UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into Renewable Energy Sources For Use in the New SUB

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Abstract

The goal of this report is to investigate the sustainable implementation of a renewable energy in the new UBC Student Union Building. The first step was to examine five of the leading renewable energies in the world and determine their feasibility for use in the new Student Union Building. The types of energy that were examined are wind energy, biogas, tidal energy, geothermal energy, and solar energy. In order to meet the 20% requirement for the LEED Platinum Plus certification, it was determined that solar energy was the most feasible to pursue.

Once solar energy was chosen as the best method to pursue, a triple bottom line analysis was done to see if solar energy is indeed the correct choice. The result is that economically, solar energy may not be the best option at the current time, but the environmental and social impacts could help offset the costs when compared to other energy sources. As far as implementing solar energy goes, the best panel type to choose would be a polycrystalline based solar panel. If needed, it might be a good idea to also implement some solar windows or roadways.

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1.0 Introduction

The new Student Union Building (SUB) that is soon to be under construction will be designed to be one of the most sustainable buildings in the world. In order to be one of the leading buildings, it will be built to receive a LEED Platinum Plus building certification. One of the requirements of this certification is that 20% of the building's energy usage be supplied by a renewable energy source. In this report, five of the leading types of renewable energy are examined. They are wind energy, biogas, tidal energy, geothermal energy, and solar energy. The feasibility of implementing each renewable energy source in the new SUB was compared and solar was chosen as the best option to implement. Following this initial analysis, solar energy was examined in more detail, including the different solar panel types. In addition, alternate means of generating solar energy from the traditional roof-mounted solar panels were researched. The main purpose of this report is to provide the new SUB stakeholders with information and recommendations on how to implement the required energy in a sustainable manner.

2.0 Overview

This section gives a basic overview of each of the five renewable energies being investigated, with a focus on the social, environmental, and economical impact of each type.

2.1 Wind Power

Wind power is one of the renewable energy that is being widely implemented around the world. It is a clean energy source that produces no air pollution while transforming wind power to electricity. Despite the benefits of wind energy, there are various issues that need to be considered before integrating them. First of all, in order for wind turbines to work, the wind speed must be at least 10mph and this has to be consistent throughout the year for economical reasons [1]. Secondly the traditional ways of wind power generation uses wind turbines generators, which require a massive amount of land. On average, for a mega watt produced, a total of 0.1 kilometer squared of area is required [2].

However, since there is a minimum distance that the wind turbines have to be separated for them to produce the maximum power the amount of land that the wind turbines occupy is actually only one percent of the total area. Therefore, the rest of the land can still be used for farming. There are also other pollutions that wind energy produces that need to be aware of. The most significant one is the noise pollution. From researches [3,4], it has been recorded that the noise of the wind turbines travels more than 7000 feet, and normally the noise level of 45 dB will disturb humans from sleeping. However, the noise at the distance of 3000 feet from the turbines is still greater than 70 dB [3].

Another concern is the visual pollution that the wind turbine produces. Current reports have shown that there are more and more protests on the pollution caused by the disturbing appearances of the wind turbines. Lastly, the wildlife hazard that the wind turbines cause is a serious problem [3]. Research has shown that there is a significant amount of bats and birds that are killed by the wind turbines; however, an interesting research has shown that painting the wind turbine purple can significantly reduce the rate of animals being killed by the wind turbines [1, 3].

The discussion above has stated the basic facts of the wind energy generation, but it is not realistic to build a wind farm just for the new SUB even though the wind speed at UBC meets the requirement since wind farm requires a massive amount of area and also the cost to build the wind farm is magnificent. Typically for 2.8-4.8 kilowatt of energy produced it costs around 1.5 million dollars. Because of all these factors, building a wind farm on campus is impossible [1, 3].

2.2 Biogas

Another source of renewable energy that can be considered for use in the new SUB is biogas. Biogas is produced by bacteria during anaerobic digestion of organic waste like manure, sewage and municipal waste. The gas is primarily composed of methane and carbon dioxide; however trace elements like hydrogen sulphide and nitrous oxides can also be present. It is typically used in boilers and electric generators to produce heat and power and it can also be refined into biomethane or renewable natural gas (RNG) and injected into an existing natural gas network for distribution and consumption [5]. However unlike natural gas biomethane is a clean and renewable carbon-neutral fuel that if utilised can help score a building carbon credits [5].

