas	$ 2,800,000	21,000	Steam	Yes	0%	100%	90%
Middlebury College	1	112,000	Oil	$ 1,500,000	50,000	Steam	Yes	25%	75%	100%
Minnesota State University at Moorhead	1	182,500	Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Montana State University	1	250,000	Natural Gas	$ 1,380,000	21,000	Steam	Yes	24%	76%	78%
Mount Holyoke College	1	100,000	Oil	N/A	10,000	Steam	Yes	10%	90%	95%
Northeastern Illinois University	1	45,000	Natural Gas	N/A	N/A	Hot Water	N/A	5%	95%	80%
Occidental College	1	9,700	Natural Gas	$ 280,000	N/A	Steam	N/A	N/A	N/A	N/A
Ohio State University	1	690,000	Natural Gas	$ 8,125,000	94,512	Hot Water & Steam	Yes	N/A	N/A	N/A
Oklahoma State University	1	345,000	Natural Gas	$ 4,650,000	53,000	Steam	Yes	5%	95%	90%
Pennsylvania State University	2	600,000	Coal	$ 2,800,000	130,000	Steam	Yes	60%	40%	85%
Phoenix College	1	16,740	Natural Gas	$ 140,000	N/A	Hot Water	N/A	N/A	N/A	99%
Pittsburgh State University	1	47,000	Natural Gas	$ 2,000,000	32,000	Steam	Yes	10%	90%	90%
Pomona College	N/A	N/A	N/A	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Purdue University	1	540,000	Coal/Natural Gas	$ 4,500,000	63,000	Steam	Yes	30%	70%	90%
Reed College	1	28,000	Natural Gas	$ 400,000	N/A	Steam	Yes	N/A	N/A	95%
Rhode Island College	1	81,500	Natural Gas	$ 930,000	16,000	Steam	Yes	100%	0%	80%
Rhode Island School of Design	1	64,000	Oil	$ 250,000	N/A	Steam	No	N/A	N/A	80%
Rochester Institute of Technology	3	264,000	Natural Gas	$ 2,400,000	N/A	Hot Water	N/A	0%	100%	70%
Saint Joseph's College	1	95,600	Coal	$ 164,000	N/A	Steam	Yes	N/A	N/A	96%
Saint Joseph's University	1	48,000	Oil	$ 500,000	3,000	Steam	Yes	100%	0%	75%
San Diego State University	1	118,000	Natural Gas	$ 3,600,000	20,000	Steam	Yes	N/A	N/A	N/A
San Jose State University	N/A	N/A	Natural Gas	$ 2,000,000	N/A	N/A	N/A	N/A	N/A	N/A
Slippery Rock University	1	77,000	Coal/Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Southern Methodist University	1	190,000	Natural Gas	$ 800,000	18,000	Steam	Yes	15%	85%	88%
Southern Oregon University	1	50,400	Natural Gas	$ 250,000	7,200	Steam	Yes	5%	95%	75%
St. Mary's College	1	170,000	Coal	$ 500,000	20,000	Steam	Yes	0%	100%	95%
Stanford University	1	720,000	Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
State University of New York at Potsdam	1	120,000	Natural Gas	$ 900,000	10,000	Steam	Yes	0%	100%	96%
State University of New York at Stony Brook	1	700,000	Natural Gas	$ 400,000	N/A	Hot Water	N/A	25%	75%	90%
Swarthmore College	1	65,000	Natural Gas	$ 400,000	12,000	Steam	Yes	90%	10%	75%
Syracuse University	1	500,000	Natural Gas	N/A	37,000	Steam	Yes	95%	5%	N/A
Texas A&M University	1	750,000	Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Texas Tech University	2	580,000	Natural Gas	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thunderbird, The American Graduate School of International Management	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Alaska -- Fairbanks	1	180,000	Coal	$ 3,200,000	105,000	Steam	Yes	0%	100%	100%
University of Arkansas	2	300,000	Natural Gas	$ 1,900,000	10,000	Steam	Yes	5%	95%	100%
University of California, Berkeley	1	426,000	Natural Gas	$ 7,800,000	85,000	Steam	Yes	N/A	N/A	70%
University of California, Los Angeles	1	234,000	Landfill Gas/Natural Gas	N/A	N/A	Steam	Yes	N/A	N/A	N/A
University of California, Riverside	1	140,000	Natural Gas	$ 7,300,000	32,000	Steam	Yes	5%	95%	90%
University of California, San Francisco	1	288,000	Natural Gas	$ 3,500,000	N/A	Steam	Yes	99%	1%	100%
University of Central Arkansas	1	6,000	Natural Gas	$ 90,000	2,100	Hot Water	N/A	100%	0%	19%
University of Colorado at Boulder	1	160,000	Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
University of Delaware	3	3,300,000	Natural Gas	$ 4,500,000	20,000	Steam	Yes	67%	33%	75%
University of Evansville	1	100,000	Natural Gas	N/A	N/A	N/A	N/A	20%	80%	90%
University of Florida	N/A	N/A	Natural Gas	N/A	N/A	Hot Water & Steam	Yes	95%	5%	95%

Heating System Data

University	# of Heating Plants	Total Capacity (lbs/hr)	Primary Fuel	Annual Fuel Expenditures	Total Linear Feet of Heating Pipe (Supply and Return)	Heat Distribution Method	If Heat Distribution Method Is Steam, Is There Condensate Return?	Heating Pipe Construction: % Direct Buried	Heating Pipe Construction: % Tunnels/ Vaults	% of Campus Energy Requirements Met by Central Plant(s)
University of Georgia	1	483,400	Oil	$ 2,734,000	70,255	Steam	Yes	4%	96%	30%
University of Idaho	1	161,000	Wood	$ 720,000	20,000	Steam	Yes	10%	90%	85%
University of Illinois East Campus	1	320,000	Natural Gas	$ 3,800,000	16,000	Hot Water	N/A	10%	90%	90%
University of Iowa	N/A	500,000	N/A	N/A	139,000	Steam	Yes	80%	20%	85%
University of Louisville	1	206,000	Coal	$ 325,000	16,000	Steam	Yes	5%	95%	75%
University of Maryland at College Park	7	546,000	N/A	N/A	N/A	N/A	N/A	95%	5%	45%
University of Massachusetts Amherst	1	560,000	Natural Gas	N/A	132,000	Steam	N/A	N/A	N/A	100%
University of Memphis	1	240,000	Natural Gas	$ 500,000	32,000	Steam	Yes	100%	0%	85%
University of Miami	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Michigan	1	1,195,000	Natural Gas	$ 10,685,000	95,000	Steam	Yes	0%	100%	N/A
University of Minnesota Duluth	1	200,000	Natural Gas	$ 750,000	20,000	Hot Water & Steam	Yes	0%	100%	80%
University of Minnesota Minneapolis	1	900,000	Natural Gas	$ 9,000,000	105,000	Steam	Yes	1%	99%	95%
University of Minnesota St. Paul	1	500,000	Natural Gas	$ 2,000,000	21,000	Steam	Yes	5%	95%	95%
University of Missouri - Columbia	1	994,000	Coal	$ 9,650,000	120,000	Steam	Yes	92%	8%	100%
University of Missouri - Kansas City	3	89,600	Natural Gas	N/A	N/A	Steam	N/A	100%	0%	50%
University of New Hampshire	1	125,000	Oil	$ 800,000	8,000	Hot Water & Steam	Yes	10%	90%	60%
University of New Mexico	1	385,000	Natural Gas	$ 3,000,000	61,000	Steam	Yes	20%	80%	85%
University of North Carolina at Chapel Hill	1	650,000	Coal	$ 5,400,000	245,000	Hot Water & Steam	Yes	4%	96%	100%
University of Northern Colorado	None	N/A	N/A	N/A	106,000	Hot Water	N/A	5%	95%	90%
University of Northern Iowa	1	345,000	Coal	$ 1,200,000	47,000	Steam	Yes	N/A	N/A	90%
University of Pennsylvania	None	N/A	N/A	N/A	37,000	Steam	N/A	100%	0%	100%
University of Pittsburgh	1	760,000	Coal/Natural Gas	$ 5,300,000	16,000	Steam	Yes	5%	95%	95%
University of Rochester	1	500,000	Oil/Natural Gas	$ 5,900,000	50,000	Steam	Yes	60%	40%	100%
University of South Dakota	1	100,000	Natural Gas	N/A	10,000	Steam	Yes	10%	90%	90%
University of Texas at Austin	1	1,146,000	Natural Gas	$ 18,683,000	81,316	Steam	Yes	8%	92%	97%
University of Texas at El Paso	2	54,000	Natural Gas	$ 400,000	10,000	Hot Water	N/A	0%	100%	85%
University of Virginia	N/A	402,000	Coal/Natural Gas	$ 1,900,000	130,770	Hot Water & Steam	Yes	0%	100%	50%
University of Washington	1	770,000	Natural Gas	$ 10,000,000	150,000	Steam	Yes	10%	90%	75%
University of Wisconsin at Madison	2	1,100,000	Coal	N/A	N/A	Steam	Yes	N/A	N/A	100%
University of Wisconsin at Milwaukee	1	420,000	Natural Gas	$ 2,500,000	16,000	Steam	Yes	10%	90%	100%
University of Wisconsin at Stout	1	205,000	Coal	$ 1,000,000	21,000	Steam	Yes	0%	100%	100%
Virginia Polytechnic Institute and State University	1	416,000	Coal	$ 2,750,000	106,000	Steam	Yes	0%	100%	90%
Wellesley College	1	160,000	Natural Gas	$ 3,000,000	26,000	Steam	Yes	20%	80%	100%
Western Michigan University	1	580,000	Natural Gas	N/A	N/A	Steam	N/A	N/A	N/A	N/A
Williams College	1	196,000	Oil/Natural Gas	$ 1,100,000	21,000	Steam	Yes	N/A	N/A	90%
Yale University	2	640,000	Oil/Natural Gas	N/A	26,000	Steam	Yes	5%	95%	97%
Sum (of institutions reporting data)		39,092,540		$ 234,261,000	4,199,163					

