LEAST-COST PATHS TO ENERGY INDEPENDENCE AT A MIDWESTERN UNIVERSITY

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ABSTRACT

In September of 2006, Wisconsin Governor Jim Doyle announced that four Wisconsin college campuses would be selected to participate in a pilot program to achieve energy independence by the year 2012. The University of Wisconsin River Falls campus was one of the sites selected for the program.

Energy independence was defined as being "capable of acquiring or producing renewable energy equivalent to…consumption."

Wisconsin Public Power Incorporated contracted with the Energy Center of Wisconsin to identify and analyze the options for UW River Falls to achieve energy independence. Given the varied approaches and potential combinations of strategies and technologies for reaching the goal of energy independence, it was necessary to narrow them down to a manageable few. The narrowing process involved calculating the degree of "independence" produced by each measure and the resulting life cycle cost of implementing it. Energy independence was measured as the percent of carbon-dioxide (CO_2) reduction from the energy consumption baseline. The final result shows the net present value cost (or savings) of various paths to achieving energy independence.

The Energy Center evaluated four scenarios to energy independence for UW River Falls. For each scenario we evaluated a combination of measures, ranging from building efficiency and conservation to biomass-fueled boiler plants.

The four scenarios are:

Standard Scenario: attempts to make full use of existing campus infrastructure with as little capital investment as possible;

Geothermal Scenario: implements a campus-wide geothermal heat pump system to meet cooling and heating needs, produces an all-electric campus;

Cogeneration: Follow Thermal Load Scenario—produces steam using biomass fuel to meet heating and cooling demand, with electric production secondary; and

Cogeneration: Follow Electric Load Scenario—produces steam using biomass fuel to meet all electric demand, with thermal needs secondary.

The key findings are:

- Energy independence can be achieved for as little as $19.1 million net present value over the existing baseline, or roughly $10 per gross square foot in today's dollars.
- Achieving partial independence costs much less. For example, 64% independence can be achieved at one-tenth of the 100% cost. Costs rise dramatically after this threshold.
- Life cycle costs are highly dependent on energy cost escalation assumptions. Under a high escalation scenario, energy independence actually *saves* money over the life cycle.

CAMPUS OVERVIEW

Campus Energy Infrastructure

The University of Wisconsin River Falls campus serves about 6,500 students and contains about 2 million square feet of facilities. A central campus area, served by a central steam utility, comprises 84% of the campus square footage and consumes 90% of the total campus energy. This study focused solely on the energy independence of the central portion of the campus.

The total energy consumption per square foot of the central campus was 121,175 Btu per square foot in fiscal year 2006. This is the second-lowest total energy use intensity for all campuses within the University of Wisconsin system. This is also a low energy use intensity compared to higher education facilities in neighboring states. Only a handful of similar institutions in the upper Midwest climate displayed a lower consumption. These other institutions were used as a benchmark in estimating remaining energy reduction potential at UW River Falls.

Historical Energy Consumption

There are two main components to central campus energy consumption at the River Falls campus – electrical and thermal. The electric component is obvious, while the thermal component is composed mostly of steam energy production. Steam is produced in the central heating plant and distributed to the central campus buildings via underground pipes. Steam provides heating in the winter but also provides domestic water heating year-round for showers, faucets, kitchens, and laboratory end uses. Steam is also used for "reheat" in the summer for use in temperature control in air conditioning systems. The primary fuel for producing steam in the cold months is coal with natural gas used in the warm months. Occasionally, fuel oil is also utilized when cost effective. Steam production is a simple indicator of thermal energy consumption because it is the end product of annually varying mixes of coal, natural gas, and fuel oil source fuels.

Campus electric consumption and annual peak demand have increased at an average of 1.7% per year since 1993. This trend is due, in part, to the steady increase in the use of electronic equipment within buildings and increasingly warmer summers producing larger air conditioning loads.

