University of Minnesota Crookston Campus

Energy Audit

02-13-09

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1. Executive Summary

McKinstry was commissioned by the University of Minnesota Crookston to perform an analysis of their campus energy use and develop options for reducing their operational expenditures. This analysis consisted of four components:

1. An analysis of the campus coal and electric use.
2. Identification of Facility Improvement Measures (FIMs) to reduce energy consumption
3. Development of a plan for energy education and awareness on campus
4. A plan for actively managing energy on campus.

The analysis of campus energy demand consisted of an energy use audit of the University's buildings and a thorough review of the heating plant records of coal use and steam production. There is an apparent level of inaccuracy in the existing recording systems as the overall efficiency of the coal plant approaches 85% combustion efficiency. This is an unusually high efficiency value for a solid fuel heating plant. Campus energy use on a per square foot basis is higher than the average regional campus energy use but the cost per square foot is lower. The use of coal as a primary fuel is chiefly responsible for both conditions.

Electrical service to the campus is provided by Ottertail Power Company and presents opportunities for alternative supply methodology as well as overall electrical use reduction within the campus. On the electrical side both conservation and renewable generation, primarily in the form of a large scale wind turbine, are goals that should be addressed.

Energy analysis and site visits resulted in the development of thirteen (13) Facility Improvement Measures. A few of the improvement measures are different options for improving the same systems. As an example, converting to biomass fuels instead of coal cannot be combined with a conversion to low pressure steam operation. The selection of either will preclude the University from being able to implement the other.

This analysis of campus energy also incorporated a plan for energy education and awareness, and a plan for actively managing energy on campus. The education and awareness plan will provide a means to help educate energy users regarding the different types of energy being used on campus,and the impact that each of them have on the environment. Additionally, it will help support the University's mission of education and research by providing access to real time and historical data regarding the campus energy consumption and supply scenarios. The plan for actively managing energy on campus will provide a means for monitoring and controlling energy consumption in a proactive manner. Actively managing the University's energy production and consumption will help to ensure that the gains made by implementing Facility Improvement Measures are not temporary, and will help to make them permanent.

2. Energy Audit

2.1 Introduction

McKinstry Co. was asked to perform a preliminary Energy Audit on the University of Minnesota Crookston Campus by the Department of Buildings and Grounds. The purpose of this audit is to:

- Identify potential energy saving opportunities on the campus.
- Quantify the energy-saving potential of those opportunities
- Identify the Facility Improvement Measures (FIMs) necessary to achieve desired energy savings
- Determine the Rough Order of Magnitude (ROM) costs for the recommended FIMS.

2.2 Energy Audit Methodology

The data presented in this report was developed from the following sources:

- Site visits
- Review of Coal use and Steam production data provided by UMC Heating Plant Staff
- Coal analysis data provided by Minnesota Valley Testing Laboratories
- Review of Electrical data derived from Ottertail Power Company's Power Profiler software
- Review of Water and Sewer data from the City of Crookston

2.3 Site Visits

Multiple site visits occurred between the months of December, 2008 February, 2009 to identify Facility Improvement Measures and begin the inventory process of the various components of the Facility Improvement Measures. Site visits included observation of equipment operation, review of energy system distribution infrastructure and discussion with UMC Maintenance and Operation Staff.

2.4 Energy Consumption Overview

Utility information was provided by UMC staff, Ottertail Power Company and the City of Crookston. This information was further consolidated and is presented below for the May, 2007 through April, 2008 season.

UM Crookston Data 540,691 Gross Square Feet
May-07 to Apr-08

Month	Coal Used (tons)	Coal Used (lbs)	Steam (lbs)	kWh	Elec $	Coal Cost (55$/ton)	Total Cost
May-07	56.2	112,400	638,000	538,896	$33,527.46	$3,091.00	$36,618.46
Jun-07	0	0	0	490,917	$31,026.60	$0.00	$31,026.60
Jul-07	0	0	0	590,232	$32,321.84	$0.00	$32,321.84
Aug-07	35.3	70,600	271,100	566,120	$30,825.91	$1,941.50	$32,767.41
Sep-07	141.2	282,400	1,570,000	603,714	$33,966.96	$7,766.00	$41,732.96
Oct-07	275.3	550,600	3,138,000	472,005	$25,770.44	$15,141.50	$40,911.94
Nov-07	390.2	780,400	5,306,000	603,559	$29,364.88	$21,461.00	$50,825.88
Dec-07	534.3	1,068,600	7,869,000	684,740	$33,398.81	$29,386.50	$62,785.31
Jan-08	561.2	1,122,400	8,126,000	539,503	$33,305.92	$30,866.00	$64,171.92
Feb-08	523.6	1,047,200	7,781,000	705,736	$51,076.56	$28,798.00	$79,874.56
Mar-08	430.3	860,600	6,382,000	660,526	$43,280.31	$23,666.50	$66,946.81
Apr-08	318.3	636,600	4,141,000	655,364	$36,696.50	$17,506.50	$54,203.00
	3,266	**6,531,800**	**45,222,100**	**7,111,312**	**$414,562**	**$179,625**	**$594,186.69**

157,659 Btu/GSF

$1.10 per GSF

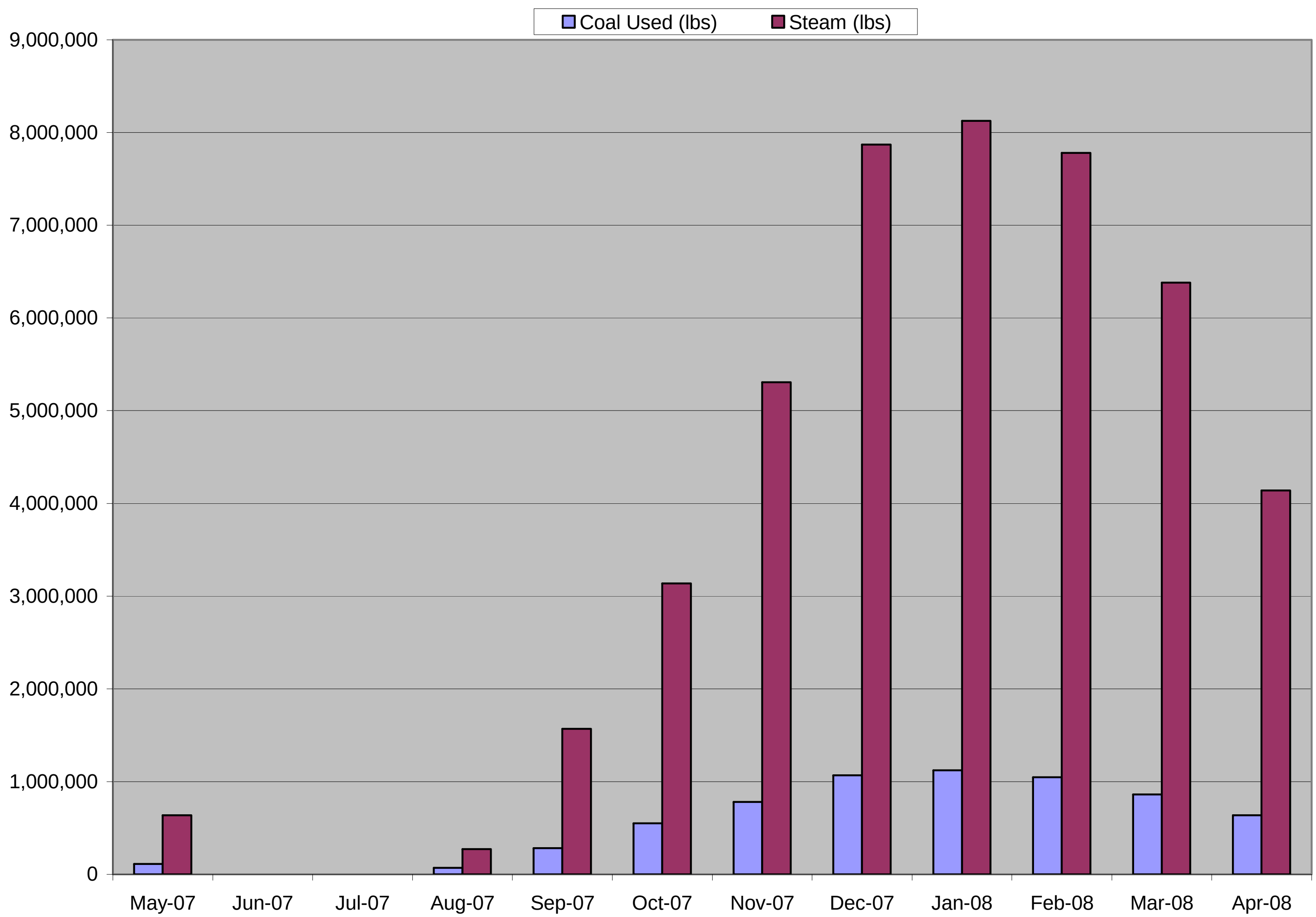
*Used Coal Data for BTU's
9336 BTU's/lb

Once this data was consolidated further analysis allowed us to compare UMC's Btu/Gross Square Foot (GSF) with that of other campuses on a regional basis. Based on the database average of 132,200 Btu/ GSF, UMC is slightly above average at 157,659 Btu/GSF when compared to other campuses.