Table 3: Heating Equipment Detail

University	Boiler Type	Fuel	Size	Quantity
Bates College	Cleaver-Brooks firetube	Natural Gas/Oil	25,000 lbs/hr	3
	Total		*75,000 lbs/hr*	*3*
Bowling Green State University	Nebraska watertube	Natural Gas	85,000 lbs/hr	3
	Total		*255,000 lbs/hr*	*3*
Brigham Young University	Babcock & Wilcox hot water boiler	Coal	100,000 lbs/hr	1
	IBW International Lamont	Coal	50,000 lbs/hr	2
	IBW Volcano hot water boiler	Oil/Natural Gas	150,000 lbs/hr	2
	IBW Volcano hot water boiler	Oil/Natural Gas	50,000 lbs/hr	1
	Total		*550,000 lbs/hr*	*6*
Bucknell University	ERI	Natural Gas	70,000 lbs/hr	1
	Indek	Natural Gas	70,000 lbs/hr	1
	Tampella	Natural Gas	70,000 lbs/hr	1
	Total		*210,000 lbs/hr*	*3*
Butler University	Cleaver-Brooks watertube	Natural Gas	39,000 lbs/hr	1
	Keeler watertube	Natural Gas	22,000 lbs/hr	1
	Total		*61,000 lbs/hr*	*2*
California Polytechnic State University	Cleaver-Brooks	Natural Gas	20,000 lbs/hr	3
	Total		*60,000 lbs/hr*	*3*
	International PowerFlame vector watertube	Natural Gas	25,100 lbs/hr	2
	Total		*50,200 lbs/hr*	*2*
Central Michigan University	Nebraska	Wood Chip	50,000 lbs/hr	1
	Wickes	Natural Gas	75,000 lbs/hr	2
	Deltek	Natural Gas	100,000 lbs/hr	1
	Total		*225,000 lbs/hr*	*4*
Central Washington University	Cleaver-Brooks watertube	Natural Gas	60,000 lbs/hr	3
	Cleaver-Brooks firetube	Natural Gas	30,000 lbs/hr	1
	Total		*210,000 lbs/hr*	*4*
Clemson University	ERI watertube HRSG	Waste Heat	75,000 lbs/hr	1
	Cleaver-Brooks watertube	Natural Gas	75,000 lbs/hr	1
	Union Iron Works watertube	Coal	75,000 lbs/hr	1
	Total		*225,000 lbs/hr*	*3*
Colby College	Babcock & Wilcox watertube	#6 Fuel Oil	30,000 lbs/hr	3
	Total		*90,000 lbs/hr*	*3*
College of New Jersey	HRSG in conjunction with co-generation	Waste Heat	43,000 lbs/hr	1
	Superior	Natural Gas	40,000 lbs/hr	2
	Cleaver-Brooks	Natural Gas	40,000 lbs/hr	1
	Superior	Natural Gas	22,000 lbs/hr	1
	Total		*185,000 lbs/hr*	*5*
College of William and Mary	Cleaver-Brooks watertube	Natural Gas	40,000 lbs/hr	1
	Babcock & Wilcox watertube	Natural Gas	60,000 lbs/hr	1
	Keeler watertube	Natural Gas	60,000 lbs/hr	1
	Total		*160,000 lbs/hr*	*3*
College of Wooster	N/A	Coal	40,000 lbs/hr	1
	Total		*40,000 lbs/hr*	*1*
Columbia University	Babcock & Wilcox watertube	Oil/Natural Gas	100,000 lbs/hr	4
	Total		*400,000 lbs/hr*	*4*
Connecticut College	Union Iron Works watertube	Oil	24,000 lbs/hr	1
	Combustion Engineering watertube	Oil	34,000 lbs/hr	2
	Total		*92,000 lbs/hr*	*3*
Dartmouth University	Zurn watertube	#6 Fuel Oil	90,000 lbs/hr	1
	Babcock & Wilcox watertube	#6 Fuel Oil	30,000 lbs/hr	1
	Nebraska watertube	#6 Fuel Oil	75,000 lbs/hr	1
	Combustion Engineering	#6 Fuel Oil	70,000 lbs/hr	1
	Total		*175,000 lbs/hr*	*4*
Denison University	Babcock & Wilcox	Coal	5,900 lbs/hr	1
	Union Iron Works	Natural Gas	2,500 lbs/hr	1
	Cleaver-Brooks	Natural Gas	5,300 lbs/hr	1
	Total		*13,700 lbs/hr*	*3*
Drake University	Cleaver-Brooks	Natural Gas	16,800 lbs/hr	4
	Total		*67,200 lbs/hr*	*4*
Duke University	Babcock & Wilcox watertube	Coal	100,000 lbs/hr	?
	Babcock & Wilcox watertube	Coal	86,000 lbs/hr	2
	Nadasko watertube	Coal	50,000 lbs/hr	?

University	Boiler Type	Fuel	Size	Quantity
	Total		*472,000 lbs/hr*	*7*
Duquesne University	Cleaver-Brooks firetube	Natural Gas	30,000 lbs/hr	3
	Waste heat boiler from co-generation	Waste Heat	25,000 lbs/hr	1
	Total		*115,000 lbs/hr*	*4*
Emory University	Foster Wheeler	Natural Gas	100,000 lbs/hr	2
	Babcock & Wilcox	Natural Gas	100,000 lbs/hr	2
	Total		*400,000 lbs/hr*	*4*
Georgetown University	Keystone watertube type O	Oil/Natural Gas	100,000 lbs/hr	3
	Total		*300,000 lbs/hr*	*3*
Georgia Institute of Technology	N/A	Natural Gas	50,000 lbs/hr	2
	N/A	Natural Gas	60,000 lbs/hr	1
	Total		*690,000 lbs/hr*	*3*
Goshen College	Kiwani low pressure steam	Natural Gas	11,200 lbs/hr	2
	Total		*22,400 lbs/hr*	*2*
Harding University	Parker watertube	Natural Gas	2,000 lbs/hr	10
	Total		*20,000 lbs/hr*	*10*
Howard University	English watertube	Natural Gas	115,000 lbs/hr	2
	Babcock & Wilcox watertube	Natural Gas	125,000 lbs/hr	1
	Total		*350,000 lbs/hr*	*3*
Idaho State University	Watertube	Coal/Natural Gas	25,000 lbs/hr	2
	Watertube	Natural Gas	20,000 lbs/hr	1
	Total		*70,000 lbs/hr*	*3*
Illinois Central College	Kiwani low pressure steam	Natural Gas	N/A	3
	Heat recovery boiler attached to co-generation	Waste Heat	N/A	1
	Total		*N/A*	*4*
Illinois Institute of Technology	Heat recovery boiler attached to co-generation	Waste Heat	68,000 lbs/hr	2
	N/A	Natural Gas	46,600 lbs/hr	3
	Total		*276,000 lbs/hr*	*5*
Indiana University -- Bloomington	Lasker	Coal	64,000 lbs/hr	2
	Erie City spreader stoker	Coal	80,000 lbs/hr	2
	Union Iron Works gas/oil co-firing spreader stoker	Natural Gas	150,000 lbs/hr	2
	Total		*588,000 lbs/hr*	*6*
Iowa State University	Reilly chain grate	Coal	100,000 lbs/hr	2
	Reilly chain grate	Coal	150,000 lbs/hr	1
	Reilly stoker	Coal	160,000 lbs/hr	1
	Reilly stoker	Coal	150,000 lbs/hr	1
	Pyro Power fluidized bed	Coal	170,000 lbs/hr	2
	Total		*1,000,000 lbs/hr*	*7*
James Madison University	Watertube	Natural Gas	25,000 lbs/hr	2
	Watertube	Natural Gas	40,000 lbs/hr	1
	Watertube	Natural Gas	35,000 lbs/hr	2
	N/A	Trash	10,000 lbs/hr	2
	Total		*180,000 lbs/hr*	*7*
Johns Hopkins University	Keeler watertube	Natural Gas	80,000 lbs/hr	1
	Babcock & Wilcox	Natural Gas	63,000 lbs/hr	3
	Total		*270,000 lbs/hr*	*4*
Kalamazoo College	Cleaver-Brooks firetube	Natural Gas	4,200 lbs/hr	4
	Cleaver-Brooks firetube	Natural Gas	7,000 lbs/hr	1
	Cleaver-Brooks firetube	Natural Gas	8,400 lbs/hr	1
	Total		*33,600 lbs/hr*	*6*
Kansas State University	N/A	Natural Gas	60,000 lbs/hr	1
	N/A	Natural Gas	50,000 lbs/hr	1
	N/A	Natural Gas	60,000 lbs/hr	1
	N/A	Natural Gas	60,000 lbs/hr	1
	N/A	Natural Gas	75,000 lbs/hr	1
	Total		*305,000 lbs/hr*	*5*
Keane State College	Cleaver-Brooks firetube	#6 Fuel Oil	16,800 lbs/hr	2
	Cleaver-Brooks firetube	#6 Fuel Oil	8,400 lbs/hr	1
	Total		*42,000 lbs/hr*	*3*
Kutztown University	N/A	Coal	20,000 lbs/hr	3
	N/A	Natural Gas	35,000 lbs/hr	1
	N/A	Natural Gas	40,000 lbs/hr	1
	Total		*135,000 lbs/hr*	*5*
Lamar University	Sellers firetube	Natural Gas	N/A	1

University	Boiler Type	Fuel	Size	Quantity
	Cleaver-Brooks firetube	Natural Gas	N/A	1
	Sellers hot water boiler	Natural Gas	N/A	1
	Total		*N/A*	*3*
Macalister University	Watertube	Natural Gas	25,000 lbs/hr	1
	Watertube	Natural Gas	27,000 lbs/hr	1
	Watertube	Natural Gas	50,000 lbs/hr	1
	Total		*102,000 lbs/hr*	*3*
Mansfield University	Watertube	Natural Gas	2,800 lbs/hr	2
	Watertube	Natural Gas	1,400 lbs/hr	1
	Total		7,000 lbs/hr	3
Massachusetts Institute of Technology	Heat recovery steam generator attached to co-generation	Waste Heat	165,000 lbs/hr	1
	Backup boiler	Oil	85,000 lbs/hr	?
	Total		*250,000 lbs/hr*	*?*
Massachusetts Maritime Academy	Cleaver-Brooks watertube	#4 Fuel Oil	28,300 lbs/hr	3
	Total		*85,000 lbs/hr*	*3*
Medical College of Ohio	Babcock & Wilcox	Coal	70,000 lbs/hr	2
	Babcock & Wilcox	Natural Gas	70,000 lbs/hr	1
	Wickes	Coal	40,000 lbs/hr	1
	Total		*250,000 lbs/hr*	*4*
Michigan State University	Wickes watertube	Coal	250,000 lbs/hr	2
	Erie City watertube	Coal	350,000 lbs/hr	1
	Tampella watertube	Coal	350,000 lbs/hr	1
	Total		*1,200,000 lbs/hr*	*4*
Middle Tennessee State University	Heat recovery boiler attached to co-generation	Waste Heat	80,000 lbs/hr	1
	Backup boiler	Natural Gas	80,000 lbs/hr	1
	Total		*160,000 lbs/hr*	*2*
Middlebury College	Babcock & Wilcox	#6 Fuel Oil	45,000 lbs/hr	1
	Wickes	#6 Fuel Oil	25,000 lbs/hr	1
	Zurn	#6 Fuel Oil	25,000 lbs/hr	1
	Cleaver-Brooks	#6 Fuel Oil	22,000 lbs/hr	1
	Total		*112,000 lbs/hr*	*4*
Minnesota State University at Moorhead	High pressure steam boiler	Natural Gas	54,200 lbs/hr	3
	Low pressure steam boiler	Natural Gas	20,000 lbs/hr	1
	Total		*182,500 lbs/hr*	*4*
Montana State University	Bros site-erected D-frame	Natural Gas	100,000 lbs/hr	1
	Nebraska packaged A-frame	Natural Gas	100,000 lbs/hr	1
	Nebraska packaged A-frame	Natural Gas	50,000 lbs/hr	1
	Total		*250,000 lbs/hr*	*3*
Mount Holyoke College	Watertube	#6 Fuel Oil	20,000 lbs/hr	4
	Watertube	#6 Fuel Oil	20,000 lbs/hr	1
	Total		*100,000 lbs/hr*	*5*
Northeastern Illinois University	Volcano	Natural Gas	*15,000 lbs/hr*	2
	International-Lamont	Natural Gas	*15,000 lbs/hr*	1
	Total		*45,000 lbs/hr*	*3*
Occidental College	N/A	Natural Gas	N/A	4
	Total		*9,700 lbs/hr*	*4*
Ohio State University	Keeler	Natural Gas	100,000 lbs/hr	1
	Erie City	Natural Gas	80,000 lbs/hr	1
	Babcock & Wilcox	Natural Gas	220,000 lbs/hr	1
	Babcock & Wilcox	Natural Gas	100,000 lbs/hr	1
	Babcock & Wilcox	Natural Gas	100,000 lbs/hr	1
	Vogt	Coal	90,000 lbs/hr	1
	Total		*690,000 lbs/hr*	*6*
Oklahoma State University	N/A	Natural Gas	40,000 lbs/hr	3
	N/A	Natural Gas	100,000 lbs/hr	1
	N/A	Natural Gas	125,000 lbs/hr	1
	Total		*345,000 lbs/hr*	*5*
Pennsylvania State University	Wickes	Coal	110,000 lbs/hr	3
	Erie City	Coal	120,000 lbs/hr	1
	Babcock & Wilcox	Natural Gas	50,000 lbs/hr	1
	Keeler	Natural Gas	100,000 lbs/hr	2
	Total		*600,000 lbs/hr*	*7*
Phoenix College	Sellers firetube	Natural Gas	8,370 lbs/hr	2
	Total		16,740 lbs/hr	2
Pittsburgh State University	Nebraska watertube	Natural Gas	5,000 lbs/hr	1

