UBC Social Ecological Economic Development Studies (SEEDS) Student Report

New SUB Atrium Features - Pavegen Energy-generating Steps

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The objective of this report is to discuss the social, environmental and economic benefits of implementing the Pavegen in the new Student Union Building. The proposed Pavegen will convert human walking into energy, which will sequentially light up the floor.

To fulfill the objectives two key analysis were conducted. The first one counts the traffic around the proposed Pavegen location to calculate the amount of energy generated and complete preliminary economics. The second is a survey which gathers student input on the Pavegen idea. This survey is used to help understand the social benefits and losses. To analyze the environmental aspect, the materials used in the Pavegen are analyzed. Also, the amount of CO_2 not being released into the atmosphere is calculated. These indicators allow for a full cycle analysis on the Pavegen project.

The results show positive energy generation which would indicate good economics and significant CO_2 reduction. On the other hand, the social survey would indicate that the Pavegen will not cause a significant social change because the majority of people will forget about its unique kinetic energy technology. Therefore, for it to make a social change, one must figure out a way to keep students interested in the Pavegen. Ultimately, more studies need to be completed to determine the amount of energy actually generated and social implications of the Pavegen.**Table of Contents**

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1.0 Introduction

The report focuses on evaluating the economic, environmental and social benefits of the proposed Pavegen system in the new Student Union Building (SUB) at University of British Columbia (UBC), to determine if it would be a sustainable feature. Pavegen steps converts kinetic energy from footsteps into electricity. Energy generated from footsteps will be used to power a feedback display that will highlight the sustainable features of the new SUB, which is scheduled to be completed in 2014. Moreover, it will promote sustainability at large on campus. AMS plans on installing 8 of these steps, each step measuring 600m x 450mm x 97mm. The product is manufactured using recycled rubber and aluminum.

2.0 Methodology

Literature search was conducted to assess the environmental implications of the materials used in the Pavegen systems. However, since the Pavegen technology had not yet been well established and documented, as well as the proprietary technologies involved in the Pavegen, peer-reviewed articles specifically for Pavegen were not readily available.

Due to the absence of material and also upon re-evaluation of the project objectives, the group decided to tackle this project in a different approach. In order to gather suitable and useful data, the group had conducted surveys to gather student opinion and estimated the amount of foot traffic in the proposed area. From the data gathered, the group could evaluate the feasibility and overall benefits of the installation of the Pavegen system in the new SUB to the student body. The surveys were used to aid with assessing the possible social impacts of this project and the foot traffic count was used in rough energy and economic calculations to understand the possible benefits of the Pavegen system.

2.2 Foot Traffic Estimation

The south entrance of the current SUB, close to the Pi R Squared shop, was chosen for estimating the possible foot traffic in the proposed area in the new SUB. As the proposed area of installation in the new SUB will be near the Pi R Squared shop, the group believed that the current area near the Pi R Squared shop would offer a fair estimate as to the possible amount of students passing through the proposed area. The group counted the amount of people passing through those doors from 10:00 to 14:00. These hours were chosen as the group believed that during these hours, the foot traffic would peak due to students heading to the SUB for purchasing food or taking a break.

Time	Foot Traffic
10:00-11:00	1024
11:00-12:00	1226
12:00-13:00	1472
13:00-14:00	1359

Table 1: Foot Traffic Count from 10:00 to 14:00

From these data, the hourly average, daily average, monthly average and Fall/Winter terms foot traffic were estimated. All values were rounded to the nearest whole number as it would be illogical to have decimal number of persons passing through. The hourly average was taken as the average of the data points from the foot traffic count and using the assumption that the majority of foot traffic would occur during school hours from 08:00 to 17:00, the daily average foot traffic was determined. From the assumption that only weekdays-schooldays would be the major contribution to the foot traffic and that there were 4 weeks in a month, the monthly average foot traffic was estimated from the daily average. In the Fall and Winter foot traffic estimation, the months of December and April were ignored due to probably decrease in students on campus during exam periods and 1 week was subtracted due to Reading Week as well for similar reasons.

