# Comprehensive Energy Proposal

## College of St. Benedict ~ St. John's University

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Environmental Studies Senior Research Seminar

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# Preface:
# The Path to a Proposed Energy Plan for CSB-SJU

This proposal represents the combined work of many people. Its primary authors are the senior Environmental Studies majors and minors from the ENVR 395 research seminar. Offered for the first time in 2004, this seminar was designed to provide senior environmental studies students opportunities to both engage in a substantial interdisciplinary research project and to gain some experience working under conditions approximating those commonly found outside academe. While environmental studies graduates prior to 2004 conducted independent research projects and wrote individual papers as their academic capstones, students now participate in the research seminar as a group. Under this new model, all senior environmental studies students work as a sort of consulting firm, sharing collective responsibility for a single project that is conducted on behalf of-- and is ultimately presented to --an actual client, in this case The College of St. Benedict and St. John's University. All stages of the scoping, research, writing, editing, and production are directed by the students, who also carry responsibility for evaluating their own performance and those of their peers.

The topic of this year's capstone project is energy. At the dawn of the 21$^{st}$ century, we live in a world of limited energy supplies and seemingly limitless demand. For Americans, in particular, there appears to be little thought given to the connection between the actions of flipping a light switch or filling the gas tank on an SUV, and the environmental impacts of the corresponding energy production and consumption. Energy is always available—through the electrical grid or at the pump –and while we might complain about its impact on our pocketbooks, there seems to be little collective will to address its environmental costs. It is our belief that this situation can be significantly improved through education, thoughtful evaluation of alternatives, and openness to changing the status quo, all things that require information like that contained in this document.

Institutions the size of CSB/SJU understandably consume a great deal of energy for lighting, heating, cooling, transportation, and many other uses. At the core of this report are the assumptions that it is good to 1) know *where our energy comes from*, 2) know *how much energy we are using*, 3) know *how that energy is being used*, 4) do everything practicable *to use less energy*, and 5) ensure what we must use *comes from the most sustainable sources available*. All five of these assumptions are contrary to current American practices. As educational institutions is it our responsibility to demonstrate alternatives in situations such as this. Happily, this report includes many technically, socially, economically feasible ways to do just that.

It is the hope of the students involved in this project that their work will ultimately inform a change of direction in policy and practice at CSB/SJU. As their report indicates, energy systems and their operation account for the largest measure of our collective impact on the environment. By making some of the small changes around the margins suggested herein, our institutions could begin the process of systematically reducing our collective environmental impact while also furthering our educational agenda. A bolder change of direction is at the heart of this project though, including recommendations that would both yield major energy savings through conservation and suggest less destructive methods of generating what energy we must use. Should the recommendations contained in this report be adopted wholesale, CSB/SJU would clearly be embarking on a new era in environmental leadership that would draw national attention not only to our immediate actions, but also to the Benedictine values that serve as the bedrock of our institutional commitments to the welfare of other people, other forms of life, and the planet that sustains us all.

As Chairperson of the Environmental Studies Program and the instructor for the research seminar, I am delighted to present this document to the community. It represents the hard work not only of the students involved, but many others with whom they consulted for advice or research assistance. The cooperation and assistance of the staff of the two campus powerhouses, the transportation department, and their physical plant colleagues is especially deserving of recognition. I believe the result speaks for itself by providing not only an excellent overview of the pressing need to move our energy system to more sustainable foundations, but also a very clear map showing us how CSB/SJU might go there in the future.

Dr. Derek R. Larson
Environmental Studies Program Chair
The College of Saint Benedict/Saint John’s University
April 27, 2005

# Executive Summary

CSB/SJU currently spend in excess of two million dollars on energy each year. Slightly over one million dollars is paid to Xcel energy for electricity; the remainder includes gas and oil to fuel boilers and diesel for the bus fleet. While this total does not include all institutional energy use – gas for pool automobiles and diesel for contract buses are excluded, for example- it is fair to estimate we are spending at least $500 per student on costs associated with the extraction, processing, transportation, and use of the energy. The types of non-renewable energy which we rely on most, i.e. coal, nuclear, oil, and natural gas, are responsible for air pollution, water pollution, greenhouse gas emissions, and other negative environmental impacts reaching from St. Joseph/Collegeville around the globe.

This report is divided into sections highlighting conservation opportunities and alternatives to standard generation technologies. This executive summary provides and overview the topics in each section and recommendations on their potential applications at CSB/SJU. Please refer to the complete report for extended discussions of current campus energy practices and cost/benefit analyses of alternatives. Suggestions for further reading on each topic also appear at the end of the document.

## Conservation Proposals

### Metering

Metering is the ability for a business or entity to determine the amount of energy used in each building. Saint Benedict currently has a metering program; however, Saint John's has very little metering capability. Metering is essential for a sound conservation program.

### Thermal Efficiency

Thermal efficiency involves both windows and insulation. Inefficient insulation leads to heating and cooling losses and is expensive. The current CSB|SJU programs are adequate because the campuses frequently monitor and revaluate the efficiency of windows throughout campus. Neither insulation or windows is a major concern at this time, although there are some buildings that could benefit from more efficient windows.

## Outdoor Lighting

Outdoor lighting in the parking lot and path light system allows for safe movement at night. Lights are in use many hours of the day and night and consume large amounts of electricity. CSB would benefit from a change to high-pressure sodium bulbs in their parking lot fixtures. Both campuses would benefit by using half the lighting after 2 AM and replacing old fixtures with photovoltaic powered units. Sodium bulb replacement and limited lighting after 2 AM are both immediately feasible. The photovoltaic units make for an excellent long-term project.

## Conservation Competitions

This proposal puts energy conservation into the hands of the students by encouraging lower energy consumption through competition. There are multiple ways to explore this project and we should encourage a campus group to construct a competition.

## Transportation

Transportation is essential for education and growth at CSB/SJU. Due to the separate campuses, The Link is an essential element of campus life as well as a major energy consumer. There are many fuel options for transportation, and the colleges should explore these as alternatives to diesel fuel. This section also includes the regulations of automobiles on campus.

## Indoor Lighting

Indoor lighting is any lighting within the confines of a building. It is important because lighting is one of the greatest energy uses on both campuses. All incandescent bulbs should be replaced with compact fluorescent bulbs. The classrooms should also have occupancy sensors and be fitted with the more efficient T-8 fluorescent bulb. The schools should do this as soon as possible to save on energy costs.

**Appliances**

Appliances are defined as any standard electric device. Washers, dryers, and stoves are some of the leaders in energy use and it is important to purchase energy efficient equipment. We should replace these appliances with Energy Star appliances as the old ones expire.

**Vending Machines**

Bernick and First Choice snack companies provide vending machines that distribute snacks and beverages to the students. The placement away from vents and other heating and cooling ducts is important to avoid machine energy waste. We should also remove the two bulbs behind the advertising panel, which contribute to unneeded energy costs. We should do these things as the old machines expire.

**Climate Control**

This is the heating of buildings in the winter and cooling in the summer. Heating and cooling is a major energy use on both campuses. Digital control systems, similar to those at CSB, would save energy and money at SJU. We should undertake this project as soon as resources are available.

**Green Roofs**

Green roofs are thin layers of vegetation installed on top of conventional roofs. This saves on heating and cooling by insulating the roof of a building and extends the lifespan of the roof by providing protection from the elements. This is a unique opportunity for education and energy savings and is feasible here in the near future.

## Alternative Generation Proposals

**Solar Power**

Solar power is capturing energy from the sun using specially designed photovoltaic panels. Solar power provides clean and sustainable energy for the lifespan of the panel, usually 20-25 years. It also provides the colleges with educational opportunities. In our area, large-scale solar power generation is not a feasible option, due largely to short days in the winter. However, powering smaller buildings, such as bus stop shelters, with PV panels is practical, cost effective, and educational.

**Methane Digester**

A methane digester captures the natural byproducts of organic decomposition, mostly methane gas. This gas is burned in much the same way as natural gas for heat and energy. To create significant quantities of gas, large volumes of organic waste would be required, and unfortunately, the SJU sewer system does not provide enough material to make this proposal economically feasible.

**Hydro Power**

Hydroelectric power uses water to turn turbines, which generates electricity. It is beneficial because it is a clean source of energy. There is potential for a small-scale micro-hydro turbine, with a maximum output of 1.5 kW. It is a feasible project because the payback time is relatively short and there are significant educational benefits.

**Geothermal Heat Pump**

A geothermal heat pump relies on the stable temperatures underground for heating and cooling. A closed loop system uses a heat transfer fluid and the Earth's relativity constant internal temperature to heat and cool a building. Such systems would significantly reduce heating and cooling costs by providing a moderate mean temperature from which to start. The best place to use this technology is in new building construction where it would pay for itself in a few years.

**Biomass**

Biomass is plant material used as a fuel or energy source. It is a renewable and readily available fuel source. At SJU, this fuel source could be economically feasible if we could secure a cheap and reliable supply of biomass and if retrofit of the current plant was inexpensive.

**Gas Microturbines**

Gas microturbines are refrigerator-sized electricity and heat generators fueled by natural gases. They are efficient and relatively clean sources of energy. They are used in any setting, but are ideal for small energy loads. The most realistic possibility for CSB|SJU is gas microturbines to heat the swimming pools.

**Wind Power**

Wind turbines convert the force of the wind into electricity using turbines and generators. They are clean, efficient, and reliable sources of energy. Wind energy is a highly feasible option that we should pursue immediately.

**Fuel Cells**

Fuel cells use the energy created by joining hydrogen and oxygen molecules to produce electricity. The only byproduct is water ($H_20$) making this technology very clean and renewable. Unfortunately, the technology is in its infancy and is not yet economically viable. Small-scale hydrogen fuel cells would have large educational benefits but could not be expected to contribute to the campus energy supply.

# Introduction

**Why Energy?**

Energy use has increasingly developed as an issue of importance on college campuses around the nation. With natural gas and oil prices on the rise and the effects of global climate change becoming more evident, colleges and universities have sought ways to be both economical and more environmentally conscious through energy conservation and alternative generation options. In order to be more conscious about energy use on Saint John's and St. Ben's campuses, it is important to understand some basics about energy: how it is measured, energy terms, different energy sources, current energy prices, US energy use compared to the global energy picture and environmental issues associated with energy use.

**What is Energy?**

Energy is the use of electrons over a period of time. Energy is central to the functioning of all sectors of modern industrialized society. It is used in electrical generation, heating, cooling and transportation in residential, commercial, industrial, and electric utility sectors. Sources of energy include conventional fossil fuels such as coal, oil and natural gas, and renewable energy sources such as hydropower, photovoltaic (solar), wind, hydrogen, and geothermal as well as partially renewable nuclear energy.

Electrical generation is used for lighting and powering appliances and equipment. National electrical consumption is divided as follows: Residential= 35 percent, Industrial= 32 percent and Commercial= 33 percent. The amount of electricity needed to operate a load is universally measured in **watts (W)**. Electrical service is measured in **kilowatt-hours (kWh)**. One kilowatt is equivalent to 1,000 watts. One kilowatt-hour is 1,000 watts used for one hour. The amount of energy that exists in one kilowatt-hour of electricity is 3,413 **British Thermal Units (Btu)**, the universal term for energy in the English system. The amount of energy needed to power an appliance is measured in watts. Wattage is calculated by multiplying the **volts** of the load by the **amperes**. Voltage is the force or pressure that causes electricity to flow. An ampere is a unit of electron current flow. This information on the following page:

W (watts) = V (volts) x A (amperes)
1000 W = 1 kW (kilowatt)
1 kW x 1 hour = 1 kWh
kWh x rate = cost of operation

More efficient appliances use less electrons to operate and have lower amps, thus the power (watts) consumed by the appliance is less, saving energy and money per hour of consumption. Currently in Minnesota, electrical energy costs about $0.075/kWh between June and September and $0.065/kWh during other months.[1]

An **electrical grid system** distributes electricity to residential, commercial and industrial consumers from a power generating facility through power lines that transfer electrons. Grid-connected homes and facilities are supplied with electrical energy in the form of 120/240 V alternating current (Vac). In an **Alternating Current (AC)** circuit, electron flow reverses direction repeatedly from negative to positive and from positive to negative at 60 Hz (cycles per second). In a **Direct Current (DC)** circuit, the electrons flow only in one direction as with a battery: from the negative end of the battery, through the conductor, into the source and then back to the positive end of the battery. At one time, both AC and DC were generated and transmitted through electrical grids. AC is preferable for safety, transmission and other practical reasons. DC is commonly found in many low-voltage applications, especially those powered by batteries, which can only produce DC. An off-grid facility can convert low-voltage electrical energy stored in the battery bank to 120/240 Vac through an inverter.

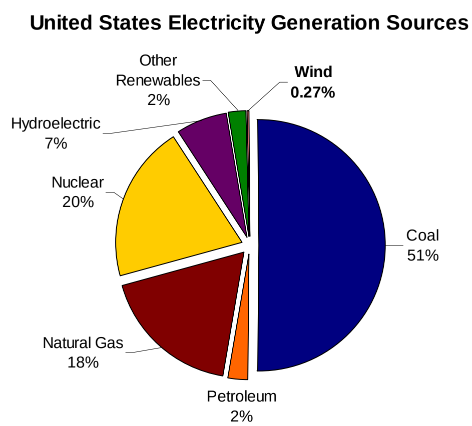
Heat is a form of energy caused by the movement of molecules in a given space. The faster the molecules move, the more heat is generated. Heat energy is constantly on the move and thus tends to escape easily. Heat energy can be slowed by use of insulation, just as electrical flow is stopped by a non-conductive insulator. Cooler air consists of slower moving molecules. Air conditioning units draw warm indoor air through a compressor to be cooled, drawing cool air indoors and sending the warm waste air outdoors. This cooling process is not efficient. The energy used to cool a given area is measured by the Btu's of heat removed or by the electrical energy consumed by the air conditioning unit. Sources for heating/cooling include: natural gas, electricity, propane, oil, wood, wood-by-products and coal. One Btu is the quantity of energy needed to raise, by one Fahrenheit degree, the temperature of one pound of water at atmospheric pressure. The energy content of some more common types of materials used for heat are as follows:

- 1 cubic foot of natural gas = 1,008 to 1,034 Btu’s
- 1 gallon of crude oil = 138,095 Btu’s
- 1 pound of coal = 8,100 to 13,000 Btu’s
- 1 standard chord of wood = 18,000,000 to 24,000,000 Btu’s

## Overall US Energy Picture

The United States, with an annual energy expenditure of $500 billion and total annual energy consumption around 100 quadrillion **British Thermal units (Btu)**, is the world's largest energy producer, consumer, and net importer. Accounting for only 5 percent of the world’s population, Americans consume more than 26 percent of the world’s energy. In 2003, the United States generated 3,848 billion **kilowatt-hours** (kWh) of electricity, including 3,691 billion kWh from the electric power sector plus an additional 157 billion kWh coming from combined heat and power facilities in the commercial and industrial sectors.[2]

The United States relies most heavily on coal, natural gas and nuclear generation for energy production. The following pie chart, from the US Department of Energy, shows the breakdown of electrical generation sources in 2002:




*Source: Energy Information Administration (US Dept. of Energy), 2002*

*Other Renewables: Wood, black liquor, other wood waste, municipal solid waste, landfill gas, sludge waste, tires, agriculture byproducts, other biomass, geothermal, solar*

## Minnesota's Overall and Renewable Energy Picture

Minnesota's energy use division closely matches the national statistics. Xcel Energy Company, Minnesota's energy supplier, obtains 51 percent of its energy from coal, 12 percent from nuclear, 10 percent oil and gas, 2 percent from renewable sources and 4 percent from Manitoba Hydro.[3] There are two nuclear plants in Minnesota: Prairie Island and Monticello. Minnesota has a state renewable portfolio standard, requiring a certain percentage of energy to be generated through renewable resources. The Renewable Energy Objective requires each Minnesota electric utility to make a good faith effort to generate or procure electricity generated by renewable technologies with the goal of 10% of electricity being provided by renewable technologies by 2015.[4]

The Renewable Development Fund (RDF) was established in 1999, as part of a renewal of the 1994 Radioactive Waste Management Facility Authorization Law, the Minnesota State legislature required Xcel Energy to contribute $500,000 to the RDF for every dry cask containing spent nuclear fuel stored at its Prairie Island nuclear plant.[5]

Minnesota law also requires that utilities offer green power to their customers.[6] The Windsource® program offered through Xcel allows Minnesota residents to purchase wind generated energy at a price premium of $2 for each 100 kilowatt-hour block of electricity monthly. The wind energy obtained by Xcel is produced mainly at Buffalo Ridge, located in southwest MN, which, as of 2003 had 470 wind turbines in operation, producing enough electricity to power more than 100,000 households.[7]

## Current Energy Technologies and Prices

Coal is the least expensive, but most polluting, form of energy used in the US. Coal prices declined slightly in 2003. The average market price of coal was $17.85 per ton in 2003, a drop of 14 cents per ton from 2002. The average delivered price of coal to electric utilities was $25.29 per ton (124.3 cents per million Btu), up 2.2 percent from the annual 2002 level of $24.74 per short ton (121.8 cents per million Btu).[8] Natural gas prices have been rising more recently. In 2001, the price of electricity derived from burning natural gas was $0.035 per kWh. Nuclear energy, as of 2001, cost around $0.11-$0.14 per kWh. Hydroelectric energy constitutes the majority of US renewable energy and costs between $0.05- $0.11 per kWh.[9] Solar electricity prices are currently around $0.30 /kWh. [10] Wind energy costs around $0.035- $0.04/kWh, although it is highly dependent on the wind speed and capacity of the turbine or wind farm. The table below summarizes the costs of major energy sources:

**Fuel costs (cents/kWh)**[11]

| | |
|---|---|
| Coal | 4.8-5.5 |
| Gas | 3.9-4.4 |
| Hydro | 5.1-11.3 |
| Biomass | 5.8-11.6 |
| Nuclear | 11.1-14.5 |
| Wind | 4.0-6.0 |

Other renewable technologies include geothermal heat pumps, hydrogen fuel cells, hydroelectric energy and alternative fuels such as ethanol which will be covered in *Alternative Source Proposals* section.

**Energy Outlook**

The Energy Information Administration (EIA), in its *Annual Energy Outlook 2005*, evaluated a wide range of current trends and issues that could impact U.S. energy markets over the 20-year forecast period, from 2005 to 2025. Trends in energy supply and demand are linked with the overall U.S. economy, advances in technologies related to energy production and consumption, annual changes in weather patterns, and future policy decisions. Fluctuations in oil prices and natural gas supply contributed to the uncertainty associated with these projections.

Total overall US energy use is projected to increase from 98.2 quadrillion Btu in 2003 to 133.2 quadrillion Btu in 2025 (an average annual increase of 1.4 percent). Despite the insecurity surrounding oil prices and natural gas supply and the negative environmental consequences of coal, the use of renewable technologies for electricity generation is projected to grow slowly. This is due to the relatively low costs of fossil-fuels, such as coal, and because competitive electricity markets favor less capital-intensive technologies. State renewable portfolio standards, which specify a minimum share of generation or sales from renewable sources, are included in the forecast as well as the extension of the production tax credit for wind and biomass through December 31, 2005 (enacted in H.R. 1308, the Working Families Tax Relief Act of 2004).[12] Total renewable generation, including combined heat and power generation, is projected to grow from 359 billion kWh in 2003 to 489 billion kWh in 2025, increasing by 1.4 percent per year.[13]

The Department of Energy's budget request of $23.4 billion for 2006 allocates $759.9 million for fossil energy activities. Included is $286 million for President Bush's Coal Research Initiative, $50 million for clean coal demonstration projects and $18 million for FutureGen, the world's first near zero-emissions hydrogen and electricity producing power plant.[14] This example illustrates the nation's currently limited vision of available technologies, ignoring the need to diversify the energy portfolio and seek more innovative and environmentally benign energy sources that have already proven reliable and cost effective, such as wind.

## Environmental Issues Surrounding Conventional Energy Production

Human activity has altered the chemical composition of the atmosphere through the buildup of **greenhouse gases** – primarily carbon dioxide, methane, and nitrous oxide. Combustion of fossil fuels such as coal, oil and natural gas is highly polluting and emits significant amounts of greenhouse gases. Methane is emitted during the production and transport of coal, natural gas, and oil. Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels. All fossil fuels and organic masses consist of carbon and hydrogen atoms. When these fuels are burned, carbon atoms unite with oxygen in the air to form carbon dioxide. Each greenhouse gas differs in its ability to absorb heat in the atmosphere. Methane traps over 21 times more heat per molecule than carbon dioxide, and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide. Estimates of greenhouse gas emissions are often presented in millions of metric tons of carbon equivalents (MMTCE), weighing each gas by its **Global Warming Potential** (GWP value).

Greenhouse gases such as carbon dioxide trap solar radiation in the earth's atmosphere in a phenomenon referred to as **global warming** or **climate change**, leading to a gradual shift in the climate. The National Academy of Sciences estimates that the Earth's surface temperature has risen by about 1 degree Fahrenheit in the past century, with accelerated warming during the past two decades. Scientists expect that the average global surface temperature could rise 1- 4.5 degrees Fahrenheit in the next fifty years, and 2.2-10 degrees Fahrenheit in the next century if emission levels of greenhouse gases do not decrease. Evidence supporting a shift in global temperatures and weather patterns are depicted on the following page:

- Global mean surface temperatures have increased 0.5-1.0 degree F since the late 19th century.
- The 20th century's 10 warmest years all occurred in the last 15 years of the century.
- The snow cover in the Northern Hemisphere and floating ice in the Arctic Ocean have decreased.
- Globally, sea level has risen 4-8 inches over the past century.
- Worldwide precipitation over land has increased by about one percent and the frequency of extreme rainfall events has increased throughout much of the United States. [15]

In 2003, U.S. emissions of greenhouse gases totaled 6,935.7 million metric tons carbon dioxide equivalent, representing about 24 percent of the world's total carbon dioxide emissions.[16] This is a remarkable amount of emissions considering that the United States comprises only 5 percent of the world population. Carbon dioxide emissions alone account for 84.6 percent of total U.S. greenhouse gas emissions and have grown by an average of 1.3 percent annually since 1990.[17]

Carbon dioxide is not the only byproduct of direct combustion of fuel. Small particulates that can become imbedded in the human respiratory system are also emitted. Particulates affect air quality and lead to negative health effects such as asthma, coughing, lung disease and even cancer.

Mercury is the byproduct of coal combustion and is precipitated from the atmosphere into nearby watersheds. Mercury pollution is a large problem in Minnesota lakes, building up in the fat tissues of fish and humans, leading to serious ecological and health problems. It is of special concern for pregnant women.

Another environmental concern surrounding combustion of fossil fuels is **acid rain**. Emissions of sulfur dioxide and nitrous oxide cause acid rain as they oxidize in the atmosphere, forming nitric and sulfuric acid. This raises the acidity of precipitation, causing soil erosion, leaching of nutrients from the environment and lowering the pH level of water bodies. Acid rain is detrimental to the health of soil, forests and lakes creating an unsuitable habitat for species.

**Why Now?**

Assessing the United States' energy future in regards to the cost and availability of nonrenewable fossil fuels and their negative impacts upon human health and the planet, reveals an imperative to invest in the future through significant efforts towards further research and development of alternative energy sources and a larger integration of these technologies into the United States' energy portfolio.

As higher education institutions, The College of Saint Benedict and Saint John's University should be forward thinking, actively supporting research and development of alternative energy sources as well as being conscious of the institutions' individual energy use patterns and opportunities for energy conservation.

# Profiles of Other Schools

College and university energy conservation programs are springing up throughout the United States. These programs are organized by an assortment of people such as campus clubs, faculty, classes, staff, committees, and students. Energy conservation programs are started for many different reasons; to reduce electrical consumption, to save students and the institutions money, to improve the local and global environment, or to enhance the quality of life on the campus. Many programs start with the help of local or corporate donors, incentive programs or awards usually obtained from the government. Energy Star provides various recognition programs to colleges and universities for their energy conservation, such as the Show Case Dorm Room award which can only be earned if the dorm room is equipped with Energy Star approved appliances.[18] Another Energy Star recognition program is called Energy Star Partner of the Year Award; this was awarded to the University of Michigan–Ann Arbor for reducing campus greenhouse gas emissions through energy management programs such as energy conserving lighting and equipment.[19] Information on alternative energy and energy conservation programs throughout the United States are categorized below. Colleges and universities are divided in each category according to their size; small campus – 0 to 10,000 students, medium campus – 10,000 to 30,000, and large campus is greater than 30,000.

## Energy Conservation Programs

### Lewis and Clark College: 3,000 students

The students and faculty at Lewis and Clark College set high standards for energy conservation by becoming the first college to fall under the Kyoto Protocol. This small school of roughly 3,000 students allocated 17,000 dollars to drop the school seven percent below the 1990 emission levels. The majority, or 83%, of the campus supported an increase in student fees.[20] The funds will go to purchasing or offsetting carbon dioxide emissions. This is done through planting trees in areas to balance a percentage of carbon dioxide that the school emits.

**Harvard University: 20,000 students**[21]

The Faculty of Arts and Sciences Computer Energy Reduction Program and Kennedy School of Government at Harvard University, in Cambridge Massachusetts, started a power management drive on 1 million computer monitors through the EPA's "Million Monitor Drive." This drive has led to a savings of $70,000, and the prevention of 500 tons of carbon dioxide emissions annually at Harvard University. The EPA noted that Harvard was one of their top contributors to their national campaign. The university was able to accomplish this through cooperation with academic and IT departments, competitions within undergraduate residences, and the distribution of an imaging disc containing energy-saving software to students and staff.[22]

**University of Michigan-Ann Arbor: 38,972 students**[23]

The University of Michigan-Ann Arbor has been facilitating energy conservation programs for the past six years. The programs included installation of energy efficient lights and equipment, updating mechanical systems, and installing efficient motors. These improvements can be found in approximately 123 major campus buildings and will save the University an estimated $9.7 million annually at the beginning of the 2005 fiscal year.[24] Ann Arbor financed its energy conservation program through the Energy Conservation Measures Fund (ECM). The fund was established in 1988 and is replenished each year with money saved from the program. It is overseen by a committee of various campus representatives who approve funding for various energy conservation projects. Projects are only funded if there is a five year or less payback period.[25]

**Michigan State University: 44,836 students**[26]

The energy conservation program at Michigan State University started with the cooperation of the construction faculty and the facilities management. This group of people provided detailed analysis and recommendations for improved campus energy efficiency to administrators and building managers. The same group of people started working with a program titled Rebuild Michigan and created a specialized program called Rebuild Michigan State University focusing on energy initiatives in campus residence halls. An estimated $36 million per year is spent on energy cost and about $5.7 million of that is spent on residence halls.

To reduce this electrical consumption many changes were proposed, the following are a few examples; create an integrated energy management plan with a lead staff position, designate an "energy manager" for each building, downsize or eliminate rarely used computers, and consolidate cafeteria operations. An Energy Star display was also created for residence halls to use in orientation programs. This display was created to curb increasing electrical devices brought to campuses by students.[27]

These energy conservation programs exist year after year because of support and initiatives within the campus community. As these programs continue to grow within their own institutions they create a blueprint for other campuses around the United States to follow. Once students, faculty, and staff see the blueprints for energy conservation occurring on other campuses they will have the knowledge and inspiration to start energy conservation programs on the CSB/SJU campuses.

## **Alternative Energy**

### Macalester College: 2,000 students

Macalester College, in St. Paul, Minnesota in April of 2003 began use of a 10 kilowatt wind turbine. The entire installation cost $40,000 and was paid for by Xcel Energy.[28] Though the turbine provides only a small percentage of the campus' energy needs, it is still heralded as a "step in the right direction."[29] According to a student study at Macalester, the school would need 300 turbines of the same size as the one currently in operation to provide for the 1.2 million kWh the campus uses every month. The turbine does provide savings on the campus' energy bill however, and the $1000 monthly savings will repay the installation expenses in 15 years.[30]

### Cal State: Hayward: 14,000 students

In 2004 California State University at Hayward put forward plans to install a large number of solar panels. Costing $7.11 million, these photovoltaic panels constitute a 1.05 megawatt system producing 1.45 million kWh annually.[31] Built to combat rising electricity costs in northern California, this solar array is one of the largest in the nation. During peak hours, these solar panels can produce 30% of the campus' need, saving the institution $200,000 each year.  This project is among the leaders in implementation of photovoltaic technology on a large scale.

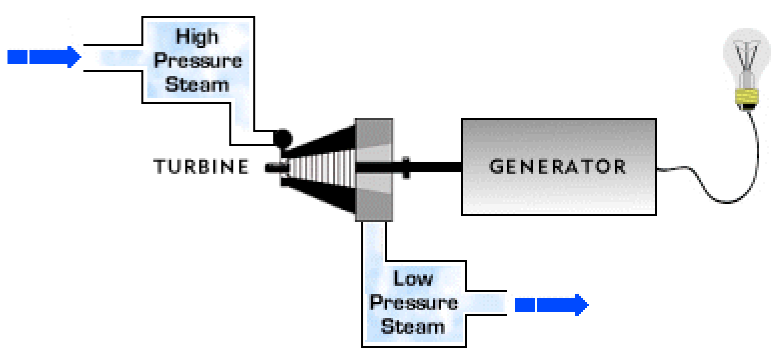
**Penn State University: 81,000 students**

In 2001 Penn State University engaged in a program to reduce the dependence of their campus on fossil fuels.  Purchasing green energy certificates, the campus was able to enter into a 5 year contract with local power companies to procure at least 5% of the campus energy requirements (about 13,300,000 kWh) from renewable power sources.[32]  As of 2005, Penn state is the largest institutional purchaser of wind power in the United States purchasing 40,000,000 kWh of electricity annually.  Their program costs approximately $300,000 each year and supplies about 10% of the campus' need.[33]  This initiative was undertaken by the institution as a way to act more responsibly towards the environment and to serve as a leader and example in the clean energy field.[34]  Support is generally high on campus, though some say more ought to be done.

# Campus Context

**SJU Power Facility Overview**

The Saint John's Power facility is classified as a combined heat and power plant because it is capable of producing heat as well as electricity. In a cogeneration facility (Combined Heating and Power CHP) such as the SJU power plant, the steam from the boiler system is used for heating and cooling the campus. Chief engineer Tom Vogel describes electrical generation at the plant as "icing on the cake", because generators act to reduce pressure on the steam system- they do not consume steam themselves. The energy necessary to drive the turbines is basically free.[35] The expense of the system is installing and maintaining the generation components. If no generator was present, the steam is usually passed through a pressure-reducing valve, which lowers its pressure[36]. A steam turbine can take that same energy available when pressure is reduced, and turn it into valuable electricity. Steam turbine generators make electricity by converting a steam pressure drop into mechanical power to spin a generator. High-pressure steam enters the turbine, drives the generator and exhausts at a lower pressure suitable for use in campus heating. A turbine does not consume steam; it only reduces its pressure.[37]




[38]

The downside to the use of generators is that the pressure must remain above a minimum level or the generators will not spin. When steam demand drops in the summer, a high steam pressure must still exist or no electricity will be generated. SJU avoids this problem because cooling is accomplished using a steam compression cooling system that employs 1-900 ton unit and 3- 750 ton units. Since cooling demand increases during the summer while heating demand drops, there is a constant steam demand that makes using the turbines as a pressure-reducing device economical.

The current power plant provides heating and cooling to all facilities on upper campus as well as the Prep School- excluding Placid and Maur, which have an independent natural gas furnace and electrical air-conditioning system. Buildings in Flynn Town are also served by independent HVAC (heating, ventilation and air conditioning) systems. The purpose of the SJU power plant is not to generate electricity. The electrical load is essentially dictated by the heating/cooling demands of the campus- if more heat is required then more steam is produced and more electricity is produced as well.

**Fuel**

The power plant can run off three different fuel supplies, coal, natural gas or fuel oil. Coal costs $2.60 per million BTU, Natural gas (Center point Energy Minnegasco) $7.11 and fuel oil $9.11. Although coal is the dirtiest of the three fuels, it saves the University over one million dollars a year in fuel costs.[39] The coal is purchased from Decker, Montana and contains .5% Sulfur. Because the Power plant has limited pollution control systems, it purchases about 17,000 tons of low sulfur coal at a higher cost per ton ($47.69/ton) compared to higher sulfur coals. The moisture content of the coal is 24-25% but varies because the coal pile sits outside uncovered so the rain and snow is sometimes brought into the stoker as well.

**Stoker/Boiler Systems**

The actual coal combustion system employed at the plant is a 1952 overthrow stoker boiler system[40]. There are three coal fired stoker steam boilers. The boilers are 70% efficient. Maximum steaming capacity of boiler # 4 which was installed in 1959 is 33,000lbs. of steam per hour; boilers # 1 & # 2 were installed in 1947 and have a maximum output of 12,000 lbs steam per hour respectively. In addition to the three coal fired boilers, which are used most of the time, there are three natural gas/fuel oil boilers. Boiler #3 was installed in 1947 it is a converted coal burner which now runs off of natural gas and has a maximum output of 9,000 lbs/hr. Boiler #5 was installed in 1973 and has a capacity of 45,000 lbs/hr. Boiler 6 was installed in 1999 and can produce 60,000 lb/hr. The three natural gas boilers are not used often because of the current cost of natural gas.

| Boiler# | Date installed | Fuel Source | Output (lbs steam/hr) |
|---|---|---|---|
| 1 | 1947 | Coal | 12000 |
| 2 | 1947 | Coal | 12000 |
| 3 | 1947 | NG | 9000 |
| 4 | 1959 | Coal | 33000 |
| 5 | 1973 | NG/Fuel oil | 45000 |
| 6 | 1999 | NG/Fuel oil | 60000 |

Summary of the boiler systems at the Saint Johns University Power Plant

The typical maximum steam demand at Saint Johns is 48,000lbs/hr.There are plans to upgrade #4 boiler from the overthrow fixed grate stoker to a underthrow stoker with a traveling floor. This upgrade will cost $935,000 it is expected to reduce emissions and increase efficiency by 10%.[41]

**Pollution Controls**

There is a limited amount of pollution control at the current facility. There is one cyclone dust collection unit on boiler #4 but emissions from boilers #1 and #2 are not regulated. Emissions all fall within EPA standards but with the creation of the Maximum Achievable Control Technology provision by the EPA, there are plans to install some type of technology to reduce emissions. A three million dollar capital project has been proposed for 2006 which covers the installation of a Venturi wet scrubber and ducting of boilers 1, 2 and 4 to it. The wet scrubber will remove pollutants by using a caustic slurry spray[42].

**Electricity at SJU**

The average electrical use at SJU over the past three years is about 17,300,000 kWh. The generator system in the power plant produces about 25% of that total- typically about 4,400,000 kilowatt hours. The remaining 75% is purchased from Xcel Energy-~13,000,000 kilowatt hours. The average cost per kilowatt hour over the past three years has been 4.32 cents per kWh. The University paid $553,155 for energy obtained from Xcel Energy in 2003. The coal for the power plant cost approximately $800,000 but this total does not reflect the true cost of electricity generation at the plant because a majority of the energy from the coal is used for heating and cooling.

## The College of St. Benedict Power Facility- Overview

The Power Facility at St. Benedict is a traditional steam generation facility. No electricity is produced at the power facility so all electricity is obtained from Xcel energy.

### Boiler Systems

Steam generation is accomplished through the use of natural gas boiler systems. There are currently two boilers which are used to provide heat to the entire CSB campus, the monastery, and the St. Joseph Catholic School and Church.[43] There are no emissions control systems required for natural gas boilers. Boiler #1 was installed in 1998; it has a capacity of 33,000 lbs/steam per hour and a rated efficiency of 88%. Boiler number two was installed in 1995 and has a capacity of 25,000 lbs per hour and an efficiency of 84%. There is a third boiler at the power house but it has been decommissioned. The maximum output of the plant on natural gas is 58,000 pounds of steam per hour. This figure drops to 47,000 when fuel oil is used. The peak demand for steam at St. Bens is 40,000 lbs/hr.

| Boiler # | Date installed | Fuel Source | Output (lbs steam/hr) | Efficiency |
|---|---|---|---|---|
| 1 | 1998 | NG/Fuel oil | 33000 | 88% |
| 2 | 1995 | NG/Fuel oil | 25000 | 84% |
| 3 | ? | NG/Fuel oil | Decommissioned | - |

Summary of Boiler Systems at the College of St. Benedict Power Facility

### Fuel

The natural gas is obtained from Xcel Energy and it costs $6.78 per million Btus or 6.7 cents per ccf. A cubic foot of gas is a unit of volume, a ccf is 100 cubic feet. The burners can also run off #2 fuel oil as a secondary fuel. 7.2 gallons of fuel oil equal the btu output of 1 million cubic feet of natural gas.[44] Fuel oil costs between $0.65 and $1.35 per gallon. This price is prone to fluctuation because fuel oil is derived from crude oil, which is at an all time high. There is a 30,000 gallon fuel oil storage tank located at the power plant so that it can be run when natural gas in unavailable. In 2004, the college used 71,236 mcf (million cubic feet) of natural gas and 83,576 gallons of fuel oil. [45]

### Cooling

60% of the cooling on the St. Bens campus is served by the central cooling plant which employs two 600 ton chillers which run off of electricity. These chillers serve the Academic services building, Ardolf Science Center, East Apartments, Clemens Library, West Apartments, Mary Commons, Monastery main Building, Teresa Hall, Gertrude Hall, Monastery Chapel, and the Art and Heritage Museum. All other buildings including the HCC have their own AC units. There are plans to expand chilled water to remaining buildings in the future because the centralized cooling plant is much more energy efficient than independent units for individual buildings.

### Electricity at the College of St. Benedict

The College of St. Benedict has a sophisticated metering system that allows them to track the use of chilled water, steam, hot water, and electricity to every building. The system allows the operator to monitor and control the environment of an individual region of a building from the workstation located in the power plant. The system also provides the ability to schedule heating/cooling periods, which allows for electrical and fuel savings. The college used 10,737,800 kWh of electricity in 2003, all of which was purchased from Xcel energy for a total cost of $496,018.[46]

# Conservation Proposals

## Introduction

Conservation is an essential component in a comprehensive energy plan. Reducing energy demand eliminates the need to produce excess energy that is unnecessarily wasted. Investigating how much energy is consumed on campus and where can highlight opportunities for energy reduction, resulting in economic savings and reduced environmental impact. The following section assesses conservation opportunities on the St. Ben's and Saint John's campuses, evaluating current practices and prioritizing various energy saving options.

Potential conservation opportunities for CSB and SJU exist in the areas of transportation, lighting, heating & cooling, appliances, computers, conservation competitions and educational campaigns. These opportunities work to minimize over consumption of energy where possible and to raise general awareness of energy consumption on campus. The most advantageous conservation proposals are those that will cost the campuses the least amount of money to enact and will save the most significant amount of energy. Emphasis should be placed on increasing energy consciousness among students, faculty and staff through educational conservation campaigns as this is a minimal cost option that could potentially cut a significant portion of unnecessary energy use.

The following proposals can serve as a resource to those who have the ability to influence the installation of more efficient appliances and lighting as well as the adoption of energy saving options for computer labs and application of metering at Saint John's.

## Conservation Competitions

### Application

A great way for students to get involved in energy conservation on campus is through student competitions. A conservation competition would consist of some form of metering how much energy is consumed and the winner would be the lowest amount of energy consumed. The purpose of implementing conservation competitions on campus is to reduce energy consumption and to create energy conservation habits in students, staff and faculty. The competitions could be hosted by environmental studies students, **RA**s and **CA**s or other clubs on campus. Conservation competitions would be beneficial because holding competitions and providing prizes is typically enough incentive to interest participants no matter the context of the competition and in this case energy would be saved.

Energy conservation competitions would increase the awareness among students, staff and faculty about excess energy usage and reduction. The typical student usually does not think of how much energy they are using. There are different ways to get people to think about their energy consumption. People can be informed through advertisements on flyers on campus, and through courses taken in environmental studies. The broad payment of room and board that students are required to pay does nothing for the realization of how much energy they are actually using to run their brand new plasma flat screen television with the latest DVD player and don't forget the old Game Cube or X-Box. By hosting competitions among students their awareness of how much energy they are consuming in their daily lives will help to have a visible reduction of energy consumption. The competitions could also be useful for residential life staff to bring together a larger sense of community and to allow for people to get to know each other as well.

There are many different options of conducting competitions and each competition can vary from the next. One possible option could be competitions between floors of a residence hall. To make it even smaller there could be competitions between rooms or apartments on a floor. Another choice is to compete against other residence halls and this would incorporate a bond among the residents. Additionally, there could be competitions between classes and have the first-year residents against the seniors and the juniors against the sophomores, or in any other order. Another selection could be competitions between majors, to incorporate both campuses into one competition. Also, there could be a competition among community living establishments on campus, perhaps between a Green Floor or a Green Building. Finally, there could be a competition of "battle of the sexes" that could possibly incorporate men and women and a larger group of students to educate the importance of energy conservation.