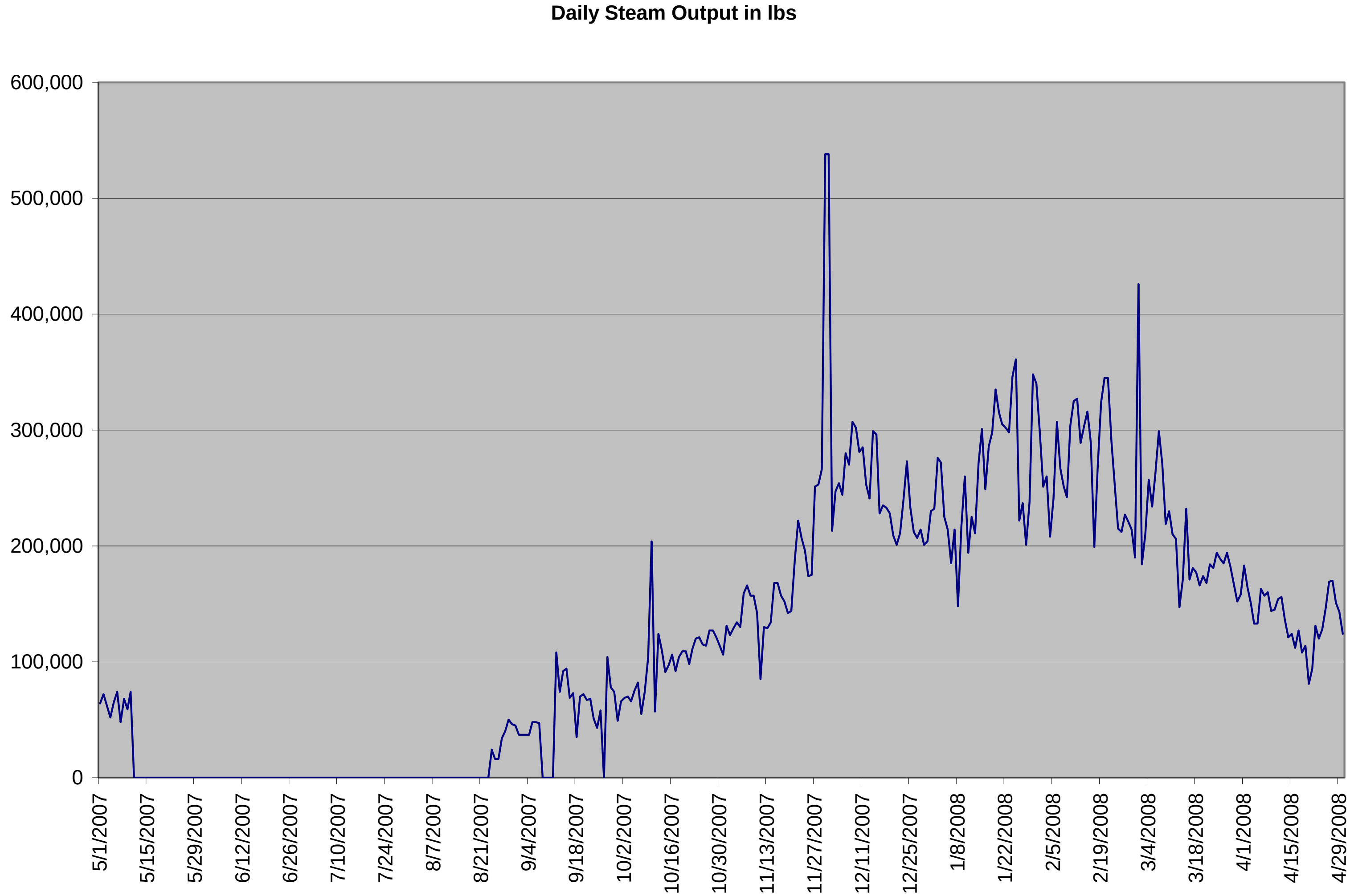
The following charts demonstrate the utility consumption over the 12 month period identified.

2.5 Data Charts

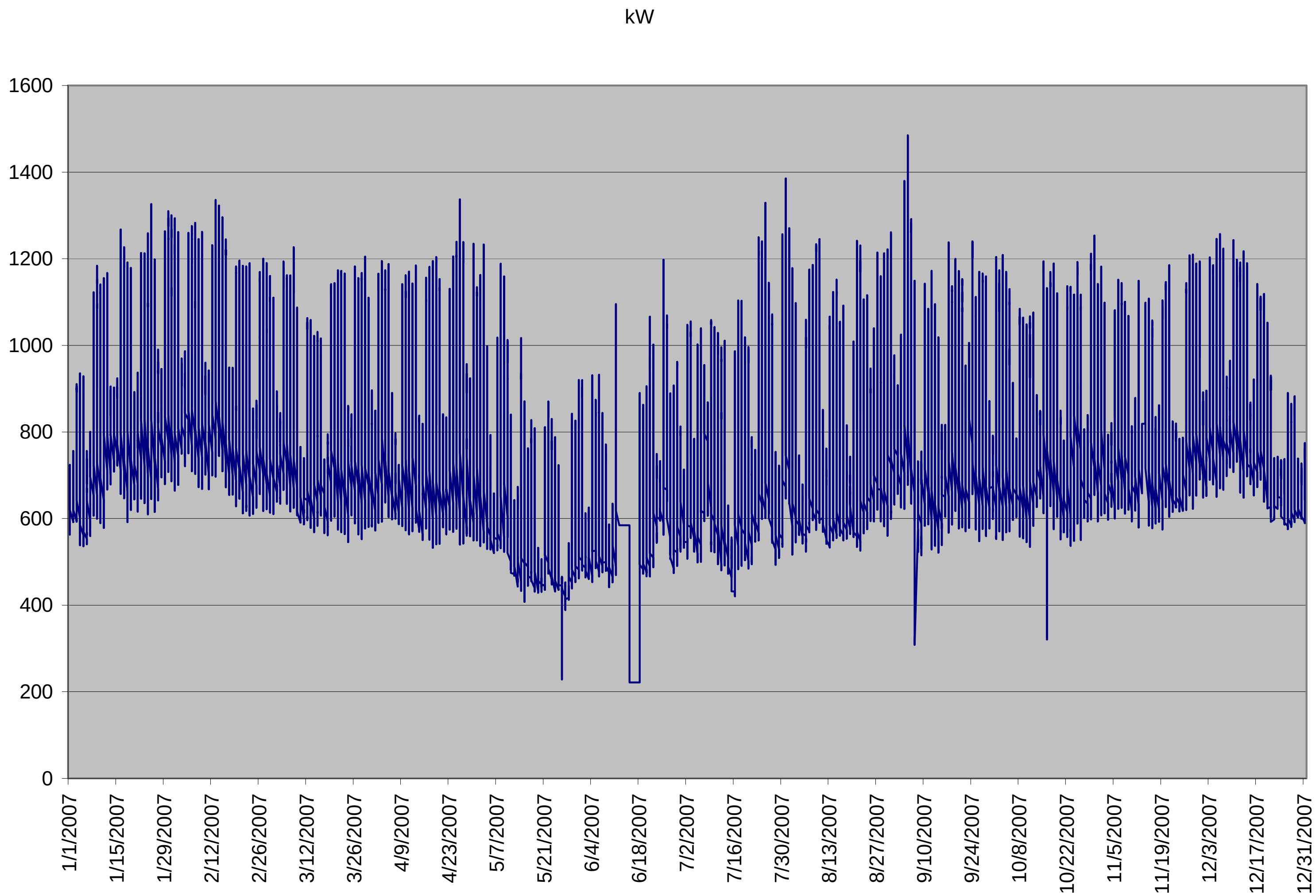
Coal consumed and Steam produced



Steam flow daily load data



Electrical Consumption



Based on the site visit information gathered and the utility analysis presented above, additional energy savings can be achieved by implementing specific Facility Improvement Measures (FIMs.)

2.6 Existing Conditions Summary

Facility Improvement Measures

The following FIMs have been identified as having the most potential for reducing energy use, improving building performance and generally upgrading the facilities at the University of Minnesota Crookston Campus. This list is followed by a discussion on the existing conditions, followed by detailed information on each measure.

FIMs

- Coal to Biomass Conversion of Existing Coal-Fired Boiler
- Natural Gas Supply System for Cleaver Brooks Boiler
- Conversion from High Pressure to Low Pressure Operation
- HVAC Equipment Upgrades
- Building Envelope Improvements
- Air Conditioning Improvements
- DDC Upgrades
- Lighting System Upgrades
- Computer Maintenance Management System
- Wind Turbine Generator
- Water Efficiency Improvements
- Lab Hood Control
- Kitchen Exhaust and Make up air Improvements
- Solar Wall Applications

Existing Conditions

1. Coal to Biomass Conversion of Existing Coal-Fired Boiler
    a. The average annual coal consumption is 3,266 tons and results in a carbon output of 6,209 metric tons.
    b. Although converting the existing coal-fired boiler to biomass – most likely wood chips would not reduce energy cost it would profoundly impact the carbon footprint of the campus as burning biomass is a carbon-neutral activity.

2. Natural Gas Supply System for Cleaver Brooks Boiler
    a. The back-up heating system, a Cleaver Brooks Scotch Marine boiler is fueled with propane stored in a 30,000 gallon vessel on campus. The cost of propane has increased dramatically in the past two years. Further cost increases are expected as demand escalates.
    b. Natural gas is available near the campus and can be extended into the boiler plant for use as primary or backup boiler fuel.
    c. The cost of extending the gas supply line to the boiler plant was the detrimental issue when the Cleaver Brooks boiler was installed. Those costs can potentially be mitigated through a properly executed fuel purchase agreement.
    d. Natural gas, while still more costly than coal, is considerably cheaper than propane.

3. Conversion from High Pressure to Low Pressure Operation
    a. Steam is currently generated at 125 psig for the primary purpose of supplying steam to the turbine driven feed water pump serving the main boilers.
    b. Steam is distributed to the campus heating load at 30 to 35 psi via pressure reducing stations located in the heating plant.
    c. Steam pressure is further reduced by pressure reducing stations located in the mechanical rooms of the buildings being served.
    d. Most terminal loads within the buildings operate on low pressure steam.

4. HVAC Equipment Upgrades
    a. Air handling units, used to distribute ventilating air and heat to the buildings, are in fair to poor operating condition.
    b. Outside air dampers leak significantly resulting in quantities of outside air well above occupancy requirements being introduced to the buildings. This is a major issue driving heating costs.
    c. Steam valves and steam traps leak through causing localized over heating and wasting energy.
    d. Heat recovery systems, where applied, are performing poorly due to control issues.

5. Building Envelope Improvements
    a. The air barrier between inside and outside environments was improperly installed or has been penetrated in many areas. Building pressurization and heat distribution has been compromised in many areas.
    b. Space separation, the barrier between occupied and unoccupied spaces is also compromised. Door seals leak or are missing entirely in most areas, especially at mechanical room accesses.

6. Air Conditioning Improvements
    a. Air conditioning is provided to areas of the campus by several small chilled water units and numerous split-system, direct expansion (DX) air conditioning units.
    b. Control and operation of the chilled water units is generally adequate.
    c. Control and operation of the DX units is poor and generally relies on occupants of the space being served to turn units on and off.
    d. Operation of the DX units in conjunction with the ventilation air delivery system often results in one unit opposing the performance of the other, driving energy costs higher.

7. DDC Upgrades
    a. Building operation is managed primarily with pneumatic-powered control systems. Portions of the newer or remodeled buildings have digital controls of varying manufacture and differing control logic programming.
    b. Time of day scheduling of ventilation units relies primarily on mechanical time clocks that appear to perform adequately for their limited capability.
    c. Demand-controlled ventilation, set-back control and ventilation-reduction strategies are not currently employed.