University	Boiler Type	Fuel	Size	Quantity
	Nebraska watertube	Natural Gas	7,000 lbs/hr	1
	Nebraska watertube	Natural Gas	25,000 lbs/hr	1
	Total		*47,000 lbs/hr*	*3*
Purdue University	Foster Wheeler watertube	Coal	200,000 lbs/hr	1
	Babcock & Wilcox spreader stoker	Coal	190,000 lbs/hr	2
	Combustion Engineering package boiler	Natural Gas	190,000 lbs/hr	1
	Total		*540,000 lbs/hr*	*4*
Reed College	Watertube	Natural Gas	13,000 lbs/hr	1
	Watertube	Natural Gas	15,000 lbs/hr	1
	Total		*28,000 lbs/hr*	*1*
Rhode Island College	Watertube	Natural Gas	34,000 lbs/hr	1
	Backup watertube boiler	Natural Gas	34,000 lbs/hr	1
	Waste heat boiler from co-generation	Waste Heat	13,500 lbs/hr	1
	Total		*81,500 lbs/hr*	*3*
Rhode Island School of Design	Cleaver-Brooks watertube	#6 Fuel Oil	17,000 lbs/hr	2
	Cleaver-Brooks watertube	#6 Fuel Oil	30,000 lbs/hr	1
	Total		*64,000 lbs/hr*	*3*
Rochester Institute of Technology	Lamont watertube	Natural Gas	37,500 lbs/hr	2
	Lamont watertube	Natural Gas	25,000 lbs/hr	2
	Lamont watertube	Natural Gas	52,000 lbs/hr	2
	Lamont watertube	Natural Gas	35,000 lbs/hr	1
	Total		*264,000 lbs/hr*	*7*
Saint Joseph's College	Erie City watertube	Coal	25,000 lbs/hr	1
	Keeler watertube	Coal	30,000 lbs/hr	1
	Wickes watertube	Coal	35,000 lbs/hr	1
	Cleaver-Brooks firetube	Coal	5,600 lbs/hr	1
	Total		*95,600 lbs/hr*	*4*
Saint Joseph's University	Johnston firetube	Oil	13,700 lbs/hr	2
	Cleaver-Brooks firetube	Oil	20,400 lbs/hr	1
	Total		*48,000 lbs/hr*	*3*
San Diego State University	Waste heat boiler from co-generation	Waste Heat	14,000 lbs/hr	1
	Supplementary boilers	Natural Gas	25,000 lbs/hr	1
	Supplementary boilers	Natural Gas	17,000 lbs/hr	1
	Supplementary boilers	Natural Gas	10,000 lbs/hr	1
	Total		*116,000 lbs/hr*	*4*
Slippery Rock University	Babcock & Wilcox	Coal/Natural Gas	20,000 lbs/hr	2
	Keeler	Coal	14,000 lbs/hr	1
	Keeler	Coal	23,000 lbs/hr	1
	Total		*77,000 lbs/hr*	*4*
Southern Methodist University	Cleaver-Brooks watertube	Oil/Natural Gas	60,000 lbs/hr	1
	Holman firetube	Natural Gas	30,000 lbs/hr	1
	B7W watertube	Natural Gas	100,000 lbs/hr	1
	Total		*190,000 lbs/hr*	*3*
Southern Oregon University	Watertube	Natural Gas	8,400 lbs/hr	3
	Watertube	Natural Gas	12,600 lbs/hr	2
	Total		*50,400 lbs/hr*	*5*
St. Mary's College	N/A	Coal	70,000 lbs/hr	2
	N/A	Natural Gas	30,000 lbs/hr	1
	Total		*170,000 lbs/hr*	*3*
Stanford University	Bigelow Sterling FHC 30	Natural Gas	100,000 lbs/hr	4
	Backup boiler	Natural Gas	80,000 lbs/hr	4
	Total		*720,000 lbs/hr*	*8*
State University of New York at Potsdam	Cleaver-Brooks	Natural Gas	40,000 lbs/hr	3
	Total		*120,000 lbs/hr*	*3*
State University of New York at Stony Brook	Erie City-Keystone watertube	Natural Gas	85,000 lbs/hr	4
	Combustion Engineering watertube	Natural Gas	90,000 lbs/hr	2
	Keeler watertube	Natural Gas	90,000 lbs/hr	2
	Total		*700,000 lbs/hr*	*8*
Swarthmore College	Keeler/Dorr-Oliver	Natural Gas	30,000 lbs/hr	1
	N/A	Natural Gas	25,000 lbs/hr	1
	N/A	Natural Gas	10,000 lbs/hr	1
	Total		*65,000 lbs/hr*	*3*
Syracuse University	Reilly stoker	Natural Gas	150,000 lbs/hr	2
	Babcock & Wilcox	Natural Gas	100,000 lbs/hr	2
	Total		*500,000 lbs/hr*	*4*

University	Boiler Type	Fuel	Size	Quantity
Texas A&M University	N/A	Natural Gas	100,000 lbs/hr	1
	N/A	Natural Gas	175,000 lbs/hr	1
	HRSG in conjunction with co-generation	Waste Heat	175,000 lbs/hr	1
	N/A	Natural Gas	300,000 lbs/hr	1
	Total		*750,000 lbs/hr*	*4*
University of Alaska -- Fairbanks	Keystone	Coal	25,000 lbs/hr	2
	N/A	Oil	50,000 lbs/hr	2
	Heat recovery boiler attached to co-generation	Waste Heat	16,000 lbs/hr	1
	Total		*166,000 lbs/hr*	*5*
University of Arkansas	Keeler watertube	N/A	40,000 lbs/hr	3
	Babcock & Wilcox watertube	N/A	80,000 lbs/hr	1
	Babcock & Wilcox watertube	N/A	100,000 lbs/hr	1
	Total		*300,000 lbs/hr*	*5*
University of California, Berkeley	Erie City watertube (for backup)	Natural Gas	80,000 lbs/hr	3
	HRSG in conjunction with co-generation	Waste Heat	186,000 lbs/hr	?
	Total		*426,000 lbs/hr*	*?*
University of California, Los Angeles	Heat recovery boiler attached to co-generation	Waste Heat	117,000 lbs/hr	2
	Total		*234,000 lbs/hr*	*2*
University of California, Riverside	Babcock & Wilcox watertube	Natural Gas	30,000 lbs/hr	3
	Babcock & Wilcox watertube	Natural Gas	50,000 lbs/hr	1
	Total		*140,000 lbs/hr*	*4*
University of California, San Francisco	Auxiliary boilers	Natural Gas	90,000 lbs/hr	2
	Heat recovery boiler attached to co-generation	Waste Heat	54,000 lbs/hr	2
	Total		*288,000 lbs/hr*	*4*
University of Central Arkansas	AERCO watertube	Natural Gas	2,000 lbs/hr	2
	AERCO watertube	Natural Gas	1,000 lbs/hr	2
	Total		*6,000 lbs/hr*	*4*
University of Colorado at Boulder	HRSG in conjunction with co-generation	Waste Heat	80,000 lbs/hr	2
	Total		*160,000 lbs/hr*	*2*
University of Delaware	N/A	Natural Gas	50,000 lbs/hr	6
	N/A	Natural Gas	750,000 lbs/hr	2
	N/A	Natural Gas	750,000 lbs/hr	2
	Total		*3,300,000 lbs/hr*	*10*
University of Evansville	Cleaver-Brooks	Natural Gas	18,600 lbs/hr	3
	N/A	Natural Gas	44,000 lbs/hr	1
	Total		*100,000 lbs/hr*	*4*
University of Georgia	Combustion Engineering	Natural Gas	130,000 lbs/hr	2
	Zurn	Natural Gas	126,600 lbs/hr	1
	Keeler rotary stoker	Coal	96,800 lbs/hr	1
	Total		*483,400 lbs/hr*	*4*
University of Idaho	Nebraska	Wood Chip	60,000 lbs/hr	1
	N/A	Natural Gas	66,000 lbs/hr	1
	Combustion Engineering	Natural Gas	35,000 lbs/hr	1
	Total		*161,000 lbs/hr*	*3*
University of Illinois East Campus	International	Natural Gas	75,000 lbs/hr	2
	N/A	Natural Gas	50,000 lbs/hr	1
	Cannon Boiler heat recovery	Waste Heat	30,000 lbs/hr	4
	Total		*320,000 lbs/hr*	*7*
University of Louisville	Vogt watertube	Coal	75,000 lbs/hr	2
	Vogt watertube	Coal	56,000 lbs/hr	1
	Total		*206,000 lbs/hr*	*3*
University of Maryland at College Park	Riley stoker balanced draft	N/A	132,000 lbs/hr	1
	Union Iron Works balanced draft	N/A	157,000 lbs/hr	1
	Union Iron Works balanced draft	N/A	117,000 lbs/hr	1
	Babcock & Wilcox pressurized boiler	N/A	60,000 lbs/hr	1
	Nebraska pressurized boiler	N/A	80,000 lbs/hr	1
	Total		*546,000 lbs/hr*	*5*
University of Massachusetts Amherst	N/A	Natural Gas, Oil, Coal	80,000 lbs/hr	7
	Total		*560,000 lbs/hr*	*7*
University of Memphis	Nebraska watertube	Natural Gas	80,000 lbs/hr	1
	Murray watertube	Natural Gas	60,000 lbs/hr	2
	Murray watertube	Natural Gas	40,000 lbs/hr	1
	Total		*240,000 lbs/hr*	*4*
University of Michigan	Combustion Engineering	Natural Gas	110,000 lbs/hr	2
	Combustion Engineering	Natural Gas	220,000 lbs/hr	1

University	Boiler Type	Fuel	Size	Quantity
	Wickes	Natural Gas	220,000 lbs/hr	1
	Murray	Natural Gas	150,000 lbs/hr	1
	Foster Wheeler	Natural Gas	250,000 lbs/hr	1
	Zurn/Keystone heat recovery steam generator	Waste Heat	65,000 lbs/hr	2
	Total		*1,195,000 lbs/hr*	*8*
University of Minnesota Duluth	Nebraska watertube	Natural Gas	80,000 lbs/hr	1
	Nebraska watertube	Natural Gas	80,000 lbs/hr	1
	Nebraska watertube	Natural Gas	40,000 lbs/hr	1
	Total		*200,000 lbs/hr*	*3*
University of Minnesota Minneapolis	Foster Wheeler circulating fluidized bed	Coal	200,000 lbs/hr	1
	Foster Wheeler watertube package boiler	Natural Gas	200,000 lbs/hr	1
	Foster Wheeler watertube package boiler	Natural Gas	250,000 lbs/hr	1
	Watertube	Natural Gas	150,000 lbs/hr	1
	Watertube	Natural Gas	100,000 lbs/hr	1
	Total		*900,000 lbs/hr*	*5*
University of Minnesota St. Paul	Foster Wheeler watertube	Natural Gas	250,000 lbs/hr	1
	Nebraska watertube	Natural Gas	80,000 lbs/hr	1
	Watertube	Natural Gas	25,000 lbs/hr	2
	Watertube	Natural Gas	60,000 lbs/hr	2
	Total		*500,000 lbs/hr*	*6*
University of Missouri - Columbia	Wickes stoker	Coal	75,000 lbs/hr	2
	Riley spreader	Coal	125,000 lbs/hr	1
	Riley spreader	Coal	200,000 lbs/hr	1
	Riley circulating fluidized bed	Coal	150,000 lbs/hr	2
	Zurn O style	Natural Gas	220,000 lbs/hr	1
	Total		*994,000 lbs/hr*	*7*
University of Missouri - Kansas City	Firetube	Natural Gas	16,800 lbs/hr	3
	Firetube	Natural Gas	8,400 lbs/hr	1
	Firetube	Natural Gas	16,800 lbs/hr	1
	Firetube	Natural Gas	7,000 lbs/hr	2
	Total		*89,600 lbs/hr*	*7*
University of New Hampshire	Babcock & Wilcox watertube	#6 Fuel Oil	35,000 lbs/hr	3
	Reilly watertube	#6 Fuel Oil	35,000 lbs/hr	1
	Cleaver-Brooks firetube	#6 Fuel Oil	12,000 lbs/hr	1
	Total		*125,000 lbs/hr*	*5*
University of New Mexico	Murray	Natural Gas	100,000 lbs/hr	1
	Babcock & Wilcox	Natural Gas	100,000 lbs/hr	1
	Combustion Engineering	Natural Gas	30,000 lbs/hr	2
	Babcock & Wilcox	Natural Gas	60,000 lbs/hr	1
	Nebraska heat recovery	Waste Heat	17,000 lbs/hr	1
	Total		*385,000 lbs/hr*	*6*
University of North Carolina at Chapel Hill	Pyro Power watertube circulating fluidized bed	Coal	250,000 lbs/hr	2
	Erie City watertube	Coal	150,000 lbs/hr	1
	Total		*650,000 lbs/hr*	*3*
University of Northern Iowa	Erie City watertube	Coal	60,000 lb/hr	2
	Babcock & Wilcox watertube	Coal	120,000 lbs/hr	1
	Pyro Power watertube	Coal	105,000 lbs/hr	1
	Total		*345,000 lbs/hr*	*4*
University of Pittsburgh	Babcock & Wilcox stoker	Coal/Natural Gas	100,000 lbs/hr	1
	Springfield Westinghouse	Coal	85,000 lbs/hr	1
	Zurn	Coal/Natural Gas	100,000 lbs/hr	1
	Springfield Westinghouse	Coal	75,000 lbs/hr	1
	Zurn	Coal/Natural Gas	100,000 lbs/hr	1
	Zurn	Natural Gas	150,000 lbs/hr	1
	N/A	Natural Gas	150,000 lbs/hr	1
	Total		*760,000 lbs/hr*	*7*
University of Rochester	Babcock & Wilcox stoker	N/A	150,000 lbs/hr	2
	Babcock & Wilcox chain grate	N/A	100,000 lbs/hr	1
	Babcock & Wilcox package boiler	N/A	100,000 lbs/hr	1
	Total		*500,000 lbs/hr*	*4*
University of South Dakota	Murray	Natural Gas	40,000 lbs/hr	1
	Babcock & Wilcox	Natural Gas	60,000 lbs/hr	1
	Total		*100,000 lbs/hr*	*2*
University of Texas at Austin	Vogt watertube	Natural Gas	75,000 lbs/hr	2
	Vogt watertube	Natural Gas	500,000 lbs/hr	1
	Babcock & Wilcox watertube	Natural Gas	150,000 lbs/hr	1
	Vogt HRSG	Natural Gas	60,000 lbs/hr	1
	Vogt HRSG	Natural Gas	286,000 lbs/hr	1
	Total		*1,146,000 lbs/hr*	*6*