**Campus Context**

There are many different ways to have competitions to reduce energy consumption. Depending who competes there could be numerous possibilities. Options will differ between competitions of first-year residence halls and upper class housing with apartments. In the first-year resident's move in and orientation information packet there could be an incentive about specific appliances they can bring to campus. There could be and a competition to see how few appliances they bring and determine how efficient appliances are compared to the rest. Initially there could be a limit on how much energy is consumed per student as well as implementing limits for move in day to first-year residents.

Other options to conservation competitions could consist of hot water restrictions. Regulated showers could be part of competitions especially for residence hall living to conserve the energy to heat the water for showers. Another possibility for heated water conservation could be to set the temperature of showers lower so there is no energy used for unnecessary high temperatures. This could be applied as a competition among floors, halls or campus wide.

At St. John's, the majority of the buildings are un-metered but if the halls were to be metered there could be monitoring competitions among any of the competition options. A log of how long lights are on and in use could be used to compete as well. If there were specific environmental halls or communities on campus they could have competitions between themselves and/or between separate campuses.

It is possible to monitor energy use for each building. It is possible on the St. Bens campus, but because St. John's is not currently monitored it makes it more difficult to hold competitions. Another possible competition could be guessing competitions of different topics; one could be how much $CO_2$ is being produced by how much coal is being burned at the power plant at St. John's.

The most important and most effective piece of the energy conservation competitions is informing the incoming first-year students on both campuses through an orientation program. This program should include the emphasis of energy conservation habits and introducing the competitions to students. One suggestion is to have students pay for their energy consumption at the end of the year. If students were to have a certain level or below they could receive credits for the next year or have a reduction in tuition. This would be difficult to monitor especially in the first-year halls because one roommate may leave lights, television, and stereo on while the other is being very energy conscious. This is not as feasible as incorporating competitions that can be monitored for a period of time.

**Potential Benefits**

There will be significant savings by the reduction of energy consumption. In looking at St. John's the total amount of energy, excluding Mary and Tommy Hall, was 1,189,484 kWh. In 2004 total energy was 11,119,870 kWh. There were specific examples in Metten Court where there were three apartments monitored and the energy consumed for #71 was 10, 165 kWh, for #72 the kWh was 3, 035 and for #74 the kWh was 8,935. In looking at these numbers there is a great deal of lifestyle differences among three apartments. Incorporating the competitions there would be a decrease in these high energy consumption residents. The data below is the amount of energy consumed on St. John's campus the last four years.

- 2001-Total kWh = 17,858,527
  Purchased 13,400,191 kWh from Xcel = $601,558.00
  Average Cost per kWh = $0.0449
  SJU Power Plant generated 4,458,335 kWh or 24.96% of campus demand
- 2002-Total kWh = 17,500, 784
  Purchased 13,189,591 kWh from Xcel = $552,208.00
  Average cost per kWh = $0.0419
  SJU Power Plant generated 4,311,193 kWh or 24.63% of campus demand
- 2003- Total kWh = 17, 381,901
  Purchased 12,926,630 kWh from Xcel = $553,155.00
  Average cost per kWh = $0.0428
  SJU Power Plant generated 4,455,271 kWh or 25.63% of campus demand
- 2004-Total kWh (January-August) = 11, 119, 870
  Purchased 8, 512,358 kWh from Xcel = $375,449.00
  Average cost per kWh = $0.0441
  SJU Power Plant generated 2,607,512 kWh or 23.45% of campus demand

Involving competition into the conservation approach will likely bring in more participants because there will be specific numbers, reduction and incentive of a reward. The results will educate the people participating and the people that read about the results in the newspaper. In addition to the actual decrease in energy consumption, awareness to reducing the environmental impact of energy use will be a result as well. This will encourage people to change their lifestyles to be more energy conscious. Reduction in costs of energy, pollution, and dependency will be a large benefit for incorporating energy conservation competitions on campus. Decreased energy consumption will save money that could in turn be used for further energy conservation through purchasing lights with more efficient bulbs, installing motion sensors in rooms, and monitoring of St. John's buildings.

**Costs**

In order to implement the energy conservation competitions on campus there would need to be a budget to provide rewards or prizes. With the rewards there is a wide range of possible options. There is the simple reward of food like candy or pizza but to make a larger impact there would be a greater incentive for participants if there was a possibility of a tuition reduction for reducing energy consumption over a long period. Also, winning an energy efficient appliance would be beneficial because the participant(s) would use their energy efficient appliance instead of a possible energy draining appliance. Signs and flyers could be made out of recycled paper and posted in very visible areas that get a lot of traffic to encourage more participants. The opportunity to advertise in the paper, e-mails, and on the **KJNB** radio station would decrease the amount of waste needed to advertise the competitions.

The larger appliances would have to be a cost for a larger competition that incorporates more students. The specific costs for appliances can be accessed through the Energystar website. If the prizes didn't have to be a specific appliance there could be gift certificates as prizes from stores that sell energy star appliances or other environmental items. Winners could also receive plants grown in our own Arboretum or green house. There could be recognition in local papers, possibly state and nation wide recognition as well, depending on the impact of the competitions.[47]

Implementing competitions on campus is effective because prizes and incentives are relatively inexpensive when considering money saved on energy conservation. Finding sources for prizes could be provided by the school or donated by Best Buy or large corporations that sell energy star appliances. Another possibility that is similar to the scholarship is the schools could implement an Environmental Award that could be awarded for winning competitions.

**Other Schools**

Below are examples of other institutions that have implemented forms of energy conservation competitions, and they can be used as a guide to implement improvements and ideas relating to competitions on our campuses. These examples of competitions offer positive reinforcement because they have been conducted and consist of results that had a positive impact on their schools.

Harvard Green Campus Initiative won a wind energy contest in designing a wind turbine to maximize energy efficiency and reduce the dependency on non-renewable sources. In their contest, they encouraged the people to pledge to reduce their energy consumption as well. This is effective because it forces people to think about reducing their consumption, but is not effective because there is no way to monitor and or regulate whether or not these pledges are actually reducing energy consumption.[48]

At Curtin University of Technology, energy competitions were held for a $1,000 Environmental Award with a team approach, along with a host of other prizes available for small groups who demonstrated their contribution towards the Energy Conservation program. Their Environmental Award was implemented three years ago to participants encouraging and enforcing awareness of environmental issues. Although their specific reward is for $1,000, it could be different for our campuses. An Environmental Award on our campuses increases awareness and efficiency. This award will increase students' creative designs.[49]

Yale University proposed to implement Green Energy Captains for each residence hall to help keep energy conservation educational programs throughout the year. They also implemented a first-year energy conservation orientation program for their incoming students. The orientation laid out tips to change behavior to make a positive impact on the reduction of energy. They also implemented a Conservation Cup that included the help of the captains, like our RAs and CAs, of the residence buildings to encourage awareness resulting in a energy consumption reduction of 15%.[50]

At the University of New South Wales, a group of students incorporated a guessing competition to determine the amount of $CO_2$ used in their coal fired power plant (similar to St. John's situation). This competition helped staff and students to realize the amount and impact of their energy consumption behavior.[51]

The University of Montana held a competition for energy reduction between dorms and the winners of the competition reduced energy by 8%. Looking at how these other schools have had a positive effect from implementing energy conservation competitions on their campuses it is very feasible for St. John's and St. Bens to participate in different competitions as well.[52]

**Priority**

Various competitions could easily be implemented within the next year. Starting with first-year residents would be most effective in changing the outlook for the future of reducing energy conservation on CSB/SJU campuses. Even if energy competitions cannot be implemented on a large scale, smaller competitions can still be an option. With the competitions there could be informative meetings where groups present their findings in how much they saved and different opportunities to increase the reduction of energy use. Overall, energy conservation competitions are very feasible for our CSB/SJU campuses and will be effective in reducing energy consumption.

## Computers

**Application - Computer Devises and Computer Software**

Computers are highly relied upon by students, staff, and faculty for papers, e-mails, and presentations, causing electrical usage to increase with demand. Besides high electrical demand for normal use, computers consume energy when idle.[53] The institutions will save electricity, money, and the health of the local and global environment by reducing their computer energy consumption. There are three computer conservation alternatives possible on the CSB/SJU campuses: PC (Personal Computer) conservation education, the purchase of Energy Star PCs, or the installation of a network power management program.

**Campus Context**

There are about 4,500 personally and institutionally owned computer **workstations** on the CSB/SJU campuses. The campuses own and operate almost 2,000 workstations, with another 2,500 workstations brought to campus by students.[54]

Refer to the table in the Appendix for more detailed specifications on models, watts, kWh, and cost of student and campus owned workstations. The campuses' three most widely used models of monitors and baseunits are given as examples of specific model requirements.

**Detailed Proposal**

There are three different ways that CSB/SJU can improve their computer efficiency is through education on energy efficient computer use, purchasing according to Energy Star guidelines, and installing a power management program through the campuses' server. All three of the methods are obtainable and would work with minimal labor costs.

The first option is to educate the campus community through informational sessions or signs from which power management features can be explained and implemented. Power management features come standard on current models of Windows and Mac operating systems. They cause inactive monitors and baseunits to move into low-power mode, often called "sleep mode," after which they can be activated by the touch of the mouse or keyboard.[55] It is estimated that only about 25 percent of people enable their energy management software. Reason why many people do not turn their power management function on is because they simply do not know how to do so, or because their computer has a delay in start-up, freezes, or other complications while the function is enabled.[56] Delays and other problems associated with power management features are usually found in older computers. New computers have a much shorter delay and rarely freeze.

Currently, CSB/SJU IT Services is using power management features on most campus owned computers, but it is unlikely that the majority of the student body uses these features on their own computers. CSB/SJU IT Services could increase the use of power management by facilitating classes highlighting such features and as well as the *Guide to Green Computing,* which is found on the campus website. The best time to do this informational class would be during freshman orientation. The current CSB/SJU *Guide to Green Computing* could be improved by including details such as: how much energy a computer uses, power management features, and the purchase of energy efficient computers.[57] If both campus-owned and student-owned PC's use power management features there will be a slight reduction in electrical demand.

The second option is the purchase and use of energy efficient workstations by the campus community. An incentive program can be set-up for students to purchase Energy Star computers. This program could be explained at informational sessions such as the one referred to above, prospective student literature, or on prospective student tours. For example, each campus could have an Energy Star showcase dorm room which can be on display for campus tours. The dorm room would be equipped with Energy Star computers and other appliances to show how easy it is to use them.[58] Incentive programs could also encourage students to purchase more energy efficient computers. For example, if a student brings an Energy Star computer to college they could get 10 percent of their $50 IT Services fee wavered. IT Services currently does take energy efficiency into consideration when purchasing computers and tries to purchase Energy Star certified computers when possible. Energy use for computers could be reduced if IT Services emphases the importance of purchasing energy efficient computers.

The third option for computer energy conservation is the purchase and installation of an energy saving network software program. Currently there is very few computer energy saving software systems available on the market. Most commonly known is Verdiem's Surveyor Network Software. This software will work on all of the college's operating systems, including most student PCs. It also allows the system administrator to create a variety of groups and categories to sort PCs according to their operating system and running time.[59] Multiple power schemes can be set-up using a profiling feature which allows the computer manager (administrator) to adjust the sleep modes and shut down features according to the time the computers are active.[60] Below is an example of one of these power schemes.

9:00 am- Standard daytime power usage
12:00 pm- Inactive computers go on **standby state** and return to "daytime" scheme at 1:30 pm
4:00 pm- Peak-hour usage
6:00 pm- Nighttime power is when computers can save the most energy while still on
8:00 pm- System-wide shut down
8:00 am- System executes wake-up for all system computers[61]

At night when workstations are about to go into shut-down mode the software will sense if the computer is active or inactive. If the computer is active and there are programs open, the user will be prompted about the shut-down and will be able to over ride the shutdown procedure. This applies to student PCs also; if a student chooses to download the Verdiem software on to their computer they can also take advantage of the power management features.[62]

Besides shutting down computers and placing them in sleep-mode, Surveyor also collects data daily on energy use and user activity for each workstation. This data is used to create consumption reports detailing the amount of time the workstation is active and which power states (on, **suspend**, **hibernate**, or off) it uses throughout the day. Surveyor then uses the consumption reports to create graphs of current network energy consumption and determine possible energy saving opportunities in both kWh and cost.[63]

The installation and maintenance of Verdiem's software is relatively quick and simple. The network administrator at CSB/SJU IT Services could set-up and monitor the software through the Surveyor Server which could be located in Wimmer Hall along with the other campus servers. There would also need to be a copy of the Surveyor software on every PC to allow communication between the computer and the server for updates and movement of data. As long as students have access to the network they too can connect their computers to Surveyor to obtain their own energy saving profiles and modes.[64]

**Costs**

Depending on which energy conservation program or combination of them, the college chooses to invest in the cost for implementation ranges from very little to costly. The cheapest and easiest method for computer energy conservation would be informational classes, posters, or pamphlets focusing on power management features and the *Guide to Green Computing*. For a little more money the college could invest in an Energy Star showcase dorm room which could be viewed during campus tours. The only fee would be the purchase of an energy efficient computer and printer in the showcase dorm room. Although this would be the easiest and cheapest route for the institution not everyone will be able to attend an informational session or read posed signs.

The majority of campus-owned workstations are energy efficient, but many student owned work stations are not. The price for Energy Star approved workstations is relatively the same as regular computers. Currently CSB/SJU has and will continue to purchase energy efficient computers, which saves the institutions money through reduced energy costs. Another way to get more energy efficient computers on campus is to provide students with incentives for purchasing Energy Star complaint computers which would not cost the institution any money. For example, they could deduct the amount saved from the electrical bill from computer or housing fees.

The final option is to install Verdiem's Surveyor Network Software which will slightly increase efficiency, but the installation and operating cost is substantial. According to David Paul Harvey, Vice President of Sales at Verdiem, software installation is included with a $19 per PC licensing fee. There is no maintenance fee the first year of installation, every year after there is a $2 per PC charge. Maintenance includes technical support, upgrades, and an annual network energy analysis. Harvey also stated the cost for customer support was very minimal, because less then 40 hours per year is used to contact Verdiem's support center.

Verdiem's software system is guarantied to save at least 15% of energy costs. With this figure the campus would save $8,400 a year based on the information in the accompanying table, but it would cost the campus $8,970 a year for maintenance. Realistically the cost of purchasing and licensing of Verdiem would out way the savings. As noted before, this is a new field and the prices for the software could become more reasonable in the future.

**Other Schools**

Many different universities and colleges throughout the United States have been implementing educational out reach programs, power management plans, and energy conservation software. At Harvard University the Faculty of Arts and Sciences organized a Computer Energy Reduction Program along with the Kennedy School of Government. This program started a power management drive on 1 million computer monitors through the EPA's "Million Monitor Drive." This drive has led to a savings of $70,000 and the prevention of 500 tons of carbon dioxide emissions produces annually by Harvard University. The university was able to accomplish this through cooperation with academic and IT departments, competitions within undergraduate residences, and the distribution of an imaging disc containing energy-saving software throughout campus. The EPA noted Harvard as one of their top contributors to the national campaign to reduce the amount of energy used by computers. [65]

Another college investing in computer conservation is Edmonds Community College, which has a student body of 10,000. Edmunds is currently running Verdiem's Surveyor software on 2,500 computers.[66] Snohomish Public Utility District, a public power provider, provided Edmonds College with 50 percent of Surveyor's cost which helped defray the initial costs for the college.[67]

**Projected Savings**

By investing in energy conservation practices, appliances, and programs the colleges and students will save more than just money. It is estimated that Energy Star computers use 70 percent less energy than conventional computers.[68] By using power management features could save energy, allow equipment to stay cooler, to last longer, and save on air conditioning costs and maintenance.

The Surveyor Network Energy Manager will save a small amount of electricity but it will not save the colleges money. The graphs and information produced by the software could be beneficial for understanding campus computing uses. But this would not justify the cost of installation or maintenance. Currently Verdiem's software is too expensive to invest in but may become cheap as the market expands. It is worth while to keep track of software, such as Verdiems, to improve energy savings on campus.

**Priority**

If the College of Saint Benedict and Saint John's University want to start saving energy, money, and the earth their best bet is to start by informing students, faculty, and staff about how to reduce their computer's energy consumption. This can easily be done by informing freshmen students at orientation or setting up an informational class. Educating the campus community will only require a small amount of labor and expense for an instructor and printed information.

## Appliances

### Application and Campus Context

Electronic appliances are an integral part of life on both CSB and SJU campuses serve as a major source of energy use. Therefore, when looking into energy conservation, using more energy efficient appliances (and using them in a wise fashion) will greatly impact yearly energy and expenditure savings. Every residence on both campuses uses several major appliances as a part of daily life. Kitchen spaces draw energy through refrigerators, microwaves and stoves, while living spaces use televisions and DVD players or VCRs. Both campuses also utilize electric washing machines and dryers for laundering clothes. Looking at each of these appliances and the living spaces on the campuses, an estimate can be made of the total power use from appliances.

| | Refrigerators | Stoves | Microwaves | Washers | Dryers | TV |
|---|---|---|---|---|---|---|
| SJU Total | 98 | 98 | 665 | 87 | 93 | 665 |
| CSB Total | 139 | 150 | 388 | 49 | 53 | 635 |
| Watts/unit | 500 | 1800 | 1100 | 1800 | 7200 | 90 |
| kW used | 118.5 | 446.4 | 1158.3 | 244.8 | 1051.2 | 117 |
| Estimated kWh/month | 19,900 | 25,000 | 16,000 | 20,500 | 118,000 | 19,700 |

### Detailed Proposal

Since appliance conservation represents a major aspect for both institutions, it is imperative that our schools take an in-depth look at replacing old equipment with new, more efficient appliances. Students must be allowed the opportunity to access energy saving appliances. Since both institutions have this abundant supply of laundry machines (washers/dryers), microwaves, TVs, VCRs, radios, and refrigerators. The switch to Energy Star compliant equipment would save CSB/SJU thousands of dollars each year. Between both campuses, 98 refrigerators, along with 87 washers and 93 dryers, serve as the main energy users amongst the entire household appliances found in both student housing and faculty areas. Combined, these three appliances use over 10,000 kWh of energy per hour.

The schools should invest in Energy Star appliances in order to curb the amount of energy wasted on inefficient products, such as refrigerators, TVs, VCRs, radios, washers and dryers, and even microwaves (which totaled over 660 between both campuses). This proposal is not an attempt to discard all of the existing equipment and replace it immediately, but rather to encourage the institutions to view the benefits of energy-saving appliances. The environment as well as the institutions would benefit if existing machines were slowly replaced with Energy Star appliances as they reached the end of their life span.

**Potential Benefits**

Aside from the obvious benefits of saving money and supporting more energy efficient appliances, the efforts to provide and offer regular household appliances to students and faculty would be sending a clear, educational message on behalf of the institutions. The schools would save money that might otherwise be spent on the energy "wasted" while appliances are turned off (even the blinking clocks on most appliances use several kWh of power). In addition, almost all of the Energy Star compliant products cost less, if not relatively the same, as standard products. Energy Star refrigerators use roughly 570 kWh, which equates to approximately $478.34. The machines not Energy Star compliant use 670 kWh, costing $562.36.[69] Environmental benefits include having to purchase less power from the energy plant (Xcel), as well as reducing the amount of water used in washing machines. Front-loading washers are beneficial not only because they conserve on energy use (in kWh), but they also have a lower impact on the Earth's natural resources due to using less water than conventional, top-loading machines.

**Costs**

The main costs involved in converting the on-campus appliances to Energy Star compliant products would be the initial cost, as well as the installation of larger, permanent items. However, the only item that would require such installation are older stoves located in apartments and freshman/sophomore housing. Excluding this appliance, most items are small and require no further installation. Refrigerators, washers and dryers are available for relatively the same price. On an average comparison, a standard Frigidaire double-compartment refrigerator costs $500-$1,000, while an Energy Star compliant Frigidaire (or any brand for that matter) is available for an equal price. Similarly, a typical Whirlpool washer and dryer cost approximately $500 each; with more expensive models (such as an LG) running over $1,350. As with refrigerators, identical Energy Star compliant washer and dryers cost roughly the same price. Clearly, purchasing an energy-efficient product of the same brand results in a reduction of energy use at no additional expenditure.

While public appliances are much easier to locate and track their usage, it is the individual property that poses problems for the schools. St. John's University holds over 1,488 rooms for student residences, with each room having any combination of the following: TVs, VCRs, radios, computers, and clocks. However, if the establishments promoted Energy Star equipment, the amount of energy purchased each year would drop significantly.

This student-led initiative would require a great deal of promotion and incentives. (see proposals on Conservation Competition and Education), but would otherwise leave the institutions with a small share of the burden. Should CSB/SJU decide to provide energy efficient appliances to students for the duration of the school year, it would be up to the school to provide the student with access to said products. Students and faculty members would be encouraged to be energy conscious by bringing their own Energy Star compliant appliances. However, the schools would be responsible for ordering new washers and dryers, refrigerators, etc., arranging for their delivery and installation. This can be done by any of the company's service workmen, electricians or maintenance workers already employed by CSB/SJU.

**Other Schools**

Schools around the country are setting guidelines and requirements for their student's home life. Many administrative boards have set forth efforts to limit, and in some cases refuse, appliances that are not energy efficient and hazardous to dorm life.

Ithaca College lists the energy requirements on its website so students have a safe dorm atmosphere. The list is very specific to what appliances are allowed and the regulations upon using that appliance. This is very helpful for both students and staff because these regulations limit the school's energy costs, and keep students safe within the dorms. The school does its best to acknowledge the needs of the students, while maintaining a safe working environment.[70]

**Priority**

Saint John's University and the College of Saint Benedict must analyze the appliances that students bring to campus to save on electric costs. We can look at the older appliances on campus and replace them with Energy Star equipment. Residential Life has made these changes in the East and West apartments on the Saint Benedict campus; however, we must focus on other outlying problems. The institution should not force students to purchase energy efficient items, but should persuade students through incentives or rebates. Saint John's must upgrade equipment to Energy Star status in order to follow suit with the College of Saint Benedict.

## Vending Machines

### Application

Vending machines are an important source of revenue for soda and snack producers, and institutions are taking advantage of the benefits by providing space for these machines. Saint John's University and the College of Saint Benedict work together with First Choice and Bernick snack and beverage companies to distribute Coca Cola, Pepsi, and other assortments of snack goods to its inhabitants, students, and staff. The companies provide the vending machines and snack products, while the establishments and businesses provide the space and electricity. The majority of the profits go back to First Choice and Bernick; however, the businesses providing the space make a small percentage of the profit. The operation of this business makes it economically beneficial for both corporations.

Energy Star appliances are more electronically efficient than older appliance models. These Energy Star machines are cost effective, saving 1300 kWh/year, and an average of 90 dollars annually on electric costs. They incorporate efficient lighting systems, fan motors, and compressors into their machines. These machines contain low power modes, allowing the machines to use less energy during inactive periods.[71] Vending machine technology has improved drastically. On the following page is a table of various models of vending machines and their efficiency ratings and costs.[72]

**Beverage Vending Machine Cost-Effectiveness Example (501 – 600 Can Capacity)**

| Performance | Base Model | Recommended Level | Best Available |
|---|---|---|---|
| Kw-hours/day | 11.1 | 7.7 | 5.7 |
| Annual Energy Use | 4,052 kWh | 2,810 kWh | 2,089 kWh |
| Annual Energy Cost | $ 243 | $ 170 | $ 125 |
| Five Year Cost | 1,055 | 740 | 545 |
| Five Year Savings | - | 315 | 510 |

### Campus Context

Depending on the location, St. John's makes between 15-25% of the profit from vending machines leaving the other 75-85% of the profits for First Choice and Bernick.[73]

Saint John's made roughly $12,500 on vending during the 2004 year.[74] Saint John's University has thirty-three total machines on campus and can be described as follows: twenty-one pop machines, five juice machines, and seven snack machines. The machines located near food establishments draw marginal profits because of other concession options. This chart on the following page explains the exact locations of vending on the Saint John's campus.[75]

**Saint John's Commission Statement (First Choice Beverage Company)**

Collects from 10/30/2004 to 11/26/2004

| Location Description | Item Description | Revenue Basis | % Rate | Amount Owed |
|---|---|---|---|---|
| 2060 Dining Service-SJU | All Vending | $457.51 | 25.00 | 114.38 |
| 5984 Great Hall-SJU | All Vending | $230.99 | 15.00 | 34.65 |
| 5741 Mary Hall-SJU | All Vending | $95.55 | 25.00 | 23.89 |
| 5743 Old Gym-SJU | All Vending | $93.61 | 25.00 | 23.40 |
| 2058 Science Hall-SJU | All Vending | $324.79 | 25.00 | 81.20 |
| 5987 Science Hall-SJU | All Vending | $318.17 | 15.00 | 47.73 |
| 2059 Tommy Hall-SJU | All Vending | $537.42 | 25.00 | 134.36 |
| 5986 Tommy Hall-SJU | All Vending | $224.70 | 15.00 | 33.70 |
| | | $2282.74 | | $492.61 |

The numbers from this statement indicate the best locations for vending machines on the campus. In order to maximize profits and save on equipment and energy costs, we must use this data for effective vending machine placement.

**Detailed Proposal**

Saint John's University and the College of Saint Benedict should require First Choice and Bernick to supply us with Energy Star equipment. These machines should have motion sensors, limited lighting, and temperature fluctuating capabilities.

David Schoenberg, the food service provider for Saint John's, was unable to comment on the current contract situation with Bernick and the First Choice companies. We must determine whether we as an institution, have the power to request these energy efficient machines.

The lighting on these machines is inefficient and is generally not needed if the machine is placed in lighted areas. The vending machines have two T-12 florescent lamps that require 180 watts of electricity.[76] These bulbs should be unplugged if not needed. It is wise to install passive infra-red sensors (PIR) to detect motion in the area. When the sensors detect little movement, the machine powers down to save on electricity costs.[77]

The proper temperature setting for the machines is important when saving on energy costs. The U.S. Food and Drug Administration state that refrigerator temperatures should be no higher than 41 F or 5 C.[78]

The vending machines should be away from vents, microwaves, stoves, and other heat sources. Machines exposed to heated areas must work harder to cool the product and waste electricity. We should study vending data to optimize total sales and efficient electrical use. If machines make little in revenue, perhaps there is a better place for vending on campus.

If it is not possible for Bernick and First Choice to provide the schools with Energy Star machines, we could raise prices on drinks and snacks to pay for the machines. Student objection to higher prices should be low because they can always use the Refectory and Sexton Dining Services for their food needs.

Saint John's and Saint Benedict could rent Energy Star Equipment to students. This method is beneficial to out of state students who cannot ship a television or small refrigerator across the country. The schools do not have to buy an excessive amount of machines, but it is another option for consideration.

**Benefits**

There are many benefits and saving opportunities when we convert to Energy Star machines. Energy Star machines save 90-200 dollars annually on electricity costs, and each machine saves 1300 kWh/ year, making them 35% more efficient then basic machines.[79] By implementing these plans, it affirms our Benedictine values. It shows that we not only say we care for the environment, but we will do what it takes to make a difference. Following many of these procedures will reduce carbon dioxide and other harmful agents that are leaking into our air, lakes, and ecosystem.

By reducing vending electricity annually, the school will save on minimal Excel and coal costs. Saint John's purchases and burns coal to provide energy for the campus. Any electricity we can save in vending will reduce the amount of coal and will limit pollution.

**Costs**

Vending Machines range in price based on the model you wish to purchase. The prices range from roughly 500 to over 3,000 dollars[80]. The machines with motion sensors and temperature fluctuation gauges are expensive, and Bernick and First Choice may choose not to purchase these items. Either we must convince them to purchase these machines, or we must buy the more expensive vending machines ourselves. Perhaps if we purchase the machines ourselves, Bernick and First Choice could compensate our schools in another form. (Ex: Reduce prices on pop, snacks, juices etc.)

These machines require a high amount of electricity and one kWh of electricity produces approximately one pound of carbon dioxide. The disposal of the two T-12 florescent bulbs also costs 0.75 cents per bulb.[81]

Vending machines also produce a waste heat that can be beneficial in the winter but harmful in summer season. The schools pay for heating and cooling costs and this vending process may change the temperatures slightly within the buildings; however, this should not be a major problem.

**Other Schools**

Colleges and Universities in Maine formed a coalition called, "The Green Campus Consortium of Maine." These schools wrote a list, labeling the important requirements schools need to consider.[82] This includes turning off machines when they are not in use, and disconnect all unneeded lighting panels.

**Priority**

As our vending machines break and reach the end of their operating periods, we need to invest in Energy Star machines. These machines will save the schools a substantial amount of money and will reaffirm our Benedictine values.

## Automobile Restrictions

### Introduction

Conservation can take many forms on campus. A main issue that surrounds the campuses everyday is the amount of automobiles clogging our air quality. This proposal is for regulation methods against the amount of automobiles allowed on campus. Excessive numbers of vehicles on the campuses of St. John's University and the College of St. Benedict affects our air as well as our natural setting. Regulations can be made to prevent the amount of automobiles students are allowed to bring on campus. In the event that every student is allowed to have a car on campus, as it is now, the institutions need to provide parking. The amount of parking at CSB/SJU often seems excessive and overwhelming. However, with fewer vehicles on campus, increased land restoration projects could be undertaken. With the Benedictine stewardship supported by CSB/SJU, involving the Abbey and monastery representatives, new ways to manage the automobiles on campus should be found. The campuses need to be looking at ways to comply with the Kyoto Protocol set in December of 1997,[83] explaining the terms the U.S. agreed to follow for a decrease in pollution nation wide.

The campus itself is a small fraction of the entire 2,400 acres that make up SJU. With smaller amounts of vehicles on campus that acreage would be increased because of decreased parking area. Schools, such as New Paltz, do not even allow first years to bring cars to school because there is not enough room for them. Some schools, for instance Emory University, require a large fee for anyone that brings cars to the university. There are many ideas that have worked and can change the way SJU and CSB handle the load of cars coming onto campus starting in September and sitting until the end of May.

### Application

Automobile cutbacks could consist of taking away around 900 cars that come to the campuses with the first and second year students. Regulating this drastic number by any means would create conservation for our air quality on both campuses. There would also be an incentive to use the Link transportation.

**Campus Context**

There are enrollments of 501 students in the first year class at CSB/SJU and 420 students in the second year class at CSB/SJU. With this sort of enrollment, potentially, we could have 900 vehicles on our campuses. Not only is this bad for parking for our visitors, but energy use is also a significant environmental concern. Our forest is a huge carbon sink for this air pollution but it certainly does not have to be used to its potential. SJU Life Safety Services database estimates the total permanent student permits sold that there are around 1,406 cars registered on campus. This number is specific to only students.

**Detailed Proposal**

Regulating automobile entry onto campus allows our institutions to have more control over automobile emissions. Elimination of some parking spaces would create space for vegetation as opposed to concrete and tar. This proposal is set to regulate automobiles from coming onto campus for first and second year students. By CSB/SJU standards, students are required to live in the dorms for their first and second year, placing the entire enrollment of these classes in walking distance from our bus system. Currently, the exception to living on campus is living with your parents who live in close proximity to the school. Along with the residential restrictions, we could make a restriction on vehicles brought to campus by first years and sophomores. There would also be a problem because of holidays. This proposal would suggest that CSB/SJU give permits to students in their first and second year, and would promote carpooling. The colleges would only give this permit under specific conditions. Other than special cases such as this with holidays, there should not be a problem with students not having a vehicle.

**Potential Benefits**

SJU would avoid taxing its power source and would save money from Excel Energy. Reducing our area of parking facilities on campus and making them available for trees and other vegetation would overpower the small financial savings. The power used by these two parking lots is minor compared to the 17,381,901 kWh[84] we use at this school annually.

By regulating automobiles on campus, our community would directly benefit by increasing the use of public transportation. The Link bus network has been good; however, the number of cars on campus has increased. The Link buses have also seen a decline in numbers. Ultimately, the trips by the Link should be energy efficient in order to keep the Link practical. By implementing the guidelines above, CSB/SJU should see an improvement pertaining to automobiles on campus.

**Costs**

Implementing this plan may reduce student enrolment at both schools. Some students may decide not to come to school here if they could not bring their vehicle. This would only be a potential problem, and would vary by student.

**Projected Savings**

Fewer cars on campus will save us financially and will create a better living environment for our students and faculty. Abiding by the Kyoto Protocol[85] will promote our school and reaffirm our Benedictine values. The science department can study the air quality and document any changes because of this study.

**Other Schools**

New Paltz University in New York has a policy that no freshman student can register a car on campus. The title of this section is "Freshman Parking Ban."[86] This title explains the importance of this issue. However, there are extenuating circumstances to this rule. The main idea is that if freshman are living on campus, they are not eligible for a parking permit at all. There seems to be no need to have a vehicle at New Paltz, so there should be no need for vehicles here at CSB/SJU, especially because of the Link. By looking at this program, we can see that this plan can work on this campus.

Emory University issued incentives for students who use bicycles and motorcycles. This saves parking lot space and reduces congestion on campus to save on parking lots and to create less congestion on campus. Emory University has an entire web page with descriptions of alternative transportation methods from bicycle usages to shuttles.[87] They are trying several options to give the students many opportunities to think about how they are using transportation. The different opportunities for the transportation systems around campus for students seems to be making an impact because students are starting to lead new projects and asking for different transportation options. Involvement with the student body is a major part of any university. If CSB/SJU can get a positive response, changes can go a long way.

**Priority**

The unused automobiles on campus are unneeded. These parking lots should be converted to carbon sinks or green spaces to better utilize the land. By regulating the automobiles on campus, we would benefit from the educational factors and promote an energy efficient lifestyle. The main goal is to lower carbon outputs, save money, and create a better living environment for all CSB/SJU students.

## Metering

### Application

**Energy metering** is a central component to an energy conservation plan. John Fetters, an editor for Energy User News, stated "A monitoring program is necessary to determine how much energy a facility uses and to evaluate the progress of energy management measures. In order to control energy use, energy has to be measured."[88] Before conservation can happen, one needs to assess where energy is used and how much. Metering tracks the amount of energy used in individual buildings. This is also called **sub-metering**. However, sub-metering can also refer to metering a certain load within a building, such as individual dorm rooms.[89] We will refer to sub-metering in the second sense; mainly in relation to dorm rooms. Presently at Saint John's, we have little clue as to how much and where energy is being used. Implementing meters to measure electricity, steam, hot and cold water, and chilled water would help alleviate the problems. Installing meters in all buildings at Saint John's and sub-meters in dorm rooms and apartments at both St. Bens and Saint John's is important in understanding what needs to be done on our campuses to conserve any significant amount of energy.

### Campus Context

St. Bens already meters all its buildings. Saint John's, however, only has metering in some buildings (see list below). The majority of energy simply leaves the Power House, without and idea of its distribution qualities. Most of upper campus is completely unaccounted for.

| **Metered Buildings** | **Unmetered Buildings** |
|---|---|
| Greg House | |
| Saint Placid House | Quadrangle |
| Saint Maur House | Saint Thomas Aquinus Hall |
| Saint Joseph Hall | Saint Mary Hall |
| Metten Court Apartments | Saint Patrick Hall |
| Virgil Michael House | Saint Bernard Hall |
| Seton Apartments | Saint Boniface Hall |
| Seidenbusch Apartments | Peter Engle Science Building |
| Frank House | Alcuin Library |
| Sexton Commons | |
| New Science Building | |
| Humphrey Theater | |
| Wastewater plant | |
| Garage | |
| Pottery Studio | |
| Warner Palaestra | |
| Saint John's Preparatory School | |
| Hill Monastic Manuscript Library | |

There is no sub-metering in individual dorm rooms on both campuses and none in individual apartments at St. Bens. There are a few individual apartments at St. John's that have sub-metering (Seton Apartments and Metten Court Apartments). Sub-metering in all dorm rooms and apartments is needed to pinpoint where the most energy is being consumed and to try and reduce this.

**Detailed Proposal**

The first step in implementing metering on campus is to make a plan and an estimate. Gary Jorgenson, the manager at the St. John's power house, made such an estimate. He added up the total number of meters needed and figured out the cost. Next, install meters in all buildings not presently with them at St. John's and connect them to the present energy management system. This allows for the data to be easily accessed and used. The present energy management system is provided by Kreuter Manufacturing Company (KMC) through Harris Mechanical Service LLC.

After metering is installed, begin to add sub-metering in all dorm rooms and apartments. The cost of retrofitting existing dorms and apartments will be very high, so sub-metering should be installed in any new housing built on campus before it is considered for any old buildings.

**Potential Benefits**

Knowledge is the main benefit of implementing a metering system for a whole building. John McBride, CEO of New Horizon Technologies metering company says, "Only when data supplied by an energy metering system are converted into information, and ultimately intelligence, can energy savings be achieved."[90] Metering provides important information to the physical plant managers, the school, and ultimately the community who use the energy about how much energy they currently use. This information can be implemented in a comprehensive conservation plan. This knowledge includes how energy is distributed throughout campus, where the greatest energy sinks are in the system, how much energy each building is using, and where conservation needs to be addressed. This information can be used to better regulate heating and cooling and to make a conservation plan accordingly. This knowledge can also be used to educate the community about how much energy we are using to promote conservation. If the community sees how much we are actually using (and spending) in different buildings, then they may work to conserve more.

There are a few important potential benefits of sub-metering in individual dorm rooms and apartments. These include possibly charging for additional energy consumption to individuals using more than a set amount, educating students about energy consumption and conservation, and better regulation of heating and cooling in individual rooms.

**Costs**

Gary Jorgenson's estimate of the cost to install electric, steam, water, and chilled water meters in all un-metered buildings at St. John's came out to be approximately $1.1 million. This estimate does not include sub-metering in individual dorm rooms or apartments nor the cost of labor. It is strictly the cost of the equipment and installation. This figure is based on the price Harris Mechanical, St. John's present energy management equipment provider, gave for equipment and installation of the KMC metering system. The cost of electrical metering in each building is $1,800. The price goes up with the addition of metering for hot and cold water, chilled water, steam and parts for all these buildings.[91]

Sub-metering individual dorm rooms and apartments would add a significant cost to this estimate. Jorgenson said, “We would have to rewire and re-plumb about everything to do that [install sub-metering in dorm rooms] and cost would skyrocket.”[92] Therefore, Jorgenson did not even consider sub-metering in his estimate. It is just not economical. Regardless, sub-metering remains a possible option in the construction of new dorms.

**Other Schools**

In recent years, the installation of meters on college campuses has caught on as an important conservation measure. Many schools throughout the country are paying large sums of money for metering. The general consensus, however, is that the large investment pays off. Generally, money saved in energy conservation from using metering ends up paying for the cost of the installation.

Texas A& M University, in College Station, Texas, is the home of Texas Engineering Experiment Station's Energy Systems Laboratory (ESL), a national leader in energy metering. John McBride, of Energy User News said, “Funds for implementing the metering system came from the campus operating budget. In essence, the University administration felt that they would achieve large enough energy savings quickly enough to spend funds designated to purchase energy for metering instead.”[93] Although the initial cost was high, the school knew it would pay for itself very quickly. The school implemented its metering system in the mid- 1990s and through 2000, had already saved over $15 million with only investing about $3 million in the project.[94]

**Projected Savings**

It is difficult to determine exactly how much St. John’s would save from implementing an energy metering system. McBride, the CEO of New Horizon Technologies, a metering company, says, “In general, energy savings estimates from the implementation of metering systems with engineering services seem to range from 5-25%, with savings in the 10-20% range commonly identified.”[95] The amount of energy saved will depend on how we react and change our energy practices in relation to what the metering tells us. The metering itself will not save anything. It is what we do with this information that will create savings.

**Priority**

John Fetters, an editor for Energy User News, stated, "Metering systems should be considered fundamental to any energy management program. The information gained on usage and patterns of use can be used to develop new energy saving strategies."[96] Metering is a central component of developing a comprehensive conservation strategy for CSB/SJU. Implementation of metering in buildings should be the first step we take towards conserving significant amounts of energy. Electricity metering should take first priority since this is the largest consumer and very important to be monitored. Other monitoring (water, chilled water, and steam) should be installed after. These are also more expensive and not as critical.

While metering in individual dorm rooms and apartments would be very beneficial, it would involve significantly more money and should be considered at a later time. Installation of metering can be done in stages and individual metering could be a future goal, as we build new buildings.

## Education

### Campus Context

The most inexpensive and effective way to decrease energy consumption on campus is to simply have students conserve energy. With average energy consumption increasing on campus, conservation efforts should be a priority. While the school has some control of how and when the students use energy, the majority of energy conservation is entirely in the students' hands.

