Energizing the Future: Meeting Future Power Needs of Grenfell College and Newfoundland

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In this paper I pose the questions: Is it feasible to install a large wind turbine(s) at Grenfell College as a pilot project, and what will the benefits of the installation be to Grenfell if the project goes ahead? My answers are based on a literature review, data analysis from previous experiments, and a SWOT analysis. I will conclude by recommending a course of action for Grenfell that will move it toward using more renewable energy, and becoming a local resource for alternative energy solutions.

Introduction

In this paper I explore options for alternative energy technologies at Grenfell College (Grenfell). My primary focus is an examination of the feasibility of introducing a large wind turbine(s) as a source of electricity, first for the Grenfell campus, but also on a larger scale for the region. I propose that the turbine(s) will serve as an educational tool for the post secondary institutions in the area, and a community based icon of positive environmental change. I will provide justifications for the installation by looking at fossil fuel use and environmental sustainability globally and regionally through the lens of a student hopeful for future improvement. This paper provides a foundation from which Grenfell will be able to move toward the goal of incorporating a greater proportion of renewable energy systems powering the campus.

I selected electrical generation from wind for the following simple reasons. Unlike solar energy, the availability of wind as a power source is not as cyclical through the seasons, and is not dependent to the same degree on daylight hours. Geothermal and hydro energy projects have already been installed in Western Newfoundland, and information is documented for these technologies. I am interested in wind energy because there is a lack of understanding about the potential for wind power in the Corner Brook area. Wind energy is an under-explored resource in Western Newfoundland. On the demand side of the equation, according to a forecast by Shell International, over the next fifty years there is predicted to be a decrease in the use of fossil fuels, and an increase in the use of renewable energy sources (Shepard, 2003, 458, Fig, 14.2). In Newfoundland the trend toward renewable energy use should be spearheaded by the post-secondary education institutions.

A Global Environmental View

The natural environment is able to function as it does because certain states necessary to support systems are met. Plants and animals have specific needs. Some are able to exist only when provided with very specific conditions; change the environment, even by a small amount, and a species could die. For example some frogs, and other small amphibians exist within a very narrow range of conditions. Other life forms such as many species of birds are able to thrive within a broader range of parameters, and may not be directly or immediately threatened by small changes in their environment. However, even those able to tolerate a broader range of environmental changes may be dependent on those that would be threatened by a small change in environmental conditions. The inter-dependencies of the earth based life web are clearly not understood at a thorough level. A plant needs clean water and moderate temperatures to survive, and similarly the air we breathe relies on plants for rejuvenation (Anderson, 2004, 3).

Humans are dependent on the environment to meet their physical needs. We depend on it for clothing, air, food and water. We use it in all products, from electronics, to books, and cars. We need nature to sustain our lives and our lifestyles. However, many of the petrochemicals and minerals that comprise our manufactured capital are only available for extraction from the environment once (Anderson, 2004, 3). Until recently there has been insufficient consideration given to the impact that production and use of manufactured products have on the environment. Now, with growth in volume and maturity in the fields of environmental-based fields of research including, resource management, ecological economics, environmental studies, and environmental science, there is an increasing awareness that production of manufactured capital is being traded for degradation of the natural environment. A societal increase in understanding of these tradeoffs has meant a corresponding increase in understanding the importance of the environment to our existence, as well as an increased knowledge of the environment's fragility.

Two dominant planning options exist for managing environmental degradation and the associated risks to humans and the environment: mitigation or adaptation (Freedman, 2004, 547). Mitigation is an act designed to repair or offset environmental degradation (Freedman, 2004, 617). Adaptation can be defined as the process of changing to become more suited to a new environment. Since at this time the footprint of human activity is not effectively mitigated, changes to our environment are likely to continue. Therefore, to permit a necessary and desirable diversity of species to survive, humans must mitigate much more aggressively the negative impacts of a growing human population and resultant environmental degradation, then adapt to the remaining environmental changes we cannot control. It is clear that a focus on mitigation would produce better results since this is the option over which we have an ability to exercise greater control.

Leaders must understand how damage is occurring, identify which damages can be avoided, analyze different mitigation approaches, and have the resolve to immediately begin implementing effective solutions. It is especially important for those with environmental awareness and in positions of influence to act at every opportunity in an attempt to try and offset the myriad of harms that go unanswered daily. One sector for which we have sufficient resources and technology to mitigate environmental damage, is the energy sector (Anderson, 2004, 8). Universities can set the tone of environmentally responsible living for the larger community by providing intellectual leadership and by physically leading by example. It is my primary objective with this paper to lay the foundation for Grenfell College to become more effective in both these realms.

Grenfell and the Talloires Declaration

Grenfell College opened in 1975 (Sir Wilfred Grenfell College, 2007). During construction society generally was not as concerned with environmental preservation as we are today. As a result, the original campus buildings are not environmentally sound. Due in part to the time in which construction took place, and a lack of mitigating environmental initiatives implemented by the university since, Grenfell has very high energy costs. Grenfell's electrical bills have been increasing for at least the last eight years. For the past three years, the actual cost of electricity has gone over budget (Newfoundland power, 1999-2007). Bills can go over budget for two main reasons. Firstly, because not enough money is being allocated. Secondly, consumption was higher than expected. In the case of Grenfell, both factors are in play, but it appears as though increased demand is a more significant cause of the budgetary imbalance (Appendix B).With new plans in the works for expanding Grenfell, the ecological footprint of the campus will increase (Wackernagel, 1996). Due to the projected increase in energy unit costs and an increase in overall demand for electricity which will result from the campus expansion, now is a good time for Grenfell to invest in renewable sources of energy. The planned development at Grenfell will see buildings constructed with LEEDS certification; this will reduce their energy demands. The impacts of energy consumption at Grenfell could be drastically reduced through the introduction of alternative energy sources. Geothermal heating is becoming a popular option in Newfoundland, however there are also opportunities for solar and wind power to be used.

Because universities play a key role in the education of individuals who manage the institutions of our society, it is of crucial importance that universities increase the awareness of technologies, tools, and knowledge, that are necessary to create an equitable and sustainable future (Association of University Leaders for a Sustainable Future, 2003). As an educational institution, Grenfell plays an important role in introducing new technologies to the local community and the province. Grenfell has a strong intellectual focus on the environment, evident from the degrees offered, such as tourism, environmental science, environmental studies, and sustainable resource management. However, the college may be losing a competitive edge by not implementing environmental literacy and sustainable living to the same degree, on campus. An imbalance has developed between the college's intellectual position and its actions as a member of the community and its role as community leader. This imbalance runs the risk of holding back Grenfell from reaching its full potential as an institution. Solving the imbalance will instill institutional passion, which will help to attract and retain a passionate faculty, as well as attract and develop passionate students.

As the programs based on the environment mature, and as students graduate, the synergy developed as a result of participating in the college's model of knowledge and implementation will spill over to the province, country and world. Therefore, I propose that Grenfell take steps toward becoming a greener and more sustainable campus with a reduced impact on the earth. This can be achieved by harmonizing green research and education with an implementation program. Grenfell has the ability to develop a plan for environmental sustainability on its own, however there are numerous existing frameworks that have done substantial work in this regard already. Given Grenfell's small size and limited resources, there are efficiency benefits to joining an existing larger coalition of like minded people or institutions.

I believe a good first step to establishing Grenfell's leadership position in environmental sustainability is to sign the Talloires Declaration (Appendix C). The declaration was written in Talloires, France, by an international body of university administrators (Association of University Leaders for a Sustainable Future, 2001) This declaration was the first time that universities from around the world collectively made an official commitment to environmental sustainability in higher education (Association of University Leaders for a Sustainable Future, 2001). The declaration, written in 1990, is a ten-point plan designed to assist universities plan and incorporate sustainability and environmental literacy into all aspects of university life: teaching, research, and operations. From the original nineteen university signatories, the document has now been adopted by three hundred and sixty-two universities in forty-nine countries, as of January 1, 2008 (Association of University Leaders for a Sustainable Future, 2008). Canada has twenty-seven universities that have already made the commitment to the Talloires declaration, including eight from Atlantic Canada (Association of University Leaders for a Sustainable Future, 2008).

Universities are the best available bodies for research and innovation to develop the intellectual and conceptual framework necessary to achieve the goal of environmental sustainability (Association of University Leaders for a Sustainable Future, 2003, 3). The Talloires declaration is one of many declarations that have been developed and that could help guide Grenfell back to a position as a community leader and a forward thinking research institution with a focus on minimizing the influences of human demands on the planet. The Halifax declaration (Appendix D), developed in 1991, is another international treaty that Grenfell could sign, or use as a template for its own green development. These declarations have a number of benefits to participants which are summarized in brief by the ULSF (Association of University Leaders for a Sustainable Future, 2003, 10). Firstly, by signing, the university will be connected to an international network of post secondary institutions that are committed to an environmentally sound and sustainable future. Secondly, signing will serve to motivate the university community and will provide a framework for designing a comprehensive plan for directing the campus toward sustainability. Finally, by signing a declaration, Grenfell will be making a public commitment to which it can be held accountable by fellow signatories, over time.

Global Energy Facts

I will deal in more depth with electricity demands and uses at Grenfell later in this paper, however I would like to take a step back and look generally at energy use globally, then do a brief review on the feasability of alternative energy use in Corner Brook.