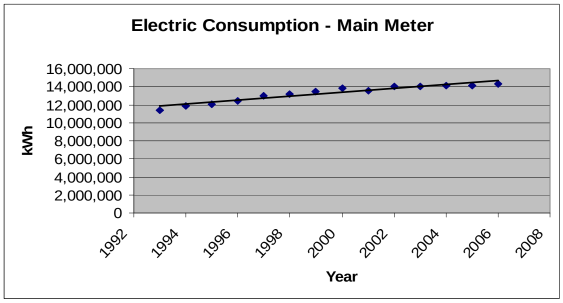

FIGURE 1: ANNUAL CAMPUS ELECTRIC CONSUMPTION

In contrast, steam consumption has remained essentially flat since 1987. Steam production is the primary use for natural gas on campus, and the sole use for coal and fuel oil. It is likely that steam production has remained flat due to the increasingly warmer winters and possibly the small, but steady, increase in heat released from electronic components within the buildings.

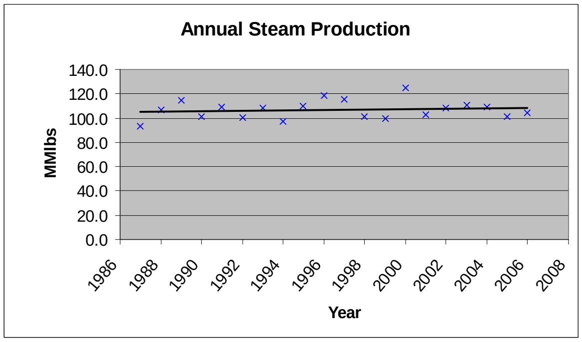

FIGURE 2: ANNUAL CAMPUS STEAM CONSUMPTION

MODELING APPROACH

The quantitative analysis of the energy independence approaches was accomplished by constructing a spreadsheet model. The amount of data and number of calculations involved was large, so a modular approach was taken to control complexity and to ease any debugging. The controlling variables for each independence measure, including efficiencies, costs, capacities, etc., are contained within a dedicated worksheet for each measure. These worksheets then act upon a central worksheet containing the hourly campus energy consumption profiles. In this manner, measures evaluated first affect the energy profile of measures evaluated later, and hence an interactive analysis of the total campus energy demand emerges.

Finally, the resulting campus energy load profiles are evaluated against utility rate structures to calculate costs, and against an emissions calculation worksheet to calculate emissions reductions.

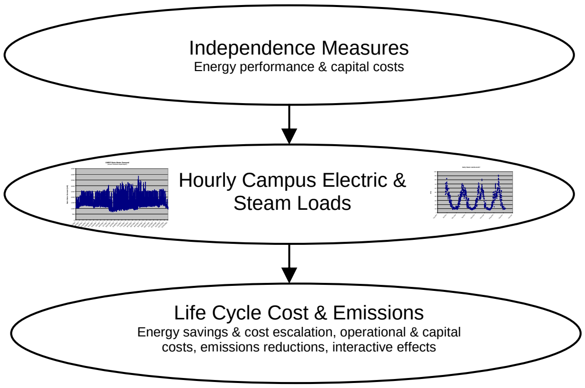

FIGURE 3: ENERGY MODEL STRUCTURE

Hourly Thermal and Electric Load Profiles

The actual hourly campus electric consumption gathered from September 2006 through September 2007 was used in the model as the baseline electric consumption profile.

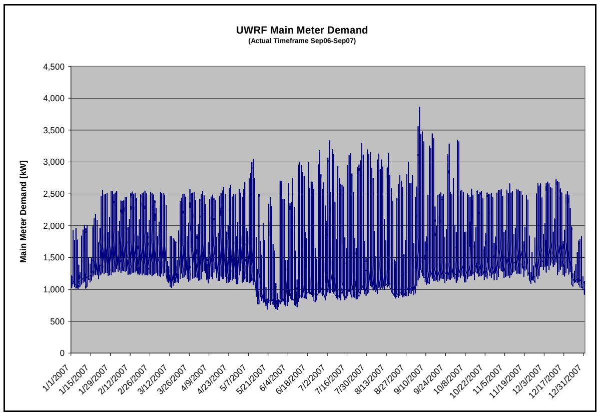

FIGURE 4: CAMPUS HOURLY ELECTRIC CONSUMPTION

Hourly campus steam consumption was developed by correlating daily steam production to daily average outdoor temperatures. Recorded hourly outdoor temperatures were then used to extract hourly steam loads.

