

UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

An Investigation into Renewable Energy Sources for the New Student Union Building

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Sustainability Project Report

An Investigation into Renewable Energy Sources for the New Student Union Building

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ABSTRACT

This report analyzes the renewable energy source for the new Student Union Building. Focus is paid on electromechanical systems that will create electricity for the new SUB lighting fixtures. Five concepts are proposed and three are filtered out for detailed analysis for a final recommendation. The five concepts are Mechanical Escalators, Generator Revolving Doors, “Spin-Me” Balls, Rain Water Collection Turbine, and Spring Board Floors.

Triple bottom line analysis on the Mechanical Escalators, “Spin-Me” Balls, and Rain Water Collection Turbine is conducted in this report and it was found that the Mechanical Escalators is the best option from the proposed electromechanical systems. Estimations and sample calculations on the Mechanical Escalators showed that it is the most cost efficient and could power up to 84 light bulbs per day. However, in the end the recommendation is that since the amount of energy produced from these concepts are so minimal compared to other known technologies, funding should be spent on other forms of renewable energy sources and these proposed ideas can be placed around the SUB to demonstrate UBC’s commitment to sustainability.

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1.0 Introduction

The new student union building (SUB) for UBC is to incorporate sustainable technology and be LEED Platinum+ certified. Being sustainable and more environmentally conscious is a movement UBC values and would like to promote every day. This new SUB will not only be built to ensure minimal negative environmental impacts are created through its lifetime, but it will also showcase the technology and educate the visitors and students on how to be greener.

One of the goals is to use a renewable energy source. Attention will be paid to this goal with several recommendations made and evaluated. After the selected technologies are evaluated a final recommendation will be made for the new SUB.

2.0 Purpose

This report focuses on taking existing renewable energy sources and evaluating their implementation through a unique and different way for the new SUB. These recommendations for the renewable energy sources will utilize mechanical energy to create electrical energy. The following are the five recommendations this report proposes:

1. Mechanical Escalators – an escalator that is sloped at the minimum angle in which a person's weight will create a downwards motion which will create rotations that can be used as mechanical input to create electricity
2. Generator Revolving Doors – use the rotations created by the doors to spin an alternator to charge a battery
3. “Spin-Me” Balls – invent a device that looks like a ball in which we place around the SUB and prompt students to spin the balls to create electricity
4. Rain Water Collection Turbine – use the potential energy of rain water in the pipes to spin a turbine and generate electricity
5. Spring Board Floors – take the user walking energy to create a displacement that would spin an armature winding to create a voltage

These five concepts are filtered to three through an initial evaluation of feasibility and implementation. The three concepts that pass initial stages will be focused on in this report.

3.0 Scope

This proposal pays attention to the following concepts in detail:

- Mechanical Escalators
- “Spin-Me” Balls
- Rain Water Collection Turbine

A review for each concept will be provided addressing their economic, environmental, and social impacts.

Limitations

The cost values in this report exclude inflation and costs fluctuations. Furthermore, the values are estimations based on calculations shown in the Appendix and online sources.

4.0 Analysis

The five concepts proposed went through an initial evaluation in which its feasibility and implementation were considered. The Spring Board Floors was quickly dismissed because the idea was not as practical. The Revolving Doors was also eliminated because the concept would not produce sufficient energy compared to the other ideas and it would be inconvenient for use since thousands of students will enter and exit the new SUB every day. Therefore, the three remaining concepts will be analyzed.

