GENERATION SOLAR

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Project #9

Generation Solar

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Abstract:

Trent University has a definite need for increased capital. An excellent way of achieving this is by improving the efficiency of the spending already occurring within the University. Taking advantage of renewable energy generation processes would be an excellent way to satisfy this. The benefits would not only be economically sound, but environmentally responsible and contribute to the environmental image of the University, which has secondary positive aspects. These are three possibilities under examination: active solar water heating, photovoltaic electricity generation and wind power electricity generation.

INTRODUCTION:

Trent University has a definite need for increased capital. An excellent way of achieving this is by improving the efficiency of the spending already occurring within the University. Taking advantage of renewable energy generation processes would be an excellent way to satisfy this. The benefits would not only be economically sound, but environmentally responsible and contribute to the environmental image of the University, which has secondary positive aspects. There are three possibilities under examination: active solar water heating, photovoltaic electricity generation and wind power electricity generation.

For an examination of the potential benefits of possible renewable energy systems, the functioning of each process must be considered. Please refer to Appendix A for clarification of physical operation of each type of system.

We will also need to first consider what exactly are the energy requirements of the College, so that the amount that can be provided by renewables may be compared. Natural gas is the only heating of water for the residences, commons block and Lady Eaton kitchen. This water is used for hot tap and shower water, as well as radiant heating, through an extensive radiator system. Natural gas is the most environmentally friendly form of fossil fuel combustion, but there is still carbon emitted into the environment, which is something that should be improved upon whenever it is feasible.

NATURAL GAS PRICING FOR LADY EATON COLLEGE:

Please refer to the Appendix A for calculations and numerical analysis. The significant figures that come out of this analysis are as follows. The College required 75480 cubic feet of gas, averaged over the last 3 years. This had an average cost of \$ 38088.$^{\underline{71}}$. There was a distinct increase in natural gas over this period, with 1996-1997 and 1997-1998 being approximately the same at \$ 0.$^{\underline{46}}$/ccf, while in 1998-1999 there was a significant increase of \$ 0.$^{\underline{17}}$/ccf to \$0.$^{\underline{63}}$/ccf (ccf represents 100 feet^3 of gas).

ENERGY NEEDS SUPPLIED BY NATURAL GAS:

Please refer to Appendix C for calculations and numerical analysis. Important information derived in the appendix is as follows. Total energy that the College required was 2.26×10^{10} J last year. This includes the low pressure that natural gas is stored at, the fractional molar mass composition of natural gas and the temperature that gas is stored at in the College basement (293°K → standard temperature).

Now that the College requirements have been established, possible renewable energy systems that can subsidize this energy use will be considered. Arguments for economic issues, environmental issues and reputation issues will be made.

WIND POWER ELECTRICITY GENERATION:

Wind power is conditionally useful, in that if there is wind power potential at a site, then that power can represent a significant electricity generation. This is because wind energy is transferred to power as a third power of the velocity, v:

$$\text{Power} = (6.1 \times 10^{-4}) \times v^3 \qquad \text{where; } 6.1 \times 10^{-4} = \text{wind constant,}$$

includes moisture, air pressure factors

This does not directly represent the total energy that can be attained by a wind machine of any kind. The apparatus must be able to avoid the wind path so as not to deflect the wind away too much, while still intercepting enough of the force from the wind to receive some useful energy. What this breaks down to is that the theoretical maximum amount of energy that can be taken from the wind is about 46% (Kraushaar, 1993). As mentioned, this is only the theoretical maximum. Much like the perfect Carnot heat engine, this maximum has yet to be obtained. The best design to date for a wind turbine is about a 70% efficiency of the theoretical maximum. This would be able to extract 32% of the power possessed by the wind that was calculated in the above power equation.

As discussed in Appendix A, the most ideal location for such a wind turbine device could be at the crest of a ridge. The most elevated region near Lady Eaton College would be the Drumlin. To do this would prove rather difficult and costly in itself. There would be some distinctly negative ramifications on the nature area that exists on top of the drumlin. Noise pollution and an 'unnatural' tower would have to become a part of the drumlin area. Fundamentally, this requires that we outweigh negative impacts with positive impacts. The benefit of having extremely visible renewable energy on campus could now be factored in to this stage as a positive impact. The Stan Adamson Dam already illustrates a renewable energy initiative at Trent, but the power plant is almost 100 years old. A vertical axis wind turbine would show more modern appreciation of wind power energy by the University, as it is more readily socially accepted as a modern alternative source of electricity.

Should this option be examined in more detail, the following facts would have to be considered. The southern Ontario region between Lake Ontario and Lake Huron receives an annual average wind energy of 350 W/m^2 overall. That is, on average there is 300 joules produced every second by wind, in every square metre area at an altitude of 50m (Kraushaar, 1993). With 3.1536x10^7 seconds in a year (Watts are J/s), then we should have a total of 1.10376x10^{10} J /m^2 from wind energy. As stated, the best conversion is 32% of the total wind power, so 32% of this energy would be 3.532x10^{9}J/m^2. This would represent about 16% of the energy needs of the school, if we assume we can transfer all energy developed into electricity and then into heat without any losses, which is not possible. This is certainly not a very significant energy savings for a great deal of time and funds. The primary downfall is the wind potential of the area. Even at an elevation of 50 metres, there needs to be significant wind power potential at the site for wind power generation to work.

This is only a general figure for the region and could vary significantly for any specific site. Assuming there was adequate potential for wind power generation, there would need to be an inverter near the wind turbine, as the turbine will produce DC (direct current) electricity. This transmits distance very poorly, so it is more efficient to immediately convert the power to AC (alternating current). This will add to the changing of the landscape factor. Not everyone will be willing to give up natural space in such close proximity to the campus for the sake of better energy generation. The argument could be made that simply reducing the College's need for electricity and sticking with current power generation methods would be more environmentally friendly and cheaper.

Another cost of a wind power generator would be the legal necessity of satisfying the Ontario Environmental Assessment Act. This would require extensive research of the project in quite a few areas (Estrin et al., 1993). The specific method of how the project will be completed, with extensive plans for alternative methods, so the Environmental Assessment Advisory Committee can have multiple views on ways of performing the same project. The environment that is affected by the project would have to be examined, in order to find what effects and possible secondary effects that come as a result of putting up a wind turbine. Remediation action in response to those effects would also have to be researched. The process may be challenged as well by an outside party. This may involve getting a Canadian Environmental Law Association (CELA) lawyer. At this point, it is important to note that the other 2 options would not involve an environmental assessment, as they only entail adding some superficial devices to currently standing buildings.

PHOTOVOLTAIC ELECTRICITY GENERATION:

Photovoltaics would certainly be more simplistic than wind power, as their application only involves installing devices to already-existing buildings. Although not as visible as a wind turbine tower, they can still be noticed. Please see Appendix A for reference on their operation and description.

This notice that they cause could be the source of an aesthetic problem. Photovoltaic panels are a crystalline structure, often appearing colourful in full daylight. Upper protective layers in the photovoltaic cell reduce reflection of light, but their presence will certainly still catch the eye of an individual not accustomed to seeing the panels on top of a familiar building. This could pose a threat to the architecture of Trent, which is a pivotal characteristic of the school. As the buildings built here are quite unique, modification to the contour view of the roof could upset the artistic creation of their design. This would be a factor that must be weighed against the benefits of electricity derived from photovoltaics.

