Solar Hot Water
Feasibility Study
For

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Prepared for:
Focus On Energy
Madison, Wisconsin

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A. Executive Summary

St. Norbert College (SNC) is situated on the west shoreline of the Fox River in De Pere, Wisconsin. Founded in 1898, the campus is a comfortable setting with many trees, walkways, and architecturally attractive buildings. The site has approximately 42 structures consisting of dormitories, classroom and support buildings. These buildings host students and a variety of other occupants year round, including during the summer months. A district hot water network that is comprised of a large underground network of pipes supports the campus. The hot water network uses two separate heating plants to heat the domestic hot water used throughout the campus. This network forms a two hot water “loops” which tie into the buildings on campus. As water circulates through the loops, the buildings draw their hot water from the loops. Since the hot water loops have long pipe runs, the water cools as it makes its journey from the boiler through the loops. Buildings at the end of the loops sometimes experience a loss of hot water during peak demand times.

Solar Mining Company conducted a feasibility study for the installation of a solar hot water system at SNC. Solar Mining analyzed the current hot water distribution network and concluded that the purpose and use were well suited for solar hot water technologies. Specifically, Solar Mining identified the hot water loops as the most efficient and effective point to introduce solar heat into the hot water system. The recirculation loops have a 40 gallon per minute flow rate and experiences a temperature drop of around 35 degrees due to standby losses. The water typically exits the boiler at 140 degrees F, circulates through the loops and returns to the boiler at approximately 105 degrees. It is then reheated to 140 and the cycle repeats. Some of the buildings along the loops have additional smaller water heaters to assist in meeting the hot water demand.

Solar Mining proposes to install a solar thermal system that would add heat along the loops to compensate for standby losses and potentially eliminate the loss of hot water during peak demand periods. Performance estimates given within this report represent a conservative outlook considering only standby losses. Actual performance should be well above these estimates, given that the system typically operates under additional load. Although the operating temperatures are not ideal for optimizing collector performance (relatively high inlet water temperature to heat exchanger), our test data indicates that the unique configuration of Solar Mining collectors minimizes losses from the solar system and allows us to consistently provide solar fluid temperatures in excess of 130 degrees. By providing heat along the loops with a distributed system closer to the point of use, we minimize thermal losses and maximize useful gain.

B. Introduction

Solar Mining Company LLC (SMC) is located in Green Bay Wisconsin and has a nationwide reputation for innovative design and installation of highly efficient solar thermal applications. SMC’s projects range in size from 1,600 to 14,000 square feet, and address various hot water requirements.

The purpose of this study is to determine the feasibility of installation, and the economic and environmental impact of a solar hot water installation for St Norbert College, De Pere, WI. This feasibility study will address the basics of site placement, provide information relating to the production of solar thermal energy, and quantify the environment benefits to the local community. Specifically, our objectives are:

I. Identify domestic hot water heating applications.
II. Determine site application compatibility for solar thermal heat.
III. Evaluate site for visual appeal of panel placement.
IV. Determine equipment and installation cost.
V. Calculate fossil fuel energy usage and proposed solar energy production.
VI. Development of a (1) one line plumbing schematic showing equipment and plumbing locations in relationship to existing equipment.
VII. Determine an implementation plan.
VIII. Provide college with application compatibility information concerning use of solar energy.

C. Methods

The project originated from initial contacts between Solar Mining Company and the Environmental Engineering Staff of St Norbert College. Upon conclusion of the meeting, both parties agreed to further study the possibility of using a solar hot water system to provide some of the energy used at the college.

Solar Mining conducted multiple site visits to various buildings on the campus. Specific hot water flows were isolated, flow rates were calculated, and hot water return loops were identified. Temperatures for the hot water loops were measured and the ability to augment these loops with solar hot water was identified. Unfortunately, RETScreen® thermal modeling software does not have the capability to address district heating applications, so an internal analysis was conducted to determine system size and annual energy production (see Attachment 6). Finally, material and system costs were determined, and economic and environmental estimates prepared.