Both campus' adamantly stress the importance of Benedictine values, one of which is stewardship. It seems logical to put this stewardship into practice by educating students about the environmental impacts of energy consumption.

### Detailed Proposal

In order to increase environmental awareness on campus a group must promote conservation. Presently at CSB/SJU the Campus Greens Club promotes environmental education and sustainability, but their main focus is not conservation. Several schools around the country have taken initiative to implement conservation efforts from the student standpoint, and Campus Greens could work on promoting conservation through campus education and student led events.

### Other Schools

A Student Union energy campaign is underway at the University of Colorado with funds given by the administration.[97] The mission of CU's "Generation Green" is to have an extensive energy education campaign. By educating students, staff and faculty about their energy use they can make a difference on an individual basis. The campaign started in 2001 in six of the buildings on campus. The goal was to decrease energy use in six buildings by promoting conservation awareness. After six months of the campaign, the goal was achieved in four of the six buildings; total energy use decreased from 1 - 3.5%. Since this "test" run, energy conservation has been promoted around campus. The tactics used to promote awareness include:

- Creating electrical use posters for each building; the posters state the cost of electricity in the building for the 1999-2000 fiscal year and how much air pollution was created by that energy consumption.

- Creating large displays with fun facts about energy use and ways to reduce use on campus and at home.
- Developing relationships with building proctors, custodial staff, resident hall staff and computer technology staff.
- Ads in the form of newspaper, radio, registration handbook, buses etc.
- Message in the football stadium during games.
- Using the slogan, "When not in use, turn off the juice!"

Energy conservation does not only rely on student groups, although energy conservation should be the responsibility of the students. Staff and faculty groups can also campaign, as proved by the "Harvard Green Campus Initiative (HGCI)."[98] The members of this campaign consist exclusively of faculty and staff of Harvard University. The mission of HGCI is "to address campus sustainability through the management of building design, construction, renovation, procurement, landscape, energy, water, waste, emissions, transportation, human health and productivity." Twenty percent of the funding is provided by the office of the president and provost at $150,000 a year. The rest of the funding comes from a fee for service partnerships that the HGCI negotiates annually with a variety of Harvard University departments. Starting in 2000, the campaign has achieved a $1 million per year reduction in utility costs and an annual reduction of 20 million pounds of carbon dioxide emissions after four years of growth. The tactics used to promote conservation include:

- Hosting forums for bringing university professionals together to learn the best practices for reducing the campus environmental impact.
- The "Computer Energy Reduction Program" influences over 10,000 computer users to shut down their computers when not in use, to purchase LCD monitors or laptop computers and to activate the sleep software for monitors.
- Employment of twenty students to engage in peer to peer training and education activities. They educate and engage the student body in a wide range of campus sustainability initiatives.
- "Green Campus Loan Fund" is an interest free revolving loan fund available to anyone within the Harvard community. The individuals must have a project that both demonstrably reduces Harvard environmental impact and directly generates associated utility or operating savings to pay back the loan within a five year period.
- The "Greenhouse Gas" inventory includes greenhouse gas emissions associated with on-campus stationary sources, purchased electricity, purchased steam / chilled water, and commuting students.
- "Longwood Campus Energy Reduction Program" is an assessment of energy conservation opportunities in Harvard laboratories, renewable energy purchasing for student dorms and more recently, wide reaching behavioral change programs to minimize unnecessary resource consumption.

## Climate Control

### Application

The heating and cooling of two college campuses that encompass over sixty buildings is a monumental task, requiring enormous amounts of energy and expenditures for the colleges. Examining the current climate control practices of each campus can highlight what, if any, measures can be taken to conserve energy and save money for CSB/SJU.

### Campus Context

A large percentage of energy use on the CSB/SJU campuses is used to heat and cool the academic and residence areas. The potential to save energy on heating and cooling is an attainable goal. CSB has an energy efficient system in place while SJU has the potential to increase its energy savings in the area of heating and cooling. By increasing the use of a digital control system throughout the academic buildings and residences of Saint John's energy use can be decreased. Also enforcing a **nightly setback** would only add to the energy savings.

By looking at CSB's energy management system, it is clear that there are opportunities SJU can implement to increase their energy efficiency. Currently, the College of Saint Benedict has a Siemen's Energy Management System (EMS), a computer-controlled heating and cooling system. Four to five thousand sensors have been installed around the CSB campus to detect certain aspects such as zone temperature, outdoor temperature, dampers, thermostats as well as carbon dioxide levels. The system is multi-faceted and has many energy saving components.[99]

The Start/Stop Time Optimization (SSTO) function allows each academic building as well as dormitory or apartment to have a specific operational schedule in which the heat is turned on at a specific time of day, usually 5:00 am for residences and between 8:00 and 9:00 am for academic buildings, and turned off on or around 5:00 pm each evening. This ability to turn down the heat at night is called a night setback, in which the heat is turned down to 60 degrees Fahrenheit. This is mostly used in the academic buildings because residences are occupied on a more consistent basis. The events schedules are also sent to the CSB Power Plant to ensure that all heating and cooling requirements will be fulfilled as the SSTO schedule can be overrode if necessary.[100]

The SSTO system has a device called the Powers Programmable Control Language (PPCL). The PPCL allows the building's sensors to read the outside temperature in order to gauge how much time is needed to heat the building. For example, depending on the day, the heat may start 45 minutes before the building will be occupied. If the outside temperature is warmer, the heat will only start fifteen minutes before the set time. This same process works at night: the building shuts down the heat according to the outside temperature and how long it will be before the building may become uncomfortable for the occupants. In both instances energy is saved due to less heat being created and used.[101]

There are two other important functions of the EMS system. The first is the monitoring of carbon dioxide levels in every academic building, sensing at which points the levels become unhealthy, until then air being circulated remains the same. This system avoids unnecessary air exchanges in which energy is wasted during the exchange of unneeded outside air being drawn in. Secondly, the system uses **free cooling**, in which the air is using the system already in place to cool the space instead of constantly drawing in outdoor air.[102]

The numerous components of EMS have been introduced to campus over a twenty-year period. The last ten years have brought the greatest change and as technology improves CSB integrates changes as needed. CSB has invested approximately a million dollars into the system but has probably saved four times that amount over the years. **Trending** has allowed the college to compare and contrast energy use as well as costs by watching and comparing usage from multiple years. With this system in place at CSB, the system remains as efficient as is possible, however changes can be made at SJU. [103]

**Saint John's University Campus Context**

The Kreuter Manufacturing Company digital heating and cooling system at Saint John's was first implemented in 1996. Currently, twenty-two buildings have been installed with the system, but six buildings still have some work to be done for them to be completely dependent on the system. These buildings mainly lack individual room controls.[104] The overall goal for the entire SJU campus is to upgrade at least one building a year, but the largest obstacle is monetary concerns. The Art Building, scheduled to be completely upgraded by July 2005, will cost $57,000 with an additional $15,000 for the wiring. Saint John's also has a bid for Simon's Hall, whose upgrade will cost $93,000 to upgrade. Clearly, each building requires different elements in order to be upgraded, causing the cost of each building to range widely.[105]

Saint Bernard Hall, Saint Patrick Hall, Saint Thomas Aquinas Hall, Saint Boniface Hall, and Saint Mary Hall need the control systems to be upgraded as well the delivery system for each individual room. SJU has had discussions regarding how best to proceed with this major upgrade project. These discussions included deciding how much the school wants to do in within these buildings, as well as establishing a budget for these projects. [106]

Another issue connected to the use of the SJU heating and cooling system involves the issue of nightly setback. Currently, some buildings are being set back at night while others are not. Numerous individuals complained that the buildings became too cool at night and thus they could not work comfortably. In order to save energy as well as use the technology appropriately a campus wide plan to enforce a nightly setback would also be beneficial in the effort to conserve energy.[107]

**Potential Benefits**

The potential benefits of upgrading SJU's energy system would be an overall reduction in the amount of energy used as well the reduced cost associated with heating and cooling the campus. The amount of information concerning specific energy use is limited on the SJU campus because not all buildings are metered.

**Costs**

The costs to upgrade Saint Bernard Hall, Saint Patrick Hall, Saint Thomas Aquinas Hall, Saint Boniface Hall, and Saint Mary Hall would be $3,000 per room for heat and air conditioning. There are a total of 423 residences between these five buildings. Therefore the total cost would be $1,269,000.[108] The cost of renovations for each academic building would depend on what needed to be done, as well as the size of the building, but a general estimate is $30,000 to $90,000.[109]

**Other Schools**

There are no concrete examples of schools that have upgraded their heating and cooling systems. Many schools, however, are following the United States Green Building Council's **Leadership in Energy and Environmental Design** (LEED) Standards for new construction as well as for renovation projects. These standards are guidelines by which communities can decide to build environmentally friendly structures.[110] Numerous schools have decided that it is important to attain LEED certification when adding onto their campuses. For example, Emory University in Atlanta, Georgia is constructing three new academic buildings with the goal of obtaining LEED Certification. The Math and Science Center alone has reduced its energy by 18% through the incorporation of new technology for its heating, ventilation and air conditioning system.[111] Other colleges and universities are also finding the importance of green building, including reducing energy use and finding better ways to heat and cool buildings.

**Projected Savings**

The projected savings are hard to calculate because of the lack of metering at SJU. The Art Building, however, has a projected energy savings of 35,082 kWh, which saves approximately $2,400 per year. This is only one example of energy and cost savings on the SJU campus. By upgrading several buildings on the SJU campus the amount of energy saved as well as cost savings will only increase.

**Priority**

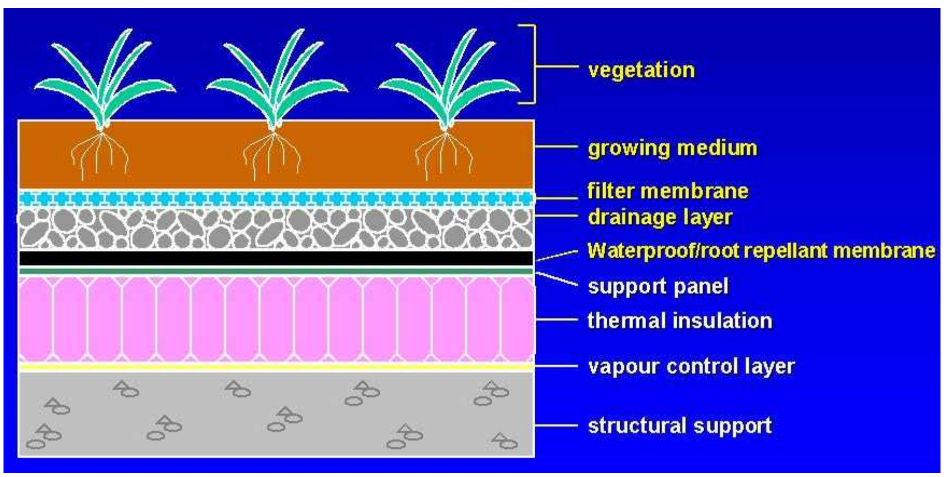
The foundation for increased energy savings in regards to heating and cooling is in place at Saint John's University, but more action needs to happen in order to ensure that successful results will occur. The first priority is to use the system SJU already has and enforce a nightly setback policy in which the temperature will be decreased after a certain designated time in the buildings that are digitally monitored. The next step is to carefully look at the remaining buildings and determine what needs to be done as well as the cost for each building. SJU should receive bids for each building, including an estimate for energy savings. In this way SJU can determine which buildings would be most cost effective to upgrade first and which ones can be postponed until a future date. In this way a general renovation plan could be created in order to assure that all buildings will eventually receive the upgraded equipment they need.

## Green Roofs

### Application

Creating **green roofs** on the buildings of CSB/SJU is a unique concept to consider. Green roofs transform the traditional roof into a garden in which people can enjoy being outside. "Green roofs, also called 'vegetated roof covers' or 'eco-roofs,' are thin layers of living plants that are installed on top of conventional roofs. Properly designed, they are stable, living ecosystems that replicate many of the processes found in nature."[112] The main benefits of green roofs include decreased energy requirements for heating and cooling, as well as extending the average lifespan of the roof.[113] Educational opportunities also need to be considered when creating a green roof as monitors can be placed on the roof and information can be gathered and compared to other buildings that are similar in size in order to see the benefits.

**Example of a Typical Green Roof**[114]




### Campus Context

Green roofs are a feasible option for either the CSB or SJU campus because there are numerous flat roofs that make designing a green roof easy. There are two types of green roofs: "**Intensive green roofs** require a minimum of one foot of soil depth to create a more traditional rooftop garden, with large trees, shrubs and other manicured landscapes. They are multi-layer constructions with elaborate irrigation and drainage systems. Intensive green roofs add considerable load to a structure and require intensive maintenance. In contrast, **extensive green roofs** range from as little as 1 to 5 inches in soil depth, adding less load to a building. Extensive green roof systems also generally require less maintenance than intensive systems. Some green roof designs incorporate both intensive and extensive elements."[115] Most likely, extensive green roofs would be more beneficial and easier to implement at CSB/SJU because they add less load to a building and require less maintenance. Green roofs can decrease the amount of energy used for heating and cooling thus the cost of heating and cooling specific buildings at CSB/SJU could be decreased. Green roofs provide an opportunity for educational research possibilities. Demonstrating the benefits of green roofs on campus can generate more support for additional green roofs.

**Detailed Proposal**

The first step is to figure out the slope of the roof, as well as how much weight a roof can handle. A structural engineer will need to provide this data because green roofs need to be planned around this requirement. The roof needs to be designed in regards to climate, amount of rainfall etcetera. A rough estimate of cost could be then established and discussed.[116] One could take any building on either campus and design a garden that would be a feasible option for implementation. The City of Chicago Department of Planning and Development states that a green roof, " …can reduce heating and cooling requirements by as much as 20 to 30 percent for a one story structure."[117] The potential for reductions in heating and cooling can be quite substantial if green roofs were to be used on numerous buildings.

**Potential Benefits**

The most important benefit of creating a green roof on campus is the possibility of reducing the cost of heating and cooling buildings on both campuses. Additionally, the life span of a green roof is twice as long as a standard roof. By using a green roof for educational purposes the students benefit as much as the schools benefit by saving money. Green roofs also control storm water runoff, as well as improve water and air quality, reduce noise pollution, create wildlife habitat, and in general improves the aesthetic environment of the surrounding area.[118]

**Costs**

The cost of a green roof depends on a number of variables. "Cost per square foot depends on many factors: the size and slope of the roof, depth and complexity of the system, height and accessibility from the ground, cost of labor, and need for specialized elements, such as drains, railings, pavers, slope stabilization measures, etc."[119] Upon determining which building would benefit from a green roof a detailed estimate could then be produced. In general, "An installed extensive green roof with root repellant/waterproof membranes and irrigation may be installed for $12-$24 US per square foot." [120] Furthermore, in the article, "Design Guidelines for Green Roofs", a chart outlines the potential costs for an extensive green roof. This chart, seen below, outlines the potential costs for a green roof, while also raising concerns and other issues to consider in the planning stages.

| | Component | Cost | Notes & Variables |
|---|---|---|---|
| a) | Design & Specifications | 5% - 10% of total roofing project cost. | The number and type of consultants required depends on the size and complexity of the project. |
| b) | Project Administration & Site Review | 2.5% - 5% of total roofing project cost. | The number and type of consultants required depends on the size and complexity of the project. |
| c) | Re-roofing with root-repelling membrane | $100.00 - $160.00 per sm. ($10.00 - $15.00 per sf.) | Cost factors include type of existing roofing to be removed, type of new roofing system to be installed, ease of roof access, and nature of flashing required. |
| d) | Green Roof System (curbing, drainage layer, filter cloth, and growing medium). | $55.00 - $110.00 per sm. ($5.00 - $10.00 per sf.) | Cost factors include type and depth of growing medium, type of curbing, and size of project. |
| e) | Plants | $11.00 - $32.00 per sm. ($1.00 - $3.00 per sf.) | Cost factors include time of year, type of plant, and size of plant - seed, plug, or pot. |
| f) | Installation / Labour | $32.00 - $86.00 per sm ($3.00 - $8.00 per sf.) | Cost factors include equipment rental to move materials to and on the roof (rental of a crane could cost as much as $4,000.00 per day), size of project, complexity of design, and planting techniques used. |
| g) | Maintenance | $13.00 - $21.00 per sm ($1.25 - $2.00 per sf) for the first 2 years only. | Costs factors include size of project, timing of installation, irrigation system, and size and type of plants used. |
| h) | Irrigation System | $21.00 - $43.00 per sm. ($2.00 - $4.00 per sf). | *Optional, since the roof could be watered by hand. Cost factors include type of system used. |

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**Schools**

Carnegie Mellon University in Pennsylvania is currently installing three Living Roofs, another term for a green roof. These roofs are being placed on Posner Gallery, Hammerschlag Hall and Doherty Hall.  The Hammerschlag Hall Living Roof was installed with the help of a grant from the Pennsylvania Environmental Protection Agency. The three main benefits of the roof are the ability to combat urban heat island effect, reducing runoff, and helping to prevent sewage overflows as well as adding extra insulation of plants and soil to help reduce energy spent for heating and cooling. Sensors will monitor the benefits of the roof and hopefully more Living Roofs will be created on their campus in the future.[122]

**Priority**

The possibility of designing a green roof for a building on the CSB/SJU campus is a feasible option that can be explored as a future alternative for energy savings. Another important aspect to consider when looking into designing a green roof is to consider the possibility of the educational benefits that could come from initiating this project.

## Indoor Lighting

### Overview

There are currently three major options for indoor lighting at the College of Saint Benedict and Saint John's University: incandescent, fluorescent and solid-state lighting (SSL). Incandescent lamps are by far the most inefficient, using ninety percent of supplied electricity for heat and only ten percent for the production of light[123]. Fluorescent lamps have become more efficient in recent years due to the conversion of ballasts from magnetic to electronic, and current fluorescent lamps and compact fluorescent lamps offer some of the best efficient lighting options for their cost. SSL technology promises to be the most efficient lighting for the future, although more research and development is needed to make it cost competitive with other sources of artificial light. SSL consists of light emitting diodes (LED) and organic light emitting diodes (OLED). While LED technology has replaced incandescent and fluorescent lamps for indicator lights (such as Exit signs) at both campuses, it is not being used to light large areas or replace fluorescent lamps at this time. Currently, both campuses rely mainly on fluorescent lamps (T12 and T8) for indoor lighting.

### Campus Context - CSB

In 1996, all the ballasts at CSB were replaced and are now electronic. With a rebate from Xcel Energy, the total cost of replacement was $150,000 and the payback for that project was under two years. CSB uses 4-foot 32 watt T8 lamps in offices, study lounges, dorm rooms and classrooms. Other lamps include lower wattage T8, 30 watt T12 lamps, compact fluorescents in chandelier fixtures, and incandescent lamps in maintenance rooms and some apartments. CSB has attempted to install the most efficient fluorescent lamps throughout campus, and its computerized energy monitor can regulate lighting in buildings such as the Haehn Campus Center and Clemens Library. Ninety to ninety-five percent of campus lighting is considered energy efficient, and seventy percent of the lamps are purchased from General Electric. Motion sensors have been installed in areas such as bathrooms, office spaces, and laundry rooms. CSB has replaced nearly all the former T12 fluorescent lamps with T8 lamps, which are up to thirty percent more efficient. A computerized schedule controls down lighting when buildings are not being used, and the types of lamps installed in each building are carefully documented. Ninety percent of the Exit sign lighting is LED, and recent lighting renovations in Claire Lynch Field

House have allowed for varying levels of light to be used depending on game and practice schedules. All of the lamps at CSB are recycled due to the mercury content.

**Campus Context - SJU**

SJU installed 6,000 electronic ballasts throughout campus in 1987. Currently, about half of the fluorescent lamps installed are T12 and the other half are T8. SJU receives rebates from Xcel Energy for the use of T-8 lamps with electronic ballasts, and up until January 1, 2005, the campus received a rebate for the installation of compact fluorescent lamps. Tommy Hall and the Refectory each contain compact fluorescent lamps, and the rest of campus utilizes a combination of T12 and T8. The only area monitored by a computer is the Palestra, and by controlling the use of light in the basketball court SJU saves $13,000 each year. Motion detectors are installed throughout two-thirds of the Quad. Although SJU purchases both types of fluorescent lamps, detailed records are not kept as to the specific technology used in each building.

**Proposal**

When T8 lamps were developed they were thirty percent more efficient than T12 lamps and were easy to install because they fit into the same medium bi-pin base. T8 lamps are currently cost competitive with T12 lamps, and it makes sense to replace T12 lamps with T8. In the last ten years, a T5 lamp has been developed which is forty-five times more efficient that T12 lamps[124]. Compared to the larger T8 or T12 lamps, T5 lamps save material. The reduced surface area allows manufacturers to use nearly 60% less glass and phosphor material when manufacturing T5 lamps as compared to T12 lamps. Manufacturers claim that a T5 lamp requires 38% less glass than a T8 lamp[125]. In addition, moving from T12 to T5 lamps can reduce packaging materials by up to 50%. However, the T5 lamp requires a new base, thereby dramatically increasing the cost of retrofitting a building to utilize T5 lamps. Although they are more efficient, a prolonged life T8 lamp actually can last 4,000-10,000 hours longer than a new T5 lamp. General Electric has developed a T8 lamp called the Ecolux XL: it lasts twenty percent longer than standard T8 lamps (approximately one year longer), uses less mercury (which lowers replacement and disposal costs) and is listed as saving $163.50 versus a standard T8[126]. While T5 fluorescent lamps use less energy once installed, the process of installation requires a lot of time and money. While T5 lamps require less material, the prolonged life of a T8 lamp does not require as many lamps to be purchased in the first place. The installation of new bases is also not required when T8 lamps are used.

The future of solid-state lighting looks very promising. Although LED technology is currently only being used for indicator lights (signs or street lights) and small scale lighting (flashlights), fixtures for large area lighting are also being developed. OLED technology is currently being used for things such as cell phones, but eventually it should be able to light entire buildings. Rather than using a single lamp to light a room, an entire wall or ceiling will illuminate. LED and OLED lighting can be developed in any color and are ninety percent more efficient than fluorescent or neon lights of similar strength. Currently, the prices and technology of LED and OLED technology do not make them a feasible option for lighting at Saint Ben's and Saint John's. A T8 lamp is rated at 83 lumens per watt and LED is rated at 30 lumens per watt. While a standard T8 costs $0.73 per 1000 lumens, LED costs $190.00 per 1000 lumens.

Rather than retrofit both campuses to accommodate T5 technology, the best idea is to purchase prolonged life T8 lamps. In the next ten years, the technology for LED and OLED is expected to improve and become more cost competitive, and it is recommended that the campuses investigate energy efficient alternatives to our current use of fluorescents. In the meantime, all incandescent bulbs should be replaced with compact fluorescent bulbs because the color rendering index (CRI) for compact fluorescents is now comparable to incandescent light. Compact fluorescent bulbs are four times more efficient and last ten times as long: that combination reduces both materials purchased and time spent replacing old lights. A 28 watt compact fluorescent bulb will cost $30 over its lifetime (including the price of the bulb plus energy purchased to power it) and a 100 watt incandescent bulb would end up costing $100 for the same amount of time.

The first priority for dual campus lighting efficiency is to replace the current T12 lamps used at Saint John's with more efficient T8 lamps. T8 lamps at both campuses should be prolonged life, and if possible, eco designs which minimize mercury. Although Saint Ben's has monitored control over many of its buildings, Saint John's could improve its efficiency and save more money by monitoring the use of lights in buildings after hours. New motion detectors, which cover a 36 x 72 area should be installed in all classrooms, offices, corridors and public spaces (each monitor runs about $50-$75 to purchase and $50 to install). The potential rebates from Xcel should be investigated.

## Other Schools

Schools around the nation are working to increase lighting efficiency in an effort to reduce energy consumption and save money. With rebates from energy companies, many new technologies pay for themselves between two and four years. In fact, most schools won't implement a new technology unless it has a payback time under four years. The University of Michigan and Brown University both participated in the EPA's Green Lights Program. By replacing T12 lamps with T8 lamps and installing compact s in place of incandescent lamps, both schools saw over a fifty percent energy savings.[127]

## Outdoor Lighting

**Campus Context – CSB**

The College of St. Benedict uses outdoor lighting, in parking lots and walkways, every night from sunset to sun rise. The outdoor lights are controlled by two systems: an "**outside eye**" and an annual calendar. The single "outside eye" is an optical sensor that detects the amount of daylight available at a given time.[128] This sensor relays information back to the control console and designates whether there is a need for light outside. The second control is a daylight schedule programmed into the computer. This calendar has estimated times of sunrises and sunsets so the lights turn on in the absence of sunlight. The system is designed to turn on in two conditions: the optical eye senses darkness and the time of day falls between the scheduled hours of darkness. In the past (before this system), the optical eye would sense brightness during a flash of lighting, or darkness during a heavily overcast day. Now, the lights are systematically controlled so the lights are not on when unnecessary and are not off when necessary.

Outdoor lighting requires a type of light classified as **high intensity discharge**. The type of lighting used at CSB is a type of high intensity discharge known as metal halide. **Metal Halide** emits a very white light (as opposed to yellow) and has an average life expectancy of 6,000 to 20,000 hours of use.[129] It is the third most efficient form of high intensity discharge lighting available.

There are three types of outdoor lights at CSB: parking lot lights, walkway lights, and security lights. There are 85 parking lot light fixtures running at 250 watts a piece. Walkways are lit by a total of 198 fixtures running at 175 watts. Security lights outside of buildings vary: 15 fixtures at 250 watts, 17 fixtures at 175 watts and 80 fixtures (at door entrances) at 75 watts. Most bulbs are purchased from General Electric.

The combination of each of these fixtures running creates an enormous amount of energy consumption. Outdoor lighting for one hour alone consumes about 68.625 kilowatts. With an average running time of 12 hours a day, outdoor lighting will consume about 840 kW hours per day and 306,600 kW hours per year. CSB purchases power from Xcel Energy at about .44 cents per kW hour. This comes to a total of about $13,500 per year for energy alone.

**Campus Context – SJU**

The outdoor lighting at St. John's University is controlled, similarly, by use of an annual calendar that has scheduled times for sunrise and sunset.[130] The lights used are also high intensity discharge, but the types and wattages are slightly more variable than at CSB.

St. John's uses almost entirely **high pressure sodium (HPS)** bulbs. These bulbs are the second most efficient high intensity discharge bulbs readily available. HPS is second only low intensity discharged which is a "monochrome" output that is aesthetically unpleasing (yellow-orange) and difficult to see under.[131] Wattages for theses HPS bulbs are typically either 75 or 150 watts. There are scattered outdoor uses for incandescent and mercury bulbs, but HPS is far more prevalent. There are 423 total outdoor lights accounted for on the SJU campus (including walkways, parking lots, emergency phones, building lights…etc

The total wattage, including the variable bulbs, is 73.95 kW per hour. This is about 890kWh per day or 32,3901kWh per year. Energy for SJU not produced at the coal plant is purchased from Xcel energy at .044 cents per kWh. This ends up with a final outdoor light energy bill of $14,251.

**Proposal- Switch CSB parking lot bulbs to HPS (High Pressure Sodium)**

One method that could improve energy efficiency is changing all light bulbs to high pressure sodium bulbs. High pressure sodium (HPS) bulbs are another type of high intensity discharge lights that are typically more efficient. These bulbs are used in almost all fixtures at St. John's University, but have been used very sparingly at CSB.

There are several reasons that CSB has not converted to high-pressure sodium bulbs. First, the CSB design committee decided that the appearance of metal halide bulbs is more aesthetically pleasing. Second, though not necessarily brighter, the light output from metal halide bulbs is considered to provide better visibility from color output. On an all-female campus, visibility on walkways at night is crucial for security purposes. Third, switching all lights over to high density sulfur bulbs would require replacement of current **ballasts**. This project would ultimately cost over $50,000 with savings coming only after over a decade.

While switching the entire campus over to high density sulfur is somewhat impractical (for aesthetic, security and financial reasons), there are parts of campus that could be feasible. The strongest bulbs are used in parking lots. The concern of security and aesthetics in these areas seems minor (the two primary reasons metal halide is the bulb of choice). The metal halide bulbs, currently in place in CSB's parking lots, have an average light output of 13,000 **lumen**. By placing HPS bulbs into these parking lots, wattage per bulb could be lowered by 100 watts while still increasing the lumen output to 13,500.[132]

New Mexico Tech School underwent a similar project in 2001.[133] The school decided that switching to HPS bulbs could "deliver improved safety and security and lower electrical bills at the university, as well as darker nighttime skies above it." Research associate and professor Dr. Dan Klinglesmith III of New Mexico Tech agreed, "It's really in the best interest of everybody involved - citizens, astronomers, city and county governments - to get the correct types of outdoor lighting installed. When you do it correctly, everyone wins: you can increase security, save money, and keep the astronomers happy all at the same time."

**Costs**

**Estimated Cost:**

| | |
|---|---|
| 85 ballasts | $11,900.00 |
| 85 hours of Installation | $ 1,275.00 |
| Total | $13,175.00 |

Costs would be primarily based in the changing of ballasts to make the fixture compatible with high-density sulfur bulbs. The approximated installation fee is $15 per fixture. This data is based on estimates from a similar project at University of Oregon along with estimates from St. John's University electrician Gary Jorgenson. The other potential costs to this alteration, though not monetary, are potential diminishment of parking lot security and/or aesthetic satisfaction (though both somewhat subjective).

**Potential Benefits**

By replacing parking lot bulbs and ballasts to HPS bulbs, savings in wattage per year would be approximately 37,230 kWh per year. This would be an annual savings of $1,638. When balanced against the initial cost, the payback time would be around seven years. Beyond these seven years; however, the school would be saving money. In addition, the life expectancy of HPS bulbs is about four times longer than metal halide bulbs, while prices are equivalent.

From an environmental perspective, the decrease in 37,230 kWh of energy saved per year is a drastic decrease in greenhouse gas emission associated with electrical generation. Decreasing the energy consumption would reduce carbon dioxide emissions by approximately 74,460lbs per year

**Use ½ of the walkway lights after 2:00am on weekdays for both campuses**

Several years ago, in an attempt to cut energy consumption on campus, Gary Jorgenson reduced lighting after 2:00am surrounding the Art building and the south side of Mary hall. He specially wired every other walkway post to switch off after 2:00 am. The results were a moderate success. Both Gary Jorgenson (campus electrician) and Shawn Vierzba (campus security) acknowledged that the ½ light in both areas was sufficient to travel safely and securely, though not the desired amount of light during heavy traffic times.[134]

In the winter of 2002; however, a group consisting of Jorgenson, Vierzba, several other employees and students along with some off campus visitors (both male and female) walked the campus at night to assess the safety of the current lighting system. The group decided, for security reasons, that more light is typically better. The half-light practice is no longer used on any part of campus for security and visibility reasons.

It seems, however, that on weekdays the number of people outside on campus after 1:00am is very minute. If, in fact, the ½ light practices provide sufficient illumination for those who walk by, be it seldom, full light is not necessary.

**Costs**

| | CSB | SJU |
|---|---|---|
| # of walkway fixtures | 198 | 306 |
| Costs | $2970 | $4590 |

Costs for this proposal alteration would be insignificant. It is estimated that each light would need to be re-wired costing approximately $15 per fixture. With 198 walkway fixtures at CSB the cost would be $2970. With 306 walkway fixtures at SJU the cost would be $4590. Additional considerations would be the potential diminishment of security and visibility on campus after 1:00am and before sunrise.

**Potential Benefits**

| | C<br>SB | S<br>JU |
|---|---|---|
| # of walkway<br>fixtures | 19<br>8 | 3<br>06 |
| Watts per fixture | 17<br>5 | 1<br>50 |
| Total Watts | 34<br>650 | 4<br>5900 |
| Total Watts Saved | 17<br>325 | 2<br>2950 |
| Hours at 1/2 light | 5 | 5 |
| **Total kWh<br>saved/year** | 31<br>618.125 | 4<br>1883.75 |
| **Money Saved** | 13<br>91.1975 | 1<br>842.885 |

The drastic decrease in energy consumption after 1:00am could lead to drastic savings in overall energy bills. If the ½ light practice were used an average of 5 hours a night, the payback time for the initial investment would be 2.5 years at SJU and only 2.1 years at CSB. From an environmental perspective, this energy consumption decrease would prevent the emission of 147,002lbs of carbon dioxide every year.

According to Gary Jorgenson, the design committee at St. John's prefers an absence of light on campus. The decrease of static light and **light pollution** on campus could make the campus look more appealing after hours.

Several years ago, St. John's used globe lights that had no reflective surface to prevent the light from escaping into the sky. Not only was this extremely wasteful from an energy standpoint, but it also unintentionally hindered astronomy on campus. There were complaints from the observatory that the excessive light pollution aimed upwards made the expensive telescopes virtually inoperable. The lights were soon changed to the downward facing fixtures currently present, but light pollution after hours is still present. By decreasing light pollution on campus using the ½ lighting technique, astronomers could make better use of the telescopes in the observatory.

### Use Photovoltaic lighting whenever a fixture is replaced or added

Another method of decreasing energy consumption on campus would be to alter the source of energy for lighting. **Photovoltaic** outdoor lights act in the same way as the walkway and parking lot lights we currently use, except that theses lights are wired separately from the energy grid and are powered by the sun. (For more information on solar power, see the solar power generation section)

A similar project was completed in October of 2004 at Eastern Connecticut University. [135] The university installed an outdoor light at one of the campus bus stops as well as two dormitory security lights supplied by SolarOne™ Solutions.[136] SolarOne a unique combination of LED lights uses a lighting controller and solar power to reduce cost to the consumer and provide reliable light throughout the night.

### Cost

According to companies such as Solar Outdoor Lighting Inc. and Solar One Solutions, the cost of solar outdoor lighting fixtures is generally comparable to a typical outdoor lighting fixture.[137] In many circumstances, when the fixture is in a location where electrical wiring is not installed or where electrical modifications would be difficult, solar lighting can be substantially less expensive. One potential cost is the loss of energy to power the fixture after an extended dark period, however that is atypical.

### Potential Benefits

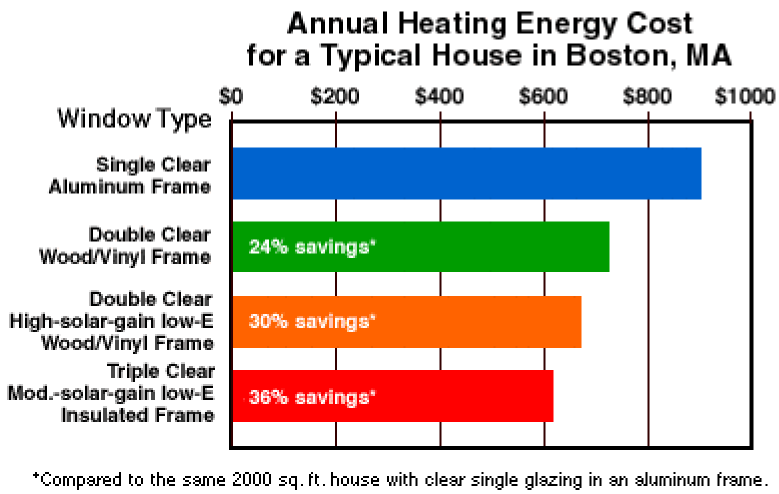
First, the school would not need to purchase any energy to power the lights. This would decrease energy bills as well as the toll of energy consumption on the environment. Second, the light fixtures can be completely separate from the energy grid. This would eliminate the need for the potential expensive wiring and connection. Third, the presence of photovoltaic cells on campus could not only serve as an educational tool but also demonstrate the schools commitment to environmental issues and alternative energy use.

For every campus light that uses photovoltaic cells instead of the energy grid, a substantial amount of energy and money can be saved. Parking Lot lights at CSB using solar could save 1095 kWh per fixture, equivalent to $50 per fixture every year. Walkway lights at CSB would save 766 kWh per year and $33 annually per fixture. SJU would save 1095 kWh ($48.18) per fixture annually for parking lots and 657 kWh ($28.9) annually.

## Windows

### Application

"In 1990 alone, the energy used to offset unwanted heat losses and gains through windows in residential and commercial buildings cost the United States $20 billion (one-fourth of all the energy used for space heating and cooling)."[138] Current options for windows have an immense impact in reducing unwanted heat loss and gain. By replacing old, inefficient windows with newer, better developed options, individuals can save money as well as maintain a more comfortable living environment.




A window's energy efficiency is measured by its U or R values. A **U value** measures the rate of heat transfer through the window. An **R value** is simply the reciprocal of the U-rating; measuring resistance to heat flow. Lower U-values indicate greater resistance to heat flow while higher R-factor means that the window has a higher insulating value.

**Solar Heat Gain Coefficient** (SHGC) is the fraction of incident solar radiation admitted through a window. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat transmitted.

The **visible transmittance** (VT) is an optical property that indicates the amount of visible light transmitted. While VT theoretically varies between 0 and 1, most values are between 0.3 and 0.8. The higher the VT, the more light is transmitted. A high VT is desirable to maximize daylight.

**Air Leakage** (AL) is heat loss and gain which occur by infiltration through cracks in the window assembly. Air leakage is expressed in cubic feet of air passing through a square foot of window area. The lower the AL, the less air will pass through cracks in the assembly.

**Recommended Properties in the Northern Zone (mostly heating)**

| U-factor | Solar Heat Gain Coefficient (SHGC) | Visible Transmittance (VT) | Air Leakage (AL) |
|---|---|---|---|
| Windows: U≤0.35<br>Skylights: U≤0.60*<br><br>Note: If air conditioning loads are minimal, windows with U-factors as high as 0.40 are also energy-efficient if the Solar Heat Gain Coefficient is 0.50 or higher. | No requirement.<br><br>Note: To reduce heating, select the highest SHGC you can find (usually 0.30-0.60 for the U-factor ranges required in colder climates) so that winter solar gains can offset a portion of the heating energy need. If cooling is a significant concern, select windows with a SHGC less than 0.55. Select skylights with a SHGC of 0.55 or less. | No requirement.<br><br>Note: Select windows with a higher VT to maximize daylight and view. | No requirement.<br><br>Note: Select windows with an AL of 0.30 or less. |

The R-value of a window is impacted by five factors; the type of glazing material, the number of layers of glass, the size of the air space between the layers of glass, the thermal resistance or conductance of the frame and spacer materials, and the presence of air leaks around the frame.[139]

The type of material available for window panes in homes has changed in recent years, introducing several types of special **glazings**, glass used for windows, that help control heat loss and condensation. **Low-emissivity** (low-e) glass has a special surface of metallic coatings which reflect infrared heat radiation back into a room while allowing the full amount of visible light to pass through.[140] This effectively diminishes heat transfer out through the window in winter; reflecting from 40% to 70% of the heat that is normally transmitted through clear glass.[141]

**Heat-absorbing**, or tinted, glass contains special tints that cause the window to absorb as much as 45% of the incoming solar energy; reducing heat gain in the interior space. Unfortunately some of the absorbed heat will pass through the window via conduction and increase the window's U-factor.[142]

Increasing the number of glass panes in a window unit increases its ability to resist heat flow, because the multiple layers of glass create pockets of air which act as an insulator. Single paned glass is the most common glazing material for windows, but it is also the most inefficient with an R-value of 1. Double or triple pane windows have the spaces between each pane filled with air or gas. The gasses used include argon and krypton, because they conduct heat at a reduced rate compared to atmospheric air. Even though the addition of panes of glass provides better insulation and decreases thermal losses, it increases the cost as well as the weight of the window; which can limit framing options.[143]

Proper spacing of glass panes is also important in window construction; the air space present between panes has a big effect on energy performance. Panes should be spaced between 1.3 and 1.6 centimeters apart.[144] Distances that are too wide or too narrow result in decreased R-values and allow too much heat transfer. The materials used to create the space between window panes also impacts heat transfer. Metal is most often used although it is very inefficient because it conducts heat. Instead brands using foam or nylon separators are best because they reduce both heat loss and condensation.[145]

Framing materials also influence the R-values of windows. Aluminum is strong and light, but has a high thermal conductivity which can lead to low R values for the window as well as condensation problems. The condensation can result in corrosion if the window is not anodized or coated to avoid this problem.[146] Thermal losses through the frame can be reduced by purchasing frames with a layer of insulation between the inner and outer frames.

Wood is another common type of framing material. While it has the highest R-value of all framing materials it requires the most maintenance including painting or staining on a 5 year basis. Rotting and warping can also be major problems if the window is exposed to constant moisture and is not taken care of properly.

Vinyl is another framing material option which has moderate R-values and is virtually maintenance free. Vinyl framing can be easily customized, are competitively priced and, while not as strong as wood, can be reinforced with steel bars. Unfortunately the production of Vinyl is toxic to the environment and to workers who manufacture the window frames.