A true advantage to photovoltaics is its universality. Once electricity is generated, that may be used for any electrical application. Power can be made and/or stored while conventional power sources are not operating, provided there is sunlight available.

The primary disadvantage of photovoltaics exists in their current level of technology. Where there are sun-hours present, photovoltaics can only convert 10% to 15% of that radiation to electricity (Johansson et al., 1993). Amorphous is the most popular type of photovoltaic panel, making it the cheaper option silicon (please see Appendix A for description). However, the efficiency of solar energy conversion is only 10% or less. This severely increases the amount of panels we would need.

In order to provide 45% of the College's needs, which is three times what could be provided by wind energy, we would need to have capacity to develop 1.02×10^{10} J, according to Appendix C in the WatSun analysis portion of the section. To develop 10% of this theoretical maximum, which ideally is the best type of panels to purchase, would only be 1.17945×10^{10} J. This means that theoretically, we can provide 52% of the College's needs through solar power, if there is adequate storage with no significant losses anywhere in the system. To develop this amount of energy, we would need significant surface area. According to the total sun-hours listed in the WatSun analysis, there are a total of 2054.95 useful sun-hours in a typical meteorological year. Power is measured in joules per seconds, so to find the power necessary, the 10% figure of the energy from the sun will be divided by the seconds of useful sunlight. This equals 82439.15 watts. If the system were designed using 100 watt panels, there would be have to be 824 panels used. These panels cost approximately $850.$^{\underline{00}}$ each, so the total price of the photovoltaic system would be about $ 700 000. This is incredibly expensive and rather unrealistic, but it is still important to calculate the payoff period of such an investment.

If we could provide for 45% of natural gas needs, then the amount spent on gas would be reduced by 45%. The College spends $ 38088.$^{\underline{71}}$ on gas, averaged over the last three years. 45% of this amount is $ 17 139.$^{\underline{92}}$. This represents the annual savings. The total amount spent on is divided by this, showing that it would take approximately 40 years to pay off the system. This model does not consider maintenance costs (which will certainly arise in 40 years of use), as well as any initial installation costs and other minor parts costs. This case is not very feasible.

ACTIVE SOLAR WATER HEATING:

In contrast to photovoltaics, active solar heating will prove far more feasible, not to mention that it is the option with the least visual impact. In fact, solar thermal collectors can easily be mistaken for skylights. Conventional collectors have a black surface, usually a flat non-reflective outer coating. This helps in reducing their presence and increasing their architectural practicality. See Appendix A for the operation of an active solar heating system.

In this case water or ethylene glycol will be heated directly by solar radiation, rather than generating electricity for using in heating applications. There exists a loss of flexibility, as the technology is only good for water heating. The advantage of using solar thermal technology is that it is the most efficient way to extract energy from the solar radiation. Consult Appendix C for the calculations of heat collection and efficiency.

In the WatSun analysis, it is shown that almost 50% of the sun's energy can be effectively put into the glycol. After losses in pipes and exchanger are factored in, there remains 8.86×10^{9} J for water heating. When compared to the energy the College receives from gas the solar thermal energy represents 39% of that. Each panel can provide 20 BTU / ft^{3}x°C. When converted to joules per panel, using panels that are 4 ft. by 8 ft., each panel should be able to produce 675 200 J/day. Over the year, that would be 2.46×10^{8} J. The total energy required from solar power (8.86×10^{9}J) divided by the energy per panel is equal to 96 panels. If these panels were $ $1300.^{\underline{00}}$ each, including tank and piping, then the total price for the system would be $ $124\ 800.^{\underline{00}}$.

The payoff period of such an investment would actually be feasible. The energy developed by solar thermal power was 39% of the total energy required. Therefore, this means that solar thermal power can save 39% of the operating costs of gas per year. This represents $ 15 132.00 per year. This should pay for itself in approximately 8.25 years, making this option a very feasible one.

SECONDARY BENEFITS OF RENEWABLE ENERGY:

Economics are important to the viability of a task, but there are other reasons that may be more important than monetary savings. Environmental responsibility for one's actions is a very good example. For most people living in the western world, it may seem that resources are always at the doorstep, so to speak. Everything is catered and the customer is number one. These ideas have proven ultimately destructive to our environment, the possibility that we may have altered our environment so much that the actual climate is changing. By combusting fossil fuels faster than carbon can be fixed by the natural environment, we have increased the most abundant greenhouse gases in the atmosphere: carbon monoxide and carbon dioxide (Manahan, 1994).

The secondary effects of average global temperature increase have been well covered in many forums; the theme in environmental circles being that we should try to right what we have may have caused. Although there exists only a threat of harm, there needs to be at least precautionary measures taken to address the potential problem. This country signed on to the Rio Conference on Sustainable Development in 1992, which stated that the undersigned will address threats of harm and apply the precautionary principle (Raffensperger, 1999).

By utilizing renewable energy, Trent University effectively comes to the call of this need. By applying a solar thermal energy system only Lady Eaton College, 39% of natural gas will not be burned. This has the positive effect of reducing greenhouse gas emissions, saving money and helping to prolong the supply of gas, which will help maintain a more stable economy. The tons of carbon not released is quickly calculated:

Moles of CH_4 at standard temperature and pressure: $2.0218457\text{x}10^6$ mol

Moles of CH_4 at 1.4 kPa (0.0138atm) = 27 942.58618 mol

Mass = moles x molar mass

where; m.m.= (12.011g/mol + 4 (1.00794g/mol))

= 16.04276 g/mol = 0.016043 Kg/mol

Mass = (27 942.58618mol) x (0.01604276)

Mass = 448.276 Kg → 0.45 Tons of carbon is effectively stopped from being released into the atmosphere.

It is important to note that this figure is only for one College, over the course of one year.

Natural gas has been deregulated from strong public sector control. This will imply that the heavy subsidization of fossil fuels from government support will be removed from the sector. Although prices are supposed to theoretically come down, there will no longer be the stabilization of central government control, so that prices could increase and decrease rather unstably. Prior to October 1998, the Ontario Energy Board regulated gas prices centrally in the province. By installing our own energy development, the effective energy fluctuation is somewhat controlled, so that the degree of uncertainty in operating costs is reduced. This lends financial planning more confidence from day 1. As can be seen in Figures B-1 and B-2 in Appendix B, that there are certainly great fluctuations in gas needs from year to year. Weather patterns, degree-days, student habits and gas prices all play a role in affecting this operating cost.

Typically, the service of energy generation has been rented from a central body. To rent anything for a long period of time is to invest a great deal, while never getting anything in return. This dependence makes the consumer vulnerable to price changes. The concept of individuals providing energy for themselves could serve to remove such vulnerability, while at the same time reducing the bureaucratic administrating of a centralized energy utility. Of course, the renewable energy systems of the present are only reducing the total load on the central electrical grid, but they will subsidize energy deficiencies very well when it is needed most in Ontario: during summer months. This will also facilitate education of the public to energy use, as users of any commercial product are more familiar with the process if the entire process involves them more.

Another excellent way that renewables help is in education, as noted above. A survey of faculty opinion, student opinion and staff opinion was conducted to examine the position that people affected by the system. The results were not very informative, as the knowledge base that the Trent University community had on renewable energy was insufficient for such an information survey. The only true value that the survey showed was that most people were quite unaware of different types of renewable energy. It could also be assumed that no subjects were opposed to learning about renewable energy, in fact a genuine curiosity was expressed about producing power using alternative methods. The school could definitely benefit from having renewable energy in high visibility areas on campus, through education of the community due to exposure and the resulting 'green' reputation. The Environmental Studies department in particular, would find such a system most beneficial in researching design fundamentals, socio-economic impacts of renewables on the public and maximization of energy extraction from solar radiation. Both the sciences and arts streams would gain from such an investment.