8. Lighting Systems
    a. Interior lighting is a mix of fluorescent fixtures equipped with electronic ballasts and T-8 lamps, magnetic ballasts and T-12 lamps, mercury vapor lamps, metal halide lamps, compact fluorescent lamps and incandescent lamps.
    b. Building remodels and upgrades have resulted in those areas being upgraded to T-8 fixtures and/or compact fluorescent lamps.
    c. Lamp inventory required to support the various fixture requirements is significant.

9. Computer Maintenance Management Systems
    a. Current Maintenance Management is a manual process consisting of paper equipment manuals, calendar-based maintenance practice, equipment failure response and inventory management.
    b. The work order system is based upon visual equipment rounds conducted by the maintenance staff and phone requests from other campus staff.
    c. Maintenance costs and equipment repair costs are not maintained by the buildings and grounds staff and were not readily available to be used for decision making.
    d. Control of maintenance activity, maintenance costs and staffing requirements appear to be lacking.

10. Wind Turbine Generator
    a. Current energy supply to the campus consists of coal delivery, propane delivery, when required, minimal natural gas service provided by Great Plains Energy, general time-of-day high voltage electrical service by Ottertail Power Company and water, sewer and fire sprinkler system services provided by the City of Crookston.
    b. There are no alternative energy applications on the campus at this time.

11. Water Efficiency Improvements
    a. Water use on campus consists of public and non-public rest rooms, shower facilities, kitchen and laboratory equipment, drinking fountains and water coolers, animal watering equipment and heating and cooling system equipment.
    b. There are minimal low-flow fixtures on toilets and urinals. Shower heads, primarily observed in the Lysaker Gym, are low-flow type.

12. Lab Hood Control
    a. Laboratory fume hoods have been equipped with variable flow controls and sash position monitors. The control system appears to be adequate but should be connected to a digital building control system to properly control air handling unit operation and air delivery control.

13. Kitchen Exhaust and Make up air Improvements
    a. Kitchen hood control consists of manual switches located in the food preparation area. The food service staff starts and stops hood exhaust fans as needed to support food preparation activities. This control method appears to be adequate at this time.
    b. A glycol-based heat recovery system is operating on the kitchen hood and toilet exhaust fans. Exhaust air heat is transferred to the 100% outside air handler serving the food preparation area.
    c. Control systems are pneumatic and appear to be marginal in performance.

14. Solar Wall Applications
    a. There are numerous air handling units throughout the campus that use large quantities of outside air for ventilation and air make-up systems. Heating of this air is currently accomplished with steam heating coils connected to the campus steam system.
    b. Preheating air is limited to the heat recovery system installed on the kitchen exhaust hoods.

2.7 Facility Improvement Measure (FIM) Details

Coal to Biomass Conversion of Existing Coal-Fired Boiler

The existing Keeler Dorr/Oliver water tube boiler was designed to convert the heat from solid-fuel combustion to high pressure steam. It is rated to produce 25,000 pounds of steam per hour at 160 psi. This boiler is equipped with a Detroit Roto-Grate stoker/traveling grate coal feed system along with required and necessary combustion air and flue gas quality control systems. The boiler and supporting appetencies were constructed and installed in 1983. The base equipment is 26 years old and appears to have been properly maintained.

The continued use of coal as a primary heating energy source is losing favor in light of Climate Change issues and the International Greenhouse Gas Protocol. Legislative efforts to ban or severely restrict the use of coal are underway through Cap-and-Trade initiatives and more restrictive flue gas emission standards. It is becoming evident that coal combustion process, as practiced on the UMC campus, will be severely challenged in the coming years.

Converting the existing boiler to biomass would significantly reduce carbon emissions and minimize the impact of future legislation, restrictions and curtailments. Of the biomass products available, wood chips appear to have the most practical application. Readily available in the Bemidji area, an adequate supply of wood chips, and the infrastructure to harvest, process and deliver them, currently exists. Future supplies, out past a five year time frame, may be dependant upon the effects of the Emerald Ash Borer, currently devastating the Ash tree populations in Michigan. Should this tree damage occur in Northern Minnesota, the supply of hardwood chips will increase dramatically.

Utilizing wood chips as fuel and applying proper combustion methodology requires the installation of a biomass gasifier. A gasifier designed to burn wood chips or any biomass source having a density of ten pounds per cubic foot or greater can be connected to the existing Keeler Dorr/Oliver boiler to produce high pressure steam. Application of the gasifier would necessitate removal of the stoker/traveling grate equipment along with nearly all of the coal handling equipment within the boiler plant. The fuel unloading and storage system is well suited for reuse with wood chips with some minor modifications. Gasifier output would be ducted to the existing boiler to generate steam.

Converting to wood chips with the existing boiler would not reduce the labor requirements for boiler operations. Full time licensed operators would still be required for the heating season. Maintenance and repair would be reduced however as there are considerably fewer moving parts on the gasifier.

Energy cost for wood chips would be higher than it is for coal at current commodity prices. The annual coal consumption is approximately 3,266 tons at a nominal heat content of 9,336 BTUs per pound. This value is based upon the data provided by Minnesota Valley Testing Laboratories that documented the "as received" caloric value of the coal. The dry value of this coal is documented to average 12,500 BTUs per pound. The dry Wood chip average heat content is 7,300 BTUs per pound, 21.8% less than the "as received" value of coal and 41.6% less than the dry value of coal. Given this relationship, off setting 3,266 tons of annual coal use would require between 4,176 and 5,592 tons of wood chips. The cost of coal for the 2007-2008 heating season was $55.00 per ton. The cost of woodchips during the same period was $80.00 per ton. The added cost of transporting wood chips from the Bemidji area would increase that cost to around $85.00 per ton.

The difference in combustion efficiency between the coal fired plant and a gasifier would be expected to improve this number somewhat but the data we have reviewed indicates that this may not be true. Current coal combustion efficiency, based upon 9,330 Btu/lb, is 85% given the quantity of steam produced. There is a level of inaccuracy apparent in this data as typical coal-fired plants do not exceed 75% combustion efficiency. Efficiency value based upon the dry value of 12,500 produces an efficiency value of 64%. It is our belief that the heat content of the coal falls somewhere between these values. We cannot speculate where that value might be at this time.

Gasifier efficiency is claimed to be 80%, assuming the fuel provided contains less than 15% moisture. The heat transfer efficiency of the water tube boiler must also be considered in this equation. Under average circumstances, thermal efficiency of the boiler is expected to be 80% assuming relatively clean tube surfaces. Combined efficiency would therefore be 64%, the bottom edge of where the plant is currently operating. Using current steam production requirements, converting to wood chips would increase heating costs for the campus between $175,000 and $295,000 over current cost.

Rough Order of Magnitude cost for converting the Keeler Dorr/Oliver boiler to biomass gasification ranges from $500,000 to $800,000.

The viability of this conversion is lost unless proposed Cap-and-Trade activity increases the cost of coal 120%.

Natural Gas Supply System for Cleaver Brooks Boiler

Natural gas appears to be available from Great Plains Natural Gas Company. The cost of gas will depend upon the volume of gas required and whether it is purchased as firm gas or interruptible gas. Given the volume of gas required, it is unlikely they would provide it on a firm basis due to transmission piping limitations. Great Plains Natural Gas Co. would need to curtail loads during periods of high consumption. This would only be possible at facilities with a back up source of energy such as propane or fuel oil.

The cost of extending the gas pipeline to the campus has been quoted at approximately $90,000.00. This cost may or may not need to be borne by the University. Data is pending from Great Plains Natural Gas Co. but discussion with their representatives indicates that a properly executed gas purchase agreement could mitigate that cost considerably.

Determining the value of Natural Gas service to the campus is necessary before those decisions can be made.

Fuel Cost Analysis

Energy cost for Natural Gas will be higher than it is for coal at current commodity prices. The annual coal consumption is approximately 3,266 tons at nominal heat content of 9,336 BTUs per pound. The annual BTU load for the campus, under current operating condition is 60,982,752,000. Converting this load to natural gas results in an annual gas consumption of 609,827 therms.

The cost of coal for the 2007-2008 heating season was $55.00 per ton and resulted in an annual fuel cost of $179,630.00. The cost of Natural gas for the same period, though fluctuating, ranged from $.56 to $1.30 per therm. The same heat load would have resulted in fuel costs of $341,503.00 to $792,775.00, between two and five times the cost of coal.

There will be reductions in steam consumption associated with conversion to Natural gas and low pressure steam operation. Parasitic loads in the power plant will be reduced or eliminated. These loads include the turbine driven feed pump, combustion air preheating coil and feedwater deaeration. While not measured as part of this audit, a reasonable consumption rate of these loads is 10% of the total steam produced. Eliminating these loads would reduce the natural gas input required to satisfy campus loads. Combustion efficiency may also improve. The actual efficiency of coal combustion would need to be determined and factored to be accurate but the consistency of gas and the improved thermal performance of the boiler heat transfer rate would also reduce the quantity of gas required.

Considering these factors, the actual Natural Gas consumption will not be 609,827 therms, but more on the order of 467,723 therms.

Annual lbs steam required for coal combustion and campus heating	45,222,100
Annual lbs steam used in power plant (parasitic load)	4,522,210
Annual lbs steam required for campus heating and DHW loads	40,699,890
Annual Therms of Natural Gas required to satisfy campus load	467.723
Coal Cost: 3,266 tons at $55.00/ ton	$179,630
Natural gas Cost range at $.056/ therm and $1.30/ therm	$261,924.00 - $608,040.00

Converting to natural gas and continuing to operate at high pressure seems counterintuitive at this time. An analysis of the conversion process follows and should be considered in conjunction with a switch to gas.

Conversion from High Pressure to Low Pressure Operation

Note: This section of the Energy Audit is a revisit of data provided in the summer, 2007 report to the University.

It was previously determined that the Keeler Dorr/Oliver coal-fired boiler could not be converted to low pressure operation. There are a number of reasons for this; chief among them is the water circulation rate within the water tubes. The relationship between the mean density of steam and the mean density of water at different pressures determines how boiler tubes are constructed. Tubes designed for high pressure operation will not conduct sufficient heat away from the tube surface to prevent localized overheating. Tube failure will occur. The size of the steam drum and steam outlet nozzle are also concerning. The small drum size coupled with a small outlet nozzle will result in much higher steam velocities and lower quality steam. Moisture content would increase sufficiently to damage valves and traps in the piping system. For these and other reasons, low pressure conversion focused exclusively on the existing propane-fired Cleaver Brooks boiler.