In 2005, the total global primary energy consumption, which describes energy which is untransformed when it reaches a user, was estimated to be 15 trillion kWh (Patel, 2006, 3). This came from both renewable and non renewable sources. Of this amount 40 percent was used in the production of electricity (Patel, 2006, 3). Electrical energy is a secondary form of energy. This means that it is produced by using a primary energy, such as fossil fuels (Shepard, 2003, 9). Energy demand is projected to increase at an annual rate of 2.6 percent globally, with developing countries reaching a growth rate of 5 percent, almost twice the world average (Patel, 2006, 3). In the year 2000, the amount of energy consumed in Canada was equivalent to using 231.8 million tonnes of oil (Shepard, 2003, 38).

Fossil Fuel Supply and Demand

Fossil fuels have been in the process of creation for 600 million years (Shepard, 2003, 32). Because of the time frame which it takes to create fossil fuels (coal, oil shale, petroleum and natural gas), they are considered a non renewable resource (Shepard, 2003, 32). In the developed world, the primary source of energy is from the combustion of fossil fuels. Fossil fuel is a form of stored solar energy that has been in use for more than two centuries. The international demand for fossil fuels has led to an increased rate of withdrawal of this finite resource (Patel, 2006, 3). It is clear that even without consideration of the environmental impacts of fossil fuels, a phase out of these products should occur because of depletion (Brower, 1992, 5).

The refining process necessary to break down crude oil into its usable components is a source of toxic emissions into the air and water, and they produce hazardous waste (Anderson, 2004, 137). The combustion of refined fuels, such as gasoline and other fuels, in engines and power plants, releases carbon monoxide, nitrogen oxide, and volatile organic compounds into almost every community (Anderson, 2004, 137). It is known that fossil fuels are a finite resource, however we cannot be sure how large the remaining reserves are, and thus we can not accurately predict the oil peak (Hubbert, 1971).Using the prediction methodology developed by Hubbert, leading industry experts are now predicting that total oil production will peak sometime between 2003 and 2020 (Daly, 2004, 114). Prior to this there is expected to be a sharp increase in the price of oil due to the increased cost in the discovery, extraction and refining of the remaining oil reserves (Brower, 1992,5). The price increase will come principally from using oil as a source of energy in the production of oil energy. With increased recovery costs, the energy content of the barrel of oil recovered will be less than the barrel(s) of oil used to extract it (Hubbert, 1971, 39).

North America, and Western Europe consume almost half of the total world's primary energy (Shepard, 2003, 29). The largest consumers of oil are USA, China, the Russian Federation, and Japan (Shepard, 2003, 29). According to Shepard (2003, 62-63), these areas in particular will face two major problems. Firstly, to find a source of liquid fuel that will serve like a diesel or gasoline in motor vehicles and aircraft, and secondly to find a primary energy source for electricity generation (based on the assumption that oil and natural gas will be unavailable).

For the purpose of this project, I am interested in the implications of the second problem, the investigation of which primary fuels can be used as a large scale alternative to oil and natural gas in electricity generation. In the short term, Shepard has identified three "band-aid" solutions: (2.1) discover new oil and natural gas fields and enhance the rate of recovery, (2.2) use coals and coal products including coal-bed methane, (2.3) increase the total energy derived from nuclear fission power and the use of breeder reactors. The preceding solutions are temporary, and are characterized by uncertainty, danger and pollution. They will however prove useful in transitioning society from dependency on nonrenewable sources of energy to renewable energy.

Renewable Energy

Renewable energy can be simply defined as an energy source that is renewed rapidly through natural processes. The amount of renewable energy available far exceeds the present and projected demand of humanity (Anderson, 2004, 144).

Renewable energies include, solar, geothermal, biofuels, wind, tidal energy, hydro, and gravitational energy (Anderson, 2004 144-148 and Shepard, 2003, 63). With renewable energies, an energy stock will not be decreased through use, thus in practical terms they can never be depleted. Renewable energies are becoming more popular because they are less toxic, and are available in almost every community (Anderson, 2004, 147).

Technology has the capability to spread very quickly. For example, from the year 2001 to 2007, the number of cellular telephones in operation increased from 995 million to two billion, a 101%

increase in six years (Brown, 2008, 238). The question remains as to why sources of green technology have not spread as quickly as other technologies. A number of market barriers exist that are limiting the proliferation of renewable energy use in the marketplace.

Market Barriers to Renewable Energy Use

Renewable energies are generally, not commercially, successful (Brower, 1992, 26). This is due to a number of factors that operate against them.

The first barrier is the profit margins for fossil fuels (Brower, 1992, 26). The oil and gas industry in the USA earns 300 billion dollars annually in revenue ,and oil companies have a large consumer surplus (Anderson, 2004, 138). The current financial situation permits oil companies to effectively lobby government and steer the political agenda in their favor (Anderson, 2004, 138). Currently, sixty-two percent of American energy comes from oil and gas, with hydro electricity being the only major renewable energy source (Anderson, 2004, 138). Large oil companies, like BP p.l.c., are now beginning to invest in renewable technologies (BP p.l.c., 2008).

The second market barrier stems from an energy market focused on the short term and one that is insensitive to the environmental and social costs of fossil fuel use (Blower, 1992, 26). This is apparent in the lack of consideration of negative externalities that are associated with energy production (Anderson 2004, 138). All energy systems have risk associated with them, however our willingness to endure the consequences of a particular energy source is linked to the alternatives that are available (Anderson, 2004, 138 and Shepard, 2003, 54). Energy risks include, workplace accidents, industrial disease, large scale accidents, sabotage, management of energy waste, ecosystem effects, water supply problems, and emissions (Anderson, 2004, 54).

In almost all categories of risk assessment fossil fuels prove to be more risky in a social context than renewable alternatives (Anderson, 2004, 55-62). The lack of concern over these risks results from the fact that many of them are difficult to quantify, and the further ahead in time they occur, the less perceived risk they pose (Pindyck, 2007,46). Some environmental and social costs are currently being accounted for implicitly in the market, if not explicitly in energy prices (Brower, 1992, 27). Environmental regulations are adding to the cost of energy from certain sources that have been flagged as damaging to the environment, such as hydro power (Brower, 1992, 30). It is projected that these environmental regulations will eventually make energy companies responsible for a greater share of the actual cost of production, and therefore lead industries toward alternative renewal sources of energy.

The third barrier to renewable energy is the high cost of infrastructure associated with energy systems. Powerplants, refineries and storage networks for energy production and distribution involve high initial capital costs and high maintenance costs. Making a transition from this type of investment to a different infrastructure in support of renewable energy takes time, money and a change in mentality.

It is proving very difficult for companies to gain the confidence of investors and customers (Brower, 1992, 27). One of the major barriers associated with consumer acceptance of renewal energy is the steep initial investment required (Brower, 1992, 28). This sticker price shock can be reduced through federal funding of research and development of renewable energies, which will result in cheaper more efficient technologies. Direct government subsidies to homeowners who are interested in increasing their energy efficiency, such as the Government of Canada ecoENERGY Retrofit Program, is another means to lessen the sticker shock and improve acceptance (Brower, 1992, 27-28 and Natural Resource Canada: Office of Energy Efficiency, 2007).

The final barrier to the development of renewable energies is the lack of public education about alternative energy sources (Brower, 1992, 27). The majority of people are unaware of the benefits of renewable energies, such as solar. Fears have been spread by horror stories such as, blades falling off wind turbines, or solar homes overheating (Brower, 1992, 27).

Although renewable energy implementation faces a number of barriers, it has a growing market share, and the number of available sources of renewable energies that are economically accessible are increasing. When choosing a new renewable energy source it is important to consider a number of different types, because one may be better suited to a given geographical area or site location.

What Renewable Energies Are There?

Renewable energy is a broad category and determining the benefits of multiple types of energy can be complex. Below I will briefly describe solar and geothermal, two types of renewable energy that are potentially feasible in the Corner Brook area. I have chosen not to address hydro power in this paper because it is already a well understood resource on the west coast of Newfoundland. I will follow up with a more in-depth look at wind energy.

Solar

According to the United States Department of Energy, the total solar energy striking the earth's surface in an hour is more than that currently used by all people in the world in one year (United States Department of Energy, 2006). Solar energy is available everywhere on earth. There are two main ways solar energy systems provide benefit. The first concentrates the sun's energy to produce higher grade heat. Provided the heat is of a high enough grade, it may be stored and released when needed, for space heating or as hot water. Some direct heat collection systems cannot produce a high enough grade of heat to be useful directly. These systems may incorporate a secondary device, like a heat pump, to concentrate heat further before it is distributed and used. An example of this type is a solar water heater, parabolic concentrator, etc. A limiting factor for these systems is that the energy produced is not easily transportable far from the collection site.

Proper siting of buildings and proper placement of windows and overhangs can build-in reduction in energy demands in summer and winter. This type of intelligent consideration of the environment, without actually using a formal heating / cooling device per se is known as passive solar engineering. As a default, all buildings should be designed to take advantage of passive solar engineering principles.