FUNDING RESOURCES:

Trent University is legally considered both a government institution and a commercial sector member. This is a very useful identity, as Trent can qualify for a few subsidies that have been recently set up by the federal government.

1) Due to the Kyoto protocol of December 1998, Canada has committed to a net reduction of greenhouse gas emissions of 6% from 1990 levels. Up to 1998, there has been accumulation of greenhouse gases, so the net reduction from this point is closer to 25%. This is a rather challenging task for the government to meet, which agreed to have the target met any time between 2005 and 2008. There has been action taken to meet such goals for government institutions and commercial facilities, which are typically larger single-sources of greenhouse gases. The primary goal of greenhouse gas emission reduction is the removal of simple gaseous forms of carbon, namely carbon monoxide and carbon dioxide.

One of these subsidies is the Renewable Energy Deployment Initiative (REDI), established in April 1998. This program can finance a portion of a renewable energy project, depending on number of applicants to the program in one given year. There is a total of $1.5 million available for this 3 year project. The deadline for application of such funding support would be April 2001.

REDI also has other indirect funding distribution methods, which need mentioning. There have been a number of contracts and tenders given to 'green' companies that will distribute subsidized thermal hot water systems. This is a very company-dependent method of distributing renewable energy benefits to the population at large, as companies come up with their own proposal for the renewable energy system distribution. The only factor controlled by the project was the total funding available. There was only 3 companies chosen across Canada for the project and a local Peterborough company was chosen as one of the pilot project distributors. Generation Solar, in conjunction with Peterborough Green-Up, is currently distributing the 50 proposed thermal hot water systems. A Toronto-based company was also chosen, using the model developed by Generation Solar, as well as the Earth Festival Society in the Comox Valley, British Columbia.

On a smaller scale, there are multitudes of ways that REDI can help finance a renewable energy project at Trent University, as long as application is made within sufficient time.

2) The public sector is not the only direct funding source for renewable energy. Through legislative control over the natural gas sector, Natural Resources Canada has effectively created private sector support of renewable energy projects. Such funding will change in the near future, as the Ontario energy sector is being deregulated. This will decrease and eventually completely separate government from energy market control.

For the time being, commercial sector members can approach Enbridge natural gas and request an energy system audit on heating, ventilation and air conditioning (H.V.AC. for short). Typically, Enbridge intends on improving an already existing natural gas system, by auditing energy flow in its use through a facility and identifying inefficiencies. This feasibility study can be 2/3 paid for, up to an amount of $3,500. A system integration installation of $0.05 / m^3 of natural gas savings will be made on qualifying projects, up to a total savings of $30,000 can be provided as well.

To this effect, a renewable energy system that complemented an upgraded natural gas hot water system could fall into such classification. Although upgrading the natural gas facilities in Lady Eaton College would cost more than simply adding solar thermal collectors, the subsidization received from Enbridge could more than outweigh the additional costs incurred depending on the amount of the gas upgrade.

CONCLUSION:

Renewable sources of energy are currently economically feasible to application in this University. The recommendation of this study is to incorporate active solar technology into campus. The rewards of doing so are only briefly examined in this study, as more could certainly be found with further consideration.

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                    *           WATSUN 13.2            *
                    *                                  *
                    *      UNIVERSITY OF WATERLOO      *
                    *           MARCH 1994             *
                    ************************************

                    DEVELOPED BY:

                        THE SYSTEMS DESIGN ENERGY GROUP
                        DEPARTMENT OF SYSTEMS DESIGN ENGINEERING

                        THE THERMAL ENGINEERING GROUP
                        DEPARTMENT OF MECHANICAL ENGINEERING

Lady Eaton Data Analysis


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Lady Eaton Data Analysis
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                      *  ENERGY ANALYSIS SUMMARY  *
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 +---+--------+--------+--------+--------+--------+--------+
  M    TOTAL   ENERGY  TOT LOAD  ENERGY   AUX.     AUX.
  O   RADIA-  COLLEC-  (DEMAND   FROM    ENERGY,  ENERGY,
  N    TION     TED    + AUX.    STOR    WATER    PUMPS
  T                    LOSSES)  TO DHW   HEAT
  H    (GJ)    (GJ)     (GJ)     (GJ)     (GJ)     (GJ)
 +---+--------+--------+--------+--------+--------+--------+
  JAN     1.68     0.58     1.62     0.49     1.13     0.00
  FEB     2.46     0.86     1.49     0.76     0.73     0.00
  MAR     2.72     1.01     1.65     0.88     0.77     0.00
  APR     2.53     1.04     1.56     0.88     0.68     0.00
  MAY     2.66     1.05     1.55     0.94     0.61     0.00
  JUN     2.42     0.98     1.43     0.82     0.61     0.00
  JUL     2.64     1.12     1.41     0.89     0.53     0.00
  AUG     2.59     1.10     1.38     0.93     0.45     0.00
  SEP     2.21     0.95     1.33     0.78     0.55     0.00
  OCT     1.77     0.72     1.42     0.65     0.76     0.00
  NOV     1.23     0.47     1.43     0.45     0.98     0.00
  DEC     1.29     0.43     1.55     0.39     1.17     0.00
 +---+--------+--------+--------+--------+--------+--------+
  TOT    26.21    10.31    17.84     8.86     8.98     0.00
 +---+--------+--------+--------+--------+--------+--------+

  PERCENT ENERGY SAVED   49.67

                        *****************************
                        *   ENERGY LOSSES SUMMARY   *
                        *****************************


 +---+--------+--------+--------+--------+
  M    LOSS     LOSS     PIPE     PIPE
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```
 O    FROM     FROM    LOSSES   CAPACI-
 N  PREHEAT    AUX.              TANCE
 T    TANK     TANK             LOSSES
 H    (GJ)     (GJ)     (GJ)     (GJ)
+---+--------+--------+--------+--------+
JAN    0.04     0.23     0.03     0.02
FEB    0.10     0.20     0.04     0.04
MAR    0.12     0.23     0.04     0.03
APR    0.13     0.22     0.03     0.02
MAY    0.16     0.23     0.03     0.02
JUN    0.15     0.22     0.03     0.02
JUL    0.17     0.23     0.03     0.02
AUG    0.19     0.23     0.03     0.02
SEP    0.16     0.22     0.03     0.02
OCT    0.12     0.23     0.03     0.02
NOV    0.06     0.22     0.02     0.02
DEC    0.03     0.23     0.02     0.02
+---+--------+--------+--------+--------+
TOT    1.44     2.66     0.36     0.28
+---+--------+--------+--------+--------+


DHWA   TMY  OTTAWA, ONT.                WATSUN 13.2 1999 11 29 02:57:33
Lady Eaton Data Analysis