University	Boiler Type	Fuel	Size	Quantity
University of Texas at El Paso	Cleaver-Brooks	Natural Gas	2,700 lbs/hr	2
	Cleaver-Brooks	Natural Gas	16,200 lbs/hr	3
	Total		*54,000 lbs/hr*	*5*
University of Virginia	N/A	Coal/Natural Gas	90,000 lbs/hr	1
	N/A	#6 Fuel Oil/Natural Gas	90,000 lbs/hr	1
	N/A	Coal/Natural Gas	90,000 lbs/hr	1
	N/A	Coal	72,000 lbs/hr	1
	N/A	Coal	45,000 lbs/hr	1
	N/A	Natural Gas	7,500 lbs/hr	2
	Total		*402,000 lbs/hr*	*7*
University of Washington	Reilly watertube	Natural Gas	120,000 lbs/hr	1
	Erie City watertube	Natural Gas	250,000 lbs/hr	1
	Foster Wheeler	Natural Gas	200,000 lbs/hr	2
	Total		*770,000 lbs/hr*	*4*
University of Wisconsin at Madison	Zurn	Coal	100,000 lbs/hr	3
	Zurn	Coal	200,000 lbs/hr	1
	Zurn	Coal	300,000 lbs/hr	1
	Trane-Murray	Natural Gas	150,000 lbs/hr	2
	Trane-Murray	Natural Gas	300,000 lbs/hr	1
	Total		*1,100,000 lbs/hr*	*8*
University of Wisconsin at Milwaukee	Cleaver-Brooks watertube	Natural Gas	120,000 lbs/hr	3
	Cleaver-Brooks watertube	Natural Gas	60,000 lbs/hr	1
	Total		*420,000 lbs/hr*	*4*
University of Wisconsin at Stout	Watertube	Coal	100,000 lbs/hr	1
	Watertube	Coal	45,000 lbs/hr	2
	Watertube	Coal	15,000 lbs/hr	1
	Total		*205,000 lbs/hr*	*4*
Virginia Polytechnic Institute and State University	Riley watertube	Coal	100,000 lbs/hr	1
	Erie City watertube	Coal	100,000 lbs/hr	1
	Keeler watertube	Oil/Natural Gas	72,000 lbs/hr	3
	Total		*416,000 lbs/hr*	*5*
Wellesley College	Nebraska watertube		45,000 lbs/hr	1
	Zurn		45,000 lbs/hr	1
	Zurn		45,000 lbs/hr	1
	Vapor Phase heat recovery boilers	Waste Heat	2,025 lbs/hr	4
	Kawanee firetube converted to waste heat with auxiliary firing	Waste Heat	17,000 lbs/hr	1
	Total		*160,000 lbs/hr*	*8*
Western Michigan University	Wickes	Natural Gas	50,000 lbs/hr	3
	Erie City	Natural Gas	150,000 lbs/hr	1
	Wickes	Natural Gas	150,000 lbs/hr	1
	ERI heat recovery steam generator	Waste Heat	65,000 lbs/hr	2
	Total		*580,000 lbs/hr*	*8*
Williams College	Combustion Engineering watertube	N/A	70,000 lbs/hr	1
	Keeler watertube	N/A	56,000 lbs/hr	1
	Nebraska watertube	N/A	70,000 lbs/hr	1
	Total		*196,000 lbs/hr*	*3*
Yale University	Nebraska	N/A	25,000 lbs/hr	2
	Nebraska	N/A	60,000 lbs/hr	3
	Nebraska	N/A	70,000 lbs/hr	1
	Nebraska	N/A	100,000 lbs/hr	1
	Nebraska heat recovery	Waste Heat	80,000 lbs/hr	3
	Total		*640,000 lbs/hr*	*10*

Table 4: Cooling System Data

University	Cooling System Data							
	Single or Multiple Central Cooling Plant(s)	Total Capacity (tons)	Thermal Storage Method	Volume of Thermal Storage	Total Linear Feet of Cooling Pipe (Supply and Return)	Cooling Pipe Construction		% of Campus Energy Requirements Met by Central Plant(s)
						% Direct Buried	% Tunnels/ Vaults	
Arizona State University West Campus	Single	3,000	Chilled Water	2,000,000 gallons	5,000	0%	100%	60%
Bates College	Multiple	640	None	N/A	2,000	100%	0%	8%
Bowling Green State University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Brigham Young University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bucknell University	Single	1,600	None	N/A	8,000	70%	30%	50%
Butler University	Single	1,800	None	N/A	N/A	100%	0%	90%
California Polytechnic State University	Single	1,200	None	N/A	10,000	50%	50%	85%
California State University, Northridge	Single	3,750	Chilled Water	2,300,000 gallons	20,800	100%	0%	65%
Central Michigan University	Single	6,200	None	N/A	32,000	100%	0%	85%
Central Washington University	Single	2,650	Chilled Water	1,000,000 gallons	21,000	100%	0%	50%
Clemson University	Multiple	8,800	None	N/A	15,000	90%	10%	90%
Cleveland State University	Multiple	7,000	None	N/A	10,000	0%	100%	75%
Colby College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
College of New Jersey	Single	4,200	None	N/A	9,000	100%	0%	80%
College of William and Mary	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
College of Wooster	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Columbia University	Multiple	12,000	None	N/A	21,600	25%	75%	97%
Connecticut College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cornell University	Multiple	28,000	Chilled Water	660,000 gallons	66,000	100%	0%	100%
Dartmouth University	Multiple	4,500	None	N/A	5,000	10%	90%	30%
Denison University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drake University	Multiple	1,200	None	N/A	7,000	90%	10%	70%
Duke University	Single	2,000	None	N/A	31,680	100%	0%	N/A
Duquesne University	Single	2,500	None	N/A	N/A	N/A	N/A	60%
Emory University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Georgetown University	Unknown, but >= 1	12,500	Chilled Water	10,000 ton-hours	20,000	75%	25%	100%
Georgia Institute of Technology	Multiple	11,000	None	N/A	N/A	N/A	N/A	N/A
Goshen College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Harding University	Multiple	1,650	None	N/A	10,000	30%	70%	80%
Harvard University	Single	13,000	None	N/A	10,500	100%	0%	N/A
Howard University	Unknown, but >= 1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Idaho State University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Illinois Central College	Single	900	None	N/A	2,000	N/A	N/A	50%
Illinois Institute of Technology	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Indiana University – Bloomington	Single	12,900	None	N/A	30,000	100%	0%	50%

	Cooling System Data							
						Cooling Pipe Construction		
University	Single or Multiple Central Cooling Plant(s)	Total Capacity (tons)	Thermal Storage Method	Volume of Thermal Storage	Total Linear Feet of Cooling Pipe (Supply and Return)	% Direct Buried	% Tunnels/ Vaults	% of Campus Energy Requirements Met by Central Plant(s)
Iowa State University	Single	12,000	None	N/A	30,000	100%	0%	95%
James Madison University	Single	3,000	None	N/A	12,000	100%	0%	20%
Johns Hopkins University	Multiple	6,500	Ice	22,000 ton-hours	N/A	25%	75%	70%
Kalamazoo College	Single	1,000	Ice	4,000 ton-hours	6,000	100%	0%	80%
Kansas State University	Single	6,420	None	N/A	N/A	N/A	N/A	45%
Keane State College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kutztown University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lamar University	Multiple	4,000	None	N/A	N/A	0%	100%	75%
Macallister University	Single	1,080	Ice	400 ton-hours	10,000	35%	65%	40%
Mansfield University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Massachusetts Institute of Technology	Multiple	N/A	None	N/A	N/A	N/A	N/A	N/A
Massachusetts Maritime Academy	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Medical College of Ohio	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Michigan State University	Multiple	27,500	None	N/A	22,000	100%	0%	32%
Middle Tennessee State University	Single	6,000	None	N/A	21,000	0%	100%	90%
Middlebury College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Minnesota State University at Moorhead	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Montana State University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mount Holyoke College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Northeastern Illinois University	Single	3,500	None	N/A	N/A	5%	95%	90%
Occidental College	Single	1,000	Ice	1,500 ton-hours	N/A	N/A	N/A	N/A
Ohio State University	Single	6,000	None	N/A	10,000	4%	96%	15%
Oklahoma State University	Multiple	16,200	None	N/A	53,000	95%	5%	80%
Pennsylvania State University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phoenix College	Single	2,600	None	N/A	5,000	14%	86%	99%
Pittsburgh State University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pomona College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Purdue University	Single	20,000	None	N/A	N/A	100%	0%	75%
Reed College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rhode Island College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rhode Island School of Design	Single	580	None	N/A	N/A	N/A	N/A	15%
Rochester Institute of Technology	Multiple	2,400	None	N/A	N/A	0%	100%	70%
Saint Joseph's College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Saint Joseph's University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
San Diego State University	Multiple	4,000	Chilled Water	2,000,000 gallons	N/A	N/A	N/A	N/A
San Jose State University	Single	4,000	None	N/A	N/A	N/A	N/A	N/A
Slippery Rock University	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A

University	Cooling System Data							
	Single or Multiple Central Cooling Plant(s)	Total Capacity (tons)	Thermal Storage Method	Volume of Thermal Storage	Total Linear Feet of Cooling Pipe (Supply and Return)	Cooling Pipe Construction		% of Campus Energy Requirements Met by Central Plant(s)
						% Direct Buried	% Tunnels/ Vaults	
Southern Methodist University	Single	12,000	None	N/A	21,600	17%	83%	88%
Southern Oregon University	Single	1,550	None	N/A	9,800	5%	95%	60%
St. Mary's College	Single	1,200	None	N/A	20,000	0%	100%	50%
Stanford University	Single	20,000	Ice	90,000 ton-hours	N/A	N/A	N/A	N/A
State University of New York at Potsdam	Single	950	None	N/A	3,000	50%	50%	33%
State University of New York at Stony Brook	Multiple	23,500	None	N/A	40,000	25%	75%	90%
Swarthmore College	Single	600	None	N/A	4,000	N/A	N/A	15%
Syracuse University	Single	4,500	None	N/A	30,000	95%	5%	N/A
Texas A&M University	Multiple	40,000	None	N/A	N/A	N/A	N/A	N/A
Texas Tech University	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thunderbird, The American Graduate School of International Management	Multiple	1,100	None	N/A	8,900	100%	0%	47%
University of Alaska -- Fairbanks	Single	900	None	N/A	5,000	100%	0%	30%
University of Arkansas	Multiple	10,300	None	N/A	12,000	10%	90%	100%
University of California, Berkeley	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of California, Los Angeles	Single	16,600	None	N/A	69,000	N/A	N/A	N/A
University of California, Riverside	Single	5,750	Chilled Water	2,000,000 gallons	32,000	5%	95%	90%
University of California, San Francisco	None	N/A	None	N/A	N/A	N/A	N/A	N/A
University of Central Arkansas	Multiple	2,150	None	N/A	9,300	100%	0%	20%
University of Colorado at Boulder	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Delaware	Multiple	3,700	None	N/A	20,000	67%	33%	N/A
University of Evansville	Single	1,900	Chilled Water	50,000 gallons	N/A	20%	80%	85%
University of Florida	Multiple	38,000	None	N/A	N/A	95%	5%	95%
University of Georgia	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Idaho	Multiple	4,385	None	N/A	10,000	10%	90%	50%
University of Illinois East Campus	Single	6,000	None	N/A	16,000	10%	90%	90%
University of Iowa	Multiple	N/A	None	N/A	82,710	90%	10%	55%
University of Louisville	Single	8,225	None	N/A	8,000	5%	95%	75%
University of Maryland at College Park	Multiple	17,250	Ice	N/A	N/A	100%	0%	80%
University of Massachusetts Amherst	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Memphis	Single	5,600	None	N/A	32,000	100%	0%	70%
University of Miami	Multiple	4,430	None	N/A	5,000	100%	0%	50%
University of Michigan	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Minnesota Duluth	Single	1,200	None	N/A	5,000	0%	100%	15%
University of Minnesota Minneapolis	Multiple	22,500	None	N/A	N/A	N/A	N/A	90%
University of Minnesota St. Paul	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Missouri - Columbia	Multiple	19,000	None	N/A	48,000	96%	4%	75%
University of Missouri - Kansas City	Single	5,000	None	N/A	N/A	100%	0%	60%