The second form of solar energy system involves using a photovoltaic cell to convert the sun's energy into electricity. Electrical energy produced from solar cells, once conditioned, cannot be distinguished from electricity produced by other means. A photovoltaic cell is capable of converting 7-17 percent of light energy into electrical energy (Anderson, 2004, 147). In both cloudy and sunny conditions, electricity can be produced by photovoltaic cells and solar energy can be collected as heat, but it is generally more effective and economical to install solar panels in areas with more sunlight annually (Anderson, 2004, 147). Costs for photovoltaic cells are decreasing as demand increases and as improvements are made in the cells. It is unlikely that photovoltaic cells will become omnipresent until their price decreases and it is unlikely that the price will decrease until popularity provides for an economy of scale (Anderson, 2004, 147-148).

Electricity production using photovoltaic cells is influenced by three major factors: the intensity of the sun, the sun angle, and the operating temperature (Patel, 2006, 171). Of the three factors, the first two also affect solar heat collectors in a similar manner.

The intensity of the sun is very important because solar technology cell conversion efficiency is no longer dependent on whether it is cloudy or sunny. Meaning that a photovoltaic cell will have a lower output on cloudy days only because of the lower solar energy impining on the cell, and not because the cell's efficiency is tied to the light intensity (Patel, 2006, 171).

The angle of the sun in relation to the photovoltaic cell is the second factor to be considered when examining solar electricity. The angle of the sun will directly impact the amount of solar energy that is available annually. Unless the photovoltaic cell has a sun tracking capability, the angle that incoming light strikes the cell will fluctuate with the seasons and the rotation of the earth (Patel, 2006, 172).

The intensity and angle of the sun can be described in terms of solar insolation. Solar insolation is the amount of electromagnetic energy incident on the earth's surface (Shepard, 2003, 398). The solar insolation is a measure of energy striking a given surface, and is routinely defined in kWh/m^2. In Corner Brook the annual average solar insolation is 3.3 - 4.2 kWh/m^2 (Natural Resource Council: Canadian council of forest Ministers, 2007). This varies seasonally, reaching 4.2 - 5 kWh/m^2 in summer, and 0.8-1.7 kWh/m^2 in winter (Natural Resource Council: Canadian council of forest Ministers, 2007).

As noted above, the final factor to influence the productivity of a photovoltaic cell is temperature. A productive solar photovoltaic cell will have a temperature that is higher than the ambient (Shepard, 2003, 412). It is generally accepted that for every degree centigrade rise in the operating temperature of a silicone photovoltaic cell, the power output will decrease by about 0.5% (Patel, 2006, 175). This means that cold weather is better for photovoltaic cells because they will produce more electricity.

Solar electricity generation and solar heating are feasible in Corner Brook, but due to the low solar insolation, particularly in winter, electricity and heating from other renewable sources would be better suited for the area.

Geothermal

Geothermal energy refers to harnessing heat held beneath the crust of the earth (Anderson, 2004, 148). Geothermal energy comes from tapping steam or hot water that has been heated inside the earth. The earth's temperature is stable in the range of 7 - 14° C a few feet below the surface of the earth (Shepard, 2003, 203). It is understood that certain places on the earth have higher grade geothermal heat readily available, and that higher grade sources improve effectiveness of geothermal installations. In some places, super heated steam is accessible close to the earth's surface, while in other locations, geothermal heat is only available from a large sink of moderately warmed mass below the surface. Generally, more heat is available at greater depths below the earth's surface, but at an access cost premium. Most geothermal installations in Corner Brook are a horizontal configuration, and in this geographical area, need only be placed six feet bellow the surface to function (Stone, 2008).

Geothermal energy is exhaustible in most concentrated geographical locations and technology does not offer solutions for this (Cassedy, 2000, 188). This means that if high density populations compete for available geothermal energy within a small geographic area, the heat source could be depleted. However, on a global scale geothermal heat is considered renewable.

Geothermal heat regulation of buildings can be beneficial in both summer and winter (Anderson, 2004, 148). Geothermal energy has a number of uses both indoors and outside as a source of heat to melt snow and ice off sidewalks and roads (Brower, 1992, 128-129). If the geothermal heat source is of high enough grade, it may be used directly for heating buildings, and may be used for other heating tasks. As well, electrical generation is possible with a geothermal electrical plant (if there is a sufficiently high grade heat source) (Shepard, 2003, 203-204 and Cassedy, 2000, 188). If geothermal sources are cooler, it may be necessary to extract heat from a large volume heat sink and upgrade the output with a heat pump to make the energy useful for building space heating.

The economic feasability of geothermal electricity depends on the depth of the well(s) that will be necessary (Cassedy, 2000, 188). A heat pump using geothermal energy in summer is able to cool buildings by transferring indoor heat into the ground and drawing up the cool temperatures from the earth (Anderson, 2004, 149). In winter, a heat pump will use the same infrastructure to bring conditioned heat into the house (Shepard, 2003, 204). The use of a heat pump consumes electricity as it conditions the source heat. The greater the degree of heat conditioning, the more electrical energy is required. It is unlikely that high grade geothermal heat is available close to the earth's surface in Corner Brook, therefore direct heating of buildings (not using a heat pump) and electrical production from a local geothermal source seem impractical.

Geothermal energy is already in use in the Corner Brook area in both residential and commercial buildings (Stone, 2008). Due to the nature of geothermal systems, it is more economically feasible in larger buildings, so it is most frequently installed in commercial buildings and large residential buildings. It is being used in the Grenfell forestry center, the Deer Lake police office, and is incorporated in the plans for a long term care center which is currently under construction nearby Grenfell (Stone, 2008). Geothermal energy is a viable heating and cooling alternative energy source for Grenfell and there is a potential to expand its use into the new buildings now being planned (Stone, 2008).

Wind

Wind energy is derived largely from solar radiation (Shepherd, 2003, 299). Wind results from air pressure differences between geographic regions, caused by solar heating. It is possible to convert wind energy into mechanical energy or to convert it to electrical energy. In this paper I will focus on generating electricity from wind. Like the other types of renewable energy addressed above, wind energy taps into a free source of energy (except of course for infrastructure and maintenance costs necessary to collect it). It is clean, and like solar power, it is renewable. Wind has been used for hundreds of years and is infinitely renewable (Ackerman, 2005, 7 and Shepherd, 2003, 299). Due to its economic competitiveness, and the wind's availability in many locations, electrical generation using wind power has become attractive to utility and electrical companies (Patel, 2006, 11).

Wind Statistics

There have been significant improvements in the reliability and efficiency of wind technologies and reductions in capital costs (Redlinger, 2002, 1). These advances brought the cost of electricity produced by wind down from about 35 cents/kWh in 1980, to 3 - 4 cents/kWh in 2004 (Patel, 2006, 11). Wind energy was the most popular means to produce electricity from a renewable source in the 1990's (Redlinger, 2002, 1). This popularity was driven mostly by economics.

Wind power had a 143 % growth rate from 2003 - 2007, with the operational wind power capacity globally in 2007 being 94 123 MW (Ackermann, 2005, 12, table 2.4 & Global Wind Energy Council, 2008). By the end of 2003, Canada produced 327 MW of electricity from wind farms (Ackerman, 2005, 14, table 2.7). This output is continuing to increase dramatically. In April of 2006, Canada's installed wind electrical energy production was 944 MW, or enough to power 280 000 of the 12 million homes in Canada (Natural Resource Canada, 2006). This is an approximate 190 percent increase in less than a three year period. Canada, at the end of 2007, had an installed electrical wind generating capacity of 1846 MW, which is 0.2 kW/km^2 (Wind energy institute of Canada: Facts, 2007).

The Wind Energy Institute of Canada (2007) summarizes the installed wind capacity per province on their facts webpage. In Atlantic Canada, P.E.I. has the most installed electrical wind generating capacity with 72.4 MW, followed by Nova Scotia with 59.3 MW, and Newfoundland and Labrador with 0.4 MW. Although P.E.I. does not have the greatest installed electrical wind generating capacity as compared to other Canadian provinces, it does produce the most Watts/capita, due to its small population. P.E.I. has 532.6 Watts/capita as compared with Alberta, the leading province in terms of wind energy production with 524 MW, but with only 159.2 Watts/capita. Compared with the national average of 56.2 Watts/capita, Alberta and P.E.I. are doing well. Newfoundland and Labrador however had a developed electrical wind generating capacity of only 0.8 Watts/capita at the end of 2007. The Newfoundland and Labrador wind energy potential is currently underdeveloped. There is a vast reserve of unused wind energy that could be tapped into using small wind turbines in areas of low population density, and large wind turbines in the population intensive centers, such as Corner Brook and St. John's. Although wind based electrical generation is growing quickly in Canada and other parts of the world, Europe is the global leader in electricity production from wind; in 2003, Europe had about 70 percent of the global installed electrical wind generating capacity (Patel, 2006, 19).

Small Wind Turbines in Newfoundland

By definition, small wind turbines generate between 300 W and 300 kW of electricity (Lacroix, A., CANMET Energy Technology Centre, 2005, V). The potential market for small wind turbines in Newfoundland is large due to the secluded nature of the communities (Lacroix, A., CANMET

Energy Technology Centre, 2005, 54). The major barriers to the development of the small wind turbine market in Newfoundland are a lack of detailed information about local wind patterns (which is necessary before installation), limited access to a variety of products, the cost of installations, and the availability of trained service technologists. In 2005 there were only two retailers of small wind turbines in Newfoundland (Lacroix, A., CANMET Energy Technology Centre, 2005, 30). Removing the aforementioned barriers to deployment would enhance small wind turbine use in Newfoundland, and improve the province's environmental footprint.