This evaluation consists of the following elements:

- Evaluation of the Cleaver Brooks propane-fired boiler for dual pressure operation.
- Modifications required to the steam outlet piping system within the ASME Power Piping scope.
- Steam piping modifications between the Power Piping and the steam distribution piping in the boiler plant.
- Cleaver Brooks burner control additions and modifications.
- Feedwater pump modification requirements.
- Operating impacts on equipment and systems.
- Analysis of expected terminal equipment performance and load profile.

Cleaver Brooks Evaluation

The Cleaver Brooks boiler is a fire tube scotch marine style boiler designed and constructed for high pressure operation. It is properly fitted with dual gaseous fuel trains to burn either Natural Gas or Propane.
It is designed for four-pass flue gas direction making it a remarkably efficient unit.

Being of scotch marine design, this boiler contains a large volume of water and a correspondingly large surface area. This is a significant attribute for operating at low pressure. Its “steaming rate” is one of the highest and most reliable in the industry. Internal water circulation is of no concern in this boiler given its large water volume and adequate steam space.

The feed water delivery system on the boiler, its vessel entry point and control valve are properly sized and positioned for low pressure operation.

This boiler is capable of producing in excess of 24,000 pounds of steam per hour in its current configuration. The limiting factor for this boiler is the size of the steam outlet nozzle. Sized for high pressure flow, it will restrict the low pressure flow rate to approximately 18,000 pound per hour.
No modification of the boiler proper is necessary at this flow rate.

The safety valves are set for high pressure operation and will not meet code requirements for low pressure operation. The Cleaver Brooks boiler must be refitted with a code compliant low pressure safety valve properly sized to relieve 100% of the generating capacity of this boiler at low pressure operation.

Power Piping Modifications
The intent of this conversion is to eliminate high pressure steam entirely and modify the campus heating system to operate permanently on low pressure steam. There would be no value in maintaining the high pressure capability of this boiler and certainly no value in spending additional dollars to enable a high or low pressure selection option. No Power Piping modifications are necessary.

Steam Piping Modifications
The existing steam piping appears to be sufficiently sized to heat the campus using low pressure steam with only minor modifications. The required modifications would include removal of pressure reducing valves and installation of spool pieces in their place. Detailed steam flow measurement of each building take off may be necessary if noise levels from stream flow across existing orifices are unacceptable.

Cleaver Brooks Burner Control Modifications
It will be necessary to add controls to manage operation at 12 psi. Twelve psi is the upper limit of low pressure operation to prevent the 15 psi safety valves from nuisance lifting. This installation will include adding a new operating controller, a new high limit cutout switch and other burner monitoring and control devices to manage all aspects of low pressure operation.

Feedwater Pump Modifications
Operating the Cleaver Brooks boiler at low pressure will require modification to the existing feedwater system. The ASME code requires two separate feedwater sources for any operating boiler. On the existing boilers, a turbine driven feedwater pump and an electric motor driven feedwater pump provide the necessary water supply. The turbine driven feedwater pump requires 125 psi steam to properly drive the pump. At low pressure operation, this pump is not available to serve the feed water needs of the system. Both the turbine driven and the electric motor driven pumps are sized and fitted for high head pressure water delivery. While they are capable of delivering feedwater to a low pressure boiler, the significant pressure disparity would cause damage to the pumps.

The feed water control valve on the Cleaver Brooks boiler has a Cv rating based upon the difference between the feed pressure and boiler pressure. If this difference is too great, the valve will be damaged or it will not close properly, causing continuous over-filling of the boiler. If the control valve were able to handle the pressure difference, the continuous dead-heading of the pump could result in seal or packing failure or serious damage to the pump impeller.

It will be necessary to add two low pressure feedwater pumps to serve the Cleaver Brooks boiler. New pumps will be installed in place of the existing abandoned feedwater pumps that used to serve the old, decommissioned boilers. Installing the pumps in this location allows reuse of the supply piping from the deaerator and will maintain the current configuration of the high pressure pumps. New discharge piping from these pumps to the Cleaver Brooks boiler may be required.

Operating Impacts
Evaluation of the steam distribution system identified the loads and equipment currently requiring steam service. Priority of steam use is based upon building use, method of heating, primary loads and terminal equipment loads. These loads can be further classified by their seasonal demand. The first requirement, manifested by system start up, is the domestic hot water heating load. The next load is a terminal equipment heating load and consists

of reheat coils and some area radiation heat. The last and largest steam load is the primary heating coils in air handling units.

Domestic Hot Water

There are twenty campus buildings that are occupied and have domestic hot water service. Of these, twelve get their domestic hot water from the water heaters in the boiler room during the school year. Seven of the remaining eight occupied buildings are served by stand-alone electric or natural gas storage water heaters.

Fifteen of the twenty buildings have electric or gas storage heaters for summer use. Five have no summer water heater and only receive hot water when the boiler plant water heater is on line.

Hot water is produced in the boiler plant by two shell-and-tube heat exchangers powered by 30 psi steam from the medium pressure header. A storage tank that holds approximately 1,000 gallons is used to buffer the heaters and maintain an inventory of hot water for campus use. Hot water is distributed to the connected buildings through a four inch hot water supply pipe routed through the tunnel system. A one and one quarter inch return pipe continuously recirculates water back to the heaters to assure a constant supply at the point of use.

One building, the Lysaker Gym, does not conform to these conditions. Its summer load is managed by a large, 525,000 btuh input water heater that serves showers, sinks and the laundry facility. During the school year, domestic water is heated with two steam powered, instantaneous water heaters. These heaters use 30 psi steam to provide high volume hot water to the significant load in that building.

Domestic water service to all of the buildings except Lysaker can be satisfied with the boiler plant water heaters operating on 12 psi steam. The shell and tube heaters have sufficient capacity to handle this load year round if so desired. The enthalpy of steam is the amount of heat it holds, and has available for use. Saturate steam, at 30 psi has an enthalpy of 1,172.3. Saturate steam at 12 psi has an enthalpy of 1,115.7, only 2% less. In real application, if the steam valves on both heaters are 100% open for ten hours per day with 35 psi steam, they will be open ten hours and twelve minutes with 12 psi steam to produce the same quantity of hot water. If either valve is open less than 100% during the use period, there will be no difference in output.

The steam piping to the boiler plant heaters is of sufficient size at 12 psi to provide the necessary steam for this service. No modification to the boiler plant domestic water heating system is necessary.

The Lysaker complex will require modification to use low pressure steam to provide the desired quantity of hot water. In addition to heating the domestic water, the 30 psi system provides the energy needed to lift condensate to the return line. The size of the pipe and distance to the vacuum pump pick up prevents 12 psi steam from doing this. It may prove to be more cost effective to install an additional gas-fired domestic water heater in Lysaker and eliminate use of steam for domestic hot water entirely in that facility. The cost difference between firm and interruptible gas, along with the difference between boiler/heat exchanger and direct fired heater efficiency would need to be considered.

Reheat and Radiation Systems

After satisfying the domestic water load the next heating system that will require steam supply is the reheat and radiation systems in the buildings. In most applications on campus this load is the shell and tube heat exchangers that provide this heat. Some buildings, such as Keiser and McCall Hall, still have steam perimeter radiation. The purpose of a reheat system is to add additional heat to small areas served by large air handling units. An air handler's discharge air temperature should be set to satisfy the unit's greatest call for cooling. Reheats trim the areas served by the air handler that need additional heat to maintain comfort. As most of the air handlers used mixed air temperature control, the reheats can provide all of the supplemental heat an area needs well into the heating season and at the end of the season when outside temperatures moderate. Perimeter radiation systems serve a similar purpose in that they are positioned to compensate for the exterior building load where cold air from outside has the most influence. Radiation is frequently located under windows because window R-value is generally less than the outside walls. The heat input requirements of the reheat and radiation systems can be satisfied by low pressure steam as effectively as high pressure steam. The heat exchanger control valves will modulate and control discharge water temperatures with low pressure steam regardless of its source.

Air Handling Units
The third load requiring steam is the heating coils in the air handling units. As the outside air temperature decreases, the ability of the air handle to maintain discharge temperatures by mixing return air diminishes. This is especially true during the day when buildings have a higher occupancy level and require higher quantities of outside air for ventilation. When the air handler's discharge air temperature departs from setpoint, preheating of the outside air is necessary. Some air handlers preheat outside air and mix return air to maintain discharge temperatures while other units mix the air first and heat all of the air together. Either way is effective and acceptable. Both methods will use the same amount of energy if properly controlled.

Cost ROM
Costs associated with this FIM include the previously documented costs of modification of boiler plant equipment including the Cleaver Brooks boiler, upgrading feed water pumps and replacement of the pressure reducing stations throughout campus with pass-through spool pieces. The addition of a back up boiler to the Cleaver Brooks is highly recommended due to the over night housing of students and guests on campus. Cost of this work can range from $300,000 to $1,300,000, depending on the second boiler and necessary building space to put it.

Savings ROM
Potential energy savings associated with conversion to low pressure operation is based upon the heat input required to satisfy space heating, domestic hot water and ventilation requirements. Steam generated at 125 psi has a total heat content of 1,149.2 Btus per pound. Steam generated at 15 psi has a heat content of 1115.8 Btus per pound. The difference of 33.4 btus per pound of steam generated reduces the heat input required by 13,594 therms. The energy cost savings is in the range of $7,600 to $17,700 per year.

HVAC Equipment Upgrades

Air handling units (AHUs), used to distribute ventilating air and heat to the buildings, are in fair to poor operating condition. Age of the units and differed maintenance on them is resulting in less than optimum performance.

Converting the pneumatic control system to distributed digital control will improve building comfort and reduce energy use if the equipment being controlled is in proper working order.

Most significant of the repairs needed are the outside air dampers. Many of these dampers leak significantly resulting in quantities of outside air well above occupancy requirements being introduced to the buildings. This is a major issue driving heating costs. In some cases areas of outside air damper have been blanked off for unknown reasons, possibly because outside air requirements have been reduced due to building load change. A detailed building load audit will be necessary to determine this.

A possible repair of the dampers would be the addition of edge and blade seals. On the newer units, where the dampers have not distorted or warped, this would be an effective, low cost repair. It would be necessary to evaluate the damper jack shafts and actuator locations before deciding on this repair. It may be more effective to replace the dampers entirely. The older units will require damper replacement to make a truly effective repair.

Steam valves and steam traps leak through causing localized over heating and wasted energy. A leaking steam valve causes artificial increases in discharge air temperatures. Control systems will open the outside air damper to compensate for the temperature rise, bring in more outside air than is required. Friction wear and velocity cutting of valve stems and seats is a common occurrence in steam systems. In most cases the most effective repair would be valve replacement.