Biogas production has several environmental benefits including reduced greenhouse gas emissions, improvement of agricultural land through production of an enhanced fertilizer and reducing the need for landfill expansions due to utilisation of waste for energy [6]. Some of the social benefits of biogas production include provision of employment though maintenance of biogas plants, reducing odours and disease causing pathogens in manure and also minimizing the dependence on fossil fuel based energy like natural gas [5]. Consideration of the economic aspects of biogas production reveals that there are two options by which a building can utilise biogas for energy production. The first option is on site production and the other is biomethane utilization through a natural gas network. On site production would require implementation of a biogas plant and use of organic waste that is abundant in that area. Small biogas plants (250 kWe) typically produce electricity at an average break even cost of $115/MWh [7], however implementation of this option is not feasible for the new SUB due to cost and space restrictions. A 2008 study into the feasibility of biogas in the fraser valley conducted by electrigaz revealed that in BC, conversion of biogas into biomethane presents economic and environmental advantages over option one. Interested consumers would be able to purchase the biomethane for about $9/GJ to $15 per GJ [5] once the process is underway. However because hydroelectricity is cheap and does not emit GHGs, on an economic basis implementation of biomethane in the new SUB is infeasible thus other cheaper alternative sources of energy should be considered if hydro is not desired.

2.3 Tidal Power

One of the newest kinds of renewable energy is tidal energy. It is still in its development stages and has only been implemented in a few places around the world. Tidal energy takes advantage of the predictable tidal currents created by the moon's pull on the earth. If feasible, this predictability makes tidal energy a better alternative than solar or wind energy. The kinetic energy of the currents is harvested through the use of turbines that are similar to wind turbines, but can be made much smaller due to water being denser than air.

Tidal energy is considered a clean energy as it gives off no toxic or CO2 emissions. That is not to say it does not affect the environment it is in. When the turbine harvests the energy, it slows the currents down. This can have an adverse effect on the surrounding sea life [8]. In order to offset organism buildup or corrosion on the turbine[9], it is given a special coating and lubrication. These coatings are slowly taken off the turbine by the currents which spread it to the surrounding ecosystem. Since tidal power is a new technology, little is known as to a how far of an extent these issues affect the environment.

In order for tidal energy to be effective, it is recommended that the tidal turbine be placed in an area where the currents average about 2 m/s or greater. The average current speed in the waters just off Point Grey is at best 0.2 m/s [10]. Using Betz Law that says only 51% of kinetic flowing energy can be converted into electrical energy, it can be calculated that there is only about 2.1 W/m^2 available for harvesting [10]. This means that the new SUB is not in an ideal spot to utilize tidal energy and is therefore not recommended.

2.4 Geothermal Energy

Another source for renewable energy that could possibly be implemented as an energy source for the SUB building is geothermal energy as it has been proven to be an efficient and low cost source of energy in many parts of the world. Geothermal energy is essentially using the hot water or steam trapped under earth's surface for heating purposes, or to generate electricity; by pressurizing the extracted hot water or steam to operate turbines.

Considering the minimal environmental and social impact, and low cost of geothermal energy source, one would consider exploiting this source of energy in constructing a building that is to be in accordance with the Leadership in Energy and Environment Design (LEED) Platinum Plus certificate. In contrast to other sources of energy, geothermal is considered to be the most clean and "green" source of energy [11, 12] with the least Co_2 emissions and low SO_2

and NO_x emissions [13]. Moreover, geothermal energy is considered to have the highest social acceptability among the renewable sources of energy [14] with second smallest plant area requirement (1.0–13.9 km^2/TW hr/yr) [15]. According to the Geothermal Power Issue Brief, the cost factor of geothermal plants is influenced by capital costs for land, drilling, and maintenance cost of the plant [16]. Even though, the capital costs may strike high, the cost per kW.h of geothermal would break even at $0.04-$0.05 [17]. Nevertheless, this economic potential can be utilized in areas where concentrated thermal water or steam is found at depths of 3 km or less [18]. According to the Centre for Environmental Research in Minerals, Metals, and Materials at UBC, Canada is considered to be on the Pacific Rim with great geothermal resources with the Greater Vancouver area encapsulating a large portion of the high-temperature geothermal fluids [11]. For the purposes of this project however, the UBC area is not considered to be a "hot spot" according to Natural Resources Canada [19]. Thus, incorporating geothermal energy is not a viable source of renewable energy for the new SUB building in UBC (Vancouver campus).