4.1 Mechanical Escalators

The mechanical escalator (see figure to the right) is a hybrid between a mechanical treadmill and an escalator. The technology behind this idea is that rather having escalators or stairs in the SUB for people

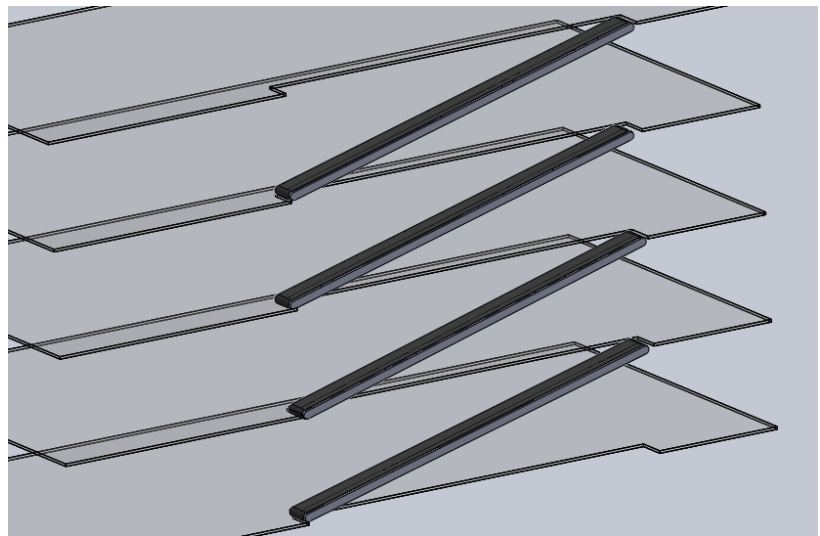


Figure 1 – Mechanical Escalators

Modelled by John Van

to travel downwards from floor to floor, the persons would step on the belt and gravity will descend the person along the escalator slope onto the bottom platform. This travelling belt will rotate a gear that is attached to a synchronous generator to produce electricity. The Mechanical Escalators are to be located on every floor. Therefore, a total of four mechanical escalators will be installed in the new SUB. These four mechanical escalators will provide electricity for the light bulbs around the new SUB.

Economic Analysis

The economic benefits and analysis will examine the capital costs, maintenance costs, recycling/disposal costs, and expand these costs over an estimated lifetime of the mechanical escalators.

The capital costs for the mechanical escalators are as follows:

- Capital Cost:
 - Materials: ~\$100,000 per escalator
 - Installation: ~\$30,000 per escalator
 - Subtract cost of stairs: ~\$50,000

The estimated cost for the materials and installation are based on the lower range of the real costs for an escalator from *Building Construction Cost Data*, 2009. The lower range is taken as the costs because the mechanical escalator does not have as many mechanical systems as the electrical escalators. Note that in the capital costs the costs of stairs the new SUB would have to incur if the mechanical escalators are not implemented are considered as marginal costs and therefore can be subtracted from the capital costs of the mechanical escalators.

- Maintenance Cost:
 - Generators: ~\$10,000/year
 - Other parts: ~\$5,000/year

The maintenance costs for running the mechanical escalators include a fraction of the staff's salary that would need to perform daily check-ups for debris that falls in between the belt and the sloped platform. Also, monthly lubrication would be required otherwise

the friction between the belt and platform would create a lot of heat and wear out the belt. Furthermore, the generators would need annual attention to ensure their operating efficiencies are adequate.

- **Recycling/Disposal Cost:**

- ~\$100,000 to recycle all materials

This estimated recycling cost of the mechanical escalators are based on assumptions of labour costs for disassembly and costs of transporting and re-use of the materials for school labs or projects.

- **Expected Lifespan of System:**

- Approximately 35 years

This works out to approximately \$1,095,000 over the entire lifetime of the mechanical escalators with a savings in energy costs of roughly \$16,000. Detailed calculations are located in Appendix A.

Environmental

The environmental benefits of this technology are that it does not produce any greenhouse gases and require no energy input. Also, it can be made from recycled materials.

Social Impacts

The social impacts created from implementing the mechanical escalators include generator noise, safety concerns, and student opportunities. The generator and the use of the mechanical escalators create noise that would disrupt people nearby. The safety concerns are from a high rate of mechanical failure due to constant human interaction.

Implementation of these mechanical escalators would also create co-op opportunities for engineering students during the assembly and installation stages.