D. Results

SNC has two heating plants that provide potable hot water, the John R. Minahan Science Hall, which provides service to the north area of the campus, and the "Heating Plant" which provides service to the south area of the campus. Both systems have a hot water loop that travels underground and within tunnels connecting the buildings on campus. Both hot water loops are served by a 2 inch copper line and each has a smaller ¾" copper line that acts as a return loop back to the heating plants. Of the 42 buildings, 11 are resident halls used by students. Each hall has a unique design and layout. Some of the buildings have smaller water heaters in the lower level that serve to assist in meeting the demand of hot water usage.

The hot water loops have an estimated pipe length of 3,391 feet, a flow rate of 40 gallons per minute, and a volume of approximately 632 gallons of hot water. The temperature of the water exiting the heating plants is 140° F, and the return temperature is 105° F.

The hot water loops experiences standby losses of 35 F, which equals approximately168 therms of lost energy per day.

The proposed solar energy system is designed to add energy at strategic locations within the hot water loops to offset some of the losses. Solar Mining estimates that a district solar hot water system could make-up 30% of the losses, and on average add 42 therms of clean energy to the loops per day.

The two heating loops exit their respective boilers (Minahan and the Heating Plant) and are subdivided into four service loops each. These service loops provide water at a flow rate of 10 gallons per minute each to eight subsections of the campus. Solar Mining collectors would be tied in to the system within these eight service loops.

Specifically, within the Minahan loop, Solar Mining would install solar collection systems on the roofs of Madeline and Lorraine Halls, Bergstrom and Cofrin Halls. The Heating Plant loop would be addressed by installing solar collections systems on the roofs of Boyle, Sensenbrenner and McCormick Hall. The solar collectors and their associated solar heating loop would be plumbed into the lower level of each building. At this location the solar energy would be transferred to the existing hot water loop to replace the losses and help balance the hot water supply. A shell and tube heat exchanger will be place in each building to transfer the solar energy into the hot water loops. As water circulates through the loop, the solar system would provide energy at different points to help make up the heat losses within the loop. At times of peak hot water demand, the solar system will also provide additional energy to the loop and reduce the number of users that experience a loss of hot water when needed. The size and location of the solar energy systems are as follows:

Building	**Solar Collector Size**
Cofrin Hall	586 Square Feet
Madeline & Lorraine Hall	880 Square Feet
Bergstrom Hall	732 Square Feet
McCormick Hall	732 Square Feet
Boyle Hall	1098 Square Feet
Sensenbrenner Hall	1318 Square Feet
Victor McCormick Hall	586 Square Feet
Total	5932 Square Feet

Maps designating the building placement of the solar systems are located at attachments 1 and 2. The plumbing design for the solar installation is shown at attachment 3, and a drawing showing the separate storage tank for Mary Minahan McCormick Hall as shown in attachment 4.

E. Solar Output

The solar energy system would produce approximately 15,156 therms of energy per year. Unlike traditional boilers that waste fuel in the combustion process (hence an efficiency rating), solar systems don’t combust a fuel and have virtually no losses in the production of energy.

Assuming that the current boilers are 75% efficient, the college would have to purchase 18,945 therms of natural gas to produce an equivalent 15,156 therms of solar energy. Taking combustion into consideration, the annual output of the solar system increases to 18,945 therms per year. Simply put, SNC would need to purchase 18,945 therms of natural gas to produce an equivalent amount of 15,156 therms of solar energy.

When comparing the solar and boiler systems, the solar energy system could be viewed as a profit center, in contrast to a boiler system that is an operating cost. Both systems have an initial cost for the equipment, but the two systems differ in that the fuel that creates energy for the solar system is free. Once the value of the solar energy produced equals the cost of the solar system, the system has paid for itself, making future energy free. The free energy has a value, since this energy would have been supplied through the purchase of natural gas. With a boiler system, natural gas must always be purchased; hence there is never a breakeven or a point at which a savings occurs.

F. Economic Value of System

If the college were to purchase the same amount of energy that is produced by the solar system, over a 20-year period it would cost the college $684,332.00 for natural gas costs. However, since the fuel that is needed to power the solar system is free, the value of the solar energy produced will exceed the cost of the solar system during the 9th year. The energy produced by the system over the following 11 years would be free, and would result in a savings to the school of $482,052.00.