Hourly Average Traffic	1270
Daily Average Traffic	11432
Monthly Average Traffic	228645
Fall + Winter Term Traffic	1326141

Table 2: Hourly, Daily, Monthly and Fall + Winter Term Foot Traffic

2.2.1 Conditions and Limitations of Foot Traffic Estimation

Beyond the data collection, the group understood that these data may be inherently inaccurate and skewed due to certain limitations and conditions. These limitation factors may be due to: Weather, Season, Amount of Data, Area of Traffic and Human Error. This foot traffic count was conducted on a cloudy day – rainy day, which may have affected the accuracy of this study. A sunny day may have cause more students to travel to the SUB more often than a day with rain or clouds. Temperature and Season may also play a role in affecting the students' willingness to heading to the SUB, thus affecting the overall foot traffic. Also, during evenings, weekends, term breaks, and summer term, the SUB would expect a much lower pedestrian traffic as there would be less students on campus during these times. Furthermore, since only 10:00 to 14:00 and only for one day, due to the small amount of data points, the data would be highly sensitive and easily influenced by random spikes than a longer array of points, thus perhaps providing an inaccurate picture. Lastly, the current Pi R Squared location may not be an accurate representation of the location in the new SUB as the students might not pass through the corridor as much as in the old

SUB. As these counts were performed by hand, there would be a high chance for human error in these data. At various times, especially 10 minutes before or an hour have passed (ie. 11:10, 11:50), there would be floods of students in numbers beyond approximately 20, that had recently finished class, entered the entrance in swarms. This situation have caused great deal of uncertainty in counting as it was very difficult to keep up with the amount of people flowing in and out.

3.0 Environmental Assessment

The data collected from the foot traffic estimation was used in calculating the amount of energy that would be generated by the Pavegen tiles. In addition to the assumptions used in the foot traffic estimation, each person was assumed to have passed through all 8 Pavegen tiles. Although this scenario would be highly unlikely to occur, this assumption allowed the energy calculations to be done and should be kept in mind when interpreting the results.

From the Pavegen pamphlet, the energy generation rate was provided as "each slab…4-8 watts per footstep over a second" and was interpreted by the group as 4 to 8 watts generated per footstep over 1 Pavegen tile when used in the calculations. The Pavegen company did not provide a reply to the group's inquiry regarding clarification about these values. It was not clearly stated whether or not these values considered the amount of energy would be consumed by the light within the Pavegen tiles themselves and the wording was unclear. The daily energy generation and Fall and Winter Term energy generation were calculated.

	MJ	kWh
Daily Gen. (min)	11853	3292
Daily Gen. (max)	23706	6585
Fall and Winter Gen. (min)	1410502	391806
Fall and Winter Gen. (max)	2821004	783612

Table 3: Daily and Term energy generation, in kilowatt-hours and mega-joules

From these estimations, the total energy generated from the Pavegen system was found to be extremely high and possibly beneficial to the environment. In terms of energy savings, these values would be equivalent to an average daily reduction of 3 barrels of oil equivalent. And over the course of the Fall and Winter term, the average energy saved from the Pavegen system would be approximately 371 barrels of oil equivalent. When converted in terms of CO_2 Reduction via the United States Environmental Protection Agency's CO_2 Equivalence Calculator, the Pavegen system could result in an average of 3.4 metric tons of CO_2 Equivalent reduced daily and 405 metric tons of CO_2 Equivalent reduced over the Fall and Winter terms! However, these environmental benefits would only be meaningful if the rate of consumption and rate of generation of electricity were similar. Otherwise, if there was a surplus of energy available, it would have to be stored in batteries, thus creating possible losses in this process.

3.1 Material Assessment

According to the Pavegen pamphlet, Pavegen steps uses Lead Acid and Lithium Iron Phosphate batteries to store the energy. Moreover, the rubber used in Pavegen steps is produced from 100% recycled car tires. Recycling tires to produce something this useful may sound like a brilliant idea, but one has to take into consideration the environmental hazard posed by the rubber used in tires. Ecotoxicity caused by car tires may be a bigger problem than first thought. Studies show that zinc, heavy metals, vulcanisation (a chemical process for converting rubber and polymer into more durable materials by the addition of sulphur), and rubber chemicals can leach into water from tires. Shredded tire pieces leach much more, creating a bigger concern, due to the increased surface area on the shredded pieces. Many organisms are sensitive, and without dilution, contaminated tire water has been shown to kill some organisms. We, however, do believe that these environmental concerns would not bother the stakeholders, since the Pavegen steps are not going to be installed near a water source in the new SUB.