Large Wind Turbines in Newfoundland

This paper's primary focus is on introduction of large wind turbine(s) to the Grenfell campus as a pilot project. Large wind turbines produce more than 300 kW of electricity (Lacroix, A., CANMET Energy Technology Centre, 2005, V). To determine the feasibility of this installation I will examine a number of factors: wind speeds, potential siting, a brief look at different turbine structures, and an analysis of the strengths, weaknesses, opportunities and threats of an installation (SWOT). In general a wind class of at least 4 is preferred for large scale wind sites (American Wind Energy Association, 2007). Wind power classes depend on three factors: the height above sea level, power density and wind speeds (Khan, 2004, 1219). At 80 m above sea level the following wind speeds correspond with wind classes (Archer, 2005, 38).

Wind Classes at 80 m	Wind Speed (m/s)
1	<5.9 m/s
2	5.9 to 6.9 m/s
3	6.9 to 7.5 m/s
4	7.5 to 8.1 m/s
5	8.1 to 8.6 m/s
6	8.6 to 9.4 m/s
7	>9.4 m/s

Wind Speeds in Corner Brook

Wind velocity is variable on a moment by moment basis, but most areas have predictable patterns of wind velocity over a one year period (Shepherd, 2003, 300). Before wind energy can be developed in Corner Brook, it will be necessary to establish test sites to obtain detailed information about wind velocity and direction. In order to justify installation of a large wind turbine it is ideal to have between five and ten years of data collected (Khan, 2004, 1213). Currently there are only a few sources that can provide an overall picture of the wind patterns in the area. The island of Newfoundland has average surface wind speeds calculated between 6 - 8 m/s (Khan, 2004, 1214). This varies only slightly with altitude. At 10 m altitude wind speeds are from 5 - 7.5 m/s and at 50 m above sea level wind speeds are 6 - 8.5 m/s (Khan, 2004, 1214). NASA reports the annual average wind speed in Corner Brook at 5.2 m/s at 10 m altitude (RETScreen International,2008). At 10 m above sea level in Corner Brook the wind produces between 300-400 Watts per m^2. In areas in the Bay of Islands at least 900 W/m^2 are available to be tapped (Environment Canada, 2004). Corner Brook appears to be a class 4 - 5 wind zone with wind speeds 5.6 - 6.0 m/s at 10 m above sea level and 7.0 - 7.5 m/s at 50 m above sea level (Archer, 9 and Khan, 2004, 1219). Near the mouth of the Bay of Islands there are areas of class seven winds. Around the main island of Newfoundland there are many sites where the offshore potential for wind turbines is strong due to the existence of class seven winds (Archer, 9, 2005). In the Bay of Islands, at altitudes of 80 m above sea level, there is a power density of at least 1000 W/m^2, or wind speeds of at least 10 m/s (Environment Canada, 2004). At heights of 80 m above sea level, Corner Brook has a power density of 600 W/m^2 or a wind speed of approximately 8 - 8.5 m/s (Appendix E) (Environment Canada, 2004). From these data it is difficult to conclusively state if wind conditions are suitable for a large wind turbine at Grenfell. It will be necessary for Grenfell to do wind velocity and direction testing at a number of potential sites and heights above sea level in the area under consideration. What is clear from the existing general data is that, although Corner Brook does not appear to have wind speeds necessary to support the installation of a large wind turbine, there are many sites close to the city which need to be measured to quantify their status.

Wind Turbine Siting

The siting of the wind turbine(s) will depend on the information collected from test sites in the Corner Brook and Bay of Islands area. A number of factors need to be considered when siting a wind turbine. Initially, geographical location needs to be determined (Shepherd, 2003, 339). In the Corner Brook area, the geographical location will be determined by conducting a wind study to determine the average wind speeds within the Bay of Islands, or the other region(s) of interest (Manwell, 2002, 370).

Under ideal conditions, a wind study can be completed by using wind atlases, but due to a lack of high resolution information for Newfoundland it would be necessary for test sites to be established and local data collected before an investment was made to place a large wind turbine near Corner Brook. After a wind study has been completed, computer modeling can help evaluate the wind resource (Manwell, 2002, 370).

The geographical location will also need to take into account such features as road access, and the proximity to the public electricity network (Shepherd, 2003, 339). Once a geographical setting is established, the precise geographical location will depend on a number of factors, most of which can be considered in a computer modeling program (Shepherd, 2003, 339). These factors include altitude, proximity to other wind machines, and the degree of exposure or chances of wind screening from nearby obstacles like hills or trees (Shepherd, 2003, 339).

At this stage, it is also important for environmental components to be considered (Manwell, 2002, 370). Environmental components are a broad category that can include influences on environmentally sensitive areas, species at risk, bird flyways, the usability of the site for animal habitats, and consideration of obstruction of natural beauty in an area (Manwell, 2002, 371 and Shepherd, 2003, 340). Legal issues including, ownership, land use rights and zoning issues can all come into play when siting a wind turbine (Manwell, 2002, 371). Permits would need to be secured and an EIA process would need to be completed in advance of development. There is potential that these processes will identify problems with a selected site (Manwell, 2002, 371). The final aspect for consideration when siting a wind turbine is the cost (Shepherd, 2003, 340). Cost includes installation, repair and upkeep, comparative costs of other sources of energy, and workers wages (Shepherd, 2003, 340). Much of the cost will be attributable to purchasing the wind turbine itself and the supporting hardware. Predicting costs of wind turbines is difficult because many factors influence the cost of installation. The Canadian Wind Energy Association states that the costs of building a wind farm will likely range between 1.8 to 2.2 million dollars per megawatt (Canadian Wind Energy Association (2), 2006, 1). This means that the cost of installing one 2.5MW wind turbine could range from 4.5 million to 5.5 million dollars.

VAWT vs HAWT

Vertical axis wind turbines and horizontal axis wind turbines are the two major types of wind turbines that exist, both have benefits and drawbacks. Wind turbines which most people are familiar with are called horizontal axis wind turbines (HAWT). These have long slender blades that spin around a horizontal axis. The vertical axis wind turbines (VAWT) spin around a vertical axis.

Horizontal wind turbines are the most common type of wind turbine currently (Gipe, 1993, 99). All commercial wind turbines connected to the electrical grid follow this design of a propeller type rotor mounted on a horizontal axis on top of a tower (Norske Veritas, & Forsknings center Riso, 2002, 2). These turbines need to be aligned with the wind so that wind flows parallel to the axis of rotation (Norske Veritas, & Forsknings center Riso, 2002, 2). HAWTs are built so that they can rotate their position depending on the direction of the wind (Gipe, 1993, 99). HAWTs have two major types, upwind and downwind rotors (Gipe, 1993, 100). An upwind rotor will face the wind and be placed in front of the mounting tower; this is the most common type in use today (Norske Veritas, & Forsknings center Riso, 2002. 2 and Gipe, 1993, 100). A downwind rotor is placed on the lee side of the mounting tower; this is a disadvantage because of the wind shadow created by the tower (Norske Veritas, & Forsknings center Riso, 2002, 2-3).

VAWTs are less common, but they were one of the earliest wind machines used (Shepherd, 2003, 332). Most VAWT's use rotating C-shaped blades or cups to capture the wind (Norske Veritas, & Forsknings center Riso, 2002, 2). These windmills are most convenient because they can be built next to the ground, which makes them easy to access for repairs (Norske Veritas, & Forsknings center Riso, 2002, 2). However, building close to the ground is also a downfall, because close to the ground there is typically less wind. The design of the C shaped blades makes it difficult to do specific repairs without removing the blades (Norske Veritas, & Forsknings center Riso, 2002, 2).

Currently the VAWT's are becoming an important tool in testing wind speeds and for generating small to medium amounts of power for homes or cottages (Shepherd, 2003, 332). This type of wind turbine is simpler to install because it does not need to be oriented into the wind; it can use wind from all directions, and is more accessible for repairs than HAWT(Shepherd, 2003, 332). VAWT's are less efficient than HAWT's (Norske Veritas, & Forsknings center Riso, 2002, 2).

For the purpose of this project, an initial investment in a small vertical axis small wind turbine would be beneficial to test wind sites for a later investment in a large horizontal axis wind turbine. The VAWT's purchased to test wind sites could continue to be used by the university to help promote and develop wind projects in other communities in the province. After the initial investment for this project, the VAWT's could continue to provide research for other sites or could be used in an attempt to develop a more comprehensive wind map of the province.

The large HAWT eventually purchased will likely need to have a low cut- in speed, meaning it will start generating electricity at a low wind speed. According to my preliminary analysis of wind data, a wind turbine with a lower cut-in speed would be beneficial, but a low cut-in speed may not be essential, depending on the wind characteristics of the site chosen.

For illustration, I will present information on one large wind turbine that has specifications similar to what I believe would be needed in the Corner Brook area. It is the General Electric (GE) 2.5xl wind turbine. The information in this paper about this wind turbine is a summary from the product brochure published by GE Energy.