Solar System Cost	$237,280.00
Estimated Focus on Energy Contribution	-$45,468.00
Cost to SNC	$202,280.00
System Payback in Years	In 9th Year
Energy Cost Savings Over 20 Years	$485,677.00
Cost of Same Amount of Natural Gas Over 20 Years	$684,332.00

Assumes: A $.74 a therm starting natural gas rate.
Natural gas rates increase at the historical 30-year average.
Current system efficiency is 75%.

However, with the advent of Hurricane Katrina, the U.S. Department of Energy, Energy Information Administration Short-Term Outlook, issued Sept. 7, 2005 (http://www.eia.doe.gov/steo), predicts natural gas prices in the Midwest may rise 69 to 77 percent this winter. Hurricane Rita has further contributed to upward pressure on natural gas prices. This type of rate increase would dramatically reduce the payback period. It would also indicate that moving ahead with the installation of the system as soon as possible would be of significant benefit to St. Norbert's to provide relief from these increases.

G. Discussion

Based on the results of this study, Solar Mining Company concludes that a solar hot water system would be an efficient and cost effective method to reduce the consumption of natural gas on campus. Introducing solar energy directly into the loop at the point of use reduces losses and maximizes useful gain, decreasing the fossil fuel demand. These results have been verified on a smaller scale at another SMC installation. Solar thermal is a viable technology in a district-heating scenario. Beyond the economic factors discussed in the previous section, the solar system would have a direct environmental impact by reducing greenhouse gases. Estimates on those reductions are as follows:

H. Reduced Emissions Per Year

Type of Pollution	**Amount of Reduction per Year**
Greenhouse Gases (CO_2)	154054 Pounds
Volatile Organic Compounds (VOC)	7 Pounds
Nitrogen Oxides (NO_x)	197 Pounds
Carbon Monoxide (CO)	32 Pounds
Particulates (PM10)	2 Pounds

I. Implementation

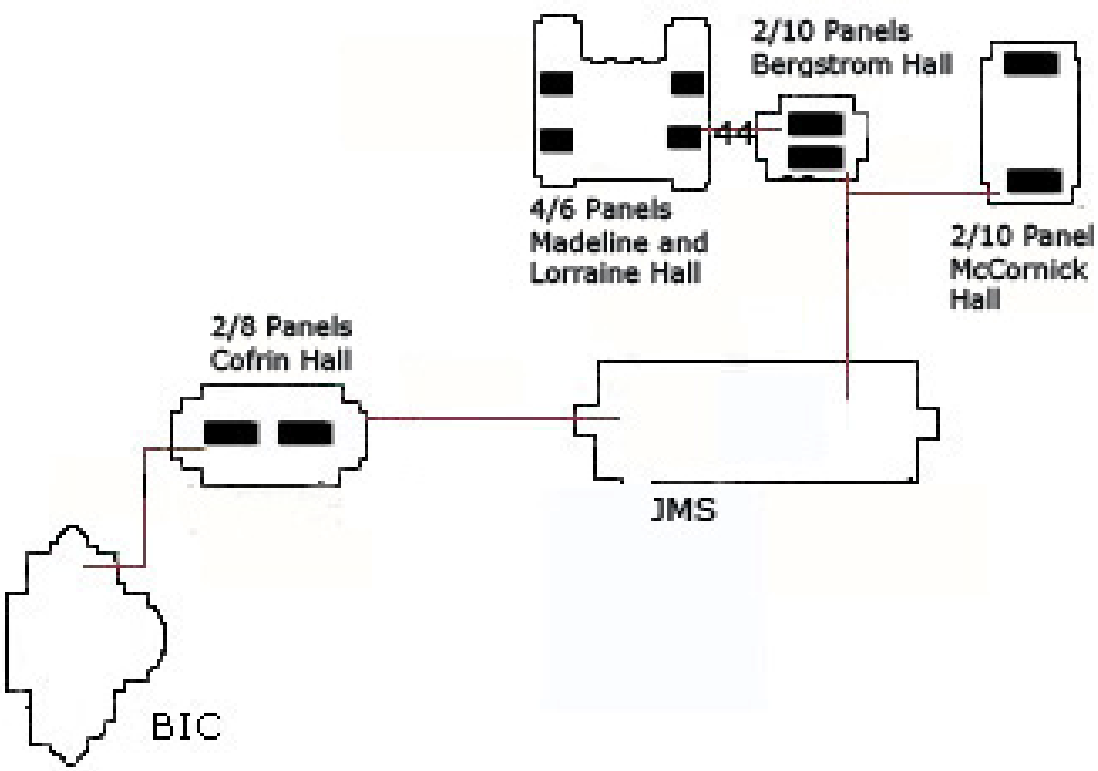
The design, build and installation process for a typical solar hot water system is as follows:

1. Solar Mining provides solar hot water proposal to SNC.
2. Solar Mining provides SNC a formal design and build agreement.
3. SNC supplies structural plans for buildings where proposed solar collectors would be installed.
4. Solar Mining provides engineering calculations for the proposed project and manages all submittals with the proper authorities.
5. Solar Mining assists SNC application to Focus on Energy and other applicable funding sources.
6. Solar Mining orders materials and schedules the manufacture of the system.
7. Solar Mining and SNC schedule installation of the system.
8. Solar Mining conducts a pre-installation meeting with SNC to finalize all aspects of the installation.
9. Solar Mining installs system and provides training to SNC personnel.
10. Joint inspection and transfer of system from Solar Mining to SNC.

Attachments:

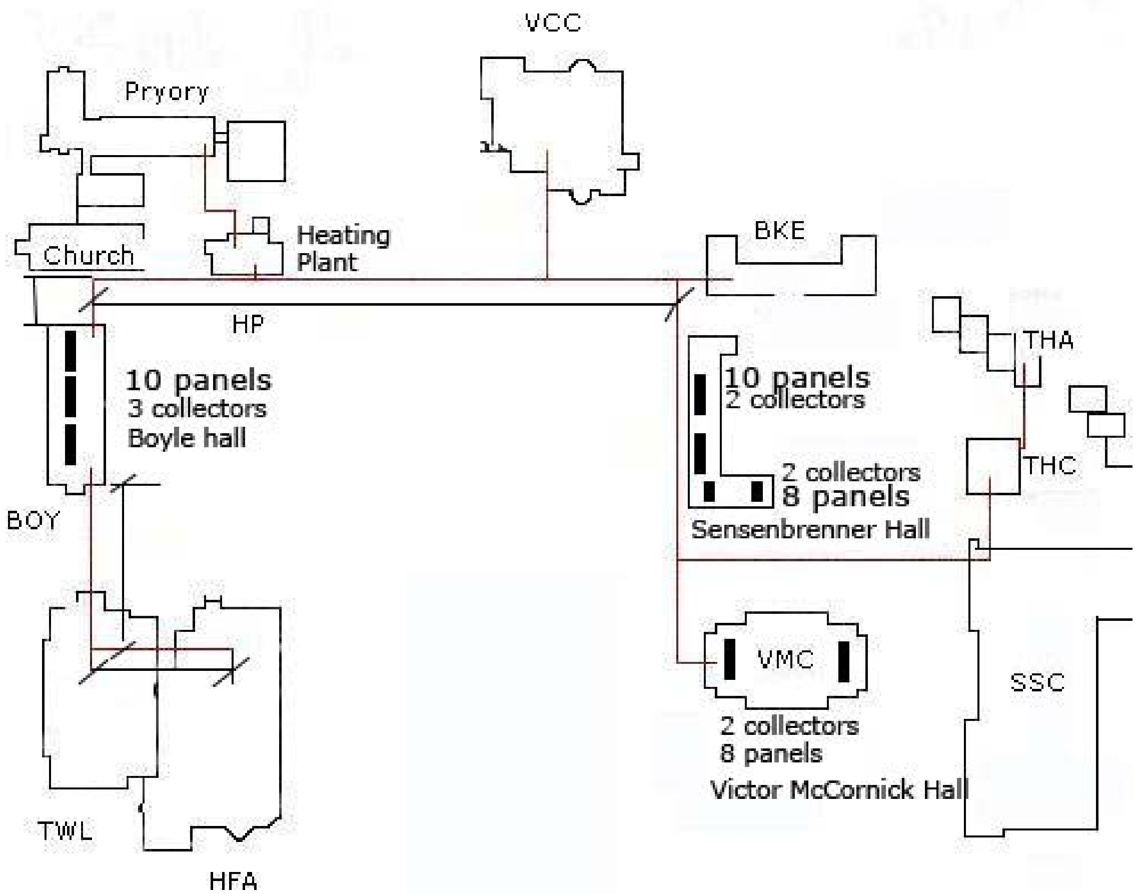
Attachment 1

Site Layout for the North area showing the location of the hot water piping and the proposed location of the solar collector panels. Drawing not to scale.



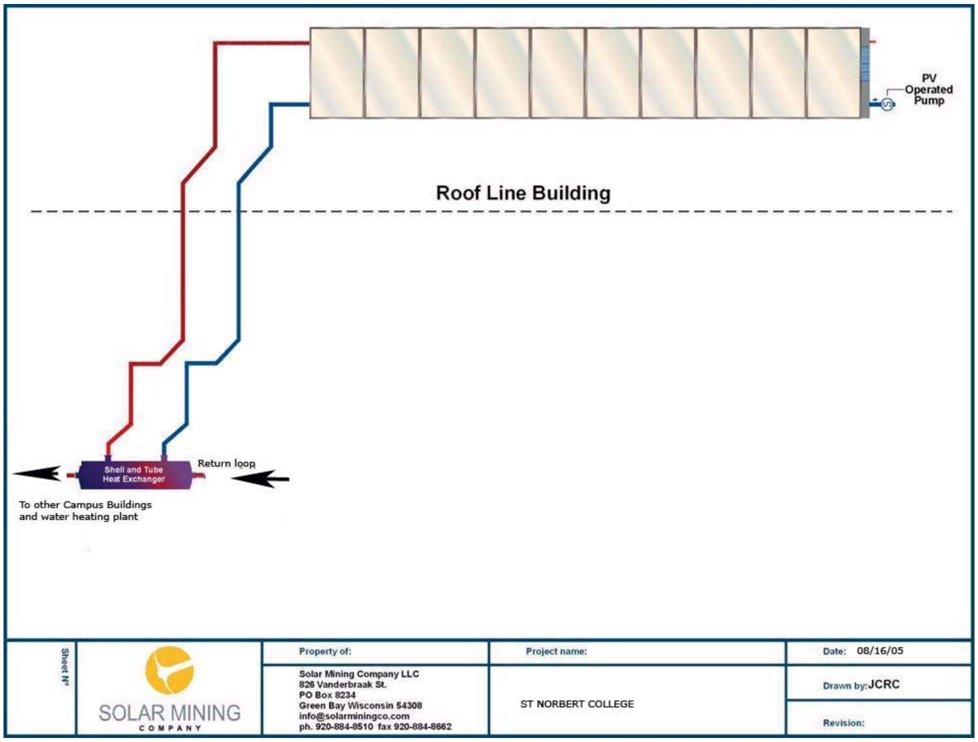
Attachment 2

Site Layout for the South area showing the location of the hot water piping and the proposed location of the solar collector panels. Drawing not to scale.