Cooling System Data

University	Single or Multiple Central Cooling Plant(s)	Total Capacity (tons)	Thermal Storage Method	Volume of Thermal Storage	Total Linear Feet of Cooling Pipe (Supply and Return)	Cooling Pipe Construction		% of Campus Energy Requirements Met by Central Plant(s)
						% Direct Buried	% Tunnels/ Vaults	
University of New Hampshire	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of New Mexico	Multiple	8,100	None	N/A	61,000	20%	80%	85%
University of North Carolina at Chapel Hill	Multiple	24,400	None	N/A	53,000	100%	0%	100%
University of Northern Colorado	Single	1,000	None	N/A	5,000	5%	95%	60%
University of Northern Iowa	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Pennsylvania	Multiple	40,000	Ice	22,000 ton-hours	26,000	100%	0%	95%
University of Pittsburgh	Multiple	10,500	None	N/A	5,000	100%	0%	50%
University of Rochester	Single	23,000	None	N/A	30,000	100%	0%	100%
University of South Dakota	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
University of Texas at Austin	Multiple	40,800	None	N/A	89,228	15%	85%	97%
University of Texas at El Paso	Multiple	4,600	Chilled Water	3,000,000 gallons	10,000	0%	100%	85%
University of Virginia	Multiple	23,150	Chilled Water	N/A	57,500	97%	3%	100%
University of Washington	Single	12,000	None	N/A	50,000	10%	90%	90%
University of Wisconsin at Madison	Multiple	44,000	None	N/A	N/A	N/A	N/A	N/A
University of Wisconsin at Milwaukee	Single	8,500	None	N/A	16,000	10%	90%	85%
University of Wisconsin at Stout	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Virginia Polytechnic Institute and State University	Single	5,400	None	N/A	19,000	100%	0%	35%
Wellesley College	Single	2,200	None	N/A	N/A	N/A	N/A	45%
Western Michigan University	None	N/A	None	N/A	N/A	N/A	N/A	N/A
Williams College	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yale University	Multiple	33,200	Chilled Water	3,000,000 gallons	16,000	5%	95%	50%
Sum (of institutions reporting data)		**829,910**			**1,436,618**			

Table 5: Cooling Equipment Detail

University	Chiller Type	Size	Quantity
Arizona State University West Campus	Trane electric	1,000 tons	3
	Total	*3,000 tons*	*3*
Bates College	Carrier centrifugal	360 tons	1
	Trane scroll	280 tons	1
	Total	*640 tons*	*2*
Bucknell University	Carrier absorption	800 tons	2
	Total	*1,600 tons*	*2*
Butler University	Carrier electric	500 tons	2
	Carrier electric	800 tons	1
	Total	*1,800 tons*	*3*
California Polytechnic State University	Carrier electric	600 tons	1
	York electric	600 tons	1
	Total	*1,200 tons*	*2*
	York electric	1,250 tons	3
	Total	*3,750 tons*	*3*
Central Michigan University	York absorption	1,250 tons	1
	York centrifugal	1,250 tons	3
	Total	*5,000 tons*	*4*
Central Washington University	McQuay centrifugal	1,200 tons	1
	McQuay centrifugal	900 tons	1
	Carrier centrifugal	550 tons	1
	Total	*2,650 tons*	*3*
Clemson University	Carrier electric	1,200 tons	2
	Trane electric	1,800 tons	3
	Trane absorption	1,000 tons	1
	Total	*8,800 tons*	*6*
Cleveland State University	Trane electric	1,000 tons	6
	Trane electric	500 tons	2
	Total	*1,500 tons*	*8*
College of New Jersey	Trane absorption	1,000 tons	2
	Trane absorption	500 tons	2
	Trane electric	1,200 tons	1
	Total	*4,200 tons*	*5*
Columbia University	Trane electric	1,100 tons	6
	York steam turbine	2,000 tons	1
	Carrier steam absorption	615 tons	5
	Total	*12,000 tons*	*12*
Cornell University	Multiple electric chillers	10,000 tons	7
	Lake source cooling	18,000 tons	1
	Total	*28,000 tons*	*7*
Dartmouth University	York absorption	650 tons	1
	York absorption	565 tons	2
	York electric	650 tons	1
	Trane absorption	300 tons	1
	McQuay absorption	350 tons	1
	Total	*4,500 tons*	*6*
Drake University	York electric centrifugal	600 tons	1
	Trane electric centrifugal	600 tons	1
	Total	*1,200 tons*	*2*
Duke University	Trane CDHF 2000 electric chiller	1,000 tons	2
	Total	*2,000 tons*	*2*
Duquesne University	Trane absorption	750 tons	2
	Trane absorption	1,000 tons	1
	Total	*2,500 tons*	*3*
Georgetown University	Worthington steam-driven centrifugal	2,600 tons	2
	Carrier electric centrifugal	1,650 tons	2
	York electric centrifugal	2,000 tons	2
	Total	*12,500 tons*	*6*

University	Chiller Type	Size	Quantity
Georgia Institute of Technology	N/A	1,300 tons	6
	N/A	1,500 tons	2
	Total	*6000 tons*	*8*
Harding University	Trane electric	330 tons	5
	Total	*1,650 tons*	*5*
Harvard University	Carrier electric centrifugal	2,500 tons	2
	Trane electric centrifugal	1,000 tons	1
	Carrier electric centrifugal	2,000 tons	1
	Carrier electric centrifugal	5,000 tons	1
	Total	*13,000 tons*	*5*
Illinois Central College	Trane steam absorption	450 tons	2
	Total	*900 tons*	*2*
Indiana University -- Bloomington	Carrier 19C	600 tons	1
	Carrier 19C	1,900 tons	1
	Trane CVHB	1,200 tons	2
	Trane CVHB	1,333 tons	3
	Carrier 17DA	4,000 tons	1
	Total	*12,900 tons*	*8*
Iowa State University	Carrier steam absorption	5,000 tons	1
	York steam absorption	5,000 tons	1
	York electric	2,000 tons	1
	Total	*12,000 tons*	*3*
James Madison University	Steam chiller	1,000 tons	3
	Total	*3,000 tons*	*3*
Johns Hopkins University	Trane open drive R22	3,500 tons	1
	Trane CVHB	1,500 tons	2
	Total	*6,500 tons*	*3*
Kalamazoo College	York screw chiller	500 tons	2
	Total	*1,000 tons*	*2*
Kansas State University	Electric chiller	900 tons	2
	Steam chiller	960 tons	1
	Electric chiller	1,250 tons	1
	Steam absorption chiller	1,150 tons	1
	Steam absorption chiller	860 tons	1
	Electric chiller	400 tons	1
	Total	*6,420 tons*	*7*
Lamar University	York centrifugal	800 tons	4
	Carrier centrifugal	800 tons	1
	Total	*4,000 tons*	*5*
Macalister University	Trane electric	580 tons	1
	Trane electric	500 tons	1
	Total	*1,080 tons*	*2*
Michigan State University	Carrier steam	360 tons	7
	Trane steam	800 tons	25
	York steam	715 tons	7
	Total	*27,500 tons*	*39*
Middle Tennessee State University	Trane absorption	1,000 tons	1
	Trane electric centrifugal	1,000 tons	5
	Total	*6,000 tons*	*6*
Northeastern Illinois University	Carrier 4160	1,500 tons	2
	Carrier 4160	500 tons	1
	Total	*3,500 tons*	*3*
Occidental College	Screw chiller	500 tons	2
	Total	*1,000 tons*	*2*
Ohio State University	York steam turbine driven	2000 tons	2
	York electric	775 tons	2
	York electric	450 tons	1
	Total	*6000 tons*	*5*

University	Chiller Type	Size	Quantity
Oklahoma State University	Carrier steam absorption	1,200 tons	1
	Carrier electric	3,000 tons	1
	Carrier electric	4,000 tons	2
	Carrier	4,000 tons	1
	Total	*16,200 tons*	*5*
Phoenix College	McQuay electric	1,000 tons	2
	McQuay electric	600 tons	1
	Total	*2,600 tons*	*3*
Purdue University	Carrier steam turbine	6,200 tons	1
	York steam turbine	3,000 tons	1
	Carrier steam turbine	4,500 tons	1
	York steam turbine	5,000 tons	1
	Trane electric	2,000 tons	2
	Total	*20,000 tons*	*5*
Rhode Island School of Design	Trane centrifugal	80 tons	1
	Carrier centrifugal	200 tons	1
	Carrier centrifugal	300 tons	1
	Total	*580 tons*	*3*
Rochester Institute of Technology	Trane absorption	600 tons	1
	Trane absorption	300 tons	1
	Trane absorption	750 tons	2
	Total	*2,400 tons*	*4*
San Diego State University	Electric chiller	1,000 tons	1
	Steam absorption chiller	1,000 tons	1
	Electric chiller	1,200 tons	1
	Steam absorption chiller	400 tons	1
	Steam absorption chiller	400 tons	1
	Total	*4,000 tons*	*5*
San Jose State University	Carrier steam absorption	1,250 tons	2
	Carrier electric	750 tons	2
	Total	*4,000 tons*	*4*
Southern Methodist University	York OM electric chiller	4,000 tons	2
	York YK electric chiller	2,000 tons	1
	Trane RVX electric chiller	1,000 tons	2
	Total	*12,000 tons*	*5*
Southern Oregon University	Trane electric centrifugal	500 tons	1
	Trane electric centrifugal	800 tons	1
	Trane electric centrifugal	250 tons	1
	Total	*1,550 tons*	*3*
St. Mary's College	Carrier electric	600 tons	2
	Total	*1,200 tons*	*2*
Stanford University	Electric rotary screw chiller	6,700 tons	3
	Total	*20,000 tons*	*3*
State University of New York at Potsdam	Trane	450 tons	1
	Marley cooling tower spray unit	500 tons	1
	Total	*950 tons*	*2*
State University of New York at Stony Brook	Carrier electric	4,500 tons	1
	Carrier steam	4,500 tons	4
	McQuay electric	1,000 tons	1
	Total	*23,500 tons*	*6*
Swarthmore College	York steam absorption	600 tons	1
	Total	*600 tons*	*1*
Syracuse University	Carrier steam turbine	3,200 tons	1
	Trane steam absorption	1,300 tons	1
	Total	*4,500 tons*	*2*
Texas A&M University	Steam absorption chiller	1,500 tons	1
	Steam absorption chiller	1,500 tons	1
	Steam absorption chiller	1,500 tons	1
	Steam absorption chiller	1,500 tons	1
	Steam absorption chiller	900 tons	1
	Steam absorption chiller	1,100 tons	1