                         *****************************
                         *   COLLECTION TIME TABLE   *
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+---+-----------+-----------+-----------+-----------+-----------+
 M     PUMP      AVERAGE      DAILY      AVERAGE     AVERAGE
 O     RUN      COLLECTOR    AVERAGE      FRTA        FRUL
 N     TIME      FLOWRATE    COLLECT.     VALUE       VALUE
 T                            TIME
 H     (HR)      (L/MIN)      (HR)         ( )       (W/M2-C)
+---+-----------+-----------+-----------+-----------+-----------+
JAN    122.         3.00        3.94        0.747       5.281
FEB    154.         3.00        5.50        0.747       5.281
MAR    164.         3.00        5.29        0.747       5.281
APR    170.         3.00        5.67        0.747       5.281
MAY    207.         3.00        6.68        0.747       5.281
JUN    215.         3.00        7.17        0.747       5.281
JUL    242.         3.00        7.81        0.747       5.281
AUG    224.         3.00        7.23        0.747       5.281
SEP    178.         3.00        5.93        0.747       5.281
OCT    157.         3.00        5.06        0.747       5.281
NOV    112.         3.00        3.73        0.747       5.281
DEC    109.         3.00        3.52        0.747       5.281
+---+-----------+-----------+-----------+-----------+-----------+
TOT   2054.         3.00        5.63        0.747       5.281
+---+-----------+-----------+-----------+-----------+-----------+

                         *****************************
                         *    EFFICIENCY   TABLE     *
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 EXPLANATION OF COLUMNS MAY BE FOUND IN WATSUN 13.2 MANUAL SECTION 4.4.
+---+---------+---------+---------+---------+---------+
  M     COL.      STO.      SYS.      C.O.P.    SOLAR
  O     EFF.      EFF.      EFF.                FRAC.
  H     (%)       (%)       (%)        ( )       (%)
+---+---------+---------+---------+---------+---------+
 JAN    34.43     84.64     29.14      0.00     30.27
 FEB    34.81     89.18     31.05      0.00     51.18
 MAR    37.26     86.74     32.32      0.00     53.24
 APR    41.11     84.94     34.92      0.00     56.42
 MAY    39.41     89.59     35.31      0.00     60.42
 JUN    40.58     83.05     33.70      0.00     57.05
 JUL    42.40     79.28     33.62      0.00     62.72
 AUG    42.47     84.30     35.80      0.00     67.39
 SEP    42.87     82.58     35.40      0.00     58.71
 OCT    40.58     90.88     36.88      0.00     46.08
 NOV    38.42     95.51     36.70      0.00     31.46
 DEC    33.61     89.40     30.04      0.00     25.02
+---+---------+---------+---------+---------+---------+
 TOT    39.35     85.93     33.81      0.00     49.67
+---+---------+---------+---------+---------+---------+

     ** MAX. HOURLY ENERGY INPUT (MJ):          4.6


DHWA  TMY  OTTAWA, ONT.               WATSUN 13.2 1999 11 29 02:57:33
Lady Eaton Data Analysis


                                   ***  ECONOMIC ANALYSIS  ***


      ** BASED ON A MINIMUM ANNUAL RATE OF RETURN OF 10.0%

      ** PRESENT WORTH (OPERATING ENERGY INCL.)($):        3762.40
                      (OPERATING ENERGY NOT INCL.)($):     2695.68

      ** ANNUAL WORTH (OPERATING ENERGY INCL.)($/YR):        441.93
                     (OPERATING ENERGY NOT INCL.)($/YR):     316.63

      ** LIFE-CYCLE UNIT COST (LUC), $/GJ:    10.545

      ** SOLAR LUC, $/GJ:    15.210

      ** BENEFIT/COST RATIO FOR SOLAR COMPONENT:     0.391

      ** SOLAR COMPONENT OF SYSTEM IS NOT COST-EFFECTIVE WITH A MARR OF 10.0%.

      ** SYSTEM COULD NOT PAY OFF WITH 0.0% MARR.


                          ** NET SAVINGS OF SOLAR ENERGY SYSTEM **
 ---------------------------------------------------------------------------
     |    UNDISCOUNTED                       |    DISCOUNTED
  YR |CASH FLOW     TOTAL                    |CASH FLOW     TOTAL
 ---------------------------------------------------------------------------
```

```
 1 |  -254.60   -254.60                  |  -231.46   -231.46
 2 |  -246.54   -501.15                  |  -203.75   -435.21
 3 |  -237.43   -738.57                  |  -178.38   -613.60
 4 |  -229.51   -968.08                  |  -156.76   -770.35
 5 |  -220.80  -1188.88                  |  -137.10   -907.45
 6 |  -211.21  -1400.09                  |  -119.22  -1026.67
 7 |  -200.67  -1600.76                  |  -102.98  -1129.65
 8 |  -192.55  -1793.31                  |   -89.83  -1219.48
 9 |  -183.87  -1977.18                  |   -77.98  -1297.45
10 |  -174.57  -2151.75                  |   -67.31  -1364.76
11 |  -164.63  -2316.38                  |   -57.70  -1422.46
12 |  -153.99  -2470.37                  |   -49.07  -1471.53
13 |  -142.60  -2612.98                  |   -41.31  -1512.83
14 |  -130.42  -2743.40                  |   -34.34  -1547.18
15 |  -117.39  -2860.78                  |   -28.10  -1575.28
16 |  -103.44  -2964.22                  |   -22.51  -1597.79
17 |   -88.52  -3052.74                  |   -17.51  -1615.30
18 |   -72.55  -3125.29                  |   -13.05  -1628.35
19 |   -55.46  -3180.75                  |    -9.07  -1637.42
20 |   -37.18  -3217.93                  |    -5.53  -1642.95
-----------------------------------------------------------------------------
```

```
DHWA  TMY  OTTAWA, ONT.                 WATSUN 13.2 1999 11 29 02:57:33
Lady Eaton Data Analysis
  HOURS IN WHICH PLATE TEMPERATURES AND HUMIDITIES OCCUR


  BIN     BIN Range      Relative Humidity Ranges
          (deg. C)
                       0.  10.  20.  30.  40.  50.  60.  70.  80.  90. 100.TOTAL
                        +----+----+----+----+----+----+----+----+----+----+----+
             < -30.     |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
   1     -30. -> -25.   |   0|   0|   0|   1|   4|   3|   0|   0|   0|   0|   8|
   2     -25. -> -20.   |   0|   0|   0|   4|  18|  21|  17|   0|   0|   0|  60|
   3     -20. -> -15.   |   0|   0|   1|   9|  63|  55|  31|  16|   8|   0| 183|
   4     -15. -> -10.   |   0|   1|   2|  17|  64|  73|  86|  77|  53|   7| 380|
   5     -10. ->  -5.   |   0|   2|   1|  13|  39|  54| 141| 187| 130|   8| 575|
   6      -5. ->   0.   |   1|   6|   3|  11|  25|  67| 125| 125| 171|  21| 555|
   7       0. ->   5.   |   1|   7|  21|  30|  76| 118| 122| 168| 162| 106| 811|
   8       5. ->  10.   |  11|   8|  16|  31|  88| 152| 159| 166| 151|  76| 858|
   9      10. ->  15.   |  15|  14|  36|  46|  81| 128| 186| 226| 206|  87|1025|
  10      15. ->  20.   |  19|  46|  41|  59|  88| 104| 159| 185| 210|  44| 955|
  11      20. ->  25.   |  67| 109|  62|  61|  87|  66|  92| 109| 106|   6| 765|
  12      25. ->  30.   | 126|  82|  50|  63|  50|  42|  33|  10|   1|   0| 457|
  13      30. ->  35.   | 160|  93|  92|  80|  45|  20|   2|   0|   0|   0| 492|
  14      35. ->  40.   | 173| 160| 153|  78|  11|   0|   0|   0|   0|   0| 575|
  15      40. ->  45.   | 191| 229| 211|  23|   0|   0|   0|   0|   0|   0| 654|
  16      45. ->  50.   |  99| 159|  71|   0|   0|   0|   0|   0|   0|   0| 329|
  17      50. ->  55.   |  18|  57|   2|   0|   0|   0|   0|   0|   0|   0|  77|
  18      55. ->  60.   |   1|   0|   0|   0|   0|   0|   0|   0|   0|   0|   1|
  19      60. ->  65.   |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  20      65. ->  70.   |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  21      70. ->  75.   |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  22      75. ->  80.   |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  23      80. ->  85.   |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
```

