Erin Rupp
Environmental State of the College Report
ES Senior Seminar
Spring 2004

# Heating and Cooling

At Macalester College, located in St. Paul, annual temperatures can fluctuate by over one hundred degrees. Thus, strategies to heat and cool the campus efficiently are essential to minimize economic and environmental costs.

**Central Heating and Cooling System**

The current heating and cooling system is a central heating/ventilation/air conditioning (HVAC) system located under the Fine Arts complex. Almost all of the campus buildings are connected to the HVAC, with the exception of the current fieldhouse (which has electric heating and cooling) and the buildings on the west side of Macalester street, south of Grand, including 77 Mac (which have self controlled systems).

The Facilities Management website has a good description of the heating and cooling system:

> "[Macalester has a] central steam water plant, central chiller plant, energy management and heating ventilation air conditioning (HVAC). Located underneath the Art building, the central high pressure steam plant supplies steam and hot water to 26 campus buildings and 11 privately and college owned houses. Plant operations typically run from September through May. Constructed during 1996-97, the subterranean chilled water plant lies just north of the Art building and supplies chilled water to 13 campus buildings through the use of centrifugal chillers and ice storage. Macalester's energy management system resides in the central plant controlling HVAC operations in campus buildings through the use of computerized controls operating both pneumatic and direct digital control equipment (Facilities Management website)."

We have three boilers on campus, two smaller ones, and one larger, which heat the condensate that warms the campus. On February 26, 2004, when I toured the boiler, we were only using one, because the weather was warm. On really cold days, we use the two smaller boilers, or the bigger one. To my knowledge, we never use all three.

**Fuel Use**

To heat and cool the water that circles through the system, Macalester uses three different fuels, #2 fuel oil, #6 fuel oil, and natural gas, all purchased from Xcel Energy. Cost and season determine which fuel we burn. Our boiler has a hard time running oil at a lower level (which is necessitated by higher temperatures), so when the weather is warm, we burn natural gas, while during the winter months (usually November, December, January, February), cost determines which fuel is burnt. Natural gas is the environmentally preferable fuel, as it is the most efficient and emits the fewest pollutants, but it is often the most expensive. #6 fuel oil is a residual product of crude oil. It is the consistency of street tar. #2 fuel oil is a distillate; it is distilled during primary crude oil refining. In terms of both emissions and efficiency, # 2 fuel oil is better than #6.

Currently, as of March 23, 2004, we are burning 100% natural gas, because the weather has gotten warmer. In the colder months of this year, Macalester burned 100% #6 fuel oil. The amount of each fuel burned fluctuates yearly with the weather, but generally follows the same pattern as the current academic year.

Historically, Macalester has used more of, and has spent more money on, natural gas than either #6 or #2 fuel oil, as evidenced by the following graphs, Figures 1 and 2.