Environmental concerns are associated with the storage batteries used in Pavegen exist. Among the two storage options, lead acid batteries are more hazardous. Some lead compounds are extremely toxic. Long-term exposure to even tiny amounts of these compounds can cause brain and kidney damage, hearing impairment, and learning problems in children. More than 40,000 metric tons of lead ends up in landfills every year, which is a serious concern. Moreover, lead acid batteries carry the risk of explosion as well. However, environmental risks associated with Lead Acid batteries can be minimized since lead acid battery recycling is one of the most successful recycling programs in the world.

On the other hand side, Lithium Iron Phosphate batteries have almost negligible impact on environment. Lithium iron phosphate is a non-toxic and contact with this chemical requires no professional medical attention. Since the recycling program of lithium products is not that big yet, Lithium iron phosphate battery is easy to dispose because it's non-toxic, non-contaminating and contains no heavy metals.

4.0 Economic Assessment

By using the energy calculations from the environmental assessment, the average daily and Fall and Winter savings were determined from BC Hydro Large General Service Conservation Rates.

To simplify the calculations, only the Basic Charge and Energy Charge (Part 1) from the BC Hydro website were used in determining the amount of savings. It would be probable that UBC and the SUB acquired electricity from BC Hydro at different rates than the Large General Service category.

Average Daily Savings	$437.08
Average Fall & Winter Savings	$52,012.26

Table 4: Average Daily, Fall and Winter Savings

From these estimations, the economic benefits of the Pavegen system would be positive. With a purchase cost of $20000 to $30800, this project would have the ability to pay itself within a period of 1 year. However, in addition to the purchase cost, the installation and maintenance costs would also have to be considered and accounted for when dealing with the economic costs and payback period as they would increase the amount of money required as start-up costs and as annual upkeep costs. To balance the additional costs from installation and maintenance costs, these tiles may be a suitable advertising medium and could potentially generate revenue. Lastly, these savings calculations, as similar to the energy estimations, should be taken with caution, as they were calculated using very optimistic and ideal assumptions and would not a total accurate prediction of the actual economic projections.

5.0 Social Assessment

The social aspects analyzed were social interest, awareness, and longevity. It is important that if implemented, the Pavegen creates social awareness for sustainable energy sources, for its entirety. To answer these questions, a survey was created and students were polled at the SUB.

5.1 Social Survey

While the foot traffic was being monitored, a member from the group asked 20 students to complete a survey to understand the public opinion. Three out of the 20 individuals refused to participate in the survey. The survey questions can be found in appendix A. The first question discusses people's knowledge on the Pavegen technology. 15 out of the 17 people polled were not aware of a technology that uses human kinetic energy to produce electrical energy. The second question asks if generating electricity via humans walking helps think about sustainability. All 17 students did have some sort of positive feeling toward sustainability after hearing about the technology. The third and final question touches upon the topic of if they would get bored of the Pavegen. 16 out of the 17 students felt they would eventually stop caring about the unique Pavegen system.

5.2 Social Discussion

The notation that humans walking can be converted into energy will attract attention. As well, as the survey illustrates, people will begin to question topics such as sustainability once they discover alternative energy sources such as the Pavegen exist. Making students reach this level is another hurdle. As the survey illustrates, three students were so busy they did not have the time to even discuss the Pavegen. This can be symbolic to the amount of students that use the SUB for its quick conveniences and are not interested in staying. One can assume these students will not benefit from the Pavegen system. The second issue that arises is the lack of Pavegen technology knowledge. If a student is to walk on top a floor that lights up, how will she/he know the importance of the lights? It is vital that students are educated on the unique energy source that is used, in the Pavegen. Thirdly, maintaining interest in the Pavegen will be difficult. Everything new is interesting, but will the Pavegen still cause social change one year after installation? These are issues can deter the Pavegen from creating social change.