4.2 “Spin-Me” Balls

The Spin-Me Balls (see figure to the right) concept is a simple idea similar to wind up flashlights. The principle is that a ball would be connected to a generator and would create electricity whenever it was spun. This idea would consist of a set of large heavy balls seated in concrete bases, free to spin. Each ball would have a different colour and correspond to one of the faculties. These balls would spin a generator whenever spun by a student and would count the amount of energy produced. There would be a monthly competition as well as a year-round competition to see which faculty produces more energy. The balls would be made of recycled Styrofoam to promote the new technology of recycling Styrofoam. Although the energy produced from these Spin-Me Balls would be negligible compared to the amount used by the SUB, it would be a good way to showcase alternate forms of energy, new ways of recycling, and to raise awareness in areas of sustainability.

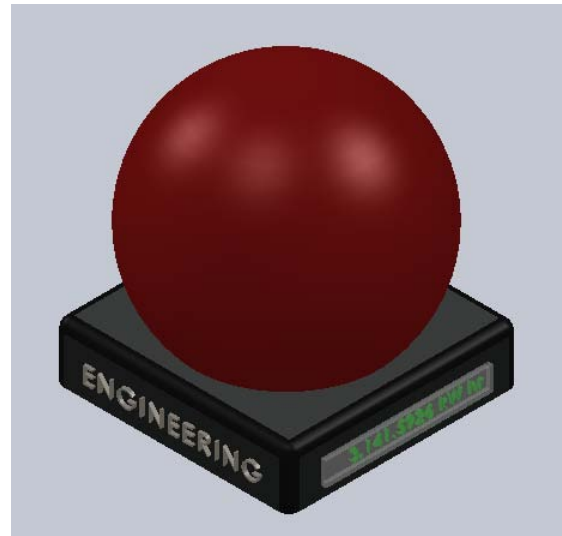


Figure 2 – “Spin-Me” Ball

Modelled by John Van

Economic Analysis

The cost benefit analysis will examine the capital costs, maintenance costs, and recycling/disposal costs, and will expand these costs over an estimated lifetime of the Spin-Me Balls.

The capital costs for the Spin-Me Balls are as follows:

- Capital Cost:
 - Materials: \$16,500 (5 home-sized generators, balls, bases, LCD screens)
 - Installation: ~\$3,000

The estimated cost for the materials and installation are based on the cost of small home-sized generators (\$3000 per unit), 200kg balls made of recycled Styrofoam (\$0.15 per

pound), concrete bases (\$40 cubic meter), and LCD screens for the counters (\$200 per screen). The installation costs were calculated based on an estimated 200 hour installation job at a wage of \$14 per hour.

- Maintenance Cost:
 - Generators: ~\$5,000/year

The maintenance costs for the Spin-Me Balls would include a monthly check up on the generator and perhaps a yearly cleaning of the generator. A daily cleaning of the ball would be necessary, as many hands would touch it every day. This would not be an extra cost though since janitors would be cleaning them as an extra duty.

- Recycling/Disposal Cost:
 - ~\$4,000 to recycle all materials

The recycling costs for the Spin-Me Balls are relatively small since most of the materials we use will be already recycled materials.

- Expected Lifespan of System:
 - Approximately 40 years

The expected lifespan of the Spin-Me Balls is based mostly on the average lifespan of a home generator as the rest of the system is not going to deteriorate as fast.

This works out to approximately \$225,000 over the entire lifetime with a negligible savings in energy costs. However, it would be a good way to showcase ways to be sustainable and to educate the student population in these areas.

Environmental

Implementation of the Spin-Me-Balls will not cause harmful impacts to the environment. Although the recycling and disposal of the LCD screens and the concrete bases may be not very good for the environment, most of this technology is environmentally friendly. The main part of the system is made from recycled materials. There is no energy consumption and no greenhouse gasses emitted during operation.

Social Impacts

As stated above, this technology would be a showcase to the student population to educate them on new forms of recycling and alternate forms of energy. It will help raise awareness in areas of sustainability and help a little with energy consumption.