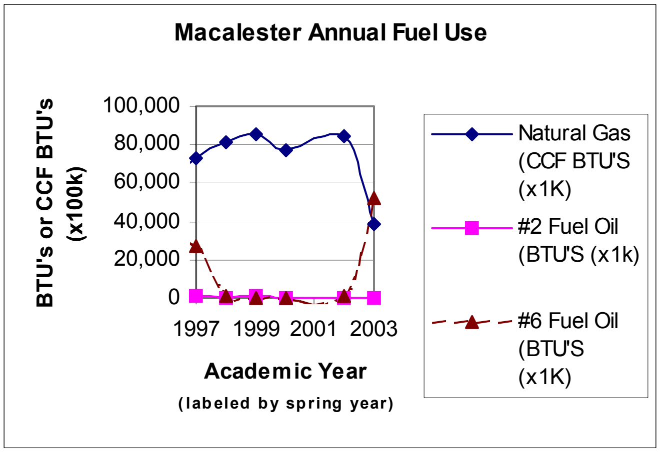


Figure 1

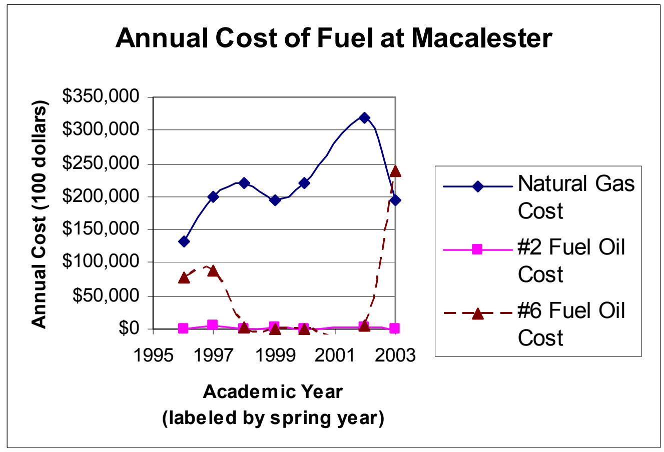


Figure 2

However, as illustrated above, during the 2002-2003 academic year, the college used more #6 oil than natural gas (52,392,450 BTU's of #6 vs. 38,942,000 CCF BTU's, each x1000). This trend has continued during the current school year. The reason for the switch is the current high cost of natural gas.

Based on calculations by MacCARES, burning this much #6 releases 3,044,465 pounds of carbon dioxide into the air annually. However, carbon dioxide is not the only pollutant of #6 fuel oil. #6 is the highest emitter of the three fuels in sulfur oxides, nitrogen oxides, and methane.

**BTU Consumption**

Macalester's annual BTU consumption has, since 1988, been gradually decreasing, despite the addition or renovation of several buildings, including the Campus Center, Kagin, and Olin Rice. (See Appendix 1 for complete list of building renovations since 1985.) Figure 3 illustrates Macalester's annual BTU consumption. Campus consumption has remained relatively constant, with highs and lows due to campus renovations that take buildings on and off line.