```
  24    85. ->  90. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  25    90. ->  95. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  26    95. -> 100. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  27   100. -> 105. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  28   105. -> 110. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  29   110. -> 115. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  30   115. -> 120. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
  31   120. -> 125. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
             > 125. |   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|   0|
                    +----+----+----+----+----+----+----+----+----+----+----+
   HUMIDITY TOTALS  | 882| 973| 762| 526| 739| 903|1153|1269|1198| 355|8760|
                    +----+----+----+----+----+----+----+----+----+----+----+
```

```
DHWA  TMY  OTTAWA, ONT.                WATSUN 13.2 1999 11 29 02:57:33
Lady Eaton Data Analysis

         MAX. ENERGY COLLECTED PER BIN (MJ)  0.531E+04

 DT/I   QCOLL    0         .2         .4         .6         .8         1.
                 +---------+---------+---------+---------+---------+
 0.00  0.460E+04|*******************************************
                |*******************************************
 0.01  0.531E+04|**************************************************
                |**************************************************
 0.02  0.383E+03|***
                |***
 0.03  0.120E+02|*
                |*
```

```
WATSUN 13.2   Date: 1999/11/29   Time:  2:57
File: C:\WATSUN\LADYEA~1\EATON.DAT
Domestic Hot Water System with Storage & Exch.


Simulation Data
---------------
 S1  Simulation Year (0 for TMY)..................       0.000  year
 S2  Simulation Period............................     365.000  days
 S3  Start Day Number (Jan 1 =1, Feb 1 =32, etc.)..      1.000  day
 S4  Detailed Print Interval (No=0, 1=hour, etc)...      0.000  hour
 S5  Starting hour of detailed print (No=0)........      0.000  hour
 S6  Detailed Analysis Period: - Start Day.........      0.000  day
 S7                            - End Day...........      0.000  day
 S8  Economic Analysis (Block E) required..........        Yes

Collector Data for Group A
--------------------------
 C1  Initial Number of Series Groups..............       1.000
 C2  Maximum Number of Series Groups..............       1.000
 C3  Incremental Number of Series Groups..........       1.000
 C4  Number of Collectors connected in series......      1.000
 C5  Area per Collector...........................       5.000  m2
 C6  Collector Control Strategy (PV, Temp., Timer).      Temp.
 C7  Differential Control Temperature (Tc-Tci).....      1.000  C
```

```
 C8  Outlet Temperature for Collect. On (Tco-Tci)..       0.000  C
 C9  Outlet Temperature for Collect. Off (Tco-Tci).       0.000  C
 C10 Maximum Collector Outlet Temperature..........      98.000  C
 C11 Minimum Acceptable Outlet Temperature.........       0.000  C
 C12 Tracking Method (No, 2-axis, 1-axis, Azmt)....          No
 C13 Collector Slope...............................      60.000  deg.
 C14 Collector Azimuth (0=to equator, +=west)......       0.000  deg.
 C15 Use Flow Rate per Collector...................   5.0E-0002  kg/s
 C16 Pump Power in Collector Loop per Unit Area....       0.000  W/m2
 C17 Fraction of Pump Power Transferred to Fluid...       1.000


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Domestic Hot Water System with Storage & Exch.


More Collector Data
-------------------
 M1  Start Day of System Failure (Stagnation Test).       0.000  day
 M2  End   Day of System Failure (Stagnation Test).       0.000  day
 M3  Output of Tplate Required (No/Yes)............         Yes
 M4  Reference Fr Value, for Tplate Calculations...       1.000
 M5  Test Flow Rate per Collector..................   5.0E-0002  kg/s
 M6  Collector Model (American, European, Unglaz.).    American
 M7  Collector Parameters (Test Values):        A...      0.750
 M8  Qc = (A-B*dT)*Akt*I - (C+D*dT)*dT -E       B...      0.000  1/C
 M9     dT  = Tci - Ta [C]                      C...      5.000  W/m2-C
 M10    Akt = Incident Angle Modifier []        D...      0.000  W/m2-C2
 M11    I   = Incident Radiation [W/m2]         E...      0.000  W/m2
 M12 Incidence Angle Modifier (Vert.)............       PROFILE
   Angle Value.................................. deg.
         0.000    30.000    45.000    60.000    90.000
   Akt Value....................................
         1.000     1.000     0.970     0.877     0.000
 M13 Incidence Angle Modifier (Horz.)............       PROFILE
   Angle Value.................................. deg.
         0.000    30.000    45.000    60.000    90.000
   Akt Value....................................
         0.000     0.000     0.000     0.000     0.000
 M14 Collector Fluid Cp vs. Temperature...........      PROFILE
   Temperature.................................. C
         0.000    25.000    50.000    75.000   100.000
   Collector Fluid Specific Heat................. kJ/kg-C
         4.200     4.200     4.200     4.200     4.200


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File: C:\WATSUN\LADYEA~1\EATON.DAT
Domestic Hot Water System with Storage & Exch.


Collector Data for Group B
--------------------------
 J1  Initial Number of Series Groups..............       0.000
 J2  Maximum Number of Series Groups..............       0.000
 J3  Incremental Number of Series Groups..........       0.000
```

```
 J4  Number of Collectors connected in series......        0.000
 J5  Area per Collector............................        5.000  m2
 J6  Test Flow Rate per Collector..................    5.0E-0002  kg/s
 J7  Collector Model (American, European, Unglaz.).     American
 J8  Collector Parameters (Test Values):       A...        0.750
 J9  Qc = (A-B*dT)*Akt*I - (C+D*dT)*dT -E      B...        0.000  1/C
 J10    dT  = Tci - Ta [C]                     C...        5.000  W/m2-C
 J11    Akt = Incident Angle Modifier []       D...        0.000  W/m2-C2
 J12    I   = Incident Radiation [W/m2]        E...        0.000  W/m2
 J13 Reference Fr Value, for Tplate Calculations...        1.000
 J14 Incidence Angle Modifier (Vert.).............       PROFILE
   Angle Value................................  deg.
         0.000    30.000    45.000    60.000    90.000
   Akt Value..................................
         1.000     1.000     0.970     0.877     0.000
 J15 Incidence Angle Modifier (Horz.).............       PROFILE
   Angle Value................................  deg.
         0.000    30.000    45.000    60.000    90.000
   Akt Value..................................
         0.000     0.000     0.000     0.000     0.000

Tank Data
---------
 T1  Preheat Tank Volume...........................        1.000  m3
 T2    Aspect Ratio (Height/Diameter)..............        0.886
 T3    (Floor Perimeter)**2/Floor Area.............       16.000
 T4    Heat Loss Factor............................        0.500  W/m2-C
 T5    Density * Heat Capacity of Fluid............     4200.000  kJ/m3-C
 T6  Auxiliary Tank Volume.........................        0.270  m3
 T7    Aspect Ratio (Height/Diameter)..............        1.532
 T8    (Floor Perimeter)**2/Floor Area.............       33.918
 T9    Heat Loss Factor............................        0.800  W/m2-C
 T10   Density * Heat Capacity of Fluid............     4200.000  kJ/m3-C
 T11 Basement Temperature..........................       20.000  C
 T12 Basement Floor Temperature....................       18.000  C
 T13 Starting Preheat Tank Temperature.............       20.000  C
 T14 Maximum Temperature in Preheat Tank...........       98.000  C
 T15 Maximum Temperature in Auxiliary Tank.........       98.000  C


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Domestic Hot Water System with Storage & Exch.