The GE 2.5xl MW wind turbine is designed for operation on land (General Electric Energy, 2006, 2). It has a low cut-in wind speed (3.5 m/s), which is consistent with wind speeds in the Corner Brook area and in the higher wind areas at the mouth of the Bay of Islands. It will cut-out at wind speeds of 25 m/s. I am unable to tell to what extent winds in the Corner Brook area will reach the 25 m/s rate frequently, because of the general nature of the wind data that I have at my disposal. With further research it may be proven more economical to invest in a wind turbine that has a higher cut-out speed. At its peak the 2.5xl generates around 2.500 kW/hr and this is achieved with 12.5 m/s winds (General Electric Energy, 2006, 2). The turbine, like most commercial turbines, has different options available for the tower height: 75 m, 85 m, and 100 m; these features allow it to be height adjusted for specific sites. This wind turbine is just one of many available commercially.

Memorial University has a partnership with the Sustainable Power Research Group from the University of New Brunswick and through this partnership it would be possible to determine which type of wind turbine would be most efficient for use in the Corner Brook/Bay of Islands area (Wind Energy Institute of Canada, 2007).

SWOT

One tool that can be used to give an over arching picture of this project is a SWOT analysis. A SWOT is designed to identify the strengths, weaknesses, opportunities and threats facing a business, project or plan.

Strengths	**Weaknesses**
Intellectual resources	Lack of information on wind patterns
Location resources	High development costs
Positive consumer perception	Lack of skilled individuals
Environmentally friendly	Technical installation barriers
Educational benefits	Long bureaucratic procedures (EIA)
Research potential	Lack of interest by the school administration
Offsetting electrical costs	Lack of financial resources
Provide jobs for maintenance	
Potential for student research	
Opportunities	**Threats**
Partnership with different levels of government	Other places with wind potential
Partnership with post secondary educational institutions	Other renewable energy sources
Growth for the wind energy industry	Getting wind turbines on site
Technology is getting cheaper	Government support of hydro energy
Tourism development	Possible failure of the project
Increase school prestige	
Potential for industrial ecology	

Strengths

Intellectual resources

Wind turbines are a well-researched source of electricity. There is a wealth of knowledge about the design, placement and maintenance of wind turbines in a variety of climatic locations.

Location resources

Locations for wind turbine placement exist within the local area, close to the campus. The topography of the area promotes tunnels of wind and through hilltop placement the turbine would be able to take advantage of increased wind speeds as it crests the hill (Cheremisinoff, 1978, 93).

Positive consumer perception

Although some people find wind turbines to be unsightly and believe they damage local aesthetics, many believe that the drawbacks are outweighed by the benefits; offsetting long-term and large scale impacts of use of more polluting energy sources (Redlinger, 2002, 163). Wind energy does seem to have an overall positive public perception and only a minority of groups are opposed to its development (Redlinger, 2002, 164).

Environmentally friendly

Wind energy has an advantage because it is known as a "green energy" and this has an attractiveness to consumers who view it as an environmentally sustainable option. Wind energy offsets emissions that would be generated by conventional fossil fueled electrical power (Anderson, 2004, 137). These emissions include sulfur dioxide, carbon dioxide, particulates, slag and ash, and oxides of nitrogen (Manwell, 2002, 44).

Educational benefits

One of the major benefits to Grenfell in the installation of this wind turbine will be the educational benefits derived for students and faculty from the research necessary for installation, the erection of the wind machine itself and the maintenance. I think that a partnership between the College of the North Atlantic (CONA) and Grenfell would increase the educational benefits that could be derived from this project in terms of economies of scale. Also, if a partnership did develop, it could split installation costs between the two institutions.

Research potential

The research potential of a wind project could be expanded beyond the necessary research for this project. As I mentioned previously, I believe that an initial investment in a VAWT would be beneficial. This turbine could be a wind cup anemometer with a wind direction indicator. After the initial use of this tool for this project, the anemometer could be used to determine wind use feasibility in other parts of the province, making it a research tool for students at both CONA and Grenfell (Marier, 1981, 20).

Offsetting electrical costs

Grenfell College's power costs are steadily increasing (Appendix B). In 2005-2006 the total cost of electricity (including the forestry center) for the year was $897,762 with 11,597,997 kWh being consumed. This increased from 2004-2005 where the consumption was 11,171,119 kWh. This is a 3.8% increase in consumption over one year. From 1999 to 2007 there has been a 18.37% increase in electricity demand at the college (not including the forestry center) and a 47.36% increase in the cost. The increase in consumption is due in part to the building annex completed in 2007. The increased cost is due in part to the rising cost of electricity. Grenfell has development plans for the next few years and the expansion of the college will add to the electricity demands and will increase the ecological footprint of the school. The GE 2.5xl wind turbine that I outlined earlier as a possible option for the school, is capable of generating 60,000 kW a day. The college has reached a peak demand in electricity of 1,219,824 kWh for February of 2007. Assuming that the 2.5mW wind turbine was getting wind speeds of at least 12.5m/s , it would be capable of generating 1,740,000 kWh for the month of February. This means that under ideal conditions it is capable of meeting the demand of the main campus, not including the forestry building. It would be less costly for the school to install two wind turbines at once because it would support future electrical consumption and create an economy of scale. Whether or not one or two turbines were installed, they would be backed up by power from the grid. There would be an agreement negotiated between Newfoundland Power and the Grenfell collegeconcerning the sale of excess electricity.

Provide jobs for maintenance personnel

Grenfell would need to hire or train someone capable of completing basic repairs and maintenance on the wind turbine. The manufacturer could provide assistance with training.

Potential for student research

A project like this could involve students from many disciplines in Grenfell, including, tourism, environmental science, environmental studies, sustainable resource management, and business administration. As well, almost all programs offered at the Corner Brook campus of CONA would have an opportunity to participate and learn. Disciplines include, civil engineering, electronic engineering, environmental technology, engineering technology, fish and wildlife, and forest resource programs.

Weaknesses

Lack of information on wind patterns

As illustrated in the section of this paper about wind speeds in the area, a lot of uncertainty exists. Before the feasibility of this project is determined, more definitive research will need to be done to determine wind speeds in the area.

High development costs

Even though there is no fuel cost for wind turbines they have a high installed capital cost, which includes more than just the purchase of the turbine (Manwell, 2002, 404). Wind turbines have a number of general categories of costs associated with them: planning and site preparation, equipment purchase, construction cost, installation cost (National Wind coordinating committee 1997, Article 11). The following have been identified by the National Wind Coordinating Committee as potential costs:

- Wind resource assessment and analysis
- Permitting, surveying, and financing
- Construction of service roads
- Construction of foundations for wind turbines, pad mount transformers and substations
- Wind turbine and tower delivery to the site, and installation
- Construction and installation of wind speed and direction sensors
- Construction of power collection system including the power wiring from each wind turbine to the pad mount transformer and from the pad mount transformer to the substation
- Construction of operations and maintenance facilities
- Construction and installation of a wind farm communication system supporting control commands and data flow from each wind turbine to a central operations facility
- Provision of power measurement and wind turbine computer control, display and data archiving facilities
- Integration and checkout of all systems for correct operation
- Commissioning and shakedown
- Final turnover to the owner or operating agency

Lack of skilled individuals

In Newfoundland and Labrador there is a lack of skilled workers who are familiar with the installation and servicing of wind machines.

Technical installation barriers

Associated with costs, installation barriers refer to the accessibility to a selected site.

Long bureaucratic experiences

It is a lengthy procedure to receive the necessary permits for development and to complete the Environmental Impact Assessment (EIA) process. This slows down the development of the project.

Lack of interest by the school administration

The university administration has not made environmental sustainability a priority and it may be difficult to receive approval for a project of this nature considering the financial costs.

Lack of financial resources

The school does not have the necessary financial capital for the initial investment in a wind turbine.

Opportunities

Partnership with different levels of government

With more collaboration between government agencies and the developers of renewable energy it is possible that there will be fewer barriers for new entrants in the sector to participate in development. In the 2008 Throne Speech the NL government identified the development of wind energy as an energy initiative (Government of Newfoundland and Labrador, 2008). It may be possible that the NL government would start subsidizing wind power development, the United States has done this federally providing 1.9 cents per kW/hr (McConnell, 2007, 111).

Partnership with post secondary institutions

The University of New Brunswick engineering department opened a test facility for wind and solar energy conversion systems in 1999 (Wind energy institute of Canada, 2007). It is one of the largest groups doing renewable energy research in Canadian universities (Wind energy institute of Canada, 2007). By partnering with UNB and CONA, Memorial at large and Grenfell will benefit from a broader base of knowledge. The connection with UNB will prove beneficial in the research and development stages of the project where as the close proximity of CONA will allow their engineering and technical students to have hands on practical experience with installation and maintenance of the wind machine. These partnerships will prove beneficial in future projects and will serve to develop social networks between the institutions, and among the students.

Growth for the wind energy industry

There is the possibility of growth of the wind energy industry. New projects will allow wind energy to make up a larger share of the electrical energy market and this will lead to further developments in the wind machine technology market. The stimulation of the Newfoundland market will promote local growth.

