RTE-NHSS PROJECT

REDUCING THE EMISSIONS OF NORTHVIEW HEIGHTS S.S.

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A PROPOSAL

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Summary

With the growing recognition of the detrimental effects of burning fossil fuels on earth systems, a global shift towards using renewable energy sources is a fast approaching convention. This report focuses on green innovative thinking and proposes to deliver one of the largest educational constituencies in North America, the Toronto District School Board, to main stream and demonstrates that investment in solar energy can be as reductive to the board's $69 million in spending in energy and waste management as are oxides and aerosols to the environment and human societies.

This report identifies the need to adopt green technology and finds that installing solar panels systems on Northview Heights will reduce it's annual electricity consumption and cost by 17% for the first ten years, then 16% for the next projected thirty years.

Purpose & Significance

Statement of Goal

The goal of this proposal was to reduce the emissions of Northview Heights by offsetting the school's electricity consumption by installing a high efficiency solar power system on a rooftop space with maximum exposure to sunlight and minimal obstruction during inauguration. IESO reported that 37.2% of electricity generated was through combustion of natural gas and coal. The process released carbon dioxide and water, two detrimental greenhouse gasses (IESO, 2013). A solar power system was proposed to reduce the amount of coal and gas required to power Northview Heights and therefore reduce the school's emissions.

Significance to Toronto District School Board

If the TDSB would initiate the project, global trendiness have indicated that media would veil the board in positive view and may allow other boards to launch similar projects or allow this project to scale. Presciently, due to an agonizing lack of Conservative green policy, the government would seize such an opportunity by increasing funding or allow the board for substantial tax rebates to show support for green policy. Corporation and big oil companies infamous for destroying the planet (such as Exxon Valdez) may also pinch the national screen and endorse or fund the project, the board or the school to heal their public image.

Statement of Problem

Research: Growing Energy Demands

Economically and fundamentally, contemporary populace is lost in growth and there is an ever increasing need for energy. As a result, the governments and corporations at large are are investing in the most economically viable sources of energy to support this socio-economic cancer; the burning of fossil fuels. Fossil fuels are inexpensive, most abundant and most polluting form of non-renewable energy. In 2011, fossil fuels delivered about 85% of energy needs North America. Recently, however, there is a growing recognition that harnessing energy from non-renewable sources is transforming earth systems and have detrimental implications for society. Take for example the combustion of bituminous coal, one of the most commonly consumed energy resources since the mid 19th century.

$$C_{75\text{-}90}H_{4.5\text{-}5.5}N_{1\text{-}1.5}S_{1\text{-}2}O_{5\text{-}20} \cdot n(H_2O)\ (s) + O_2(g) \rightarrow CO_2(g) + H_2O(l) \qquad \Delta H \approx -25.6\text{-}34.8\ \text{kJ/g}$$

The vast majority of coal is used for electricity generation and the most efficient plants can convert just 37% of released by one gram of bituminous coal. Energy is delegated from the combustion process to gives rise to evaporated water. The steam revolves turbines that transform the kinetic energy of water to electric potential energy that is then transformed again upon consumption to light, heat, or again to kinetic energy for example. The remaining quantity of coal is coked in the steel industry and other industrial applications, with a small quantity used in heating homes or offices or exported (Solomon, 2010).

In essence, coal is the accumulation of tightly packed dead vegetation compressed and heated under layers of earth, the formation of coal is largely dependent on the type of vegetation present it's formation. The four major factions being, anthracite, bituminous, sub-bituminous, and lignite which are classified based on fixed-carbon content and the magnitude of joules released. The most globally abundant economically recoverable coal is bituminous. Bituminous produces smoke and ash when burned and releases 25.6-34.8 kilojoules of energy per gram. As the more pollutant variant with 46–86 percent fixed-carbon content, the relatively fewer strong carbon-carbon bonds in it's structure makes bituminous softer than thee three (Stranges, 2004).

Coal and fossil fuels customarily produce green house gasses when fueling combustion such as carbon dioxide (CO_2), water (H_2O), sulfurous and nitrous oxides. These gasses reach altitudes where they impede terrestrial radiation from radiating out of the plane, inevitably becoming the the catalysts global warming (Stranges, 2004; Solomon, 2010). Whilst intentionally ignored since the industrial era, the flaw in this combustion process is now agonizingly revealed by earth systems in the shape of ecological and societal and industrial disruptions.