Heat recovery systems, where applied, are performing poorly due to control issues. The most effective repair of this system would be valve replacement with digital control to circulate fluid through operating exhaust systems only. A variable frequency drive on the circulating pump would help maximize system performance and reduce energy use.

Building Envelope Improvements

The air barrier between inside and outside environments was improperly installed or has been penetrated in many areas. Building pressurization and heat distribution has been compromised in many areas. Space separation, the barrier between occupied and unoccupied spaces is also compromised. Door seals leak or are missing entirely in most areas, especially at mechanical room accesses.

The most effective correction to envelope issues is to conduct a thorough scan of each building using infrared thermography. When combined with blower door testing each penetration is identified, allowing a repair methodology to be developed.

Identification of space separation can be accomplished with smoke tests that identify air flow movement and patterns throughout a building. This would be effective in identifying building pressurization issues, from which proper control of outside air dampers and exhaust fans can be identified.

These test methodologies require skilled, experienced tradesmen to conduct tests properly, interpret the results and make appropriate repair recommendations. ICS Consulting, a consulting firm that specializes in this work, recommends the following steps
ICS Consulting, Inc. recommends that a preliminary needs survey of various building envelopes on the campus of the University of Minnesota, Crookston be conducted. The purpose of this preliminary survey will be to provide critical information regarding the need to conduct more-focused investigation on specific facilities and components. Ultimately our goal is to establish a comprehensive construction repair/restoration process for the campus as a whole, from which critical budget decisions can be based.

The primary goal of our preliminary assessments will be to identify areas requiring further analysis. By completion of a campus-wide preliminary survey, the University is able to utilize its resources both efficiently and effectively, allowing more detailed assessment work to be focused in only those areas that require intensive analysis. We will provide preliminary information as to the existing conditions of each facility, its envelope components, and systems. We will document general existing conditions and identified deficiencies, and areas recommended for further analysis. All information will be provided in a format intended to facilitate and ease the Owner's planning and prioritization process.

The Scope of work for the preliminary survey and assessment work will include an evaluation of the following:

- Preliminary review of existing facility-related documentation and information
- Visual observation of all major building envelope components including:
    - Roof Systems
    - Window and Glazing Systems
    - Masonry and Exterior Finishes
    - Preliminary Review of Exterior Wall Assembly / Section Detail
    - Building Expansion Joints and Sealants
    - Thru-Wall Penetrations
    - Wall – Roof Connection Assemblies
- Photo Documentation of any Identified Deficiencies or Areas of Concern
- Preliminary Thermal Imaging Scans of any Areas of Concern

Our preliminary survey work will include site tour(s), preliminary construction plan review (as available); spot thermal imaging of exterior building components. In addition, we will work to identify opportunities for building envelope improvements for consideration from the perspective of:

- Energy Savings and Optimization
- Reduction of Unwanted Air and/or Moisture Infiltration
- Corrective Measures to Reduce or Eliminate Sources of Potential Future Damage

It is acknowledged by all parties that ICS Consulting, Inc.'s scope of services does not include any services related to asbestos, hazardous, or toxic materials that may be encountered or found to be present at or in areas adjacent to the site. Any such materials that are encountered shall be immediately brought to the attention of the owner, who will be solely responsible for any required abatement and/or removal of the materials in full compliance with applicable laws and regulations.

DDC Upgrades

Building operation is managed primarily with pneumatic-powered control systems. These controls use receiver/controller devices to receive input signals from a variety of sensors, interpret the sensor information and send pneumatic signals to control devices such as damper and valve actuators. When properly calibrated, these devices will effectively control the systems they are connected to. Pneumatic controls lose their effectiveness when loads vary, when a change in operating parameters occurs, when they go out of calibration or when oil or moisture permeates the control air system. Each of these situations requires a manual response to correct. Without correction to these situations, building performance is compromised, energy is wasted, or both. Maintenance and recalibration of a pneumatic system the size of the system at UMC requires a minimum of one skilled FTE.

Portions of the newer or remodeled buildings have digital controls of varying manufacture and differing control logic programming. These systems were installed at part of an upgrade or remodel project and were apparently selected on a first-cost basis. We identified control systems by Siemens, Johnson Controls, and Barber Coleman on our building walk throughs. Because they all use different program language, different logic and different communication methods, there is very limited ability to integrate them under a common control center on campus. This inability will be a continuing issue as the use and application of DDC is expanded.

Time of day scheduling of ventilation units relies primarily on mechanical time clocks that appear to perform adequately for their limited capability. Converting this activity to digital control allows enhanced scheduling activity that is much more consistent with space use. Areas that are unoccupied for as little as 30 minutes can have the ventilation shut off with no detrimental impact. Scheduling can be applied to entire buildings for ventilation control, to individual air handling units for specific zone control and individual classrooms or offices for complete terminal space control. Exhaust fans can be programmed to operate in conjunction with air handling units or separately, as would be desired for toilet exhausts. Occupancy sensors, smart switch technology and override switch controls can be incorporated for beneficial ventilation response.

Demand-controlled ventilation, set-back control and ventilation-reduction strategies are not currently employed. Existing controls operating on a time clock will start at a prescribed time and shut off at a prescribed time. When the air handler starts the outside air damper generally opens to a prescribed minimum position and remains there until a call for economizer cooling occurs. This ventilation rate is applied from the time of start to the time of stop every day, regardless of space needs. Demand control ventilation will also start and stop the air handler if required by a time of day schedule, occupancy alert or manual operation requirement. Using continuous measurement and monitoring of the return air carbon dioxide levels, the controls will modulate the outside air dampers as necessary to introduce the exact amount of fresh air required. Make up requirements of exhaust fans, kitchen and lab hoods can be accommodated on a time-of-day schedule or whatever control parameter is desired.

Industry standards for potential energy savings associated with DDC upgrades are approximately 3% of the overall energy cost of the facility if demand control ventilation is applied holistically. Using that figure as a preliminary value, the savings would approach 30,000.00 annually. There would be significant labor savings associated with this upgrade if calibration and adjustment of pneumatic devices was being performed. It would appear that much of this activity falls into the differed maintenance category for which no savings can be calculated. There is potential that with the lack of calibration and adjustment activity, energy savings could be higher than industry standards.

Cost of installing a practically applied DDC system is calculated on a system basis. For the purpose of this audit, systems already converted to DDC controls have not been excluded. The various manufacture issue will need to be addressed either through selection of a common control system, which would include replacement of some existing DDC systems, or installation of a supervisory interface that can convert program languages of various manufacturers to a common language.

The table below demonstrates rough order of magnitude costs for a DDC system upgrade.

System	Number of Units	Cost per Unit	Total Cost
Air Handling Units	54	$6,000.00	$324,000.00
Exhaust Fans	117	$1,200.00	$140,400.00
VAVs & Reheats	46	$1,200.00	$55,200.00
CUHs, UHs & Radiation	95	$900.00	$85,500.00
Interface and Peripheral Equip.			$50,000.00
			$655,100.00

Air Conditioning Improvements

Air conditioning is provided to areas of the campus by several small chilled water units and numerous split-system, direct expansion (DX) air conditioning units. Most of these units were installed after building construction was completed. Because of this, data on the individual units, Manufacturer, model numbers, size, age and area served is not documented on the building plans or in the equipment schedules. Collection of this information will be necessary but it will be a manual process outside the scope of this audit.
Evaluation of the electrical energy use indicates that there is only an approximate 20% reduction in energy use in the summer months when students are not on campus. This would indicate that a significant electrical load, most likely attributable to air conditioning loads, is occurring.

Control and operation of the chilled water units is generally adequate. These units are mechanically connected to central air handling units and use the supply fans in those units to circulate cooling. The air handling unit controls, even though pneumatic, will manage cooling loads simultaneously with ventilation requirements. The air condition units will not run unless the air handling unit calls for cooling.

Control and operation of the DX units is poor and generally relies on occupants of the space being served to turn units on and off. Space temperature management is left to the discretion of the occupant and is seldom uniformly applied. It is also likely that units are left on after occupants leave the area. This may be unintentional but frequently results in over cooling or cooling non existent loads. Either case is inefficient use of energy.

Most of the split systems observed operate independent of the ventilation system, controlled by their own thermostat. The conditions space will receive ventilation air from the air handling unit and cooling from the DX unit. If these controls are not synchronized, or if either is out of calibration, the DX unit can be attempting to cool a space while the air handler is introducing ever increasing volumes of outside air in attempt to warm the space. This opposing performance drives energy consumption and costs higher.

Four options exist for correcting these conditions: constructing a central chiller plant and distribute chilled water throughout the campus; strategically locate liquid chillers to serve specific areas; integrate DX systems with existing air handling systems; improve control of existing systems. Each of these options has merit but could be a singularly difficult and expensive activity.

Constructing a central chiller plant is feasible but retrofitting the distribution piping would be a complex endeavor. Tunnel space, vertical wall chases and above-ceiling distribution potential is very limited. Required supply and return pipe sizes would be quite large and in many areas and would require soffit additions to accommodate. A complete central plant to serve the entire campus would cost in the range of 10 to 15 million dollars.

Strategically locating liquid chillers throughout the campus has much better potential. Liquid chiller packages, similar to the one serving the student center, can be installed at various locations and serve multiple loads. This option reduces the number of packaged units the campus would need, significantly reduces pipe sizes, can be located on roof tops or in hidden alcoves and be very well controlled with a DDC system. This option would also take advantage of and continue to use the existing chiller packages on campus. Rough order of magnitude cost of the additional chillers needed would be in the one to four million dollar range.

Integrating DX systems with existing air handling systems would provide a modular approach to campus air conditioning. DX packages would be sized to serve specific air handler requirements and could be installed in mechanical rooms, on rooftops or on ground-based equipment pads. This option would allow integration of controls between the air handler and DX unit to provide the desired level of air conditioning, reduce energy cost and be less expensive to install. Rough order of magnitude cost for this option would be in the $300,000 to one million dollar range.

Improving control of the existing packaged and split systems would be a short term but lower cost, practical solution. Integrating this control with a new DDC system would allow the air handler and DX unit to use the same space temperature sensor to manage space conditions and eliminate over-ventilating, allow time-of-day scheduling of the DX unit and allow space temperature reset when desired. All of these functions would be automatic and have adjustment capability from sources other than space occupants. Rough order of magnitude cost for this option would be in the $100,000 to $300,000 range.