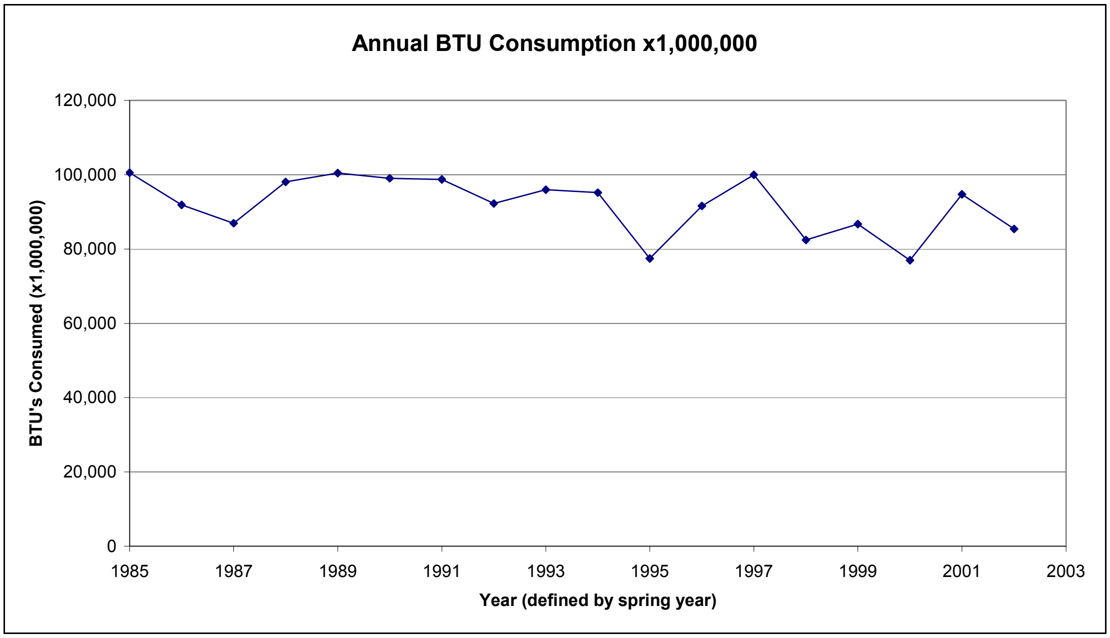


Figure 3

Currently, as of January 2002, all of campus building are on-line. However, BTU consumption has been decreasing since 2002, and the current academic year follows this trend. This decline can be attributed to the use of energy saving technologies in new buildings, like Kagin Commons and the Student Union. A more in depth look at these technologies is beyond the scope of this audit, but is recommended for future audits.

Macalester's annual BTU consumption per square foot has shown a more remarkable decline. Although the campus's square footage has increased slightly since 1985 with the addition and renovation of several buildings mentioned earlier, the efficiency with which this area is heated and cooled has increased. Figure 4 illustrates BTU consumption per square foot.

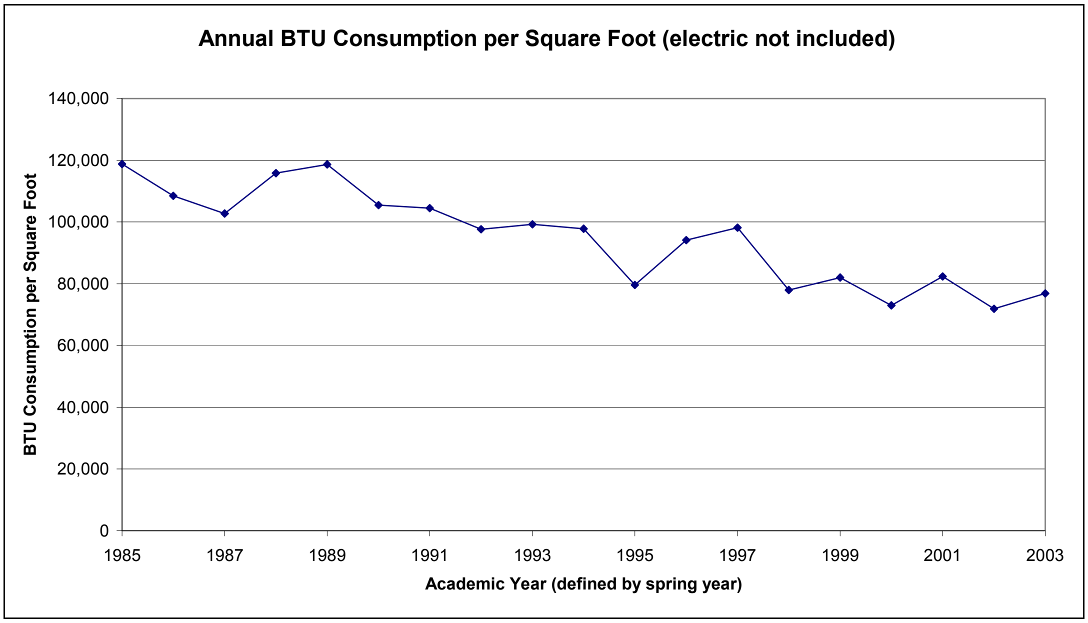


Figure 4

Again, this decline is due to the more efficient technologies used in the recent construction of campus buildings.

Despite these decreases, the total cost of BTUs at Macalester has gone up since 1985 (See Figure 5).