University	Chiller Type	Size	Quantity
	Steam absorption chiller	930 tons	1
	Steam centrifugal	3,350 tons	1
	Steam centrifugal	3,350 tons	1
	Steam centrifugal	3,350 tons	1
	Electric centrifugal	3,350 tons	1
	Electric centrifugal	1,100 tons	3
	Electric centrifugal	1,000 tons	1
	Electric centrifugal	1,000 tons	1
	Electric centrifugal	2,000 tons	1
	Steam centrifugal	1,100 tons	1
	Steam (exhaust) absorption	900 tons	1
	Steam centrifugal	1,100 tons	1
	Steam (exhaust) absorption	900 tons	1
	Steam centrifugal	1,100 tons	1
	Steam (exhaust) absorption	900 tons	1
	Electric centrifugal	1,334 tons	3
	Electric centrifugal	280 tons	1
	Electric centrifugal	280 tons	1
	Electric reciprocating	32 tons	1
	Total	*40,000 tons*	*29*
Thunderbird, The American Graduate School of International Management	York electric chiller	200 tons	4
	York electric chiller	300 tons	1
	Total	*1,100 tons*	*5*
University of Alaska – Fairbanks	York steam absorption	900 tons	1
	Total	*900 tons*	*1*
University of Arkansas	Carrier 19EX centrifugal	1,300 tons	1
	Carrier 17M44 centrifugal	2,000 tons	1
	York OMS 3000 centrifugal	3,000 tons	1
	Carrier 17DA71 Centrifugal (turbine)	4,000 tons	1
	Total	*10,300 tons*	*4*
University of California, Los Angeles	Steam turbine driven centrifugal chiller	N/A	2
	Electric chiller	N/A	1
	Steam absorption chiller	N/A	4
	Total	*16,600 tons*	*7*
University of California, Riverside	Trane electric	1,000 tons	2
	Trane electric	1,250 tons	3
	Total	*5,750 tons*	*5*
University of Central Arkansas	Trane electric	720 tons	1
	Trane electric	300 tons	1
	Trane electric	250 tons	1
	Trane electric	215 tons	2
	Trane electric	150 tons	3
	York electric	150 tons	1
	Total	*2,150 tons*	*9*
University of Delaware	Trane electric	750 tons	2
	Trane electric	1,000 tons	1
	Trane electric	600 tons	2
	Total	*3,700 tons*	*5*
University of Evansville	Carrier electric centrifugal	750 tons	2
	Steam absorption chiller	400 tons	1
	Total	*1,900 tons*	*3*
University of Florida	Carrier electric/steam turbine	1,200 tons	11
	York electric	650 tons	5
	Trane electric	1100 tons	20
	Total	*38,000 tons*	*36*
University of Idaho	Trane steam absorption	420 tons	1
	Trane steam absorption	330 tons	1
	Trane steam absorption	465 tons	1
	Trane electric	60 tons	1
	Carrier steam absorption	620 tons	1
	Trane steam absorption	1,200 tons	1
	Trane air cooled	90 tons	1
	York electric centrifugal R134a	1,200 tons	1
	Total	*4,385 tons*	*8*

University	Chiller Type	Size	Quantity
University of Illinois East Campus	York electric centrifugal	2,000 tons	2
	Trane absorption	1,000 tons	1
	Carrier absorption	500 tons	2
	Total	*6,000 tons*	*5*
University of Louisville	Trane electric	2,500 tons	1
	Carrier electric	2,100 tons	1
	Trane electric	1,250 tons	2
	York electric	1,125 tons	1
	Total	*8,225 tons*	*5*
University of Memphis	Trane electric centrifugal	1,600 tons	4
	Total	*5,600 tons*	*4*
University of Miami	Trane electric	1,000 tons	1
	Trane electric	850 tons	1
	Trane electric	600 tons	1
	Trane electric	580 tons	2
	Trane electric	350 tons	3
	Trane electric	450 tons	1
	Trane electric	350 tons	2
	Trane electric	250 tons	2
	Total	*4,430 tons*	*13*
University of Minnesota Duluth	Trane electric	800 tons	1
	Trane electric	400 tons	1
	Total	*1,200 tons*	*2*
University of Minnesota Minneapolis	Trane electric	1,100 tons	10
	McQuay electric	450 tons	4
	Carrier electric	350 tons	2
	Trane steam absorption	750 tons	12
	Total	*22,500 tons*	*28*
University of Missouri - Kansas City	York centrifugal	2,500 tons	1
	York centrifugal	1,250 tons	2
	Total	*5,000 tons*	*3*
University of New Mexico	York centrifugal	1,000 tons	2
	Carrier centrifugal	1,000 tons	1
	Carrier centrifugal	1,500 tons	1
	Trane centrifugal	600 tons	1
	Trane absorption	1,000 tons	3
	Total	*6,100 tons*	*8*
University of North Carolina at Chapel Hill	Trane CV electric centrifugal	1,000 tons	6
	Carrier 19CB electric centrifugal	1,000 tons	2
	Trane CV electric centrifugal	650 tons	2
	Trane CVHE electric centrifugal	1,000 tons	3
	Trane ABS steam absorption	1,500 tons	5
	Carrier 17FA electric centrifugal	2,000 tons	1
	York YK electric centrifugal	2,000 tons	2
	Trane CVHE electric centrifugal	700 tons	2
	York YS electric centrifugal	1,200 tons	1
	Total	*24,400 tons*	*24*
University of Northern Colorado	Carrier absorption	500 tons	2
	Total	*1,000 tons*	*2*
University of Pittsburgh	Carrier electric centrifugal	2,000 tons	2
	York electric centrifugal	2,250 tons	2
	Carrier electric centrifugal	1,000 tons	2
	Total	*10,500 tons*	*6*
University of Rochester	Carrier	1,500 tons	1
	Carrier	4,500 tons	3
	York	6,300 tons	1
	Total	*23,000 tons*	*5*
University of Texas at Austin	Worthington steam turbine	2,000 tons	1
	Worthington steam turbine	3,000 tons	1
	York electric	3,000 tons	4
	York electric	4,000 tons	2
	Carrier steam turbine	2,800 tons	1
	York electric	5,000 tons	2
	Trane steam turbine	3,000 tons	1

University	Chiller Type	Size	Quantity
	Total	*40,800 tons*	*12*
University of Texas at El Paso	York electric	1,000 tons	1
	York electric	600 tons	1
	Carrier	1,000 tons	3
	Total	*4,600 tons*	*5*
University of Virginia	Electric chiller	1,500 tons	1
	Electric chiller	1,200 tons	10
	Electric chiller	800 tons	2
	Electric chiller	700 tons	2
	Electric chiller	600 tons	1
	Electric chiller	500 tons	3
	Electric chiller	400 tons	1
	Electric chiller	300 tons	1
	Electric chiller	250 tons	2
	Electric chiller	175 tons	2
	Chilled water storage	3,000 tons	1
	Total	*23,150 tons*	*26*
University of Washington	Trane electric	1,000 tons	1
	Trane steam absorption	1,000 tons	1
	York electric	2,000 tons	4
	Carrier electric	2,000 tons	1
	Total	*12,000 tons*	*7*
University of Wisconsin at Madison	York steam turbine chiller	8,500 tons	2
	York steam turbine chiller	4,000 tons	2
	York steam absorption chiller	1,000 tons	1
	Carrier steam turbine chiller	3,500 tons	2
	Carrier steam turbine chiller	5,500 tons	1
	Carrier electric chiller	5,500 tons	1
	Total	*44,000 tons*	*9*
University of Wisconsin at Milwaukee	York steam turbine driven	2,750 tons	2
	Carrier electric centrifugal	3,000 tons	1
	Total	*8,500 tons*	*3*
Virginia Polytechnic Institute and State University	Trane electric	1,500 tons	2
	Trane electric	1,200 tons	2
	Total	*5,400 tons*	*4*
Wellesley College	Trane centrifugal	400 tons	1
	Trane centrifugal	800 tons	1
	Trane hot water absorption	250-400 tons	1
	Trane steam absorption	700 tons	1
	Total	*2,200 tons*	*4*
Yale University	York steam absorption	5,600 tons	1
	York steam absorption	5,000 tons	1
	York steam absorption	2,750 tons	2
	York electric	2,000 tons	1
	Carrier	2,250 tons	4
	York	5,600 tons	1
	Total	*33,200 tons*	*10*

Table 6: Electricity Generation Data

University	Electricity			
	Is Power Generated or Co-generated on Campus?	Total Installed Capacity (MW)	Year Electric Generation Commenced	% of Campus Electrical Load Served
Arizona State University West Campus	No	N/A	N/A	N/A
Bates College	No	N/A	N/A	N/A
Bowling Green State University	No	N/A	N/A	N/A
Brigham Young University	No	N/A	N/A	N/A
Bucknell University	Co-generated	6	1991	95%
Butler University	No	N/A	N/A	N/A
California Polytechnic State University	Co-generated	0.35	1989	1%
California State University, Northridge	Co-generated	0.18	2001	2%
Central Michigan University	Co-generated	4.4	1988	50%
Central Washington University	No	N/A	N/A	N/A
Clemson University	Both	9.4	2000	30%
Cleveland State University	No	N/A	N/A	N/A
Colby College	Co-generated	0.6	1999	25%
College of New Jersey	Co-generated	5.2	1993	80%
College of William and Mary	No	N/A	N/A	N/A
College of Wooster	Co-generated	0.375	1992	N/A
Columbia University	No	N/A	N/A	N/A
Connecticut College	No	N/A	N/A	N/A
Cornell University	Co-generated	8	N/A	0%
Dartmouth University	Co-generated	7	1920	40%
Denison University	No	N/A	N/A	N/A
Drake University	No	N/A	N/A	N/A
Duke University	No	N/A	N/A	N/A
Duquesne University	Co-generated	5	1997	80%
Emory University	N/A	N/A	N/A	N/A
Georgetown University	No	N/A	N/A	N/A
Georgia Institute of Technology	No	N/A	N/A	N/A
Goshen College	No	N/A	N/A	N/A
Harding University	No	N/A	N/A	N/A
Harvard University	No	N/A	N/A	N/A
Howard University	No	N/A	N/A	N/A
Idaho State University	No	N/A	N/A	N/A
Illinois Central College	Co-generated	0.65	1988	30%
Illinois Institute of Technology	Co-generated	8	N/A	N/A
Indiana University – Bloomington	No	N/A	N/A	N/A
Iowa State University	Co-generated	34	1891	75%
James Madison University	No	N/A	N/A	N/A
Johns Hopkins University	No	N/A	N/A	N/A
Kalamazoo College	No	N/A	N/A	N/A
Kansas State University	Co-generated	3.75	1928	1%
Keane State College	No	N/A	N/A	N/A
Kutztown University	No	N/A	N/A	N/A
Lamar University	No	N/A	N/A	N/A
Macallister University	No	N/A	N/A	N/A
Mansfield University	No	N/A	N/A	N/A
Massachusetts Institute of Technology	Co-generated	22	1995	85%
Massachusetts Maritime Academy	No	N/A	N/A	N/A
Medical College of Ohio	Generated	1	N/A	Backup power only
Michigan State University	Co-generated	61	1901	86%
Middle Tennessee State University	Co-generated	5	1998	55%
Middlebury College	Co-generated	0.885	1982	15%
Minnesota State University at Moorhead	No	N/A	N/A	N/A
Montana State University	Co-generated	1	N/A	6%
Mount Holyoke College	Co-generated	0.4	1984	3%