Technology is getting cheaper

Wind technology is getting cheaper as it evolves and becomes more popular. The stimulated growth resulting from this and similar projects will lead to further research and development. This means that there will be opportunities for economies of scale and therefore the market will grow (Anderson, 2004, 128). If wind power develops in NL it is possible that providers of wind turbines will station a supplier in the province.

Tourism development

Wind machines and particularly wind farms are becoming a popular tourist attraction where they exist. At North Cape wind farm in P.E.I. there are 60,000 visitors annually (Canadian Wind Energy Association (1), 2006, 4). There is potential for the development of tourism in association with the wind turbine that would be installed for Grenfell.

Increase school prestige

With a wind turbine the school would be able to increase its prestige as a provider of environmental programs.

Potential for industrial ecology

The wind turbine could be used to power an on-campus hot house to grow vegetables for the cafeteria.

Threats

Other places with wind potential

If the project is to be subsidized by government, it is likely that they will look for a wind site with the most potential and that may not necessarily be in the Bay of Islands area. Government involvement in this project may alter the purpose of the project.

Other renewables

Within my brief analysis of alternative sources of energy, I believe that both geothermal and solar energies are feasible in this area, and depending on the initial and maintenance costs associated with these other energy sources, it may prove more economically feasible in the short term to develop a different alternative energy source.

Getting wind turbines to the area

There are no retailers for large wind turbines in the area which means that it will be costly to purchase a wind turbine and have it professionally installed. These costs could be reduced through the purchase of second hand wind turbines, as was the case in P.E.I.

Government support of hydro energy

Newfoundland Hydro is the primary source for electricity for the province and they have a focus on hydro electricity. Because of the close link between government and business there may not be interest in the promotion and development of wind energy.

Possible failure of the project

The project may fail due to a number of barriers. For instance, funding may not be available, wind studies may suggest that the project isn't feasible.

The preceding SWOT analysis provides a brief overview of the project and allows for the quick identification of some of the major positive and negative aspects of it. If Grenfell were to move ahead with the installation of a large wind turbine, a working committee should be struck to develop a plan.

Conclusion

For reasons of institutional passion and to secure its position in the future as a relevant institution, Grenfell should restore the balance between what it teaches environmentally and how it behaves as an institutional and community leader. To assist, Grenfell should consider working with other universities to implement an environmentally sustainable campus plan, such as detailed in the Talloires declaration. A commitment to the Talloires declaration will, as a matter of process, help to define priorities and an environmentally sound future direction for Grenfell. As part of future energy plans for the campus there is an opportunity to implement alternative energy projects, providing substantial learning and societal benefits. This paper has identified that solar, geothermal and wind energy installations at the campus are viable environmentally responsible forms of alternative energies that could help Grenfell achieve a greener footprint.

Due to a lack of research on the topic of wind power in the Corner Brook area, I chose as the primary focus of this paper an examination of the strengths and weaknesses of investing in a large wind turbine to produce electricity for Sir Wilfred Grenfell College. From this study I have determined that wind power is a good option in the Grenfell area. Preliminary wind studies suggest that the highest wind speeds occur near the mouth of the Bay of Islands, but it is likely that wind speeds would be high enough for certain wind turbine designs to be placed closer to the Grenfell campus.

It is well understood that the cost of purchasing, installing, and maintaining alternative energy systems is high when compared to simply expanding today's oil-based infrastructure. There is however a lot more in-play now that dollars and cents as measured today. Through investment in wind energy, Grenfell will take an important first new step towards environmental energy leadership. The project will become a landmark for the college and the community, and promote environmental awareness; it will serve as a powerful statement of Grenfell's commitment to environmental excellence. Beyond this, by investing in renewable energies, Grenfell will reduce its ecological footprint and may be able to help lead a movement toward use of green energy in the province.

Numerous stages of research and development would be necessary to implement the wind turbine project and it would be of great advantage for students to be involved in all stages. Firstly, more site specific research is necessary to determine location, wind speeds, and the ideal height of the wind turbine. Secondly, Grenfell could use the geographical information systems (GIS) program to determine the best route of access to the site, if road construction were necessary. Thirdly, Students could lead the study of environmental impacts, including potential impacts on bird flight patterns. Fourthly, students could generate an accurate wind map of the area using existing data and the data collected from test sites established as a result of the project. Fifthly, students could perform tests to determine the baseline state of the environment, from which environmental impacts could be compared. Lastly, students could learn from the preparation of the site and the installation and maintenance of the wind turbine(s) itself.

This project will include a broad range of student and faculty expertise, and by drawing on local abilities, this project has a potential to benefit not only the post secondary educational institutes in the area, but Corner Brook and Newfoundland at large. The project has the potential to propel the province into the market for large electrical wind generating machines.

More planning and research are still necessary to determine if a large wind turbine project is truly viable. After having done the preceding preliminary assessment, I believe that taking the series of next logical steps to assess this project, and following the project through to completion if further evaluations result in a positive outcome, could be one means for Grenfell College to reassert itself as a green research institution, and a leader in environmental excellence. At the same time it will simultaneously provide a more positive place for students and staff, and a better environment for all species under stress from man's footprint on the environment.