Heat Exchanger Data
-------------------
 X1  Coll-Stor Exch. (N. Conv., Ext., Wrap, Coil)..     External
 X2  Exchanger Effectiveness.......................        1.000
 X3  Tank Side Flow Rate (0=same both sides).......        0.000  litre/s
 X4  Parameter not used
 X5  Stor-Load Exch. (Ext., Wrap, Coil, TinT)......     External
 X6  Exchanger Effectiveness.......................        1.000
 X7  S/L Tank Side Flow Rate (0=same both sides)...        0.000  litre/s
 X8  Parameter not used
 X9  Tank Fluid Cp vs. Temperature.................      PROFILE
   Temperature................................  C
```

```
            0.000    20.000    40.000    60.000   100.000
      Tank Fluid Cp................................  kJ/kg-C
            4.196     4.185     4.178     4.192     4.205
    X10 Tank Fluid Density vs. Temperature...........     PROFILE
      Temperature..................................  C
            0.000    20.000    40.000    60.000   100.000
      Tank Fluid Density...........................  kg/m3
         1002.280  1000.520   994.590   985.460   960.630

   Pipe Data
   ---------
    P1  Collector Inlet Pipe Surface Area............        0.800  m2
    P2  Fraction of Inlet Pipe Inside Building........       0.000
    P3  Collector Outlet Pipe Surface Area...........        0.800  m2
    P4  Fraction of Outlet Pipe Inside Building.......       0.000
    P5  Pipe Heat Loss Coefficient Inside Building....       1.000  W/m2-C
    P6  Pipe Heat Loss Coefficient Outside Building...       1.000  W/m2-C
    P7  Thermal Mass per Unit Pipe Area Inside........      18.000  kJ/m2-C
    P8  Thermal Mass per Unit Pipe Area Outside.......      18.000  kJ/m2-C
    P9  Average Indoor Room Temperature for Piping....      20.000  C


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   Domestic Hot Water System with Storage & Exch.


   Load Data
   ---------
    L1  Minimum Annual Mains Water Temperature........      10.000  C
    L2  Maximum Annual Mains Water Temperature........      18.000  C
    L3  Specific Heat of Incoming Load Fluid..........       4.200  kJ/kg-C
    L4  Type of Load (Energy/Volumetric)..............      Volume
    L5  Number of Days in "weekdays"..................       7.000  days
    L6  Number of Days in "week"......................       7.000  days
    L7  Total Daily Load for "weekdays"...............     275.000  l/day
    L8  Total Daily Load for "weekends"...............       0.000  l/day
    L9  Minimum Load Temperature for "weekdays".......      50.000  C
    L10 Maximum Load Temperature for "weekdays".......      50.000  C
    L11 Minimum Load Temperature for "weekends".......      50.000  C
    L12 Maximum Load Temperature for "weekends".......      50.000  C
    L13 Maximum Factor for Load Flowrate Increase.....       1.000  times
    L14 Available Auxiliary Heater Power..............     PROFILE  kWh
          1:    10.000   7:    10.000  13:    10.000  19:   10.000
          2:    10.000   8:    10.000  14:    10.000  20:   10.000
          3:    10.000   9:    10.000  15:    10.000  21:   10.000
          4:    10.000  10:    10.000  16:    10.000  22:   10.000
          5:    10.000  11:    10.000  17:    10.000  23:   10.000
          6:    10.000  12:    10.000  18:    10.000  24:   10.000
    L15 Hourly Load for "weekdays"...................     PROFILE  percent
          1:     2.250   7:     1.500  13:     3.600  19:    6.750
          2:     0.000   8:     4.650  14:     5.100  20:   11.600
          3:     0.000   9:     7.250  15:     2.700  21:    9.600
          4:     0.000  10:     8.490  16:     2.400  22:    6.900
          5:     0.000  11:     6.900  17:     2.100  23:    5.460
          6:     0.000  12:     4.500  18:     3.750  24:    4.500
    L16 Hourly Load for "weekends"...................     PROFILE  percent
```

```
      1:     0.000   7:     6.190  13:     6.190  19:    12.380
      2:     0.000   8:    12.380  14:     2.480  20:    12.380
      3:     0.000   9:     6.190  15:     2.480  21:     6.190
      4:     0.000  10:     2.480  16:     2.480  22:     6.190
      5:     0.000  11:     2.480  17:     2.480  23:     6.190
      6:     0.000  12:     2.480  18:     6.190  24:     2.170
 L17 Normalized hourly load temperatures "wdays"...        PROFILE
      1:     1.000   7:     1.000  13:     1.000  19:     1.000
      2:     1.000   8:     1.000  14:     1.000  20:     1.000
      3:     1.000   9:     1.000  15:     1.000  21:     1.000
      4:     1.000  10:     1.000  16:     1.000  22:     1.000
      5:     1.000  11:     1.000  17:     1.000  23:     1.000
      6:     1.000  12:     1.000  18:     1.000  24:     1.000
 L18 Normalized hourly load temperatures "wends"...        PROFILE
      1:     1.000   7:     1.000  13:     1.000  19:     1.000
      2:     1.000   8:     1.000  14:     1.000  20:     1.000
      3:     1.000   9:     1.000  15:     1.000  21:     1.000
      4:     1.000  10:     1.000  16:     1.000  22:     1.000
      5:     1.000  11:     1.000  17:     1.000  23:     1.000
      6:     1.000  12:     1.000  18:     1.000  24:     1.000
 L19 Monthly load scale factors...................         PROFILE
      1:     1.000   4:     1.000   7:     1.000  10:     1.000
      2:     1.000   5:     1.000   8:     1.000  11:     1.000
      3:     1.000   6:     1.000   9:     1.000  12:     1.000


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File: C:\WATSUN\LADYEA~1\EATON.DAT
Domestic Hot Water System with Storage & Exch.