Lighting Systems

Interior Lighting

Interior lighting is a mix of fluorescent fixtures equipped with electronic ballasts and T-8 lamps, magnetic ballasts and T-12 lamps, mercury vapor lamps, metal halide lamps, compact fluorescent lamps and incandescent lamps.
Building remodels and upgrades have resulted in those areas being upgraded to T-8 fixtures and/or compact fluorescent lamps.
Lamp inventory required to support the various fixture requirements is significant.
An upgrade of all campus interior lighting would reduce energy consumption, reduce labor costs for maintaining lighting systems and significantly reduce inventory requirements.

T8 Lighting Upgrade

Most of the buildings audited are currently using T8 lamps and electronic ballasts. However, there are areas still using T12 lamps and ballasts that should be addressed. Further, in recent years advancements have been made to acquire more energy savings using the T8 product. Below are optional scenarios to enhance energy savings:

- Convert the whole system to a scotopically enhanced, high performance lighting system. This strategy would use a 5,000K lamp and be advantageous by reducing the number of lamps in the fixture. Scotopically enhanced lighting works on the premise of perceived light versus actual lumens. Because of this, the amount of total lumens (lamps) can be reduced.
- Convert the whole system to reduced wattage T8, either 25 watt or 28 watt lamps. This measure requires some planning as well before proceeding. In order for this retrofit to work, the ballasts must be instant start, and there must not be in-board/outboard switching (or at least have separate ballasts for the inner lamps).
- Convert the entire system to high performance T8s. This retrofit pairs a high lumen lamp with a high performance, low ballast factor ballast. This combination affords you the best lumens per watt of the three options. However, there is more upfront dollars required due to ballast purchases.

In all three cases, there are certain aspects that require more investigation and testing. We recommend mocking up a few fixtures in each scenario and solicit comments from the administration and staff on the option that best fits their needs. The goal is to get adequate lighting levels for the space while maximizing energy savings.

It should be noted that in certain cases, the reflectors are badly discolored and/or cracked and broken. In these cases, it is recommended that the fixture not only be retrofitted for energy savings, but also the reflectors be replaced in order to achieve maximum light output.

Safety Lighting
The safety lighting in most the buildings that we looked at seemed to be more than what would be required by code. There are two potential options for achieving energy savings with safety lights. The first is installing occupancy sensors in the corridors that would allow the lights to turn on and based on people in the space. The second option is to rewire the fixtures to allow for a reduced number of lights to remain on 24/7. In either case, more investigation of circuitry, switching, etc. would have to be done to determine the best option.

Occupancy Sensors
In most of the buildings that were audited, there are opportunities for occupancy sensors. It was observed that random offices, classrooms, and restrooms had lights on with no one in the room. Installing occupancy sensors allows for the lights in the room to be turned off when the room has periods of inactivity. In some cases, the occupancy sensor can also be tied into the HVAC system to reduce ventilation during prolonged unoccupied periods.

Metal Halide to High Performance Fluorescents
In both the main gym and the fitness center, there are metal halide fixtures that should be retrofitted to high performance fluorescent fixtures. In order to properly retrofit these spaces, a lighting design should be done to ensure that the Illuminating Engineering Society of North America (IESNA) recommendations are being met. High Performance Fluorescent lighting systems provide the following advantages over standard metal halide lighting systems:

- Multiple Lighting Levels – High performance fluorescent lighting systems allow for multiple lighting levels within the same fixture. By setting up the fixtures for inboard/outboard switching, the appropriate lighting levels can be achieved for the activity by switching lamps on and off.
- Decreased Lumen Depreciation – High performance fluorescent lamp lumen depreciation is about 5%-7% while standard metal halide lamp lumen depreciation is about 40%-50%. This being said, the fluorescent fixture will provide design light conditions longer than the metal halide system.
- Ability to Switch On/Off - Since fluorescent systems have instant start, electronic ballasts, they have the ability to be switched on and off instantaneously. This switching ability allows for occupancy sensors to be added ensuring maximum energy savings.

Recessed Can Fixtures
In many of the buildings we audited, there were numerous instances of recessed can lighting being used for various functions. Some of the recessed cans were incandescent lamps used to highlight art and other recessed cans were metal halide lamps used for corridor or general purpose lighting. In all cases, an energy efficient retrofit is available and should be investigated to see its cost effectiveness.

Greenhouse Fixtures
The greenhouses were the final area that had the potential for lighting upgrades. Most the greenhouses had a combination of metal halide lamps and high pressure sodium lamps based on the growing criteria of the plant and the parameters of the experiment being conducted. There is a potential for a retrofit of these fixture with fluorescent but it would need to be cleared with the researchers in the greenhouses.

Exterior Lighting
Although some exterior lighting within the UMC Campus is owned and operated by the utility company, many of the exterior light fixtures along campus sidewalks and in the parking lots is owned and operated by the campus. An opportunity exists to upgrade this lighting to a more efficient technology.

Two particular technologies that are under investigation include induction lighting and LED lighting. Each of these technologies has their advantages and disadvantages, however both will provide considerable energy reduction.

Technology	Advantages	Disadvantages
Induction	Energy Savings, Lower First Cost Compared to LED, Anticipated Long Life Expectancy, Electrodeless Technology, Good Lighting Quality	Long Life Expectancy is Suspect in Cold Climates, Ballast and Starter Still Required Compared to LED
LED	Considerable Energy Savings, Very Long Life Expectancy, No Starter or Ballast Required, Excellent Lighting Quality	Higher First Costs

Induction Lighting

LED “Cobra Head” Fixture

A more detailed analysis, as could be provided in the Detailed Engineering Study (DES) phase, a few of these type fixtures should be installed and evaluated. The individual characteristics and performance will ultimately help UMC determine a future direction associated with exterior lighting.

Computer Maintenance Management Systems

Current Maintenance Management is a manual process consisting of paper equipment manuals, calendar-based maintenance practice, equipment failure response and manual inventory management. This method of maintenance management is inefficient, misuses skilled assets and fails to accurately document true maintenance costs.

While the use of equipment manuals is a necessary and vital portion of the maintenance process, rote functions defined in those manuals ought to be captured, capsulized and documented in readily accessible tasking forms.

Calendar-based maintenance practices are applicable when equipment use is uniform and constant from season to season. Scheduling fan bearing lubrication the first of each month may be practical and effective but scheduling filter changes in that manner will stave air flow or waste filter media. No two systems load filters in the same manner or at the same rate.

Equipment failure response is the most common maintenance practice and generally keeps maintenance staff busy “putting out fires.” A staff burdened with equipment failures is unable to perform preventive maintenance properly resulting in more equipment failures. It is a viscous and well-recognized cycle.

The work order system is based upon visual equipment rounds conducted by the maintenance staff and phone requests from other campus staff. How this work is managed and scheduled is not readily apparent.

There does not appear to be any priority assessment or assignment of individual work orders. It tends to parallel the putting out fires scenario applied to equipment maintenance.

Maintenance costs and equipment repair costs are not maintained by the buildings and grounds staff and were not readily available for review. This data is a critical element in capital planning, operations and maintenance budget planning and equipment repair/replace decision making. Control of these activities appears to be lacking.

Inventory management is the remaining element of a maintenance management program. Spare parts, fan belts, air filters and other consumables appear to be randomly stored and dispersed. Many of the mechanical rooms visited were filled with boxes of filter media waiting to be installed. When they were ordered, how they were purchased and then released for shipment was not apparent. Belt, lamp and repair parts inventory was not observed.

There are three options for converting the campus to a computer-based maintenance management system. A commercially available, packaged software system can be purchased and implemented; the campus could interface via the internet to the CMMS being used by University Twin City campuses; a third-party management program can be implemented.

Commercially available maintenance packages such as Datastream or CyberMetrics can be purchased and integrated with most DDC systems. These are relatively low cost programs that provide all of the necessary software to develop, produce, publish and manage all of the desired maintenance functions on campus. The major drawback to any of these programs is the vast amount of data input required and the on going data maintenance required. It is not unusual for the data input activity to consume more than a man-year of labor. Further complicating this work is the skill sets needed to properly organize the data. Staff skilled in the maintenance processes for equipment and systems is generally not skilled at data input or data management. People skilled at data entry do not understand equipment maintenance functions and frequently intermingle tasks within maintenance plans.

Accessing and using the University system would extend the Twin City campus's consistency of processes to the Crookston campus. Participating in this system would give Crookston access to the same maintenance methodology, common work order management and inventory control employed in the Twin Cities. System inconsistencies, software issues and feature abnormalities will have already been identified and resolved. UMC would get a superior product with minimal capital infusion. UMC would also have access to a support network that could be a big help to the system administrator.

The down side of connecting into this system is the requirement that UMC conform to the Twin City methods of performing work. Things that work well in the Twin Cities may not work in Crookston at all. Access to resources, vendors and supply streams are dramatically different between the two cities. Response time by vendors and service contractors will be different. Travel time and their associated costs will be higher in Crookston than in the Twin Cities. Vetting this option properly with the Twin City campuses will be necessary before a correct decision can be made.

A third party maintenance management program is another option to consider, especially since little investment has been made in a program to this point. Using a knowledge center type service that can perform the initial set up and data entry work, manage the day-to-day work assignments, establish a robust work order management system and manage inventory properly would relieve the Buildings and Grounds department of many of these responsibilities. Organizations that use this type of service have minimized staff additions through improved productivity and reduced operating costs through effective procurement planning. Capital planning and resource management has been more accurate and timely as well.

Instituting a computer based maintenance management system will be a major but necessary activity for UMC that will have long term impacts on campus operations. It would be in UMC's best interests to take the necessary time to fully evaluate options before making decisions.