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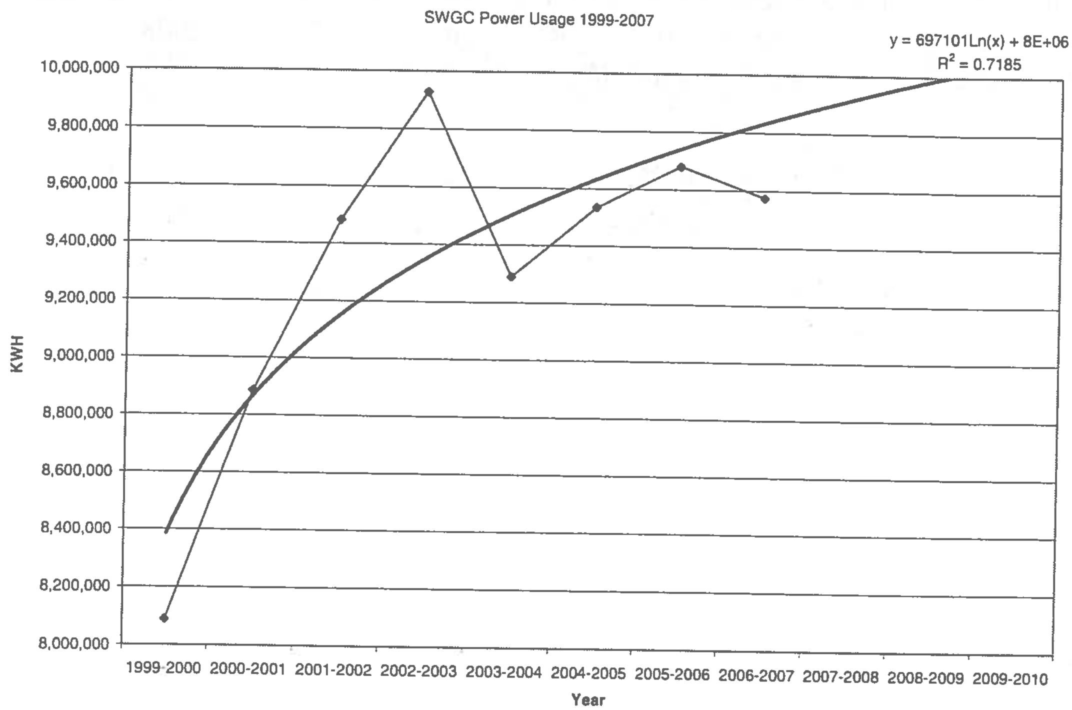
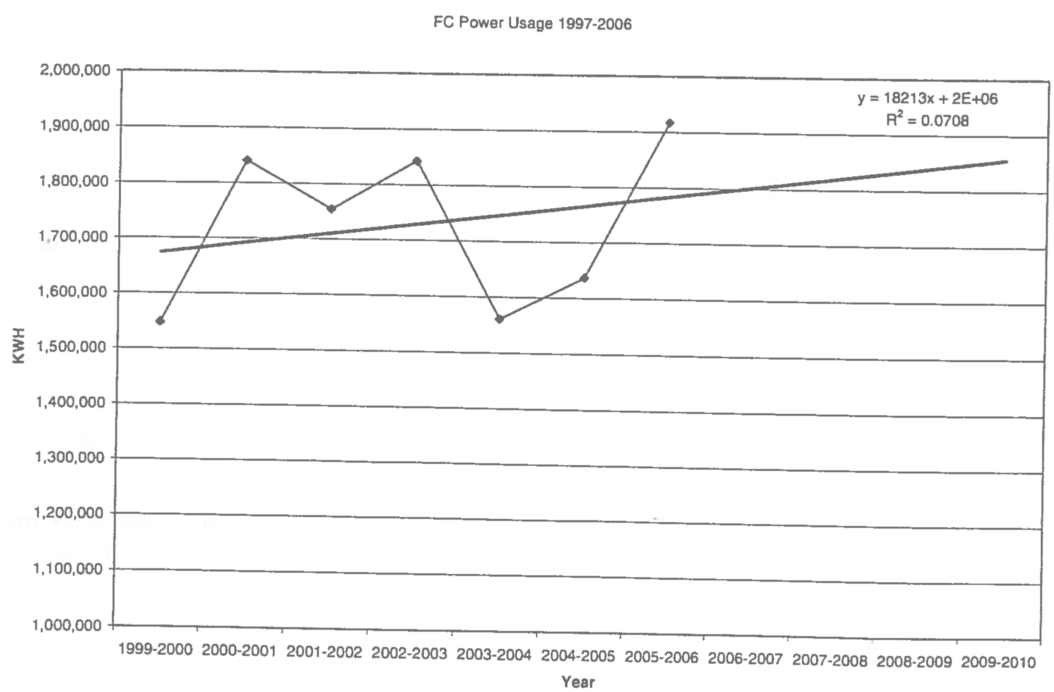
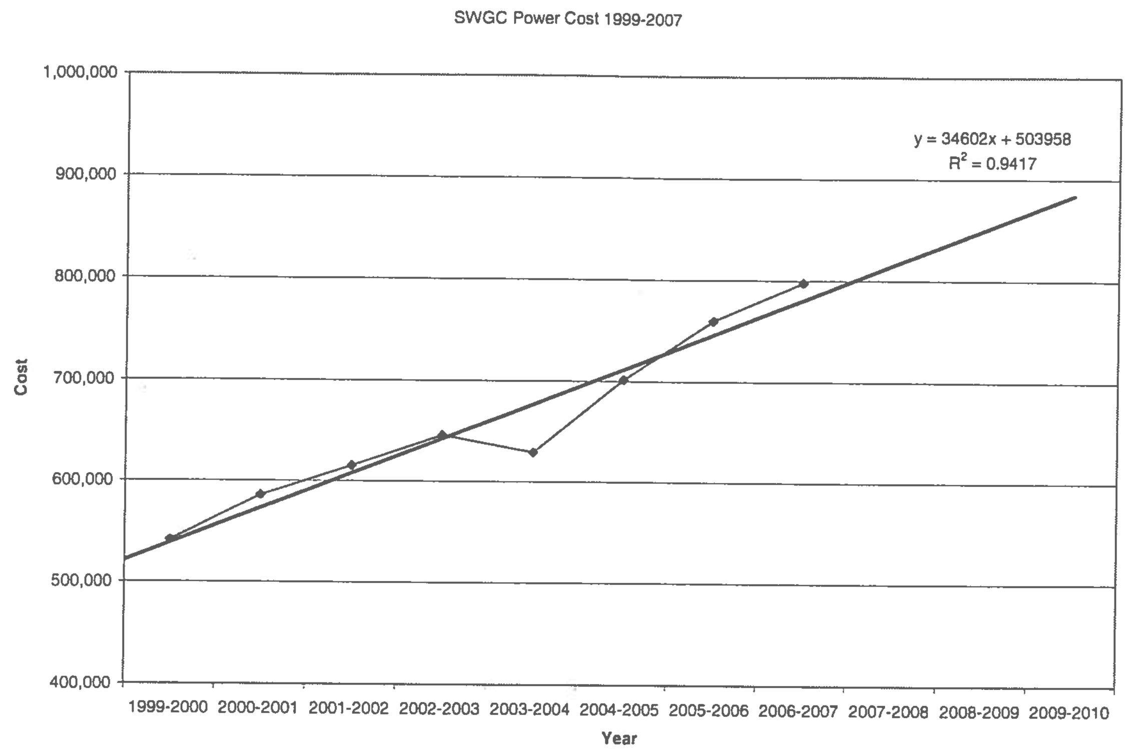
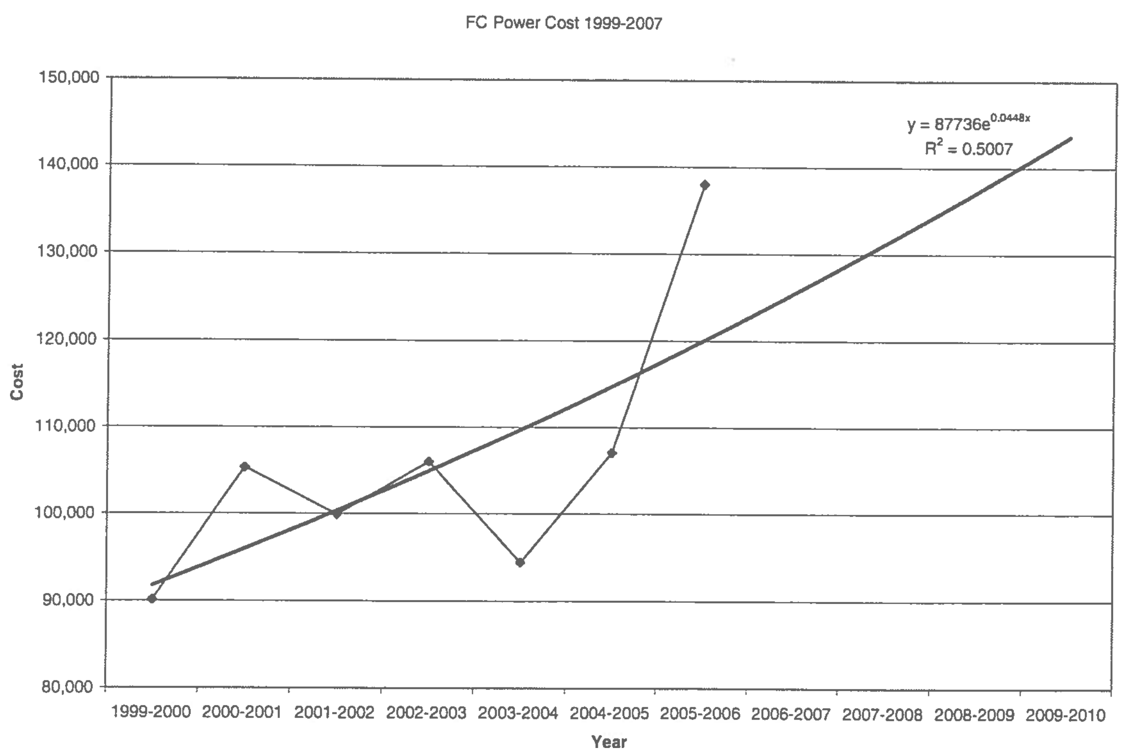
Appendix A

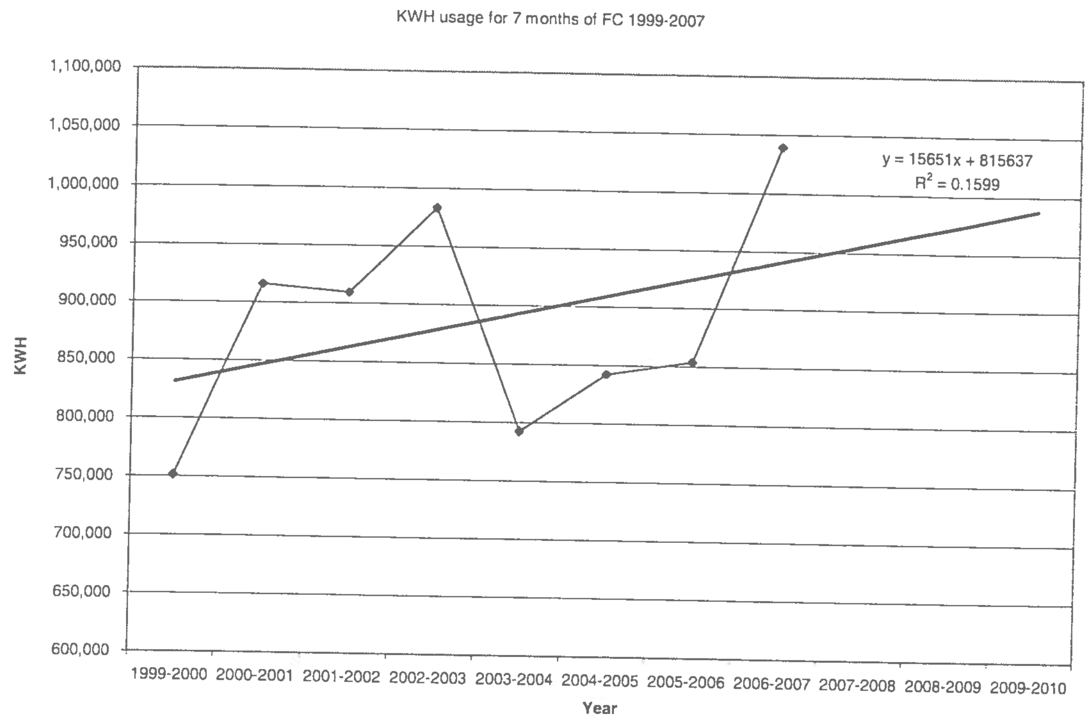
SWGC power use and cost from 1999 to present