2.5 Solar Energy

Solar energy is one type of renewable energy source considered for the new SUB. It provides mainly positive social impacts. An important impact is that solar energy poses no health and safety issues during its operation [20]. Solar energy can promote sustainability and green building design by creating local job opportunities and using the site to raise awareness to students. On the other hand, students could view the solar panels as visual burden that interfere with the building aesthetics and the roof garden.

Solar energy is positive for the environment because it uses the sun's radiation as a renewable resource when generating energy. In addition, it reduces CO_2 emissions by 0.6 to 1.0 kg/kWh compared to coal fired plants [21]. While solar energy is positive for the environment during operation, the solar panels do require toxic substances to manufacture and they produce e-waste after a 20 to 25 year lifespan [22]. To generate the 20% required energy required for the new SUB, an initial investment of about $4.3 to $5.1 million is needed. This is equivalent to a cost of $0.33 to $0.50 per kWh. As a result, solar energy is the most expensive energy type. Even though solar energy is expensive to implement in the new SUB, the positive social and environmental impacts help offset this cost. This is especially true when compared to non-renewable energy sources. Since the positive impacts outweigh the negative impacts, solar energy is the most viable renewable energy source for the new SUB.

3.0 Solar Energy Analysis

This section provides a detailed triple bottom analysis of solar energy as a renewable energy source for the new SUB. The social, environmental, and economic impacts that were presented in the Overview will be expanded in this section.

3.1 Social Impacts

Solar energy provides mostly positive social impacts. During the operating lifetime of the solar panels, they pose no health and safety issues [20] to the UBC community. The solar panels simply collect the already present solar radiation and the system converts this to electrical energy without endangering the public. A second positive social impact is that implementing solar energy in the new SUB creates job opportunities for the local renewable energy industry [20]. Local companies such as Energy Alternatives and Vancouver Renewable Energy Cooperative are experienced with installing solar energy systems. By creating more such job opportunities in Vancouver, we can further promote green building design. Finally, the solar energy system in the new SUB can become an educational site and promote sustainability. Similar to the UBC Farm, engineering students could learn about the operation of solar energy and implementing renewable energies in buildings. Non-engineering students can also benefit from learning about renewable energies and help raise awareness of sustainability. In addition, student volunteers can help with the cleaning of the solar panels.

One negative impact is that the solar panels could potentially be viewed as a visual burden [23]. Depending on how the system is constructed, the panels could protrude from the building for example, or otherwise make the new SUB aesthetically unpleasing. Furthermore, a green garden is expected to be built on the new SUB roof. The use of solar panels on the roof can interfere with the natural scenery because the sight of technology opposes the view of the garden.

3.2 Environmental Impacts

One of the main environmental benefits of solar energy is that the energy is generated from a renewable energy resource. Sunshine, and more importantly solar radiation, is readily available and will not run out during the new SUB's lifetime. Solar energy provides the best renewable resources because of “its abundance and more even distribution in nature than any other renewable energy type" [23]. Compared to coal fired plants, solar energy reduces CO_2 emissions by 0.6 to 1.0 kg/kWh [21]. If the entire 20% renewable energy requirement for the new SUB comes from solar energy, this would result in 310-515 tonnes of annual CO_2 savings.

Looking at the life cycle of solar energy, the manufacture stage produces negative environmental impacts. Silicon tetrachloride is a toxic by-product of solar cell production [22]. In addition, cadmium is another toxic substances found in the compounds within solar panels. Negative environmental impacts due to transportation also exist. However, during the operation stage of solar energy systems, no negative impacts are present. The actual solar panels do not pollute and do not produce greenhouse gasses. But one must note that "precautions should be taken for emergency situations like fire" [23]. Toxic substances within the panels could be released into the environment in such a scenario. The solar panels are expected to operate 20 to 25 years [22] before needing to be replaced. Finally, during the demolition stage, e-waste is created from the defunct solar panels. Recycling can help alleviate this negative environmental impact. Some solar panel manufacturers provide recycling panels for their products. First Solar, for example, recycles "approximately 90% (by mass) ... into new products, including new solar modules" [24].

3.3 Economic Impacts

According to information provided by one the stakeholders for the new SUB, Andreanne Doyon, the new SUB will require about 2,576 MWh of energy per year. Therefore, to meet the LEED Platinum Plus standard, 20% or about 515 MWh per year of the new SUB's energy must be generated from renewable energy sources. First, we need to consider whether enough space exists on the roof to install traditional solar panels. Then, we can calculate the cost of solar energy.