4.3 Rain Water Collection Turbine

The rain water collection system (see figure to the right) came up in the initial brainstorming stage because we wanted to exploit the large amounts of rainfall we receive in Vancouver. A tank will be installed on the roof of the SUB to collect rain water. Once the water level reaches a set volume, it will be drained through a large pipe leading towards the ground. We

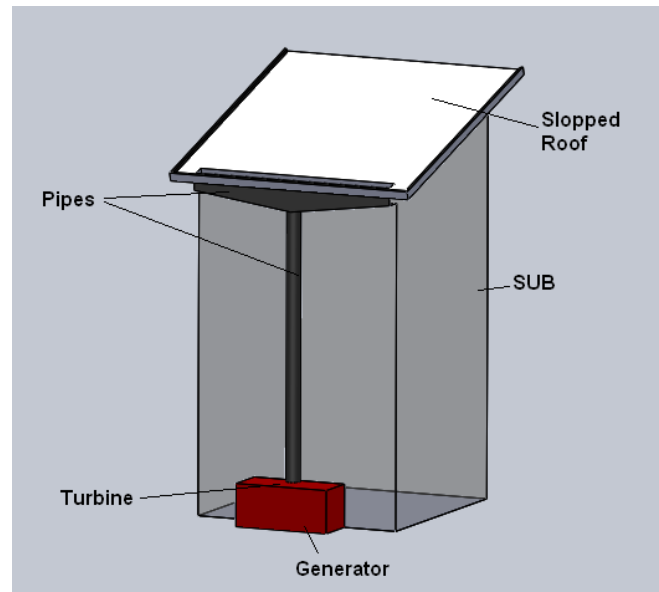


Figure 3 – Water Collection Turbine with Piping

Modelled by John Van

capture this energy by placing a turbine at the bottom of this pipe and the rain water turns the turbine to produce electricity. The goal of this system is to produce electricity to power the lights in the new SUB.

Economic Analysis

The economic analysis of the rain water collection system will include capital costs, maintenance costs and disposal costs over an expected life span of the system.

The capital costs for the rain water collection system are shown below:

- Capital Cost:
 - Turbine: ~\$100,000
 - Water Storage Tank: ~\$2,000
 - Installation: ~\$35,000

The estimations for the cost of the turbine are based on large hydroelectric turbines for homes. This is because we do not get a constant flow of water through the turbine so we do not require a large commercial turbine. The cost of the one extra pipe is excluded from our analysis because new SUB will require piping even without the rain water collection system.

The operating costs for the system include semi-annual maintenance of the water storage tank to ensure that there are no leaks due to wear and tear. This is important because we want to retain as much water as possible. Furthermore, annual attention is required for the turbine to maintain its efficiency is satisfactory. The costs listed below are estimations of total labour cost for maintenance personnel:

- Maintenance Cost:

- Turbine maintenance: ~\$2,500/year
- Tank leaks: ~\$1,000/year

The recycling cost of the system at the end of its lifespan is as follows:

- Recycling/Disposal Cost:

- Turbine: ~\$25,000 to recycle all materials
- Water Storage Tank: ~\$500

At the end of the system's lifespan, the disposal cost includes the labour to disassemble the parts and to recycle all materials used. Most of the materials in the turbine are metal hence they can be melted and reused.

The expected lifespan of the rain water collection system is approximately 25 years. This is because the system is constantly in contact with water and materials erode quicker when oxidation is a factor. Piping will start to degrade and the tank's maintenance cost would also rise quickly.

The total cost of the system calculated over its lifespan of 25 years results in a total of \$250,000. However, the energy savings that we gain from the system is approximately \$420. This savings, compared to the cost of implementing the system, is clearly negligible. Detailed calculations are located in Appendix B.

Environmental

The environmental impact of this system is very low because the rain water collection system is generating energy. There are no greenhouse gases during its operation and there

is no energy consumption. The only stage in its life where there may be environmental impacts is during its manufacturing and recycling stages where the factory emits harmful gases. Otherwise, the implementation creates a small footprint to the environment.

Social Impacts

The operation of the turbine and the water releasing from the storage tank may be noisy but since the system is in minimal contact with everyday users, the social impacts are very low. One consideration we must consider is that using the rain water for electricity will take away its use for water supply. Additional pumps may be required to relocate the water for supply uses after it has passed through the turbine.