Societal, Ecological & Industrial Disruptions

Terrestrial Radiation is radiation reflected from the earth back towards space.

Sulfate aerosols are mixtures of solid or liquid particles that include sulfuric acid. The particles are a few microns in size. Most sulfate aerosols exist as a haze in the troposphere, the layer of the atmosphere that goes from the ground up to about 15 km.

Pertaining to the societal; vast stretches of islands, such as the Maldives, are due to drown in rising sea levels caused by the melting of Antarctic icebergs (Quiret, 2012). The Maldives consist of 1,190 coral islands, forming an archipelago of 26 major atolls. Collectively, these islands stretch 820 kilometers north to south and 120 kilometers east to west. Scientists warn that many species of coral will not have the means to survive in a one degree celsius warmer world. Today, 202 of these islands are inhabited by 320,081 people and are 87 are mass revenue generators for the locals as they are exclusive resort islands (*World Bank Group*, 2012; unknown, 2009).

In the atmosphere, sulfur dioxide reacts with water vapor, oxygen, and nitrogen oxides to create acid rain. Acid rain is known to destroy protective tissues of plants and wrecks havoc in pH sensitive ecosystems like those in freshwater water bodies. Small marine organisms are incapable of subsisting in acidic conditions. Their depletion affects fish higher in the food chain and ultimately the entire chain. Acid rain is also economically very damaging as it consists of ions that accelerate the process of corrosion in buildings, cars and large plants (DiGiuseppe, et. al. 2012). Furthermore, when sulfur dioxide, water vapor, and nitrogen oxides are mixed with very fine smoke or dust particles, there is a potential for sulfate aerosol to be produced that influences cloud cover and regional temperature (*Climate Change: In Context,* 2008). Sulfate aerosols in the stratosphere scatters electromagnetic radiation coming from the sun and absorbs terrestrial radiation, unnaturally imposing a cooling effect on the environment. Sulfate aerosol have also reduced the ozone layer by about a third by reacting with ozone (*Sulfate Aerosol*, 2008). High cancer rates in Canadians as a result (unknown, 2012).

What should have clearly been a fad has trended on long enough. Basking in our ignorance, the combustion of fossil fuels to power human activities have actualized a considerably disturbing number of problems. In 2003, the Toronto District School Board (TDSB) the board allocated $48 million of its annual budget to the energy and waste requirements of 600 schools, but within three years, found that the energy and waste expenditures had escalated to more than $69 million (Christie 2003, 2007; Christie & Coppinger 2006; Yeomans, 2012). More specifically, Northview Heights S.S. consumed 1,475,990 kWh, this accounts for about $101,900 in spending for lights and electronics alone (WolframAlpha, 2013). Fossil fuels are now loosing their status quo, populaces looks only to increase and the price for this commodity is rising by the day. Although it never was, It is no longer the feasible solution. The time has come for TDSB, privileged to oversee the largest education constituency within Canada, to look forward and invest to remove itself from this euphoric sham. This report focuses on collaborative, cyclic and renewable means by which we can harness energy to support not only ourselves but earth systems at large.

Objectives & Procedure

Objectives:

- To identify a favorable contract with a certified SunPower© dealer that will allow for the installation of solar power system on the predetermined rooftop sites of Northview Heights Secondary School
- To reduce annual costs of electricity consumption at Northview Heights Secondary School
- To reduce the emissions of CO_2, SO_2, and NO_2 gases

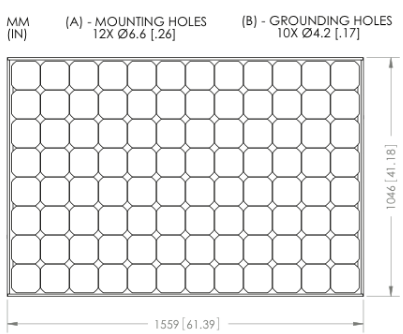
Procedure & Methods for Achieving objectives