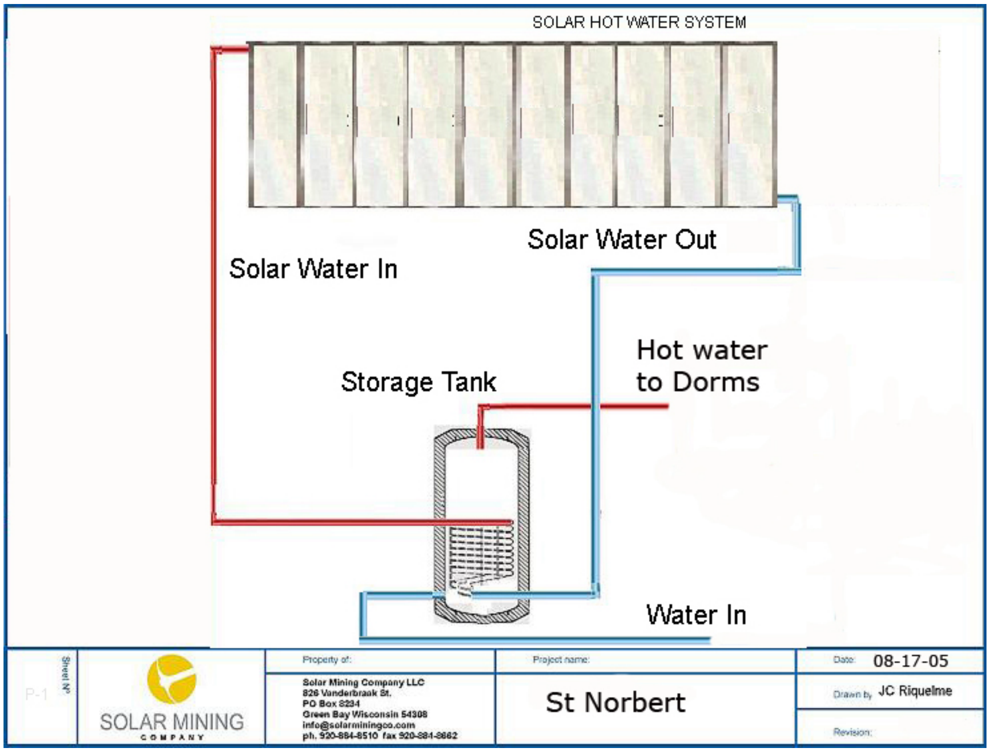
Attachment 3

Typical piping design to be located in the lower level of the dormitories. This excludes the Mary Minahan McCormick Hall. Drawing is not to scale.