5.0 Conclusion and Recommendations

At first, we explored renewable forms of energy more related to mechanical concepts. We observed that there is a lot of unused mechanical energy wasted on a daily basis. We wanted to try to put these unused forms of mechanical energy to use. Wasted energy from rain water, students walking through the SUB and walking up and down stairs are the forms of unused energy we explored. We took advantage of these three forms of wasted energy by using rainwater collection, Spin-Me balls, and mechanical escalators. Of the three types of technology we looked into, we found the Mechanical Escalators to be the most cost efficient. However, none of these technologies compare to the energy that can be produced by photovoltaic cells or wind turbines. Therefore we recommend the funding that would have been used to implement these escalators to be put to further research and implementation of another type of renewable energy. Nonetheless, these technologies should be excellent showcases of the new sustainability movement at UBC and promote a more environmentally conscious lifestyle.

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Appendix A: Mechanical Escalators

The following are calculations for determining a rough number of light bulbs the mechanical escalators can power per day.

Height of each Floor, $H = 4\text{m}$

Slope of Escalator, $\theta = 150$

Length of Escalator, $L=H/\sin(\theta)=15.45\text{m}$

Average Mass of Person, $m = 80\text{kg}$ (assumption is made that the person is carrying a bag)

Time of descent, t

Radius of Generator Gear, r

Efficiency, $\eta = 0.95$ (from EECE 365 Course)

Torque

$$T = mg \times r \cos\theta$$

Speed

$$\omega = \frac{L}{t \times 2\pi r}$$

Power Out

$$P = \eta T \omega$$

Energy

$$E = Pt = 1771.4 \frac{\text{J}}{\text{person}}$$

Note: the radius and time are independent of energy.

Number of people on each floor per day	
Floor No.	No. of people
1	5000
2	4000
3	2400
4	2000
5	2000

Note: No. of people per floor are estimates based on head count on each floor during lunch hour.

Total Electricity created per day converted to kW hr

$$P_{\text{created}} = 18.80 \text{ kW hr}$$

Light Bulb Power Rating: $P_{\text{bulb}} = 14 \text{ W}$

Operation Time of each light bulb: $T_{\text{op}} = 16 \text{ hours per day}$

Total No. of Light Bulbs we can power per day:

$$\# \text{ of light bulbs} = \frac{P_{\text{created}}}{P_{\text{bulb}} T_{\text{op}}} = 83.91 \text{ light bulbs per day}$$

Cost Savings

Electricity Charge Rate: \$0.0672 per kW hr

Savings per day = \$1.263 per day

Savings per year = \$461.03 per year

Appendix B: Rain Water Collection

In calculating the energy generation of the rain water collection system, the following assumptions and values were used:

- Vancouver's annual rainfall is approximately 1117.2 millimetres per year.
- The area of the new SUB roof is 5000m²
- The height of the SUB is 20m

First calculate the volume of rain per day:

$$\frac{1.1172m}{year} \times \frac{1 year}{365 days} \times 5000m^2 = 15.3 m^3 per day$$

Next calculate the total possible energy that can be extracted:

$$\begin{aligned} Energy &= \eta mgh = 0.95 \times \left(15.3m^3 \times 1000 \frac{kg}{m^3} \right) \times 9.81 \frac{m}{s^2} \times \left(5 floors \times \frac{4m}{floor} \right) \\ &= 2852533 J \end{aligned}$$

Convert into a unit that is used by BC Hydro for measuring energy use:

$$Total energy = 0.792 kW \cdot hr per day$$

Each light bulb requires 14W under a 16 hour operation condition each day:

$$0.792kW \cdot hr \times \frac{1000W}{1 kW} \times \frac{1 lightbulb}{14W} \times \frac{1}{16 hrs} = 3.54 lightbulbs per day$$

Cost Savings:

Electricity Charge Rate: \$0.0672 per kW h

Savings per day = \$0.0532 per day

Savings per year = \$19.43 per year