To realize Northview Heights as an energy efficient school and offset the school's emissions, it was paramount that an energy solution be derived from the principles of sustainable science. Thus, it was necessary that the system operate by means of cyclic, infinitely reusable energy sources. That it should not alter the surrounding ecosystems and must reduce the emissions of the school. Such a system would also have to be cost effective and reliable with little maintenance. Through comparative research, It was discovered that solar power ranked highest in providing for the aforementioned needs. Solar power technologies convert electromagnetic radiation into electricity with no emissions; the method by which they achieve this was cyclic and infinitely reusable. The system allowed for no change in land use, therefore, didl not alter surrounding existing ecosystems. Solar panels were reliable, they were made from silicon crystals which lasted well over 40 years. The electricity generated Solar panels would replace the need for burning fossil fuels which would have ultimately reduced the emissions of Northview Heights (Böer, 2004).

Solar panels consists of smaller units called solar cells. Solar cells are usually created from a mixture mainly composed of silicon crystals merged with atoms such as boron and phosphorous. When a photon of light is absorbed by a silicon atom in the solar cell, electrons in that atom jump to higher energy levels. Photons with high energy levels sometimes allow the electron to escape the atom altogether. This creates a positively charged silicon ion and a free electron. The ionized state of silicon in a crystal lattice is mobile and acts much like a free electron because the state can jump from neighboring atom to neighboring atom. Usually, the electron and the positively charged ion do not stray far and recombine eventually. However, since a conducting wire from an battery connects to the silicon crystals at opposite ends; one end functions as the cathode and the other as the anode, they create an electric field. In the electric field, the mobile ionized state tends to move toward the cathode and the electrons to the anode. The excited electrons, complete the circuit by performing a specific task such as heating an oven or producing light, then return to the cathode to reduce a silicon ion. Energy and current in a solar cell is augmented as sunlight penetration increases (Böer, 2004). Scientists have optimized this process through the years and today solar cells achieve astonishing efficiencies. The cycle and this method of harnessing energy to power human activities collaborates infinitely well with earth systems when compared to conventional methods of energy production because it is emission free and infinitely reusable.

After comprehensive and comparative research, it was found that the E-20 series developed by SunPower© was most suitable for conditions in Toronto. The chosen SPR-327NE-WHT-D model has an estimated cost including labour, wiring, mounting, stands, & connection of $490 per panel when installing large systems. SunPower©'s patented Maxeon™ cell technology allows for up to 50 percent more power than conventional solar panels and up to 3 times better reliability. Maxeon™ cells hold the world efficiency record of 24 percent. SunPower© claims that this is the highest efficiency available in the market today. Maintenance for these panels is delivered by annual showers. The panels can also be cleaned by garden hoses to improve output. Additionally, SunPower© also provides maintenance for the panels. Furthermore, SunPower© guarantees parts and labour for 10 years and over 90% power output for the first ten years and over 80% for 25 years (SunPower, 2011). It is known that solar panels still output 80% of power after twenty-five years. (Solart, 2012). Refer to product specification on Table 1. *Note: For detailed calculations for estimated power output refer to Appendix

Table 2: SunPower© E-Series: Model: SPR-327NE-WHT-D Panel Specifications

SunPower© E-Series: Model: SPR-327NE-WHT-D		
	Peak Power (+5% to -3%)	327W
	Panel Efficiency	20.1%
	Rated Current	5.98 A
	Open Circuit Voltage	64.9 V
	Maximum System Voltage	600 V
	Functional Temperature Range	–40° C to +85° C
	Max Load	550 kg/m^2
	Impact Resistance	Hail: (25 mm) at 51 mph (23 m/s)
	Dimensions	1.559m x 1.046m x 46mm
	Surface Area	1.6310714 m^2
	*Estimated Power Output	1.2286125 kWh/day

Management & Evaluation

SunPower© trains and employs it's own qualified branch of professional installers for solar systems and fulfills contracts through it's dealer network. Dealers handle all aspects of solar panel installation, including design, permitting, rebate processing and system maintenance. Since management will be covered by SunPower©, the TDSB will not be involved in the installation or management process.

SunPower® Monitoring System will track the performance of the solar power system through phone applications and a dedicated website (via account sign-up). This will allow the school to evaluate the project over the years and hopefully give this project the opportunity to scale not only to other TDSB schools but to other school boards across Ontario.