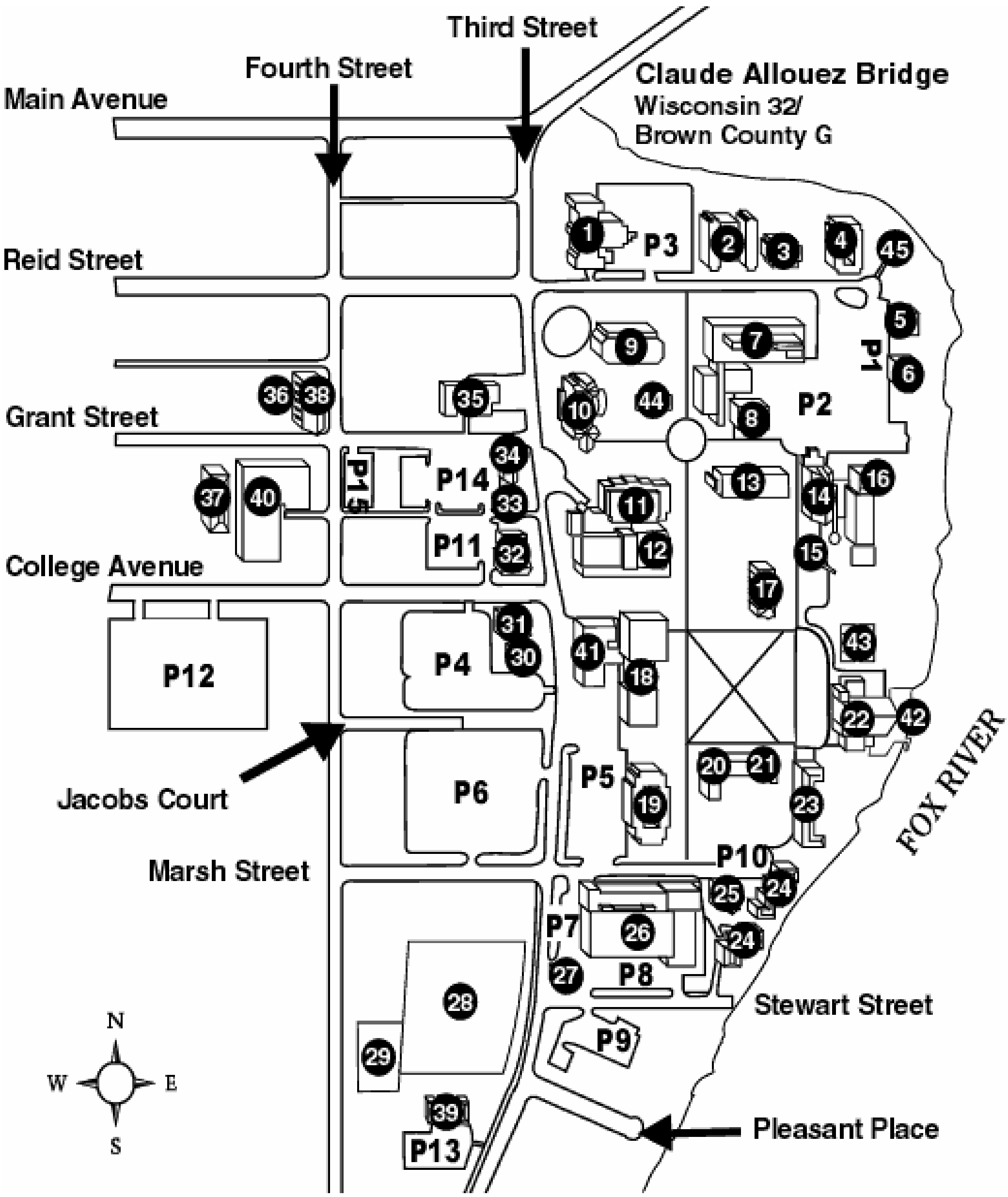
Attachment 4

Typical piping design to be located in the lower level of the Mary Minahan McCormick Hall. Drawing is not to scale.



Attachment 5

Campus Map



Attachment 6

Sizing Information

Parameters

U_L = overall standby losses for the recirculation loop, Btus/day
m_{recirc} = mass flow rate through the recirculation loop, lbm/hr
$m_{w,hx}$ = water side mass flow rate through the heat exchanger = 2505 lbm/hr
T_o = Temperature of water exiting the boiler, 140 ^oF
T_i = Temperature of water returning to the boiler from the recirculation loop, 105 ^oF
m_s= mass flow rate of the solar fluid = 10,440 lbm/hr
$c_{p,water}$ = specific heat of water = approximately 1 btu/lbm- ^oF
$c_{p,solar}$ = specific heat of 50/50 water/propylene glycol mixture = 0.86 btu/lbm- ^oF
$T_{w,in}$ = Temperature of water entering the heat exchanger, ^oF
$T_{w,out}$ = Temperature of water exiting the heat exchanger, ^oF
$T_{s, in}$ = Temperature of solar fluid entering the heat exchanger, ^oF
$T_{s, out}$ = Temperature of solar fluid exiting the heat exchanger, ^oF

The SNC solar thermal system is sized to compensate for standby losses from the campus wide hot water recirculation loop without over heating said recirculation loop under no load or low load conditions (eg. when school is not in session). At its most basic level, we consider the overall recirculation loop standby losses, which can be denoted by the equation

$U_L = m_{recirc} * c_{p,water} * \Delta T$

where $\Delta T = T_o - T_i = 35\ ^oF$

The recirculation loop volumetric flow rate is 40 gallons per hour, which equates to a mass flow rate of 20,040 lbm/hr (assuming 8.35 lbm/gallon). If we assume an average seven hours per day operating period for the solar system, the equation works out as follows

U_L = 20,040 lbm/hr*1 btu/lbm- ^oF*35 ^oF*7 hrs/day = 4,909,800 Btus/day
= 49.098 therms/day

If we look at the points were the solar system ties into the recirculation line, we see that actual heat transfer is limited by the minimum fluid capacitance rate (mass flow rate times the specific heat of the fluid). On the water side of the heat exchanger, assuming the 20,040 lbm/hr flow is divided evenly between the eight buildings being serviced