An important aspect of determining the required space is calculating how much solar energy is available in the new SUB. A common misconception is that implementing solar energy in Vancouver is not feasible due to the frequent rain and mild weather. However, data from Environment Canada shows that Vancouver receives about 1928 hours of bright sunshine per year [25]. This corresponds to an average of 5.3 hours of bright sunshine per day and ranges from 1.8 hours per day in December to 9.5 hours per day in July. A more important statistic is the insolation value. Insolation is the measure of solar radiation energy received on the ground over a given time period and is typically measured in units of $kWh/m^2/day$. According to measures from Natural Resources Canada, the mean insolation throughout the year for Vancouver is 3.3 to 4.2 $kWh/m^2/day$ [26].

A typical solar panel of 150W is 1 m^2 in size and produces energy at 15% efficiency. Note that solar panel efficiencies can range from 5% to 19% depending on the panel technology [27]. Using this information, the required space for the solar energy system can be computed:

$$\text{Space} = \text{Energy} \div \text{Insolation} \div \text{Efficiency}$$

$$\text{Space} = \frac{515000\ \text{kWh}}{365\ \text{days}} \div [3.3\ \text{to}\ 4.2]\ \text{kWh/m}^2/\text{day} * \frac{1}{0.15} * \frac{10.764\ \text{ft}^2}{\text{m}^2} = 24100\ \text{to}\ 30700\ \text{ft}^2$$

According to AMS documents, the new SUB will have a 50,000 ft^2 and the roof garden will take up about 18,000 ft^2. That leaves 32,000 ft^2, which is enough space for even the upper estimation.

A normal estimate shows that solar electricity costs $10 to $12 per Watt installed [28]. Using this information and the previous values, the total cost can be computed:

$$\text{Cost} = \text{Space} * \frac{\text{Power}}{\text{Space}} * \frac{\text{Price}}{\text{Power}}$$

$$\text{Cost} = 30700\ \text{ft}^2 * \frac{1\ \text{m}^2}{10.764\ \text{ft}^2} * \frac{150\ \text{W}}{1\ \text{m}^2} * \frac{[\$10\ \text{to}\ \$12]}{1\ \text{W}} = \$4.3\ \text{to}\ \$5.1\ \text{million}$$

By our estimate, the new SUB will require $4.3 to $5.1 million to install the required solar energy system. Using the 20 to 25 year lifespan, the cost works out to $0.33 to $0.50 per kWh. That makes solar energy the least cost effective energy source.

3.4 Analysis Results

If we were to look strictly at the economic analysis of solar energy, we would conclude that this is not a feasible energy source because it costs several times more than other energy types. However, triple bottom analysis looks at more factors than just the economics. Solar energy is easy to install and operate, and it provides some of the best social and environmental impacts when compared to the other energy sources. In addition, the advancements in solar panel technologies will help lower the prices in the future. The following section will explore the different solar panel technologies and provide suggestions for non-traditional ways of collecting solar energy.

4.0 Solar Energy Implementations

4.1 Types of Solar Systems

In today's prevalent market of solar panels, there are three types of semiconductors that can be utilized in photovoltaic cells. Essentially, solar cells are created from monocrystalline, polycrystalline, or amorphous silicon. Each type is made from different structures of silicon and yields different efficiency. A brief description of the three types along with their advantages, disadvantages, and implementation feasibility for the new SUB building that can benefit the HBBH+BH firm in the design process will be outlined in the following sections.

4.1.1 Monocrystalline solar systems

Monocrystalline silicon is made from single-crystal silicon. The monocrystalline solar panels are made of uniformly stacked rounded cells with practically zero defects or impurities in the array of the panel. Due to the complexity and relatively more involved procedure of fabricating and manufacturing of the monocrystaline cells, the price of such panels is higher than the polycrystalline and amorphous types. For instance, a monocrystalline solar panel would cost $5.99 per watt. On the contrary, monocrystalline silicon based panels yield the highest efficiency (15-18%) with respect to the other types of solar cells available on the prevalent market [29].

Monocrystalline solar systems are not commonly used for applications that are not limited by the area verses efficiency. Moreover, monocrystalline systems need to be mounted on rigid frames; thus, this system may not be able to utilize all possible surfaces exposed to sunlight. For the purposes of the new SUB building, where the area available for implementing solar panels exceeds the area required by lower efficiency solar panels, it is not viable to invest in more expensive solar panels.