University	Electricity			
	Is Power Generated or Co-generated on Campus?	Total Installed Capacity (MW)	Year Electric Generation Commenced	% of Campus Electrical Load Served
Northeastern Illinois University	Co-generated	3	N/A	80%
Occidental College	Co-generated	0.3	N/A	N/A
Ohio State University	Co-generated	8.125	N/A	N/A
Oklahoma State University	Co-generated	9.5	1950	10%
Pennsylvania State University	Co-generated	6	Early 1900's	7%
Phoenix College	No	N/A	N/A	N/A
Pittsburgh State University	No	N/A	N/A	N/A
Pomona College	No	N/A	N/A	N/A
Purdue University	Co-generated	40	Early 1900's	60%
Reed College	No	N/A	N/A	N/A
Rhode Island College	Co-generated	0.45	1990	40%
Rhode Island School of Design	No	N/A	N/A	N/A
Rochester Institute of Technology	No	N/A	N/A	N/A
Saint Joseph's College	No	N/A	N/A	N/A
Saint Joseph's University	No	N/A	N/A	N/A
San Diego State University	Co-generated	3	N/A	38%
San Jose State University	Co-generated	6	1985	50%
Slippery Rock University	No	N/A	N/A	N/A
Southern Methodist University	No	N/A	N/A	N/A
Southern Oregon University	No	N/A	N/A	N/A
St. Mary's College	No	N/A	N/A	N/A
Stanford University	Co-generated	49.9	1987	100%
State University of New York at Potsdam	No	N/A	N/A	N/A
State University of New York at Stony Brook	Co-generated	45	1996	100%
Swarthmore College	No	N/A	N/A	N/A
Syracuse University	Co-generated	80	1992	All sold to utility
Texas A&M University	Co-generated	37.5	N/A	60%
Texas Tech University	N/A	N/A	N/A	N/A
Thunderbird, The American Graduate School of International Management	No	N/A	N/A	N/A
University of Alaska -- Fairbanks	Co-generated	22	1964	100%
University of Arkansas	No	N/A	N/A	N/A
University of California, Berkeley	Co-generated	30	1986	All sold to utility
University of California, Los Angeles	Co-generated	48	1994	N/A
University of California, Riverside	No	N/A	N/A	N/A
University of California, San Francisco	Co-generated	13.5	1998	76%
University of Central Arkansas	No	N/A	N/A	N/A
University of Colorado at Boulder	Co-generated	16	1992	100%
University of Delaware	No	N/A	N/A	N/A
University of Evansville	Generated	1.1	1997	80%
University of Florida	No	N/A	N/A	N/A
University of Georgia	No	N/A	N/A	N/A
University of Idaho	No	N/A	N/A	N/A
University of Illinois East Campus	Co-generated	20	1993	100%
University of Iowa	Co-generated	21.5	Early 1900's	30%
University of Louisville	No	N/A	N/A	N/A
University of Maryland at College Park	No	N/A	N/A	N/A
University of Massachusetts Amherst	No	N/A	N/A	N/A
University of Memphis	No	N/A	N/A	N/A
University of Miami	No	N/A	N/A	N/A
University of Michigan	Co-generated	48.5	1897	N/A
University of Minnesota Duluth	No	N/A	N/A	N/A
University of Minnesota Minneapolis	Co-generated	16.2	2001	10%
University of Minnesota St. Paul	No	N/A	N/A	N/A
University of Missouri - Columbia	Co-generated	52	N/A	72%
University of Missouri - Kansas City	No	N/A	N/A	N/A

University	Electricity			
	Is Power Generated or Co-generated on Campus?	Total Installed Capacity (MW)	Year Electric Generation Commenced	% of Campus Electrical Load Served
University of New Hampshire	Co-generated	0.5	1986	1%
University of New Mexico	Co-generated	4	1985	15%
University of North Carolina at Chapel Hill	Co-generated	28	1992	35%
University of Northern Colorado	Co-generated	N/A	N/A	All sold to utility
University of Northern Iowa	Co-generated	7.5	1902	40%
University of Pennsylvania	No	N/A	N/A	N/A
University of Pittsburgh	No	N/A	N/A	N/A
University of Rochester	No	N/A	N/A	N/A
University of South Dakota	No	N/A	N/A	N/A
University of Texas at Austin	Co-generated	85	1928	100%
University of Texas at El Paso	No	N/A	N/A	N/A
University of Virginia	No	N/A	N/A	N/A
University of Washington	Co-generated	5	1921	12%
University of Wisconsin at Madison	Co-generated	9.8	1963	20%
University of Wisconsin at Milwaukee	No	N/A	N/A	N/A
University of Wisconsin at Stout	No	N/A	N/A	N/A
Virginia Polytechnic Institute and State University	Co-generated	6.25	1974	N/A
Wellesley College	Co-generated	7.4	1994	100%
Western Michigan University	Co-generated	9.5	1992	N/A
Williams College	Co-generated	0.5	1987	7%
Yale University	Co-generated	22.5	1997	95%
Sum (of institutions reporting data)		**947.715**		

Table 7: Electricity Generation Equipment Detail

University	Type	Size	Quantity
Bucknell University	Solar gas turbine	4.8 MW	1
	Skinner steam turbine	1.2 MW	1
	Total	*6 MW*	2
California Polytechnic State University	Caterpillar gas-fired reciprocating engine	0.35 MW	1
	Total	*0.35 MW*	*1*
California State University, Northridge	Capstone microturbine	0.18 MW	1
	Total	*0.18 MW*	*1*
Central Michigan University	Elliott steam turbine	1 MW	1
	Solar gas turbine	3.4 MW	1
	Total	*4.4 MW*	2
Clemson University	Solar gas turbine	4.8 MW	1
	Solar gas turbine	3.8 MW	1
	Caterpillar diesel internal combustion	0.75 MW	1
	Capstone microturbine	0.03 MW	1
	Total	*9.4 MW*	*4*
Colby College	Elliott backpressure turbine	0.6 MW	1
	Total	*0.6 MW*	*1*
College of New Jersey	Solar gas turbine	5.2 MW	1
	Total	*5.2 MW*	*1*
College of Wooster	Steam turbine	0.375 MW	1
	Total	*0.375 MW*	*1*
Cornell University	Steam turbines	8 MW	?
	Total	*8 MW*	?
Dartmouth University	Dresser Rand steam turbine	2 MW	1
	Dresser Rand steam turbine	2 MW	1
	Dresser Rand steam turbine	3 MW	1
	Total	*7 MW*	*3*
Duquesne University	Solar gas turbine	5 MW	1
	Total	*5 MW*	*1*
Illinois Central College	Caterpillar natural gas-fired reciprocating engine	0.65 MW	1
	Total	*0.65 MW*	*1*
Illinois Institute of Technology	Natural gas-fired combustion turbine	4 MW	2
	Total	*8 MW*	2
Iowa State University	GE steam turbine	3 MW	1
	GE steam turbine	6.25 MW	1
	Turbodyne steam turbine	13.3 MW	1
	Turbodyne steam turbine	11.5 MW	1
	Total	*34 MW*	*1*
Kansas State University	Steam turbine	2.5 MW	1
	Steam turbine	1.25 MW	1
	Total	*3.75 MW*	2
Massachusetts Institute of Technology	ABB combustion turbine	22 MW	1
	Total	*22 MW*	*1*
Michigan State University	DeLaval controlled extraction/condensing steam	12.5 MW	2
	GE backpressure turbine	15 MW	1
	GE controlled extraction/condensing steam	21 MW	1
	Total	*61 MW*	*4*
Middle Tennessee State University	Solar gas turbine	5 MW	1
	Total	*5 MW*	*1*
Middlebury College	Coppus steam turbine	0.085 MW	1
	Coppus steam turbine	0.550 MW	1
	Coppus steam turbine	0.250 MW	1
	Total	*0.885 MW*	*3*
Montana State University	Coppus steam turbine	1 MW	1
	Total	*1 MW*	*1*

University	Type	Size	Quantity
Mount Holyoke College	Allice-Chalmers	0.4 MW	1
	Total	*0.4 MW*	*1*
Northeastern Illinois University	Caterpillar gas engine	0.75 MW	4
	Total	*3 MW*	*4*
Occidental College	N/A	0.15 MW	2
	Total	*0.3 MW*	*2*
Oklahoma State University	Steam turbine	1.5 MW	3
	GE steam turbine	5 MW	1
	Total	*9.5 MW*	*4*
Pennsylvania State University	Elliot steam turbine	2.5 MW	1
	Elliot steam turbine	3.5 MW	1
	Total	*6 MW*	*2*
Purdue University	GE steam turbine	30 MW	1
	GE steam turbine	10 MW	1
	Total	*40 MW*	*2*
Rhode Island College	Garrett gas turbine	0.45 MW	1
	Total	*0.45 MW*	*1*
San Diego State University	Solar Centaur gas turbine	3 MW	1
	Total	*3 MW*	*1*
San Jose State University	Allison Engine gas turbine	6 MW	1
	Total	*6 MW*	*1*
Stanford University	General Electric gas turbine	39.2 MW	1
	Steam turbine	10.7 MW	1
	Total	*49.9 MW*	*2*
State University of New York at Stony Brook	GE LM 6000 gas turbine	45 MW	1
	Total	*45 MW*	*1*
Syracuse University	GE LM 5000 gas turbine	40 MW	2
	Total	*80 MW*	*2*
Texas A&M University	Steam turbine	4 MW	1
	Steam turbine	5 MW	1
	Steam turbine	12.5 MW	1
	Gas turbine	16 MW	1
	Total	*37.5 MW*	*4*
University of Alaska -- Fairbanks	GE steam turbine	4.3 MW	3
	Fairbanks-Morse diesel	9.6 MW	1
	Total	*22 MW*	*4*
University of California, Berkeley	GE LM 2500 gas turbine	25 MW	1
	Terry backpressure steam turbine	5 MW	1
	Total	*30 MW*	*2*
University of California, Los Angeles	Combustion turbine generator	14.5 MW	2
	Steam turbine	19 MW	1
	Total	*48 MW*	*3*
University of California, San Francisco	Solar gas turbine	5 MW	2
	Murray steam turbine	3.5 MW	1
	Total	*13.5 MW*	*3*
University of Colorado at Boulder	Gas turbine	8 MW	2
	Steam generator for power augmentation	0 MW	1
	Total	*16 MW*	*3*
University of Evansville	Cooper gas-driven engine	1.1 MW	1
	Total	*1.1 MW*	*1*
University of Illinois East Campus	Cooper-Bessemer diesel engine	6 MW	2
	Wartsila reciprocating engine	4 MW	2
	Total	*20 MW*	*4*
University of Iowa	Elliott steam turbine	3 MW	1
	Worthington steam turbine	3 MW	1

University	Type	Size	Quantity
	Worthington steam turbine	18 MW	1
	Total	*21.5 MW*	*3*
University of Michigan	Worthington steam turbine	12.5 MW	1
	General Electric steam turbine	4 MW	1
	Worthington steam turbine	12.5 MW	2
	Solar gas turbine	3.5 MW	1
	Solar gas turbine	3.5 MW	1
	Total	*48.5 MW*	*6*
University of Minnesota Minneapolis	Ansaldo back pressure single automatic extraction/exhaust	16.2 MW	1
	Total	*16.2 MW*	*1*
University of Missouri - Columbia	Westinghouse steam turbine generator	6 MW	1
	Worthington steam turbine generator	12 MW	1
	GE steam turbine generator	19.5 MW	1
	Turbodyne steam turbine generator	13 MW	1
	Caterpillar diesel internal combustion	0.5 MW	1
	Caterpillar diesel internal combustion	1 MW	1
	Total	*52 MW*	*6*
University of New Hampshire	Steam turbine	0.5 MW	1
	Total	*0.5 MW*	*1*
University of New Mexico	Solar gas turbine	2.5 MW	1
	Kato backpressure turbine	1.5 MW	1
	Total	*4 MW*	*2*
University of North Carolina at Chapel Hill	Dresser Rand steam turbine	28 MW	1
	Total	*28 MW*	*1*
University of Northern Iowa	Elliott steam turbine	7.5 MW	1
	Total	*7.5 MW*	*1*
University of Texas at Austin	Westinghouse gas turbine	36 MW	1
	Westinghouse gas turbine	15 MW	1
	General Electric steam turbine	25 MW	1
	Westinghouse steam turbine	6 MW	1
	Westinghouse steam turbine	6 MW	1
	Total	*88 MW*	*5*
University of Washington	Worthington steam turbine	5 MW	1
	Total	*5 MW*	*1*
University of Wisconsin at Madison	Murray steam turbine	9.8 MW	1
	Total	*9.8 MW*	*1*
Virginia Polytechnic Institute and State University	Worthington steam turbine	6.25 MW	1
	Total	*6.25 MW*	*1*
Wellesley College	Jenbacher reciprocating engine	1.39 MW	4
	Jenbacher reciprocating engine	1.9 MW	1
	Total	*7.411 MW*	*5*
Western Michigan University	Allison Engine gas turbine	4.75 MW	2
	Total	*9.5 MW*	*2*
Williams College	Coppus steam turbine	0.5 MW	1
	Total	*0.5 MW*	*1*
Yale University	Nova Pinoni gas turbine	6 MW	3
	Mitsubishi diesel engine	1.5 MW	3
	Total	*22.5 MW*	*1*