Fiberglass frames are relatively new and are not as widely available as the other options; making them relatively expensive to purchase. However fiberglass frames will not warp, shrink, swell, rot, or corrode and they boast some of the highest R-values.

Window treatments can be used on older windows to help reduce heat loss or they can be used in conjunction with new windows to further improve thermal efficiency. Window treatments offer the benefits of increased insulation values, aesthetics, and flexibility to the user. Blinds, shades and drapes can be opened on sunny days in winter to take advantage of solar gain and then closed at night to increase the R-value of the window and reduce heat loss. Awnings, shades and shutters can also be used on the exterior of buildings to keep out the summer heat. Some R-values for typical materials used in blinds and drapes are shown in the figure below. [147]

| | **R-value** |
|---|---|
| Foylon | R = 2.02 |
| Fiberfill, 1 layer | R = 2.5 |
| Fiberfill, 2 layers | R = 4.0 |
| Fiberfill, 3 layers | R = 5.5 |
| Window fleece | R = 4.0 |
| Hollofil | R = 2/inch thickness |
| Polar Guard | R = 3.5/inch |
| Thinsulate | R = 4 per 3/4 inch |
| Warm Window | R = 7.5 + (includes single glazing) |
| Window Quilt | R = 4.25 (includes single glazing) |
| Window Comforter | R = 5.0 + (includes single glazing) |
| Texolite® | R = 7.0 + (includes single glazing) |

## Campus Context

There are currently four buildings on the campus of Saint John's University with single paned windows; they include: St. Patrick, St. Boniface, and St. Bernard residence halls located on upper campus which house mainly sophomore students. Such standard single-pane glass windows have very little insulating value (approximately R-1). It provides only a thin barrier to the outside and can account for considerable heat loss and gain.

Traditionally, the approach to improve a window's energy efficiency has been to increase the number of glass panes in the unit, because multiple layers of glass increase the window's ability to resist heat flow. The windows in these buildings were checked in 1985 when the Department of Energy offered a 50 cent on the dollar rebate for energy efficiency upgrades. The University underwent most of the upgrades with a payback period of seven years or less. Upon testing the windows in these buildings in 1991, they found that the glass in these windows was so thick that the windows matched or exceeded most of the newer efficient windows of that time.[148]

In 1998, the New Science center was constructed. Peter Engel Science Center was renovated in 1999. The windows in this building were tested for thermal efficiency at this time. These windows also had such thick panes of glass that replacement was deemed unnecessary. The Quad underwent a renovation in 2001 that included window upgrades so now all windows in the quad are double paned.

Saint John's University currently employs a monitoring system to ensure that their windows are efficient. Currently, the University will be conducting tests on windows in St. Placid/St. Maur buildings. The buildings were constructed as recently as 2001, but the windows may not be performing up to manufacturers specifications. There is a noticeable draft of cold air coming from the bottom side of the windows in the winter.

## Detailed Proposal

The colleges should maintain their system of monitoring the efficiency of the windows and working to upgrade the units that are currently installed. They should also re-evaluate the decision not to replace the windows of Peter Engel science center because 6 years have elapsed since the last evaluation and there may be much more efficient windows on the market. The addition of thermal rated shades/blinds to the interior of any older windows should also be considered if the thermal efficiency of the window is very poor and upgrades are not readily possible.

**Benefits/costs**

The major benefit of replacing windows in any building is the reduction in heat loss the building experiences. By minimizing building heat loss, internal temperature can more effortlessly be maintained and the heating system does not need to be utilized as often; extending the heating system's lifetime. The addition of thermal blinds, drapes and shades would also reduce the heat loss experienced by buildings.

**Priority:**

The monitoring programs are something that both campuses should utilize; it seems to be very effective. The replacement of windows in Peter Engel is probably a project that should be done in the future, but is not necessary at this time. The windows have been tested and are acceptable. Labor and downtime costs of window removal and replacement probably make this option infeasible.

## Insulation

### Application

Insulation is a very important component to maintaining the thermal efficiency of a building. Insulation is designed to resist heat flow, which naturally flows from a warmer location to a cooler one. When the environmental temperatures are high, the hot air from the outside wants to enter and heat up a cool, air conditioned building. The insulation acts as a barrier to reduce the amount of heat traveling into the building and also limits the work the air conditioner must do in order to maintain the building temperature. Insulation also keeps the heat, produced by the heating system, inside and prevents the heating system from working overtime to heat a building. When insulation is sufficient and at recommended levels fluctuations in the building's internal temperature are not drastic. As a result, less energy is used for heating in the winter and cooling in the summer.[149]

Insulation is rated by its **R-value**, its resistance to heat flow. The higher the R-value, the greater the insulator material. The R-value is dependent on several factors including the type of material, its thickness, and density.

The most common form of insulation that is used today are blankets in the form of **batts** or rolls. This variety is generally fitted between joist and stud spaces and ranges in widths from 15 to 23 inches and lengths of 4 to 8 feet. This insulation is generally made from **fiberglass fibers** but can also be made from: **mineral** or **rock wool**, **cotton**, which is made primarily from scraps of blue-jeans that have been collected from factories, and **wool**.[150] The R-values per inch of insulation batts are 3.14.[151]

**Loose-fill** is an insulation product that is comprised of small particles, which are blown into place and form a fluffy insulating material that conforms to the spaces in which they are installed. The process of installing this insulation requires special equipment in order to blow it in place. This material can be used to fill in the cavities of already finished walls, floors, and attics; providing more complete coverage in difficult to reach places.

There are three primary types of Loose-fill insulation; rock wool, fiberglass fiber, and **cellulose fiber**, all of which are considered to be "environmentally positive" because they utilize recycled waste materials in their production.[152] Cellulose loose-fill insulation is comprised of recycled newspaper which has been treated with chemicals so that it is fire retardant and requires less energy to produce than other types of insulation.[153] Fiberglass loose-fill are fibers spun from molten glass that has a 20 to 30% recycled glass content. Rock wool is similar to fiberglass except that it is spun from the scum that forms on the surface of molten metal; a by-product that would be otherwise wasted.[154] Blown-in products have R-values that range from 2.20 to 3.13 per inch and are blown in, in any depth in order to meet the recommended R-values.[155]

**Rigid foam** is a board insulation which comes as panels of insulation made of molded or extruded polystyrene or polyurethane. Both of these materials have high R-values ranging from 4 to 6.25 per inch; however the materials are combustible and must be covered with drywall to prevent a fire hazard.[156]

Insulation is installed in many areas of the home, including the walls, ceiling, floors and basement; unfortunately it is often difficult to add additional insulation into already existing locations. Different locations of a building have different recommended R-values.

### Campus Context

Insulating attic spaces is the wisest place to look at adding insulation because it will provide that biggest savings in money and energy and its installation does not require a professional. The first step in this process would be to re-evaluate current attic insulation in campus buildings and determine which need additional insulation.

The next step is to add insulation to the desired R-value. An R-value of 49 is recommended for the attic space in this area of the country and can be most easily achieved through the use of blown-in insulation, which can be added to any depth. Batt insulation is another option, which can be laid in layers throughout the attic to attain a desired R-value.[157] The basement is another common location requiring improved insulation. Air leaks are frequently found along the top of the basement wall where the cement or block comes in contact with the wood frame, which provide ideal locations for heat to escape.

### Potential Benefits

The main benefit to insulating a building is that with the proper insulation temperatures throughout the building are maintained and as a result the structure does not gain or lose heat as quickly. This allows buildings to stay warmer in winter and cooler in the summer. Consequently the operating cost of the heating and cooling systems are reduced because there is not as much demand placed on them. By reducing the pressure on these systems, the lives of the systems can be extended.

### Costs

The costs for this project are incurred from the insulation material, caulk or foam, and labor costs. The materials are generally higher in price as the R-value increases. The average loose-fill insulating cost, for materials only, per R-value per square foot was about 0.8 cents for cellulose and rock wool and 1.1 cents for fiberglass. Installed prices range from 1.2 to 1.3 cents per R-value per square foot.[158] Since a homeowner is capable of insulating their own home, there is no requirement or need for a professional to install the insulation. General maintenance costs are incurred and the time required for the installment is dependent on the conditions of the area to be insulated. One rough estimate showed that insulation of a 1000 square foot attic to an R-value of 49 would take 6.5 hours.[159]

### Projected Savings

The upgrade on new insulation can bring varying amounts of annual savings in heating and cooling. When the existing insulation R-value was 8, $8.95 can be saved annually per 100 square feet of ceiling by adding new insulation to achieve and R-value of 45. When the existing R-value was 15, $4.40 is saved and at an existing R-value of 19 savings of $3.00 per 100 square feet of ceiling can be seen.[160] As a result of less demand placed on the systems and using less energy, greenhouse gas emissions are reduced and air quality is improved.

### Priority

The greatest benefit would be achieved if the insulation in the attic of buildings was evaluated and insulation was added in those locations. Cellulose blown-in insulation would probably provide the greatest benefit, because it provides complete coverage in difficult to reach areas. This insulation is made of recycled newspaper and it requires less energy to produce than other types of insulation making it better for the environment. While special equipment is required for the installation it is possible to do it yourself and its benefits include reducing the demand on heating and cooling systems, maintaining a more comfortable temperature and reducing energy use and greenhouse gas emissions.

# Alternative Generation Proposals

## Introduction

Current CSB/SJU heat and electrical systems are based on fossil fuels. Many of these systems were installed in the 1950-1980s before viable alternative generation technologies became available and fossil fuels were inexpensive. Over the past few decades, the cost of fossil fuels has been rising, especially for petroleum and natural gas, making alternatives comparatively affordable. This document includes generation systems which utilize technologies that range from emissions free and renewable to systems that run on fossil fuels but have a higher efficiency than current technology.

Reasons for investing in alternative generation are three fold: environmental, economic and educational. Environmentally, the burning of fossil fuels for power generation is a major contributor to acid rain, global warming, and mercury contamination in lakes and particulates in the air. Many alternative generation systems, such as solar and geothermal, are emissions free. There is a finite supply of fossil fuels; several proposed generation systems use fuel which is entirely renewable, such as wind and biomass.

Some of these proposals have economic incentives. Untapped fuel sources, such as waste paper, methane gas from the wastewater treatment plant and flowing water underneath the Stumpf bridge, can be utilized as an economical source of energy; provided that CSB/SJU invests in alternative energy generation technologies like biomass, methane digesters and hydroelectric generators.

Generation systems such as fuel cells may not prove themselves to be economically feasible, but they provide an educational role. As a liberal arts institution, CSB/SJU should be committed to providing its students with an education that includes technology with the potential to change the way we live and energy affects almost every aspect of our lives.

Alternative generation systems are already in use at undergraduate institutions throughout the United States. At Carleton College in Northfield, MN a 1.65 MW turbine was recently installed which will provide 40 percent energy needs on campus. The University of Iowa is working with Quaker Oats to use oat hulls as a biomass fuel for the University's combined heat and power plant. This arrangement has reduced the University's coal demand by 30,000 tons annually and the school expects to save $500,000 a year.

These proposals have been ranked using a system that takes into account prospective economic, environmental and educational effects. The best proposals are environmentally benign, beneficial educationally, stand as symbols of CSB/SJU Benedictine values, and are economically feasible.

# Hydroelectric Generation

## Introduction

Hydroelectric generation has been proving itself useful in the world of electric power for centuries. Grasping different amounts of power from flowing water producing just the right amount of energy needed for a particular job has been experimented with. However, what we are looking at here is electric power from water flow. Electricity produced from water power dates back to the $19^{th}$ century.

Hydroelectric power was first successful in1882 in Munich, Germany, where it was transmitted 37 miles away. After '82 many people were investigating this new source of renewable energy. Appleton, Wisconsin was the first place in the United States to have a central hydroelectric system. By early in the 1940s, 33% of the U.S. electric loads were being provided by hydroelectric power.

Today, hydroelectric power is in local business districts as well as world renown Universities. The popularity is growing today as it did in the 70s when people realized the need for alternative generation. In spite of hydroelectric power supplying a great percentage of energy needs throughout the country, St. John's University does not have a micro hydro system implemented on its campus.

Our location in central Minnesota, the land of over 10,000 lakes, is a prime location for production of hydropower, and will help cut back on the SJU electric bill. A new form of alternative electricity production at SJU will provide an educational resource on campus and cut down on our electricity concerns.

## Application

**Hydro electric power** is a source of renewable power provided by a river or a stream. Hydro power only needs a small amount of moving water to produce a current of electricity. The power supplied by the movement of water is dependent upon two things: **head** and **flow**. Head is used to term the fall of the water as it leaves the pipe or the structured drop and is measured in height (ft). The flow is considered by the movement of water from one point to the next in the given location and is measured in gallons per minute (gpm) or centimeters per second (cfs).[161] The location of the unit is altered to get the most flow and head towards the micro hydro unit.

The hydro power system is made up of a turbine that spins, much like that of a wind turbine. The water flows into the unit by way of the **penstock**, turning the turbine and creating electric power from the rotation. With the situation at SJU, we would be directly placing the penstock in the flow of the water or actually connecting the unit to the exit pipe that already exists at the Stumpf dam.[162] The electric current being produced is sent from the unit directly to the grid or a set of batteries, which are connected into storage. As with many renewable sources of electricity, the power collected over a given time is usually not the same as when the power is needed. Only if the power is not able to be sent directly into the grid is power stored in a battery system which is connected to the grid of the desired community.

**State of Technology**

Hydropower is a technology that has been tested for centuries and scientists are continuing to makes advancements to this technology. Small amounts of water passed over micro hydro systems can still produce energy of a reasonable amount. The more flow and power of water will generate more electricity from the generator. Micro hydro systems have been proven on both large and small scales.

*Large Scale: Canada*

Canada's use of hydro power technology has proven to be a major player in the electricity world. Canada was one of the first producers nearly a century ago and is now the major hydropower producer. In 1898 construction of the first major hydro power facility began at Shawinigan Falls, Quebec. Today, Canada generates about 350 TWh/year. This amount represents somewhere around 62% of the Canada's total electricity production[163].

*Small Scale: Micro Hydro Systems*

Micro Hydro generators are effective on small scale of hunting or fishing cabins, located off the grid. From a small generation from a drop of only 2 feet and a gross head of 5 gpm, many cabins already have electricity plans and receive 4000 kWh of electricity from these small turbines. These numbers prove very effective and efficient.

Both large scale as well as small scale tests have proven similar hypothesis that power supplied by water from rivers, streams, or lakes, at the outflow or inflow, is sufficient to create electric power for a variety of needs.

**Campus Context**

The location of this potential renewable source would be at the end of the pipe system already present between Stumpf and East Gemini Lake. The flow coming from Stumpf Lake, with much of its power coming from Watab, has high potential in the range 3 to 4 kWh. The amount of power depends entirely on the ability to alter the location to reach its highest potential. However, SJU needs to follow a few steps before they can install a Hydro power unit. They need to test both the Gross Head and Flow coming over the area. The US Department of Energy has a website that suggests some tests we can use without professional help.[2] SJU must test the amount of power available from the stream, and make sure it is sufficient to meet power requirements. To do this, we need to determine the amount of head. One method suggested from the Department of Energy is the "hose/tube" method[164].

The second factor is to determine the amount of water flow over the given location. Using the U.S. Geological Survey (USGS)[165] as a guide, water movement can be determined by data. A common method for measuring flow on very small streams is the "bucket" method. Another recommended do-it-yourself option is the **"wading technique"**[166]. Many of the units present on the market have an efficiency of around 55%. The last number needed to complete the equation is constant: 0.085. With all the numbers now present the formula [Gross Head * Flow * System Efficiency * Constant = Power (kW)] can be calculated.

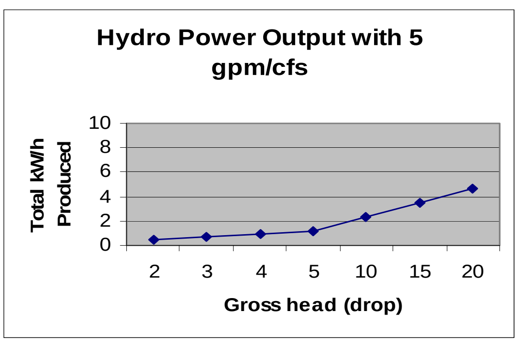
Despite all the tests and systematic instructions given by the US Department of Energy, there is still room for error. The highly recommended approach is to bring a surveyor out to the site for professional direction. The second step would be to bring out an engineer to the location to see how to fit the right generator for the area. Professional instruction will maximize the electrical production we can draw from this area.

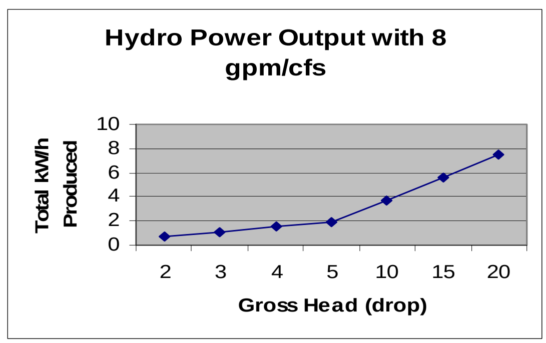
The restrictions set for a hydro power plant are very specific dealing with water contamination and water taken from the source. However, restrictions for a smaller unit, although they fall under the same lines, can also be looked over by SJU Arboretum. With a micro hydro power unit placed in the water near the bridge, no water will be taken out and no chemicals will be added to the water.

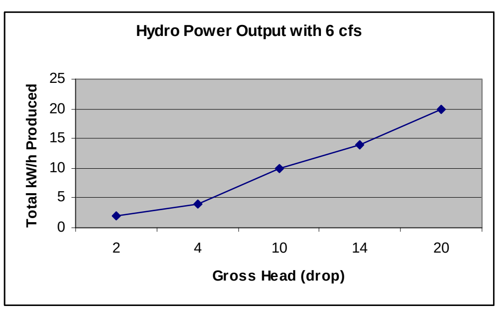
The load a potential micro hydro power unit could provide to campus would be a small percentage of the total power (17,381,901 kWh July 2003 to June 2004) that SJU used during a given fiscal period. As technology continues to strengthen, Flynntown could potentially be powered off the grid.

The power supplying the entire campus is somewhere around 17 million kilowatts for a given fiscal period. With this number in mind, some of the metered buildings on campus especially dormitories use 500 thousand to 20 thousand kilowatts each. With some additional conservation of energy on campus a micro hydro turbine would supply enough power for all of Virgil Michael which uses around 40 thousand kWh/year. A micro turbine as suggested in this proposal would supply around 36 thousand kWh/year.

With these numbers in mind it would take a large drop as well as a good amount of flow to produce enough power for all of Flynntown, but possibly a percentage of Flynntown (one Seton apartment) could be accounted for under the power of a micro hydro unit. A hydro generator of size to fit the location talked about above could have the potential to produce around 40,000 kW per year.




-Potential power production for flow rates at various drops

As the graphs show there is always more power when both the flow as well as the gross head is larger. However, as some of the data shows, there is not always need for both to be large. Shown in the graphs the increase is clear with more drop as well as more flow there is more power generated. Sometimes with a small drop but a large flow a great amount of power can be provided. With one turbine producing power in this way only one Seton apartment could be taken off the main grid by a hydro power unit. However, if we investigate more possibilities, near the South side of Watab or other wetland areas, we could generate more power using the same methods.

**Proposal for load and capacity: 1→500 watt hydro power unit supplying power to one Seton apartment building.**

The micro hydro systems that are available for a reasonable price of around $2000 would have a maximum power output of 500 watts continuously, allowing SJU to provide one Seton apartment with power. Also, other areas around SJU are capable of hydroelectric power. Proposal in this site would only take one micro hydro unit located at or even in the piping under the main hwy to SJU. The power output depends entirely on the testing process and the amount of flow and drop we can draw from that location.

**Potential Benefits**

Generate enough power to support one Seton apartment building. An alternative energy source would save us around 36,000 kWh. The Benefits created from this renewable source are specific. There will be less coal needed to power campus because a percentage will be run off hydro power. SJU will gain the recognition as a school using renewable resources and hydropower. Educational purposes will allow this new source of power to be experimented with and adjusted to get the maximum power allowable from our dam system. As shown earlier, there are opportunities to increase the output of the dam, and with class research, this is possible. The instructions are very detailed and accurately explain the steps of experimentation pertaining to the possible location of a hydroelectric power source. The new technologies of micro hydro turbine generators consist of one small unit. With the majority of power plants there are major safety issues to be dealt with when allowing different students to look and possibly take apart the system. With this system, the safety precautions are only in the moving water around the unit. Allowing different majors on campus to investigate the technology gives high potential to the rest of the SJU acreage. We can calculate the output for studies and comparisons with other schools as could possibly have internships in the summer at SJU.

**Costs**

The costs of a micro hydro system for the specific location between East Gemini and Stumpf Lake would be around $2000. The unit and labor would be cheaper because all the information needed for setting up is easily found and actually comes with the system. SJU will need to maintain the system one placed in the dam. The work would consist of monitoring and cleaning the unit, and could be done by a crew with few training requirements. With this information, this could be a project for any of our staff at St. John's University or even a project for a class to test and measure the exact location on the fall for the best power.

**Other Schools Practicing Hydro: Cornell University; SUNY College;**

Cornell University restored and continues to operate the hydroelectric plant built in the early 1900's. Some of the flow of Fall Creek enters a buried pipe (penstock) at the north face of the Beebe Lake dam. The water travels underground to the plant located just below the suspension bridge. The facility generates an average 5 million kWh, which is enough for 600 homes. The University as also received awards for its use of different energy sources.[167]

State University of New York College of Environmental Science and Forestry (SUNY) has a program called "Engineers Without Barriers." This program has several chapters located all over the country, one being SUNY. In December of 2004, students with this program took a trip to Dominica to participate in a project to learn the construction of a micro hydro system. They were able to work with the system and have a hands-on experience with the workings of the technology. They learned piping placement, creating the maximum power out of the water. Since Dominica gets of 300 inches of rain over a year, there is a high potential for waterpower. The students were able to develop a 140 foot drop into the micro hydro turbine creating the highest potential of electricity.[168]

**Projected Results**

Proposed results of a hydro energy turbine placed at the downfall of our dam between Stumpf and East Gemini can in theory take a percentage of Flynntown apartments off the grid, meaning we would be powering that area for just maintenance costs. Depending upon the adjustments allowable for the projected area, as far as water drop off, there is potential to power the entire Flynntown area.

Saving results are based on the numbers:

> (Head = 14/Flow= 6) 3.94 kW/hr * 24 hours * 365 days * = 34,514 kWh/year
> The current rate of electricity bought from Xcel Energy is $0.04 / kWh. Using these numbers for the micro turbine at the Stumpf dam the savings can be calculated as follows: 34,514 kWh/year * $0.04 = $1380.56 savings/year

SJU would be saving $1380.56 each year if the turbine were implemented. Due to the cost of the turbine and some additional maintenance costs, the turbine would be paid for in under 2 years, supplying us with renewable energy at just maintenance costs.

**Priority**

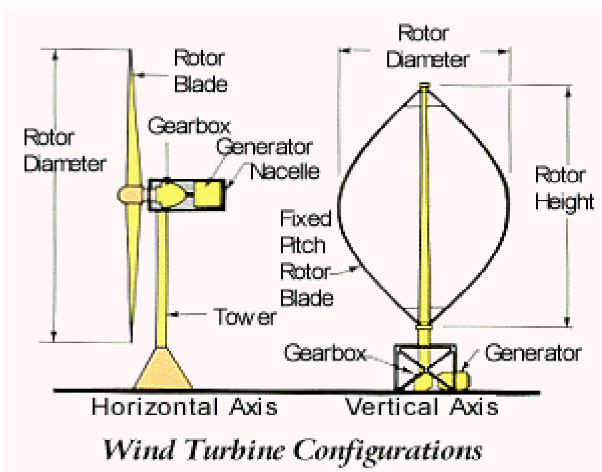
The hydroelectric system placed on the SJU campus would benefit many campus residents. The Arboretum, along with other educational classes could use this project to get more power out of the system. Since the pay back period would be a little under 2 years and the investment is not that great, little funding will go into this system. Over many years, we could save a great deal of money on our electric bill. Hydroelectric power is a wise choice for us here at SJU.

## Wind Energy

### State of Technology

Wind energy is a promising form of **renewable energy**. Wind is created by unequal heating of the Earth's surface by the sun. Wind turbines rely solely on the input of wind for energy production. Harvesting wind resources is a clean form of energy that does emit pollutants associated with the combustion of **fossil fuels** or hazardous waste associated with nuclear energy. Wind also does not cause habitat destruction as associated with large scale hydropower.

Electricity is generated through the conversion of wind from kinetic energy to mechanical power as the wind's force turns the blades of a wind turbine containing a generator. Turbine subsystems include: a rotor, or blades, which convert the wind's energy into rotational shaft energy; a nacelle (enclosure) containing a drive train, usually including a gearbox and a generator; a tower, to support the rotor and drive train; and electronic equipment such as controls, electrical cables, ground support equipment, and interconnection equipment. The blades, transmission, control system, and electrical generator are all mounted on a tower. See Diagram below.




Taken from *American Wind Energy Association* [169]

Turbines must be capable of operating so as to collect power efficiently at low speeds and shed excess power at high speeds. The output of a wind turbine depends on the turbine's size and the wind's speed through the rotor. Wind turbines come in various sizes, producing different electrical outputs relative to their size and watt rating. Small scale turbines are 100 kW or less. Small turbines may be designed to charge batteries to supply electricity to homes that are not connected to the utility system (stand alone systems) or as backup in times of low production. Such systems usually include an inverter that modifies the power from **direct current** to **alternating current** so that it is suitable to run typical appliances. The quantity of electricity available is limited by the battery storage capacity. Turbines can also be connected to the **grid system** and receive backup electricity from the local utility in times of low production and sell back excess energy to the utility through **net metering** in the case of overproduction, allowing the customer to receive full retail value per kWh produced.

Utility scale wind turbines manufactured today range from 100 kW – 4.5 MW, the 500 kW to 1.5 MW range being most typical for onshore wind farms. Onshore wind turbines, located inland away from coastlines, tend to have smaller watt ratings. Offshore turbines have high MW ratings as they are equipped to handle higher wind speeds on coast lines. The United States has large onshore areas suitable for wind farm development and less suitable offshore areas, in comparison to European countries that have relatively large offshore areas.

Improved designs in turbines have lowered investment costs to a fourth of what they were in the late 1980's and maintenance costs are falling as designs improve. The taller the turbine tower and the larger the area swept by the blades, the more powerful and productive the turbine. Advances in electronic monitoring and controls, blade design, and other features have also contributed to a drop in cost. A modern 1.65-MW turbine generates 120 times the electricity at one-sixth the cost of an older 25-kW turbine.[170] Wind generated electricity in the US currently costs as little as 3 cents per kWh, with incentives included, down from 50 cents per kWh in 1981.[171] The cost of wind energy was projected to decline to below 3 cents/kWh by 2013 and to 2.5 cents/kWh by 2020.[172] It is important to keep in mind that the cost of wind energy is highly dependent on the wind speed at the project site.

Wind energy production in the United States increased by 40.8 percent between 1998 and 1999, but as of 2001, made up only 1.6 percent of the renewable energy sector and represented only 0.2 percent of the entire energy supply.[173] About 6,374 megawatts of wind power capacity were installed in the U.S. as of January 2004, generating over 16 billion kilowatt-hours annually.[174] Unfortunately, there has not been a significant increase on a national level in wind production since 2001, although there are incentives in place to encourage investment in wind energy. Federal wind energy production tax credits offer energy companies using wind power a tax credit of 1.8 cents per kilowatt-hour of electricity produced in the first 20 years of a project.[175] The expiration of the original wind tax credit at the end of 2003 put many wind energy projects on hold, but following its renewal at the beginning of 2004, 480 megawatts of new capacity were installed. US wind energy capacity reached 6,374 megawatts at this time, which is the amount of electricity used annually by about 1.6 million average American households.[176] In November 2004, Congress decided again to extend the federal wind energy production tax credit through the end of 2005 in order to make it more affordable for utility companies. A record number of new US wind energy projects are planned for 2005.[177] According to the American Wind Energy Association (AWEA), 2005 wind projects will add to about 2,500 megawatts of generating capacity, surpassing the previous record of 1,696 megawatts in 2001.[178]

The United States ranks second among the leading countries in wind production as of 2003, keeping in mind that wind makes up less than 0.5 percent of US total energy supply as compared to Denmark who generates 20 percent of its energy from wind.[179] The "top 10" nations listed in the table below accounted for over 95% of the total wind energy produced in 2003. [180]

**World Leaders in Wind Capacity**

December 2003

| **Country** | **Capacity (MW)** |
|---|---|
| Germany | 14,609 |
| United States | 6,374 |
| Spain | 6,202 |
| Denmark | 3,110 |
| India | 2,110 |
| Netherlands | 912 |
| Italy | 904 |
| Japan | 686 |
| United Kingdom | 649 |
| China | 568 |

*Table taken from American Wind Energy Association at www.awea.org*

From 1990-2002, wind has been the fastest-growing power source worldwide on a percentage basis, with an annual average growth rate exceeding 30%, world wind capacity reaching 39,294 MW in 2003[181].

Rising prices for natural gas and coal, currently fueling most of America's power plants, make renewable energy sources such as wind power an attractive means to diversify utility companies' supply portfolios. The upfront capital cost of wind energy is large in comparison to energy sources such as coal and natural gas due to **economies of scale** and existing infrastructure that favor these conventional energy sources. However, as previously stated, due to improved technology, costs for wind energy has declined sharply in recent years. The US Department of Energy set a goal of 5 percent of total electricity production to come from wind by 2020.[182] This is a conservative aim, but an increase nonetheless. Current generation and storage potential limits wind's ability to stand on its own as a national energy source at this point, but combined with other energy sources, wind is a clean alternative that can lead the nation in a positive direction away from fossil fuel dependence.

**Application**

Wind is a viable option for meeting at least a portion, if not a majority of the energy needs on our two campuses. In fact, its application at the College of Saint Benedict and Saint John's University has been studied in the past. In May 1995, the College of Saint Benedict and Saint John's University were awarded a $10,580 grant from The Charles A. and Anne Morrow Lindbergh Foundation to conduct a wind speed testing study on the two campuses, to integrate the study of wind power into the curriculum, and to see if wind power on both campuses is economically feasible.[183]

The amount of energy produced by a turbine depends on the wind speed and density. According to the Minnesota Department of Commerce's wind speed map[184] and the aforementioned study conducted at CSB/SJU, the wind class rating for our campuses is a Class II, which would make wind energy economical with a sizeable turbine that was able to maximize generation at lower wind speeds.

One 1. 5 – 2.0 MW turbine would require about 0.5 acres for the site. However, the addition of a second turbine of the same size would require more land because turbines cannot be placed right next to each other as they will shadow the other from the wind resource. In this case, 50 to 75 acres must be dedicated to each turbine.[185] If CSB or SJU decided to invest in multiple turbines situating the turbines on a nearby location off campus, perhaps on a cooperating farmer's property, may be the best option. On the other hand, one turbine could be positioned near the radio tower on Saint John's campus. One turbine of equivalent capacity could also be installed at CSB by the water tower on the west side of campus or on a hilltop location near campus.

An option that does not involve the installation of wind turbines on campus is purchasing a portion of wind generated energy from Xcel through the Windsource program, which became available to MN residents starting in April 2003.[186] The Minnesota Public Utilities Commission approved a price premium of $2 for each 100 kilowatt-hour block of electricity purchased monthly through the program.[187] Purchasing wind generated power through Windsource can accelerate the rate of growth in Minnesota's wind industry as more turbines will be built, depending on the number of customers that sign up for the program. However, the downside of purchasing wind energy generated off-campus through this program is that it would not allow CSB or SJU to benefit from net metering, would not provide the environmental symbolism of a physical turbine on site and is, in fact, very costly considering the amount of energy the two campuses consume.

**Capacity**

For the wind density and wind speeds in St. Joseph and Collegeville areas, the ideal sized turbine would be 1.5 MW or 2 MW capacity, as these size turbines would maximize the amount of energy generated by lower wind class ratings and wind speed ratings around 11.6 meters/second. Examples include: Vestas V82 1.65 MW turbine, which Carleton College installed, or a NEG Micon 2MW turbine.[188] One 1.65 MW wind turbine could generate between 5 and 6 million kWh annually, three turbines of this size could potentially power the entire SJU campus, provided that there is backup for low production times when the turbines do not generate enough energy to meet demand. The coal-fired power plant would remain as it provides Saint John's campus with heat energy, but the turbines could minimize the amount of electrical energy purchased from Xcel.

One 1.65 MW turbine installed at CSB could potentially offset about half of the campus' energy demand and two turbines of this size placed off campus could potentially power the entire campus at current demand, again provided backup during low production times or times of peak demand.

**Cost**

Wind turbines are an expensive capital investment. However, the fuel is free and it produces immediate savings on electricity costs. In addition, there exist many incentives for wind energy production in Minnesota that can help fund such an investment. The capital cost of a turbine, tower and generator total approximately $1.3 million per MW including installation costs, making a 1.5 MW class turbine $1.95 million.[189] Maintenance cost estimates for newer machines range around 1.5 to 2 percent per year of the capital turbine cost.[190] Two percent of $1 million (the cost of the turbine alone) would be an additional $20,000 in maintenance costs per year. Maintenance costs can also be calculated by a fixed amount per kWh of output around $0.01/kWh. Most of the maintenance cost is a fixed amount per year for the regular service of the turbines, but it is important to keep in mind that wear on the turbine generally increases with greater production, so the cost per kWh of production is most helpful for this estimate. A turbine generally has a lifetime of about 20 years.

If CSB/SJU were to purchase 100 percent of their energy demands from Xcel through the Windsource program at a price premium of $2 per 100 kWh block, this would cost CSB approximately $275,000 annually on top of their normal energy costs and SJU approximately an additional $312,500 annually according to energy demand for 2003-2004. This is less costly upfront than investment in wind turbines; however, it would end up costing CSB the same amount as would investing in a $2 million turbine project after 7 years ($2 million /$275,000 per year = 7.27 years) and SJU after 6 years ($2 million/$312,500 per year = 6.4 years). Since wind turbines generally have a 20 year lifetime and the fact that the two institutions will be around for a long time into the future, it is preferable to invest in turbines that the campuses could own rather than to pay Xcel for wind generated electricity. The Windsource program is more economical for individual households as they consume much less energy than a college campus. However, if CSB and SJU wanted to demonstrate support for wind energy in Minnesota and are not currently able to purchase their own turbines, it is possible for the campuses to invest in a portion of energy purchased through Xcel's Windsource program for the meantime.

## Opportunities for Funding

Xcel Energy offers grants through the Renewable Development Fund (RDF). This fund was established in 1999, as part of a renewal of the 1994 Radioactive Waste Management Facility Authorization Law, the Minnesota State legislature required Xcel Energy to contribute $500,000 to the RDF for every dry cask containing spent nuclear fuel stored at its Prairie Island nuclear plant.[191] In 2001, Xcel issued its first request for proposals and funded about $9 million worth of projects. The second, 2003 funding cycle ended March 2004. The cap on new development projects for this past cycle was $2 million and $1 million for research and development funding.[192] The Mainstay Energy Rewards Program offers production incentives to costumers in commercial or residential sectors. Participating customers receive payments per kWh for energy generated through wind, solar thermal electric, photovoltaic (solar), biomass, geothermal electric, small hydroelectric and renewable fuels.[193] In Minnesota, one may receive between $0.023-0.030 per kWh depending on the agreement length of 3-10 years through this incentive program.[194]

Being a campus with active student involvement and concern for the environment, we also have the opportunity to vote and pass a voluntary student tariff per semester to help fund wind energy projects. This need not be a large tariff (University of Colorado charged only $1 per student per semester), and if necessary it could even be applied without a student vote. Perhaps the Regents and Trustees or Alumni and Alumnae of the two campuses would also be willing and interested in investing in a wind project at CSB/SJU.

## Schools Using Wind Energy

Carleton College in Northfield, MN, installed their own wind turbine in September 2004. The turbine is a Vestas 1.65 MW turbine and provides 40 percent of the campus' energy need, 5-6 million kWh annually. Carleton received a $150,000 grant from the MN Department of Commerce plus receives production incentives for each kWh within the first 10 years of production. Between these two grants, Carleton will pay off the $1.8 million capital cost of the turbine and installation in 10-12 years.[195]

Macalester College in St. Paul, MN also purchased their own 10 kW wind turbine. The relatively small turbine generates 18,000 kWh annually, only a fraction of their 12 million kWh annual energy demand. The turbine, tower and equipment cost totaled $40,000 and this was supplied by grant from Xcel Energy.  Macalester paid $15,000 out of its own budget for installation.  The energy generated from the turbine allows Macalester College to save about $1,000/yr in electricity costs.[196]

St. Olaf University in Northfield, MN obtained a MNNEG Micon NM82 turbine through a grant offered by Xcel Energy called the Renewable Development Fund (RDF). St. Olaf asked Xcel for $1.5 million to fund a $1.8 million dollar project for a single 1.65 megawatt turbine, (the same capacity turbine as Carleton College).  The turbine will begin operation within the year, and will generate about 6 million kilowatt-hours of energy annually, replacing about one-third of the college's electricity purchases.[197]

The University of Colorado, Boulder does not own its own wind turbine on campus, but purchases wind energy from a local energy supplier, similar to the Windsource program offered through Xcel Energy.  Students voted in 2000 to raise student fees by $1 per student per semester for four years in order to fund purchasing wind power to cover a portion of the campus' energy need.[198]

There are several Higher Education organizations around the nation committed to supporting and educating about the benefits of renewable energy.  The Upper Midwest Association for Campus Sustainability was recently created and is hosted by CSB/SJU.  Other organizations include: University Leaders for a Sustainable Future, Second Nature, Education for Sustainability Western Network, and the Higher Education Network for Sustainability and the Environment.

**Projected Results, Benefits, Savings**

*Economic*

If Saint John's were to install two 1.65 MW wind turbines, in addition to the electricity generated by the coal-fired power plant, the campus could eliminate the need to purchase 12.5 million kWh of energy from Xcel annually.  This is a savings of $625,000 per year in electricity costs at current rates.   The College of Saint Benedict paid $984,159.77 in energy costs to Xcel last year.  The installation of one 1.65 MW wind turbine could cut the amount of energy purchased from Xcel in half, saving the school $492,079.88 annually at current rates.

*Educational*

Being a higher education institution with a growing Environmental Studies department, investing in wind turbines at CSB and SJU offers a rich educational opportunity to students, our campus community and the larger community in Stearns County and Central Minnesota. A wind turbine could create many opportunities for classes or for outside groups to see how turbines function, to inspire learning about wind energy and other forms of renewable energy which will be an important part of our national energy portfolio in the years to come. The Saint John's Arboretum, for example, currently draws many elementary and secondary aged students from the local area, offering environmental education in a hands-on manner within the Arboretum that demonstrate the school's commitment to stewardship of the land and the value of being educated about the ecology of one's local environment.

*Public Relations*

Committing to a significant wind project for the College of Saint Benedict and Saint John's University also has great public relations value. Other Minnesota Private Colleges such as Carleton, St. Olaf and Macalester have already demonstrated their commitment to renewable energy and recognized its educational value on their campuses and within their surrounding communities. These schools have taken a leadership role in forward thinking in terms of renewable energy. If CSB/SJU wants to maintain their leadership in this area and visibly demonstrate such a commitment, it would be advantageous to pursue an impressive wind project on the two campuses. What better symbol of the schools' leadership in alternative energy generation and environmental stewardship than a wind turbine? A turbine would compliment the radio tower broadcasting Minnesota Public Radio and the Abbey church's bell banner on the Saint John's skyline, speaking of the values and progressive vision which characterize this institution.

*Environmental*

Turning to wind power and replacing the conventional energy that the two campuses purchase from Xcel would allow the schools to internalize the negative environmental externalities associated with nuclear energy and the burning of fossil fuels. Xcel Energy accounted in their 2004 Annual Environmental Report that they emitted 5.04 pounds/MWh of sulfur dioxide ($SO_2$), 3.91 lbs/MWh of nitrogen oxide (NOx), 0.26 lbs/MWh of particulates, 0.000025 lbs/MWH mercury and 2,215 lb/MWh of carbon dioxide ($CO_2$) in 2003.[199] From this data, it is possible to configure the amount of emissions that CSB and SJU are personally responsible. CSB purchases around 10.884 million kWh annually from Xcel, this is the same as 10,884 MWh (1 MWh = 1,000 kWh). So, CSB is personally responsible for emitting 54,855.36 pounds $SO_2$, 42,556.44 pounds NOx, 24.108 million pounds $CO_2$, 2,829.84 pounds of particulates, and 0.2721 pounds of mercury per year. Saint John's purchases around 12.5 million kWh or 12,500 MWh from Xcel annually. SJU is personally responsible for emitting 63,000 pounds $SO_2$, 48,875 pounds NOx, 27.6875 million pounds $CO_2$, 3,250 pounds of particulates, and 0.3125 pounds of mercury per year. This adds up to a whopping 51.8 million pounds of carbon dioxide between the two institutions per year in electricity and heating alone!