Mass capacitance, water = $m_{w,hx}$* $c_{p,water}$ = 5010 lbm/hr*1 Btu/lbm-F = 5010 Btu/hr-F
Mass capacitance, solar = m_s* $c_{p,solar}$ = 10,440 lbm/hr*0.86 Btu/lbm-F = 8978.4 Btu/hr-F

Therefore we find the minimum fluid capacitance rate on the water side of the heat exchanger. We have found that in our existing installations, collector temperatures consistently reach 130 ^oF or above due to reduced collector losses from the reduction in exposed piping and increased insulation levels of our panels. Thus it is reasonable to assume a 130 ^oF inlet temperature to the heat exchanger on the solar side and an inlet temperature of 110 ^oF on the water side (as a midpoint temperature in the recirculation loop). Assuming a heat exchanger efficiency of around 75% based on the performance of similar systems that are currently installed, we can expect a gain through the heat exchanger of roughly 15 ^oF.

$\Delta T_{w,hx} = T_{w,out} - T_{w,in} = 15\ ^oF$

This leads to a gain of

$m_{w,hx} * c_{p,water} * \Delta T_{w,hx} = 5010$ lbm/hr*1 Btu/lbm- ^oF*15 ^oF = 75,150 Btu/hr

or

526,050 Btus/day = 5.26 therms/day per heat exchanger

Multiplied by eight heat exchangers equals roughly 42 therms per day

On the collector side, annual collector performance data indicates that SMC collectors/systems in Wisconsin (from systems located in Madison, Green Bay and Stevens Point) deliver to their load a yearly average of roughly 400 to 830 btus/ ft^2/day. The system that is most similar to the St. Norbert system (a recirculation loop in Stevens Point) delivered an average of roughly 700 btus/ ft^2/day (it is currently being repaired due to tornado damage). If the standby losses from the St. Norbert recirculation loops are 4,909,800 Btus/day, then to meet this load will require 7014 square feet of collector.

4,909,800 Btus/day / 700 btus/ft^2/day = 7014 ft^2

Or, at 36.6 square feet per collector

7014 ft^2 / 36.6 ft^2/collector = 191 collectors

Upon conducting the site survey, it was concluded that the following arrays could be placed without obtrusion:

Boyal Hall 3 ten panel collectors or	30 panels
Sensb. Hall 2 ten and 2 eight panels or	36 panels
VMC Hall 2 eight panels or	16 panels
Cofrin Hall 2 eight panels or	16 panels
M&L Hall 4 six panels or	24 panels
Berg. Hall 2 ten panels or	20 panels
MMM Hall 2 ten panels or	20 panels
Total	162 panels

Attachment 7

Key Personnel

Partners in the LLC are Richard Lane, founder has 23 years experience at all levels of the solar thermal industry including over ten years as CEO of solar energy companies. Mr. Lane brings a wide range of experience covering all aspects of the renewable energy industry. Richard Lane directs all Engineering and R+D efforts. The second partner, John Kress, brings over 10 years of financial management experience along with a track record of two previous successful business startups. Mr. Kress is the President of the G. F. Kress Foundation.

Other key personnel include George Zachariasen, with over 15 years of solar engineering experience. George has extensive experience in solar thermal applications and is very involved in the R&D and design of our products.

Juan Carlos Requelme, a bi-lingual Chilean national, is a former business manager and mechanical engineer. Juan Carlos provides additional engineering support, and is a strong asset for our R&D efforts in Chile.

Clarence "Wick" Wickham heads sales and marketing. Wick has 8 years of sales and marketing experience along with 22 years of senior management experience in both the U.S Army and Transportation Operations.

Bob Boerst manages the installation team. Bob has over 20 years of construction design and building experience. He is also skilled in boiler and HVAC operations. Bob directs all installation efforts and is responsible for overall system quality control. In addition, Bob leads the organizational Information Technology efforts.

Laurie Neverman has recently rejoined the team at SMC as a solar engineering consultant. Laurie has a Masters in Mechanical Engineering from the Solar Energy Lab at UW-Madison and worked for several years with Public Energy Systems.

Jeff Danen is responsible for all financial aspects of the organization. Jeff is a CPA with over 6 years of financial accounting experience.