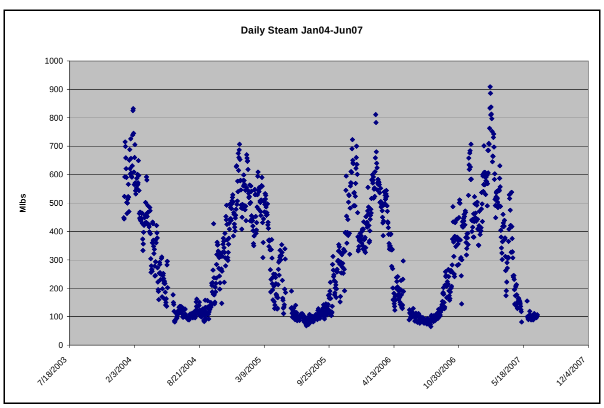

FIGURE 5: DAILY STEAM CONSUMPTION OVER THREE YEARS

Life Cycle Cost Analysis

A life cycle cost analysis was performed for each savings measure, with the main result being the net present value of all additional costs or savings above the campus baseline. Important costs included annual energy and capital costs to implement the measures, and any additional annual operational costs (or savings in some cases). The life cycle cost calculations assume a study period of 20 years, and discount rate of 6.0%, and a general inflation rate of 3.0%.

The life cycle cost calculations are generally based upon approaches outlined in NIST Handbook 135 *Life-Cycle Costing Manual.*

The energy costs in place at the time of this study were used in the model. Biomass energy cost estimates under several scenarios were developed by an in-house study at the Energy Center.

Particular effort was placed upon determining energy cost escalation rates. Net present value costs for the study are very sensitive to this parameter. Three sets of energy costs escalation rates were developed – low, medium, and high.

TABLE 1: ENERGY ESCALATION RATES

	Low	Middle	High
Electricity	1.9%	3.9%	6.3%
Coal	2.2%	5.5%	15.8%
Natural Gas	1.4%	7.4%	9.2%
Biomass	5.0%	6.5%	8.0%
	EIA 2028 Projection	EIA 39 yr history	Actual 3.5 yr increase

The low set of rates for electricity, coal, and natural gas was collected from the Department of Energy's Energy Information Administration (EIA) future energy cost projections. The middle set of rates was determined from EIA thirty-nine year historical cost records. The high set of rates reflects actual cost increases experienced by the campus from January 2004 to June 2007. The low, medium, and high escalation rates for biomass fuel were developed by an in-house study at the Energy Center of Wisconsin.

INDEPENDENCE SCENARIOS

The Energy Center evaluated four potential scenarios to achieve energy independence. Each scenario contains a group of measures that together achieve 100% energy independence. Within the four scenarios twelve measures in ten various combinations were evaluated. Not all of the measures within each scenario are necessary to achieve 100% independence. However, within each scenario, at least one of the measures must be able to replace all remaining electric demand, and another must replace all remaining steam demand. Other measures may be involved in reducing energy demand or in strategic fuel-switching before this "final replacement."

A larger body of independence measures was considered initially, but a number were rejected due to obvious barriers. Examples include: landfill gas reclamation (no nearby landfills), hydropower (only a small nearby resource), industrial waste heat reclamation (none nearby), or centralized ground source heat pump systems using surface water (nearby water bodies have environmental temperature constraints for native trout populations).

The four scenarios are shown in graphical format below. Note that all four scenarios first make use of the building energy efficiency savings measure to first reduce consumption in the buildings.

Standard Scenario

The Standard Scenario is the most complex grouping of independence measures, involving up to nine measures over five potential paths. Not all the measures are necessary to achieve complete independence. In fact, the least-cost path is achieved by using just five of the independence measures – building energy efficiency, steam-to-water distribution retrofit, pressure reduction turbine, purchased renewable electricity (windpower), and biomass combustion. This approach is known as the "Optimized Standard Scenario." The Standard Scenario attempts to make full use of existing campus infrastructure with as little capital investment as possible.