From the survey it is noticed that the unique energy generation system of the Pavegen will cause an initial social buzz. If implemented properly, one can assume students will begin to discuss this alternative energy technology. This discussion may lead to students researching other alternative energy sources and become more interested about these unique energy producing methods.

Therefore, a social change is possible using the Pavegen. Nonetheless, the Pavegen alone lacks interactivity to capture attention in the long run.

6.0 Conclusions and Recommendations

In order for successfully implementation of Pavegen, the group came up with some recommendations. To begin, better foot traffic estimation is needed. To achieve this task, longer sampling time is required. Data should be collected for weekdays and weekends for longer time intervals. Formation of small groups, who would conduct this study, is recommended. Also, the group believes that establishing contact with Pavegen Systems to gather more credible data about this new feature would definitely help with the energy estimation calculations. Since this technology is fairly new, not a lot of studies have been conducted on the various aspects of this technology. Therefore, it would be beneficial to contact the company regarding the life cycle analysis and maintenance cost data. Moreover, the group believes that it's very important to make sure that students remain engaged with this technology. In order for Pavegen to captivate students interest, the group recommends organizing events, such as Power smart week and Career fairs around the Pavegen.

In conclusion, the Pavegen is a great theoretical idea but the practical social gains will be hard to achieve. Due to the tendency to be forgotten, it may lose its social benefit. It is not recommended that the Pavegen be implemented elsewhere in UBC, but because of the high foot traffic it is best situated in the new SUB. Overall, the theory is unique and interesting, but using it to create a continuous social change will be difficult.

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Appendix A

Sample Calculations

State problem, approach to ~~sta~~ solution

- Daily Average Foot traffic

Given data from counting in the current SUB:

Time	Foot Traffic
10:00 - 11:00	1024
11:00 - 12:00	1226
12:00 - 13:00	1472
13:00 - 14:00	1359

the average hourly traffic was calculated as the average of the data points.

$$\text{Average hourly Traffic} = \frac{(1024+1226+1472+1359)}{4}$$

$$= 1270 \text{ trips/hour}$$

The Assumption that most traffic would occur during school hours (08:00 - 17:00) was used in the daily average calculation.

$$\text{Daily Average} = \text{Hourly Average} \times 9 \text{ School hours.}$$

$$= (1270) \times 9$$

$$= 11432 \text{ trips/day.}$$

- Monthly Average. Foot Traffic

In this calculation, the assumptions of only school days play a significant role in the Foot Traffic (i.e. 5 days in a week). and 4 weeks in a month were used.

amount of energy per step not power

Similarly this was repeated for the Daily Generation Max. with (8 watts/step.) The Fall + Winter Term Generations were determined in a similar fashion.

For the conversions to barrels of oil equivalent, 1 barrel of oil was taken to have the ability to provide 5.7 gigajoules worth of energy. (From CHBE 483, chapter notes).

$$\text{Daily boe} : \frac{\text{Daily Max} + \text{Daily Min}}{2} \times \frac{1\ \text{boe}}{5.7\ \text{GJ}}$$

$$= 3.11\ \text{boe/day}.$$

Similarly, the Winter + Fall term boe was determined.

- USEPA Greenhouse Gas Equivalence Calculations

The daily and Fall & Winter Term average generations in kWh were inputted into the USEPA Calculator to obtain the tons of CO_2 equivalent.

Economic Calculations

The Large General service rates were used for the Calculation. BC Hydro charged at a rate of \$0.0885 per kWh of energy use.

$$\text{Daily Saving} = \frac{\text{Daily Max Gen.} + \text{Daily Min Gen}}{2} \times \frac{\$0.0885}{\text{kWh}}$$

$$= \$437.08$$

Similar procedures were repeated for the Winter + Fall term savings.

Social Questionnaire

1. Have you heard about technologies that convert walking into energy?

2. Does the idea of generating energy via walking cause you to think about sustainability/alternative energy?

3. If implemented, do you think you will get tired of the Pavegen in the new SUB eventually?