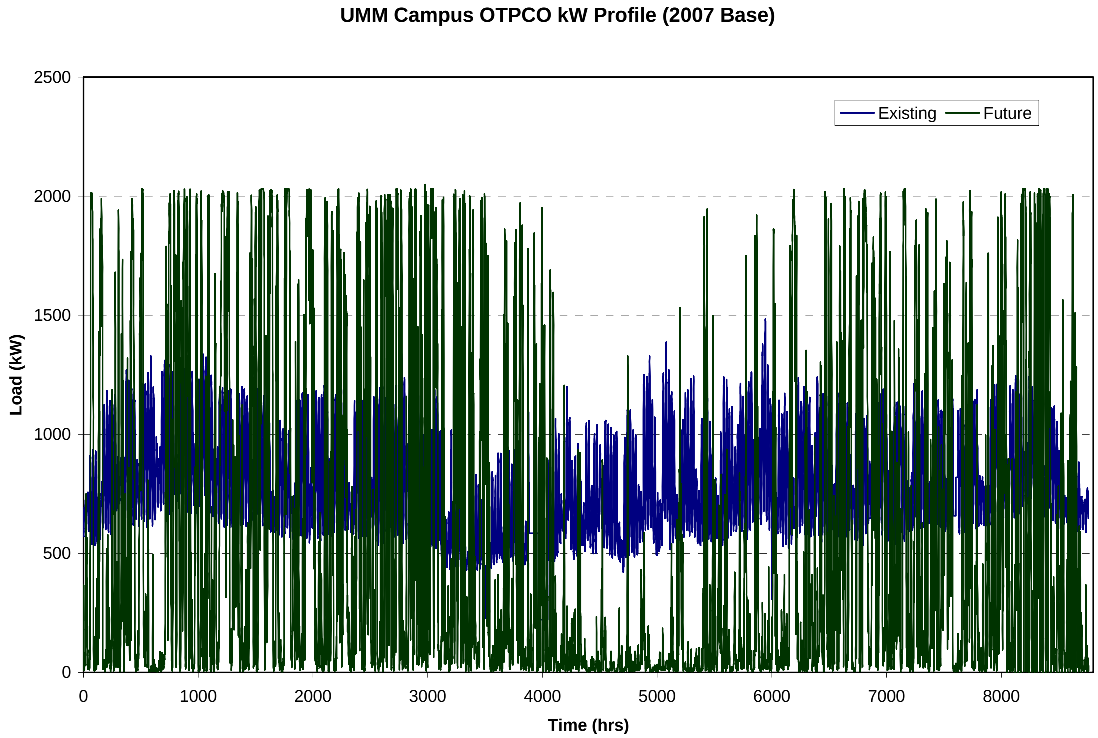
Costs of a maintenance system are very difficult to identify. Further detailed analysis of options will be required before costs can be determined.

Water Efficiency Improvements

Water use on campus consists of public and non-public rest rooms, shower facilities, kitchen and laboratory equipment, drinking fountains and water coolers, animal watering equipment and heating and cooling system equipment.
There are minimal low-flow fixtures on toilets and urinals. Shower heads, primarily observed in the Lysaker Gum, are low-flow type.
Data that was required for this report was not made available until 2-9-09, leaving insufficient time to conduct an analysis for this report.
Water conservation measures, costs and savings will need to be provided as addenda to this report.

Wind Turbine Generator

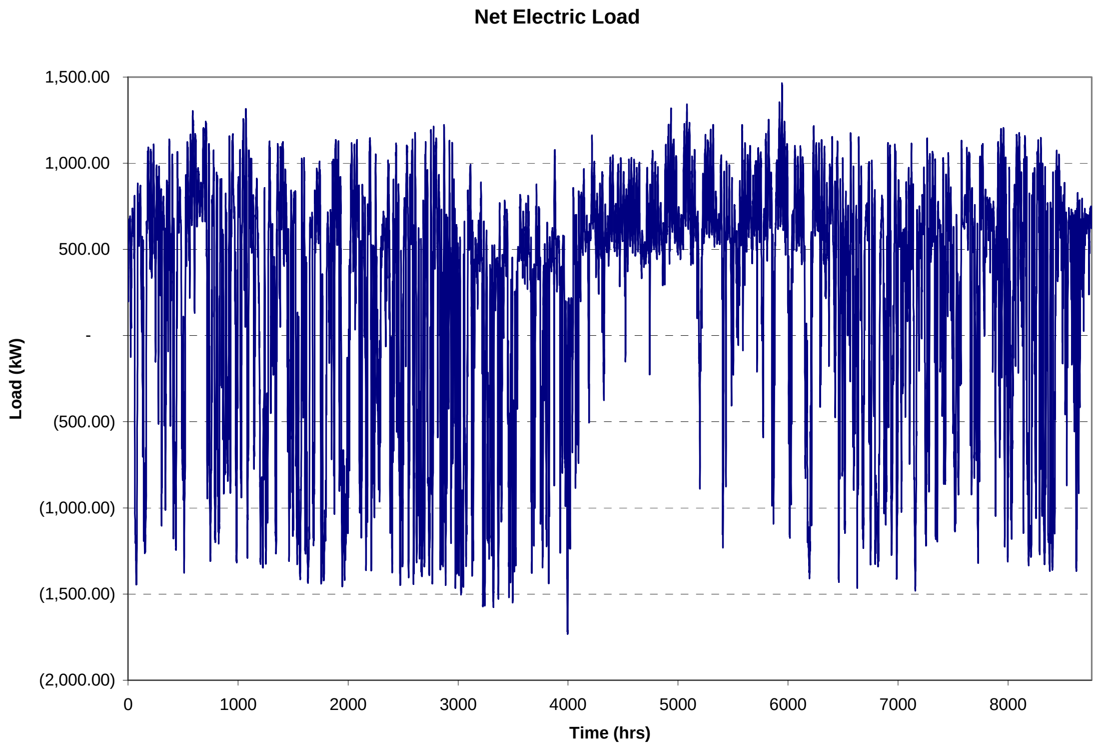
Current energy supply to the campus consists of coal delivery, propane delivery, when required, minimal natural gas service provided by Great Plains Energy, general time-of-day high voltage electrical service by Ottertail Power Company and water, sewer and fire sprinkler system services provided by the City of Crookston.
There are no alternative energy applications on the campus at this time.



The existing power demand profile is from Ottertail Power Company's online power profiler that provides hourly data for electric meters. This profile shown above in blue is the sum of the two main electric meters from Ottertail to the campus.

In order to determine the potential production of a wind turbine installed at Crookston, the performance curve for a 2MW DeWind wind turbine generator and wind data at 230 ft collected 3 miles SW of Crookston between 1995-2005 by the state of Minnesota were used. The wind data was available in monthly averages for a year and averages at each hour throughout a day. These two data sets were combined to form hourly data for an entire year. This hourly wind data was used with the performance curve at each hour to find kWh production on an hourly basis for one year shown above in green.

One standard method for measuring the potential production of a wind turbine is the Capacity Factor. Using the calculated hourly wind data we arrived at a capacity factor of 26.78%. This number matches well with a report on capacity factors by the State of Minnesota Commerce Department from 2003 rating the region where Crookston resides, as having a capacity factor between 24.21 - 27.14%. This report verifies the calculated hourly wind averages are accurate.



The above graph shows the difference between the power demand for the Crookston campus and what could be provided by a wind turbine. When the profile is negative, power is sold back to the grid, when it is positive, power is purchased from Ottertail. For the sample year, the campus would reduce their annual electric purchase by 2,908,056 kWh and be able to sell back 1,880,226 kWh.

Lab Hood Control

Laboratory fume hoods have been equipped with variable flow controls and sash position monitors. These controls adequately respond to the isolation requirements of the lab hoods preventing potential contaminants from leaking into the occupied spaces of the laboratory.
Periodic testing and verification of the control performance is necessary to assure continued safe operation. Preliminary checks on the performance of the hoods indicate that the control system appears adequate in its current state.

These controls should however be connected to a digital building control system to assure proper control of air handling unit operation and air delivery control. The remote monitoring capability of the control system would also be beneficial to campus operations and student and staff safety.

There did not appear to be other issues or concerns at the time of our visits.

Kitchen Exhaust and Make up air Improvements

Kitchen hood control consists of manual switches located in the food preparation area. The food service staff starts and stops hood exhaust fans as needed to support food preparation activities. This control method appears to be adequate at this time.

A glycol-based heat recovery system is operating on the kitchen hood and toilet exhaust fans. Exhaust air heat is transferred to the 100% outside air handler serving the food preparation area. The base equipment in this system appears to be adequate. Improved filtration on the exhaust fans would benefit the heat recovery coils and improve heat transfer. More frequent chemical and mechanical cleaning of the coils would also improve heat transfer.

Control systems are pneumatic and appear to be marginal in performance. Replacement of the control valves and upgrading the sequences of operation would improve heat recovery and optimize system performance.

Solar Wall Applications

There are numerous air handling units throughout the campus that use large quantities of outside air for ventilation and air make-up systems. Heating of this air is currently accomplished with steam heating coils connected to the campus steam system. Connecting a solar-heated air preheater would reduce fuel consumption and carbon footprint of the buildings. While south-facing wall space appears quite limited, especially in the campus areas that would benefit from solar preheating, the use of a solar duct would achieve similar results. Solar ducts are mounted to flat roofs and, when fitted with a proper air by-pass, can be configured to fit any air handler application.

Currently preheating air is limited to the heat recovery system installed on the kitchen exhaust hoods. Solar walls can be applied ahead of existing heat recovery systems as well as on any air handling unit that requires large quantities of outside air. Skyberg, Dowell, Bergland and Sahlstrom would be candidates for solar thermal applications.

2.8 Facility Improvement Measure Summary

The following table summarizes the impact of each FIM on campus operations.

FIM	Rough Order of Magnitude (ROM) Cost of Conversion	Potential Energy Cost Savings	Carbon Footprint reduction (tons)
Coal to Biomass Conversion of Existing Coal-Fired Boiler	$650,000	-$175,000 to -$295,000[1]	6,471
Natural Gas Supply System for Cleaver Brooks Boiler	$100,000	$358,864[2]	573
Conversion from High Pressure to Low Pressure Operation	$1,200,000	$4,450	154
HVAC Equipment Upgrades	$550,000	$29,709	723
Building Envelope Improvements	$5,000,000	$8,981	310
Air Conditioning Improvements	$1,000,000	$20,728	413
DDC Upgrades	$655,000	$17,826	434
Lighting Systems	$250,000	$32,006	637
Computer Maintenance Management System	$500,000	N/A	N/A
Wind Turbine Generator	$3,800,000	$197,732	5,557
Water Efficiency Improvements	$200,000		
Lab Hood Control	$10,000	<$1,000.00	Minimal
Kitchen Exhaust and Make up air Improvements	$25,000	<$1,000.00	Minimal
Solar Wall Applications	$150,000	$1,796	62

[1]Savings are inversely proportional to cost of gas.
[2]Savings calculated on replacing propane, at full campus load, with Natural gas.

3. Energy Awareness and Education Plan

In recognition of the University of Minnesota, Crookston's (UMC) primary function of education we have developed an energy awareness and education plan. This plan outlines a system which could be put into place on the University campus, and which would be accessible via touchscreen monitors, and through the internet. This system would be made available to all students and campus occupants. The purpose of this system would be to help foster behavioral modifications, enhance the learning environment in regards to sustainability and renewable energy sources, and to help attract and retain students and staff.