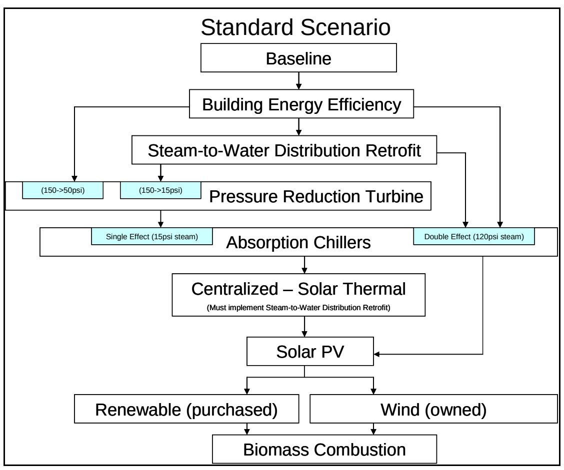

FIGURE 6: STANDARD SCENARIO

Geothermal Scenario

The Geothermal Heat Pump Scenario is a very simple approach. Campus energy consumption is reduced as much as possible, and then both cooling and heating needs are converted to electricity through implementation of a campus-wide geothermal (ground-source) heat pump system. This results in an all-electric campus where renewable electric power (windpower) can be purchased through the local municipal utility. The Geothermal Heat Pump Scenario is the only scenario to avoid the use of biomass combustion to achieve independence. The all-electric nature of this scenario allows for more predictable future energy costs, while the ground source heat pump system lowers summer peak electric demand.

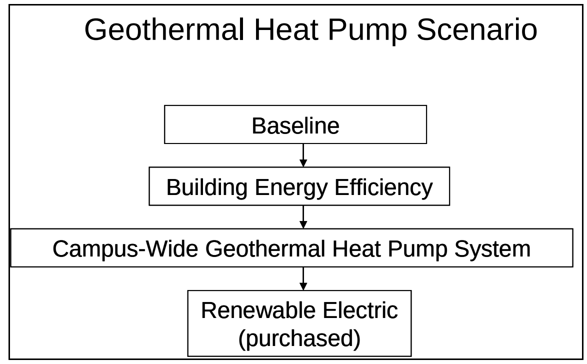

FIGURE 7: GEOTHERMAL SCENARIO

Cogeneration Scenarios

Two cogeneration scenarios have been developed – one where steam production follows the thermal demand (heating and cooling) and generates as much electricity as possible, and another where steam production follows and satisfies all of the electric demand. Each of the two scenarios are actually *trigeneration* situations where steam, electricity and chilled water can be simultaneously produced. Both scenarios assume the construction of a new campus central plant – new boilers that burn biomass, steam turbine generators, steam turbine chillers, and a new chilled water distribution system. Each scenario operates with or without the implementation of the steam-to-water distribution retrofit, changing the efficiency of the steam turbine generators to suit the ability to reject low or medium pressure steam. The *Follow Thermal Load* scenario produces steam to satisfy the campus heating and cooling demands, with electricity produced as a by-product. Not meeting the entire electric demand means that some renewable electricity must still be purchased via the local municipal utility.

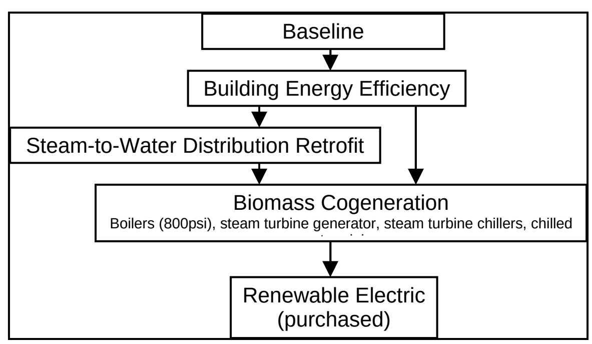

FIGURE 8: COGENERATION – FOLLOW ELECTRIC LOAD

The *Follow Electric Load* scenario produces steam to satisfy the campus electric demand, with waste heat produced as a by-product for heating and cooling. This is the only scenario that is a truly off-grid solution.