Carbon dioxide is the leading greenhouse gas emission in our nation today, contributing largely to global warming. Emissions of sulfur dioxide and nitrous oxide cause acid rain as they oxidize in the atmosphere, forming nitric and sulfuric acid. Acid rain causes soil erosion and is detrimental to the health of forests and lakes, leaching nutrients from the environment and creating an unsuitable habitat for species. Particulates affect poor air quality and lead to negative health effects such as asthma. Mercury is the byproduct of coal combustion and is precipitated from the atmosphere into nearby watersheds. Mercury pollution is a large problem in Minnesota lakes, building up in the fat tissues of fish and humans, leading to serious ecological and health problems.

Turning to wind to meet the energy needs at the College of Saint Benedict and Saint John's University could significantly decrease the two colleges' personal contributions to pollution associated with conventional energy production and dramatically lessen their ecological footprint. Even a shift to half wind generated energy on both campuses could prevent the emission of around 25 million pounds of carbon dioxide per year, as well as a 50 percent reduction in $SO_2$, $NO_x$, particulates and mercury. This is a step in the right direction.

*Benedictine Values and Stewardship*

The College of Saint Benedict and Saint John's University are founded on the Benedictine tradition. This unique trademark that shapes the values and actions of the two institutions requires attention to environmental responsibility and stewardship of natural resources. In July 2001, the two presidents, Mary Lyons and Dietrich Reinhart, recognized this in their release of the *Environmental Statement of the College of Saint Benedict/Saint John's*

*University.* Remarking that stewardship has been an important component of the Benedictine tradition, they state:

> As Benedictine institutions of higher education, [at] Saint John's University and the College of Saint Benedict…we see ourselves as responsible for good stewardship of the natural environment and seek to take a leadership role in exercising this responsibility, affirming our commitment to use educational activities to promote environmental awareness, global thinking and collaboration on the local level. [200]

Surely then, CSB/SJU should take the opportunity to demonstrate this mission concretely by committing to a wind project that carries with it educational opportunities to promote environmental awareness, responsibility for our personal contribution to global warming and supporting growth in Minnesota's wind industry.

**Priorities**

Seeing as there are many benefits associated with investment in wind energy technology for the College of Saint Benedict and Saint John's University, it would be advantageous for the two colleges to pursue a progressive wind project. Seeking a grant through Xcel's Renewable Energy Fund for one or more wind turbines to be installed on each campus would be ideal. However, other possibilities exist for supporting wind energy offsite as well. This includes investing in turbines at the Buffalo Ridge wind farm in southwestern Minnesota or purchasing turbines as part of a joint community project with local land owners or other willing investors. Derek Larson, Head of the Environmental Studies Department and Professor of History at Saint John's, stated in a recent issue of *The Record* pertaining to wind energy:

> The energy committee is exploring a variety of options for wind energy, including purchasing power from or investing in turbines in the Buffalo Ridge area in southwest Minnesota, constructing turbines on a site somewhere in western Stearns County in a partnership arrangement or installing two towers near St. John's. We could own the turbines ourselves, engage in a joint venture to operate them with an existing wind company or simply buy wind power off the grid at retail rates. Some mix of these options may be best, like installing turbines at St. John's to meet part of our demand and joining with St. Ben's or other large energy users in St. Joseph to invest in wind at another location.[201]

Thomas Stuck, a guest columnist that appeared in the January 20, 2005 issue of *The Record*, feels that "There are many reasons why Saint John's should consider being powered by wind turbines". He encourages us that there are many opportunities for funding and creating partnerships with Xcel that could help with the costs of installing one or more turbines at Saint

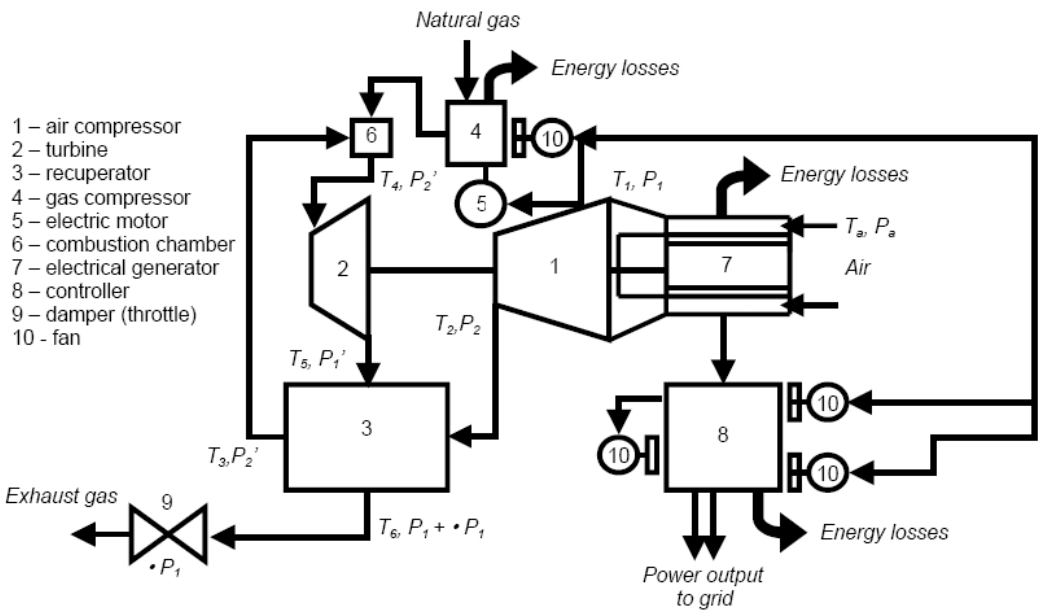
John’s, and that, despite the costs, “It's a win-win situation” because, “… whatever the costs would amount to, Saint John's would be highly reimbursed in money terms as well as in the form of knowledge”.[202]

In conclusion, first priority for wind energy technology at the College of Saint Benedict and Saint John’s University would be to invest in multiple college-owned turbines, two 1.5 or 2 MW capacity turbines at Saint John’s and one turbine of the same capacity at Saint Bens, which would be located on or near the respective campuses. Such an investment, while costly upfront, would maximize the long-run economic benefits, as opposed to investing in wind energy elsewhere. A progressive wind project would also highlight these institutions’ commitments to raising environmental consciousness and carrying out the Benedictine value of stewardship while making a name for itself in wind energy technology as many Minnesota higher education institutions have already invested in wind projects.

## Gas Microturbines

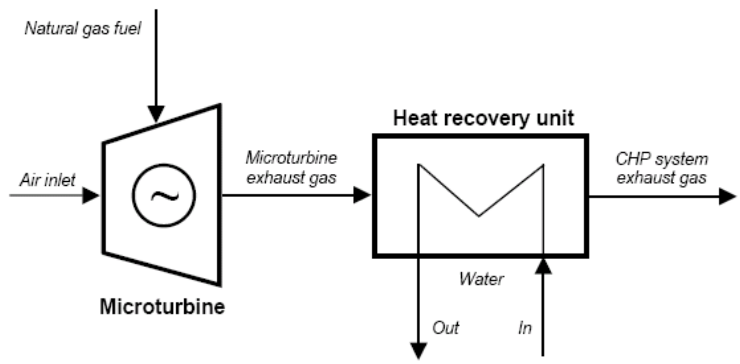
### Application

Derived from turbocharger technologies found in large trucks or the turbines in aircraft auxiliary power units (APUs), gas microturbines are refrigerator-sized electricity and heat generators fueled by natural gases. Most microturbines are **single-stage, radial flow devices** with high rotating speeds of 90,000 to 120,000 revolutions per minute (RPM) and can be used both on and off-grid.[203]




[204]

Known for their outstanding energy efficiency, they come in two forms, co-generation and non-cogeneration. Co-generators utilize waste heat produced during the generation of electricity making them up to 80% efficient, 80 units of electricity and heat per 100 units of gas, making them one of the most efficient non-renewable fuel-based technologies of energy.[205]

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Many types of natural fuels have been used in these turbines including, but not limited to: natural gas, ethanol, and bio-fuels.[207]

**State of Technology**

Capstone Turbine Corporation, a microturbine manufacturer, has claimed to have shipped more than 3,000 units[208] and has a total fleet operating at a total of approximately 8,500,000 hours.[209] New technologies are being developed extensively, mainly in Europe, with the use of sour oilfield and landfill waste gases that are not being utilized otherwise.[210] There is much interest to provide a lightweight and efficient fossil-fuel-based energy source for hybrid electric vehicles, especially buses in collaboration with gas microturbines. Technologies for more heat recovery, cogeneration, and fuel flexibility are ongoing.[211]

**Campus Context**

On either campus, gas microturbines can be used to generate electricity and heat any building, up to the turbines' kW capacities. Current technology allows for outputs of anywhere from 25 kW to 500 kW,[212] making them ideal for small loads. In developing the technology of these microturbines on campus, waste gases from the waste-water treatment plant at St. John's University could be researched for potential use. Also, because of their size, they can easily be stored in closets and storage units in any building. One negative issue, however, is the price of natural gas on campus. According to Tom Vogel, the Power House Chief Engineer, natural gas currently costs $7.13 per 1 million BTUs, comparatively more expensive than elsewhere in the state. Other forms of natural fuels are also just as expensive.

More specifically, the load for which these microturbines can be used on the campuses is any building that uses under 500 kWh of electricity per day, the maximum capacity of current gas microturbines. The buildings on the St. John's University campus that would allow for such use include: the garage, pottery studio and HMML. The buildings on the College of St. Benedict's campus that would allow for such use include: Academic Services, bakery, Claire Lynch and the Main Kitchen, as each of these buildings use under 500 kWh of electricity per day. All other buildings and electrical systems could also benefit from gas microturbine use, but only up to the respected kW capacity of the specific microturbine.

**Costs**

The costs of such uses of gas microturbines on the campuses are calculable. At $7.13 per 1 million BTUs of natural gas, at 500 kW (full capacity), total BTU use is 1,706,500. At this capacity, 500 kWh would cost $12.17, or $.024 per kWh minus the value of the co-generated heat produced. Since the heat generated on campus comes in the form of steam from burning coal, and different kW capacity turbines utilize differing amounts of waste heat, the savings in heat generated from co-generation microturbines is difficult to assess. The best option would be to install a small system, and calculate the savings this way. The cost of the gas microturbine infrastructure is roughly < $500 per kW, so, for example, a 500 kW microturbine would cost the schools approximately $250,000.[213] The general maintenance period is approximately 11,000 hours with a total of 45,000 hours of service life. The approximate cost for each maintenance session is $0.005-$0.016 per kWh of use. [214]

**Examples of Other Schools**

Two examples of universities that have utilized gas microturbines, and used Capstone Turbine Corporation's products, are the University of Colorado at Boulder, Colorado, and Pasadena City College, California. Both colleges are using gas microturbines to run and heat their pool. The University of Colorado at Boulder installed a 30 kW Capstone microturbine in 2004 at their Recreation Center. Fueled by natural gas, the microturbine generates electricity for operating the center's swimming pool pumps and its 530-degree-Farenheit exhaust is used to heat the pool water. The microturbine is expected to provide 200,000 kilowatt hours of power annually and save more than $10,000 per year.  Not only are the financial savings a benefit for the school, but there is also a decrease in toxic emissions and a co-generation educational piece that serves the school.[215]

The Pasadena City College installed two Capstone C60 gas microturbines, a total of 120 kW, to run and heat their 750,000 gallon swimming pool. Kept at a constant 81ºF, the use of these microturbines offsets 2,500 kWh of utility power demand every day. This technology saves the college $100,000 dollars annually and was a return investment in less than 4 months. The overwhelming success of the turbines has caused the school to look into the installation of 24 more gas microturbines to provide electricity and heat for other various systems.[216]

**Projected Results**

Projected results from the use of co-generated gas microturbines in small load capacities on the campuses are promising. Even though the cost for natural gas is high, St. John's could expect savings in money, energy and the environment by using gas microturbines. The current cost of power coming from Xcel Energy for both St. John's University and the College of St. Benedict is at $.0428 per kWh. As calculated above, the cost of producing electricity from gas microturbines would be $.024 per kWh, plus the cost in heat savings. Coal currently costs $2.60 per million BTUs to heat St. John's University, and is considered comparatively cheap.

If the university, for example, were to buy a 30 kW co-generated gas microturbine at the cost of $35,000 dollars for the St. John's University pool, there could be a return investment of that $35,000 dollars in just over 4 months, as the aforementioned colleges claimed, due to high natural gas prices and cheap current heating prices. These figures do not include, however, the beneficial environmental impacts of these gas microturbines that undoubtedly would save the external costs of current energy practices, such as health deterioration of humans, other animals and plants and medical bills associated with these health concerns as well as visual impairments. It is estimated that these turbines release <7 ppm of NOx, much lower than burning coal, which could release upwards of 100s of ppm of NOx, as is the main power source coming to the campuses from Xcel Energy.[217]

**Priority**

The priority for the use of gas microturbines at CSB/SJU should be second-rate for small systems, 500 kW and under, becoming higher as the system gets smaller. Ideally, a "practice run” could be done cheaply by installing a co-generated microturbine for the St. John’s or St. Bens pools, as similar to the aforementioned schools and could also serve as a co-generation educational element. The priority of gas microturbine use would be low for systems larger than 500 kW as the technology thus far only allows up to 500 kW. The larger the capacity of the gas microturbine, the more exponentially expensive they are.

## Geothermal Heat Pumps

### Application

A **geothermal heat pump** moves heat out of or back into the earth using the Earth as a **heat sink** in the summer and a heat source in the winter. Through high-density polyethylene pipes buried underground, from depths of 6 to 400 feet, a transfer of heat is possible from the earth to a building.[218] The heat exchange is possible by use of an environmentally-friendly antifreeze heat **transfer fluid** that travels through the pipes. During the winter, the fluid extracts heat from the earth and carries it into the building. During the summer it takes heat from the building and deposits it into the cooler ground. A fan in the heat pump enclosure then blows the warm or cool air through ductwork, which is used to distribute air throughout the building, just like a conventional central forced air system.[219]

Various types of geothermal heat pump pipe setups can be used under different conditions. **Horizontal ground closed-loop** is a configuration of piping that is installed in locations where soils can be easily excavated. Trenches three to six feet below the ground are dug and pipes are buried horizontally in one continuous loop or a series of parallel loops. These installations are best done for new building constructions, although new technology allows for horizontal boring under existing buildings and driveways.[220]

**Vertical ground closed-loops** are configurations that are often used where land is limited and large loads are needed. During construction, several pairs of pipes with a U-bend assembly at the bottom are inserted into a series of deeply bored holes ranging from 150 to 450 feet underground.[221] Due to digging costs, these arrangements are generally more expensive.

A **pond closed-loop** is a system arrangement which utilizes a nearby body of water, such as a pond or lake, as a heat source and sink. The pipe runs from the building to the water body, where it is submerged underwater in a coiled shape, allowing it to fit in the space. It is important that the water level of the lake or pond never drops below six to eight feet; this ensures adequate heat-transfer capability and that the entire lake or pond will not freeze solid.[222] Unfortunately, a major downfall of this system configuration is the potential for adverse impacts on the aquatic systems. Ponds and smaller water bodies may experience fluctuations in temperatures that can be stressful and often deadly to various types of aquatic life including fish, aquatic plants and other aquatic organisms.

**Open loop systems** are the fourth type of geothermal heat pump system. These systems involve directly using ground water from an aquifer and pumping it from the well to the building, where the heat is transferred to a heat pump. The water is then discharged back into the aquifer through a second well that is located a suitable distance from the first.[223] Unfortunately, with this system, there is potential for contamination of groundwater. This could negatively impact the localized groundwater supply, flora and fauna.

A **desuperheater** is a device that transfers excess heat from the heat pump's compressor to the hot water tank, which can provide free hot water. The desuperheater uses heated gases from the heat pump's compressor to heat water, which then circulates to the water heater tank through a pipe.[224] This system results in free hot water during the summer while water heating costs are cut in half during the winter.[225]

### State of Technology

Geothermal heat pumps have been in common use since the early 1970s, proving themselves to be highly reliable as well as durable. These systems have very few moving parts which need minimal maintenance, require few repairs and generally only require scheduled cleanings. The geothermal heat pumps themselves last 20 years or more while the underground piping often carries warranties of 25 to 50 years and have life expectancies of 200 years.[226]

### Campus Context

Almost all geothermal systems are installed when constructing a new building. Current buildings can be retrofitted with a geothermal heat pump system; however they are very challenging to install in a building not designed with heat pumps in mind and generally require a lot of extra labor to upgrade the building. Sizing a geothermal system to a current building is also very complicated and difficult to do properly.

The loop system can go almost anywhere from under a parking lot to under landscaped terrain. It cannot go directly under a building structure, in case there is a need to reach the pipes.

Geothermal heat pump systems can be used in any climate because they utilize the heat inside the earth; temperatures that remain relatively constant year round at about 50 F. The transfer fluid that flows between the pipes and allows for heat transfer has an anti-freeze in it that prevents ice up and continues heat transfer, even on the coldest days.

**Load and Capacity**

An average residence of 2,000 to 2,400 square feet requires a pump with a capacity of 3 tons or 36,000 BTUs.[227] However heating systems can be fitted to any size structure; from homes to business centers of 36,000 square feet to hotels of 1.7 million square feet.

**Potential Benefits**

One benefit of geothermal heat pumps is that they use 25-50 percent less electricity than the conventional heating and cooling systems. Geothermal heat pumps also eliminate the need for separate heating and cooling systems. Another benefit is the potential for providing free hot water, with a desuperheater to transfer excess heat from the heat pump's compressor to the hot water tank. This results in free hot water during the summer and water heating costs cut in half during the winter.[228]

Geothermal heat pumps are also environmentally friendly because they use so little electricity, do not burn any fossil fuels and produce no emissions of greenhouse gases. Every 100,000 units of residential geothermal heat pumps will save more than 24 trillion BTUs of electrical energy and save approximately $500 million in heating and cooling costs over a 20 year period. These units will also reduce greenhouse gas emissions by almost 1.1 million metric tons of carbon.[229]

**Costs**

Geothermal heat pumps cost more up front due to the expensive ground loop piping system and the costs of drilling or trenching; they can cost anywhere from 30-50 percent more than a conventional system when all equipment is considered. Generally prices run about $2,500 per ton of capacity with an average home of 2000 to 2400 square feet requiring a capacity of 3 tons or 36,000 BTUs.[230]

When installing a geothermal heat pump system in a new construction scenario, installation for a 2,000 square foot home costs between $12,000 and $15,000. These installation prices include labor, heat pump, pumping unit, thermostat, vertical ground loop, electrostatic filter, auxiliary/backup heater, desuperheater, and ductwork.[231]

Qualified installers/contractors are needed who can properly size your system as well as handle the specialized installation tasks. International Ground Source Heat Pump Association provides a list of accredited installers, trainers, and certified GeoExchange Designers at: http://www.igshpa.okstate.edu/business_directory/bdaccins.asp.[232]

When considering a horizontal loop system, roughly 220 feet of piping is required for every ton of compressor load or 12,000 **BTUs** of heat. The prices for digging the trenches for a horizontal system vary but generally start from $600 for every ton of capacity.

For vertical loop systems typically 300 feet of piping per ton is required. The cost for drilling in these systems increases to about $750 to $950 per **ton** of compressor capacity.[233]

The operation and maintenance costs for geothermal heat pump systems are generally much lower than a conventional system, allowing for quicker **payback**. Maintenance costs generally range from 6 to 11 cents per square foot. The maintenance prices break down to around 8 cents per square foot when in-house labor is used and closer to 11 cents per square foot when a contractor is used.

Scheduled maintenance is required, just like a conventional system, and costs range from 1.10-1.61 cents per square foot depending on in-house wage and contractor wage. However there is no outside unit that requires cleaning or maintenance.

Unscheduled maintenance costs range from 3.70 to 4.06 cents per square foot.[234] There is generally very little unscheduled maintenance because the heat pump units are located indoors. This sealed environment prevents debris and dirt damage that can cause problems for other systems.

The general maintenance for these systems does not require a professional. A survey of 38 sites with geothermal heat pumps indicated that such maintenance most often consists of changing air filters, checking the unit pieces and occasional heat exchanger coil cleaning. The underground piping requires little to no maintenance and generally has a life span of 200 years.[235] However, should a pipe leak or break, complications are minimal because the flow to and from individual pipes can be shut down. Also, the transfer fluid in the pipe is environmentally friendly and leaks are not hazardous.

**Examples from other Schools**

Clarke College is a small, 55-acre liberal arts institution in Dubuque, Iowa with an enrollment of 1,180 students. Clarke College recently added a new apartment complex to its campus and they chose to use geothermal heat pumps to heat and cool the building. The idea began when the Director of Clarke's Physical Plant was introduced to geothermal heat pumps, he then researched the topic and discovering the low costs needed to run the system and the clean source of heating and cooling that is provided, decided that geothermal was their best option.[236]

Clarke College used the vertical loop structure for their system. To do so 48 individual wells were drilled to depths of 230 feet. At this depth the ground temperature is a relatively constant 50 degrees Fahrenheit. The system works by a solution in the pipes being circulated through the ground and being drawn up by the heat pumps, where the heat is then collected and distributed throughout the apartment complex. The solution in the pipes is continuously transmitted through the system to the pipes underground so they can be reheated by the warm groundwater. The only cost for running this system is the electricity required to keep the heat pumps running.

The cost for this system is fairly expensive; it cost roughly 20% more than the usual heating/cooling system. The source of higher cost comes mainly from the drilling and piping necessary for a vertical loop geothermal system. While the upfront price is higher the long term paybacks are much more appealing; Clarke College expects the system to pay for itself within 3 years because the electricity bill for this 30,000 square foot housing complex, which has 96 individual rooms, is only $1400 per month.[237]

Richard Stockton College is another college that has taken an interest in energy conservation by way of utilizing geothermal systems. Richard Stockton is an undergraduate college of arts and science with an enrollment of 6,300 students that is located in Pomona, New Jersey. The decision to use geothermal technology on campus arose from several circumstances including the pressing of a physics teacher, the interest in reducing heating and cooling costs as well as the planned replacement of many of the school's heating, ventilation, and air conditioning (HVAC) units.[238]

The college first called on an engineering service to perform a feasibility study while the school began searching for funding sources. Eventually the college was able to obtain $5.1 million in grants from the New Jersey State Department of Environmental Protection and

Energy, New Jersey Department of Higher Education, and in the form of installation rebates from Atlantic City Electric Company. The grants and feasibility resulted in the advancement of the project.

The projected design consisted of 400 heat exchange wells that were dug to a depth of 425 feet in a 3.5 acre area that included one of the college's parking lots as well as some adjacent open space. The system also uses 62 Trane rooftop water-source heat pump units that total 1,480 tons in capacity which allows the heating and cooling of 440,000 square feet of floor space.[239]

The installation of the geothermal system has resulted in a reduction of the school's electric consumption by roughly 25% and natural gas consumption by 70 percent as well as $330,000 saving per year in energy costs. Additional benefits include a 13% reduction in college $CO_2$ emissions despite a 25% growth by the college in the recent years.[240]

**Projected Results**

Savings potential, on average, include 30-70% in heating costs and saving 20-50% in cooling costs. Generally, a typical 3-ton residential exchange system will produce one pound less $CO_2$ per hour of use than a conventional system. The U.S. Environmental Protection Agency considers geothermal heat pumps to be the most environmentally friendly form of home heating and cooling because they use so little electricity and do not burn any fossil fuels and produce no emissions of greenhouse gases.[241]

**Priority**

It would be most feasible to use a geothermal heat pump in the construction of a new building. While the price of the system seems expensive up front, the system can begin to pay for itself in as little as 3 years. These systems also have very little maintenance, are quiet, and are a good way to reduce pollution.

An excellent opportunity would be to use a geothermal heat pump system in the construction of the new Abbey Guest House at St. John's University. This would use a smaller system than a dormitory and would show the benefits of such a system before a larger system was implemented. Utilizing a geothermal heat pump would also provide a concrete example of St. John's interest in caring for the community as well as the environment by reducing $CO_2$ emissions. Rough estimates are placing the Abbey Guest House at 27,178 square feet.[242] A qualified contractor would be required in order to accurately size the system for the building dimensions.

## Biomass

### Application

**Biomass** is defined as plant material, vegetation, or agricultural waste used as a fuel or energy source.[243] More than 95 million tons of agricultural wastes are generated in the United States each year.[244] This includes agricultural residues such as wheat straw, and corn stover. Corn alone provides more waste than all other sources of biomass in this country. U.S. farmers plant about eighty million acres of corn each year, with a potential stover (leaves, stalks, and cobs) harvest of some 120 million dry tons. This total is nearly four times greater than the biomass available from wood waste and paper, the next largest feedstock category.[245] **Corn stover** and **straw** are usually baled and used as bedding or windbreaks for livestock, especially in the winter months. **Annual plants** such as corn stover may be an abundant source of biomass energy but they contain relatively large amounts of alkali materials which cause maintenance problems in electrical generation facilities because the alkali materials, which are non-flammable, form deposits on equipment such as burners which must be removed.

It is estimated that over a hundred million tons of forestry wastes could be collected in the United States each year. Forestry waste includes underutilized wood, logging residues, imperfect trees, and noncommercial trees that need to be thinned from crowded, unhealthy, or fire-prone forests[246]. This category could also include wood scraps, shavings, and dust from wood working shops, lumber and paper mills. Most of the available inexpensive forestry waste sources have already been tapped for biomass energy because they are a relatively cheap source of energy. Remaining sources of forestry wastes are likely prohibitively expensive due to shipping costs because there are very few forestry operations in the area around St. John's University which means that they would probably have to be shipped in by semi truck. There is a large paper mill in the area (Sartell) but they have an existing biomass operation that utilizes the mill and lumbar residues that the plant generates.

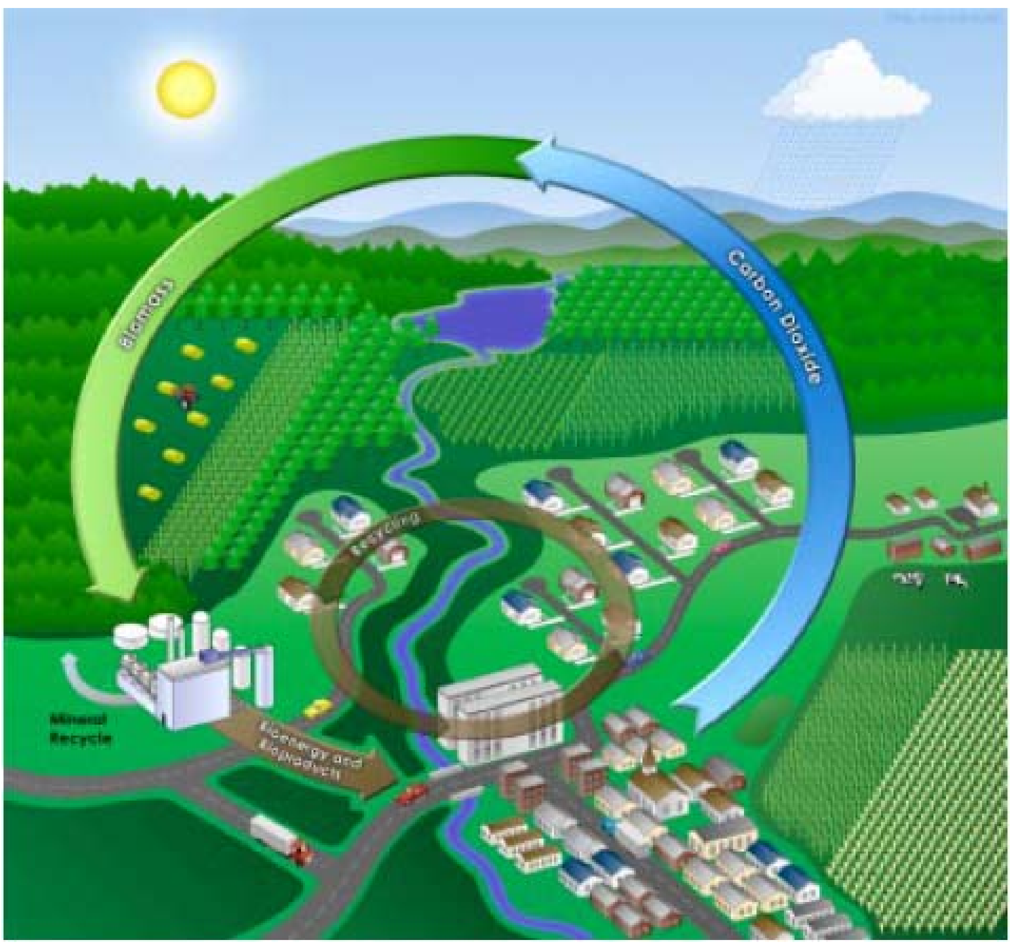
Approximately 216 million tons of **municipal solid wastes** are generated annually in the United States. American industry generates about 12 billion tons of wastes requiring treatment and disposal each year.[247] Landfills are becoming more and more strained to cover this demand as environmental regulations get more stringent. Some are even being forced to close even though demand for their services is increasing. Instead of burying all of this waste in landfills, some of it could be used as a source of energy. Current technology allows some wastes, such as paper, cardboard and even some plastics, to be processed into combustible fuel which can be used in power facilities.

In the United States, it is estimated that about 190 million acres of land could be used to produce energy crops without impairing food production.[248] **Energy crops** are crops developed and grown specifically for fuel. These include fast-growing trees, shrubs, and grasses. Specific examples of these plants are hybrid poplars, willows, and switchgrass. Energy crops can be grown on agricultural lands not suitable for the growth of feed or fiber crops. Farmers can plant energy crops along riverbanks, around lakeshores or between farms, forests, and wetlands to create habitat for wildlife, renew the soils, and encourage biodiversity.[249] Opponents argue that energy crops would lower biodiversity because these crops would be displacing the local plant life in areas like riverbanks and lakeshores which is undesirable. If farmers are allowed to plant energy crops in conservation reserve program land, then the farmers could get an economic return on the land while maintaining soil protection without government payments. This is not allowed under the current Conservation Reserve Program (CRP) but some biomass advocates are lobbying for a policy change.[250] There are some downsides to the cultivation of energy crops. Soil erosion can be a problem if entire stands of trees are harvested simultaneously or if soil preparation before planting does not limit the exposure of the soil to the elements. Energy crops can also tap the soil of vital nutrients if the ash from the combustion of the crop is not redistributed back into the soil. The ethics of growing crops for energy production on land that could or was previously used for food production may be questionable to some people because feeding the hungry may be more of higher priority to them than meeting the nation's energy demand in a sustainable manner.

**Photosynthesizers**, which include many green plants, harness the energy of the sun to power biochemical reactions which remove carbon dioxide from the atmosphere surrounding the plant and sequester it in high energy chemical bonds such as those in glucose, and cellulose. The biochemical reaction that takes place in order to make carbohydrates requires sunlight, water, and mineral nutrients from the soil; the product is energy in the form of chemical bonds and gaseous oxygen. The energy from these bonds can be tapped by mankind as a renewable source of energy.

The burning of biomass fuels is not considered **green energy** because particulates and gases such as carbon dioxide are emitted into the air, although at decreased levels compared to fossil fuels.  Biomass is a form of renewable energy because, unlike coal and other fossil fuels, we can renew our supply continuously in our lifetimes. Biomass energy also has no net effect on the amount of carbon dioxide emitted into the atmosphere. When biomass is burned, the water, carbon dioxide, and energy that the plant stored during its lifetime is released back into the environment.

The process of energy extraction is the same for fossil fuels such as coal because they are technically sources of biomass. But fossil fuels have been buried underground- sequestered away for millions of years, so burning them actually introduces that prehistoric stored away carbon dioxide back into the atmosphere increasing the total amount in the global carbon cycle. Although biomass energy does not reduce the amount of carbon dioxide in the air, the replacement of fossil fuels with biomass fuels has a net reducing effect compared to using fossil fuels. Biomass fuel production operations such as designated fuel crops are classified as "**closed-loop biomass**" because the carbon goes through the cycle depicted below.




Closed Loop Biomass Schematic[251]

The technology used to retrieve the energy stored in biomass has come a long way since prehistoric man's campfire but it relies on basically the same premise- burn the fuel to make heat and then turn that heat into useful mechanical or electrical energy. Technological innovations have allowed increases in efficiency and decreases in associated costs of energy extraction to compete with fossil fuel sources.

**Biomass to heat/power conversion**

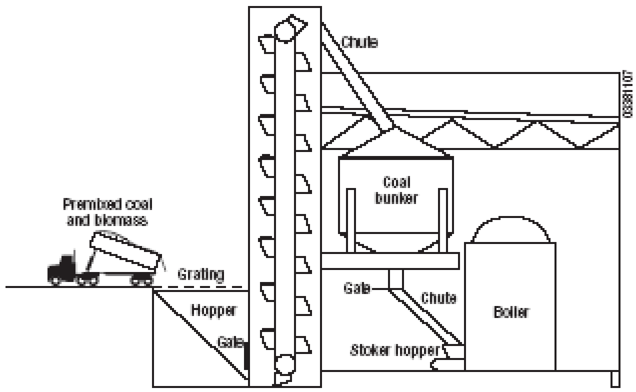
In a direct firing operation, biomass is burned in a burner system much like coal and the hot gas is used in a boiler to produce steam. The steam can then be used to drive a turbine for electricity generation. In a cogeneration facility (Combined Heating and Power CHP) such as the SJU power plant, the steam from a boiler system is distributed throughout the campus for heating and also used to accomplish cooling. Electrical generation is a byproduct of heat generation because the generators are used to reduce the pressure of the steam from the boiler system. If no generator was present the steam is usually passed through a pressure-reducing valve, which lowers its pressure for normal delivery of heat. A low pressure steam line in a building is preferred over a high pressure line for numerous reasons including safety.

Whole tree combustion is a new process intended to reduce labor costs associated with wood biomass preparation by burning trees as a whole unit. This idea makes sense because it removes the labor intensive activities of sectioning and chipping wood for use as biomass fuel. Technical hurdles that need to be overcome before full implementation are proper drying technologies for the large pieces of timber and design of burner/boiler systems.

**Cofiring**

In co-firing operations, biomass is used as a replacement or supplement to **fossil fuels** especially coal. Co-firing is particularly attractive for use in coal plants because of the similar characteristics in fuel handling compared to gas and oil. This process involves injecting combustible biomass into the fossil fuel combustion chamber to be burned along with the fossil fuel. Co-firing offers many of the benefits of biomass fuels like renewability, lower fuel costs, avoidance of landfills and their associated costs, and reductions in sulfur oxide, nitrogen oxide, and greenhouse-gas emissions without the major capital costs. Retrofit of old electrical generation plants usually costs between $180 and $200 per kWh capacity.[252]

Most coal fired plants are able to handle fuel mixtures of up to 5% biomass without any special modifications to the furnace/boiler itself, the capital costs come from storage, transportation and mixing systems. Higher percentages of biomass can be accomplished by retrofitting burners so that the fuel delivery of biomass is independent from the coal delivery system. This gives the operator greater control over the combustion process and allows constant adjustment but comes with increased installation and maintenance costs.




A typical stoker boiler conveyor system receiving premixed coal and biomass [253]

**Biomass Gasification**

When biomass is heated with no oxygen or only about one-third the oxygen needed for efficient combustion it gasifies to a mixture of carbon monoxide and hydrogen—synthesis gas or syngas. Combustion is a function of the mixture of oxygen with the hydrocarbon fuel. Gaseous fuels mix with oxygen more easily than liquid fuels, which in turn mix more easily than solid fuels. Syngas burns more efficiently and cleanly than the solid biomass it was derived from because the original biomass was a solid and the syngas can mix with the oxygen to produce a much more efficient combustion process. Biomass gasification can thus improve the efficiency of power generation facilities. Syngas can also be converted into a more pure form of hydrogen gas for use in fuel cells.[254]

**State of the Technology**

Biomass is one of the oldest sources of energy known to mankind. It was the predominant form of energy up until the mid 1800's when coal and oil became predominant. It is estimated that biomass currently accounts for about 15% of world energy use and 38% of energy use in developing countries.[255] Wood is the largest source of biomass fuel with over five hundred electrical generation facilities already operating on wood in the United States. Biomass source electricity has grown from 200 megawatts (MW) in the 1980s to more than 8000 MW today. This is a 4000% increase.[256] Electric utilities generated 12 trillion Btu's of energy using wood biomass in 1998 alone. Overall, 3,052 trillion **Btu's** were produced using biomass in 1998.[257]

Biomass is an economical renewable energy source that provides **base load electrical generation**. Current baseload producers are nuclear, hydroelectric and fossil fuel plants. These producers provide a majority of the electricity that we used everyday. These sources have the ability to modulate their output of electricity to meet the current electrical demand. Electricity on the grid cannot be stored. When you turn on a light in your house, somewhere a generator kicks up its output to meet the additional demand. The problem with some renewable energy sources is that their output is dependant on their power source, not the electrical demand. Because of this inability, there has to be baseload backup to cover wind sources in case the electrical demand outstrips the wind electricity being generated. Electrical generators like nuclear and coal can only be scaled back to a certain point beyond which they become inefficient or uneconomical. It is difficult to incorporate renewables into the energy production system in place of baseload stations because their output cannot be modulated. Most heating and cooling facilities currently rely on fossil fuels because they can be depended on as energy sources. Biomass is a great renewable option for heat generation because of its dependability and affordability.

**Campus Context**

The most appropriate site for biomass use would be at the current SJU power plant. Because the use of biomass would be integrated into the current system, the review of campus energy generation provided earlier in this report should be referenced. The current power plant at the College of St. Benedict is run off of natural gas so the implementation of biomass fuels would be difficult and costly due to fuel handling differences. Natural gas in piped directly into the boilers – no fuel handling is required. Both biomass and coal are solid fuels which must be fed into the burner so handling systems for coal and biomass should be similar.

The rationale for biomass use at Saint John's is based on the fact that for the foreseeable future the power plant at SJU will need to burn some type of fuel in order to heat and cool the campus. Wind, PV, hydroelectric and geothermal can all generate electricity but the infrastructure at St. John's is based on central steam heating and cooling-not electric heating systems. The use of biomass should be encouraged because although it is not emissions free, biomass fuels offer lower emissions than fossil fuels and environmental sustainability at a comparable cost to other fuels.

The load that the biomass will handle is dependant on the source of biomass, its abundance, heat value and density, as well as the infrastructure that the plant invests in. A co-firing project with a 5% biomass mix would cover 5% of the current heating and cooling load and 5% of electricity generation. If an entire boiler were converted to wood biomass than a much more significant portion of heating and cooling could be accomplished using biomass fuels although at a much greater capital cost.

**Campus sources of biomass**

The Saint John's wastewater treatment plant produces 12-15 dry tons of biomass annually.[258] This could be used as a fuel source or the **wet sludge** could be used to generate methane. Currently the 200,000-250,000 gallons of wet sludge generated at the plant annually are being spread on lands contracted or owned by the University. There has recently been a proposal to utilize this dewatered sludge as fuel at the power plant but it was rejected in favor of the current system due to economic reasons. In order to burn the sludge it would need to be dewatered in a separate facility situated somewhere near the wastewater treatment plant. The cost of this operation along with the additional cost of double material handling first to the dewatering facility and second to the Power Facility made this project uneconomical. If the sludge was burned, the unburned slag may have heavy metal contamination which would have to be hauled to a landfill at additional cost to the University because land spreading requires no landfill use.

St. John's has 3,000 acres of mostly wooded land which could be used as a potential biomass source. Dead or dying timber could be harvested from the woods to be used as an energy source. Retrieval of this wood would be labor intensive but could improve the overall health of the forest. It is unlikely that this source could provide the 850 tons of biomass required for a 5% cofiring operation. The labor costs associated with the retrieval of waste wood in standing forest would also have to be investigated because it is a highly labor intensive process which could make this source uneconomical. Many of the products utilized at St. John's are shipped on pallets. These pallets could be chipped and used as biomass. Wood shavings and extra wood from the carpentry shop could be collected for use but this would be a small contributor to any biomass supply.