Table 2: SunPower© Certified Dealer's Panel, Materials and Labour Costs

	Estimated Materials/Panel Cost	Additional (Labour)
Oak Electric	$271,950	$30,000 ± $3,000 (Premium Dealer)
Mechanical Energy Systems, Inc.	$271,950	$30,000 ± $3,000 (Premium Dealer)
Solar Winds Power Systems, LLC	$271,950	$25,000 ± $3,000

Timeline

Day 1: Contract and Survey

Toronto District School Board representative will sign a favorable agreement with one of the three aforementioned dealers and initiate survey conducted by the hired personal. Desired locations for panel placement will be outlined and a bulk order will be placed.

Day 2 - Day 5: Installation

SunPower® estimates that it's team of professional installers can mount 18 panels per hour. Thus it is estimated that installing solar panels at all three sites will require approximately 31 work hours and with the assumption of eight hour work days, this installation is projected to require four days of work (Refer to Figure 1 for site information). At this stage, during the construction and assembly of the solar systems, it is paramount that media assets be mobilized onto the scene. TDSB will only gain from this and may even receive increased funding or incentives from the government to scale the project to other schools.

Day 6: Connection and Initiation

At this stage, the solar power systems will be connected in parallel circuits to Northview's main inverter. Communication systems will be installed alongside the panel to allowing for monitoring power output and verifying efficiency as well as troubleshooting any incidental problems such as drilling required for passing wires throughout to the inverter.

Day 7: Inspection

SunPower® will investigate the solar power performance and also identify safety protocols for the school administration. Additionally, the company will provide an account that will allow the administration to monitor the power output of panels through the dedicated global web server (SunPower, 2011)

Equipment, Materials & Facilities

The proposed project requires no special facilities. The total cost of materials and equipment for this project is estimated to be $271,950. The installation sites chosen for this project were determined to be the rooftop directly above the auditorium, the main gym, and the grade 9 hallway as these sites provided maximum exposure to sunlight and unobstructed space for mounting solar panels. (Refer to Table 3).

Table 3: Solar Panel Quantities, Cost & Installation Site Metrics

	Site A: Auditorium	Site B: Main Gym	Site C: Grade 9 Hallway
Estimated Dimensions	17.0m x 76.5m	27.2m x 25.3m	36.0m x 18.0m
Estimated Space Used	408m^2 (15.59m x 26.15m)	300m^2 (12.47m x 24.06m)	197m^2 (17.15m x 11.5m)
Number of Panels	250 (10 x 25)	184 (8 x 23)	121 (11 x 11)
Total Cost	$122,500	$90,160	$59,290

Budget & Personnel

Personnel

Because SunPower© trains and employs it's own branch of professional installers for solar systems the TDSB will not be involved in the installation or management process. However, it is known that SunPower© would employ personnel with an electrical background to complete the project. This would include electricians, electrical engineers & architects and systems analysts. Generally, electrical architects survey space, design panel layout and conduct the project into maturity. Electricians assemble the framework and complete manual procedures. Electrical engineers check, maintain, and provide technical solutions and support.

Projected Costs

As previously mentioned, the cost of one E-20 series SPR-327NE-WHT-D model solar panel was estimated to be about $490. The accumulated total number of panels for all three sites was discovered to be 555. Thus, the total initial cost for all three systems was calculated to be $271,950.

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	First 10 Years (90% output)	Next 15 years (80% output)
SPR-327NE-WHT-D Panel Output	448.4 kWh/year	428.4 kWh/year
System Output	248,886 kWh/year	237,742.02 kWh/year
Net Savings	$17,180	$16,413

Projected Income

The SPR-327NE-WHT-D model has 24% efficiency according to SunPower©. However, the company guarantees a 90% power output for the first ten years, therefore, it was assumed that it would operate at a 20.1% efficiency. (SunPower, 2012). On average, weather conditions in Toronto allow for about 3.57 kilowatt hours of energy to reach a square meter fully exposed to sunlight per day (GreenToronto, 2010). It was calculated that the three systems would generate a 248,886 kWh/year (90% output) for the first ten years and 237,742.02 kWh/year (80% output) for fifteen years after that.