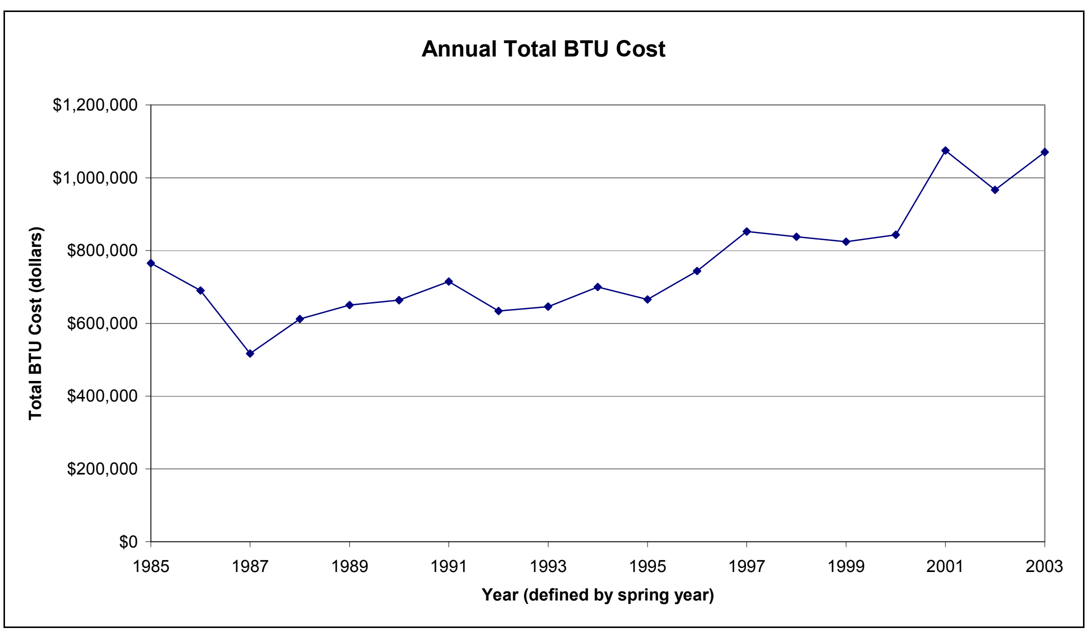


Figure 5

However, annual BTU cost is an indicator of the current energy market, not of the amount of energy that the campus is consuming. It is therefore extremely important in budget considerations; energy saving techniques become increasingly more cost effective as energy prices rise.

**Rebates**

Since 1994, Macalester has received $553,207.03 in rebates from Xcel Energy. Most of these are small rebates given for electrical reasons, but more than half of the total money received, $352,527.88, has gone toward heating and cooling improvements.

A number of these rebates were given due to the size and flexibility in our system. Xcel provides disproportionately more electricity during the day than at night. Macalester received a rebate in December of 1996 ($200,000 on $3.5 mil project) to build ice storage and an ice chiller, which made it possible for Macalester to produce ice at night, therefore reducing Xcel's energy demand during the day. The college receives reduced fuel rates for running the chiller at night. In addition, chilling water at night is more energy efficient, because the temperature difference between the air and ice is less. The chiller provides the campus with air conditioning.

Macalester also has an agreement with Xcel to keep its natural gas use below a certain level during peak fuel usage times, like early evening, in exchange for discounted natural gas prices. This "peak control system" is most used in the summer. Xcel has the capacity to pump only so much natural gas into lines at one time. During peak use times, the gas is drained too quickly from the pipes, making the pipe pressure dangerously low. At these times, Xcel asks the college to reduce its energy use, which it does.

**Campus Energy Saving Strategies**

One of the main energy saving measures that the college takes is to turn off the condensate pumped to academic buildings at night. Individual radiators are used to maintain temperature. The amount of time that each building is off the system varies from building to building.

Macalester's three main boilers, which provide steam for heating and steam for hot water, are shut off in the summer, from Commencement to September or October. Individual hot water heaters are maintained in all buildings.

Macalester Facilities Management maintains an Energy Committee, a group that has been meeting on and off for the past ten years, to focus on making the HVAC and campus electric systems more efficient. The committee has been meeting regularly for the past four months. It consists of Mark Dickinson: Director, Mike O'Connor: Chief Engineer, Kevin Maynard: Mechanical Systems Manager, and Ed Gerten: Master Electrician.