Waste paper and cardboard from the campus could be mechanically processed to form cubes or pellets that would be suitable for firing in the stoker furnace. This plan would require the purchase of a mechanical shredder/cubing machine which could cost anywhere from $20,000-$100,000 depending on the volume it would be expected to process. Saint John's produces approximately 8 cubic yards of cardboard per week when school is in session. I was able to contact Steve Key at Bliss industries regarding pelletizing mills which could process this amount of cardboard into combustible fuel. He recommended a small system because of the relatively small supply of material it would need to process. He has not responded with any information on this machine as of this time. The **process engineered fuel (PEF)** facility at the Federal Savannah River Site cost $850,000 but it processes enough biomass to meet more than 50% of SJU's heating, cooling and electrical load. The machine we would need would be much smaller and more economical.

St. John's is located in an area with a high intensity of corn agriculture. Corn stover could be an abundant source of biomass if the right processing equipment were installed. The stover would likely be brought onto campus in the form of round bales wrapped in twine. These bales would have to be shredded and pelletized much like the paper/cardboard waste to ensure fuel consistency. Corn stover is currently used by farmers as bedding and as a feedstock so there are competing interests. The price willing to be paid is a major determinant of the availability of corn stover. Corn stover has drawbacks as a biomass fuel. Annual crops like switchgrass, corn stover and straw have high concentrations of alkali (potassium) and chlorine which lead to increased ash deposits and slagging during combustion.[259] The deposits of ash and slag increase production costs because they result in more downtime and labor put into maintenance.

### Rationale for the use of wood as biomass fuel at SJU

Wood is one of the most attractive options for applying biomass energy at St. John's. Untreated wood has very low concentrations of heavy metals compared to coal which is the number one contributor to mercury emissions in the state. Wood burning also eliminates the slagging problems associated with the combustion of annual plants because wood is very low in chlorine and potassium. The use of wood also has advantages in the material handling aspect of the operation. Wood can be chipped to a similar size as the stover coal so that similar material handling procedures can be employed.[260] Biomass fuels with smaller particle sizes can be difficult to handle and present dust particulate issues on site.

**Detailed Proposal**

There are two viable options that St. John's can pursue. The first option is to co-fire wood/PEF biomass with the coal. A 5% biomass mix would reduce our coal use by 850 tons annually (based on a typical usage of 17,000 tons of coal). It also means that a source for 850 tons of biomass would need to be located. The other option is to dedicate one of the smaller boilers to biomass fuel. Both of these options have advantages and disadvantages.

Cofiring of wood at SJU could be economically feasible if a cheap/reliable supply of wood biomass can be located or produced and if modifications required at the current plant are minimal. Plant requirements would include a chipper which could chip the wood to less than 3inches in diameter. Wood chips this size work best in stoker coal operations.[261] These chips would then have to be stored in a covered area with a concrete floor so that they could dry. The moisture content of fresh cut wood is about 50% and the desired range for wood fuel is 20-30%. Burning wet wood is possible but the heating value of the fuel is reduced due to the increase in moisture.

The current power plant has no indoor storage. The coal is exposed to the elements until it is loaded into the hopper for combustion. This practice has negative economic and environmental effects. When the coal is wet or has snow mixed with it, the efficiency of combustion is lowered because the water with the coal absorbs heat and vaporizes. The water is essentially "stealing" heat from the burning coal so there is less to heat up the boiler system. After heavy snows, the workers at the power plant have to shovel off the snow accumulation on the pile to avoid bringing in snow.

The current system of storing the coal in an outdoor pile also has negative environmental effects. A recent assessment of campus hot spots of water pollution identified the coal storage area as the number two priority area for improvement.[262] There is a drain from the storage area that feeds directly into Stumpf Lake. Hydrocarbons and particulates from the pile are washed into the lake every time it rains and is blown into the lake whenever the pile is disturbed during loading of the hopper or during high winds. A covered facility would eliminate this problem and could also be used as a storage/drying site for biomass if waste process heat were piped into the building from the power facility. A covered facility has already been looked into and the cost has been quoted at $2.4 million. This figure includes the covered facility as well as new conveyor systems for loading the coal into the main hopper within the facility.[263]

The use of biomass as a cofiring fuel would be accommodated if there are multiple hoppers feeding into each stoker. If this were the case, the biomass fuel could be loaded into one hopper and the coal into another and the mixing could occur in the stoker. The system in the power plant is not so accommodating to the use of multiple fuel supplies. One large hopper feeds a movable hopper on rails that delivers coal to all the stokers manually. Mixing of the biomass/coal would have to be done before loading the hopper. This presents several material handling problems. The coal and biomass would have to be mixed somewhere on campus prior to the fuel being loaded in the main hopper. The wood biomass may be the same size as coal but the coal is much more dense so even if the two are mixed consistently beforehand, loading the mix into the hopper and then into the stoker may lead to separation by density. It is essential that the mix be consistent or fluctuations of temperature in different parts of the stoker will occur. A trial run of this system would be required to insure that the mix stays mixed and temperature is even in the stoker.

A method to avoid the headaches of material pre-mixing is to retrofit the fuel delivery system so that the biomass is injected into the stoker separately. This plan costs more (upwards of $350 per kWh in an electrical generation facility[264]) because a whole new system of material handling equipment must be installed. This system does give the user greater control of the process because the amount of biomass injected into the stoker can be varied at any given time. With a premixed fuel, the operator only has control over how much fuel is entering the stoker, not over the proportions of that fuel. This is important because the heating value of biomass is less than that of coal and is also variable depending on its moisture content. The proposal to build a covered facility for coal storage includes a plan to build a new fuel conveyor system. The planned construction of a second supply hopper and delivery system for biomass could be incorporated into this plan because designing a biomass supply system into the new facility would be easier than trying to work one into the old plant.

**Dedicated Biomass Boiler System**

Another proposal would be to dedicate one of the smaller stoker/boiler systems (boiler 1, 2 or 3) at the power plant to biomass fuel. This would be more expensive than a cofiring operation because the current system only accommodates the delivery of coal to a central hopper where it is distributed to each stoker. This system would not accommodate a separate/different fuel source without modification. In the power house, boiler number 3 is rarely used because it was converted to natural gas when the fuel was inexpensive. Now the fuel is much more expensive than coal so the boiler sits idle. The fact that this boiler is not relied upon makes it a perfect candidate for the use of biomass fuels because if problems were encountered at startup or fuel supply problems were encountered down the road, the boiler could be shut down. One problem is that the boiler could not run biomass as now configured so it would have to be reconfigured back to a stoker type boiler system. The problems with fuel delivery also apply to this situation because a supply of wood would need to be delivered to the boiler but the mixing problems of cofiring would be eliminated.

**Proposal for sources of PEF and Wood**

Process engineered fuel can be derived from cardboard and wastepaper that the University currently pays to have disposed. A machine called a pelletizer or a cuber shreds the paper into little pieces then compresses them to form a pellet or cube. In this manner a consistent fuel can be formed to a preferred dimension so as to better mix with coal for cofiring or burn independently. Savannah River paid $850,000 for their processing system.[265] The main determinant of cost is the amount of material that must be processed. The advantage of this system is that the machine allows you to generate fuel from something that the university must pay to have hauled away. The University currently pays $500-600 a month just to shred confidential documents, a PEF processing facility would eliminate the need for this as well as landfill space taken up by paper products.[266]

There are significant incentives to produce electricity via closed loop biomass through dedicated energy crops. The federal government offers a 1.8 cent incentive per kWh and the State of Minnesota also offers a 1.5 cent per kWh incentive. The state quota for biomass is currently unavailable because it has been filled by poultry manure combustion biomass electrical plants. If we burned solely biomass in one burner we may be eligible to receive payback from federal sources for the electricity produced from the steam production of that boiler. In Minnesota, the incentive would be prorated to the kWh Btu adjusted amount of the biomass specifically. According to Minnesota Department of Commerce State Energy Office, Minnesota does have a 10% by 2015 renewable energy goal that does technically reserve 1% for biomass but that is already taken up by garbage burning for the most part (it "fits" under the statute). Xcel Energy has a 125 MW biomass mandate which has been filled by 50 MW of turkey litter burning in Benson, 33 MW of urban waste wood burning in Saint Paul and a proposed plant in Virginia-Hibbing.[267]

The financial incentives to generate electricity by using biomass fuels should not be the primary goal in promoting biomass fuel use at St. John's because as stated before- the plant is not set up to produce electricity- it is merely a byproduct of heating/cooling.

**Dedicated Energy Crops at Saint John's**

Saint John's currently owns 150 acres of agricultural land north of campus. Some of that land is used as a disposal site for the wastewater treatment plant. An additional 350 acres could be leased from local farmers on a long term basis (10-15 years) in order to establish a grove of fast growth poplars. These trees have been shown to produce an average of three to five dry tons per acre per year without irrigation. Harvesting of the trees can cost between $18-35 per ton.[268] A rough estimate of electrical generating potential is that 1,000 acres of fast growth poplars will produce 5 dry tons of biomass per acre per year. Five thousand dry tons of biomass roughly equates to 1 MW of electrical generation capacity assuming plant conversion efficiency of 30% and operating capacity of 80%. These estimates are for dedicated electrical generation facilities, the Saint John's power plant is a cogeneration plant which means that most of the energy in the fuel is used for heating, not electrical generation. A more accurate method of estimating the energy input from this source of biomass would be to use Btu values. A 500 acre plot of hybrid poplar would provide around 2,500 dry tons of biomass annually.[269] 2,500 dry tons of hybrid poplar equates to 42.5 billion Btu's of heat (assuming 8,500 Btu/pound). This Btu total equates to 2,213 tons of coal (assuming 9600 Btu/pound) which represents 7.7% of the coal demand in 2004.

**Potential Benefits**

Closed loop biomass fuels result in a net zero effect on carbon dioxide emissions, the carbon that is emitted is the same amount or less than the amount that the plant absorbed while growing. Five thousand tons of coal replaced by biomass annually is essentially stopping the release of an additional 13,550 tons of $CO_2$ into the atmosphere.

Combustion of wood is also much cleaner than the combustion of coal. Wood contains only a small percentage of sulfur compared to coal and results in lower emissions of So2.[270]

| Pollutant (tons per year) | Biomass Gasification[1] | Wood Direct Combustion[2] | Diesel Fired Turbine[2] | Natural Gas Fired Turbine[2] | Coal Fired Generation Plant[2] |
|---|---|---|---|---|---|
| $SO_2$ | >1 | >1 | 41 | 38 | 377 |
| $NO_x$ | 275 | 140 | 1,487 | 357 | 549 |
| Total VOC | 1 | 13 | 67 | 20 | 6 |
| $PM_{10}$ (controlled) | 22 | 55 | 47 | 34 | 14 |
| CO | 4 | 98 | 38 | 6 | 27 |
| $CO_2$ | Zero net | Zero net | 129,808 | 122,290 | 259,000 |
| Acetaldehyde | na | 0.07 | 0.02 | na | 0.03 |
| Acrolein | na | 0.00 | 0.01 | na | 0.02 |
| Benzene | na | >0.01 | 0.63 | na | 0.07 |
| Formaldehyde | na | 0.15 | 0.06 | na | 0.01 |
| Toluene | na | 0.01 | 0.23 | na | 0.01 |
| Naphthalene | na | 0.00 | 0.11 | na | >0.01 |
| Xylenes | na | 0.00 | 0.16 | na | >0.01 |
| Radionuclides | 0.00 | 0.00 | na | na | 0.48 |

Comparison of emissions of different fuel types.[271]

Biomass may be a cheaper form of fuel as well. The material for PEF costs essentially nothing and actually saves money in shipping and landfill disposal. The cost comes from investment in the equipment to process the PEF and retrofitting of the current power facility to accommodate it as a fuel source. The use of waste wood would involve similar costs except that the equipment cost would be in the form of a shredder. There would also be a labor cost associated with the collection of waste wood from the forest. Dedicated energy crops are probably the most expensive option of the three but they are also the most reliable and would provide the largest amount of biomass. There are also incentives available for the use of dedicated energy crops including a 1.5 cent per kWh Federal incentive for electricity generated through use of close loop biomass.

**Examples from other schools**

The University of Iowa has installed a special fluidized bed boiler to burn a 70% coal/ 30% oat hull mixture which has reduced annual coal demand by 30,000 tons.[272] The burning of biomass has decreased sulfur dioxide emissions by 60 tons and carbon dioxide emissions by 72,000 tons annually. The University obtains the oat hull biomass from the Quaker Oats processing facility in Cedar Rapids, Iowa 15 miles away. The product is brought to campus on trucks with pneumatic tankers which reduce dust. Typical coal costs are $2.00/mBtu (includes ash and limestone) while biomass purchased during a test burn was $0.50 to $1.00/mBtu. These savings allow for rapid recovery of capital costs required to modify the power plant for biomass use. A long-term (four-year) contract for biomass purchases is now in place. The anticipated annual fuel and associated cost savings with this contract are in excess of $500,000 per year.

The University of North Dakota operates a steam facility that currently fires 50,000 tons of coal/yr providing 75,000 Btu/hr of 130-psig saturated steam to the campus.[273] An assessment has identified several very promising biomass fuels, including sunflower hulls, turkey manure, sawdust, and municipal wood. The most attractive options include sunflower hulls or sawdust based on delivered costs in the $15 to $25/ton range (Coal $30/ton). The economic target is to achieve a 25% return on investment. A potential case for UND could be cofiring sunflower hulls at 50%, with a $500,000 investment, generating $125,000 per year in fuel cost savings.

The University of Minnesota at Morris is in the planning stage of a biomass project. Peak steam load at UMM is approximately 30,000 lb/hr. A 15,000-lb/hr boiler is recommended based on the financial analysis. The capital required for the project is over $3 million. The project has a projected first-year savings of $329,000, which is 36% of the annual budget for natural gas and electricity. Planned fuels include wood residue and corn screenings.[274] Wood-based fuel on the order of seven thousand tons/yr is required.

**Projected Results**

With a 5% reduction in coal use due to cofiring with biomass we could expect a fuel savings of $20,000 annually assuming that the price of coal remains at the current $47.94/ ton delivered and that the biomass costs $25/ ton delivered. The cost of biomass fuel would also become more feasible if coal prices continue to rise or stricter environmental controls on coal burning plants are enacted. Already we are seeing the effects of more stringent air pollution legislation because the University is voluntarily complying with the Maximum Achievable Control Technologies provision of the Clean Air act by adding a pollution control system to the current plant.

If biomass is used to offset coal use at the power plant the result will be a reduction in emissions which is symbolic of the stewardship advocated in the Rule of Benedict. Reduction of up to 13,550 tons of carbon dioxide annually could be accomplished if a 5% cofiring of biomass is implemented. Sulfur dioxide and mercury emissions would be reduced as well because wood and PEF contain negligible amounts of sulfur and mercury. The construction of a covered storage facility for the coal/ biomass would be environmentally beneficial as well. Even if the biomass plan is rejected, the covered facility should be built because of economic and environmental reasons. Wet coal does not burn as efficiently as dry coal because the extra water essentially steals heat from the combustion. By eliminating this excess moisture, the University will save money due to increased efficiency and will also eliminate coal dust accumulations on campus. Environmentally, a covered facility will be beneficial because there will not be a constant stream of pollution into Stumpf Lake which is contributing to its **eutrophication**.

**Priority**

This is a project that would require significant research before an investment is made. There are many variables to consider including constantly changing federal emissions legislation, escalating fossil fuel costs, biomass availability and capital investments. This is a project that SJU can do - there are some inexpensive sources of biomass near campus and there is the potential to create our own biomass supply through cultivation of energy crops.

# Solar Power

### Application

Solar power has become one of the most promising sources of alternative energy within the last few decades, and has begun to be included into the power supply during periods of peak demand in various regions around the country. Solar power can be broken into three basic concepts: collecting and using solar heat, converting solar light into energy, or using the sun's energy directly as a way to heat objects. The first concept, **solar-thermal heating**, uses reflective surfaces, such as mirrors, to reflect the energy from solar heat into a smaller, concentrated space filled with water. The energy from the heat transfers into the liquid, boiling the water and producing steam for conventional generators. The second concept is referred to as **solar photovoltaic**, and relies on a semiconductor to absorb the photons in sunlight and convert them into electricity. The final concept is called **passive solar heating**, which uses design methods and features, such as south-facing windows, to help absorb the sun's thermal energy.

### Solar Thermal

Solar thermal energy relies on the use of light to create heat and generate electricity. Solar thermal heat can be used directly as a heat source, or it can be converted into electricity. The higher the temperature of heat, the more electricity is generated in the process. This happens because higher temperatures produce more steam, whose force is then exerted on the turbine to generate electricity. By using liquid as a source of conduction (typically water), light hits the liquid, and increases the temperature. Once heated, the energy in the gas turns a turbine to generate electricity.

There are three main types of solar thermal systems: parabolic troughs, parabolic dishes, and a central receiver or power-tower.[275] **Parabolic troughs** are the most advanced and well researched of the three, and have the lowest cost for solar-generated power. They tend to be independent, curved reflector systems that follow the sun. By concentrating the light, parabolic troughs use the sun's rays to heat a fluid circulating through the main section of the system. Steam is produced by heat exchangers, which is then used to drive the electricity-generating **turbine.** Steam can then be reused as the fluid in the troughs. Overall, the temperatures produced by troughs (reaching on average 400°C) are ideal for industrial purposes.[276] A typical parabolic trough system includes a set of reflectors, a support system, receiver tubes, and a tracker. The main problems associated with parabolic troughs deal with water availability and disposal, as well as emissions produced from the heat transfer fluid, if the liquid is not water. Parabolic troughs, however, are ideal for large systems connected to the grid, which require 30 to 300 **megawatts (MW)**.[277]

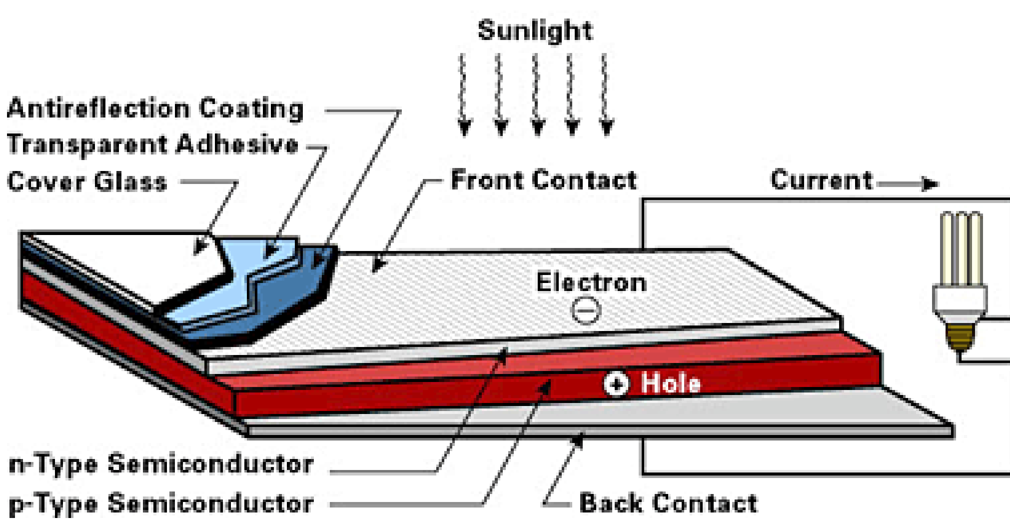
Although perhaps more efficient than the other two, **parabolic dishes** remain in the prototype phase. With a self-contained electricity generating system, parabolic dishes heat the internal fluid to extremely high temperatures. The tracks on which dishes are mounted rotate on two axes, allowing the movement to be vertical as well as horizontal. These modular and bowl-shaped systems typically stand as single units, and consist of a series of mirrors, which both reflect and concentrate the sunlight into a receiving holder. Again, the liquid in the system is heated, and by using the heat to convert the liquid into a gas, it can be used to drive an engine-like alternator. A single dish generates an average of 10 to 30 **kilowatts (kWh)**.[278] Unlike the troughs, dishes possess less possibility of damaging the environment, and aside from being an obviously large eye catcher, produce very little sound.

The last of the three, the **power-tower**, has yet to be installed in more than one plant. In this system, the tower stands amongst a circular arrangement of solar-tracking mirrors, which then reflect light onto the tower. A receiver captures the light, and uses it to heat the contained liquid. Relatively untested, the power-tower incorporates the use of a salt mixture in the liquid, which enables the system to generate and store more power (salt is a high conductor of energy).[279] The only known plant to have a power-tower is a considerably large operation, and it is decidedly best for large power facilities. Due to the premature stage of research, at this time, the power-tower may not be a wise investment for CSB/SJU.

**Solar Photovoltaic**

The general principle of electricity is that energy is created when **electrons** flow through a wire in a straight line. Therefore, the concept of using photovoltaic cells to generate electricity relies on the strength of light to force electrons into a single line. As **photons** of light hit the **atoms** in the photovoltaic cells, electrons are pushed loose and gravitate to one side of the PV cell, creating a negative charge. The opposing side produces a positive charge, and when connected to the negative side, creates an electric current.

Photovoltaic cells can be created from a wide selection of materials, with silicon being the most common. Cells are produced in several different ways, ranging from single-crystal cells, polycrystalline cells, and noncrystalline or amorphous cells. **Single-crystal** silicon cells are extremely efficient but very difficult to make, while polycrystalline cells offer just the opposite. Less efficient, **polycrystalline** cells are less expensive to produce and therefore used more frequently than single-crystal silicon cells. The last type, **noncrystalline** cells are capable of absorbing light easily but are not efficient or easily mass-produced. Often referred to as amorphous, these noncrystalline cells use a process called thin film technique, in which the silicon layer is a mere 1-2 micrometers thick. Single-crystal silicon cells (typically only a few inches in width) generate roughly .43 volts of energy, while amorphous cells generate about .5 volts. It is important to remember that the surface area exposed to light is a major determinant of the voltage produced—the larger the cell, the more voltage incurred. Aside from silicon, however, PV cells are made from materials such as gallium-arsenide, copper-indium-diselenide, and cadmium-telluride. Other materials include stainless steel, silver, amorphous silicon, and transparent electrodes.[280]

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Cross-section of a photovoltaic cell.

Individual PV cells, again, are able to produce anywhere from .6 to 1.2 volts of electric current, but are often grouped together into larger module systems. It is this ability to “add on” panels that makes solar power a desirable and easy source of energy to manipulate according to demand and use. **Modules** can be obtained with output power levels ranging from just one watt to over 240 watts, varying of course, with the size of the panels. A clear day of sun provides roughly 1 kilowatt of power per square meter, but top quality modules produce 10 or 11 watts per square foot. Most modules consist of 36 photovoltaic cells in a series, which generate about 15.5 volts at optimum sun exposure. In order to ensure maximum productivity, however, the module cannot be shaded even at the lowest sun angles. If one cell is shaded from the sun, it prevents the current from flowing through the panels, and blocks the generation of power.

To prevent this situation, modules can be mounted in a series of ways. Roof/ground, on top of a pole, on the side of a pole, and tracking mounts are all effective methods of maintaining sun exposure. **Roof mounts** require less space and consist of less wiring between the solar panel and the battery bank, but demand roof penetrations in multiple places. **Ground mounts** are susceptible to vandalism, subject to excessive snow accumulation, and require a precise foundation setup. **Top of pole mounts** reduce the risk of vandalism or theft, and are relatively easy to install. More suitable for cold climates, panels on top of poles are not subjected to snow accumulation as the snow melts off. **Side of pole mounts** are easy to install as well, but cannot support a large number of modules (only 1-4), and are best for remote lighting systems.[282]

In settings that require more power than just one module can provide, multiple modules can be mounted on a rack, called a **panel**. Able to hold up to a dozen modules, panels can be mounted in a fixed position or tilted at an angle to the sun. This tilt can be subsequently adjusted with the changing seasons to promote maximum energy output. However, if the modules are not perpendicular to direct sunlight, there will be a reduction in output. Therefore, mounting the modules on a **tracker** is far more effective, and can use reflectors to help heat liquid and move the tracking system so as to follow the sun. This large grouping of module panels onto one system is referred to as an **array**, and is still interconnected to produce a single source of energy.[283]

In a **concentrating system**, the sunlight is transferred directly into the cell, hitting at an exact 90-degree angle, producing a highly efficient energy system. In addition to the panels themselves, a concentrating system is often tied into a grid system, which then requires switches in order to connect to the power to the grid, as well as circuits and storage units such as batteries, for excess power. The necessity of being tied to the main electrical grid is a result of the inability of solar energy systems to support large energy demand loads on its own. Whether the system is tied to the grid or not, batteries can help buffer sunless periods where little energy is being produced, thus still minimizing the amount of energy being used from the main grid. Concentrating systems often rely on the use of trackers, which come complete with motors, multiple speeds, and a controlling device. Without the use of a tracker, the sunlight becomes diffused and the direct, concentrating effect of sunlight penetrating into the cells at a 90-degree angle is lost. If installed or mounted improperly, the tracking system will not work. Not all PV systems are concentrating, since these units are difficult to install on residential roofs and not suitable for other small areas. The advantage to concentrating units is the amount of silicon used in the cells, which is about 100 to 1,000 times less than other flat panel systems. As with any manufacturing process in which silicon, metals, or minerals are used, the amount of silicon used is proportionate to the amount of pollutant expelled during the production. The less silicon used, the less emissions are released from fumes.[284]

Photovoltaic systems, capable of producing 100 watts or more, generally cost between $5.00 and $30.00 per watt.[285] When installing PV systems, larger systems are recommended since small systems are expensive to install and have lower return values. The larger the solar energy system, the more power it will produce, making the investment itself more profitable. The actual cost of PV modules is often 1/3 to 1/2 of the cost of the entire system, with the production of each PV watt averaging at about 2-6 watt-hours of energy per day.[286] However, location and season affect these results, and panels often produce more or less energy outside of this range.

**Passive Solar Heating**

While more difficult to implement on older and already existing buildings, passive solar heating is one of the best ways to use the sun's energy for free. By using designs specifically geared towards absorbing the sun's direct energy, electric bills can be reduced by as much as 50%.[287] This third technology is essentially cost-free, and requires no additional mechanical means except window installation or use of existing window placement.

There are two main principles to passive solar energy, passive solar heating and passive solar cooling. The first involves using south-facing windows specifically designed to let in the sun's light and heat, while acting as an insulation device in cold weather. (For additional information on windows and insulating or heating efficiency techniques, see the Windows Conservation Proposal section.) In warm weather, passive solar heating allows light into the building while reducing the heat absorption.[288] The most common design, and by far simplest, is the **direct gain system**. In this system, the building absorbs the sun's energy as the light shines directly into the structure. The heat is then stored by the building's **thermal mass**, which includes materials such as brick, stone, concrete, or other masonry walls that retain and slowly release heat.[289] An **indirect gain system** relies on the thermal mass being placed between the sun's rays and the building's interior. An **isolated gain system** involves a separate location, such as a sunroom, in which the heat is distributed to other areas in the building by means of a **convective loop**.[290]

The second aspect to passive solar heating is **passive solar cooling**, which operates on a similar level by maximizing the sun's energy when it is most needed, and reducing heat when outdoor temperatures are high. Since most passive solar heating systems include natural ventilation for cooling, the installation of operable windows and vertical panels (wing walls) can actually increase the airflow within the interior of a building. This added benefit of solar passive heating/cooling helps reduce the amount of electricity purchased for summer cooling.[291] Two of the most outstanding benefits of passive solar heating and cooling systems include a higher quality of health as well as the reduction in electric bills for lighting, cooling, and heating. Often referred to as **daylighting**, this increased exposure to sunlight and natural air venting has been shown to improve productivity and health. Already implemented in many schools, daylighting has also had clear impacts on helping improve student grades and attendance.[292]

**State of Technology**

Homeowners who invested in the installation of solar photovoltaic systems in their homes have experienced a positive downshift in energy purchased from large electric companies. Since the energy produced by PV panels is factored into the total electrical current flowing into the house, solar powered systems not only help decrease energy bills for cooling, heating, and lighting, but also run even the smallest home appliances. While most home installation systems are off the grid, the future hopes to generate an energy source in which the customer helps produce much of the public power and adds to the utility-supplied sources. Many businesses, commercial and government sectors have used PV technology to power offices, stores, educational centers, and even hospitals. Industries such as communications and transportation use solar energy for boats, cars, and recreational vehicles, while agriculture and manufacturers have found it a clean and reliable way to produce consumer goods or pump water. It has been proven and used since the late 1970s and is now a confirmed, reliable, clean source of energy.

**Campus Context**

Minnesota has high potential for rich solar resources, and has radiation levels comparable to those of Houston, Texas and Jacksonville, Florida.[293] (See below.)

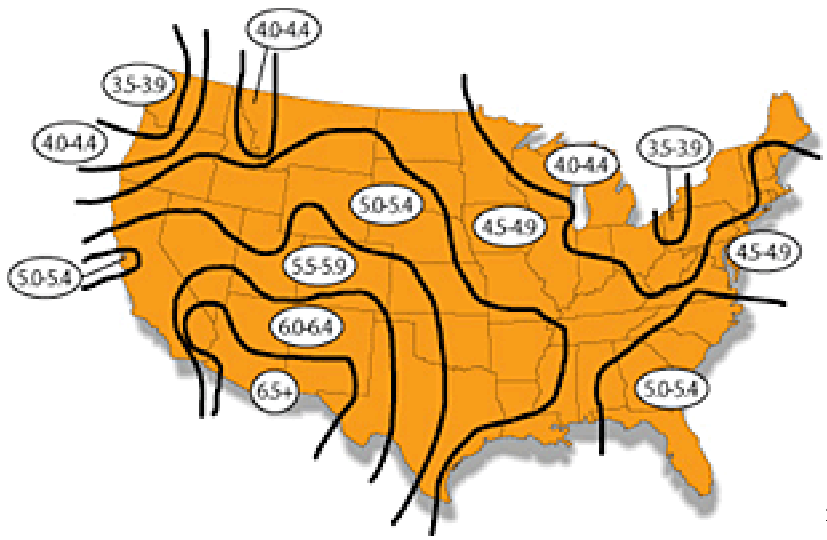


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Illustration showing location and solar radiance

Even in Minnesota's coldest weather, PV panels are durable and able to function without impediments. Being located in central Minnesota, both institutions would have ample space to install solar photovoltaic panels or solar thermal units. Smaller sections of PV panels could be installed on remote campus buildings, experimental dorms, or even independent campus housing locations. Hard to wire locations, such as Flynntown bus stop, Clemens bus stop, or the St. John's sugar shack would be ideal places to install solar panels. Installing PV panels in these places would reduce wiring costs as well as reduce the unnecessary amounts of energy lost in transferring electricity to remote locations. Other ideal locations for solar trackers or mounted arrays would be open fields, such as near the St. John's soccer field, or the St. Ben's soccer field. Any large, open space would be suitable for a large-scale installation of solar panels, provided that the panels or arrays are pointed in the proper direction and angle for best results. (See diagram below.)

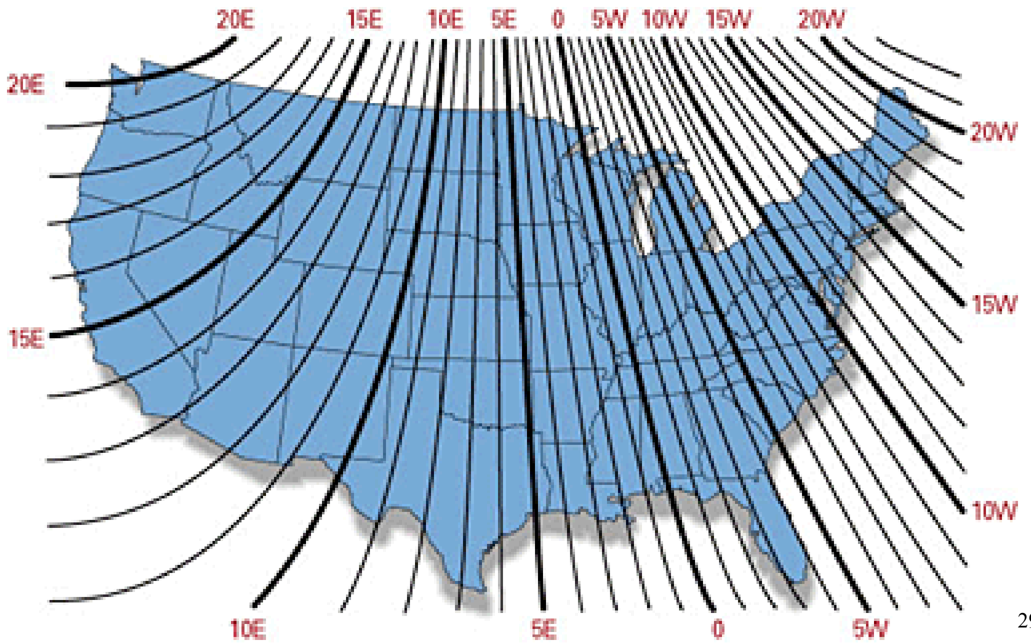

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Figure shows the relative angle of proper positioning for solar panels or dishes according to location in United States

**Detailed Proposal**

The proposal for solar power in the form of photovoltaic panels would be to address the more remote areas of electrical use. Both bus stops, Flynntown and Clemens, can be installed with 1 to 10 photovoltaic panels in order to support the lighting needs during the day, as well as the hours of nighttime use—a total of several hundred watts. This investment would range between $1,000.00 and $5,000.00, depending on the number of panels installed. Solar panels typically range in the area of 100 to 150 watts, and will, at most, produce around 30 kilowatt hours of electricity per day. At $5.08 per watt, a panel capable of producing 115 watts would cost $585.00. [296] Therefore, the installation of five panels at the Flynntown Bus stop would produce around 750 watts and cost just under $3,000.00.

Installation of several arrays of solar modules is recommended for off-campus housing (such as the Environmental house, Margaret House, Edelbrock, and the Annex), as well as residence halls on campus. These buildings should have a minimum of twenty solar panels installed, which could at most produce around 3,000 watts—a small load of the total energy demand. Costs for twenty solar panels on a building roof averages between $10,000.00 and $12,000.00. Other large academic buildings with potential for solar power include the CSB

Academic Services Building, CSB residence halls such as Regina, Corona, Aurora, SJU residence halls such as Tommy and Mary. Since these buildings tend to be larger in capacity, it would be wise to make an initial installation of a few panels on smaller campus buildings and then make gradual progress.

However, if a much larger investment is desired, a large capacity solar power dish at either campus could be installed in order to cut purchasing of electrical needs from Xcel. The dish should range from 100 kWh to 300 kWh, and offers a larger investment and higher energy production than an installation of PV panels. This dish should be installed in any of the large open areas at either campus, such as near the soccer fields or on the outskirts of the campus grounds. In essence, any location with ample sunshine is suitable for a large solar dish.

**Benefits**

Solar power has many substantial benefits that other alternative sources do not offer. Since the sun is always giving off direct energy, photovoltaic systems are usable anywhere that has direct sunlight. Even on the cloudiest days, small amounts of energy are absorbed and converted into electricity. Solar energy itself is pollution-free, infinitely renewable, and helps create a sustainable system of energy provided across the globe. PV systems help offset fossil fuel use and reduce costs of energy as well as pollution. Solar energy and photovoltaic systems tend to be less expensive than grid electricity connections, especially in remote places or for small buildings. In fact, photovoltaic panels produce roughly four times the amount of energy used in its production, a statistic which continues to increase. The public benefit of using an energy source such as solar power is the confirmed knowledge that the environment is not being harmed or the atmosphere being polluted. For those people concerned about wise land use, photovoltaic panels are excellent ways to promote efficient land use by installing them on rooftops.

Solar power has other wide-scale benefits, such as net metering, distributed applications, and green marketing.[297] Solar PV systems are immune to energy price shocks, and the average payback period is five years. PV systems produce power during periods of peak energy demand and energy prices, while reducing demand from the expensive plants providing power during those periods.

On an educational and institutional level, the implementation of solar power sends a powerful message to other schools and businesses. It enforces the environmental ethic deemed to be important by both the College of St. Benedict and St. John's University. While not a significant source of energy, solar power is the recognition of the need for alternative and clean energy sources. At the same time, it provides students with a learning opportunity, and the schools with tax incentives and financial benefits.

**Costs**

Costs for solar photovoltaic systems are still relatively expensive, yet worthwhile in the simplicity and low-maintenance electricity-generating system they offer. Recent state and federal funds and grants help make the installation and financing of solar photovoltaic panels easier for homeowners, businesses, and institutions. While the bulk of the cost depends on the size and extensiveness of the system desired, the average single PV panel costs $400.00 to $1,000.00. However, a good indicator of how much a small dorm complex would cost, an entire typical, off-grid household system (complete with batteries and inverter) ranges anywhere from $10,000.00 to $40,000.00.[298] Installation costs for a high-efficiency silicon solar panel runs $3.00 per watt, but is projected to be $1.00 a watt by 2007.[299]

Again, the initial costs of installing a PV system at the College of Saint Benedict or Saint John's University depends on the type installed. If the institutions are looking at a larger system, a parabolic solar dish or trough would be the best solution. A parabolic dish typically runs from $300.00 to $3,100.00 per square meter, while a parabolic trough costs $275.00 to $630.00.[300] Solar dishes, more practical for a large institution, are projected to cost roughly $15.00 per watt, but are expected to drop by 90% by 2006. [301] By 2010, solar cells are expected to generate electricity at a mere $0.06 per kWh. In general, the cost of photovoltaic-generated energy ranges from $0.20 to $1.00/kWh.

As research advances and economic improvements are made Manufacturing costs for solar panels have declined. While professional installation teams are provided for by many of the solar panel producers to help with the installation of large systems, it is not completely necessary to receive outside help for small systems involving only a few panels. Once the solar panels are installed, they are virtually maintenance-free. On a typical building or home, solar panels are installed on low-profile mounts, and lay flush against the roof. The average PV panel has a lifetime of 25-30 years, and is able to withstand most weather conditions without constant care or maintenance, including snow or ice. Photovoltaic panels, as with most solar power sources, remain simple in design and are attractive to the eye. Unless installed on a tracker, the panels themselves contain no moving parts and are not subject to wear.

A positive aspect to cost issues is the payback period for solar photovoltaic modules. Falling from 6.4 years in 1977, the payback period for any major investment or large system was estimated to range from 0.9 to 1.6 years just fifteen years later in 1992.[302]

**Examples from other Schools**

Universities and colleges have made considerable progress in installing solar powered systems for energy and are now witnessing the benefits of a clean, renewable, and reliable energy source. In 2002, Clark College in Vancouver, Washington, installed solar photovoltaic panels on the overhead crosswalk flashers and in-pavement warning lights. While the city itself has already progressed to solar-powered buildings, telecommunications equipment, bus stop and street lighting, and crosswalks, the campus is making small steps with remote locations that are otherwise expensive to wire and run electricity to. The on-demand nature of crosswalks was deemed prefect for the PV panels, since even on a cloudy day energy is being produced and stored in battery packs. In order to fund the small-scale project, Clark College received a grant funding from the Washington State Transportation Improvement Board, in the hopes of promoting solar-powered applications.

In 2003, Stanford University installed a 54-panel PV solar energy system on one of the student housing buildings, Synergy House. A historic, wood-framed mansion, Synergy House was in need of major repairs and most importantly, a new roof. The three-year long project resulted in the array of panels being installed on the roof of the building. While members of the house are involved in other environmental initiatives, the solar panels is the most recent and most ambitious. The PV panel system, arranged in three arrays with 18 panels each, produces more than 11,000 kilowatt-hours of electricity per year, and reduces carbon dioxide emissions by a staggering 15,444 pounds. Cutting energy costs by 20%, the panels on Synergy House originally cost roughly $50,000.00. However, the college qualified for a $30,000.00 rebate from the state for the installation of PV panels. Student Housing funded the remaining $20,000.00 for the project.

The University of Oregon is another major advocate for environmental awareness and also took great measures to launch a large-scale "green" project. The University Ecological Design Center (EDC) was awarded a $100,000.00 grant by the student government to install a grid-tied photovoltaic system on university rooftops. The Ecological Design Center further expanded the project by 25%, by taking advantage of a tax credit available by Oregon's Department of Energy for renewable energy projects. Started in 2001, the project is now currently in its second phase. In 2004, the University installed eighty-four *Isofoton* 150-watt solar modules and four PV Powered 2800-watt inverters onto the roof of the University's Rec Center. The University is expecting the solar panels to produce approximately 40-kilowatt hours of electricity a day, or 14,500-kilowatt hours each year. However, due to a new technology designed by Energy Design Co., *Isofoton* modules were mounted to the metal roof without penetrating the roof, unlike standard roof mounts. The University hopes to finish the third phase by installing a solar information kiosk in the student center, which would allow people to monitor the energy use, costs, savings, and environmental impacts of having solar powered buildings.

**Projected Results**

Depending on the size and extent of the solar PV panels or type of dish installed, the projected savings in dollars averages $5,000.00 or more per year. Similarly, the savings of kilowatt-hours used would be substantial, totaling several thousand kWh produced on site and not purchased.