Net

In it's 2011-2012 fiscal year, Northview Heights consumed 1,475,990 kWh, this accounts for about $101,900 in spending for lights and electronics (WolframAlpha, 2013). The proposed system reduces usage and cost by estimated

17% for the first ten years and 16% for fifteen years after that. In total, the system pays back for itself in 16 years and makes a total profit of $392,240 over it’s presumed 40 year life span (Solart, unknown).

Appendix

Estimating Average Power Output for SunPower© E-Series: Model: SPR-327NE-WHT-D

The average Sunlight Energy Penetration for Toronto Ontario was researched to be 3.75 kWh/m2/day. Since the warranty SunPower states a 90% power output for the first ten years, the SPR-327NE-WHT-D model efficiency was adjusted from 24% to just 20.1%.

24% x 0.90 = 20.1%

Next, the surface area for one SPR-327NE-WHT-D model panel was found to be about 1.63 m^2

1.559m x 1.046m = 1.6310714 $m^2 \approx$ 1.63 m^2

Based on this data, the energy output of one panel was found to be about 1.23 kWh/day by multiplying the surface area of one panel by the amount of solar energy received by one squared meter in Toronto and by the conversion efficiency of one solar panel.

3.75 kWh/m2/day (1.63 m^2) (0.201) = 1.2286125 kWh/day

This was adjusted to annual output per solar panel by multiplying by 365 days.

1.2286125 kWh/day (365 days) = 448.4435625 kWh/year/panel

Finally, the total output was found by multiplying the output of one panel by the total number of panels, 555, from all three sites. This was calculated to be about 248,886 kWh/yea for the first ten years.

448.4435625 kWh/year/panel (555 panels) = 248,886.1772 kWh/year

The next fifteen years, SunPower guarantees an 80% power output, thus the efficiency was adjusted to 19.2% efficiency.

24% x 0.80 = 19.2%

The process was repeated for a system with 80% power output. It was found that for the next fifteen years, the system would provide about 237,742 kWh/year

3.75 kWh/m2/day/panel (1.63 m^2) (0.192) (365 days) (555 panels) = 237,742.02 kWh/year

Calculating Net Electricity Usage and Cost.

In it's 2011-2012 fiscal year, Northview Heights consumed 1,475,990 kWh, this accounts for about $101,900 in spending for lights and electronics (WolframAlpha, 2013). The system reduces usage by 17%.

1,475,990 kWh/year - 248,886 kWh/year = 1,227,104 kWh/year

This was calculated by using the difference formula:

[(kWh used - kWh generated) / (kWh used)] x 100%

= [1,227,104 kWh/year / 1,475,990 kWh/year] x 100% = 83.14%

Since the original 1,475,990 kWh/year costs the TDSB $101,900, the amount of savings was also confirmed to be 17% which was calculated to be $17,180 per year for the first ten years.

(1,475,990 kWh/year) ÷ ($101,900) = (1,227,104 kWh/year) ÷ x

x = (1,227,104 kWh/year) ($101,900) ÷ (1,475,990 kWh/year) = (0.8314) ($101,900) = $84,719.66

These methods were repeated for the next fifteen years with an adjusted power output of 80%. It was found that there is not much difference in performance of the system in offsetting electricity usage after ten years of usage as the the system manages to offset 16%, just 1% off the first ten years. The savings for the next fifteen years were calculated to be $16,413.

1,475,990 kWh/year - 237,742.02 kWh/year = 1,238,247.98 kWh/year

[1,238,247.98 kWh/year ÷ 1,475,990 kWh/year] x 100% = 83.89%

$101,900 (0.8389) = $85,486

Calculating Feasibility of the system

Multiplying the savings for the first ten years by ten years and adding this to the savings for the next fifteen years by fifteen years produces by fifteen years allows for a rough estimate for the total amount of savings, $417,995, generated by this system in it's warrantee life time.

$17,180 x 10 + $16,413 x 15 = $417,995

Furthermore, it was found that the system ($271,950) would pay for itself in about 16 years.

$17,180 x 10 + $16,413 x 6 = $270,278

As reported by Solart Canada, most solar panels last 40 years. Thus absolute value for the entire system was estimated to be $664,190, assuming the power out remains at 80%.

$17,180 x 10 + $16,413 x 30 = $664,190

Subtracting this from total cost of the system produced net income of $392,240

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