Economic Data
-------------
 E1  System Life...............................       20.000  year
 E2  Term of Loan..............................       20.000  year
 E3  Interest Rate on Loan.....................        0.100  decimal
 E4  Rate of Return (Discount Rate)............        0.100  decimal
 E5  Cost of Collector A per Unit Area.........      230.000  $/m2
 E6  Cost of Collector B per Unit Area.........      230.000  $/m2
 E7  Cost of Storage per Unit Volume...........      120.000  $/m3
 E8  Cost of Auxiliary Energy..................        7.000  $/GJ
 E9  Salvage Value at the End of System Life...        0.000  $
 E10 Other Fixed Costs.........................     1000.000  $
 E11 Yearly Maintenance Cost...................       50.000  $/year
 E12 Pro-Rate Energies over One Year (No/Yes)......      Yes
 E13 Yearly Fuel Escalation for Life...........      PROFILE  %
      1:     0.000   6:    10.000  11:     7.000  16:     7.000
      2:    13.000   7:    10.000  12:     7.000  17:     7.000
      3:    13.000   8:     7.000  13:     7.000  18:     7.000
      4:    10.000   9:     7.000  14:     7.000  19:     7.000
      5:    10.000  10:     7.000  15:     7.000  20:     7.000

PV Pump Array Data
------------------

 Block not needed (see item C6 ).
```

Detailed PV Array Data

Block not needed (see item C6).

Motor/Pump Data

Block not needed (see item C6).

Natural Convection Heat Exchanger Data

Block not needed (see item X1).

□

APPENDIX A:

INTRODUCTION:

The purpose of this study is to examine the viability of renewable energy in Canada and specifically for use at Trent University. Passive solar heat collection will be compared with photovoltaic electricity generation and wind power technology. The need of such alternative energy generation will now be demonstrated, as well as the brief history of the energy production and where renewable sources of energy fit into the picture.

JUSTIFICATION:

Canadians used 469 974 GW•hr 1993, which implies the highest per capita electrical energy use in the world (Harker, 1995). However, Canada does not produce this electricity using environmentally unfriendly methods. Over 40% of electrical generation is done using natural gas, hydropower and renewables, which are relatively green sources of energy as compared to coal and oil energy production (Harker, 1995). Globally, electrical energy generation is done primarily by the combustion of fossil fuels; approximately 68% of world energy is produced using oil and coal (Flavin et al., 1990). The fact that Canada uses less fossil fuels than the global average does not exclude the country from being responsible for contribution to excess CO_2 emissions in the atmosphere. Canada must first address the problem of energy demand per capita, while also producing future energy using low-impact sources.

HISTORICAL DEVELOPMENT:

Until the late 1970s, energy utility companies had the philosophy that the more energy that was consumed by the country, the more beneficial it would be to the economy. Economic growth derived from greater use of energy, which in turn encouraged more energy production; a vicious cycle was formed. Energy utility companies were known as 'energy producers.' This mentality helped lead Canada into the current social energy habits we currently have. This mentality started to be phased out after 1978, most likely due to the oil crisis of the time (Flavin et al., 1990). This crisis was caused by Middle East oil extractors, uniting against corporate oil refiners, in order to set prices according to their standards (Flavin et al., 1990). Before this time oil refiners were in control, dictating to oil extractors the price they would pay for crude oil. Pricing infrastructure and the formation of Organization of Petroleum Exporting Countries

(OPEC) were the real sources of the oil crisis, not supply as the media had portrayed the problem. The bottom line is that once developed nations experienced how oil prices could affect them, they became apprehensive about using imported oil as a primary energy source.

The reaction to the oil crisis did not lead to a sudden use of renewable energy sources; it only led to the focus on the further exploitation of domestic energy sources. Although renewable energy would be an excellent domestic source of energy, the widespread use of renewables was not yet popular. The philosophy of energy utilities was starting to change, more toward managing the demand rather than increasing (Flavin et al., 1990). Later in the 1980s, end-user energy efficiency started to become popular, but the sudden drop in oil prices stopped this rise in efficiency (Johansson et al., 1993). In the 1990s, efficiency became again popular, but now due to the economic recession in Canada (Harker, 1995). In principle this should make for an ideal climate for renewable energy to flourish.

RENEWABLE ENERGY MARKET POTENTIAL:

Currently, nuclear power seems to be on the way out in Ontario (Washington Post, 1997). This trend of phasing out nuclear technology further allows for a niche in the energy market for renewable energy sources. Another source to compensate for the loss of nuclear energy will be required. The Electricity Competition Act, Bill 35, may also make room for renewables in Ontario. This bill has split Ontario Hydro into 2 entities: generation will be done by Genco and transmission/distribution will be done by Servco (Toronto Star, 1998). There will also be a third company, which will be a financing company in charge of dealing with the $30 billion dollar debt that Ontario Hydro had accumulated. With this expansion, Genco will become the largest North American Electricity Utility. Although these companies will still be publicly owned, it is likely that Genco will be subdivided into private generation companies as well. This effectively opens up the electricity generation market in Ontario. The climate is now ideal for new energy generation, namely renewable energy sources. This could also set a precedent for other provinces, which could privatize their electricity generation.

Many renewable energy technologies are fast approaching the benchmark price of coal. Laboratory photovoltaic technology was approximately twice the price of coal in 1992 in dollars per watt (Johansson et al., 1993). The challenge that remains is getting the political climate ready for the conversion to alternative energy technology; indeed, the ‘ current political climate’ is geared toward more traditional sources. There simply exists much dependence on an oil-based energy infrastructure. To change such a system involves sweeping changes. In order to replace such an established market, renewables will certainly need subsidization from government and intense public education.

However, it must first be established which type of renewable energy is best to use. The most abundant energy source this world has ever known is the Sun. In fact, the solar energy striking the United States every 40 minutes is equivalent to oil-derived energy of one year, just to demonstrate the potential (Johansson et al., 1993). This makes solar-derived energy sources potentially more plentiful. These derivations include wind energy (due to uneven heating of the Earth), photovoltaic electricity and direct solar thermal energy.

The main goal of the feasibility study will be to apply additional energy for water heating at Trent University. Each following section will demonstrate how it will serve this purpose.

WIND POWER GENERATION:

Wind energy is a very promising energy option if the necessary resource is present, which is good wind speed. Enhancement of wind potential is achieved often by placing the apparatus at the crest of an elevation, where air of lower elevations is effectively pushed upwards. Wind potential can be increased by as much as 200% with such innovation (McKirdy, 1999). Two very effective ways of capturing energy from the wind and transferring it into electrical energy are using a vertical axis turbine and a horizontal axis turbine. Each design has similar potential for energy development, but the horizontal axis design is much more popular, perhaps due to it's similarity with wind mills for grain milling of previous times.

The horizontal axis design consists of a cable-tethered tower with a turbine electrical generator mounted in such a way as to rotate to face the wind by using a directional tail. Three blades are attached to a rotor on the turbine engine, which effectively delivers the wind energy to the turbine generator. As the rotor is turned, an attached drive shaft is turned within the turbine, which drags magnets through small coils of wire to induce current. This has the effect of generating a flow of uniform frequency electricity in the individual coils, which will be a direct current in a wire (DC) (Kraushaar et al., 1993). This power must now be converted to alternating current (AC) in order to be useful in practical applications, as the North-American continent runs on 60Hz electricity (pulses back and forth 60 times every second). An inverter can complete this task, by cycling the electricity into 'sinusoidal wave' form.

Wind energy can be used in Canada throughout the Rocky Mountains, Great Lakes, Appalachians and the Gaspé regions, all with great wind potential. The infrastructure to capitalize this potential is what is missing. This is also responsible for keeping to cost of wind energy higher than that of coal (McKirdy, 1999). Through initialization subsidies, renewables could be started off with the ability to compete against major energy corporations, at least to set up a substantial niche market. Already, Ontario has a major turbine generator manufacturer and an internationally established propeller blade company. What remains to be seen is whether small business can capitalize on the potential market available in Ontario and across Canada.