**Campus Buildings**

Campus buildings require different amounts of condensate to maintain a comfortable temperature, based on their size and function. Olin Rice has the highest level of condensate consumption, using twenty-five percent of the campus's condensate (Figure 6). Of the dorms, the highest condensate consumer is Dupre, using about nine percent of total condensate consumption.

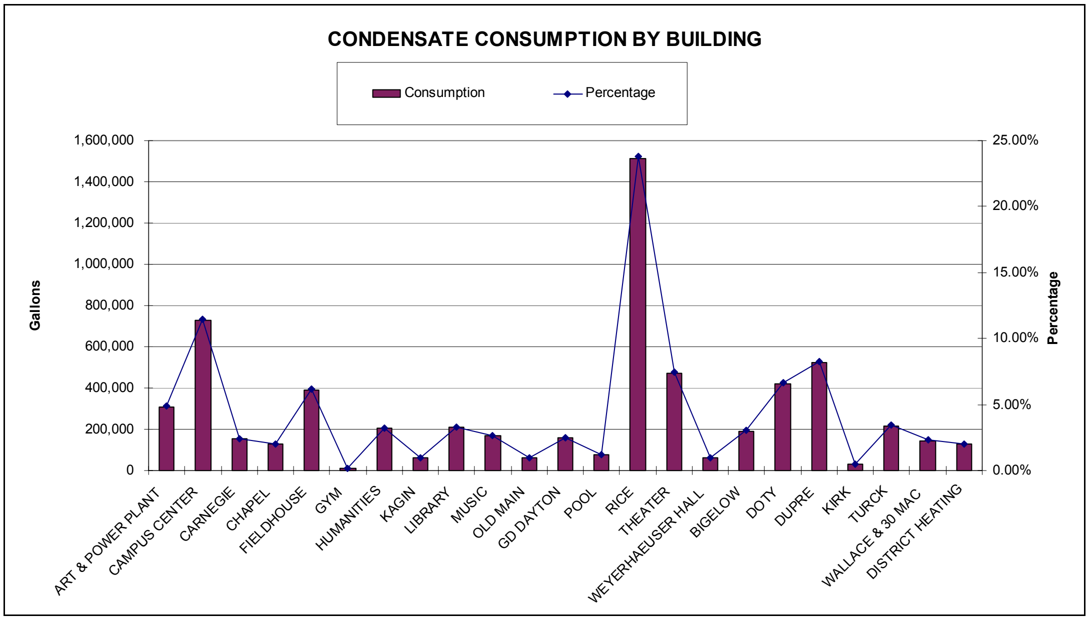


Figure 6

The reason for the discrepancy among buildings in terms of condensate use is in part because different buildings are used for different things. In terms of dorms, the difference in condensate use is directly correlated with the number of residents (See Figure 7).