Table 8: Expansion Projects in Planning Stage -- Heating

University	Heating			
	Are Expansions Planned?	Timing of Expansion	Expansion Capacity Amount	Notes
Dartmouth University	Yes	Unknown	70,000 lbs/hr	Also adding 5,000 feet of steam pipe
Harvard University	Yes	Unknown	Unknown	Expansion of distribution system
Indiana University -- East Campus	Yes	Five years from now	Unknown	Replacement of central heating plant with CHP
James Madison University	Yes	Unknown	Unknown	City-owned plant supplies East Campus; expansion under consideration
Kalamazoo College	Yes	Within two to three years	Unknown	Expansion of distribution system
Keane State College	Yes	Unknown	Unknown	Expansion of central steam plant
Kutztown University	Yes	Unknown	Unknown	Ongoing plans to bring new campus buildings online
Macallister University	Yes	Within five years	400 feet	Expand steam distribution pipe
Pittsburgh State University	Yes	Within five years	Unknown	Expansion of distribution system
Rochester Institute of Technology	Yes	Unknown	Unknown	Plan to merge multiple plants and move to 250 degree hot water loop system
Saint Joseph's University	Yes	Unknown	3,000 feet	Renewal of underground steam pipe being planned
San Diego State University	Yes	Unknown		Waste heat boilers tied to co-generation project
State University of New York at Potsdam	Yes	Unknown	Minus 40,000 lbs/hr	Refurbishing of heating plant; reduction in capacity, see co-generation
Swarthmore College	Yes	Unknown	Unknown	Revamp of existing heating plant and peripheral equipment; no net capacity addition
Syracuse University	Yes	Two to three years from now	Unknown	Expansion of steam distribution
University of California, Berkeley	Yes	Unknown	30,200 lbs/hr	Laboratory extension
University of Delaware	Yes	Unknown	350,000 lbs/hr	Addition of boiler capacity under preliminary planning
University of Georgia	Yes	Unknown	Unknown	Preliminary planning underway with respect to emissions compliance
University of Memphis	Yes	Unknown	Unknown	Actively pursuing move to low pressure boilers
University of Pittsburgh	Yes	Unknown	Unknown	Hooking new or planned campus buildings to distribution network
University of South Dakota	Yes	Unknown	Unknown	Installation of new boiler control systems
University of Wisconsin at Madison	Yes	Unknown	Unknown	Construction of new cogeneration plant in conjunction with local utility is in design phase

Table 9: Expansion Projects in Planning Stage -- Cooling

University	Cooling			
	Are Expansions Planned?	Timing of Expansion	Expansion Capacity Amount	Notes
California Polytechnic State University	Yes	Two years from now	12,000 ton-hours	Chilled water thermal storage will be added
Central Michigan University	Yes	Unknown	Unknown	Extension of the chiller loop is in planning stages
Central Washington University	Yes	Within two years	1,000 tons	Steam absorption chiller as part of larger co-generation project
Columbia University	Yes	Unknown	2,000 tons	Installation of new steam turbine chiller
Dartmouth University	Yes	Unknown	1,600 tons	
Georgetown University	Yes	Unknown	Unknown	Preliminary evaluation of adding additional cooling capacity
Harvard University	Yes	Unknown	Unknown	Expansion of cooling capacity with satellite cooling system
Indiana University -- East Campus	Yes	Unknown	4,000 tons	Expansion of cooling capacity under consideration
Iowa State University	Yes	Three years from now	4,000 tons	Implementation of satellite chilled water plant with corresponding distribution network extensions
Johns Hopkins University	Yes	Unknown	Unknown	Looking at changing out an existing chiller
Kalamazoo College	Yes	Within two to three years	Unknown	Expansion of distribution system
Macallister University	Yes	Within five years	400 feet	Expand cooling distribution pipe
Medical College of Ohio	Yes	Unknown	Unknown	Currently centralizing/looping chilled water system
Middlebury College	Yes	Unknown	Unknown	Preliminary planning underway for central chilled water plant
Ohio State University	Yes	Unknown	Unknown	Addition of cooling capacity in design phase
Oklahoma State University	Yes	Five years from now	4,000 tons	Might add additional chiller capacity
Pennsylvania State University	Yes	Unknown	Unknown	Investigating addition of two more chiller plants
Rhode Island School of Design	Yes	Within two years	300 tons	Campus additions may require additional cooling capacity
Rochester Institute of Technology	Yes	Online in 2004	Unknown	Study underway regarding replacement of existing chillers with new and larger equipment
San Jose State University	Yes	Summer 2003	2,000 tons	Addition of ice storage to cooling system
St. Mary's College	Yes	Unknown	Unknown	Addition of cooling capacity is in process of being funded
State University of New York at Stony Brook	Yes	Unknown	Unknown	Addition of chiller with piping modifications
Swarthmore College	Yes	Within two years	1,200 tons	Electric chiller to be installed
Syracuse University	Yes	Within three years	3,000 tons	Addition of centrifugal chiller
University of Alaska -- Fairbanks	Yes	Unknown	5,000 feet	Proposal to add to distribution systems is under consideration
University of Arkansas	Yes	Unknown	Unknown	Addition of cooling capacity in design phase
University of Central Arkansas	Yes	Unknown	1,200 tons	Providing cooling to new construction planned on campus
University of Idaho	Yes	Three to five years from now	2,000 tons	Addition of a third cooling plant
University of Louisville	Yes	Unknown	4,200 tons	Replacement of two chillers
University of Maryland at College Park	Yes	Unknown	Unknown	Addition of cooling capacity in evaluation phase
University of Memphis	Yes	Within five years	2,800 tons	Addition of two chillers
University of Miami	Yes	Within five years	5,000 tons	Addition of cooling capacity
University of Minnesota Duluth	Yes	Unknown	At least 1,000 tons	Expansion of chilled water capacity
University of Missouri - Kansas City	Yes	Within five years	8,600 tons	Renovation and expansion of chilled water plant

University	Cooling			
	Are Expansions Planned?	Timing of Expansion	Expansion Capacity Amount	Notes
University of Pittsburgh	Yes	Unknown	Unknown	Hooking new or planned campus buildings to distribution network
University of Rochester	Yes	Unknown	Unknown	Addition of cooling capacity in design phase
University of Virginia	Yes	Unknown	Unknown	Addition of cooling capacity in design phase
University of Wisconsin at Madison	Yes	Unknown	50,000 tons	Addition of cooling capacity planned over next twenty years
University of Wisconsin at Stout	Yes	Within five years	2,500 tons	Planning underway for development of central chilled water plant
Virginia Polytechnic Institute and State University	Yes	Unknown	2,200 tons	Replacement of one chiller and addition of another in central cooling plant
Wellesley College	Yes	Two to three years from now	800 tons	Expand cooling capacity
Williams College	Yes	Unknown	2,000 tons	Installation of central chiller

Table 10: Expansion Projects in Planning Stage -- Electricity Generation

University	Electric			
	Are Expansions Planned?	Timing of Expansion	Expansion Capacity Amount	Notes
Central Washington University	Yes	Within two years	5 MW	Discussing actively with public utilities department; hope to have design underway in Spring 2002, and be online Summer 2003
Clemson University	Yes	Unknown	600 kW	Turbine inlet air cooling
Colby College	Yes	Unknown	Unknown	Preliminary planning being done for expansion of co-generation capacity
College of New Jersey	Yes	Year 2006	5 MW	Additional co-generation capacity to be installed
Denison University	Yes	Unknown	Unknown	Co-generation feasibility study underway
Drake University	Yes	Unknown	Unknown	Investigating co-generation for emergency power
Georgetown University	Yes	Unknown	Unknown	Preliminary evaluation of combined heat and power
Idaho State University	Yes	Unknown	Unknown	Co-generation feasibility study underway
Indiana University -- East Campus	Yes	Five years from now	Unknown	Conversion to CHP
Iowa State University	Yes	Five years from now	10 MW	Addition of another turbine generator
Medical College of Ohio	Yes	Unknown	Unknown	Investigating co-generation
Ohio State University	Yes	Unknown	Unknown	Designing backup generation capability
San Diego State University	Yes	Unknown	Unknown	Installation of 2 gas-fired combustion turbines to provide14.4 MW co-generation capability
San Jose State University	Yes	2004	18 MW	RFP out for co-generation expansion
Southern Methodist University	Yes	Unknown	Unknown	Preliminary evaluation of combined heat and power
State University of New York at Potsdam	Yes	Unknown	5 MW	Addition of co-generation capability, still in design phase
University of Arkansas	Yes	Unknown	Unknown	Improved metering of energy usage under design
University of Delaware	Yes	Within two years	10.8 MW	Power will be generated across two locations using natural gas firing
University of New Hampshire	Yes	Three years from now	10 MW	Feasibility study of co-generation expansion underway
University of Rochester	Yes	Unknown	Unknown	In design phase
University of Texas at Austin	Yes	Unknown	25 MW	Expanding co-generation capacity with a new steam turbine; additional scope of work involves upgrading electrical substation to 100 MVA and replacing cooling tower with one that can handle flow of 61,680 GPM
University of Wisconsin at Madison	Yes	Unknown	Unknown	Construction of new cogeneration plant in conjunction with local utility is in design phase

Table 11: Expansion Projects in Construction Stage -- Heating

University	Heating			
	Are Expansions in Progress?	Timing of Expansion	Expansion Capacity Amount	Notes
Pomona College	Yes	Within one year	Unknown	Taking central steam plant offline, moving to standalone boilers
Slippery Rock University	Yes	Unknown	Unknown	Construction of new smokestack, improvements to coal handling facilities, and conversion of a boiler to gas firing
University of California, San Francisco New Mission Bay Campus	Yes	Ongoing over 10 year period	Unknown	New Mission Bay campus being built; project will be underway for next ten years
University of Idaho	Yes	Within one year	55,000 lbs/hr	Refurbishing of an out-of-service Babcock & Wilcox natural gas-fired boiler which will be brought back on to the system
University of Iowa	Yes	Unknown	Unknown	Refurbishing of boiler currently underway
Williams College	Yes	Unknown	70,000 lbs/hr	Replacement of boiler in conjunction with co-generation
Yale University	Yes	Unknown	Unknown	Installation of new boilers in medical school plant

Table 12: Expansion Projects in Construction Stage -- Cooling

University	Cooling: Are Expansions in Progress?	Cooling: Timing of Expansion	Cooling: Expansion Capacity Amount	Cooling: Notes
Arizona State University West Campus	Yes	Within one year	1,000 tons	Also adding 1 million gallons thermal storage; 800 ft distribution pipe
Central Washington University	Yes	Within one year	1,500 feet	Expanding cooling distribution pipe system
College of New Jersey	Yes	Within one year	2,000 tons	Installing 2 York centrifugal chillers to replace existing capacity
Duke University	Yes	Unknown	Unknown	Addition of cooling capacity
Harding University	Yes		200 tons	Part of dormitory project
Illinois Central College	Yes	Unknown	900 tons	Addition of cooling capacity
Pennsylvania State University	Yes		10-15,000 tons	Beginning to install central cooling plant and associated distribution piping
Southern Methodist University	Yes	Unknown	Unknown	Expansion of cooling capacity and distribution pipe system
University of California, Riverside	Yes	Unknown	2,700,000 gallons	Addition of a second thermal storage tank
University of California, San Francisco	Yes	Within one year	3,600 tons	Two 1,200 ton steam absorbtion chillers and one 1,200 ton electric chiller will be online within one year
University of California, San Francisco New Mission Bay Campus	Yes	Ongoing over 10 year period	6,000 tons	Chiller plant is under construction; construction will occur in multiple phases
University of Delaware	Yes	Unknown	3,400 tons	Addition of one steam absorption and two electric chillers
University of Missouri - Columbia	Yes	Unknown	Unknown	Addition of cooling capacity
University of New Mexico	Yes	Within one year	12,000 tons	Consolidate and expand cooling capacity at main chiller plant
University of North Carolina at Chapel Hill	Yes	Unknown	Unknown	Addition of cooling capacity
Yale University	Yes	Unknown	Unknown	Installation of new chillers in medical school plant

Table 13: Expansion Projects in Construction Stage -- Electricity Generation

University	Electric			
	Are Expansions in Progress?	Timing of Expansion	Expansion Capacity Amount	Notes
University of California, San Francisco New Mission Bay Campus	Yes	Ongoing over 10 year period		New Mission Bay campus being built; project will be underway for next ten years
University of Maryland at College Park	Yes	Within one to two years	26 MW	Installing co-generation capability with two GE gas turbines, 11 MW each, and one backpressure turbine at 6 MW
University of Missouri - Columbia	Yes	Unknown	Unknown	Installation of additional co-generation capacity
Williams College	Yes	Unknown	3 MW	Co-generation in conjunction with boiler replacement project