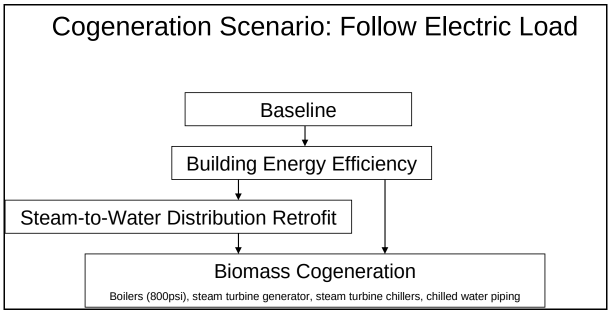

FIGURE 9: COGENERATION – FOLLOW ELECTRIC LOAD

RESULTS

Below are the life cycle cost results for each of the four scenarios. The middle energy cost escalations rates shown in table 1 were assumed along with a study period of 20 years, a discount rate of 6.0%, and a general inflation rate of 3.0%.

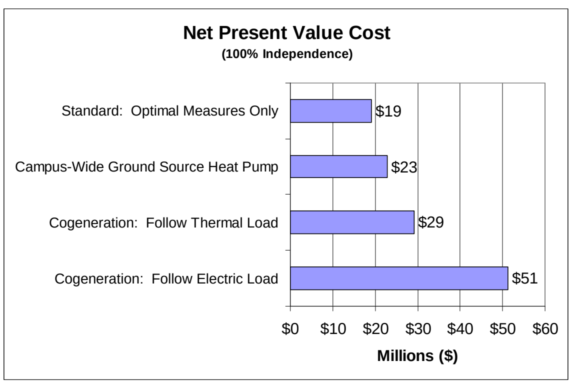

FIGURE 10: LIFE CYCLE COST RESULTS

The Optimized Standard Scenario is the least-cost path to 100% energy independence at UW-River Falls, costing $19.1 million net present value over the baseline.

The resulting net present value cost to reduce CO_2 emissions is shown in figure 11 below.

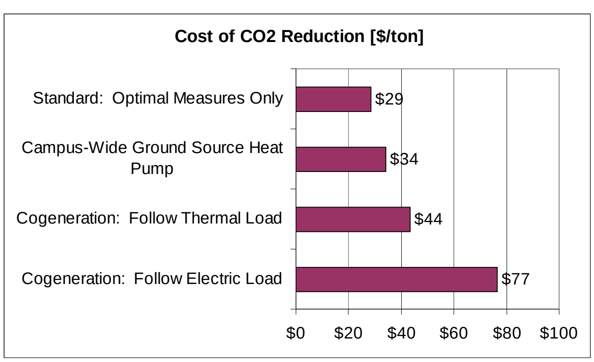

FIGURE 11: CO_2 REDUCTION – COST PER TON (2000lbs)

Energy escalation rates are very influential on the final net present value cost. Figure 12 below illustrates how the cost for the optimized standard scenario can vary from $24 million to negative $1 million based on sets of assumed escalation rates (low, middle, and high). If energy costs increase at the same rate over the next 20 years as they have the last 3.5 years, achieving energy independence at UW River Falls would *save* money. See the negative net present value cost under the "high" energy cost escalation rate scenario.

The low, middle, and high escalation rates for figure 12 are shown in table 1.

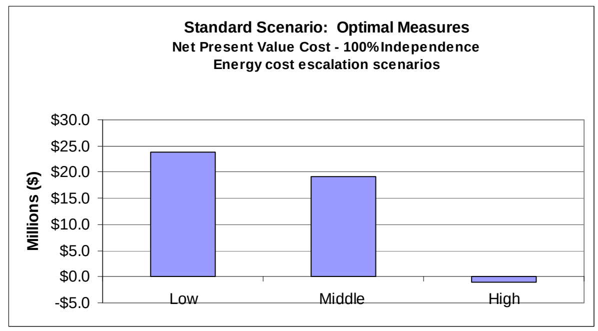

FIGURE 12: SENSITIVITY TO ENERGY ESCALATION RATES

Achieving 100% energy independence may not be the most attractive economic approach. Figure 13 illustrates that achieving 64% energy independence (64% CO_2 reduction) costs one-tenth as much as 100% reduction. This economic sweet spot suggests that achieving partial independence at many campuses may provide greater environmental benefits than achieving 100% independence at only four campuses. This trend is primarily the result of applying cost-effective energy efficiency and purchased wind energy first, with the more expensive biomass combustion measures following.