In order to help foster behavioral modifications, we have outlined the system to provide real time, quantitative data. Our belief is that educated decision makers will make better choices, and voluntarily curtail at least some of their energy impacts. The information provided to the students and staff will show:

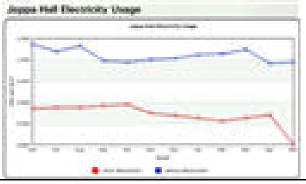
1. The current energy mix being utilized on campus, clearly identifying each energy supply source on a real time basis.
2. The environmental impact of each energy source and compare them against the impact of the local utility mix. In this way the public will see the real time impact of their energy use and the impact of the different energy sources. The impact time of day energy use has on emissions will also be highlighted since most members of the public are unaware of the differences in environmental impact that time of day energy use has.
3. That in order to meet peak demand loads, the utility has to use different energy sources with different emission profiles (coal baseline plants versus gas peaking plants) than they use to meet baseline loads.
4. That the impact of conserving energy during peak demand times has a significantly higher impact financially and environmentally than saving energy during non-peak times.

This system is also intended to enhance the learning environment in regards to sustainability and renewable energy sources. In the intermediate and advanced levels of this system, we have included the ability for staff and students to query this system for both real time and historical data. This includes the ability to export, graph, and manipulate data, along with the ability to modify the system and publish results. It is our intention that in the intermediate and advanced levels, that this system could be used as a teaching tool in classes, and as a data source for research and thesis work for advanced degrees.

In this competitive climate for student and staff attraction, sustainability is an area of interest for more and more of the general public. Because of this increased interest in sustainability and renewable resources, it only makes sense to be sure and highlight investments and achievements in these areas. This system has been designed in order to communicate to both current and potential campus occupants, the important steps that UMC has been taking. It is important to leverage the achievements that UMC has achieved - thus increasing the interest of students and staff to learn and work there.

The following pages outline three different levels of an Energy Awareness and Education System.

	Components	Samples

1st level
Basic
 	
$35,000
Budget
 	
$3,000
Annual
Maintenance
	• Basic template Design
	• Green Energy Features Map
	• Basic dorm competition – static competition
	    o Comparison of building performance between buildings
	    o Comparison by % improvement per sq ft and total usage
	• Basic system animation
	• Basic current weather
	• Basic energy supply information pages that describe, gauge, and graph energy supply sources:
	    o Wind turbine
	    o Biomass Boiler
	    o Ottertail Power Electric grid
	    o Natural gas boiler system
	    o Coal fired boiler system
	• All information to be contained on a website with a link from the UMC site
	• One new touchscreen station (to be located)
		
		Basic
		
		
		Live Data Gauge & Graphs
		

<table>
<tr><th></th><th>Components</th><th>Samples</th></tr>
<tr>
<td>2nd level
Intermediate

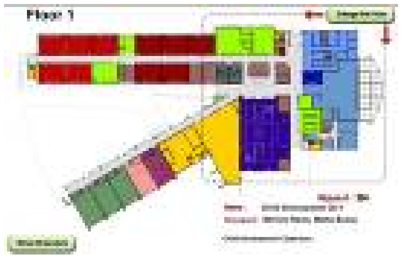
$120,000
Budget

$3,000
Annual
Maintenance

$1,500
Monthly
Subscription</td>
<td>All of the above and…
• Customized web interface design matching existing UMC marketing /source materials
• Robust dorm competition – dynamic competitions
1. Comparison of building performance between buildings
2. Comparison by % improvement per sq ft and total usage
3. Ability for multiple tiered competition ie: floor to floor competition within a dorm as well as ability to engage in competitions with other dorm buildings
4. Administrative logon and password provided to set up and establish different types of competitions at will
5. Ability to run multiple competitions simultaneously
• Basic donor recognition
• Campus map
• Ability for students to interact with live building data, publish results and design components (monthly subscription fee)
• Six additional workstations to be located on campus (Qty 6)– assuming 32” in each location
</td>
<td>
Custom Interface

Site Map


Data Portal</td>
</tr>
</table>

	Components	Samples
3rd level Advanced $175,000 Budget $3,000 Annual Maintenance $2,500 Monthly Subscription	All of the above and… • Foreign language • Weather forecasting – robust and complete • Robust and searchable building and campus directories with site map integration and room scheduling • Robust Donor Recognition – including 'donate now' feature and Donated Items Map • Points of interest map 	 Campus Map  Points of interest  Campus Directory

4. Active Energy Management Plan

As the University of Minnesota Crookston (UMC) continues down the path towards energy conservation, it is important to become more proactive when it comes to energy consumption and energy costs. This is becoming even more important in this current state of energy price instability and escalation.

In order to be truly effective at managing energy on campus, several things must occur. First, there must be a way to gather and collect real time energy data. Second, there must be a methodology in place to analyze that data, and compare it against targets in order to determine if changes need to be made or not. Lastly, there must be a method to make corrective changes when the data supports making changes. We have developed a plan to assist the University of Minnesota Crookston campus to achieve all three of these goals. This plan consists of both technology solutions for the automated gathering and collection of appropriate data, and a human interface component to perform the analysis and prepare and execute corrective actions as necessary.

The plan we have developed for UM Crookston consists of incorporating the campus DDC system into the active energy management plan components for monitoring and trending. In addition to the automated controls and existing campus operations staff, we will be supplementing them with remote expertise. This remote expertise will be constantly monitoring all data being collected on a real time basis and will contact the campus staff anytime we see established key performance indicators moving out of an acceptable range. In addition, they will be having regular scheduled interface with the systems and operational staff on a monthly basis. This remote access will accomplish the following activities:

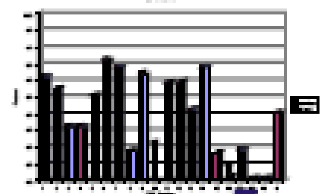
- Perform system check up to identify any potential issues
- Establish responsibilities and action plan for any potential issues found
- Gather and back up trend data
- Analyze trend data to establish operating efficiencies
- Identify any efficiency improvements and develop action plan for them
- Report back to campus point of contact with activities performed and outcomes

Every quarter a report will be generated and delivered to UMC. This report will highlight the operating efficiencies which have been achieved, and any potential efficiency improvements which have been identified. This quarterly report will serve a report card function in regards to the operation of the energy supply and demand systems on campus. It will highlight achievements, as well as outline plans and methods for improving operations.

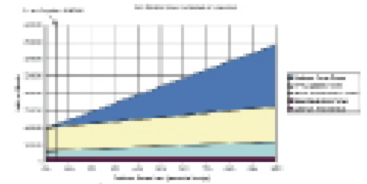
The budget for this level of active energy management has a one time implementation budget of $30,000, and a budget of $40,000.00 annually for the remote expertise.

ACTIVE ENERGY MANAGEMENT

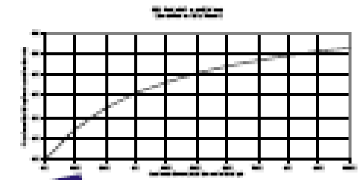
PDU LOAD ANALYSIS



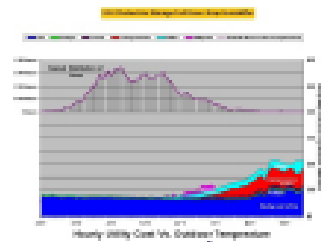
MONTHLY POWER CONSUMPTION



SITE EFFICIENCY

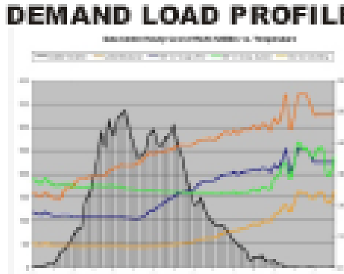


UTILITY COST DATA



ENERGY & UTILITY INFORMATION MANAGEMENT PLATFORM

DEMAND LOAD PROFILES

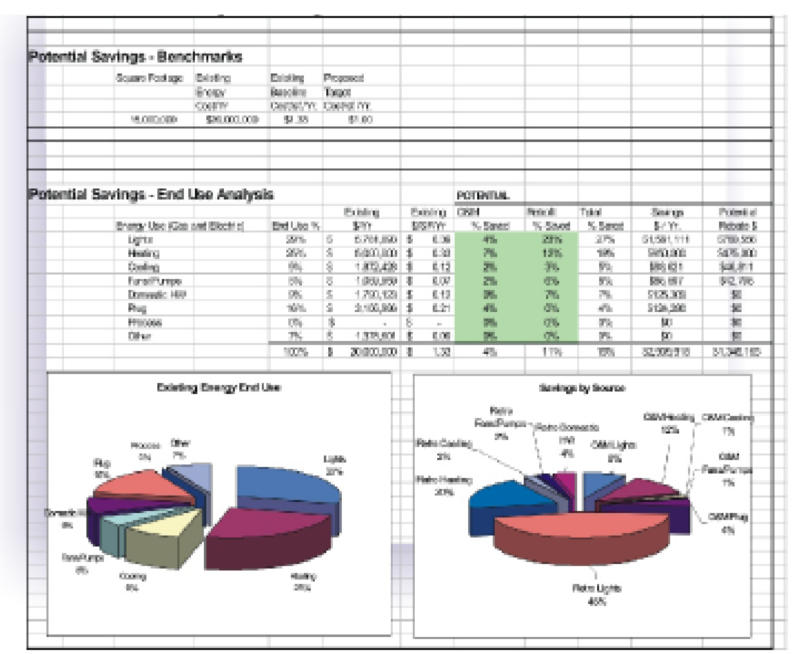


UMC Key Performance Indicators

- $/ Sq. Ft./Yr.
- Maintenance Labor / Sq. Ft.
- KWh/Ton-hr
- BTU/Sq. Ft./Yr.
- Load Factor
- Carbon Emissions / Yr.

ENERGY BENCHMARKING & ANALYSIS

Energy Cost Reduction Targets



Active Energy Monitoring

- Site Specific Energy Management
- System Wide Measurements
- Comparisons and Benchmarks
- Active Energy Management Interface

Supply Side Management Cost Reduction Strategies

- Open Market Purchase Programs
- Lead Aggregation Initiatives
- Tariff and Rate Schedule Audits
- Bill Paying Services

Guide and Inform Design & Construction Activities

- Active System & Equipment Selection
- Create Predictive Cost Models
- Utility Rebate Programs
- Lease Central Utility Solutions
- Life Cycle Cost Analysis
- Renewable Energy Applications
- Co-Generation Approaches

Demand Management Cost Reduction Strategies

- Peak Demand Limiting
- Enhanced Control Strategies
- Evaporative Cooling Strategies
- Load Shearing Approaches
- Site Specific Conservation Measures
- Thermal Storage Systems
- Revised Operational Parameters

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