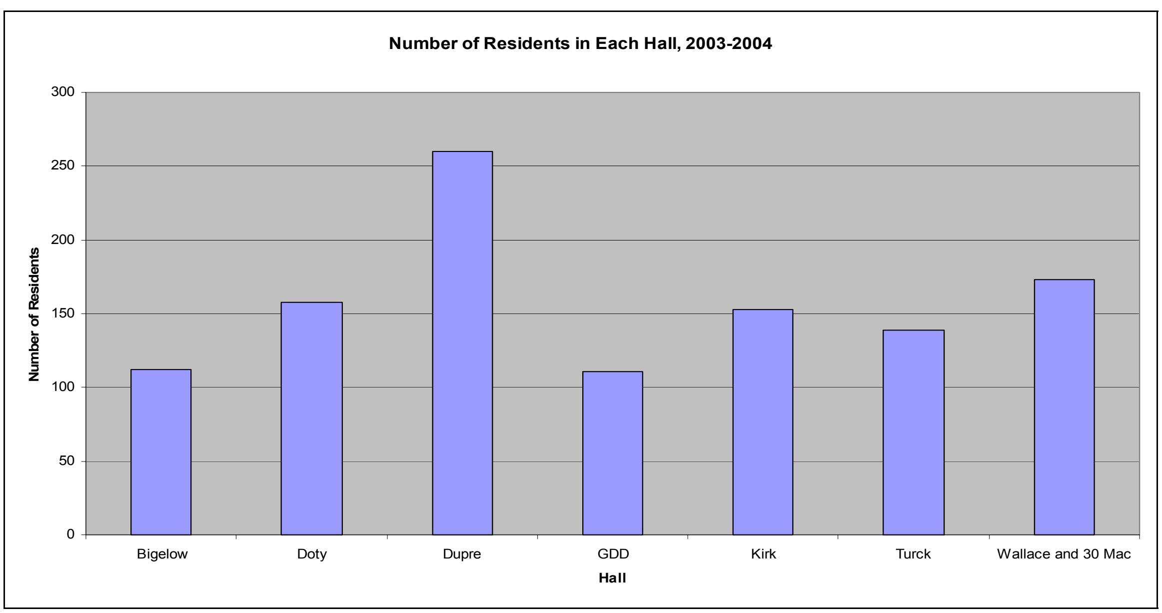


Figure 7
(http://www.macalester.edu/reslife/halls.html)

**Data Gaps**

Individual building efficiency in terms of heating and cooling is extremely important. An in-depth assessment of individual buildings needs to be done in order to assure building efficiency. The level of assessment necessary is beyond the scope of this audit.

**Macalester's Heating and Cooling Ranking: C**

This audit provides a basic overview of the Macalester heating and cooling system. Based on the assessment done, the efficiency of the heating and cooling system at Macalester is good. An in depth look at individual building efficiency is required for a better understanding of the overall system efficiency.

Fuel choice on campus is average. #6 fuel oil is one of the dirtiest fuels on the market, and we burn more of it than natural gas, but for a shorter amount of time. Natural gas is the fuel of choice for, on average, 5 out of 9 months of the year. Considering both efficiency of the system and emissions linked to fuel choice, the college receives a C for the heating and cooling system. In order to receive a very good or excellent rating, the college needs to take a more proactive stance to decreasing emissions.

**Other Schools**

Other colleges and organizations have implemented more sustainable heating and cooling systems into their campus buildings. The Adam Joseph Lewis Center for Environmental Studies at Oberlin College in Oberlin, OH provides the heating and cooling needs for the building with geothermal wells and heat pumps. The pumps are powered with solar power.

Carnegie Mellon University also has incorporated sustainable technologies into its heating and cooling system. It recently built/ retrofitted the "Intelligent workplace."

They have a HVAC system as we do. The University wanted to develop improvements to health and well-being of building occupants, technological adaptability, organizational flexibility, and energy and environmental effectiveness. One feature is the use of natural light and the ability to control natural light with light redirection louvers, and metal shades (Wright, 1998.)

The MIT Cogeneration Project is a ten-year project that is underway to generate electrical and thermal power for the Massachusetts Institute of Technology. Cogeneration involves placing a turbine in the smokestack of a boiler, which utilizes waste heat to create steam. The new technology is eighteen percent more efficient than the old, and will reduce MIT emissions by forty-five percent. Current work is involved with connecting the Project with academic departments for mutual benefit. (http://cogen.mit.edu/).

An obvious close to home example, although not a college campus, is the Phillips Eco-Enterprise Center in Minneapolis. A geothermal exchange heat pump system similar to Oberlin's provides a majority of heating and cooling needs.