Included in the projected results are the environmental benefits. Carbon dioxide ($CO_2$) emissions would be reduced by millions of tons, and nitrous oxide (NOx) emissions would be reduced by several thousands of pounds as well.[303] These two emissions are the leading causes for environmental problems such as ozone depletion, as well as health issues, and when combined in the atmosphere with other gases, have been shown to destroy the environment and property.

Solar power is an attractive and beneficial source of energy for both institutions. Used especially as an educational tool, the addition of using an alternative and renewable, as well as clean, energy source will have a profound impact on future classes of students at the College of Saint Benedict and Saint John's University. The alternative energy source simultaneously provides opportunity for students to be actively involved and participate in not only the future of the schools, but in the future of our environment and planet. By student-lead initiatives, such as fundraising or campaigns for clean energy awareness, solar power as an educational tool is used and reused every year. In addition, the long lifespan of solar power will pay off the investment in only a few years, producing more energy and returns than simply purchasing power from Xcel.

**Priority**

In addressing the issue of what the two institutions can do to begin increasing the use of solar power, the main objective would be to start small. Installing panels on office windows, on the roofs of buildings, smaller campus apartments or houses, would help begin the move towards a new, renewable source of energy. The primary goal is to establish an idea for how effective the panels would be on the CSB and SJU energy use, and upgrade from there. It would be fairly unwise to invest in a large system until both schools were competent in how much energy was being used yearly, and to where energy was being sent. St. John's University has no concrete metering process, and therefore it would make the task much harder to see any improvement or reduction in purchased energy from Xcel. Priority should first be placed on establishing an efficient metering system, and then invest in installing solar PV panels on several of the smaller buildings or remote bus stops, etc.

The College of St. Benedict and St. John's University are responsible for leading the way in our local community for advocating solar energy and other sustainable energy sources. In order to gain support for such a decision, it is imperative for the institutions to create awareness for students and faculty when addressing the need and benefits of solar power. Without awareness or encouragement on behalf of the faculty and staff, the application of solar power (or any conservation effort) would be fruitless. Several schools have established competitions in order to raise funding or increase student awareness, and similar competitions could be easily instituted between CSB/SJU education facilities, student housing, or even between the two schools. Such incentives could include a monetary award, a tuition cut, or even winning an honorary award or special privileges for the outstanding "team". (For more information on competitions and incentives, see the Competition Conservation Proposal section.)

# Fuel Cells

### Application

As ways to decrease our dependence on fossil fuels are explored, fuel cells have recently received a lot of media attention. And rightly so – fuel cells are an exciting technology because they have the ultimate possibility of taking only water molecules, creating electricity and heat, with a by-product of oxygen, all fueled by the endlessly renewable solar power. As wonderful as this sounds, the fuel cell industry is unfortunately not quite at the point to be able to offer those technologies.

The technology for large-scale energy production from water is not yet available – hydrocarbon sources are currently used. Although these sources are much cleaner than some alternatives for energy generation, i.e. the coal plant at St. John's, they are still using fossil fuels. However, the industry is making great strides each day; and, although they may be far from offering us the utopian situation described above, they are close to offering excellent intermediate options.

### State of Technology

The fuel cell industry is a growing industry. As of December 2004, the number of complete systems built (defined as capable of independent power production) is 11,000, over 10,000 of them built since 1995[304]. In a survey of all large stationary power applications, phosphoric acid fuel cells are the most popular, with molten carbonate fuel cells taking second place, although lots of developments with proton exchange membrane fuel cells and solid oxide fuel cells are happening, so technologies in this sector are still somewhat diverse. The number of companies getting involved with the large stationary fuel cell sector is also increasing[305]. With all of this information, General Motors (GM) hopes to be able to develop and market a large stationary fuel cell for use in powering buildings and large building compounds.

A company named Dow is making an exciting technology innovation for large-scale energy generation fuel cells. Dow has partnered with GM to supply the fuel cell for their project. This project gives GM the opportunity to test and further develop its technologies in large scale, real world application, in hopes of preparing their fuel cells for more widespread and commercial use[306]. GM and Dow have now moved into Phase II of their project. Phase I, the pilot stage, involved learning about hydrogen purity requirements, fuel cell waste heat recovery, and improving the power reliability of the fuel cells[307].

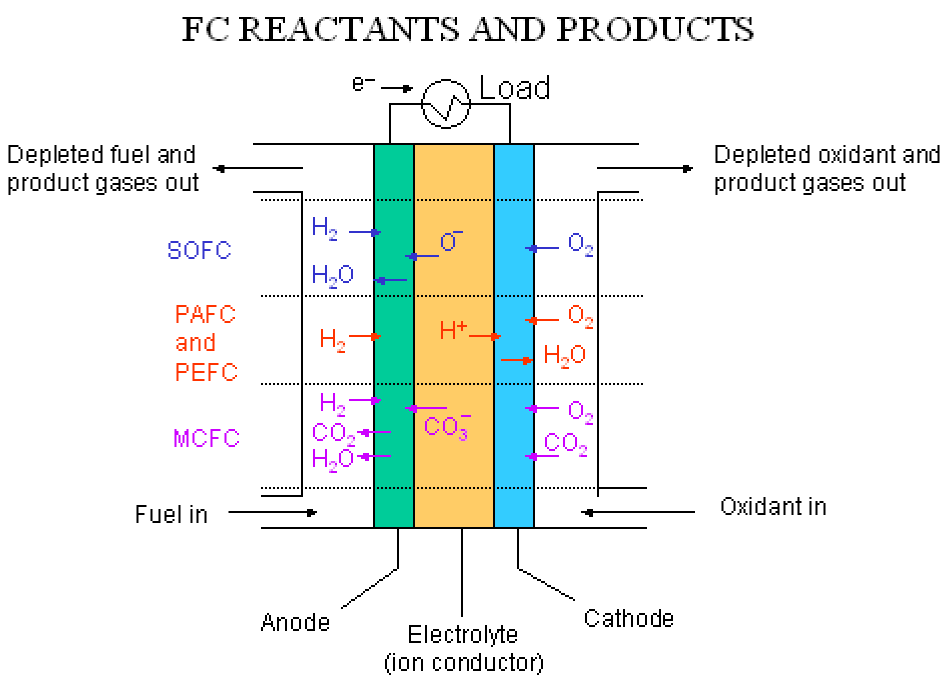
Some skeptics say that hydrogen fuel cells will never end global warming because fossil fuels are still needed to produce pure hydrogen – renewable energy does not currently produce enough energy here in the United States to support the amount of hydrogen needed to make the kind of widespread changes that are being talked about. However, there are many more possibilities and opportunities for the development of processes that create hydrogen without using fossil fuels, so although those changes might not be possible at this moment, once those processes are perfected or improved, fuel cells truly will[308].

Other skeptics say that hydrogen gas leaks could be very dangerous. Hydrogen is an odorless and colorless gas, and if compressed, as would be if it were used as an efficient fuel, then a cell phone or a lightning storm could potentially provide enough energy to ignite hydrogen. On the other hand, proponents of hydrogen would say that it is no less dangerous than gasoline, with vapors that can be ignited by a cell phone. On a political note, although President Bush has pledged his support to fuel cell research, as well as the development of other forms of renewable energy, much more money needs to be committed if the government wants to get serious about the further development of hydrogen. In 2003, the federal government budgeted more money for promoting healthy marriages ($1.9 billion) than it did for fuel cell research ($1.5 billion)[309].

Despite all of these objections proposed by the skeptics of fuel cells, there are many more optimistic researchers and developers who strongly believe that fuel cells are a viable option for our energy future. Switching to an energy source that is not derived from combustion greatly reduces pollutant emissions. The ideal fuel cell would use a fuel of pure hydrogen gas that was easily created and stored, along with oxygen from the air to create water as the only byproduct. However, since pure hydrogen is not easy to create and store, there are alternative fuels that can be used in fuel cells until our hydrogen technology advances. Fuels such as natural gas, and ethanol are easy to find, with an infrastructure already in place for them, and, although they may not be the ultimate fuel source for hydrogen fuel cells, they are a step in the right direction. They are cleaner than the current coal plants, and are safer than nuclear power, as they create no toxic waste, or waste storage problems.

## How Fuel Cells Work

Fuel cells use electrochemical reactions to convert a fuel's chemical energy into electrical energy that we can use to power buildings, lights and appliances. Fuel cells are very efficient because they do not use combustion to generate their electricity. They operate very similar to the way a battery operates. On one end of the fuel cell is a positively charged cathode, and on the other end, a negatively charged anode. In between these is an electrolyte[310]. The substance that this electrolyte is made of determines the type of fuel cell it is. For example, molten carbonate fuel cells (MCFC) have an alkali carbonate as their electrolyte, whereas a proton exchange membrane fuel cell (PEMFC) uses a solid polymer for it's electrolyte.[311]




The electrochemical reactions occurring in of few of the principle types of fuel cells – Solid Oxide (SOFC), Phosphoric Acid (PAFC), Proton Exchange Membrane (PEFC), and Molten Carbonate Fuel Cells (MCFC).

Some fuel cells, such as SOFCs, and MCFCs, need to be run at high temperatures – up to 1800 ºF. Not only can this heat be recaptured and used for cogeneration, but it can also be taken advantage of because internal reforming of fuels, like natural gas, can be performed.

Instead of obtaining hydrogen by extracting it from fossil fuels, electrolysis is a possible process that could be utilized. The basic process of electrolysis is just running the fuel cell backwards. Water would be used as an input, and hydrogen and oxygen would be the outputs. However, electricity and energy would also be needed to run the electrolysis process. Currently it is still more economically efficient to use fossil fuel energy sources for electrolysis, because those sources are so cheap. Ultimately, the goal is to run all of electrolysis processes with solar, hydro or wind energy[312]. This would make the whole process a truly sustainable and renewable cycle. It would first separate and obtain pure hydrogen and oxygen from water molecules with electrolysis, powered by a renewable energy source. Then it would efficiently convert the chemical energy in those hydrogen and oxygen atoms into electrical energy, and in the end, recombine the hydrogen and oxygen molecules to regain the output of water. This water could then be looped back to the beginning electrolysis process, completing the cycle.

**Campus Context**

The best application for fuel cells at our schools might be at CSB, simply because the energy use on the St. Ben's campus is metered and therefore known, which aids in choosing the right fuel cell type and size. It would also allow the fuel cell's energy production to be monitored more easily than on the St. John's campus. There are many possibilities and options when choosing to install a fuel cell. Here are two possible suggestions. For educational purposes, a possible location on the CSB campus that might make the most sense would be near the Ardolf Science Center, which houses the chemistry department.

If a smaller scale project is desired, a 250 kW direct fuel cell from FuelCell Energy, Inc. has an internal reformer and can run with a variety of hydrocarbon fuels, including natural gas. FuelCell Energy's fuel cells run at high temperatures, making them good options for cogeneration[313]. If run at peak levels year round, this would create approximately 2,190,000 kWh. If this fuel cell were applied on the St. Ben's campus, it would save approximately 27% on energy costs, based on energy uses during the 2003-2004 school year, and not including extra savings if the collection and use of the exhaust heat were used. This type of fuel cell could be installed in a way that it would take one or two of the buildings off the grid. The dimensions of this size fuel cell are 10.5 feet high, 9 feet wide and 28.1 feet long. This fuel cell would generate 300,000 Btu/hr of exhaust heat, all would be available to help with cogeneration[314].

If a larger project is something the colleges are interested in, there are also fuel cells that would cover the energy needs of the whole CSB campus. This type of fuel cell would be something similar to FuelCell Energy Inc.'s 1000 kW model. At yearly peak energy generation rates, this fuel cell would generate as much as 8,760,000 kWh. These models are modular and scalable, and so there would be the possibility of adding more units, or moving units around to different parts of campus, to accommodate any changing energy needs. A larger area would be needed to house a unit like this. The dimensions are 26.5 feet high, 43 feet wide and 40 feet long. It would also be suitable for cogeneration as well, with 1.4 million Btu/hr available from its exhaust heat[315].

Although the current infrastructure and technology in the United States is simply not ready to switch over to hydrogen yet, it would be an excellent solution to many of our energy problems when fuel cell technologies, as well as the hydrogen infrastructure needed to apply those new technologies, have time to further develop. As of now, it seems that intermediate alternative technologies are the key to start decreasing our dependence on fossil fuels as well as our greenhouse gas and pollutant emissions[316].

**Costs**

Due to the newness of this technology, fuel cells carry a high initial price. Also, little field data about the reliability and endurance of fuel cells has been collected, so unexpected and unknown complications may come up[317]. Pure hydrogen is the cleanest and easiest type of fuel for fuel cells to use, but pure hydrogen is very expensive to make and store. There is also very little infrastructure for the distribution of pure hydrogen[318]. Getting hydrogen from other sources can also be difficult and expensive, and using impure hydrogen in fuel cells can cause the fuel cells to deteriorate faster, as well as run inefficiently.

At this time, fuel cells cost around an average of $4,000+ per kW to purchase and install. The competitive energy industry price for stationary power generation is around an average of $1,500 per kW[319]. The fuel cell industry sees this factor as one of the largest factors in the limited penetration of fuel cells into the energy market. They are trying to research and develop better and more inexpensive ways to reduce the installed cost of fuel cells[320]. Some institutions have been able to receive state, federal, or private funding for larger projects, but at this time there does not seem to be outside funding available to help.

**Benefits**

Some advantages of fuel cells include a high energy to electricity conversion, good part load characteristics, the generation of unused heat, which makes the cogeneration of heat possible, quick response to load changes, and of course, low environmental impact. Other advantages include having few moving parts that might break, being nearly silent while operating, as well, as requiring little maintenance[321]. If heat from the fuel cell's processes is recycled, as in cogeneration systems, its energy efficiency can be as high as 75%[322]. In 1999, The New York Times reported that fuel cells are 25% less expensive to operate than power plants[323]. Also, since fuel cells are typically placed onsite, they do not rely on the energy grid. This is an advantage when disruptions due to storms or high area usage occur to those completely dependent on the grid[324]. Another advantage is that at times of low energy usage on campus, it might be possible to sell some of the energy produced by the fuel cells back to Xcel. The fact that fuel cells facilitate distributed electricity generation also contributes to their efficiency, eliminating the energy lost during transmission[325].

Many fuel cells need to be run at high temperatures, and if the heat from the fuel cell processes is captured, it can be easily used for cogeneration purposes. Not only will the fuel cell supply electricity to power our campuses, but if the right type of fuel cell is chosen, it can also help to heat and cool our buildings[326].

When pure hydrogen is used as the fuel for fuel cells, the process is 100% clean, and produces only water. The problem with using pure hydrogen is that it is not found in any natural state and is currently very expensive to produce and store. When other fuels are used – such as methane, natural gas, propane, etc. – pollutants are created, although at significantly less amounts than other sources of energy production[327]. Natural Gas is the cleanest of the fossil fuels. The sulfur it contains is easily removed, it produces no ash, only molecular nitrogen, and has a high H:C ratio, which minimizes the emission of $CO_2$[328].

Even if economic benefits are minimal due to the high capital cost of fuel cells, there would be important educational, public relations and environmental benefits gained if the colleges decided to implement fuel cells into their campus energy profile. If fuel cells were acquired to help generate energy and electricity for some of the buildings on the CSB|SJU campuses, our colleges would be put on the map as innovators, forward thinkers, and true stewards of the Earth. Educational benefits would come not only from learning how fuel cells work, but also from having something so symbolic here on campus – it could help to heighten the awareness of CSB|SJU students of how their energy use and actions affect the environment, as well as their general environmental awareness.

There are many negative environmental externalities associated with the current way of producing energy at CSB|SJU, which is the combustion of fossil fuels, or production of toxic waste. In most of the current energy applications in the United States, up to 90%, are generated by the combustion of fossil fuels[329]. This method produces lots of pollution – fossil fuels release into the air pollutants, such as, hydrocarbons, $NO_x$, $SO_x$ and $CO_2$, all of which contribute to acid rain, smog and other detrimental effects on the environment[330]. Combustion is also an inefficient way to produce energy - the conversion of the energy bound in the fossil fuels into electricity can be inefficient because it is limited by the temperature at which the heat may be utilized[331]. Fuel cells convert the energy in the hydrogen molecules directly into electricity[332].

**Other Schools**

The Canadian-based company Fuel Cell Technologies Ltd. is supplying 4 of its 5 kW fuel cell systems to the University of Toronto – Mississauga to power some of their student residences. The project costs a total of $1.9 million and is also sponsored by Ontario Power Generation, Technology Partnerships Canada and the U of T. The fuel cells will use natural gas for its hydrogen source, and will be used for the hot shower water, space heating, and electrical power for their computers and TV's [333]. Yale University also has a fuel cell installed on their campus in New Haven, Connecticut. The Connecticut Clean Energy Fund, along with Yale University and FuelCell Energy, Inc, helped to make it possible for the 250 kW direct fuel cell to generate 25% of the Environmental Science Center's electricity needs, as well as assisting in temperature and humidity controls in the building.[334]

A direct fuel cell from FuelCell Energy installed on the Yale University campus in New Haven, CT.

**Priority**

At this time, we do not recommend fuel cells for St. Bens and St. John's. This is due to the still developing industry and technologies of fuel cells, the high capital cost of fuel cells, and the current lack of available infrastructure to support fuel cells. If adequate funding was found or made available, or as technologies advance enough to bring the capital cost down for the entire market, fuel cells would then be something that would add many benefits to our campuses.

## Methane Digester

### Application of methane digesters

The methane digester is a well proven technology that relies on natural processes of anaerobic bacteria decomposing organic wastes to produce methane gas. This gas is then captured and burned to produce electricity or to be a heat source, similar to propane. The main part of the digester is a large tank in which organic materials, usually animal wastes, are decomposed. Waste flows into the digester in the form of a slurry, a mix of organic material and water. Once in the tank, a combination of acid producing bacteria and methane producing bacteria break down the organic material. The overall product is a byproduct of bacterial respiration. Methane, along with other gasses such as nitrogen and carbon dioxide, mix together to become biogas. This biogas is then collected from the digester and moved to a storage tank. It is important for the tank to stay at a constant temperature because of the sensitivity of the methanogenic bacteria. In addition, the higher the temperature is in the tank, the faster the bacteria will produce methane. Most digesters are maintained at about 95 degrees Fahrenheit.

Use of biogas as a fuel source has several advantages. The first is that it is clean; the burning of biogas does not release any harmful particulates or heavy metals into the air, and it combusts efficiently into carbon dioxide and water. Biogas also has an advantage in that it is renewable. Because it is made from the organic wastes of animals, there will never be any threat of running out of this fuel source. Additionally, biogas replaces the need to burn fossil carbons, such as coal. Methane is also one of the most potent greenhouse gasses and so its combustion would reduce SJU's impact on global climate change.

Methane digesters do have draw backs, however, especially in a university context. First, it needs a relatively large and constant source of organic waste. While human waste does work, the campus flow may not be large enough to support significant methane production. Second, the digestion process does not use all of the solid material present in the input and does nothing with the nitrates, phosphates and other inorganic compounds found in manure. As such, a use for the effluent would need to be found. In an agricultural context, this effluent is used, quite effectively as a fertilizer and St. John's would be able to use it in this way. The third drawback is the sensitivity of the digesters. In addition to the energy cost of maintaining the high temperatures needed, they require a certain amount of maintenance and personnel would need to be trained in its upkeep.

**Campus context**

A methane digester at St. John's could reduce the campus' dependence on coal for heat and electricity. The private sewer system at St. John's and the on-site waste water treatment plant seems to provide a perfect opportunity for this generation system. Currently, waste from the campus sewers is brought to the treatment plant where it is processed. The waste water is first mixed with Alum to lower the concentration of phosphorous in the waste. Then the wastes are allowed to settle and a large portion of the water is decanted off and deposited into East Gemini Lake. The remaining material is then moved through an aerobic digester to break down the active organic components. The digested material is moved to a storage tank. Semi-annually, the contents of the tank are transported and spread on farmland owned by St. John's.

The digester would most easily be located in the immediate vicinity of the waste water treatment plant and would essentially become part of that complex. The space needed for the digester would likely not be an issue, though the energy produced would need to be transported to a usable area, creating certain logistical problems.

**Cost**

Haubenschild Dairy Farm, near Princeton, MN installed a digester costing approximately $350,000 in 1999 for a relatively simple plug flow digester system designed for a capacity of 1,000 cows. The US EPA estimates the cost of a digester for the average farmer at approximately $550/cow. St. John's does not produce as much waste as a large dairy operation. According to an interview with Paul Stock, the manager of the wastewater treatment plant, SJU produces 200-250,000 gallons of usable waste every six months, with a slurry concentration between 2 and 2.3 percent solids. This translates to approximately 330 kg of solids each day.

Installation is done by private contractors and two have been located within a reasonable distance of St. John's. IEC Covers and Applied Technologies Inc. both install digesters, but because the specifics are so dependant on the specific project and site, no estimate of installation cost has been obtained.

Most descriptions have labeled digesters as relatively maintenance intensive, as they require daily upkeep. The bacteria systems are sensitive and heat reliant, which could produce problems especially in the deepest part of winter. Personnel would certainly need to be trained in the upkeep and maintenance of the digester, though this is hardly different from any other form of power generation or mechanical system.

Fund raising possibilities for this project are not promising. Many agricultural initiatives offer loans to farms for the installation of digesters, though there was no mention of municipal applications. Because the technology is well established, it is also unlikely that government funded grants would be available. The most likely source of funding would be though private donations or university capital.

**Current uses and results**

Methane digesters have been in use in agriculture since the late 1970's and the technology is well established. Many livestock operations throughout the world make use of this technology as a way to generate power and process manure. The sizes of these digesters vary greatly depending on the individual place and its waste potential. Larger municipal waste treatment plants have also used this technology with consistent success. Information dealing with agricultural uses of digesters is common and abundant, most showing an average power production of somewhere around 50 kW, though the St. John's campus could not produce enough organic material to run at that level most of the time.

**Projected results**

Installation of a methane digester would provide several advantages to the St. John's campus. First, it would contribute a non-fossil based form of electricity reducing the campus' dependence on power from Xcel Energy and therefore lowering fossil carbon emitted into the atmosphere. It also has the potential for augmenting the current heat/electricity cogeneration system used by the campus. This would allow for the current infrastructure to remain largely the same, but reduce the amount of coal the campus uses to keep the boilers heated.

Based on current waste volumes and conversion factors found in Peter-John Meynell's book "Methane: Planning a digester" the gas produced by a digester using only waste from the St. John's campus could be burned to daily produce as much heat as 271 pounds of coal. Reducing coal use by this annually would save the university about $2000 dollars annually.

**Priority**

The installation of a methane digester on the St. John's campus would probably not make economic sense in the long run. The cost of the new equipment to refit the wastewater plant, combined with the energy costs required to keep the digester at an optimal temperature would vastly outweigh the marginal savings such an undertaking would bring. If an anaerobic methane digester were to be installed it would be largely for the educational and environmental benefits it could bring.

# Detailed Recommendations

## Introduction

Our knowledge of the different proposal changes on the St. John's University and the College of St. Benedict's campuses have lead to conclusions of the specific recommendations. These conclusions have helped to narrow down the specifics of the certain issues of alternative generation for electricity as well as conservation options for the campuses. Certain issues are more feasible and applicable to our campuses, and have a higher priority. The following summarizes priority recommendations for these two institutions.

## Alternative Generation

*Top Priority Recommendations*

**Wind Powered Turbines**

Wind energy is an excellent option for alternative generation. Two 1.5 MW or two 2 MW turbines installed at CSB/SJU could supply a large amount of electricity for each respective campus. With educational awareness of environmental benefits and public relations in upholding the Benedictine value of stewardship, the investment in wind energy is a legitimate and rational proposal. Through a combination of turbine(s) on campus, the two institutions can demonstrate our leadership and environmental awareness as a community.

**Solar Power**

Solar power is a viable option for renewable energy generation. The most economical application of photovoltaic panels on campus would be at the Flynntown and Clemens bus stops. On an educational and institutional level, the implementation of solar power sends a powerful message to other schools or businesses.

*Marginal Recommendations:*

**Hydro Electric**

Hydro electric systems can be installed into any moving water source. Initial tests need to be administered in order to determine the flow of the actual water source. A hydro electric system can be installed in a location for $3000, including the installation and machinery required to operate the system. Potential results include providing electricity to our campus via water, therefore reducing the need to purchase power from Xcel.

**Biomass**

Biomass fuel could be incorporated into the current combined heat and power facility at SJU. There are two possible options for the use of biomass as a fuel source. Cofiring would involve burning a percentage of biomass with the coal that is currently used. This option is relatively inexpensive because the same fuel handling systems could be used. An entire boiler could be dedicated to biomass. This option would be more expensive because upgrades to the fuel handling system would be necessary. Economic savings from the installation of a biomass system would be dependant on the cost of the biomass used. A detailed feasibility study would need to be conducted in order to determine how appropriate this fuel source would be for SJU.

**Gas Microturbines**

Gas microturbines are also an alternative option at CSB/SJU. They can be used to generate electricity and heat any building on either campus depending on the individual turbine's capacities. Unfortunately, the price of natural gas on these campuses is more expensive than anywhere else in Minnesota. The cost of producing electricity and heat from gas microturbines would be $.024 per kWh. The best option for CSB/SJU should be to use microturbines for heating and pumping the pools, as many other colleges have done.

**Geothermal Heat Pumps**

Geothermal heat pumps are usually installed during the construction of a new building, however they can be retrofitted to current buildings if done properly. A loop system can fit almost anywhere, from under a parking lot to under landscaped terrain. As most geothermal systems are used in construction of a new building, it would be most viable for the institutions to implement this system in future buildings, such as the construction of the Abbey Guest House.

*Low Priority Recommendations:*

**Methane Digesters**

Methane Digesters would provide several advantages to SJU campus. First, they contribute a non-fossil fuel based form of electricity, reducing the campus' dependence on power from Xcel Energy and lowering fossil carbon emissions into the atmosphere. It also has the potential for augmenting the current heat/electricity cogeneration system used by the campus. This would allow for the current infrastructure to remain largely the same, but reduce the amount of coal SJU uses to keep the boilers heated. The installation of a methane digester at SJU would not be economical. If an anaerobic methane digester were to be installed, it would be largely for the educational and environmental benefits it could bring.

**Fuel Cells**

Fuel cells are not recommended for our campuses even though the technology has great potential. Hydrogen is the fuel source for fuel cells, but is expensive and not readily available in this area. The technology is not fully developed and is uneconomical at this time.

## Conservation Proposals

*Top Priority Recommendations:*

**Conservation Competitions**

Conservation competitions would help reduce energy consumption and build awareness of consumptive habits among students, staff, and faculty. Conservation competitions are cost effective and simple, providing an easy way to encourage energy conservation.

**Computers**

Computers are a major source of energy consumption on both campuses. A combined conservation plan of energy usage monitoring and computer sleep techniques on both campuses would be cost effective and save money. Specific software designed to assist in turning off idle computers can be downloaded onto any network-connected PC. Once connected to the network, the software would monitor the computer's energy consumption and control computer sleep and shutdown modes.

**Appliances**

More efficient appliances should be installed on campus. It is recommended that CSB/SJU invest in Energy Star appliances in order to curb the amount of energy used in inefficient products, such as refrigerators, TVs, VCRs, radios, washers and dryers, and microwaves.

**Vending Machines**

Energy Star vending machines **s**hould be supplied by First Choice and Bernick. These machines would include motion sensors, limited lighting, and temperature fluctuating capabilities. Converting the current vending machines to Energy Star would be cost effective.

**Automobile Restrictions**

Regulating the number of automobiles on campus would allow some parking lots to be eliminated, creating space for vegetation. This proposal is directed primarily at first and second year students, who typically live within walking distance of the bus stops. Major benefits include the improvement of air quality on both campuses and an overall reduction of carbon dioxide emissions.

**Metering**

Metering on the SJU campus is a priority because accurate information regarding the amount and location of energy use is a vital component to conserving energy. Meter installation at SJU is expensive but necessary in executing a complete conservation plan.

**Education**

On-campus awareness of energy use is an important component to energy conservation. Education offers a cost-free means of reducing individual energy consumption through campaigns and efforts to raise energy consciousness on campus.

*Marginal Recommendations:*

**Climate Control**

Currently, the CSB has a Siemen's Energy Management System (EMS) that is a computer controlled heating and cooling system. Four to five thousand sensors have been installed around the CSB campus to detect certain aspects such as zone temperature, outdoor temperature, dampers, thermostats as well as carbon dioxide levels. The system is multi-faceted and has many energy saving components. A campus wide plan to enforce a nightly setback would also be beneficial in the effort to conserve energy.

**Green roofs**

Green roofs can be installed on either campus after several considerations. Determining factors include slope of the roof, structural capacity, and environmental conditions. A detailed study should be conducted to determine location and feasibility of green roofs on campus.

**Indoor Lighting**

The campuses should purchase prolonged life T8 lamps rather than retrofit both campuses to accommodate T5 technology. All incandescent bulbs should be replaced with compact fluorescent bulbs. Currently, the prices and technology of LED and OLED technology do not make them a feasible option for lighting at CSB/SJU. Although CSB has controlled monitoring over many of its buildings, SJU could improve its efficiency and save more money by monitoring the use of lights in buildings after hours. New motion detectors should be installed in all classrooms, offices, corridors and public spaces.

**Outdoor Lighting**

While focusing on energy conservation through lighting methods is an important consideration, the current outdoor lighting technology used by CSB/SJU is appropriate.

*Low Priority Recommendations:*

**Windows**

The current window monitoring system is effective and should be continued. The replacement of window is not necessary at this time. The current windows have been tested and are acceptable. Labor and downtime costs of window removal and replacement probably make this option infeasible.

**Insulation**

Insulation of existing buildings is not cost-effective at this time due to the extensive construction necessary for its installation. Future building should be properly fitted with insulation R-values recommended for this location. The main benefit to insulating a building is that, with the proper insulation, temperatures throughout the building are evenly maintained, resulting in less heat loss/gain.

## Transportation

*Top Priority Recommendations:*

**Biodiesel**

Switching to B20 fuels would be the easiest and quickest way to decrease fossil fuel use and dependence. Biodiesel produces a cleaner exhaust than current 100% diesel fuel. The current Link buses are capable of running on biodiesel, but the fuel itself is more expensive than pure diesel. The fuel would need to be heated in order to work, making this the primary concern with switching to biodiesel.

**Hybrid/Electric**

CSB/SJU should seek the implementation of hybrid-electric Link buses as old buses need to be replaced. This proposal can also be applied to the monastic fleet and college-owned vehicles, as St. Ben's Monastery has already purchased several hybrid automobiles.

*Marginal Recommendations*

**Ethanol**

Ethanol may be a viable option for a fuel source in the future, but the purchase of ethanol-blended diesel is not currently available to the public. Flex-fuel vehicles with the ability to use E85 fuel should be incorporated into campus-owned vehicles and the monastic fleet system.

**CNG**

The engines of the existing buses cannot accommodate CNG and would need to be retrofitted for the new fuel source. CNG buses have considerably lower emissions than standard diesel engine buses. As the Link buses need to be replaced, the campus should consider the addition of CNG-fueled buses.

**Methane (LNG)**

CSB/SJU could consider slowly replacing the Link buses with LNG buses. This transition would require building a fueling station, since none exist in the immediate area. LNG fuel costs less than regular gasoline, and reduces engine wear, extending its lifespan.

*Low Priority Recommendations*

**Propane**

While propane-fueled vehicles are quieter and require less maintenance than standard vehicles, they are impractical for CSB/SJU. Propane-fueled vehicles require larger engines, additional storage facilities, and unavailable methods of fuel production.

**Fuel Cells**

Fuel cells are extremely expensive option. The current market price for a single fuel cell bus is over 1 million dollars, not including the cost of generating a hydrogen source as well as a fueling station. The potential for a fuel cell bus application on campus is a highly impractical solution and not recommended.

# Appendix

**Campus-owned base units**

| Model | Number of Units | Metered Watts | kWh/yr per unit | kWh/yr for all units | Unit operating cost/yr | Cost/yr all units |
|---|---|---|---|---|---|---|
| HP Evo D510 | 865 | 60 | 180 | 155,700 | $9.00 | $7,785.00 |
| HP d530 | 541 | 55 | 165 | 89,265 | $8.25 | $4,463.25 |
| HP dc7100 | 185 | 70 | 210 | 38,850 | $10.50 | $1,942.50 |
| Other | 394 | *62* | *185* | 72,890 | *$9.25* | $3,644.50 |
| **Total for all base units:** | **1985** | | | **356,705** | ***$9.25*** | **$17,835.25** |

**Campus-owned monitors**

| Model | Number of Units | Metered Watts | kWh/yr per unit | kWh/yr for all units | Unit operating cost/yr | Cost/yr all units |
|---|---|---|---|---|---|---|
| HP 1730 & 1720 | 575 | 25 | 75 | 43,125 | $3.75 | $2,156.25 |
| CPM-5017 | 395 | 20 | 60 | 23,700 | $3.00 | $1,185.00 |
| CPM-1520 | 184 | 20 | 60 | 11,040 | $3.00 | $552.00 |
| Other | 831 | *22* | *65* | 54,015 | *$3.25* | $2,700.75 |
| **Total for all Monitors:** | **1985** | | | **131,880** | ***$3.25*** | **$6,594.00** |
| **Total campus-owned workstations** | **1985** | | | **488,585** | **$12.50** | **$24,429.25** |

**Student-owned computers**

| | Number of Units | Metered Watts | kWh/yr per unit | kWh/yr for all units | Unit operating cost/yr | Cost/yr all units |
|---|---|---|---|---|---|---|
| Unknown - Base unit | 2500 | *62* | *186* | 465,000 | *$9.30* | $23,250.00 |
| Unknown - Monitor | 2500 | *22* | *66* | 165,000 | *$3.30* | $8,250.00 |
| **Total for all Student Workstations:** | **2500** | | | **630,000** | ***$12.60*** | **$31,500.00** |
| **Total for all workstations** | **4,485** | | | **1,118,585** | | **$55,929.25** |

Assumptions:
Campus-owned machines are in use approximately 300 days/yr at 10 hrs/day
Student-owned machines are in use approximately 200 days/yr at 10 hrs/day
Cost per kWh was estimated at $0.05
Averages, as noted by italics, came from averaging the units within that category

# Resources

## Appliances

**Alltronics**
PO Box 730
Morgan Hill, CA 95038-0730
Telephone: (408) 778-3868
Fax: (408) 779-2608
http://www.alltronics.com/

**Best Buy**
http://www.bestbuy.com/

**Circuit City**
http://www.circuitcity.com/ccd/category.do?catOid=-12867&N=20012866+20012867&department=Televisions&WT.mc_n=19475&WT.mc_t=U

**Energy Star**
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.

**Wholesale Electronics Inc.**
http://www.weisd.com/

## Biomass

**ALSTOM Power Inc.** *(Formerly, ABB-Combustion Engineering Inc.)*
2000 Day Hill Road
P.O. Box 500
Windsor, CT 06095
Telephone: (860) 285-3654
www.power.alstom.com

**The Babcock & Wilcox Compan**y
20 South Van Buren Avenue
Barberton, OH 44203-0351
Telephone: 1-800-BABCOCK
www.babcock.com

**Babcock Borsig Power** *(Formerly DB Riley, Inc.)*
5 Neponset Street
Worcester, MA 01606

Telephone: (508) 852-7100
www.dbriley.com

**Bliss Industries**
P.O. Box 910
Ponca City, OK 74602
Telephone: (580) 765-7787
www.bliss-industries.com

**Constellation Energy Source**
7133 Rutherford Rd.
Suite 401
Baltimore, MD 21244
Telephone: (410) 907-2002

**Cooper Equipment Inc.**
227 South Knox Drive
Burley, ID 83318
Telephone: (208) 678-8015

**CPM Acquisitions Group**
2975 Airline Circle
Waterloo, IA 50703
Telephone: (319) 232-8444
www.cpmroskamp.com

**Detroit Stoker Company**
1510 East First Street
P.O. Box 732
Monroe, MI 48161
Telephone: 1-800-STOKER4
www.detroitstoker.com

**DTE Biomass Energy, Inc.**
54 Willow Field Drive
North Falmouth, MA 02556
Telephone: (508) 564-4197

**Energy Systems Group**
101 Plaza East Boulevard
Suite 320
Evansville, IN 47715
Telephone: (812) 475-2550 (x2541)

**Foster Wheeler Corporation**
Perryville Corporate Park

P.O. Box 4000
Clinton, NJ 08809-4000
Telephone: (908) 730-4000
www.fwc.com

**SNC-Lavalin Constructors Inc.** *(Formerly Zurn/NEPCO)*
P.O. Box 97008
Redmond, WA 98073-9708
Telephone: (425) 896-4000
www.nepco.com

**Sprout Matador, Div. of Andritz**
35 Sherman Street
Muncy, PA 17756-1202
Telephone: (570) 546-5811
www.sprout-matador.com

**Systems Engineering and Management Corp.**
1820 Midpark Road, Suite C
Knoxville, TN 37921-5955
Telephone: (865) 558-9459

**Trigen Development Corporation**
One North Charles Street
Baltimore, MD 21201
Telephone: (937) 256-7378

**UMT (Universal Milling Technology) Inc.**
8259 Melrose Drive
Lenexa, KS 66214
Telephone: (913) 541-1703
www.umt-group.com

## Computers

**Businesses selling energy efficient PC's**
Local stores:
http://www.EnergyStar.gov/index.cfm?fuseaction=store.store_locator_submit
Online stores:
http://www.Energystar.gov/index.cfm?fuseaction=store.store_locator_submit

**CSB/SJU Guide to Green Computing**
http://www.csbsju.edu/itservices/guides/misc/greencomputing.htm

**Harvard's Green Campus Initiative**
http://www.greencampus.harvard.edu/CERP/faqs.html

**Information about energy efficient PC's**

http://www.EnergyStar.gov/index.cfm?c=computers.pr_computers

**The State University of New York Buffalo Green Computing Guide**

http://wings.buffalo.edu/ubgreen/content/programs/energyconservation/guide_computing.html

**Verdiem's Surveyor Network Software**

http://virtual.pnw.com/default.asp

## Education

**Free The Planet**

http://www.freetheplanet.org/index.shtml

**Harvard Green Campus Initiative**

http://www.greencampus.harvard.edu/index.php

**University of Colorado Student Union**

http://www.colorado.edu/cuenvironmentalcenter/energy/gen_green.html

## Fuel Cells

**FuelCell Energy, Inc.**

*Attention:* Frank Wolak
Eastern Region Sales
Telephone: (203) 825-6000
E-mail: sales@fce.com

**InnovaTek Inc.**

Address: 350 Hills Street
Richland, WA 99352
Telephone: (509) 375-1093
Website: www.tekkie.com

## Geothermal

**ECONAR Energy Systems, Corp.**

33 West Veum Street
Appleton, MN 56208
Telephone: (320) 289-1403
http://www.econar.com/econar.html

**The HVAC Shop**

1301 S. 2nd Avenue
Waite Park, MN 56301
Telephone: (320) 259-6962
http://www.hvacshop.us/index.html

**Mid-American Energy**
1871 Design Dr. N
Baxter, MN 56425
Telephone: (218) 828-4375
http://www.mid-americanenergy.com/

**Schwab-Vollhaber-Lubratt Inc,**
4600 Churchill Street
St. Paul, MN 55126
Telephone: (651) 481-8000
http://www.svl.com/

## Green Roofs

**American Hydrotech, Inc.**
303 E. Ohio Street
Chicago, IL 60611
Phone: 312-337-4998
Fax: 312-661-0731

**Barrett Company**
(information@barrettroofs.com)
P.O. Box 421
Millington, NJ 07946
1.800.647.0100
1.908.647.0278 (FAX)

**Central Region - Sales**
Weston Solutions, Inc.
20 N. Wacker Drive
Chicago, IL 60606

**Roofscapes, Inc.**
7114 McCallum Street
Philadelphia, PA 19119-2935
Telephone: (215) 247-8784
Fax: (215) 247-4659
cmiller@roofmeadow.com.