4.1.2 Polycrystalline solar systems

Polycrystalline silicon based solar panel is made from silicon that has more than one crystal. Such panels are made from square shaped stacked cells. Polycrystalline cells benefit from lower manufacturing costs as they are simpler to produce and the manufacturing process is less involved than the monocrystalline cells. With comparable durability and longevity to monocrystalline cells, polycrystalline solar systems cost far less to manufacture and are thus the most commonly used type of panel. On the contrary, polycrystalline panels yield slightly lower efficiencies (12%) than monocrytalline panels [30].

Polycrystalline solar cells are the most common type of panel used due to their cost effectiveness [30]. A typical polycrystalline solar system would cost $5.39 per watt. Likewise to the monocrytsalline systems, however, polycrystalline systems also need to be mounted on rigid frames. Thus, if such solar systems are to be employed, considerations need to be made by the design team (HBBH+BH). For the purposes of the new SUB building, polycrystalline solar system would be an optimal choice of panels due to their abundance in the market, efficiency, and lower cost.

4.1.3 Amorphous solar systems

Amorphous solar systems are made of thin homogenous layer of silicon rather than crystal structures that were employed in the monocrytalline and polycrystalline systems. Due to their higher absorbability of light, amorphous systems are more effective and as a result can be made thinner. Another feature of the amorphous systems is that they can be deposited on various types of substrates. This allows amorphous systems to be implemented as rigid or flexible panels, which makes them ideal for curved or irregular shapes surfaces. On the contrary, amorphous solar systems are not as efficient (6%) and are thus not as commonly used as the other types of solar systems even though the cost of manufacturing amorphous systems is less than polycrystalline solar systems [31]. Another disadvantage of amorphous systems is that their power productivity diminishes faster than other types of solar systems.

Amorphous solar systems are considered the most versatile type of solar system due to their flexibility to be applied on various substrates. In some applications, amorphous systems have actually been used as a roofing material to maximize the surface usage. The versatility of amorphous solar systems however would not benefit the new SUB, as the roofing area is limited. The area required to utilize amorphous solar system for the energy production of the new SUB building would far exceed that of the available surfaces where such solar systems can be implemented.

4.2 Alternative Methods to Solar Panels

One of the alternatives that can be implemented into the new SUB building is the energy generating windows developed by the Oxford Photovoltaics. The idea is to produce a screen-printed organic cell that can be placed onto windows to produce energy just like a solar cell [32]. These cells are dye-sensitive cell instead of ordinary silicon-based cells, which enable the photosynthetic process to produce electrical currents. These windows can be made transparent because only on the edges are the polymers closely packed while the center is thin. For optimal solar radiation absorption, these panels should be installed on the windows facing the south side of the new SUB. This must be considered during the construction of the building. If the building is narrow along the south-facing side, then less of these solar panels can be mounted. This idea can be combined with other solar generating method such as solar roof, solar blinds, and solar road lamp to produce an overall efficient solar-powered building.

Solar Windows
Picture from http://inhabitat.com/transparent-solar-material-could-lead-to-photovoltaic-windows/

Another idea is to build the sidewalk with solar panels. This is an innovating and interesting idea since the roads take up most of the area around the building. There are two benefits of this kind of roadway. First it enhances the ability to collect solar energy for the building. Second, it replaces the current petroleum-based asphalt driving surfaces, which decrease the dependency on fossil fuels. Finally, with this new roadway it is possible to generate signals and signs on the road, which further enhances the usage of the roadway. The road way consist three layers [33]. The first layer is the road surface layer, which provides great strength just like the normal road; however, there is also heating components included that can be used for snow removal.

Furthermore, it is embedded with LEDs that can be used to produce various signals. The second layer is the electronic layer, which is essentially like a breadboard that connects everything together with microprocessors controls everything that is happening on the first layer. Finally the last layer is the solar panel layer collecting solar energy to produce electricity. Given the weather in Vancouver, the solar sidewalks are likely to be covered by snow during the winter months if implemented. They should not be relied upon as the primary source of generating solar energy.

Solar Roadway
Picture from http://www.solarroadways.com/main.html

5.0 Conclusion and Recommendations

Of the five renewable energies looked at in this report, solar energy was deemed the most feasible for the new SUB. While the cost of building a solar system for the SUB may be high, the environmental and social impacts that come with using solar energy help with the cost. As to the type of paneling that should be used, it is recommended that a polycrystalline panel be used on the roof of the SUB. Alternative ways of using solar energy could be used as well such as solar windows or solar roadways.

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