**Future Improvements**

Future improvements for the heating and cooling system at Macalester should take a number of directions. Burning number 6 fuel oil is an environmental problem for our campus, and efforts to decrease and eventually stop burning such dirty fuel are necessary. Ratifying the Kyoto protocol, as the campus organization MacCARES suggests, is an important first step. The Kyoto protocol involves decreasing Macalester's emissions to seven percent below the 1990 level. Most of this reduction is in electric use, as electricity is a much larger contributor to carbon dioxide emissions than is heating and cooling. However, #6 fuel oil is the highest emitter of carbon dioxide of the three fuels that Macalester burns, and 3,044,465 pounds of $CO_2$ are released into the air annually as a result of Macalester's burning of it. Considering cogeneration as an option for our campus, as MIT is doing, would be a great initial step in reducing $CO_2$ emissions.

This audit assesses the heating and cooling of the campus as a whole, with individual building use compared but not analyzed. Although individual building efficiency was not assessed, improvements should be made on the scale of individual buildings in heating and cooling efficiency. In order to determine what these improvements need to be, a recommissioner ought to be hired to assess each building and target areas that need to be improved.

With plans to rebuild the fieldhouse in the near future, green building design should be taken into account to minimize the heating and cooling energy needed to keep the building at a comfortable temperature. Although other methods of heating and cooling should be explored, including solar thermal and geothermal, the fieldhouse is outfitted with pipes to connect it to the HVAC.

## Thanks To

Kevin Maynard, Mechanical Systems Manager
Mike O'Connor, Chief Engineer
Bev Johnson, Facilities Management Office Manager and Assistant to the Director
Richard Graves, MacCARES

## Bibliography

Energy Consultancy Services. "Burning Residual Fuel Oil: Characteristics of No.6 (Residual) Fuel Oil." http://energyconcepts.tripod.com/energyconcepts/heavy_oil.htm.

"Facilities Management Heating Plant Crew on Campus" www.macalester.edu/facilities/HP.htm.

Graves, Richard. Personal Interview. March 25, 2004

MIT cogeneration project: http://cogen.mit.edu/.

Oberlin College. "Adam Joseph Lewis Center for Environmental Studies, Heating, Cooling, and Ventilation." 2003. www.oberlin.edu/envs/ajlc/Systems/Hvac/HvacIndex.htm.

O'Connor, Michael. Personal Interview. February 26, 2004.

Wright, Gordon. “Refining systems integration: Carnegie Mellon University's 'Intelligent Workplace' develops methods of increasing building efficiency and occupant productivity.” *Building Design & Construction*. May 1998 v39 n5 p70(3) .