**Sandra McCullough**
*Phone:* (312) 424-3306

*Fax:* (312) 424-3330
Sandra.McCullough@westonsolutions.com

**<u>Hydroelectric</u>**

**ABS Distribution Center**
297 SW 41st St.
Renton, WA 98055
Telephone: (425) 251-5745
US Toll Free: (888) 606-4949
Fax: (425) 251-5748

**Canadian Hydro Components Ltd.**
P.O. Box 640
16 Main Street
Almonte, Ontario
K0A 1A0
Canada
Telephone: (613) 256-1983
Fax: (613) 256-4235

**Energy Systems & Design**
P.O. Box 4557
Sussex, NB
Canada E4E 5L7
Telephone: (506) 433-3151
Fax: (506) 433-6151

**<u>Indoor Lighting</u>**

**Border State Electric**
Tom Rudolph or Scott Hinde
Telephone: (320) 269-7872

**<u>Transportation</u>**

**Biodiesel**

**Chamberlain Oil Company, Inc.**
*Contact:* John Chamberlain
PO Box 488
St. Cloud, MN 56302
Telephone: (800) 666-8815

**Lake Region Coop**
*Contact:* Brian Yager

Maple Lake, MN 55358
Telephone: (320) 963-3137

**Missouri Better Bean**
*Contact*: Steve Nappier
Bunceton, MO
Telephone: (660) 427-5444
Email: dooser@iland.net

**Soy Solutions**
710 E. 13th. Street
Milford, IA 5131
Telephone: (712) 338-2223
Email: soysolutions@iowaone.net

**Upsala COOP**
*Contact:* Keith Ripplinger
PO Box 666
Albany, MN 56307
Telephone: (320) 845-2351

**Upsala Coop Creamery**
*Contact*: Claire Rice
PO Box 160
Upsala, MN 56384
Telephone: (507) 573-2186

## CNG

**Clean Vehicles**
Union of Concerned Scientists
http://www.ucsusa.org/clean_vehicles/trucks_and_buses/page.cfm?pageID=244

**Natural Gas School Buses**
Energy Efficiency and Renewable Energies
http://www.eere.energy.gov/afdc/pdfs/natural_gas_school_buses_mar_2001.pdf

## Ethanol

**Agricultural Marketing Services Division**
Ralph Groschen, Agriculture Marketing Specialist
Telephone: (651) 297-2223
Ralph.Groschen@state.mn.us
http://www.mda.state.mn.us/ams/default.htm

**Bioenergy Development Program CANMET Energy Technology Centre Natural Resources Canada**

580 Booth Street, 13th Floor
Ottawa, Ontario
Canada K1A 0E4
Bill Cruickshank
Phone: (613) 996-8732
Fax: (613) 996-9416
E-mail: wcruicks@nrcan.gc.ca

**Cenex**

1030 33rd St S
St Cloud, MN 23509
Telephone: (320) 240-7990

**First Fuel Bank III**

621 Franklin Ave SE
Telephone: (320) 252-2265
www.firstfuelbank.com

**Little Falls Central Minnesota Ethanol Co-op**

17936 Heron Road
Little Falls, MN 56345
Telephone: (320) 632-1614
Toll Free: (877) 711-2676
Fax: (320) 632-1656

**Twin Cities Clean Cities Coalition (TC4)**

Tim Gerlach
490 Concordia Avenue
St. Paul, MN 55146
Telephone: (651) 223-9577 or 651-281-0242
gerlach@alamn.org

## Fuel Cells

**Ballard Power Systems**

USA Offices
15001 Commerce Drive N.
Dearborn, MI 48120 USA
Phone: 313.583.5980
Fax: 313.583.5990
Ballard Material Products
Two Industrial Avenue
Lowell, MA 01851-5199 USA

Phone: 978.452.8961
Fax: 978.454.5617
Product Inquiriesmarketing@ballard.com

**Greenlight Power Technologies**
Unit C, 4242 Phillips Avenue
Burnaby, BC
Canada V5A 2X2
Telephone: (604_ 676-4000
Fax: (604)676-4111

**Hino Motors**
Hino Motors Manufacturing USA, Inc.
451B North Cota Street, Corona
California 92880-2008

**Hino Motors Sales USA Inc.**
25 Corporate Drive
Orangeburg, NY 10962

**Sales and General Information**
sales@hydrogenics.com

**UTC Fuel Cells**
195 Governor's Highway
South Windsor, CT 06074
Voice: (866) FUELCELLS [(866) 383-5235]
Fax: (860) 727-2319

**LNG**

**Cummins Northwest, Inc.**
4711 N. Basin Ave.
Portland, OR 97217

**Hybrid**

**Fleets and Fuels**
*Contact:* Rich Piellisch
560 Fourth Street, Street B
San Francisco, CA 94107 USA
Telephone: (415) 896-5988
Fax: (415) 896-5989
piellisch@fleetsandfuels.com

### Propane

**Suburban Propane**
Sauk Centre
Telephone: (320) 352-2487

## Metering

**Harris Mechanical Service, LLC**
*Contact:* Ross Nelson
909 Montreal Circle
St. Paul, MN 55102
Telephone: (651) 602-6548

**Kreuter Manufacturing Company (KMC)**
http://www.kmc.ca/

**The U.S. Environmental Protection Agency's (EPA)**
Energy Star
http://www.oakland.edu/energy/EPA%20EnergyStar%20Submeter%20Report.pdf
.

## Methane

**Applied Technologies Inc.**
http://www.ati-ae.com/

**Biorealis Systems**
http://biorealis.com

**Colorado State Extension Service**
http://www.ext.colostate.edu/

**Ecological Farming Association**
http://www.eco-farm.org

**EPA AgStar Program**
http://www.epa.gov/agstar/

**IEC Covers**
http://www.ieccovers.com

**"Methane Digesters" by L. John Fry**
http://journeytoforever.org/biofuel_library/MethaneDigesters/MDToC
.html#ToC

**The Minnesota Project**

http://www.mnproject.org/

## Microturbines

**Capstone Turbine Corporation**

21211 Nordhoff Street
Chatsworth, CA 91311
866-4-CAPSTONE

**General Electric Company**

http://www.gepower.com/prod_serv/products/gas_turbines_cc/en/contact_us.htm

**INGERSALL-RAND Company**

IR Energy Systems
800-A Beaty St.
Davidson, NC 28036
SOLAR TURBINE, A CATEPILLAR COMPANY
https://solarws.cat.com/ecom/showContactUs.do

**United Technologies Corporation**

United Technologies Building
Hartford, CT 06101

## Outdoor Lighting

**General Electric**

http://www.ge.com/en/

**IREC: Interstate Renewable Energy Council**

http://irecusa.org/articles/static/1/1099061160_1001629193.html

**SolarOne Solutions**

http://www.solarone.net/Products/soled_pathway.html

**Tri-State Generation and Transmission Association**

http://tristate.apogee.net/lite/blthlps.asp

## Solar Power

**BP Solar**

630 Solarex Court
Frederick, MD 21703 (USA)
Telephone: 1-301-698-4200
Fax: 1-301-698-4201
http://www.bpsolar.com/

**Evergreen Solar, Inc.**
259 Cedar Hill Street
Marlboro, MA 01752 (USA)
Telephone: 1-508-357-2221
Fax: 1- 508-357-2279
http://www.evergreensolar.com/

**PowerLight Corporation**
2954 San Pablo Avenue
Berkeley, CA 94702 (USA)
Telephone: 1-510-540-0550
Fax: 1-510-540-0552
http://www.powerlight.com/

**US Department of Energy**
http://www.eere.energy.gov/

**Database of State Incentives for Renewable Energy**
http://www.dsireusa.org/

**The Renewable Energy Policy Project (REPP)**
http://www.repp.org/

**Center for Renewable Energy and Sustainable Technology (CREST)**
http://www.crest.org/

**Energy Efficiency and Renewable Energy Network**
http://www.eere.energy.gov/

**Solar Energy Industries Association**
http://www.seia.org/

**Global Energy Marketplace**
http://www.crest.org/gem.html

## Thermal Insulation

**Ado Products**
21800 129th Avenue North
Rogers, MN 55374
Telephone: (763) 428-7802
http://www.adoproducts.com/

**Budget Building Supply**
1724 County Road 82 NW

Alexandria, MN 56308
Telephone: (302) 763-5426

**The Environmental Home Center**
Telephone: 1-206-682-7332
http://www.environmentalhomecenter.com/home.shtml

**The Home Depot**
401 2nd Street South
Waite Park, MN 56387
Telephone: (320) 252-3262
http://www.homedepot.com

**Lowe's**
2700 Main Street
Coon Rapids, MN 55448
Telephone: (763) 367-1340
http://www.lowes.com/lkn?action=home

**Ultraseal Insulation**
6721 190th Lane NW
Ramsey, MN 55303
Telephone: (612) 803-5827

## Vending Machines

**Bernick**
P.O. Box 7008
St Cloud MN 56302
Telephone: (320) 252-6441
Fax: (320) 656-2121
General Information: info@bernicks.com
Sales: SL@bernicks.com
Customer Support: Customerservice@bernicks.com
Webmaster: webmaster@bernicks.com

**Energy Star**
*Contact:* Maria T. Vargas
1200 Pennsylvania Ave NW
Washington, DC 20460
Telephone: (202) 343-9451

**First Choice**
PO Box 1014, 4610 Rusan ST N
ST. Cloud, MN 56302

## Wind Energy

**Advanced Concrete Innovation**

*Attention*: Nick Nixon
15870 Johnson Memorial Drive
Jordan, MN 55352
Telephone: (952) 496-4071
Fax: (952) 492-2111
nicknixon@aol.com

**American Wind Energy Association (AWEA)**

122 C Street, NW, Suite 380
Washington, DC 20001
Telephone: (202) 383-2500
Fax: (202) 383-2505
Fax: (800) 634-4299
Email: windmail@awea.org
Website: www.awea.org

**American Wind Energy Association Great Plains Region**

*Attention:* John Dunlop
448 Morgan Avenue S, Suite 300
Minneapolis, MN 55405-2030
Telephone: (612)377-3270
Fax: (612) 374-2181
E-Mail: jrdunlop@igc.org

**Database of State Renewable Incentives (DSIRE)**

http://www.ies.ncsu.edu/dsire/library/includes/map2.cfm?CurrentPageID=1&State=MN

**GE Energy**

Business type: manufacturer, service
Address: 13000 Jameson Road
P.O. Box 1910, Tehachapi, California USA 93561
Telephone: (661) 823-6700
FAX: (661) 822-7880

**M. A. Mortenson Company**

*Attention*: Jerry Grundtner
700 Meadow Lane North
Minneapolis, MN 55422-4899
Telephone: (763)522-2100
Fax: (763) 287-5581
jerry.grundtner@mortenson.com

**Navitas Energy**
*Attention*: Gregory Jaunich
3001 Broadway Street NE, Suite 695
Minneapolis, MN 55413-1707
Telephone: (612) 370-1061
Fax: (612) 370-9005
Email: info@windpower.com
Website: www.windpower.com

**NEG Micon USA**
*Attention*: Jay Gislason
PO Box 375
Marshall, MN 56258
Telephone: (507) 532-0369
Fax: (507) 532-0361
E-Mail: jay@neg-micon-us.com

**Northern Alternative Energy, Inc.**
*Attention*: John Jaunich
15600 Wayzata Blvd. Suite 209
Wayzata, MN 55391
Telephone: (952) 476-1202
Fax: (952) 476-1203
jjaunich@naewindpower.com

**Vestas USA**
2850 West Golf Road, Suite 405
Rolling Meadows, IL 60008-4030
Telephone: (847) 806-9500
Fax: (847) 806-9100
E-mail: vestas-usa@vestas.com

**Windustry**
2105 First Avenue South
Minneapolis, MN 55404
Telephone: (800) 365-5441 or (612) 374-2261
Fax: (612) 374-2601
E-mail: info@windustry.org
Web site: http://www.windustry.org

**Wind Turbine Industries Corp**
*Attention*: Steve Turek (General Manager)
16801 Industrial Circle SE
Prior Lake, MN 55372
Telephone: (952) 447-6064
Fax: (952) 447-6050

E-Mail: wtic@windturbine.net
Website: www.windturbine.net

**Renewable Development Fund, Xcel Energy**

http://www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-1_11824_11838- 801-0_0_0-0,00.htm
Questions submitted in writing:
*Attention:* Michelle Swanson
Xcel Energy Manager of Policy Analysis
Telephone: 1-800-354-3060
Fax: (612) 330-7601
E-mail: michelle.m.swanson@xcelenergy.com

**List of project operators:**

http://www.awea.org/directory/developers.html

**List of consultants:**

http://www.awea.org/directory/consultcde.html

## Window Insulation

**The Efficient Windows Collaboration**

http://www.efficientwindows.org/technologies.cfm

**Hirshfield's Wallcoverings and Blinds**

217 3rd St. NE
Waite Park, MN 56387
Telephone: (320) 259-0627
http://www.hirshfields.com/

**Local Minnesota Window Contractors Locator**

Homeimprovementportal.com

**Renewal by Anderson**

127 6th Ave. No.
St. Cloud, MN 56303
Telephone: (320) 252-1920
http://www.renewalbyandersen.com

# Recommended Readings

## *Biomass*


Gene Rebeck. March 2002. Power Shift. *Twin Cities Business Monthly.*, pgs.48-52.

Hia Zaq. Biomass for Electricity Generation. Energy Information Administration. <http://www.eia.doe.gov/oiaf/analysispaper/biomass/index.html> (accessed 4/03/05).

M.K. Mann, P.L. Spath. A life cycle assessment of biomass cofiring in a coal-fired power plant. Clean Prod Processes. <http://www.treepower.org/cofiring/NREL-lifecycle.pdf> (accessed 4/03/05).

Robert D. Perlack et al.. eds., Biomass Fuel from Woody Crops for Electric Power Generation. Oak Ridge National Laboratory. <http://bioenergy.ornl.gov/reports/fuelwood/toc.html> (accessed 4/03/05).

Shalini Gupta. Plant Power: Biomass to Energy for Minnesota. Minnesotans for Energy-Efficient Economy Communities. <http://www.state.mn.us/mn/externalDocs/Commerce/ME3_Biomass_Report_110204031416_BioMass2004.pdf> (accessed 4/03/05).


## *Climate Control*


Department of Energy. Heat and Cool Smartly. <http://www.energystar.gov/index.cfm?c=heat_cool.pr_hvac> (4/3/05)

United States Green Building Council. LEED Build Green. Everyone Profits <http://www.usgbc.org/DisplayPage.aspx?CategoryID=19> (2/16/05)


## *Fuel Cells*


Dicks, Andrew and James Larminie. 2003. Fuel Cell Systems Explained. Indianapolis: Wiley, John & Sons, Incorporated.

Hoogers, Gregor. 2002. Fuel Cell Technology Handbook. Boca Raton, FL: CRC Press.

Kendall, Kevin and Subhash C. Singhal. 2003.High-Temperature Solid Oxide Fuel Celss:

Fundamental, Design, and Applications. San Diego: Elsevier Science.

Peavey, Michael. 2003. Fuel From Water. Jeffersonville, IN: Merit Products, Incorporated.

Romm, Joseph J. 2004. The Hype About Hydrogen: Fact and Fiction in the Race to Save the Climate. Chicago: Island Press.

## Geothermal

Cane, D., et al. Survey and Analysis of Maintenance and Service Costs in Commercial Building Geothermal Systems. Geothermal Heat Pump Consortium, Inc. http://www.geoexchange.org/pdf/RP-024.pdf (accessed 1/30/2005).

Consumer's Research Magazine. 1999. Geothermal Heat Pumps: Savings in Long Run. Issue 27.

Geothermal Heat Pump Consortium. How it Works: GeoExchange <http://www.geoexchange.org/about/how.htm> (accessed 2/3/2005).

Henkenius, Merle. Geothermal Heating. Home Journal <http://www.popularmechanics.com/home_improvement/smart_consumer/1274631.html?page=1&c=y> (accessed 2/4/2005).

Manitoba Hydro. Geothermal Heat Pumps for Homes. PowerSmart <http://www.hydro.mb.ca/saving_with_ps/geothermal_handbook.pdf> (2/4/2005).

## Green Computing

College of Saint Benedict/ Saint John's University. Guide to Green Computing. <http://www.csbsju.edu/itservices/knowledgebase/data/misc/greencomputing.htm>

Harvard University. Computer Energy Reduction Program. <http://www.greencampus.harvard.edu/CERP/faqs.shtml>

State University of New York—Buffalo. Guide to Green Computing. <http://wings.buffalo.edu/ubgreen/content/programs/energyconservation/guide_computing.html>

## Green Roofs

Cardinal Group, Inc. Green Roofs for Healthy Cities.

Carnegie Mellon Green Practices. Living Roofs at Carnegie Mellon. <http://www.cmu.edu/greenpractices/green_initiatives/living_roof.html (2/14/05)<http://www.greenroofs.org/index.php?page=index > (3/10/05)

"Green Roofing 101." Roofscapes Inc. <http://www.roofmeadows.com/faqs2.html> (2/16/05)

Kuhn, Monica, B.E.S., B. Arch, O.A.A., Peck, Steven. Design Guidelines for Green Roofs. City of Chicago. <http://egov.cityofchicago.org/webportal/COCWebPortal/COC_ATTACH/design_guidelines_for_green_roofs.pdf > (15 March 2005)

### *Insulation*


Gilliand, Chris. Insulating Your New Home. Dream Home Source. http://www.dreamhomesource.com/xq/asp/XQ.1/ArticleID.219/Type.2/qx/Article.htm (accessed 2/4/2005).

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# Glossary

**Acid Rain:** Also called **acid precipitation** or **acid deposition**. Acid rain is precipitation containing harmful amounts of nitric and sulfuric acids formed primarily by sulfur dioxide and nitrogen oxides released into the atmosphere when fossil fuels are burned. It can be wet precipitation (rain, snow, or fog) or dry precipitation (absorbed gaseous and particulate matter, aerosol particles or dust). Acid rain has a pH below 5.6. Normal rain has a pH of about 5.6, which is slightly acidic. The term pH is a measure of acidity or alkalinity and ranges from 0 to 14. A pH measurement of 7 is regarded as neutral. Measurements below 7 indicate increased acidity, while those above indicate increased alkalinity.

**Aerobic Digester:** Machine that decomposes organic material in the presence of oxygen.

**Alternating current (AC):** An electric current that reverses its direction at regularly recurring intervals.

**Alum:** Aluminum Sulfate ($Al_2(SO)_4$), often used in waste water treatment plants to remove phosphates.

**Amorphous:** A chemical term for a non-crystalline substance, often used in photovoltaic panel production. (see ***noncrystalline*** and ***thin film cell***).

**Ampere:** A unit of electric current in the meter-kilogram-second system. It is the steady current that when flowing in straight parallel wires of infinite length and negligible cross section, separated by a distance of one meter in free space, produces a force between the wires of $2 \times 10^{-7}$ newtons per meter of length.

**Anaerobic Bacteria:** Bacteria that lives in environments lacking oxygen.

**Annual Plants:** Plants that typically complete their lifecycle in a year or less.

**Anode:** The electrode at which oxidation occurs. For cells that create potential, it is also the electrode towards which the negative ion flows.

**Array:** A number of photovoltaic modules electrically connected to produce a single electrical output.

**Atom:** Any of the smallest particles of an element that combines with similar particles of other elements.

**Ballast**: A device required by electric-discharge light sources such as fluorescent or HID lamps to regulate voltage and current supplied to the lamp during start and throughout operation.

**Ballast:** an electrical component that conducts electricity at each end of the light bulb tube, supplying the initial electricity and regulating the flow.

**Base Load Electricity Generation:** Base load is the amount of electrical demand that the grid must supply at a consistent level. These sources must be reliable and scalable to the demand of the grid. For example if it is an extremely warm day outside, the demand will increase because in addition to normal electricity consuming activities more air conditioners will need to run. Base load producers like coal, nuclear gas and biomass can scale their output to meet the demand. Solar and wind producers cannot do this unless battery storage is incorporated into their systems.

**Batt insulation**: strips of insulation that fit between studs or other framing.  Can be made from fiberglass fibers, mineral wool, cotton, and wool.  The most common form of insulation.

**Bernick Snack and Beverage Company**: Vending and food administrator to Saint John's/Saint Ben's.

**Biodiesel:** A renewable, low polluting fuel for most diesel internal combustion and turbine engines, containing methyl or ethyl esters made from fresh or waste vegetable or animal oils (triglycerides).

**Biodiesel:** An environmentally safe, low polluting fuel for most diesel internal combustion and turbine engines. Can be mixed with petroleum fuel and stored anywhere petroleum is. Made from fresh or waste vegetable oils (triglycerides) that are a renewable energy source. Both commercially and privately made around the world. Relatively safe and easy to process when conscientiously approached. Benefits are substantially reduced engine emissions with as little as 20% biodiesel with 80% petroleum.

**Biogas:** The name for the mixture Methane, Nitrogen and Carbon dioxide, created in decomposition and used for a fuel.

**Biomass Gasification**: Burning biomass in a low oxygen environment in order to collect syngas, which is composed of a mixture of hydrogen and carbon monoxide.

**Biomass:** plant material, vegetation, or agricultural waste used as a fuel or energy source.

**British Thermal Unit (Btu)**: Unit of heat measurement – The amount of heat required to raise one pound of water from 60 to 61 degrees Fahrenheit. Prefixes can be added to denote higher orders such as mBtu which is 1 million Btu.

**British Thermal Units:** The quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit).

**Bucket method**: A method that involves damming the stream with logs or boards to divert the stream flow into a bucket or container.

**CA:** *(Community Assistant)* an upper class student hired to be a mentor on the floors of upper class on-campus housing.

**Carbon Emission Particles:** composed of nanoparticles and ultrafine soot particles. These particles penetrate deeper into the lungs and pose greater non-cancer health risks than larger particles.

**Catalyst:** A chemical substance that increases the rate of a reaction without being consumed; after the reaction it can potentially be recovered from the reaction mixture chemically unchanged. The catalyst lowers the activation energy required, allowing the reaction to proceed more quickly or at a lower temperature.

**Cathode:** The electrode at which reduction occurs.

**Cellulose fiber**: a type of loose-fill insulation that is made from shredded wastepaper such as used newsprint and boxes. Less energy is required in the production of this insulation compared to other insulations.

**Cetane Value:** A measure of ignition quality of diesel fuel. The higher the cetane value, the easier the fuel ignites when injected into an engine.

**Climate Change:** A term used to refer to all forms of climatic inconsistency, but especially to significant change from one prevailing climatic condition to another. In some cases, "climate change" has been used synonymously with the term "**global warming**"; scientists, however, tend to use the term in a wider sense inclusive of natural changes in climate, including climatic cooling.

**Closed-loop biomass**: The idea behind the closed loop biomass concept is that the carbon dioxide that is released when a biomass fuel source is burned is the same carbon dioxide that it removed from the atmosphere during its lifetime. Closed loop biomass fuel sources are usually defined as dedicated energy crops because their sole purpose is to provide fuel.

**Cogeneration:** The simultaneous on-site production of electric energy and process steam or heat from the same power source.

**Compact Fluorescent Lamp**: A family of single-ended fluorescent-discharge light sources with small-diameter [16-millimeter (5/8-inch) or less] tubes.

**Compressed Natural Gas (CNG)** – is filtered and compressed allowing it to be easily stored in a small space in a pressurized storage tank.

**Concentrating system:** A PV array, which uses concentrating devices (reflectors, lenses) to increase the intensity of the sunlight striking the array.

**Convective loop:** Integral part of the isolated gain heating system, which allows the heat in one room to be distributed to other living areas in a circular venting loop.

**Corn Stover:** A residue formed by the husk, stalk, and core of a corn cob which are removed during the harvesting of corn.

**Cotton Insulation:** An insulation that is made primarily from scraps of blue-jeans that have been collected from factories, resulting in a product that generally contains 85% post-industrial recycled natural fibers. Chemicals are then applied for fire-retardant, fungi resistance and corrosiveness. Is considered a sustainable building material.

**Daylighting:** Using south-facing windows to increase the amount of light and heat in a given area, as well as providing natural ventilation.

**Direct Current (DC):** An electric current in which electrons flow in one direction only. Direct current is produced by batteries.

**Direct gain system:** Heating system in which the building uses a thermal mass to absorb the sun's energy from light shining directly into the structure. (See ***thermal mass***).

**Direct Methanol Fuel Cell (DMFC):** A type of fuel cell in which the fuel is methanol (CH3OH), in gaseous or liquid form. The methanol is oxidized directly at the anode with no reformation to hydrogen. The electrolyte is typically a proton exchange membrane.

**Distributed Generation:** Any small-scale power generation technology that provides electric power at or closer to the customer's site than centrally sited generation stations.

**E85:** fuel with 85% of the content being Ethanol

**Economies of Scale**: Larger size of output often leads to lower cost per unit of output.

**Electolysis:** Using electricity to split water into its constituent elements, hydrogen and oxygen. The splitting of water is accomplished by passing an electric current through water. The electricity enters the water at the cathode, a negatively charged terminal, passes through the water and exists via the anode, the positively charged terminal. The hydrogen is collected at the cathode and the oxygen is collected at the anode. Electrolysis produces very pure hydrogen for use in the electronics, pharmaceutical and food industries.

**Electric power grid system:** A system of synchronized power providers and consumers connected by transmission and distribution lines and operated by one or more control centers. In the continental United States, the electric power grid consists of three systems: the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. In Alaska and Hawaii, several systems encompass areas smaller than the State.

**Electrical Generator**: An electrical generator is a device that takes the mechanical energy of the turning turbines and converts it into electrical energy.

**Electrode:** An electric conductor through which an electric current enters or leaves a medium, whether it be an electrolytic solution, solid, molten mass, gas, or vacuum.

**Electrolyte:** A non-metallic electrical conductor in which current is carried by the movement of ions.

**Electron:** A negatively charged elementary particle that forms a part of all atoms.

**Electronic Ballast**: A ballast that uses electronic components instead of a magnetic core and coil to operate fluorescent lamps. Electronic ballasts operate lamps at 20 to 60 kHz, which results in reduced flicker and noise and increased efficacy compared with ballasts that operate lamps at 60 Hz.

**Energy Crops**: Plant species developed and grown specifically for fuel. These include fast-growing trees, shrubs, and grasses, such as hybrid poplars, willows, and switchgrass.

**Eutrophication**: Reduction of dissolved oxygen content in a body of water due to pollution such as excess nutrient loading. It is characterized by a loss of dissolved oxygen below the thermocline in the summer and complete lack of 02 in the winter. Algal blooms are also fairly common as evidenced by the condition of the Gemini lakes on campus which are severely eutrophic.

**Extensive green roofs:** Range from as little as 1 to 5 inches in soil depth, adding less load to a building. Extensive green roof systems also generally require less maintenance than intensive systems.

**Fiberglass fiber**: a type of loose-fill insulation that is spun into fibers from molten glass.

**First Choice Snack and Vending:** Vending and food administrator to Saint John's/Saint Ben's.

**Flat-plate array:** A PV array which does not use concentration.

**Flex-fuel Vehicles (FFV):** the vehicles has a single fuel tank, fuel system, and engine that is designed to run on regular unleaded gasoline and an alcohol fuel (either ethanol or methanol) in any mixture - for example, 100% gasoline or E85 (85% ethanol).

**Fossil fuel:** An energy source formed in the earths crust from decayed organic material. The common fossil fuels are petroleum, coal, and natural gas.

**Fossil Fuels:** Fuels that were created in prehistoric times and cannot be regenerated (naturally) in our lifetimes. Examples include oil and coal.

**Free cooling:** Using the air already in place to cool the space instead of constantly drawing in outdoor air.

**Fuel Cell:** An electrochemical device that continuously converts the chemical energy of a fuel and an oxidant to electrical energy. The fuel and oxidant are typically stored outside of the cell and transferred into the cell as the reactants are consumed. See also Reversible Fuel Cell, PEMFC, SOFC, MCFC, PAFC, DMFC.

**Geothermal heat pump:** A device that transfers heat from a lower temperature reservoir to a higher temperature reservoir by doing work through a compressor.

**Global warming potential (GWP):** An index used to compare the relative radiative forcing of different gases without directly calculating the changes in atmospheric concentrations. GWPs are calculated as the ratio of the radiative forcing that would result from the emission of one kilogram of a greenhouse gas to that from the emission of one kilogram of carbon dioxide over a fixed period of time, such as 100 years.

**Global warming:** An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is today most often used to refer to the warming some scientists predict will occur as a result of increased anthropogenic emissions of greenhouse gases.

**Glycerin:** A by-product of biodiesel production, which has a number of uses e.g. it, is used in the manufacture of soap.

**Green roofs:** Green roofs, also called 'vegetated roof covers' or 'eco-roofs,' are thin layers of living plants that are installed on top of conventional roofs

**Greenhouse effect:** The result of water vapor, carbon dioxide, and other atmospheric gases trapping radiant (infrared) energy, thereby keeping the earth's surface warmer than it would otherwise be. Greenhouse gases within the lower levels of the atmosphere trap this radiation, which would otherwise escape into space, and subsequent re-radiation of some of this energy back to the Earth maintains higher surface temperatures than would occur if the gases were absent.

**Greenhouse gases:** Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface.

**Grid:** The layout of an electrical distribution system.

**Ground mount:** System for stabilizing arrays on the ground; based on precise foundations, but often susceptible to vandalism.

**Heat sink**: a substance or medium that absorbs unwanted heat from an object that it hotter than it.

**Hibernate State:** Saves the complete state of the computer in a hiberfile, which the computer refers to upon start-up.  In hibernation stat the computer reduces power uses so much it appears to be off. This is the lowest power sleeping state available and is secure from power outages.

**High Intensity Discharge:** a type of lighting that replaces the typical filament with a capsule of gas that creates intense light.

**High Pressure Sodium**: A type of High Intensity Discharge Light that uses sodium for illumination that emits a yellow light.

**Horizontal ground closed-loop**: a heat pump system in which pipes are buried horizontally in shallow trenches. Most cost effective type of configuration for residential installations where there is sufficient land available.

**Hybrid-Electric (HEV)**: Automobiles powered by both the electricity and standard fossil fuels. When both fossil fuel and electric systems work together, the process saves on gas mileage and petroleum costs.

**Hydro electric power**: Power generated by the flow of water.

**Indirect gain system:** Heating system that relies on the thermal mass being placed between the sun's rays and the building's interior.

**Intensive green roofs:** Requires a minimum of one foot of soil depth to create a more traditional rooftop garden, with large trees, shrubs and other manicured landscapes. They are multi-layer constructions with elaborate irrigation and drainage systems. Intensive green roofs add considerable load to a structure and require intensive maintenance.

**Isolated gain system:** Heating system that involves a separate location, such as a sunroom, being heated with the sun's direct energy, but distributed throughout the living areas by a looped venting system. (See ***convective loop***).

**Kilowatt:** *(abr. kWh)* A unit of electrical power, equal to 1,000 watts.

**Kilowatt-hours (kWh):** A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour. One kWh is equivalent to 3,412 Btu. *Eg*: One 50-watt light bulb left on for 20 hours consumes one kilowatt-hour of power.

**KJNB:** Student run radio station on Saint John's University campus.

**Leadership in Energy and Environmental Design:** Standards by which communities can decide to build environmentally friendly structures.

**Light Pollution**: excess light that escapes upwards towards the sky rather than towards the target needed to be lit.

**Loose-fill insulation:** an insulation product that is comprised of small particles that are blown into place using special equipment to from a fluffy insulating material that conforms to the spaces in which they are installed.

**Lumen:** A measurement of light output.  One candlepower equivalent equals 12.57 lumens.

**Megawatt:** *(abr. MW)* A unit of electrical power, equal to 1,000,000 watts.

**Metal Halide**: a type of high intensity discharge lighting that emits a white light.

**Methanogenic Bacteria:** Bacteria that produces methane at a waste product.

**Mirco Hydro Turbines**: Small scale hydro electric turbines used in a scream or small river.

**Module:** A number of solar cells electrically connected to provide one single output; cells are protected from environmental stresses and self-contained.

**Molten Carbonate Fuel Cell (MCFC):** A type of fuel cell consisting of a molten electrolyte of Li2CO3/Na2CO3 in which the speciesCO3 2- is transported from the cathode to the anode. Operating temperatures are typically near 650 □C.

**MTBE:** (methyl tertiary-butyl ether) is a chemical compound that is manufactured by the chemical reaction of methanol and isobutylene; oxygenate, which raises oxygen levels in gasoline; know to be a carcinogenic

**Municipal solid wastes:** consists of items like product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries.

**Net Metering**: Net metering is a utility resource usage and payment scheme in which a customer who generates their own power is compensated monetarily. Net metering originated with electric companies as a way to encourage consumers to invest in renewable energy sources such as solar or wind power. In a net metering program, the electric company allows a customer's meter to actually run backwards if the electricity the customer generates is more than they are consuming. At the end of the billing period, the customer only pays for their net consumption: the amount of resources consumed, minus the amount of resources generated.

**Nightly Setback:** A predetermined time at which point the heat is turned down for the night in order to save energy.

**Noncrystalline:** Type of photovoltaic cell made from amorphous silicon; absorbs light easily but not as efficient.

**Open loop systems**: A heat pump that uses wells as the heat transfer fluid.  Once the water has circulated through the system the water returns to the ground.  Requires meeting various local codes and regulations regarding groundwater discharge.

**Oxidation:** Release of electrons through the cell's active mass to the external electric circuit.

**Parabolic dish:** Efficient, modular bowl-shaped reflectors that stand in single units in open spaces.

**Parabolic trough:** Independent, closely placed, curved reflector units that track the sun and concentrate the light to produce heat.

**Particulate Matter:** Tiny particles of solid or liquid suspended in the air, composition primarily unburned fuel (hydrocarbons), elemental carbon, sulfur, mineral salts, and often contain traces of toxic metals, along with secondary emissions including a combination of ammonia with either sulfuric acid or nitric acid and water. The health effects of inhaling particulate matter has been widely studied in humans and animals and include asthma, lung cancer, and premature death. Particulate matter pollution is estimated to cause thousands of deaths per year in the United States.

**Passive solar cooling:** A side benefit of passive solar heating, this system relies on window placement and structure material to help aid natural ventilation and reject heat absorption during warmer months.

**Passive solar heating:** Heating system that relies on design methods and features to help absorb the sun's thermal energy without having to purchase electricity.

**Payback:** The amount of time required (usually in years) for positive cash flows to equal the total investment costs. This is often used to describe how long it will take for energy savings resulting from using more energy-efficient equipment to equal the premium paid to purchase the more energy-efficient equipment.

**Petrodiesel:** Petroleum diesel, the conventionally used petroleum-based diesel, with no biodiesel products blended into it.

**Phosphoric Acid Fuel Cell (PAFC):** A type of fuel cell in which the electrolyte consists of concentrated phosphoric acid (H3PO4) and protons (H+) are transported from the anode to the cathode. The operating temperature range is generally 160 – 220°C.

**Photon:** A quantum of electromagnetic energy.

**Photosynthesizers**: Organisms that have the ability to use light energy as a power source to fuel the production of carbon compounds (glucose) which can be used for energy.

**Photovoltaic**: solar powered.

**PM:** particulate matter

**Polycrystalline:** Type of photovoltaic cell; lower efficiency and lower cost.

**Pond closed loop**: heat pump system that uses a lake as its source and sink for heat by running pipe into a water body. Has the potential to cause severe damage to inadequate bodies of water.

**Power-tower:** System of reflecting light onto a tower-mounted receiver, which then heats liquid to create electricity.

**Process Engineered Fuel (PEF):** PEF is usually derived from waste products such as paper or cardboard. It is shredded and compacted into variable sizes to be used as a fuel source.

**Proton Exchange Membrane (PEM):** The separating layer in a PEM fuel cell that acts as an electrolyte (which is proton conducting) as well as a barrier film separating the hydrogen-rich feed in the cathode compartment of the cell from the oxygen-rich anode side.

**Proton Exchange Membrane Fuel Cell (PEMFC or PEFC):** A type of acid based fuel cell in which the exchange of protons (H+) from the anode to the cathode is achieved by a solid, aqueous membrane impregnated with an appropriate acid. The electrolyte is a called a proton-exchange membrane (PEM). The fuel cells typically run at low temperatures (<100°C) and pressures (< 5 atm).

**RA:** *(Resident Assistant)* an upper class student hired to be a mentor on the floors of first and second year residence halls.

**Reduction:** Increase in the number of electrons. In the case of a cell, this term refers to the electron transfer to the active mass.

**Reformer:** A vessel within which fuel and other gaseous recycle stream(s) (if present) are reacted with water vapor and heat, usually in the presence of a catalyst, to produce hydrogen rich gas for use within the fuel cell power plant.

**Renewable energy resources:** Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include: biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

**Rock wool insulation**: A type of loose-fill insulation that is spun into fibers from blast furnace slag (the scum that forms on the surface of molten metals). The production of rock wool uses by-products that would otherwise be wasted. Also known as mineral or slag wool.

**Roof mount:** System for stabilizing arrays on top of building roofs; keep wire lengths to a minimum, but often require roof penetration.

**Side of pole mount:** Easy to install, provides a system for stabilizing arrays of smaller numbers; more susceptible to vandalism.

**Single-crystal:** Type of photovoltaic cell; most efficient but difficult and expensive to make.

**Small wind turbines** (SWT) are defined as having a generating capacity up to 100 kilowatts (kW) (~60 ft rotor diameter).

**Solar panel**: A group of photovoltaic modules mechanically mounted on a single frame.

**Solar photovoltaic:** Converting light directly into electricity by forcing electrons into an electric current.

**Solar-thermal heating:** Involving the use of a liquid as an intermediate, solar thermal heating uses solar light to create heat, which can then be used directly or converted into electricity.

**Solid Oxide Fuel Cell (SOFC):** A type of fuel cell in which the electrolyte is a solid, nonporous metal oxide, typically ZrO2 doped with Y2O3, and O2- is transported from the cathode to the anode. Any carbon monoxide (CO) in the reformate gas is oxidized to carbon dioxide (CO2) at the anode. Temperatures of operation are typically 800 – 1000□C.

**Standalone system**: A power system not connected to the utility grid (mains.) Sometimes referred to as an autonomous system.

**Stand-by State:** An intermediate system-dependent state which attempts to conserve power. Stand-by is entered when the central processing unit (CPU) is idle and no device activity is known to have occurred within a specific period of time. The computer will not return to ready until normal activity is resumed by an external event, such as a key stroke. All data and operational parameters are preserved when your computer is in the Stand-by state.

**Straw:** Straw is a generic term used to describe the dried out stalks of short grains such as oats, wheat, and barley. Typically these plants are grown for grain production and a combine is used to collect the grains. Straw is the dried out stems of what is left after reaping. It is usually baled and used as bedding for livestock.

**Suspended State:** The lowest level of power consumption available which preserves operational data and parameters. In this state the computer will not compute until normal activity is resumed by an external event such as a button press or timer alarm.

**T12 and T8 Lamps**: "T" designation in fluorescent lamps stands for tubular; the shape of the lamp. The number immediately following the T gives the diameter of the lamp in eighths of an inch. A T12 lamp is therefore twelve-eighths of an inch, or one-and-one-half inches in diameter. A T8 lamp is eight-eighths of an inch, or one inch in diameter.

**Thermal mass:** Materials inside a building, such as brick, stone, concrete, or other masonry walls, that absorbs and retains the sun's energy, while slowly releasing heat.

**Thin film cell**: A PV cell formed by depositing thin layers of conductive and semi-conductive materials, usually using a chemical vapor deposition (CVD) process. Also referred to as *amorphous* cells because they have no crystalline structure, such cells use less material than cells sawn from crystalline ingots. (See ***amorphous*).**

**Ton:** A 'ton' unit of air cooling capacity equals 12,000 Btu per hour.

**Top of pole mount:** Easy to install, provide a system for stabilizing arrays; reduce risk of vandalism.

**Tracker:** Any collector that changes its orientation throughout the day in order to follow the path of the sun and receive maximum sunlight.

**Transesterification:** process of creating esters from vegetable oil (a triglyceride), and methoxide. The products are methyl and ethyl esters (i.e. biodiesel) and glycerine.

**Trending:** Watching and comparing energy use from multiple years to distinguish patterns and gather information.

**Turbine:** An engine driven by the pressure of steam, water, or air against the curved vanes of a wheel.

**Vertical ground closed loops**: heat pump systems in which pipes are placed in deeply drilled holes. Most common for large commercial buildings and schools.

**Volt:** A measure of the force making electrons flow in a current. The International System unit of electric potential and electromotive force, equal to the difference of electric potential between two points on a conducting wire carrying a constant current of one ampere when the power dissipated between the points is one watt.

**Wading technique**: A technique used to find the flow of a given water source.

**Watt (W):** A measure of the power of electricity to do work. A Watt is the unit of electrical power equal to one ampere under a pressure of one volt. A Watt is equal to 1/746 horsepower.

**Wet Sludge:** Wet sludge is the indigestible solids left over after the bacterial treatment of wastes.

**Wool insulation –** a type of insulation that uses wool treated with pest-repellants and preservatives to provide building insulation in hot, cold, dry and wet seasons. Is considered a safe, healthy and environmentally friendly alternative to traditional fiberglass insulation.

**Workstations:** A combination of monitor and baseunit or a laptop.

**Yellow Grease**: Grease left over from fryers and cooking.

# Index

## A



## B



## C



## D



## E



## F

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