Trent could apply wind power at Trent simply by using the generated electricity to heat water directly, so the existing facilities for heating water would involve minimal changes. The external facilities however, would involve some significant changes. There would need to be a tower erected on the highest elevation, namely the drumlin. This tower would need to be higher the trees, as this would greatly contribute to the available wind. This would mean some noticeable alterations to the visible landscape, some intense construction and long distance wire burying. For these reasons, it would seem to that wind power is the most socially abrasive option. However, there exists the argument that because Trent University possesses a formidable Environmental Studies program a typical horizontal axis wind turbine spinning on campus would enhance the image of the school. By 'practicing what we preach', the visibly noticeable wind turbine would be more acceptable.

PHOTOVOLTAIC POWER GENERATION:

Another leading method of renewable energy use is the photovoltaic cell. The photovoltaic cell is a junction, typically an excellent semiconductor, with one side being treated with a slightly negative substance (n-doped) and the other side being treated with a slightly positive substance (p-doped) (Anderson, 1993). In the dark, this cell would have slightly more electrons on the n-doped side and slightly more holes for electrons on the p-doped side. The term 'holes' simply refer to a possible location for an electron to go, until an electron does go there, the hole effectively represents a positive charge. These electrons and holes are always moving around when the temperature is higher than 0° K, so they will possess some thermal energy at all times (Ebbing, 1996). This is not to say that there are no loose electrons on the p-doped side, because the thermal energy within the cell, at room temperature, would be adequate to knock loose electrons on that side as well, creating additional holes on the p-doped side (Johansson et al., 1993). This results in some arbitrary current being created, but this is insignificant.

The photovoltaic effect occurs in the presence of light, where the n-doped side is facing the light source. This radiation bombardment on the n-doped side loosens a pool of electrons, which are attracted to the holes on the p-doped side, but cannot reach the holes due to the negative charge at the edge of the junction and p-doped side, which comes from the loose electrons on the p-doped side. The electrons can follow a path leading to the p-doped side instead of across the junction, such as when a wire connecting the n-doped side and the p-doped side; thus creating a useful current along this wire. The process is maintained by electrons coming from the p-doped side back to the n-doped side to restart the cycle (Johansson et al., 1993).

The fabrication of photovoltaic panels involves the use of pure silicon for the junction; although this element is very abundant, it is still costly to reduce it to a pure form (Johansson et al., 1993). Crystalline lattice-structure silicon yields one of the highest conversion of sun energy to electrical energy, which is 35% (Anderson, 1993). However, this process is rather costly and arduous, making the technology economically unfeasible. The same drawback also applies to thin layer crystalline photovoltaic panels, even though less work goes into the manufacturing compared to lattice-structure photovoltaics, they are still an unfeasible option.

The most promising application that will get photovoltaics up and running will probably be amorphous silicon (Johansson et al., 1993). Amorphous silicon can give 10% efficiency, which is economically feasible, using a layer of photovoltaic cells which is 100 times thinner than crystalline silicon initially. This efficiency mentioned is the effectiveness of the panel to convert the available solar energy hitting it. The only problem with amorphous silicon is that as the cell structure ages, the effectiveness decreases, stabilizing at an efficiency less than the initial value (Johansson et al., 1993). Once this decay problem has been reduced, amorphous silicon can come on-line, hopefully as the cheapest and easiest way of producing photovoltaic cells. The current technology was applied to over 32% of all solar panels in 1990 and has grown since that time, making amorphous silicon feasible for small-scale technology (Johansson et al., 1993). The technological advances needed for amorphous silicon strictly apply to large-scale power generation, which would not be viable with such low efficiencies, such as less than 10% (Flavin et al. 1990).

Amorphous silicon photovoltaics could very easily be applied to Trent, simply by adding a solar grid to rooftops on campus and using the generated electricity directly to heat water. This would involve very little aesthetic disturbance, as compared to wind power development, and probably cost less. The technology is more fragile and damage due to accidents, ice or other weather elements could prove costly. It remains to be seen whether wind is more abundant than sun.

DIRECT SOLAR POWER:

A process that is the most commercially viable at present is active solar thermal heating (McKirdy, 1999). By using energy from the sun directly, water and air may be warmed for residential or commercial needs. Conventional hot water heaters can be quite easily retrofitted with a solar collector, in order to reduce the cumulative heating costs of hot water over time, and reduce the amount of fossil fuels or electricity used. The fact that the system can be added to the average home easily is a primarily why the technology is so cost-effective.

The principles of a solar collector are quite simple. Effectively, a photovoltaically powered pump is responsible for pumping a heat transferring liquid to a solar collector outside a building, ideally on a roof, where a maximum amount of solar energy may be captured (Kraushaar et al., 1993). This liquid is usually glycol, an alcohol that freezes at a lower temperature than water. The collector consists of glazed glass and a black resin-coated metal underneath. As high-energy light enters, it becomes thermal energy when it hits the metal. The glazed glass serves the purpose of allowing light to enter, but will not let light reflect out as easily. The resin-coated metal has a high absorbency coefficient and a low emmisivity coefficient, so that all forms of energy may be absorbed yet very little heat will escape. The overall effect is similar to the Greenhouse Effect.

Glycol passes through the centre of the metal, in a tube, and absorbs a large percentage of the heat in the metal, as this glycol will be quite cold (for reasons to be outlined in a moment) (McKirdy, 1999). The system works more efficiently when there is a greater temperature difference between systems that will be passing heat. Thermodynamically, it is more energy efficient to transfer heat from very high potential to very low potential. The two pools want to achieve equilibrium and the temperature will change more dramatically in order to reach the equilibrium.

This heated glycol will now enter a heat exchanger, to pass the heat from the glycol to the cold water, which is what is to actually be heated. Through this process, the glycol has most of the recently acquired thermal energy removed, as it is passed to the water, and cold glycol returns to the solar collector (Serway, 1996). The warmed water is placed within a storage tank separate from the hot water tank that is heated by gas or electricity. This is due to the fact that most of the heated water will not always be provided by the solar collector. The collector will only give a percentage of the necessary energy. Of course, the solar collector will be the default operator, in that it will be used up before turning to the less efficient technology. The percentage of hot water produced by the solar collector is a function of the amount of the amount of sunlight received resulting in some days not being very productive, making a more conventional system as backup a necessity.

The estimated lifetimes of these systems are quite long, as compared to more conventional hot water systems, involving less maintenance (McKirdy, 1999). Typically, only the pump of a solar collector or the turbine generator needs to be serviced regularly, as they do have moving parts. All other components should yield a lifetime over 30 years. That kind of durability is unheard of in fossil fuel applications. This is simply that for all the energy being created in the combustion of fossil fuels, no more than a third actually accomplish useful work (Kraushaar et al., 1993).

This technology would be best suited for Trent, as it is proven to withstand Canadian weather. As well, it would be quite easy to add to existing facilities and working parts would be easily serviceable by existing staff, as they would be familiar with water pumps and heat exchangers. As with photovoltaics, the solar collector would need to be added to rooftops, which would not alter the architecture of buildings greatly, as they would not be very noticeable. This type of system also has the most data collected on it, as Environment Canada already has a testing facility exclusively testing active solar direct heating technology in Missisauga, Ontario (McKirdy, 1999).

CONCLUSION:

Overall, renewable energy sources have definite need in a Canadian energy market and have definite potential for their use at Trent Univerity. Although active solar thermal heating does seem to be the most viable application of solar energy technology, there still exists practicality in wind and photovoltaic energy systems. With coercion from tax breaks and other government benefits, Canada may in fact be able to meet its commitments made at the Kyoto

Conference in 1997. Renewable energy has many practical applications for solving problems that could not be solved by conventional energy development. Emergency power sources during ice storms to remote power generation in northern climates are excellent examples. From this perspective, we must explore the full potential of this sensible technology.

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