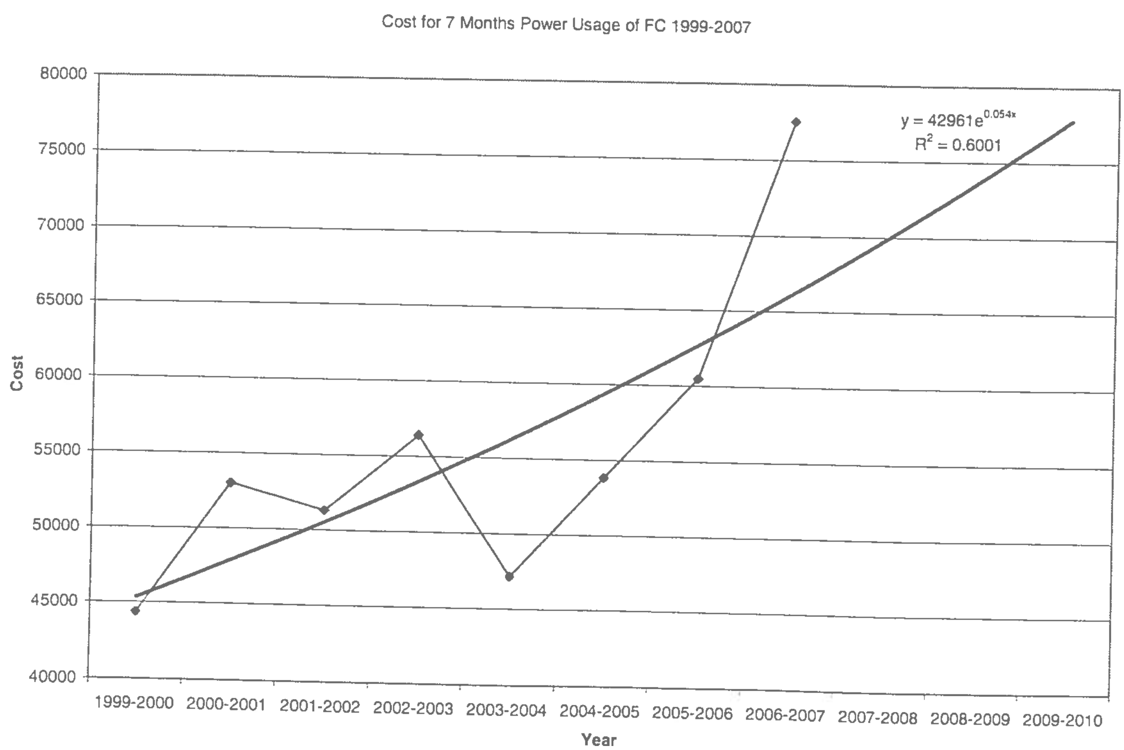





SWGC Power Cost 1999-2007
y = 34602x + 503958
R² = 0.9417
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
Cost
1999-2000 2000-2001 2001-2002 2002-2003 2003-2004 2004-2005 2005-2006 2006-2007 2007-2008 2008-2009 2009-2010
Year


FC Power Cost 1999-2007
y = 87736e^0.0448x
R² = 0.5007
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
Cost
1999-2000 2000-2001 2001-2002 2002-2003 2003-2004 2004-2005 2005-2006 2006-2007 2007-2008 2008-2009 2009-2010
Year


KWH usage for 7 months of FC 1999-2007
1,100,000
1,050,000
1,000,000
950,000
900,000
850,000
800,000
750,000
700,000
650,000
600,000
KWH
y = 15651x + 815637
$R^2 = 0.1599$
1999-2000 2000-2001 2001-2002 2002-2003 2003-2004 2004-2005 2005-2006 2006-2007 2007-2008 2008-2009 2009-2010
Year


Cost for 7 Months Power Usage of FC 1999-2007
80000
75000
70000
65000
60000
55000
50000
45000
40000
Cost
$y = 42961e^{0.054x}$
$R^2 = 0.6001$
1999-2000 2000-2001 2001-2002 2002-2003 2003-2004 2004-2005 2005-2006 2006-2007 2007-2008 2008-2009 2009-2010
Year

Appendix B

Talloires Declaration

We, the presidents, rectors, and vice chancellors of universities from all regions of the world are deeply concerned about the unprecedented scale and speed of environmental pollution and degradation, and the depletion of natural resources.

Local, regional, and global air and water pollution; accumulation and distribution of toxic wastes; destruction and depletion of forests, soil, and water; depletion of the ozone layer and emission of "green house" gases threaten the survival of humans and thousands of other living species, the integrity of the earth and its biodiversity, the security of nations, and the heritage of future generations. These environmental changes are caused by inequitable and unsustainable production and consumption patterns that aggravate poverty in many regions of the world.

We believe that urgent actions are needed to address these fundamental problems and reverse the trends. Stabilization of human population, adoption of environmentally sound industrial and agricultural technologies, reforestation, and ecological restoration are crucial elements in creating an equitable and sustainable future for all humankind in harmony with nature.

Universities have a major role in the education, research, policy formation, and information exchange necessary to make these goals possible. Thus, university leaders must initiate and support mobilization of internal and external resources so that their institutions respond to this urgent challenge.

We, therefore, agree to take the following actions:

1. **Increase Awareness of Environmentally Sustainable Development**
   Use every opportunity to raise public, government, industry, foundation, and university awareness by openly addressing the urgent need to move toward an environmentally sustainable future.

2. **Create an Institutional Culture of Sustainability**
   Encourage all universities to engage in education, research, policy formation, and information exchange on population, environment, and development to move toward global sustainability.

3. **Educate for Environmentally Responsible Citizenship**
   Establish programs to produce expertise in environmental management, sustainable economic development, population, and related fields to ensure that all university graduates are environmentally literate and have the awareness and understanding to be ecologically responsible citizens.

4. **Foster Environmental Literacy For All**
   Create programs to develop the capability of university faculty to teach environmental literacy to all undergraduate, graduate, and professional students.

5. Practice Institutional Ecology
Set an example of environmental responsibility by establishing institutional ecology policies and practices of resource conservation, recycling, waste reduction, and environmentally sound operations.

6. Involve All Stakeholders
Encourage involvement of government, foundations, and industry in supporting interdisciplinary research, education, policy formation, and information exchange in environmentally sustainable development. Expand work with community and nongovernmental organizations to assist in finding solutions to environmental problems.

7. Collaborate for Interdisciplinary Approaches
Convene university faculty and administrators with environmental practitioners to develop interdisciplinary approaches to curricula, research initiatives, operations, and outreach activities that support an environmentally sustainable future.

8. Enhance Capacity of Primary and Secondary Schools
Establish partnerships with primary and secondary schools to help develop the capacity for interdisciplinary teaching about population, environment, and sustainable development.

9. Broaden Service and Outreach Nationally and Internationally
Work with national and international organizations to promote a worldwide university effort toward a sustainable future.

10. Maintain the Movement
Establish a Secretariat and a steering committee to continue this momentum, and to inform and support each other's efforts in carrying out this declaration.

Appendix C

The Halifax Declaration

Human demands upon the planet are now of a volume and kind that, unless changed substantially, threaten the future well-being of all living species. Universities are entrusted with a major responsibility to help societies shape their present and future development policies and actions into the sustainable and equitable forms necessary for an environmentally secure and civilized world.

As the international community marshals its endeavors for a sustainable future, focused upon the United Nations Conference on Environment and Development in Brazil in 1992, universities in all countries are increasingly examining their own roles and responsibilities. At Talloires, France in October, 1990, a conference of university presidents from every continent, held under the auspices of Tufts University of the United States, issued a declaration of environmental commitment that has attracted the support of more than 100 universities from dozens of countries. At Halifax, Canada, in December 1991, the specific challenge of environmentally sustainable development was addressed by the presidents of universities from Brazil, Canada, Indonesia, Zimbabwe and elsewhere, as well as by the senior representatives of the International Association of Universities, the United Nations University and the Association of Universities and Colleges of Canada.

The Halifax meeting added its voice to those many others worldwide that are deeply concerned about the continuing widespread degradation of the Earth's environment, about the pervasive influence of poverty on the process, and about the unsustainable environmental practices now so widespread. The meeting expressed the belief that solutions to these problems can only be effective to the extent that the mutual vulnerability of all societies, in the South and in the North, is recognized, and the energies and skills of people everywhere be employed in a positive, cooperative fashion. Because the educational, research and public service roles of universities enable them to be competent, effective contributors to the major attitudinal and policy changes necessary for a sustainable future, the Halifax meeting invited the dedication of all universities to the following actions:

1. To ensure that the voice of the university be clear and uncompromising in its ongoing commitment to the principle and practice of sustainable development within the university, and at the local, national and global levels.

2. To utilize the intellectual resources of the university to encourage a better understanding on the part of society of the inter-related physical, biological and social dangers facing the planet Earth.

3. To emphasize the ethical obligation of the present generation to overcome those current malpractices of resource utilization and those widespread circumstances of intolerable human disparity which lie at the root of environmental unsustainability.

4. To enhance the capacity of the university to teach and practise sustainable development principles, to increase environmental literacy, and to enhance the understanding of environmental ethics among faculty, students, and the public at large.

5. To cooperate with one another and with all segments of society in the pursuit of practical capacity-building and policy measures to achieve the effective revision and reversal of those current practices which contribute to environmental degradation, to South-North disparities and to inter-generational inequity.

6. To employ all channels open to the university to communicate these undertakings to UNCED, to governments and to the public at large.

7. *Done at Dalhousie University, Halifax, Canada, the 11th day of December, 1991.*

Appendix D

Mean Wind Speeds at 80m (Environment Canada, 2004).