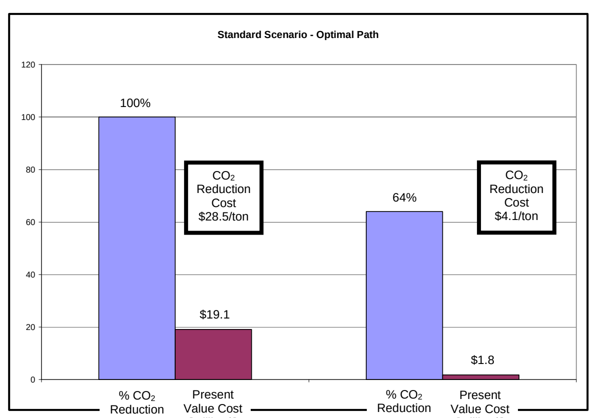

FIGURE 13: ECONOMIC BENEFIT OF PARTIAL INDEPENDENCE

Finally, figure 14 provides a breakdown of the CO_2 reduction and life cycle cost of each independence measure within each scenario. Note that under the *Standard Scenario – Optimized* you can see the point at "Purchase Windpower" where a 64% reduction in CO_2 has been attained for only a $1.8 million net present value cost. This is the optimal economic point discussed previously.

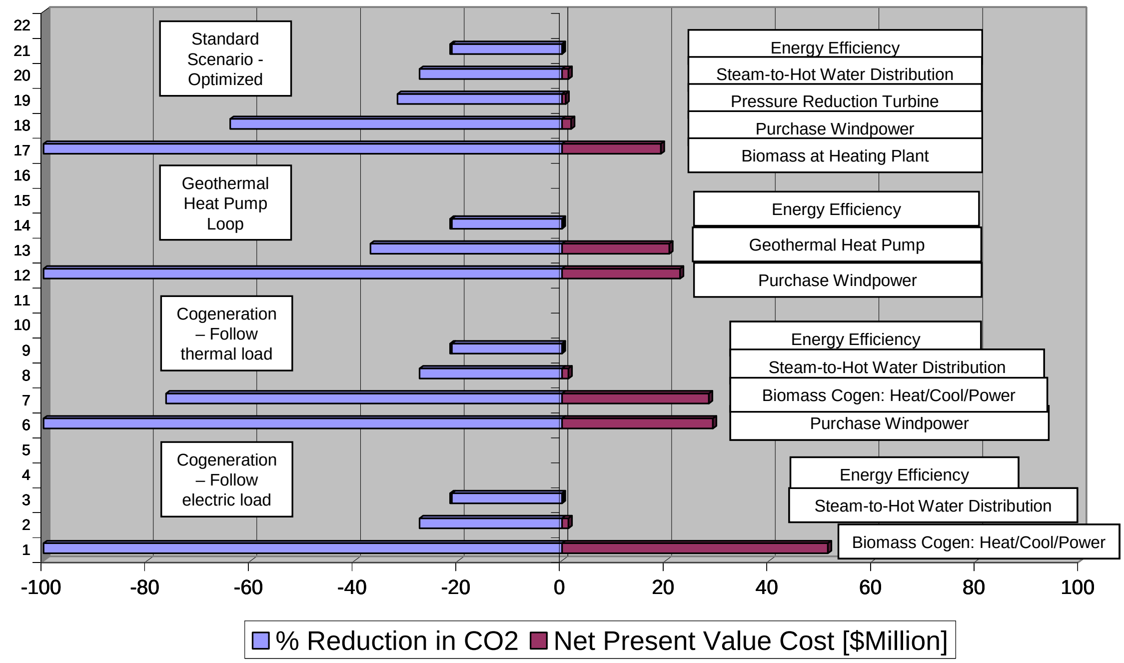

FIGURE 14: SUMMARY OF MEASURE CO2 REDUCTION AND LIFE CYCLE COST