APPENDIX 1. PAST DATA

| YEAR | ACTUAL HEATING DEGREE DAYS | BTUs CONSUMED x1,000,000 | TOTAL FUEL COST | FUEL COST per 100k BTU | KWH CONSUMED | TOTAL ELECTRIC COST | ELECT COST per KWH | TOTAL SQUARE FEET | TOTAL BTU CONSUM (x1000k) | TOTAL BTU COST | BTU CONSUMP per FOOT | COST per x1000k BTUs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 84-85 | 7,632 | 100,514 | $401,058 | 0.3990 | 8,767,200 | $364,038 | 0.042 | 846,365 | 130,428 | $765,096 | 154,103 | $5.8661 |
| 85-86 | 7,852 | 91,852 | $328,917 | 0.3581 | 8,611,200 | $361,161 | 0.042 | 846,365 | 121,233 | $690,078 | 143,240 | $5.6921 |
| 86-87 | 6,238 | 86,956 | $186,058 | 0.2140 | 8,407,200 | $330,664 | 0.039 | 846,365 | 115,641 | $516,722 | 136,633 | $4.4683 |
| 87-88 | 7,138 | 98,071 | $235,637 | 0.2403 | 8,894,600 | $376,025 | 0.042 | 846,865 | 128,419 | $611,662 | 151,641 | $4.7630 |
| 88-89 (1) | 7,817 | 100,426 | $231,792 | 0.2308 | 9,900,000 | $418,470 | 0.042 | 846,365 | 134,205 | $650,262 | 158,566 | $4.8453 |
| 89-90 (2) | 8,181 | 99,062 | $232,017 | 0.2342 | 9,614,400 | $431,765 | 0.045 | 938,865 | 131,866 | $663,782 | 140,453 | $5.0337 |
| 90-91 (3) | 7,795 | 98,739 | $251,671 | 0.2549 | 10,459,200 | $463,053 | 0.044 | 944,865 | 134,426 | $714,724 | 142,270 | $5.3169 |
| 91-92 | 7,915 | 92,268 | $159,770 | 0.1732 | 10,699,200 | $473,973 | 0.044 | 944,865 | 128,774 | $633,743 | 136,288 | $4.9214 |
| 92-93 (4) | 7,296 | 95,977 | $165,834 | 0.1728 | 10,420,800 | $480,192 | 0.044 | 966,865 | 131,533 | $646,026 | 136,040 | $4.9115 |
| 93-94 (5) | 7,098 | 85,173 | $212,107 | 0.2490 | 10,384,173 | $487,722 | 0.047 | 972,865 | 120,604 | $699,829 | 123,968 | $5.8027 |
| 94-95 | 6,139 | 77,444 | $155,667 | 0.2010 | 10,454,200 | $509,883 | 0.049 | 972,865 | 113,114 | $665,550 | 116,269 | $5.8839 |
| 95-96 (6) | 7,921 | 91,589 | $211,776 | 0.2312 | 10,836,825 | $531,951 | 0.049 | 972,865 | 128,564 | $743,726 | 132,149 | $5.7849 |
| 96-97 (7) | 7,297 | 99,991 | $293,146 | 0.2932 | 11,983,679 | $559,179 | 0.047 | 1,018,615 | 140,879 | $852,326 | 139,404 | $5.8647 |
| 97-98 (8) | 6,589 | 82,412 | $223,642 | 0.2714 | 12,782,400 | $613,894 | 0.048 | 1,056,615 | 126,026 | $837,536 | 119,273 | $6.6458 |
| 98-99 | 6,788 | 86,690 | $197,453 | 0.2278 | 12,972,000 | $626,697 | 0.048 | 1,056,615 | 130,950 | $824,150 | 123,934 | $6.2936 |
| 99-00 (9) | 6,669 | 76,959 | $221,394 | 0.2877 | 12,117,600 | $621,699 | 0.051 | 1,053,903 | 118,370 | $843,093 | 112,316 | $7.1225 |
| 00-01 (10) | 7,959 | 94,701 | $506,962 | 0.5353 | 11,611,968 | $567,550 | 0.049 | 1,149,717 | 134,321 | $1,074,512 | 116,830 | $7.9996 |
| 01-02 (11) | 6,681 | 85,416 | $326,532 | 0.3823 | 12,739,200 | $640,022 | 0.050 | 1,187,717 | 128,882 | $966,554 | 108,513 | $7.4995 |
| 02-03 | 7,787 | 91,334 | $432,450 | 0.4735 | 13,257,600 | $637,914 | 0.048 | 1,187,717 | 136,569 | $1,070,364 | 114,984 | $7.8375 |

**1. Library built and on line.**
**2. Weyerhaeuser Hall renovated--a/c added.**
**3. Carnegie Hall renovated--a/c added along with more usable area.**
**4. Humanities renovated--additional space and a/c.**
**5. Old Main renovated-additional space and a/c.**
**6. Rice renovation under way--construction heat throughout the year.**
**7. Rice operational with new mechanical systems, Olin's construction heat supplied by gas kiln meter--not reflected in this report.**
**8. New Residence Hall put on-line in August 1997. Additional 38,000 square feet of area. First air conditioned residence hall.**
**9. Old Dayton Hall and Student Union torn down summer of 1999. Temporary heat for Campus Center Construction.**
**10. Kagin taken out of operation during January 2001. Campus Center comes on line in January.**
**11. Kagin comes back on line January 2002.**